ICAAS
An Edited Book

Volume-3

Chief Editor : Dr. S.P. Singh

Compiled & Edited for

Astha Foundation, Meerut (U.P.) INDIA

www.asthafoundation.in

Published By :

Astha Foundation, Meerut

Suman Villa, 85, Phool Bagh Colony, Main Road, Meerut-250002

Mob. : 08273775051, 09450068438

ISBN : 978-81-958010-7-7

Innovative and Current Advances in Agriculture & Allied Sciences

ICAAS

An Edited Book

Volume-3

Compiled & Edited for

Astha Foundation, Meerut (U.P.) INDIA

www.asthafoundation.in

Chief Editor : Dr. S.P. Singh

Editors

Dr. Mahender Singh, Shimla
Dr. P.B. Singh, Udaipur
Dr. Rohit Rana, Shamli
Dr. B.V. Tembhurne, Raichur
Dr. Hiranmayee Nayak, Bhubaneswar
Dr. Harish Pal Bhati, Jewar, G.B. Nagar

Published By :

Astha Foundation, Meerut

Suman Villa, 85, Phool Bagh Colony, Main Road, Meerut-250002
Mob. : 08273775051, 09450068438

Composed by:

Yash Computers, Meerut (U.P.) Mob. : 08979897661

Printing At : New Rishabh Offset Printers, Delhi Road, Meerut (U.P.) India

ICAAS
An Edited Book
Volume-3

Chief Editor

Dr. S.P. Singh

Department of Genetics & Plant Breeding

CSAUAT-Agriculture Research Station, Kalai, Aligarh (U.P.) India

Editors

Dr. Mahender Singh Thakur : Deptt. of Biosciences, Himachal Pradesh University, Summer Hill, Shimla, H.P.

Dr. B.V. Tembhurne : Deptt. of Genetics & Plant Breeding, University of Agricultural Sciences, Raichur, Karnataka

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, C.C.S. University, Government College, Jewar, G.B. Nagar, U.P.

Published by :

ASTHA FOUNDATION

MEERUT

P *Published by :*

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

P **Edition, 2024**

P **ISBN : 978-81-958010-7-7**

P *Laser Typesetting at :*

Yash Computers
Meerut

P *Printed at :*

New Rishabh Offset Printers
Delhi Road, Meerut

ICAAAS-An Edited Book
(Volume-3)

Contents

Website : www.asthafoundation.in
ICAAAS–An Edited Book (Volume-3)
ISBN : 978-81-958010-7-7
Published by : Astha Foundation, Meerut (U.P.) India
Edition-2024

From Chief Editor's Desk

ICAAAS : An Initiative towards Sustainable Agriculture & Allied Sciences

S.P. Singh
Scientist (GPB), ARS, Kalai, Chandra Shekhar Azad University of Agriculture and Technology, Kanpur (U.P.) India
***President,** Astha Foundation, Meerut (U.P.) India*
***Secretary,** Society for Scientific Development in Agriculture and Technology, Meerut (U.P.) India*
***Chief Editor,** ICAAAS Series of Edited Books and Souvenior*
***Chief Editor,** Frontiers in Crop Improvement Journal, NAAS Accridated Journal (NAAS Rating **4.20**)*
***Chief Editor**, Progressive Research–An International Journal, NAAS Accridated Journal (NAAS Rating **4.32**)*

About ICAAAS

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

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

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

Cited as : Singh S.P. (2024). ICAAAS : An initiative towards sustainable agriculture and allied sciences. *ICAAAS–An Edited Book.* Volume-3 : 1-8. Astha Foundation, Meerut (U.P.) India.

Vietnam C14 Tran Binh Trong Street, Hoan Kiem District, Hanoi, Vietnam. This time more than **500** participations with 80 offline participation is expected including some foreign experts.

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.

ICAAAS : The beginning

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

Global Agriculture Research institutes

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

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

There are several key principles associated with sustainability in agriculture.

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

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

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

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

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

Initiatives by United Nations for sustainable development

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

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

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

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

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

Proposed 17 Sustainable Development Goals (SDGs)

End poverty in all its forms everywhere

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

Ensure healthy lives and promote wellbeing for all at all ages

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

Achieve gender equality and empower all women and girls

Ensure availability and sustainable management of water and sanitation for all

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

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

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

Reduce inequality within and among countries

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

Ensure sustainable consumption and production patterns

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

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

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

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

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

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

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

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

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

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

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

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

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

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

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

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

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

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

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

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

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

Responses to soils today

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

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

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

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

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

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

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

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

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

Functions of ITPS : The ITPS have the following functions :

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

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

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

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

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

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

Intergovernmental Platform on Biodiversity and Ecosystem Services : The

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

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

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

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

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

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

Sustainable development in Indian Agriculture

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

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

For promoting sustainable agriculture, following components can be considered :

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

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

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

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

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

Website : www.asthafoundation.in
ICAAAS–An Edited Book (Volume-3)
ISBN : 978-81-958010-7-7
Published by : Astha Foundation, Meerut (U.P.) India
Edition-2024

Chapter 1

Sandalwood : Enhancing Farmer's Income and Climate Change Adaptation in the Foothills of Nagaland

Pempa L. Bhutia[1], Z. Kawikhonliu[1], B.U. Choudhury[2], Krishnappa Rangappa[3], Pradip Kumar Sarkar[2], N. Raju Singh[3], and H. Kalita[1]

[1]*ICAR Research Complex for NEH Region, Nagaland Centre, Medziphema-797106, Nagaland*

[2]*ICAR-Research Complex for NEH Region, Tripura Centre, Lembucherra, West Tripura-799210, Tripura*

[3]*ICAR-Research Complex for NEH Region, Umiam-793103, Meghalaya*

**Corresponding Author Email : pempadenzongpa66@gmail.com*

Abstract

Sandalwood (*Santalum album*) presents a valuable agroforestry opportunity for enhancing farmer income and adapting to climate change in the foothills region of Nagaland. This study explores the growth potential and economic viability of sandalwood cultivation in this region, characterized by diverse topography, climate, and soil conditions. Sandalwood, known for its aromatic heartwood used in various industries, thrives in well-drained, sandy loam soils and requires specific host plants for optimal growth. Despite the significant global demand for sandalwood, its cultivation faces challenges because it is hemi-parasitic and requires certain host plants. This paper examines sandalwood cultivation in the foothills of Nagaland, highlighting growth attributes under different conditions and spacings. The findings suggest that sandalwood cultivation, particularly when combined with host plants with proper spacing and management can be a promising venture for local farmers, contributing to both economic benefits and sustainable land management.

Introduction

Nagaland, a north eastern state in India, covers an area of approximately 16,579 sq. km, with elevations ranging from 200 m to about 3,840 m amsl and an average annual rainfall between 1,800 and 2,500 mm. The state's terrain is predominantly mountainous, covering 70% of its area, with the remaining 30% consisting of plains. As an agrarian state, Nagaland relies heavily on agriculture, with 70% of its population engaged in farming activities. The state's diverse topography, climate, and soil conditions provide ample opportunities for cultivating a wide range of crops, fruit trees, and forest trees. However, with climate change becoming a reality, Nagaland has not been spared. Recent years have seen a reduction in average annual rainfall and changes in rainfall distribution. To address these challenges, various adaptation and mitigation strategies are available, with agroforestry systems emerging as a particularly effective approach. These systems not only help counteract climate change effects but also offer economic benefits to farmers. India's diverse climatic and geographical regions support a variety of tree species, each suited to specific conditions. Among these, white sandalwood, also known as Chandan, stands out as one of the most lucrative forest tree species which can be viable agroforestry species. It is prized for its aromatic heartwood, which finds application in the cosmetic and pharmaceutical sectors.

Santalum album

Santalum album commonly known as

Cited as : Singh S.P. (2024). ICAAAS : Sandalwood : Enhancing farmer's income and climate change adaptation in the foothills of Nagaland *ICAAAS–An Edited Book.* Volume-3 : 9-15. Astha Foundation, Meerut (U.P.) India.

Sandalwood, Chandan, belonging to the family Santalaceae is a small to medium-sized evergreen tree species, indigenous to the Indian Peninsula with high distribution in Karnataka, Tamil Nadu and Kerala (Luna, 2005). The species naturally occurs in Southern Tropical Dry Deciduous Forests, particularly in the subtypes 5A/C2 - Red Sander Bearing Forests, 5A/C3 - Southern Dry Mixed Deciduous Forests, and Southern Tropical Thorn Forests (Champion and Seth, 1968). Santalum album is renowned for its high oil concentration (6–7%) and excellent quality oil, possessing a sweet, fragrant, and persistent aroma. This makes it highly valued in perfumes, cosmetics, and medicine. The softwood of sandalwood is also used in carvings and intricate designs. The amount of heartwood and the quality and percentage of oil generated by the trees, especially the sesquiterpenic alcohols known as á and â-santalols, determine the sandalwood's value the most.

The value of sandalwood is primarily determined by the volume of heartwood and the oil percentage and quality produced by the trees, particularly the sesquiterpenic alcohols - á and â-santalols. Sandalwood matures and bears fruit after seven years, with significant heartwood formation occurring after ten years of development (Pullaiah and Swamy, 2021). A study examining the heartwood and oil content of *Santalum album* across different locations in Assam and Karnataka found that heartwood formation begins at a girth class of 41-50 cm, corresponding to age of around 10-12 years, with over 50% heartwood in the 51-60 cm girth class and about 70% in the 71-80 cm class. The rate of heartwood formation is rapid up to a girth class of 81-90 cm, corresponding to age of around 25-30 years. The oil content ranges from 1.5% to 3.0% for trees with girth classes of 51-80 cm, reaching a maximum of 4% in trees with a girth class of 91-100 cm. The patterns of heartwood formation and increases in heartwood and oil content in Assam are similar to those observed in Karnataka (Sandeep *et al*., 2016).

Ecological requirements:

Sandalwood (*Santalum album*) thrives in a range of conditions but prefers shade in its early stages and abundant sunlight at the later stage. It can grow on dry, degraded lands and various soil types, especially deep, fertile, sandy loam soils with good drainage, and is intolerant of waterlogging. In its natural range, it experiences annual temperatures between 17.8°C to 33.8°C and rainfall from 510 mm to 2000 mm, flourishing at elevations from sea level to 1250 m, with optimal growth between 375 to 1100 m and in dry monsoon climates with 600–1600 mm of rainfall (Troup, 1921). Variations in edaphic factors and rainfall influence sandalwood oil content. Trees on rocky, xerophytic soils and in semi-arid regions tend to have higher oil content than those on fertile, well-watered soils. The tree is a hemi-root parasite, that requires primary, intermediate, and long-term secondary host plants for successful growth, making it suitable for agroforestry (Misra *et al.,* 2018).

Global demand and Economic Potential of Sandalwood

An estimated 6000–7000 metric tons of sandalwood are needed annually worldwide, while India produces about 200 tonnes annually, with 400 tonnes coming from other nations. This results in a significant gap of approximately 5400 tonnes (Viswanath and Chakraborty 2022). In 2017, Karnataka Soaps and Detergent Ltd. procured sandalwood at an av. price of Rs. 6400 per kg of heartwood from farmers. A 15-year-old sandalwood tree, under cultivated conditions, is estimated to yield 15 kg of heartwood.

Sandalwood Agroforestry

The increasing demand and diminishing supply of sandalwood from its natural habitats present a significant opportunity for cultivation, not just in forests but also on private lands like home gardens and other agroforestry systems. Sandalwood thrives with host plants, making it ideal for multistorey cropping systems, particularly in the foothill regions of Nagaland. Viswanath (2014) noted that Assam's lower foothills, with a hot humid climate, 2000 mm annual rainfall, and 650 m elevation, support luxuriant sandalwood growth. It is extensively planted in various districts of Assam, including Karbi Anglong, Nagaon, Golaghat, Kamrup, Sonitpur, and Dhemaji. Despite these favourable conditions, successful sandalwood cultivation requires understanding host-parasite relationships, quality planting materials, and deeper knowledge of sandalwood silviculture. With farmers in this region open to new species, and often have extensive lands under multistorey cropping systems, making the region ideal for sandalwood agroforestry. By addressing the challenges and leveraging the region's favorable conditions, sandalwood cultivation can become a viable and profitable venture, significantly boosting farmers' incomes and promoting sustainable land management practices.

Silvics: Key to Sandalwood Plantation Success

Sandalwood trees are among the most lucrative agroforestry species, yet there is a significant gap in knowledge transmission regarding best practices. This lack of knowledge often results in major challenges in

Table-1 : Primary Host Species for *Santalum album.*

Suitable Primary host	Location	Age (yr)	Recommendation	References
Cajanus cajan	GKVK, Bengaluru	Seedling	Significant greater growth and chlorophyll content	Mohapatra and Anil, 2022
Mimosa pudica	IWST, Bengaluru	Seedling (2 leaf stage)	Effective primary host for sandalwood in root trainers/poly bags. Provides maximum chlorophyll content and haustoria size.	Annapurna et al., 2006
Cajanus cajan	IWST, Bengaluru	Seedling (2 leaf stage)	Effective primary host. Promotes larger haustoria size and better growth.	Annapurna et al., 2006
Alternanthera sessilis	IWST, Bengaluru	Seedling (2 leaf stage)	Effective primary non legumionous host for sandalwood seedlings; supports maximum chlorophyll content.	Annapurna et al., 2006

the cultivation of this forest tree species, preventing them from reaching their maximum potential. Therefore, understanding and implementing good practices for sandalwood plantation are crucial not only for enhancing growth but also for gaining acceptance among farmers in new regions.

Pruning : Pruning practices for sandalwood (*Santalum album*) are not well-documented, and research by Sundararaj *et al.* (2019) advises against it. Any form of mechanical injury can have negative impact on sandalwood health, sometimes causing tree death. Negative effects include loss of tree erectness, increased susceptibility to decay fungi and insect pests, especially stem and wood borers and significant heartwood loss, ranging from 22.6% to 34.5%. However, if pruning is essential, Anju et al. recommend performing it on young trees. Younger trees have smaller wounds that heal more quickly, reducing decay. While the season of pruning doesn't significantly affect decay or fungal infections, pruning at the beginning of the dry season is suggested to minimize the risk of heartwood rot fungal diseases (Burgess *et al.,* 2018).

Host-plant Dependency : Santalum album, an aggressive hemi-parasite, depends on host plants for mineral nutrients and water from seedling to maturity. About 70% of seedlings develop haustoria within 30 days of germination (Nagaveni and Srimathi 1985). As Sandalwood lacks root hairs, without a host, sandalwood lacks essential elements like N, P, K, S, Ca, Mg, Fe, Zn, and Cu. According to Annapurna *et al.* (2006), sandalwood requires a primary host in the nursery stage, a secondary long-term host, and a permanent field host. Ehrhart and Fox also highlight three stages of host requirement: the seedling stage (primary or pot host), an intermediate stage, and a long-term field host. Both researchers emphasize the use of hosts during the seedling stage (6 months to 2 years) and as secondary hosts in the field for sustained growth. Secondary hosts are crucial during the exponential growth phase, impacting plant establishment, heartwood development, and oil content. Rocha *et al.,* 2014 note that fast-growing species are generally better hosts due to higher-quality organic resources and enhanced photosynthesis, which benefit sandalwood growth. However, nutrient addition can reduce fast-growing hosts' quality, making slow-growing hosts viable due to stable nutrient contributions. Hosts with nitrogen-fixing ability and light shade are most suitable for sandalwood growth (Surata, 1995; da Silva et al., 2016). Ideal hosts have thin, watery lateral roots and high water use efficiency. The xylem sap composition, rich in amino acids, sugars, and organic acids, is crucial, with C- and N-rich xylem streams being particularly beneficial. Not all N2-fixing species are superior hosts. Studies on long-term host success in tropical sandalwood plantations are limited. Some studies show different host affinities in different regions, with leguminous plants' basic amino acids making them more efficient hosts than non-leguminous plants, although performance varies (Radomiljac et al. 1998; Nagaveni and Vijayalakshmi, 2003).

Host at the seedlings stage : The primary host is crucial for healthy and robust sandalwood seedling production. While transplanting seedlings from the seed bed into polybags or root trainers, host species seeds can be sown simultaneously. Annapurna *et al.* (2006) recommended providing the host plant within a week after transplanting the sandalwood seedlings. The host should be managed regularly to prevent it from overtopping the sandalwood seedlings. *Mimosa pudica* and *Cajanus cajan* are suitable primary hosts in polybags/root trainers. *Cajanus cajan*, especially in 1500 cc containers, shows rapid growth and requires frequent pruning to limit competition with sandalwood (Annapurna, 2006; Mohapatra and Anil, 2022).

Table-2 : Secondary Host Species for *Santalum album.*

Secondary Host species	Location	Agroclimatic Region	Age of Sandal-wood (yr)	Spacing	Recommendation	References
Casuarina equisetifolia	KAU, Thrissur district, Kerala	Warm humid climate	6	2x2 m alternate pattern	Host plant is essential for better carbon assimilation, water potential, and nutrient uptake in sandalwood trees. Maintain host plants in the main field for optimal sandalwood growth and productivity.	Rocha *et al.,* 2014
Citrus aurantium	Kherva village, Mehsana, North Gujarat	Semi-arid, Gujarat	6	5×3m (alternate rows with sandal-wood)	Best host up to 6-7 years of age for *Santalum album* growth by efficiently utilizing soil resources	Singh *et al.*, 2018
Punica granatum	Kherva village, Mehsana, North Gujarat	Semi-arid, Gujarat	6	5×3m (alternate rows with sandal -wood)	Suitable long-term host for *Santalum album*; relatively greater DBH: height ratio indicating its suitability	Singh *et al.*, 2018
Prosopis juliflora	Northern Dry Zone of Karnataka	Hot Semi-Arid	11	-	Recommended due to better growth in terms of height, canopy spread, volume, stem girth, main stem volume, early heartwood development, and summer hardiness.	Srikantaprasad *et al.*. 2022
Cajanus cajan,	Narmada district, Gujarat	-	5	3 x 3 m	Ideal as an initial host and bridging agent between early and long-term growth	Rot *et al.*, 2022
Cassia siamea	Narmada district, Gujarat	-	5	3 x 3 m	Second best growth performance, recommended long-term host	Rot *et al.*, 2022
Sesbania grandiflora	Chikkballapur	Eastern Dry Zone of Karnataka	12	5×3 m (alternate rows with sandalwood)	High clear bole height and good growth.	Venkatesh *et al.* (2023)
Casuarina equisetifolia	Chikkballapur	Eastern Dry Zone of Karnataka	12	5×3 m (alternate rows with sandalwood)	High clear bole height and good growth.	Venkatesh *et al.* (2023)
Emblica officinalis	Chikkballapur	Eastern Dry Zone of Karnataka	12	5×3 m (alternate rows with sandalwood)	Highest heartwood content and oil concentration.	Venkatesh *et al.* (2023)
Morus alba	Kolar	Eastern Dry Zone of Karnataka	13	5×3 m (alternate rows with sandalwood)	Highest clear bole height and stem volume.	Venkatesh *et al.* (2023)
Sesbania grandiflora	Uttara Kannada district	-	7	-	Significant increase in clear bole height, tree girth, and main stem volume, though it had lower heartwood and oil content compared to *Casuarina equisetifolia.*	Venkatesh *et al.,* 2023
Casuarina equisetifolia	Uttara Kannada district	-	7	-	Significant increase in heartwood content and oil content	Venkatesh *et al.*, 2023

Mimosa pudica offers several advantages: it can be propagated through cuttings, has a prostrate growth that reduces water loss from the potting medium, eliminates competition for light, requires minimal management input (pruning), and is resistant to diseases. Below is a table summarizing suitable primary host:

Secondary host: At the initial stage after transplanting in the field, planting sandalwood in the same pit with a host at a distance of 20–30 cm is beneficial. Care should be taken to manage the growth rate of the host to avoid negatively impacting the sandalwood. Initially, shading from the host can be beneficial, but in later stages, the host needs to be pruned frequently to ensure adequate sunlight for the sandalwood. Long-term hosts can be planted at a suitable distance to support sandalwood growth. Fruit-based and timber-producing hosts are suitable choices. Below is a summary of studies on secondary hosts for Santalum album:

Case Study of Sandalwood Growth in the Foothills Region of Nagaland

Farmers in the foothills of Nagaland have started cultivating white sandalwood (*Santalum album*) in their homegardens, either as individual trees or mixed with other species. Some have extended this practice to plantations, especially with arecanut. A survey was conducted in Peren districts, to study the growth attributes of sandalwood trees planted at different years and under different conditions like spacing, management, etc.

Study Area

The study was conducted in Peren district, located at an elevation of around 300 meters above mean sea level (amsl). Weather data from the past four years was collected from a meteorological station (ICAR Research Complex for NEH Region, Nagaland Centre) within a 20 km radius of the sandalwood site :

Year	Temperature (°C)		Relative humidity (%)		Total rainfall (mm)
	Max	Min	Max	Min	
2020	29.5	18.3	94	62	1253.7
2021	30.5	18.3	93	56	985.2
2022	29.7	18.4	93	62	1563.1
2023	30.2	18.5	92	61	1299.1

Site 1: This plantation site included both sloping and flat areas. The four-year-old sandalwood plants were spaced haphazardly at intervals of 3 to 5 m, with arecanut seedlings interspersed among them. The average collar girth of sandalwood was found to be 25.74± 3.15 cm, and the average height was 3.66 ± 0.29 m. The growth was quite good.

Fig.-1 : 4 years old Sandalwood plantation at site 1.

Site 2: This location has two different plantations.

Plantation-1 : This site is primarily on level ground. The plantation was established 10 years ago with a spacing of 1.5 to 2 m, and no host species were provided. The average collar girth of the 10-year-old sandalwood plants was found to be 16.96± 2.36 cm, and the average height was recorded as 3.09±0.26 m.

Fig-2 : 10 years old Sandalwood plantation at Site 2.

Plantation-2 : The second plantation site is on sloping land. The plantation was established 4 years ago, with trees randomly spaced at 1.5 to 4 m and intermixed with arecanut plants. The average collar girth of these 4-year-old sandalwood plants was found to be 16.96±1.26 cm, and the average height was 3.06±0.28 m.

Fig.-3 : 4 years old Sandalwood plantation at Site 2.

The differences observed in growth parameters of sandalwood plants between different sites, as well as within the same site, may be attributed to several factors. A notable factor is the absence of host plants in Plantation 1 of Site 2. Despite being established 10 years ago, this plantation exhibits poorer growth compared to the 4-year-old sandalwood plantations at both sites. Another contributing factor could be the close spacing of the trees and the presence of the grass species *Imperata cylindrica*, which may compete for nutrients with the sandalwood plants. The close spacing among sandalwood trees in Plantation 1 of site 2 might also contribute to intra-species competition. In contrast, the second plantation at Site 2, despite having better growth than the 10-year-old sandalwood trees at Site 1, shows inferior growth compared to the sandalwood at Site 1. This discrepancy may be attributed to the closer spacing in Site 2, which likely increases inter-species competition and affects growth.

Conclusion

The cultivation of sandalwood (*Santalum album*) offers a promising opportunity for farmers in the foothills of Nagaland to enhance their incomes while adapting to climate change. Sandalwood has demonstrated strong growth potential under varied conditions in this region, with its performance influenced by factors such as spacing, site conditions, and the presence of suitable host plants. Plantations with optimized spacing and appropriate host species show better growth and productivity By integrating sandalwood into diverse agroforestry systems, including home gardens, fruit plantations, and even agricultural or jhum lands, farmers can benefit economically and contribute to ecological sustainability. To fully realize sandalwood's potential, it is crucial to enhance knowledge and awareness of its silvicultural needs. Understanding its growth characteristics, host-plant interactions, and optimal management practices is key to achieving faster and more substantial benefits. With effective training and dissemination of best practices, farmers can achieve faster and more substantial benefits from sandalwood cultivation

References

1. Annapurna D., Rathore T.S. and Joshi G. (2006). Modern nursery practices in the production of quality seedlings of Indian sandal wood (*Santalum album* L.) – stage of host requirement and screening of primary host species. *Journal of Sustainable Forestry* 22: 33–55; doi:10.1300/J091v22n03_0
2. Burgessa T.I., Howarda K., Steel E. and Barbour E.L. (2018). To prune or not to prune; pruning induced decay in tropical sandalwood. *Forest Ecology and Management* 430: 204–218.
3. Champion H.G. and Seth S.K. (1968). A Revised Survey of the Forest Types of India. Government of India Publication, New Delhi, India.
4. da Silva J.A.T., Kher M.M., Soner D., Page T., Zhang X., Natara M. and Ma G. (2016). Sandalwood: Basic Biology, Tissue Culture, and Genetic Transformation. *Planta* 243: 847–887.
5. Luna R.K. (2005). Plantation Trees. International Book Distributors, Dehradun, UK, India. 968p.
6. Mishra B., Chakraborty S., Sandhya M.C. and Viswanath S. (2018). Sandalwood farming in India: Problems and Prospects. *Indian Journal of Tropical Biodiversity* 26: 1–12.
6. Mohapatra U. and Anil V.S. (2022). Primary Host Interaction of Root Parasite Sandalwood (*Santalum album* L): Morphological and Biochemical Responses during Interaction with Legume Host Cajanus and Non-Legume Host Alternanthera. *Mysore Journal of Agricultural Sciences,* 56(1): 367-380.
8. Nagaveni H.C. and Srimathi R.A. (1985). A note on haustoria-less sandal plants. *Indian Forester,* 111: 161–163.
9. Nagaveni H.C. and Vijayalakshmi G. (2003). Growth performance of sandal (*Santalum album* L.) with different host species. *Sandalwood Research Newsletter,* 18:1–4.
10. Pullaiah T. and Swamy M.K. (2021). Sandalwood: The green gold. Sandalwood: Silviculture, Conservation and Applications, *Springer,* Singapore, pp.1-8.
11. Radomiljac A.M., McComb J.A., Pate J.S. and Tennakoon K.U. (1998). Xylem transfer of organic solutes in *Santalum album* L. (Indian sandalwood) in association with legume and non-legume hosts. *Annals of Botany,* 82: 675–682.
12. Rocha D., Ashokan P.K., Santhoshkumar A.V., Anoop E.V. and Sureshkumar P. (2014). Influence of host plant on the physiological attributes of field-grown sandal tree (*Santalum album*). *Journal of Tropical Forest Science,* 26(2): 166–172.
13. Rot J.R., Prajapati D.R., Mevada R.J., Jani M., Jha S.K, Vanapariya H.P. and Sasikumar K. (2022). Growth performance of *Santalum album* L. association with different host species in South Gujarat Region. *Indian Forester,* 148(11): 969-985. DOI: 10.36808/if/2022/v148i11/156796
14. Sandeep C., Gogoi R., Rahman R., Boruah R.K. and Viswanath S. (2016). Variation in heartwood and oil content of *Santalum album* in Assam and Karnataka. *Journal of Bioresources,* 3(1): 80-88.
15. Singh B., Singh, G. and Rathore T.S. (2018). The effects of woody hosts on *Santalum album* L. tree growth

under agroforestry in Semi-arid North Gujarat, India. *Indian Forester,* 144(5): 424-430.

16. Srikantaprasad D., Gowda A.M., Pushpa T.N., Thimmegowda M.N., Umesha K., Ravikumar R.L. and Prasanna K.T. (2022). Identification of suitable host for sandalwood cultivation in northern dry zone of Karnataka. *Industrial Crops and Product,s* 182: 114874.
17. Sundararaj R., Mondal S. and Kanthareddy M. (2019). Pruning Effects on the Health of Indian Sandalwood (*Santalum album* Linn) in Agroforestry conditions of South India. *American Journal of Plant Biology,* 4(1): 1-6. doi: 10.11648/j.ajpb.20190401.11
18. Surata K., Harisetijono A. and Sinaga M. (1995). Effect of intercropping system on sandalwood growth (Santalum album L.). *Santalum,* 20: 17–24.
19. Troup R.S. (1921). The Silviculture of Indian Trees. *Clarendon Press, Oxford*.
20. Venkatesh L., Dattappa, Maheshnaik B.L. and Ganesha B.H. (2023). Influence of secondary host tree on growth, heartwood initiation and oil content of twelve year-old of Sandalwood plantations at Eastern dry zone of Karnataka, in Peninsular India. *Biological Forum-An International Journal,* 15(8a): 227-232.
21. Venkatesh L., Channabasappa K.S. and Manjunath G.O. (2023). Performance of host trees on heartwood and oil content on seven year old sandalwood plantations in Uttara Kannada district. *The Pharma Innovation Journal,* 12(5): 2137-2139.
22. Viswanath S. and Chakraborty S. (2022). Indian sandalwood cultivation prospects in India. In: Arunkumar A.N., Joshi G., Warrier R.R., Karaba N.N. (eds) Indian sandalwood. Materials horizons: from nature to nanomaterials. *Springer,* Singapore, pp 281–292.
23. Viswanath S. (2014). Sandalwood, An unexplored treasure. Inside Fact, *National Monthly,* 1(2): 10-13.

Website : www.asthafoundation.in
ICAAAS–An Edited Book (Volume-3)
ISBN : 978-81-958010-7-7
Published by : Astha Foundation, Meerut (U.P.) India
Edition-2024

Chapter 2

NEMATODES PEST EMPHASIZING IN VEGETABLES CROPS AND THEIR MANAGEMENT IN ORGANIC AND NATURAL FARMING

Ajay Kumar Maru[1], R.K. Thumar[1] and R.N. Kumhar[2]
[1]*Department of Nematology, BACA, Anand Agricultural University, Anand, Gujarat*
[2]*Department of Nematology, RCA, MPUAT, Udaipur, Rajasthan*

Organic Agriculture/farming is a production system that sustains the health of soils, ecosystems, and people. It relies on ecological processes, biodiversity and cycles adapted to local conditions, rather than the use of inputs with adverse effects. Organic Agriculture combines tradition, innovation, and science to benefit the shared environment and promote fair relationships and good quality of life for all involved. Whereas, Natural Farming is a chemical-free alias traditional farming method. It is considered as agroecology based diversified farming system which integrates crops, trees and livestock with functional biodiversity.

One of the numerous dangerous organism groups that rely on plants for survival is the plant parasitic nematode (PPN), often known as the "hidden enemy" of crops (Khan, 2016). It is commonly known that plant parasitic nematodes are among the most destructive pest groups and are to blame for subtle disease symptoms that cause significant losses in a variety of crops. Plant parasitic nematodes are estimated to cause annual output losses in the world's primary crops of roughly 21.3%, and about 14% in underdeveloped nations. According to a recent estimate, nematodes cause yield losses in India that are both quantitative and qualitative, totalling almost Rs. 21 billion annually (Jain *et al.,* 2007). Beside direct damage, plant parasitic nematodes serve as predisposing agents in development of disease complexes with fungi, bacteria and viruses. In many situations, plant varieties resistant to fungi, bacteria are rendered susceptible when parasitized by nematodes.

When it comes to controlling plant parasitic nematodes, it can be more challenging in organic farming systems than in dealing with foliar diseases and insect pests because workable management strategies and monitoring mechanisms aren't always accessible (Oka *et al*., 2007). Using cultural, physical, and biological control techniques, organic farmers combat nematode issues, particularly during the transitional phase from conventional to organic farming (van Bruggena and Termorshuizen, 2003). However, in other cases, problems with plant-parasitic nematodes started 5 to 10 years after conversion to organic system (Hallmann *et al.,* 2007). It is assumed that PPN should not be a problem in well-managed, long-term organic farms as stimulating soil life by organic means will enhance the antagonistic potential in the soil thus reducing PPN (Hallmann *et al*., 2007).

Important nematode threats of vegetables

There are mainly six major plant parasitic nematodes pest of vegetable crops *i.e.* Root-Knot Nematodes, Reniform Nematodes, Lesion Nematodes, Cyst Nematodes, Lance Nematodes and Stem and Bulb Nematode (Anonymous, 2017).

One of the major obstacles to the production of adequate supplies of food in many developing nations is damage caused by plant parasitic nematodes, especially the root-knot group, *Meloidogyne* spp. (Sasser, 1980). It is very widely distributed and causes serious damage to crops particularly in vegetables. Worldwide more than 97 known species of root-knot nematode have been recorded and only 14 known species of Meloidogyne are recorded in India. Four species of root knot nematodes *viz*., *Meloidogyne*

Cited as : Singh S.P. (2024). ICAAAS : Nematodes pest emphasizing in vegetables crops and their management in organic and natural farming *ICAAAS–An Edited Book.* Volume-3 : 16-25. Astha Foundation, Meerut (U.P.) India.

indica, M. lucknowica, M. triticooryzae and *M. piperi* have been described from India. Root-knot nematodes (*Meloidogyne* spp.) are one of the potential constraints for cultivation of vegetables particularly in the developing countries of tropics and subtropics. Among vegetable crops, tomato, okra, chilli, brinjal, bottlegourd, snakegroud, bittergourd, cucumber and pumpkin suffered yield losses between 11- 35%, 10-29%, 8-23%, 10-42%, 21-23%, 17%, 13-14%, 6-18% and 13%, respectively due to the infestation of root knot nematodes in different parts of the country (Khan *et al.,* 2014).

According to Khan *et al* (2014), the most predominant species of root-knot nematodes are *Meloidogyne incognita*, *M. javanica*, *M. arenaria* and *M. hapla*. All the species of root-knot nematodes produce a characteristic 'root gall 'or 'knotted root symptom, which could be easily recognized by naked eye. There is hardly any vegetable crop which is not attacked by the root-knot nematodes. Therefore, it has widely been considered as a limiting factor for cultivation of vegetables.

The major hindrance for protecting the vegetable crops from root-knot nematodes are as following :

(i) The lack of awareness among the farmers about the nematode problems.

(ii) Non-availability of suitable package of practices to extension workers for managing the root knot nematodes

(iii) Chemical approach of nematode management is no doubt effective but high doses of nematicides required for managing nematodes are neither economical nor environmentally safe.

The infection of root-knot nematode produces characteristic disease symptoms on the below ground root system popularly known as 'root gall' or 'knotted roots'. Different sizes of galls are induced depending on their host and the species of the nematode involved. On cucurbits, the nematode induces large galls, whereas in chilli small size of galls is produced.

Usually the infection of *M. hapla* produces small galls as compared to *M. incognita* and *M. javanica*. The size of galls also differs with the level of infection as in case of heavy infection large size or multiple galls or secondary galls develops. Besides galling, forking of taproot in carrot and tubercle on potato tubers are also noticed (Khan, 2016).

Above ground symptoms are non-specific in nature. Infected plants exhibit symptoms of general mineral deficiency, yellowing, stunting, wilting during hotter part of the day, chlorosis, premature shedding of leaves and poor look of plants resulting in low yield. The nematodes are also involved in interaction with other soil borne fungi, bacteria, and viruses and cause serious damage to crops. The interaction of root-knot nematodes is known in many vegetables, fibre, pulses and plantation crops. However, the most common problem is the breakdown of disease resistance and wilting of healthy plants. The most common interaction of root knot nematode with *Ralstonia (=Pseudomonas) solanacearum* is causing "Pseudomonas wilt" in tomato, brinjal and potato.

Ecofriendly management of nematode

It is not an easy task under intensive crop cultivation system to manage root-knot nematode. Therefore, the idea of keeping the nematode population below the economic damage level by adopting different available ecofriendly tactics are to be followed. The young seedlings of various crops are very much vulnerable to attack by nematode while the older plants can to some extent tolerate the damage. Following are the strategies which can be followed in organic vegetable cultivation to manage root knot nematodes.

(a) Cultural practices : It involves various strategies such as crop rotations including fallowing, cropping systems, soil solarization during summer, sanitation, use of phyto-therapeutic substances and organic amendments, inter-cropping, age of transplantable nursery, use of antagonistic crops and physical removal of infected plants and burning of infected crop residue after harvest, altering the dates of sowing etc (Khan *et al.,* 2014).

a.i. Crop rotation : It is one of the best methods to reduce the population of root knot nematode in soil. Root knot nematodes usually survive in the soil either in the form of eggs or second stage juveniles (Khan et al., 2014). In the absence of a host plant, the populations of root knot nematode juveniles have been observed to decline by 75% in a period of 3-4 months due to starvation, desiccation, heat etc., if weeds or other hosts are not available. Certain cropping sequences, including non-preferred hosts like mustard, sesame, maize, wheat etc. were found to suppress the nematode population (Haque and Gaur, 1985; Siddiqui and Saxena, 1987). Kanwar (1990) investigated the use of different cropping systems for management of root knot nematode (*M. javanica*). The findings revealed that carrot, chilli, cauliflower, clusterbean, garlic, onion, radish, mustard, wheat, maize and resistant tomato were poor host of this nematode. Out of the 15 cropping sequences studied, tomato-onion- resistant tomato-okra was best in terms of reducing nematode population and giving better economic returns. Gommers et al (1980) described Marigold (*Tagetes* sp.) as a nematode antagonistic crop as its root exudates in the form of á-terthienyl have been found to have

Common name	Scientific name	Important hosts	Damage and brief life cycle
Root-Knot Nematodes	*Meloidogyne* spp	Vegetables belonging to solanaceous crops (brinjal, tomato, chilli), cucurbitaceous (biter ground, cucumber, pumpkin, bottle gourd) leguminous (cowpea, bean, pea), cruciferous cauliflower, cabbage, broccoli, brussels, sprout), okra and several other root and bulb crops (onion, garlic, lettuce, celery, carrot, radish) (Anonymous, 2017)	Root knot nematode damage results in poor growth, a decline in quality and quantity and reduced resistance to other stresses (e.g. drought and other diseases). A high level of root-knot nematode damage can lead to total crop loss. Nematode damaged roots do not utilize water and fertilizers as effectively leading to additional losses for the grower. Below ground symptoms *Meloidogyne* spp. cause severe galling, stunting and chlorosis of crops. The male and female root-knot nematodes are easily distinguishable morphologically. The males are wormlike and about 1.2 to 1.5 mm long by 30 to 36 nm in diameter. The females are pear shaped and about 0.40 to 1.30 mm long by 0.27 to 0.75 mm wide. The life cycle includes egg, juvenile and adult stages. A life cycle is completed in 25 days at 27°C, but it takes longer at lower or higher temperatures. The female lays about 400-500 eggs per in a gelatinous matrix secreted by rectal glands. (Anonymous, 2017)
Reniform Nematodes	*Rotylenchulus reniformis*	Okra, cabbage, sweet potato, cucumber, tomato, squash, radish, brinjal, lettuce (Wang, 2007)	Reniform nematode know kidney-shaped body of the mature female. Reniform nematodes in the genus *Rotylenchulus* are semiendoparasitic (partially inside roots) species in which the females penetrate the root cortex, establish a permanent-feeding site in the stele region of the root and become sedentary or immobile. The anterior portion (head region) of the body remains embedded in the root whereas the posterior portion (tail region) protrudes from the root surface and swells during maturation. Eggs hatch one to two weeks after being laid. The first-stage juvenile molts within the egg, producing the second-stage juvenile (J2) that emerges from the egg. The infective stage is reached one to two weeks after hatching. Once root penetration occurs, one or two more weeks are required for females to reach maturity. The male, which remains outside of the root, can inseminate the female before female gonad maturation. Sperms are stored in the spermatheca. Soon after female gonad maturation, the eggs are fertilized with sperm, and about 60 to 200 eggs are deposited into a gelatinous matrix. The life cycle of this nematode is usually shorter than three weeks, but depends on soil temperature. However, it can survive at least two years in the absence of a host in dry soil through anhydrobiosis, a survival mechanism that allows the nematode to enter an ametabolic state and live without water for extended periods of time (Radewald and Takeshita 1964).
Lesion Nematodes	*Pratylenchus* spp.	Cucumber, okra, tomato (Anonymous, 2017)	The plants show chlorosis, stunting and general lack of vigour resulting into wilt. The plant form patches or zones in the field. The roots show necrosis and lesions which become ideal for infection of other microorganisms. The presence of small brown to black lesions on the root surface is the most important symptoms or damage produced by the lesion nematode. Crop yields are reduced. Both male and female of these nematodes are wormlike, 0.4 to 0.7 mm long and 20 to 25 μm in diameter. They are migratory endo-parasitic nematodes. The life cycle of the various species of *Pratylenchus* is completed within 45 to 65 days. Temperature, soil type, moisture and tillage operations are important environment factors which greatly affect the development and reproduction of nematode species as well as disease development. Reproduction is sexual. Females lay eggs singly in roots or in soil. (Anonymous, 2017)

Common name	Scientific name	Important hosts	Damage and brief life cycle
Cyst Nematodes	*Heterodera* spp. and *Globodera* spp	Cabbages, chinese cabbages, cauliflowers, Brussels sprouts, broccoli, turnip, beets (red and silver), spinach(Anonymous, 2017)	The above ground symptoms resemble these associated with root damage and include stunting of shoot, yellowing of foliage and reduced size of various shoot parts. An experienced observer can often see cyst nematode, *Heterodera* spp. on the roots of their hosts without magnification. The young adult females are visible as tiny white colour. After a female cyst nematode dies, her white body wall is tanned to a tough brown capsule containing several hundred eggs. The mature female bodies are found attached to roots by their head end embedded almost in the stele. The site of feeding is modified into a syncitium similar to that found in case of Meloidogyne spp. On the surface of infected roots, white to brown bodies of females can be discerned with naked eyes. The intensity of body colour depends upon the maturity stage of the young female or cyst. In case of cyst nematode matrix with eggs may also be found attached to the posterior region of the female body. The male is wormlike, about 1.3 mm long by 30 to 40 µm in diameter. Fully developed females are lemon shaped, 0.6 to 0.8 mm in length and 0.3 to 0.5 mm in diameter. Approximately 21-30 days is required for the completion of life cycle of this nematode. (Anonymous, 2017).
Lance Nematodes	*Hoplolaimus* spp.	Mungbean and cluster bean (Gupta and Atwal, 1971, Rashid et al., 1973)	Sometimes they feed at a particular site for a long time with nearly half of the body inside the root system (sedentary ectoparasite). In many cases, juveniles of the lance nematode completely enter the cortical tissue (endoparasite). These symptoms also can be caused by drought or nutrient deficiency. *Hoplolaimus* spp. multiplies slowly in comparison to endoparasitic nematodes but they inflict significant crop damage at a lower level of infection. The availability of feeder roots and temperature are important factors for population build up of this nematode. The nematode acts as a vagrant endoparasite causing root lesions, thickening of cell wall and formation of tunnels in the cortical region.
Stem and Bulb Nematode	*Ditylenchus* spp.	Onion, garlic, potato, pea and carrot etc (Anonymous, 2017)	The symptoms of injury differ from different plants and different parts of the same plant. Infected seedlings become twisted, enlarged and deformed, leading to death of the plant. The plants become stunted. The nematode feeds on stem leaves and bulbs and is rarely found in soil. The nematode is 1.0 to 1.3 mm long and about 30 pm in diameter. The total duration of life cycle ranges from 19-23 days at 15°C with four moults and four Juveniles stages, the first moult being within the egg. (*Anonymous,* 2017).

nematicidal value. Choudhary (1981) also found that inter-cropping of marigold adversely affected root knot nematodes and reduced galling in brinjal when it was planted in association with marigold. It is obvious that crop rotation with non-host crops can restrict the build-up of nematode populations. The okra-cowpea-cabbage and okra-cucumber-mustard sequences showed maximum suppressive effect on M. Incognita in West Bengal conditions (Chandra and Khan, 2011). In potato inter-cropping with onion and maize has been found to reduce galling due to *M. incognita* (Khan *et al.,* 2014).

a.ii. Summer ploughing: Deep summer plowing is used in root knot-infested fields in various parts of India in May and June to expose the nematodes in the soil and affected tissue to solar heat and dehydration. Jain and Bhatti (1987) discovered that this method worked well for controlling the nematodes known as root knots. According to experiments conducted by Gaur and Perry (1991), the combination of soil plowing and polythene sheet mulching resulted in the greatest reduction in the population of M. javanica. This method also inhibits bacteria, fungi, and weeds in the soil.

a.iii. Antagonistic and Trap crops: Some plants are there which release certain root exudates in the rhizosphere having nematicidal values, when inter-cropped with the susceptible crop or grown as cover crop such as African marigold, mustard, sesame and asparagus (Asparagus officinalis) can also help in reducing the population of root knot nematodes (Gaur, 1975; Haque and Gaur, 1985). In the method of trap crop, a highly susceptible crop in the root knot infested filed is intentionally grown to trap the infective juveniles of root knot nematode followed by destroying the trap crop.

a.iv. Altering or shifting time of sowing/planting: Most nematode species are active during warm summer months and can't penetrate roots at soil temperatures below 64°F. Therefore, farmers can reduce nematode injury to fall-planted crops such as carrots, lettuce, spinach, and peas by waiting until soil temperatures have dropped below 64°F. Plant summer vegetables as early as possible in spring before nematodes become active. Plants with larger root systems, even though nematode-infested, might be able to remain productive longer. It is also helpful to remove annual vegetables, including their roots, as soon as harvest is over, to prevent nematodes from feeding and breeding on root systems. In the Netherlands, good quality carrots could be produced in a field infested with *Meloidogyne fallax* when sowing was postponed until June (Molendijk and Brommer 1998). Trutmann et al. (1993) also used a variation of sowing time and sowing density to manage nematodes in French beans. The altering the time of transplanting influences tomato yield and root-knot nematode multiplication on roots (Kumar and Khanna, 2006). The planting tomato during the first week of November in nematode-infested fields of the middle Gujarat region of India is the most suitable planting period for the minimum infection of root-knot nematodes and produces a comparatively high yield, and may offer useful non-chemical options to manage these ubiquitous and damaging nematode (Maru and Patel, 2024).

(b) Phytotherapy and use of organic amendments: Leaf extracts of a number of plants viz. *Allium sativum*, *Calotropis procera*, *Datura stramonium*, *Ricinus communis*, *Xanthium strumarium*, *Mentha viridis*, *Cassia fistula* etc. Have been found to have nematicidal properties (Nath et al., 1982; Haseeb et al., 1982). Sangwan et al (1985) reported Geronoil, citrol and citronellol isolated from essential oils of *Cymbopogon* grasses to have nematicidal properties. Leaves of Neem (*Azadirachta indica*) and Subabool (*Leucaena lucocephala*) used as nursery soil treatment @ 50 q/ha in tomato gave better seedling growth and reduced galling (Jain and Bhatti, 1983; Jain et al., 1988; Mojumder and Mishra, 1993). Green manuring with legumes have been adopted by the farmers to add organic matter in the soil and to improve the nitrogen status of the soil. This practice also helps in suppressing the population of plant parasitic nematodes perhaps by adding organic matter into the soil, thereby favouring the build-up of natural enemies, besides enhancing crop tolerance to nematodes (Khan *et al,* 2014).

Crop residues, farm yard manures (FYM), animal manures, poultry litter, etc. are the typical examples of soil amendments used for management of root knot nematodes. Among the concentrated organic amendments, neem cake not only provides nitrogen in slow-releasing form but also helps in controlling soil-borne plant parasitic nematodes (Khan *et al.,* 2014). Seed treatment with neem seed kernel powder @ 5-10 g/kg seed in combination with bioagents (*Trichoderma viride*, *Pseudomonas fluorescens*) or latex of *Calotropis procera* @ 1% (v/w) have been found to be effective against root knot nematode (Anonymous, 2012). The FYM application in sufficient quantities has been found to be beneficial not only in preventing build-up of nematode population but also due to induction of tolerance in plants to sustain the damage by root knot nematodes. The practice of rabbing tobacco nursery beds with paddy husk has been found effective against root knot nematodes (Krishnamurthy et al., 1969). In addition to these, organic amendments like sewage sludge, spent compost, distillery sludge and vermicompost etc. has been found to be effective for management of plant parasitic nematodes (Sundararaju, *et al.,* 2002).

(c) Resistant varieties/cultivars : In integrated management of root knot nematodes, resistant varieties play an important role.

Some of the resistance varieties exhibited resistance or tolerance reaction to root-knot nematodes as mentioned by Khan (2016) are as given below :

Tomato	:	SL-120, Hisar Lalit, PNR-7, Hisar N-1, Hisar N-2, Hisar N-3, NT-3, NT-8 NT-12, Ronita, Patriot, PAU-5, Mangla and Karnataka Hybrids
Chilli	:	Pusa Jawala, CAP-63, CA-2057, Sindhuri, NP-46 A, Mohini, SP-26, P-6-3, K-235
Brinjal	:	Giant of Banaras, Black beauty, Gola, Gachha Baigan, Pbr-91-2, IC-95-13, HOE-101, Red Wonder
Cowpea	:	Barasati mutant, 82-IB, C-152, IHR-29-5, GAU-1
Pea	:	B-58, C-50
Potato	:	Kufri Dewa
Okra	:	Kanki local green, Harichickni,Vaishali Badher
Pumpkin	:	Dasna, Jaipuri
Water melon	:	Shahjanpuri
Ridge gourd	:	Panipati

(d) Biological Control : To manage the root knot nematodes in organic agriculture, the major emphasis these days is on the biological means. The use of biocontrol agents (BCAs) for effective nematode

Root-knot nematode infected tomato plant shows yellowing of leaves, stunted growth and galls on roots.

Root-knot nematode infected tomato roots

Root-knot nematode infected tomato roots.

Root-knot nematode infected pointed guard roots.

Healthy and Root-knot nematode infected okra plant

Root-knot nematode infected roots of brinjal

management offers economical long lasting and eco-friendly management options.

Among the endozoic fungi, *Moniliales*, *Acrostatagmus*, *Harposporium* and *Meria* are frequently encountered in crop field and have been cultured axenically. Some endozoic fungi like *Meria contospora*, *Hirsutella rhossiliensis* and few members of *Verticillium* and *Cephatosporium* produce adhesive spores, whisch get firmly attached to nematode cuticle, produce germ tube and finally penetrate into nematode body and destroy body contents (Khan *et al.,* 2014).

Among the facultative egg parasitic fungi, *P. lilacinusis* (*Paecilomyces lilacinus/ Purpureocillium lilacinum*) one of most effective and successful biocontrol agents, commercialised as ‘Yorker’/ ‘Bionematon’ in India for several nematodes including root knot nematodes in vegetables (Khan and Goswami, 2002; Verdejo-Lucas *et al.,* 2003; Goswami *et al.,* 2006).

The filamentous fungi, *Trichoderma* spp. has been reported to be an effective bioagent for the management of root knot nematodes infesting vegetable and other crops (Windham *et al.,* 1989; Rao *et al.,* 1998; Haseeb and Khan, 2012). Sharon *et al* (2001) obtained reduced root galling on tomato by *M. javanica* after soil preplant treatment with a peat bran preparation of *Trichoderma harzianum* Rifai. According to Sahebani and Hadavi (2008), *T. harzianum* BI showed two main suppression mechanisms against nematode as direct parasitism of eggs through increase in extracellular chitinase activity and inducing plant defense mechanisms leading to systemic resistance.

According to Khan *et al* (2014), *Pasteuria* sp. among the various bacteria, is widely and effectively used for biocontrol of nematodes. *P. penetrans* is an obligate, ubiquitous soil bacterium. Widespread and natural infection of phytopathogenic nematode is well known in agricultural fields. Somasekhar and Gill (1991) studied the effects of application of *P. penetrans* and carbofuran alone and in combination on *M. incognita*. Application of the bacterium and nematicide alone and in combination (half of their individual dose) significantly reduced gall formation by *M. incognita* and improved plant growth character of tomato cv. Pusa Ruby seedlings. Application of *P. penetrans* alone followed by combined application of *P. penetrans* and carbofuran recorded maximum reduction in galling and improvement in plant growth characters.

Pseudomonas fluorescens and other rhizospheric bacteria (viz. *Azotobacter chroococcum* and *Gluconacetobacter diazotrophicus*) have been investigated for their antagonistic effects causing decreased nematode infestation in soil ecosystem (*Khan et al., 2014*). Seed treatment with *P. fluorescens* alone or nursery treatments with *P. chlamydosporia* proved effective against root knot nematodes (Santhi and Sivakumar 1995; Rao *et al.,* 2004).

(e) Natural Farming inputs : The natural farming inputs like *Neemastra*, *Agniastra* and *Brahmastra* are prepared by proper fermentation therefore, we kept the container in the shaded area and also covered it by gunny bags. The main components, cow urine and cow dung were common in all the natural farming inputs, that enhancing the fermentation process and release more amount of ammonia and other gases. That may affect root-knot nematodes and reduce Root Knot/gall Index (RKI). Several studies have shown that when organic amendments applied in soil, especially those with high nitrogen/carbon ratios, have been reported to exhibit nematicidal and fungicidal activity, mainly through the release of ammonia from the amendments during their decomposition in the soil or through increased populations of antagonistic microorganism (Rodrý´guez-Ka´ bana, 1986; Rodrý´guez-Ka´bana *et al*., 1987; Spiegel *et al*., 1987; Oka *et al*., 1993). These ammonia concentrations were probably high enough to account for the control of nematodes (Oka and Pivonia, 2002; Tenuta and Lazarovits, 2002; Ben-Yephet *et al*., 2005; Oka *et al*., 2006). The cow urine (93.76%) @ 10% concentration was most effective for the juvenile mortality of *M. incognita* followed by *Agniastra* (91.81%) at 2% concentration (Gupta *et al*. 2020). Whereas the egg hatching inhibition of *M. incognita* was found effective in cow urine (75.00%) followed by *Agniastra* at 2%. The neem leaf extract alone accounted for maximum per cent juvenile mortality of *M. incognita* after 72 h (Feyisa *et al.* 2016). *A. indica* was an effective inhibitor of egg hatch of root-knot nematode *Meloidogyne incognita* (Adegbite, 2011). The leaf extract of *Azadirachta indica* extract was the most effective in preventing egg hatching (Haroon *et al.* 2018). *Azadirachta indica* accounted for maximum egg hatch inhibition over the control (Ladi *et al.* 2019). The Drenching *Agniastra,* 800 mL/10 L water gave a maximum reduction of RKI and was superior over all the treatments. Because it contains neem leave paste, garlic paste, green chili paste and tobacco dust that may responsible to minimizing the RKI (Maru *et al.,*2021; Chaudhari and Maru, 2023). The tobacco dust having nematicidal action of nicotine and organic acids are very well reported by several scientists (Davis and Rich, 1987; Rich *et al*., 1989; Yu and Potter, 2008; Desai *et al*., 1972).

References

1. Adegbite A.A. (2011). Effects of some indigenous plant

extracts as inhibitors of egg hatch in root-knot nematode (*Meloidogyne incognita* race 2). *American Journal of Experimental Agriculture,* 1(3): 96-100.

2. Anonymous (2012). Consolidated Annual Report, AICRP (Nematodes) (R.K. Jain, A.U. Singh, V. Kumar, eds.), P.C. Cell, Division of Nematology, IARI, New Delhi. pp.160.
3. Anonymous (2017). http://www.biologydiscussion.com/plants/plant-diseases/6-major-types-of-nematodes-pests-of-vegetable-crops/43272. Article Shared by Shivani R. (visited on 24-07-2007)
4. Ben-Yephet Y., Tsror L., Reuven M., Gips A., Bar Z., Einstein A., Turjeman Y., and Fine P. (2005). Effect of Ecosoil and NH4 in controlling soilborne pathogens. *Acta Hortic*., 698: 115–121.
5. Chandra B. and Khan M.R. (2011). Dynamics of soil nematodes in vegetable based crop sequences in West Bengal, India. *J.Pl. Prtoec. Res.,* 51: 7-13.
6. Chaudhari D.R., and Maru A.K. (2023). Effect of natural inputs against root-knot nematode (*M. incognita*) on potato in pot conditions. *International Journal of Pharmaceutical Research and Applications,* 8(5): 354-363. DOI: 10.35629/7781-0805354363
7. Chaudhary B.S. (1981). In: *Proc. Third. Imp. Res. Plan. Conf. on Root-knot nematodes*. Region VI Jakarta, Indonesia, pp. 142–145.
8. Davis E.L. and Rich J.R. (1987). Nicotine content of tobacco roots and toxicity to *Meloidogyne incognita J. Nematol.,* 19: 23-29.
9. Desai M.V., Shah H.M. and Pillai S.N. (1972). Effect of *Aspergillus niger* on root-knot nematode *Meloidogyneincognita*. *Indian J. Nematol.,* 2(2): 210-214.
10. Feyisa B., Lencho A., Selvaraj T. and Getaneh G. (2016). Evaluation of some botanicals and *Trichoderma hazrianum* against root-knot nematode (*Meloidogyne incognita* (Kofoid and White) Chitwood) in tomato. *Journal of Entomology and Nematology,* 8(2): 11-18.
11. Gaur H.S. and Perry R.N. (1991). The biology and control of the plant parasitic nematode, *Rotylenchulus reniformis*. Pp. 177-211, In: *Agricultural Zoological Review* Vol.-4.(K. Evans, ed.), Intercept Ltd., UK.
12. Gaur H.S. (1975). Crop damage in relation to the density of nematode population and an integrated approach of nematode population management. *Ph.D Thesis, IARI,* New Delhi, 184p.
13. Gommers F.J., Bakker J. and Smith L. (1980). Effect of singlet oxygen generated by the nematicidal compound –terthienyl from Tagetes on the nematode *Aphelenchus avenae*. *Nematologica,* 6: 369–375.
14. Goswami B.K., Pandey R.K., Rathour K.S., Bhattacharya C. and Singh L. (2006). Integrated application of some compatible biocontrol agents along with mustard oil seed cake and furadan on *Meloidogyne incognita* infecting tomato plants. *J. Zhejiang Univ. Sci.,* 7: 873–875.
15. Gupta H., Kumar S. and Sharma R. (2020). Eco-friendly management of root-knot nematode, *Meloidogyne incognita* (Kofoid & White) chitwood using seed kernel extracts, cow urine and agniastra. *Journal of Entomology and Zoology Studies,* 8(2): 1115-1118.
16. Gupta J.C. and Atwal A.S. (1971). Biology and ecology of *Hoplolaimus indicus* (Hoplolaiminae : Nematoda). II. The influence of various environmental factors and host plants on the reproductive potential. *Nematologica,* 17: 277-284.
17. Hallmann J., Frankenberg A., Paffrath A. and Schmidt H. (2007). Occurrence and importance of plant-parasitic nematodes in organic farming in Germany. *Nematology,* 9: 869-879.
18. Haque M.M. and Gaur H.S. (1985). Effect of multiple cropping sequences on the dynamics of nematode population and crop performance. *Indian J. Nematol.,* 15: 262–263.
19. Haroon S.A., Hassan B.A.A., Hamad F.M.I. and Rady M.M. (2018). The efficiency of some natural alternatives in root-knot nematode control. *Advances in Plants and Agriculture Research,* 8(4): 355-362.
20. Haseeb A. and Khan M.R. (2012). Prospects of *Trichoderma* in nematode management, Pp.42-56. In: *Status and prospects for enhancing the uptake of antagonistic organisms for nematode management in India* (Nagesh, M., Rajkumar, B.S., Bhumannavar, N.K. and Krishna Kumar, eds.), NBAII (ICAR), Bangalore, India, 187p.
21. Haseeb A., Khan A.M. and Saxena S.K. (1982). Toxicity of leaf extracts of plants to root-knot and reniform nematode. *Indian J. Parasitol.,* 6: 119–120.
22. Jain R.K. and Bhatti D.S. (1983). A note on seed treatment with systemic for the control of *Meloidogyne javanica* in okra. *Haryana J. Hort. Sci.,* 12: 143–144.
23. Jain R.K. and Bhatti D.S. (1987). Population development of root-knot nematode (Meloidogyne javanica) and tomato yield as influenced by summer ploughings. *Tropical Pest Manage* 33: 122–125.
24. Jain R.K., Mathur K.N. and Singh R.V. (2007). Estimation of losses due to plant parasitic nematodes of different crops in India. *Indian Journal of Nematology,* 37: 219-221.
25. Jain R.K., Paruthi I.J. and Bhatti D.S. (1988). Control of

root-knot nematode (*Meloidogyne javanica*) in tomato through nursery bed treatment alone and in combination with application of carbofuran at transplanting. *Indian J. Nematol.,* 18: 340–341.

26. Kanwar R.S. (1990). Studies on cropping systems for management of root knot nematode, *Meloidogyne javanica* (Trueb, 1885) Chitwood, 1949, *Ph.D. Thesis*, *HAU,* Hisar, India, 118p.
27. Khan M.R. and Goswami B.K. (2002). Evaluation of *Paecilomyces lilacinus* isolate 2 against *Meloidogyne incognita* infecting tomato, *Int. J. Nematol.,* 12: 111–114.
28. Khan M.R., Jain R.K., Ghule T.M. and Pal S. (2014). Root knot Nematodes in India-a comprehensive monograph. All India Coordinated Research Project on Plant Parasitic nematodes with Integrated approach for their Control, *Indian Agricultural Research Institute,* New Delhi.
29. Khan M.R. (2016). https://www.firefoods.co.uk/current-options-for-managing-nematodes-pest-of-crops-in-india-2/ (visited on 23.07.2017).
30. Krishnamurthy G.V.G., Elias N.A., Chandwani G.H. and Reddy N.S. (1969). Studies on root knot control on tobacco in Hunsur (Mysore State) and Rajamundry (Andhra Pradesh). Pp. 42-43. In: *Abstracts of All India Nematology Symposium*, August 21-21, 1969, IARI, New Delhi, India.
31. Kumar S. and Khanna A.S. (2006). Influence of transplant spacing and planting date on fruit yield, plant status of tomato and population development of *Meloidogyne incognita. Nematol. Medit.,* 34: 135-140
32. Ladi B.Y., Muhammad A.K., Joy B., Alake N.M. and Sarah O.J. (2019). Inhibitory effect of neem (*Azadirachta indica*) and moringa (*Moringa oleifera*) leaf extracts on egg hatch of root-knot nematode *Meloidogyne incognita*. *World Journal of Advances Research and Review*, 1(2): 28-33.
33. Maru A.K., Thumar R.K. and Prajapati M. (2021). Evaluation of *Neemastra, Agniastra* and *Brahmastra* for the management of root-knot nematodes, *Meloidogyne* spp. in tomato. *Environment and Ecology*, 39 (4A): 1144-1149.
34. Maru A.K., Patel B.A. (2024). Field study on the effect of different planting periods on root-knot nematodes, Meloidogyne spp. infecting tomato. *Indian Phytopathology*, https://doi.org/10.1007/s42360-024-00781-7
35. Mojumder V. and Mishra S.D. (1993). Management of nematode pests. Pp. 40-48. In: *Neem in Agriculture*, IARI, Res. Bull., No. 4 (Parmar, B.S. and R.P. Singh, eds.), New Delhi, India.
36. Molendijk L.P.G. and Brommer E. (1998). Postponement of sowing reduces quality damage in carrots (*Daucus carota*) caused by *Meloidogyne fallax.* Proceedings 5th International Symposium on Crop Protection, Gent, Belgium, 5th May, 1998. Part II. Mededelingen Faculteit Land Bouwk Undige entoegepaste Biologische Wetenschappen, Universiteit. *Gent.,* 63(2b): 655-658.
37. Nath A., Sharma N.K., Bhardwj S. and Thapa C.D. (1982). Nematicidal properties of garlic. *Nematologica,* 28: 253–255.
38. Oka Y., Chet I. and Spiegel I. (1993). Control of the root-knot nematode *Meloidogyne javanica* by Bacillus cereus. *Biocontrol Sci. Technol*., 3: 115–126.
39. Oka Y., Shapira N. and Fine P. (2007). Control of root-knot nematodes in organic farming systems by organic amendments and soil solarization. *Crop Protection,* 26(10): 1556-1565.
40. Oka Y., Tkachi N., Shuker S., Rosenberg R., Suriano S. and Fine P. (2006). Laboratory studies on the enhancement of nematicidal activity of ammonia-releasing fertilisers by alkaline amendments. *Nematology*, 8: 335–346.
41. Radewald J.D. and Takeshita G. (1964). Desiccation studies on five species of plant-parasitic nematodes of Hawaii. *Phytopathology,* 54: 903-904.
42. Rao M.S., Naik D. and Shylaja M. (2004). Biointensive management of root-knot nematodes on bell pepper using *Pochonia chlamydosporia* and *Pseudomonas fluorescens*. *Nematol. Medit.,* 32:159–63.
43. Rao M.S., Reddy P.P. and Nagesh M. (1998). Evaluation of plant based formulations of *Trichoderma harzianum* for management of *Meloidogyne incognita* on egg plant. *Nematol. Medit.,* 26: 59–62.
44. Rashid A., Khan F.A. and Khan A.M. (19730. Plant parasitic nematodes associated with vegetables, fruits, cereals and other crops in North India. I. Uttar Pradesh. *Indian J. Nematol.,* 3: 8-23.
45. Rich J.R., Rahi G.S., Opperman C.H. and Davis E.L. (1989). Influence of castor bean (*Ricinus communis*) Lectin (Ricin) on mortality of *Meloidogyne incognita. Nematotropica*.19: 99-103.
46. Rodrý´guez-Ka´ bana R., Morgan-Jones G. and Chet I. (1987). Biological control of nematodes: soil amendments and microbial antagonists. *Plant Soil*, 100: 237–247.
47. Rodrý´guez-Ka´ bana R (1986). Organic and inorganic amendments to soil as nematode suppressants. *J. Nematol*. 18, 129–135.
48. Sahebani N. and Hadavi N. (2008). Biological control of the root-knot nematode *Meloidogyne javanica* by *Trichoderma harzianum*. *Soil Biol. Biochem.,* 40: 2016–2020.
49. Sangwan N.K., Verma K.K., Verma B., Malik M.S. and

Dhindsa K.S. (1985). Nematicidal activity of essential oils of Cymbopogon grasses. *Nematologica,* 31: 93–99.

50. Santhi A. and Sivakumar C.V. (1995). Biocontrol potential of *Pseudomonas fluorescens* (Migula) against root-knot nematode, *Meloidogyne incognita* (Kofoid and White, 1919) Chitwood, 1949 on tomato. *J. Biol. Contr.,* 9: 113-115.
51. Sasser J.N. (1980). Root-knot nematodes: A global menace to crop production. *Pl. Dis.,* 64: 36–41.
52. Sharon E., Bar-Eyal M., Chet I., Herrera-Estrella A., Kleifeld O. and Spiegel Y. (2001). Biological control of the root-knot nematode *Meloidogyne javanica* by *Trichoderma harzianum*. *Phytopathology,* 91: 687–93.
53. Siddiqui M.A. and Saxena S.K. (1987). Effect of interculture of margosa and Persian lilac with tomato and egg plant on root knot and reniform nematode. *Int. Nematol., Netw. Newsl,* 4: 5–8.
54. Somasekhar N. and Gill J.S. (1991). Efficacy of *Pasteuria penetrans* alone and in combination with carbofuran in controlling *Meloidogyne incognita*. *Indian J. Nematol.,* 21: 61–65.
55. Spiegel Y., Chet I. and Cohn E. (1987). Use of chitin for controlling plant parasitic nematodes. II. Mode of action. *Plant Soil*, 98: 337–345.
56. Sundararaju P., Cannayane I. and Ramesh R. (2002). Penetration and development of *Pratylenchus coffeae* and *Meloidogyne incognita* in susceptible cultivars of Banana, Pp. 189. In: *Abstracts of National seminar of Nematological Research in India* at C.S. Azad and University of Agric. and Tech. Kanpur, India.
57. Tenuta M. and Lazarovits G. (2002). Ammonia and nitrous acid from nitrogenous amendments kill the microsclerotia of *Verticillium dahliae*. *Phytopathology,* 92: 255–264.
58. Trutmann P., Voss J. and Fairhead J. (1993). Management of common bean diseases by farmers in the Central African Highlands. *Int. J. Pest Manag.,* 39(3): 334-342.
59. Van Bruggena A.H.C. and Termorshuizen A.J. (2003). Integrated approaches to root disease management in organic farming systems. *Australasian Plant Pathology,* 32(2): 141-156.
60. Verdejo-Lucas S., Sorribas F.J., Ornat C. and Galeano M. (2003). Evaluating *Pochonia chlamydosporia* in a double-cropping system of lettuce and tomato in plastic houses infested with *Meloidogyne javanica*. *Pl. Pathol.,* 52: 521–528.
61. Wang K. (2007). Reniform Nematode, *Rotylenchulus reniformis* Linford and Oliveira (Nematoda: Tylenchida: Tylenchoidea: Hoplolaimidae: Rotylenchulinae). EENY-210 (IN367). Entomology and Nematology. Florida Cooperative Extension Service. University of Florida IFAS. Published 2001, revised 2007.
62. Windham G.L., Windham M.T. and Williams W.P. (1989). Effects of *Trichoderma* spp. on maize growth and *Meloidogyne arenaria* reproduction. *Pl. Dis.,* 73: 493–494.
63. Yu and Potter J.W. (2008). Selective nematicidal activity of nicotine. *Journal of Food, Agriculture and Environmental,* 6: 428-432.

Website : www.asthafoundation.in
ICAAAS–An Edited Book (Volume-3)
ISBN : 978-81-958010-7-7
Published by : Astha Foundation, Meerut (U.P.) India
Edition-2024

Chapter 3

Biostimulant : A Viable Path to a Greener Future and Sustainable Agriculture

Nirupma Singh[1]*, Kajal Nagre[1], Ajay Setia[2] and S.P. Singh[3]
[1]Division of Genetics, ICAR-Indian Agricultural Research Institute, Pusa Campus, New Delhi
[2]Yara Fertilizers India Pvt. Ltd., Gurugram, Haryana-122003, India
[3]CSAUAT–Agrticulture Research Station, Kalai Aligarh, U.P.
[*]Corresponding Authour Email : nirupmasingh@rediffmail.com

Natural plant biostimulants (PBs) have attracted a lot of attention attention (Yakhin *et al.;* (2017), Crouch *et al.;* 1993, Bulgari, *et al.;* (2015). Biostimulants provide a potentially innovative method for controlling or altering physiological processes in plants to promote growth, reduce stress-related restrictions, and boost output. Determining whether the effects of biostimulants are direct or mediated by microbes will ultimately be crucial for the advancement of this technology. According to Herve *et al*. 1994, Huang *et al*. 2007, and Basak *et al*. 2008 biostimulants are subgroups of growth regulators, plant growth regulators, and bioregulators. According to Bulgari *et al.* (2015), biostimulants may have minute amounts of natural plant hormones, but their biological effects should not be attributed to regulators; otherwise, they must be registered as plant growth regulators, Like how they cannot be pesticides or fertilizers, by their mode of action (Russo and Berlyn *et al;* 1991; Karnok *et al;* 2000; Hamza and Suggars *et al;* 2001; Banks and Percival *et al;* 2012; Du *Jardin et al;* 2012; Torre *et al;* 2013, 2016).

Biostimulant is defined as "naturally or biologically derived substances that, when applied to plants, seeds, or root environments, stimulate the natural biological processes that benefit the Nutrient Used Efficiency (NUE), resilience to abiotic and biotic stresses, regardless of their nutrient composition," according to the Traon *et al*. 2014. According to the research's findings and observations, several terminologies have been documented. Biostimulants are natural substances that could potentially be used in plants, seeds, and soil. Increasing abiotic stress tolerance and boosting seed yield and performance in terms of seed vigor and field emergence cause changes in the essential and cellular systems that govern plant growth. They also lessen the demand for fertilizers (Rouphael *et al;* 2018). These substances have the potential to enhance plant growth but are not classified as fertilizers, pesticides, or soil amendments (Kunicki *et al;* 2010).

Figure 1 : Graphical representation of the biostimulant impact on human/animal and plant growth and development.

Biostimulants India Market Analysis

With a compound annual growth rate (CAGR) of 10.42% (Fig.-2), the size of the Indian biostimulants market is projected to reach USD 171.11 million in 2023 and USD 310.14 million by 2029. A wide range of biostimulants, including humic acid, fulvic acid, amino acids, protein hydrolysates, seaweed extracts,

Cited as : Singh S.P. (2024). ICAAAS : Biostimulant : A viable path to a greener future and sustainable agriculture. *ICAAAS–An Edited Book.* Volume-3 : 26-32. Astha Foundation, Meerut (U.P.) India.

chitosan, biopolymers, and other biostimulants like plant and animal derivatives, are employed as active components in the Indian biostimulants market. The market for biostimulants in India increased by 15.7% between 2017 and 2022, with a valuation of USD 153.2 million. With a market value of USD 57.2 million in 2022, seaweed extract biostimulants hold the most market share in the Indian biostimulants industry, accounting for 37.4% of the total. This is because they have the power to enhance the plant's overall health as well as its capacity to increase crop output, stress tolerance, root growth, nutrition and water intake, and plant growth. In 2022, row crops made up 86.2% of the market value for biostimulants. This is because, in 2022, row crops made up about 82.3% of all organic cropland in the nation. In 2022, cash crops and horticultural crops will hold respective shares of 11.2% and 2.6% of the biostimulants market.

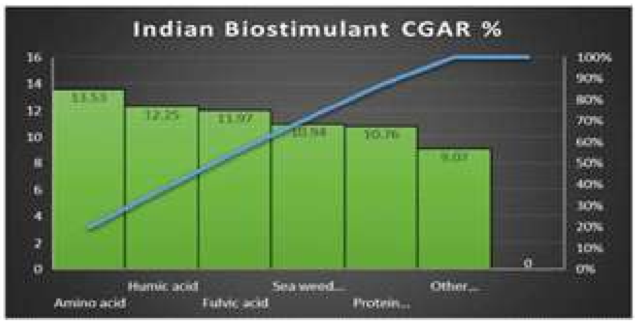

Figure-2 : Indian Biostimulant CGAR %.

The National Horticulture Mission, Horticulture Mission for North East and Himalayan States, Rashtriya Krishi Vikas Yojana, National Project on Management of Soil Health and Fertility, National Project on Organic Farming, Network Project on Organic Farming under Indian Council of Agricultural Research, and Paramparagat Krishi Vikas Yojana are just a few of the programs the Indian government is using to encourage the production of organic crops, fruits, and vegetables in response to the growing demand for organic food items (https://www.marketsandmarkets.com/Market-Reports/biostimulantmarket1081.html#:~:text=The%20global%20biostimulants%20market%20was,11.8%25from%202022%20to%202027). These programs would increase the market for biostimulants in India.

Modern Farming : Role of Biostimulants in Agriculture

Modern farming relies heavily on biostimulants, which are cutting-edge agricultural agents that improve plant growth, development, and general health. These chemicals, different from pesticides and fertilizers, are made to increase plant productivity, nutrient uptake, stress tolerance, and disease resistance. Due to their ability to boost crop yields while lowering the dependency on chemical inputs, biostimulants have grown in popularity in sustainable agriculture .

The primary roles of biostimulants in contemporary farming are as follows:

1. Nitrogen efficiency : Enhancing the efficiency of nitrogen uptake by plants is one benefit of biostimulants. They encourage the growth of root systems, enabling plants to acquire nutrients from the soil more successfully. Alfalfa hydrolysate (AH) and red grape extract (RG) were tested on the growth and nitrogen metabolism of Capsicum chinensis pepper plants by Ertani *et al.* (2014). Previous studies (Calvo *et al;* 2014, Rose *et al;* 2014) have found evidence that biostimulants may improve macronutrient intake. These studies attribute this evidence to an influence on sink activity or stimulation of nitrogen metabolism. It was significantly improved by the foliar application of a biostimulant produced from microbial fermentation of cereal grains in sunflowers (Tian *et al;* 2015).

2. Increased Stress Tolerance : Biostimulants can aid plants in surviving a variety of environmental challenges, including salinity, heat, and drought. They increase a plant's resistance to stress by causing the development of proteins and enzymes that are connected to stress. According to reports, biostimulants also raise levels of free amino acids, protein, carbs, phenolic compounds, pigment, and other enzymes Numerous biostimulants have been shown to have protective effects against biotic and abiotic stresses. These effects have been linked to decreased levels of stress-related reactive oxygen species, activated antioxidant defense mechanisms in plants, or elevated levels of phenolic compounds (Ertani *et al;* 2011, Ertani *et al;* 2015).

Abiotic Stress : It is challenging to pinpoint and is currently being researched on what pathways are triggered by biostimulants in response to stressful situations. The metabolic pathways that biostimulants activate may become intensified under stressful circumstances, enabling the plants to adapt and either avoid or postpone the most difficult situations (Van *et al;* 2017). It is interesting to note that metabolites with antioxidant characteristics frequently increase in plants exposed to biostimulants. It is generally recognized that these anti-oxidant compounds play a crucial part in minimizing the damaging effects of free radicals that build up in plant tissues during stressful situations. Several growth-promoting features were discovered when various halotolerant PGPR (Bacillus spp.) isolates from the rhizosphere of durum wheat grown in hypersaline settings were characterized (Verma *et al;* 2018). These PGPR strains can be combined in various ways to enhance mungbean's plant development characteristics. The scientists concluded that certain strains, including Bacillus sp. BHUJP-H1 and Bacillus sp. BHUJP-H2 can be employed as PGPRs in open fields that are drought-resistant. By improving transpiration use efficiency, it was discovered that the use of a legume-based Protein hydrolysate (PH) (including amino acids and soluble peptides), as foliar and particularly as drench substrate, can reduce the detrimental impacts of drought in tomatoes produced in controlled environments. As a result of the biostimulant treatment, the metabolomic technique used in this study enabled the identification of the molecular mechanisms of increased drought tolerance, including

(i) improved resistance to ROS-mediated

(ii) modification of phytohormones and lipid profiles.

It has also been found that microbial biostimulants based on AMF help tomato plants tolerate drought stress. The effects of the two arbuscular mycorrhizal fungi (AMF) strains *Funneliformis mosseae* and *Rhizophagus intraradices* on the physiological and molecular responses of tomatoes were assessed in the study by Volpe *et al.* 2018.

The study discusses the effects of biostimulants, such as chitosan, on the tolerance of artichoke and cardoon plants to saline stress, which indirectly enhances their resistance to biotic stresses (Elsharkawy et al; 2017). This research investigates how a combination of chitosan (a biostimulant) and Trichoderma species enhances resistance to Phytophthora capsici, a common pathogen in cucumbers.

Biotic Stress : Biostimulants have been found to play a significant role in improving the tolerance of crops to biotic stresses. They are natural or naturally derived substances that can enhance a plant's tolerance to various biotic stresses, including pests and pathogens. They do so by stimulating plant defense mechanisms, improving nutrient uptake, and promoting overall plant health. These biotic stresses include various pests, diseases, and other harmful organisms that can negatively impact crop health and yield.

Using biostimulants can enhance the resistance of plants to these harmful elements by stimulating certain activities like enhancing nutrient uptake, increasing photosynthesis, promoting hormone production, and stimulating the activity of soil enzymes and rhizosphere microorganisms (Niewiadomska *et al;* 2019). These activities collectively contribute to the overall improvement in plant health and resilience, allowing them to better withstand biotic stresses.

3. Improved Nutrient Absorption : Biostimulants can help increase crop yields and produce of higher quality by encouraging improved nutrient absorption and stress tolerance. Rouphael *et al.;* 2018 reported on the advantageous effects of tiny bioactive compounds (500 Da), such as omeprazole (OMP), a benzimidazole inhibitor of animal proton pumps. The root system architecture of salt-stressed tomato plants treated with 10 or 100 uM of OMP as a substrate drench was altered in terms of total length and surface, which increased nutrient uptake and biomass output. OMP had a significant impact on the hormonal network, causing an increase in ABA, a decrease in auxins and cytokinin, as well as a tendency for GA to accumulate less.

4. Improved Photosynthesis and Metabolism : Biostimulants may speed up photosynthesis and promote plant metabolism, resulting in greater growth and productivity. The study's findings demonstrated that tobacco plants exposed to Cladosporium sphaerospermum continued to develop at faster rates, and these increased rates of growth were linked to several hypothesized physiological and molecular mechanisms, including cell division and cycle, photosynthesis, phytohormone homeostasis, and defensive responses (Li *et al;* 1959).Numerous compounds containing sugars, phenols, and quarternary nitrogen showed significant, dose-dependent alterations. The advantage was less pronounced when there was a lack of nutrients, but rubidium uptake which is like K uptake rose significantly. A distinct response to the use of a biostimulant based on nitrophenols (Przybysz *et al;* 2014) was observed to have uneven growth benefits in non-stressed growth circumstances and large and consistent growth and photosynthetic improvements under drought and heavy metal stress (platinum). Like this, Wu *et al.* 2018 showed that exogenous treatment of 5-aminolevulinic acid reduced the toxicity of NaCl in cucumber seedlings by enhancing chlorophyll synthesis, light harvesting capability, photosynthetic capacity, and delaying thylakoid breakdown.

5. Root Growth and Development : Biostimulants can promote branching and root growth, resulting in a deeper and more substantial root system. Better water and nutrient uptake is supported by a robust root system, which benefits the overall health of the plant. The physiological and metabolomic responses to a biopolymer-based biostimulant containing lateral root stimulating peptides and lignosulphonates as well as micronutrients were also examined in a short-term experiment on melon by Lucini *et al.* 2018. In comparison to 0.06 ml plant^{-1} and untreated melon plants, the root trait parameters (total root length and surface area) in biostimulant-treated plants were significantly increased at 0.24 ml plant^{-1} and to a lesser extent at 0.12- and 0.48-ml plant^{-1}. Better shoot and root biomass production in treated melon transplants was brought on by both direct and indirect physiological mechanisms. According to Matsumiya and Kubo (2011) the signaling molecules in particular bioactive peptides and lignosulfonates may have activated the signal transduction pathway by stimulating the manufacture of the target endogenous phytohormones. According to Schiavon *et al.* (2008) (69), peptide signaling is crucial for several aspects of plant development and growth regulation, such as meristem organization, leaf morphogenesis, and defense reactions to biotic and abiotic stress. According to research (Matsumiya *et al;* 2011, Colla *et al;* 2014), certain signaling peptides present in a protein hydrolysate derived from plants have been shown to influence plant growth and development, defense reactions, callus growth, meristem organization, root growth, leaf shape regulation, and nodule development. According to research by Lachhab *et al.* (2014), soybean and casein protein hydrolysates can increase grapevine immunity to Plasmopara viticola.

6. Biological interactions : Interactions between living species and helpful microbes in the soil can be facilitated by several biostimulants, which also enhance soil health and nutrient cycling. Bitterlich et al. 2018 demonstrated that in tomato cultures, mycorrhizal plants do indeed exhibit greater water extraction rates per unit root length and biomass, which is a result of AMF-mediated substrate hydraulic characteristics. When the potential soil water flow to root systems was restricting transpiration rates during progressive drought, the alleviation of substrate water flow resistances in AMF pots allowed for increased root extraction rates and maintenance of transpiration. The same group of authors conducted a second study to determine whether AMF substrate colonization under root exclusion is sufficient to alter substrate hydraulic properties because this study showed that enhanced water extraction capacity in mycorrhizal pots was related to the flow of water from the bulk substrates to the root surface (Bitterlich *et al.* 2018). AMF that participated in a functional symbiosis on the substrate stabilized water retention and improved unsaturated hydraulic conductivity. The water depletion zone around roots is essentially expanded by the increased hydraulic conductivity in AMF substrates. The authors concluded that additional research should be done to determine the quantitative impact on plant water uptake as well as the variability of the effect across various soil types.

7. Lessened Environmental Impact : Compared to synthetic chemical inputs, biostimulants are generally regarded as eco-friendly and have less of an environmental impact. It is crucial to remember that biostimulants are not a universally effective solution; rather, their effectiveness might change based on the type of crop, the soil, the environment, and the way it is applied. The availability of biostimulants on the market and how they are used may be impacted by national regulations and classifications of these substances. Many biostimulants contain simple and complex carbohydrates that, when added to plants, may change metabolism by either directly providing energy to populations of endophytic and non-endophytic microorganisms or by serving as signaling molecules. In a review of the nuanced functions of carbohydrates in plant immunity, Trouvelot *et al.* (2014) proposed that carbohydrates trigger defense responses through pathogen-associated molecular patterns (PAMPs), microbe-associated molecular patterns (MAMPS), and damage-associated molecular patterns (DAMPs). The authors examine how the kind of oligosaccharides and degree of polymerization affect biological activity while highlighting the major carbohydrate classes involved in plant immunology (beta-glucans, chitin, and pectin).

Challenges and Prospects of Biostimulants

In addition to agrochemicals like synthetic fertilizers, PBs like natural substances and microbial inoculants appear as a novel and potential category of agricultural inputs, improving tolerance to abiotic stresses as well as improving the quality of agricultural and horticultural commodities. Scientists and businesses are still very interested in characterizing the bioactive components of PBs and understanding the molecular and physiological stimulation mechanisms. The most effective method for creating new biostimulants is to use small, medium, or large high-throughput phenotyping since complex matrices with various groups of bioactive and signaling molecules exist (Rouphael, *et al;* 2018). The use of high-throughput phenotyping and metabolomics together could make it easier to find new bioactive and signalling substances with biostimulant properties and could open a biochemical, morpho-physiological, and metabolomic door to the mechanisms underlying PHs action on tomato. While biostimulants have the potential to completely transform current agriculture

Table : The following are some of the major issues and restrictions with biostimulants.

1.1.	An unclear regulatory framework	Biostimulants are defined and regulated differently in different nations and areas. Manufacturers, farmers, and consumers may experience uncertainty because of the absence of a standardized regulatory framework.
2.2.	Variable Efficacy	Depending on the crop, soil, climate, and application techniques, the efficiency of biostimulants might vary greatly. It can be difficult to choose the best biostimulant and application rate for certain crops and circumstances.
3.3.	Limited Scientific Understanding	Although biostimulants are gaining popularity, our knowledge of their mechanisms of action and operational modes is still developing. To completely understand how various biostimulants interact with plants and the environment, more research is required.
4.4.	Lack of Repeated Data from Rigorous Scientific Trials	Many biostimulant drugs lack repeated, consistent data from rigorous scientific trials to support their efficacy in a variety of settings. This can make farmers and other agricultural experts doubtful.
5.5.	Market Confusion	As interest in biostimulants grows, a wide range of products with various claims have flooded the market. Choosing the best product for their needs from among the many possibilities available may prove difficult for farmers.
6.6.	Compatibility Problems	When used in conjunction with specific fertilizers, insecticides, or other agrochemicals, some biostimulants may not perform as intended. Compatibility problems may make it difficult for them to integrate into current farming techniques.
7.7.	Considerations for Cost-Benefit Analysis	Biostimulants, especially those obtained from unusual or specialized sources, might be more expensive than conventional fertilizers and insecticides. Farmers must carefully weigh the advantages and disadvantages of utilizing biostimulants in their farming systems.

and provide several advantages, they also have some drawbacks that must be considered (Du Jardin *et al;* 2015).

Future thought must be given to the following pertinent issues :

1. Are living cultures of microorganisms that might boost plant growth considered to be biostimulants?

2. Are non-essential components considered biostimulants if they increase plant productivity?

3. How should complicated wholly unexplained structures in biostimulants be registered and regulated in national and international law? All the components and modes/mechanisms involved have not been established.

4. What acceptable standard of efficacy proof will promote innovation while discouraging the selling of useless goods?

5. What criteria, and what categories, should the final classification of biostimulants be based on?

6. Finally, Rouphael and Colla 2018 proposed that soon, the primary PB players (scientists, private industries, legislators, and stakeholders) should concentrate on the development of a second generation of these products (biostimulant 2.0) with specific synergistic bio-stimulatory action through the application of both microbial and non-microbial PBs to make agriculture more resilient and sustainable.

Conclusion

Biostimulants play a crucial role in sustainable agriculture, offering numerous benefits such as improved crop yields, higher-quality output, and plant resistance to environmental stresses. They promote stable agroecosystems, reduce environmental impact, protect biodiversity, and minimize soil and water pollution. Regardless of the local environment, this versatility guarantees that biostimulants can be incorporated into numerous agricultural systems all over the world. Biostimulants are essential for organic farming, allowing farmers to produce more crops while maintaining organic standards. Their versatility allows for customization to suit specific crops and environmental conditions, making them suitable for various agricultural systems worldwide. The future of sustainable agriculture will be shaped by biostimulants, providing a more resilient, ecologically friendly, and environmentally friendly approach to agriculture. To adjust to the local and temporal use of biostimulants in agriculture, monitoring tools for their efficacy are required. It is anticipated that, with the trend towards replacing chemical fertilizers, biostimulants will be used more frequently if the chain of value is well established and the mode of action is further investigated.

References

1. Yakhin O.I., Lubyanov A.A., Yakhin I.A., Brown P.H. (2017). Biostimulants in plant science: A global perspective. *Front. Plant Sci.,* 7: 2049.
2. Crouch I.J. and Van Staden J. (1993b). Evidence for the Presence of Plant Growth Regulators. In Commercial Seaweed Products. *Plant Growth Reg.,* 13: 21-29.
3. Bulgari R., Cocetta G., Trivellini A., Vernieri P. and Ferrante A. (2015). Biostimulants and Crop Responses: A Review. *Biol. Agric. Hortic.,* 31: 1–17. doi: 10.1080/01448765.2014.964649
4. Herve J.J. Biostimulants (1994). a new concept for the future; prospects offered by the chemistry of synthesis and biotechnology. *Comptes Rendus Acad. Agric. Fr.,* 80: 91–102.
5. Basak A. (2008). Biostimulators–definitions, classification and legislation. In Monographs Series: Biostimulators in Modern Agriculture. *General Aspects,* Editor H. Gawrońska, 7–17.
6. Russo R.O., Berlyn G.P. (1991). The Use of Organic Biostimulants to Help Low-Input Sustainable Agriculture. *J. Sustain. Agric.,* 1: 19–42. doi: 10.1300/J064v01n02_04
7. Karnok K.J. (2000). Promises, promises: can biostimulants deliver?. *Golf Course Manag.,* 68: 67–71.
8. Hamza B. and Suggars A. (2001). Biostimulants: myths and realities. *Turf Grass Trends.,* 8: 6–10.
9. Banks J. and Percival G.C. (2012). Evaluation of biostimulants to control Guignardia leaf blotch (*Guignardia aesculi*) of horse chestnut and black spot (*Diplocarpon rosae*) of roses. *Arboric. Urban For.,* 38: 258–261.
10. Torre L.A., Battaglia V. and Caradonia F. (2013). Legal aspects of the use of plant strengtheners (biostimulants) in Europe. *Bulg. J. Agric. Sci.,* 19: 1183–1189.
11. Torre L.A., Battaglia V. and Caradonia F. (2016). An overview of the current plant biostimulant legislations in different European Member States. *J. Sci. Food Agric.,* 96: 727–734. doi: 10.1002/jsfa.7358
12. Traon D., Amat L., Zotz F. and du Jardin P. (2014). A Legal Framework for Plant Biostimulants and Agronomic Fertiliser Additives in the EU-Report to the European Commission; DG Enterprise & Industry: Copenhagen, Denmark.
13. Rouphael Y., Raimondi G., Lucini L., Carillo P., Kyriacou M.C., Colla G. and De Pascale S. (2018). Physiological and metabolic responses triggered by omeprazole improve tomato plant tolerance to NaCl stress. *Front. Plant Sci.,* 9: 249.
14. Kunicki E., Grabowska A., Sêkara A. and Wojciechowska R. (2010). The effect of cultivar type, time of cultivation, and biostimulant treatment on the yield of spinach (*Spinacia oleracea* L.). *Folia Hortic.,* 22: 9–13.
15. Calvo P., Nelson L. and Kloepper J.W. (2014). Agricultural uses of plant biostimulants. *Plant Soil,* 383: 3–41. doi: 10.1007/s11104-014-2131-8
16. Rose M.T., Patti A.F., Little K.R., Brown A.L., Jackson W.R. and Cavagnaro T.R. (2014). A meta-analysis and review of plant-growth response to humic substances: practical implications for agriculture," in Advances in Agronomy, Vol. 124, ed D. L. Sparks (New York, NY: Academic Press), 2014, 37–89.
17. Tian S.K., Lu L.L., Xie R.H., Zhang M.Z., Jernstedt J.A. and Hou D.D. (2015). Supplemental macronutrients and microbial fermentation products improve the uptake and transport of foliar applied zinc in sunflower (Helianthus annuus L.) plants. Studies utilizing micro X-ray florescence. *Front. Plant Sci.,* 6: 87. doi: 10.3389/fpls.2014.00808
18. Ertani A., Francioso O., Tugnoli V., Righi V. and Nardi S. (2011). Effect of commercial lignosulfonate-humate on *Zea mays* L. metabolism. *Journal of Agricultural and Food Chemistry,* 59(22): 11940-11948.
19. Ertani A., Schiavon M., Muscolo A. and Nardi S. (2013). Alfalfa plant-derived biostimulant stimulate short-term growth of salt stressed *Zea mays* L. plants. *Plant and Soil,* 364: 145-158.
20. Van Oosten M.J., Pepe O., De Pascale S., Silletti S. and Maggio A. (2017). The Role of Biostimulants and Bioeffectors as Alleviators of Abiotic Stress in Crop Plants. *Chem. Biol. Technol. Agric.,* 4: 5-10.
21. Verma J.P., Jaiswal D.K., Krishna R., Prakash S., Yadav J. and Singh V. (2018). Characterization and screening of thermophilic Bacillus strains for developing plant growth promoting consortium from hot spring of Leh and Ladakh region of India. *Front. Microbiol.,* 9: 1293.
22. Volpe V., Chitarra W., Cascone P., Volpe M.G., Bartolini P., Moneti G. and Balestrini R. (2018). The association with two different arbuscular mycorrhizal fungi differently affects water stress tolerance in tomato. *Front. Plant Sci.,* 9: 1480.
23. Elsharkawy M.M., Shimizu M., Takahashi H., Hyakumachi M., Hyakumachi M. (2017). Enhancement of resistance to Phytophthora capsici in cucumber plants by combinations of chitosan and *Trichoderma* spp. *Plant Pathol.,* 66(5): 789-798.
24. Niewiadomska A., Sulewska H., Wolna-Maruwka A., Ratajczak K., Waraczewska Z., Budka A. and G³uchowska K. (2019). The influence of biostimulants and foliar fertilisers on the process of biological nitrogen fixation and the level of soil biochemical activity in soybean (*Glycine max* L.) cultivation.

Applied Ecology and Environmental Research, 17(5): 215-220.

25. Li N.C., Lindenbaum A. and White J.M. (1959). Some metal complexes of citric and tricarballylic acids. *Journal of Inorganic and Nuclear Chemistry,* 12(1-2): 122-128.
26. Przybysz, A.; Gawronska, H.; Gajc-Wolska, J. (2014). Biological mode of action of a nitrophenolates- based biostimulant: case study. Front. Plant Sci., 2014, 5,713. doi: 10.3389/fpls.2014.00713
27. Lucini L., Rouphael Y., Cardarelli M., Bonini P., Baffi C. and Colla G. (2018). A vegetal biopolymer- based biostimulant promoted root growth in melon while triggering brassinosteroids and stress-related compounds. *Frontiers in Plant Science,* 9: 472.
28. Matsumiya Y. and Kubo M. (2011). Soybean peptide: novel plant growth promoting peptide from soybean," in Soybean and Nutrition. Ed. El-Shemy, H. (Rijeka: In Tech Europe Publisher), 215–230. doi: 10.5772/19132
29. Schiavon M., Ertani A. and Nardi S. (2008). Effects of an alfalfa protein hydrolysate on the gene expression and activity of enzymes of the tricarboxylic acid (TCA) cycle and nitrogen metabolism in *Zea mays* L. *J. Agric.* Food Chem., 56(24): 11800-11808
30. Colla G., Nardi S., Cardarelli M., Ertani A., Lucini L., Canaguier R. and Rouphael Y. (2015). Protein hydrolysates as biostimulants in horticulture. *Sci. Hortic.,* 196: 28–38.
31. Lachhab N., Sanzani S.M., Adrian M., Chiltz A., Balacey S., Boselli M. and Poinssot B. (2014). Soybean and casein hydrolysates induce grapevine immune responses and resistance against *Plasmopara viticola Front. Plant Sci.,* 5: 716.
32. Bitterlich M., Sandmann M. and Graefe J. (2018). Arbuscular mycorrhiza alleviates restrictions to substrate water flow and delays transpiration limitation to stronger drought in tomatoes. *Front. Plant Sci.,* 9: 154.
33. Trouvelot S., Héloir M.C., Poinssot B., Gauthier A., Paris F. and Guillier C. (2014). Carbohydrates in plant immunity and plant protection: roles and potential application as foliar sprays. *Front. Plant Sci.,* 5: 592. doi: 10.3389/fpls.2014.00592
34. Rouphael Y. and Colla G. (2018). Synergistic Biostimulatory Action: Designing the Next Generation of Plant Biostimulants for Sustainable Agriculture. *Front. Plant Sci.,* 9: 1655.
35. Du Jardin P. (2015). Plant biostimulants: definition, concept, main categories and regulation. *Sci. Hortic.,* 196: 3–14. doi: 10.1016/ J. Scienta. 2015.09.021

Website : www.asthafoundation.in
ICAAAS–An Edited Book (Volume-3)
ISBN : 978-81-958010-7-7
Published by : Astha Foundation, Meerut (U.P.) India
Edition-2024

Chapter 4

CHROMATIN REMODELING MECHANISMS IN PLANT STRESS TOLERANCE : IMPLICATIONS FOR FUTURE CROP BREEDING

Rohit Kumar[1], B.V. Tembhurne[1*], K.M. Shivaprasad[2] and Sampath Kumar[1]
[1]*University of Agricultural Sciences, Raichur-584104, Karnataka*
[2]*ICFRE-Institute of Forest Biodiversity, Hyderabad-500100, Telangana*
**Corresponding Author's Email : bvtembhurne@gmail.com*

Abstract

Plants are constantly exposed to fluctuating environmental conditions, requiring them to adapt flexibly to survive. This adaptability hinges on a sophisticated signal-response network that enables rapid reprogramming of development, physiology, and metabolism in response to stress. Central to this process is the dynamic regulation of gene expression, which depends on overcoming the barriers posed by chromatin structure. In eukaryotes, tightly packed genomic DNA within nucleosomes obstructs transcriptional machinery access, necessitating chromatin remodeling. This involves ATP-dependent chromatin remodelers and histone modifications, which reposition nucleosomes, making regulatory regions accessible for transcription. Understanding these mechanisms is crucial for grasping how plants navigate environmental stress at the molecular level.

Key words : *Chromatin remodeling, gene expression, environmental adaptation, nucleosomes, stress response.*

Introduction

Plants experience an ever-changing environment, ranging from fast fluctuations of light and humidity caused by clouds, wind or rain, to larger diurnal and seasonal changes in temperature, light, rainfall and nutrient availability. In some environment plants have to deal with extreme conditions of permanent or frequent nature, whereas in other environments serious stress only occurs sporadically and therefore does not provide evolutionary pressure for permanent adaptations. Nevertheless, plants need to have a safety net in place to deal with occasional stress events. Flexibility is an essential requirement for surviving stress at a sedentary life style. Plants maintain this flexibility by operating a signal-response network that allows them to rapidly re-programmed their development, physiology and metabolism in response to environmental stress. The ability of plants to perceive and integrate an enormous amount of environmental information and to respond to any given situation in an *ad hoc* manner. What is common to adaptive responses in all life forms is that they depend to a large extent on dynamic changes in gene expression.

Gene regulatory mechanisms have evolved along with ways to package genomic DNA. In eukaryotes, genomic DNA is tightly packaged by an octamer of the four core histone proteins (H2A, H2B, H3, and H4) to make an array of nucleosomes, where linker histones facilitate further compaction to create a higher order chromatin structure. Thus, chromatin structure becomes a general obstacle for eukaryotic transcription by blocking the access of the basic RNA polymerase machinery, as well as most transcription factors. Interestingly, the DNA sequences at promoters, enhancers, and transcription factor-binding sites

Cited as : Singh S.P. (2024). ICAAAS : Chromatin remodeling mechanisms in plant stress tolerance : Implications for future crop breeding. *ICAAAS–An Edited Book.* Volume-3 : 33-43 Astha Foundation, Meerut (U.P.) India.

generally have high affinity for histone octamers, which results in higher nucleosome occupancy. Therefore, transcription factors and transcriptional machinery need to overcome this nucleosome barrier to activate their target genes.

To overcome this nucleosome barrier, a cell chromatin must "open" in order for gene expression to take place. This process of opening is called as "chromatin remodeling", and it is of vital importance to the proper functioning of all eukaryotic cells. The packing of genomic DNA around nucleosomes provides topological order but hides one face of the DNA, thus nucleosomes often block the access of transcription factors to their genomic binding loci. Binding sites that are located close to the center of the 147 bp of genomic DNA regularly covered a nucleosome are generally inaccessible to transcription factors. In contrast, those closer to the edge of the nucleosome- covered sequence are a bit better accessible, but only those in the linker are fully accessible. This inaccessibility of a larger part of the genome leads to a dependence of gene expression on chromatin remodeling. To maintain topological order and to allow rapid and regulated access to the DNA, cells have evolved a set of chromatin remodeling complexes that alter nucleosome position, presence and structure. Importantly, repositioning a nucleosome by only a few bp can be sufficient, in order to make a regulatory genomic region, such as a promoter or an enhancer, accessible.

The regulation of gene expression comprises a dynamic balance between packing genomic transcription factor binding sites into inaccessible chromatin and allowing proteins to access these sequences. This is controlled by histone modifications by chromatin modifiers, and ATP-dependent chromatin remodeling by chromatin remodelers. Chromatin remodeling factors are multi-protein complexes that use the energy of ATP hydrolysis, in order to remodel or remove nucleosomes regulating the exposure of genomic DNA to transcription factors.

What is 'Chromatin'?

Chromatin is a complex which is formed to achieve a highly condensed form by winding of DNA around proteins called histones.

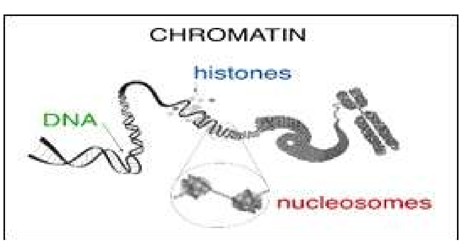

Fig. 1: Structure of chromatin.

What are the types of chromatin?

(a) Euchromatin (loosely packed): Euchromatin is a lightly packed form of chromatin (DNA, RNA and Protein) that is enriched in genes, and is often (but not always) under active transcription. Euchromatin comprises the most active portion of the genome within the cell nucleus.

(b) Heterochromatin (tightly packed) : Heterochromatin is a tightly packed form of DNA or condensed DNA, because it is tightly packed, it was thought to be inaccessible to polymerases and therefore not transcribed.

Heterochromatin are of two types :

(i) Constitutive heterochromatin : These are regions of DNA found throughout the chromosomes of eukaryotes. The majority of constitutive heterochromatin is found at the pericentromeric regions of chromosomes, but is also found at the telomeres and throughout the chromosomes. Constitutive heterochromatin is composed mainly of high copy number tandem repeats known as satellite repeats, minisatellite and microsatellite repeats, and transposon repeats.

(ii) Facultative heterochromatin : These regions of DNA is the result of genes that are silenced through a mechanism such as histone deacetylation or Piwi-interacting RNA (pi RNA) through RNAi. It is not repetitive and shares the compact structure of constitutive heterochromatin.

Constitutive heterochromatin	Facultative heterochromatin
(i) Found in regions of chromosome where there are many genes.	(i) Found in a region of chromosome where there are few to no genes.
(ii) Unfolded structure.	(ii) Twotypes:constitutiveand facultative.
(iii) Functions in the active transcription of DNA to mRNA.	(iii) Function as a regulator of gene expression.

What is 'Chromatin remodelling':

The process of making DNA more or less accessible in the eukaryotic genome using a series of specialized proteins.

Chromatin remodelling is the dynamic modification of chromatin architecture to allow access of condensed genomic DNA to the regulatory transcription machinery proteins, and thereby control gene expression.

Chromatin remodelling is the enzyme-assisted process to facilitate access of nucleosomal DNA by remodelling the structure, composition and positioning of nucleosomes.

Why chromatin remodelling is important and needed :

Chromatin-structure dynamics are important for the regulation of gene expression and chromosome function. The basic components of chromatin are nucleosomes, which comprise octamers of histone proteins around which DNA is wrapped. The majority of nucleosome assembly occurs during DNA replication, directly in the wake of the replisome, and involves the delivery of histones to nascent DNA by histone chaperones. Chromatin dynamics involve the action of specialized ATP-dependent chromatin-remodelling complexes (herein termed remodellers). Remodellers include enzymes that ensure the proper density and spacing of nucleosomes and that can also contribute to gene repression. Another set of remodellers cooperates with site-specific transcription factors and histone- modification enzymes to move or to eject histones to enable the binding of transcription factors to DNA. Yet another set of remodellers is involved in creating specialized chromosomal regions where canonical histones are replaced by histone variants. Thus, genome-wide nucleosome occupancy and composition are tailored by specialized remodellers. Genetic experiments have revealed that ATP-dependent chromatin-remodelling enzymes are essential regulators of nearly every chromosomal process, and their deregulation leads to a variety of diseases, including cancer.

Chromatin remodelling is needed to allow access of condensed genomic DNA to the regulatory transcription machinery proteins, and thereby control gene expression (‘switch on’ or ‘switch off’).

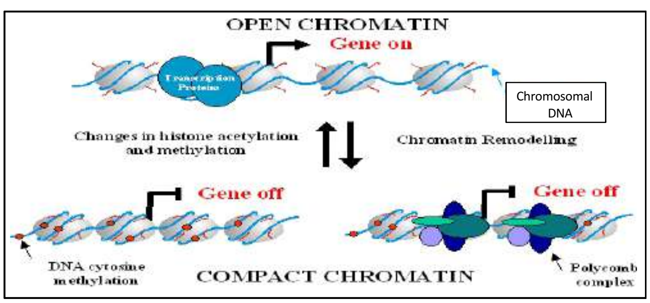

Fig.-2 : Function of chromatin remodelling.

How chromatin remodelling occurs :

Chromatic remodelling is carried out by a number of remodellers (ISWI-Imitation Switch, CHD-Chromodomain Helicase DNA-binding, SWI/SNF-Switch/Sucrose Non-fermentable, INO80- Inositol 80) and histone modifiers (Histone Acetylases/ deacetylases, methylases/demethylases, phosphory-lases etc.).

Chromatin remodellers :

Cells utilize diverse ATP-dependent nucleosome-remodelling complexes to carry out histone sliding, ejection or the incorporation of histone variants, suggesting that different mechanisms of action are used by the various chromatin-remodelling complex subfamilies. However, all chromatin- remodelling complex subfamilies contain an ATPase–translocase ‘motor’ that translocates DNA from a common location within the nucleosome.

Chromatin remodellers can be classified by their phylogenetic relationships and/or by their different functionalities.

On the basis of Phylogenetic relationship i.e. similarities and differences in their catalytic ATPases, they are classified into four groups :

(i) ISWI
(ii) CHD
(iii) SWI/SNF
(iv) INO80

ISWI (Imitation SWItch) :

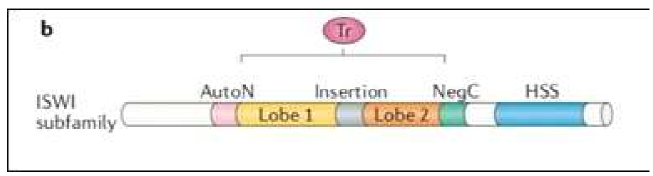

Fig.-3 : Structure of ISWI.

Structure :

AutoN (Auto-inhibitory N-terminal) & NegC (Negative regulator of coupling) : Two domains that flank the ATPase lobes and regulate the activity of the ATPase domain.

ATPase Domain : Contains two Rec A-like lobes i.e. Lobe 1 (DExx) and Lobe 2 (HELICs), which are separated by a small insertion sequence.

HSS (HAND SANT SLIDE) : Binds the unmodified histone H3 tail and the linker DNA flanking the nucleosome.

Functions :

Assemble and regularly space nucleosomes to limit chromatin accessibility and gene expression.

A subset, Nucleosome remodelling factor (NURF) complex, have accessory subunits that confer access and that promote transcription.

SWI/SNF (SWItch/Sucrose Non-fermentable):

Structure :

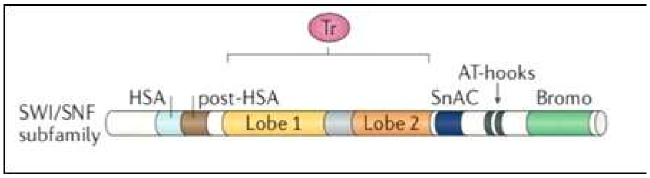

Fig.-4 : Structure of SWI/SNF.

HSA (Helicase SANT associated) Domain: Binds actin and/or actin-related proteins (ARPs).

ATPase Domain: Contains two Rec A-like lobes i.e. Lobe 1 (DExx) and Lobe 2(HELICs), which are separated by a small insertion sequence.

Two AT Hooks, SnAC (Snf2 ATP coupling): It is a histone binding domain (HBD), maintain octamer attachment during forcible DNA translocation, a property that is necessary for nucleosome ejection.

C-terminal Bromodomain.

Function :

Typically facilitates chromatin access, as they slide and eject nucleosomes, and are used for either gene activation or gene repression.

CHD (Chromodomain Helicase DNA binding) :

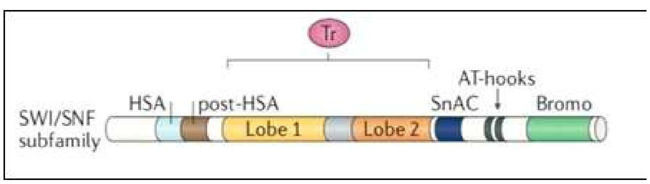

Fig.-5 : Structure of CHD

Structure :

Resemble that of ISWI sub-family but differ in its two signature amino terminus of tandemly arranged **Chromodomains.**

ATPase Domain: Contains two Rec A-like lobes i.e. Lobe 1 (DExx) and Lobe 2 (HELICs), which are separated by a small insertion sequence.

NegC Domain.

DBD (DNA binding domain): Comprised of only SANT and SLIDE domains.

Function :

➢ Nucleosome assembly (spacing nucleosome), Chromatin access (exposing promoters), Nucleosome editing (substitute histones or histone variants).

INO80 (INOsitol requiring complexes):

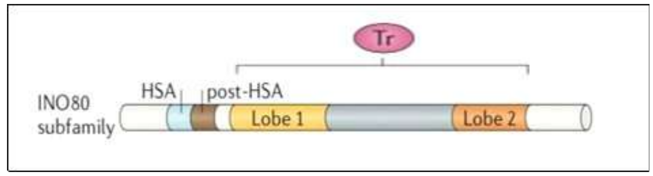

Fig.-6 : Structure of INO80.

Structure :

HSA (Helicase SANT associated) Domain: Binds actin and/or actin-related proteins (ARPs).

ATPase Domain:

Contains two Rec A-like lobes i.e. Lobe 1 (DExx) and Lobe 2 (HELICs), which are separated by a long insertion sequence (Binds to a hetero-hexameric ring of the helicase related (AAA + ATPase).

It scaffold three modules: N-terminus, Rvb 1 and Rvb 2, and C-terminus.

Function :

INO80 subfamily remodellers have unique editing functions.

Although INO80C also conducts chromatin access and nucleosome spacing functions.

The SWR1C, p400 and Snf2-related CBP activator protein (SRCAP) complex subtypes replace canonical H2A–H2B dimers with H2A.Z histone variant-containing H2A.Z–H2B dimers, whereas INO80C can catalyse the reciprocal reaction.

The vertebrate p400 subtype may also replace H3.1 with the variant H3.3.

Yeast INO80C removes the variant H2A.X, which probably underlies its DNA repair functions, as well as its chromatin access and transcription activation functions.

On the basis of functions they are classified as:

(i) Nucleosome assembly and organization. (ISWI and CHD)

(ii) Chromatin access. (SWI/SNF)

(iii) Nucleosome editing. (INO80)

Chromatin modifier : Chromatin modifiers are the enzyme complexes generally participate or does histone modification which involves covalent bonding of various functional groups to the free nitrogens in the R-groups of different amino acids in the N-terminal tail. Early research has linked differing levels of

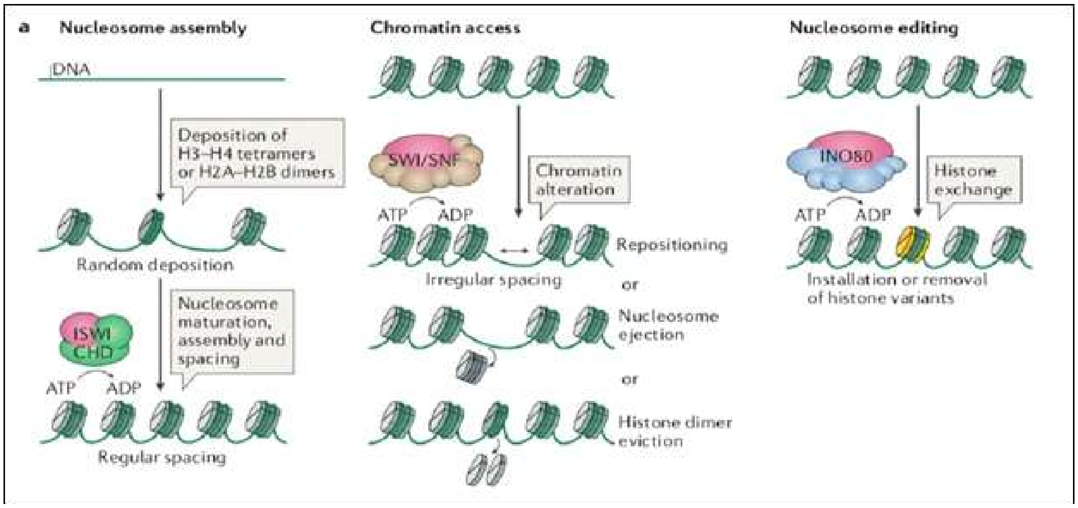

Fig.-7 : Outcomes of chromatin remodelling.

acetylation and methylation on the histones to altered rates of DNA transcription. While the most common additions are acetylation and methylation of lysine residues, many more types of modifications have also been observed, including phosphorylation, a common post-translational modification. The different types of modifications, which have been called the "histone code," are put in place by a variety of different enzymes.

Histone code : It is a hypothesis that the transcription of genetic information encoded in DNA is in part regulated by chemical modifications to histone proteins, primarily on their unstructured ends and recruit some proteins (remodellers). These recruited proteins then act to alter chromatin structure actively or to promote transcription.

Types of modification :

(i) Histone acetylation/Deacetylation.

(ii) Histone phosphorylation/de-phosphorylation.

(iii) Histone methylation/demethylation.

(iv) Deimination.

(v) Ubiquitylation.

Histone acetylation : Acetylation of lysine is highly dynamic and regulated by the opposing action of two families of enzymes, histone acetyl-transferases (HATs) and histone deacetylases (HDACs). The HATs utilize acetyl CoA as cofactor and catalyze the transfer of an acetyl group to the amino group of lysine side chains. In doing so, they neutralize the lysine's positive charge and this action has the potential to weaken the interactions between histones and DNA. It also recruits remodeler which have bromo- domains. Bromo-domains recognize the acetylated site and go and bind them.

Histone phosphorylation : Like histone acetylation, the phosphorylation of histones is highly dynamic. It takes place on serine, threonine and tyrosine, predominantly, but not exclusively, in the N-terminal histone tails. The levels of the modification are controlled by kinases and phosphatases that add and remove the modification, respectively.

All of the identified histone kinases transfer a phosphate group from ATP to the hydroxyl group of the target amino acid side chain. In doing so, the modification adds significant negative charge to the histone that undoubtedly influences the chromatin structure. For the majority of kinases, however, it is unclear how the enzyme is accurately recruited to its site of action on chromatin.

Histone methylation : Histone methylation mainly occurs on the side chains of lysine and arginine. Unlike acetylation and phosphorylation, however, histone methylation does not alter the charge of the histone protein. Furthermore, there is an added level of complexity to bear in mind when considering this modification; lysine may be mono-, di- or tri-methylated, whereas arginine may be mono-methylated, symmetrically or asymmetrically di-methylated. It is regulated by the opposing action of two families of enzymes, Histone methyl-transferases (HMTs) and Histone de-methylases. It sometimes involves in loosening the histone-DNA interaction and opening of chromatin and accessibility of DNA and sometimes in tight packing of chromatin and inaccessible DNA.

Deimination : This reaction involves the conversion of an arginine to a citrulline. In mammalian cells, this reaction on histones is catalyzed by the peptidyl deiminase PADI4, which converts peptidyl arginine to citrulline. One obvious effect of this reaction is that it effectively neutralizes the positive charge of the arginine since citrulline is neutral. There is also evidence that PADI4 converts mono-methyl

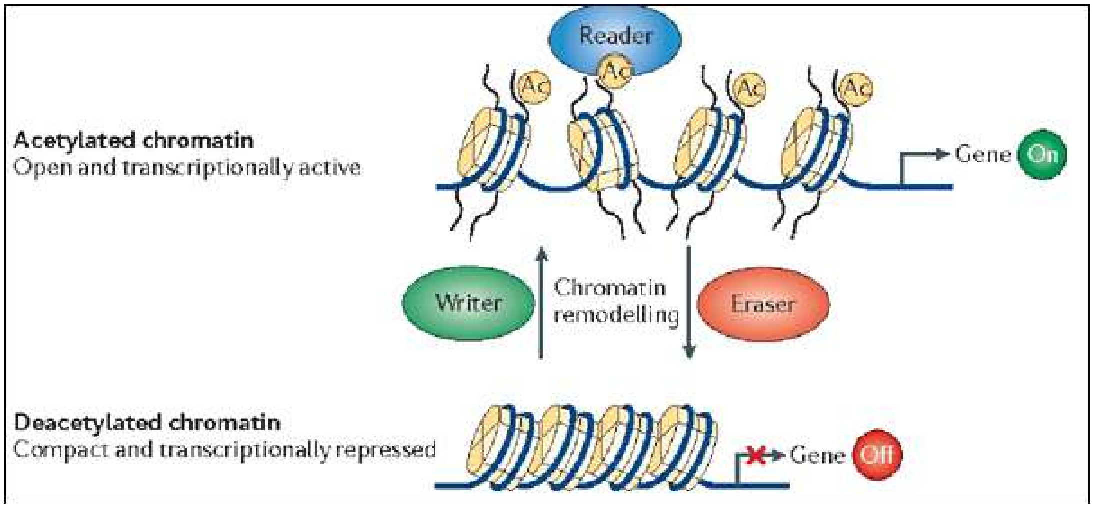

Fig.-8 : Histone acetylation.

Writer-Histone acetyltransferase (HATs).
Eraser-Histone deacetylase (HDACs).
Reader-Chromatin remodeler complexes.

arginine to citrulline, thereby effectively functioning as an arginine demethylase. However, unlike a 'true' demethylase, the PADI4 reaction does not regenerate an unmodified arginine.

Ubiquitylation : Ubiquitylation results in a much larger covalent modification. Ubiquitin itself is a 76-amino acid polypeptide that is attached to histone lysine via the sequential action of three enzymes, E1-activating, E2-conjugating and E3-ligating enzymes. The enzyme complexes determine both substrate specificity (i.e., which lysine is targeted) as well as the degree of ubiquitylation (i.e., either mono-or poly-ubiquitylated). For histones, mono-ubiquitylation seems most relevant although the exact modification sites re- main largely elusive. However, two well characterized sites lie within H2A and H2B. H2AK119-ub1 is involved in gene silencing, whereas H2BK123-ub1 plays an important role in transcriptional initiation and elongation. Even though ubiquitylation is such a large modification, it is still a highly dynamic one. The modification is removed via the action of iso- peptidases called de-ubiquitin enzyme and this activity is important for both gene activity and silencing.

What is histone modification crosstalk?

The large number of possible histone modifications provides scope for the tight control of chromatin structure. Nevertheless, an extra level of complexity exists due to cross-talk between different modifications, which presumably helps to fine-tune the overall control.

This cross-talk can occur via multiple mechanisms :

(a) There may be competitive antagonism between modifications if more than one modification pathway is targeting the same site(s). This is particularly true for lysine that can be acetylated, methylated or ubiquitylated.

(b) One modification may be dependent upon another. A good example of this *trans*-regulation comes from the work in *Saccharomyces cerevisiae;* methylation of H3K4 by scCOMPASS and of H3K79 by scDot1 is totally dependent upon the ubiquitylation of H2BK123 by scRad6/Bre1. Importantly, this mechanism is conserved in mammals, including humans.

(c) The binding of a protein to a particular modification can be disrupted by an adjacent modification. For example, as discussed above, HP1 binds to H3K9me2/3, but during mitosis, the binding is disrupted due to phosphorylation of H3S10. This action has been described as a 'phospho-switch'. In order to regulate binding in this way, the modified amino acids do not necessarily have to be directly adjacent to each other. For instance, in

S. pombe, acetylation of H3K4 inhibits binding of spChp1 to H3K9me2/3.

(d) An enzyme's activity may be affected due to modification of its substrate. In yeast, the scFpr4 proline isomerase catalyzes interconversion of the H3P38 peptide bond and this activity affects the ability of the scSet2 enzyme to methylate H3K36, which is linked to the effects on gene transcription.

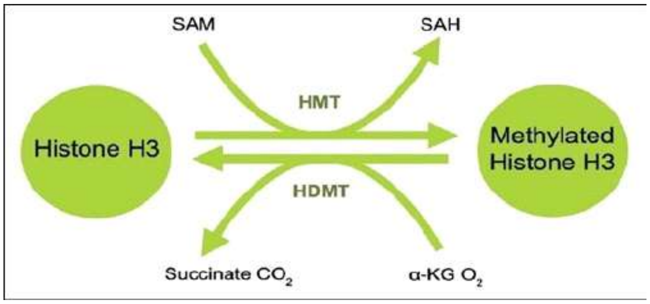

Fig.-9 : Histone methylation.

SAM-S-Adenosyl methionine. (Methyl group donor).
HMTs-Histone methyl-transferase.
HDMT-Histone de-methyltransferase.

(e) There may be cooperation between modifications in order to efficiently recruit specific factors. For example, PHF8 specifically binds to H3K4me3 via its PHD finger, and this interaction is stronger when H3K9 and H3K14 are also acetylated on the same tail of H3. However, this stabilization of binding may be due to additional factors in a complex with PHF8 rather than a direct effect on PHF8 itself.

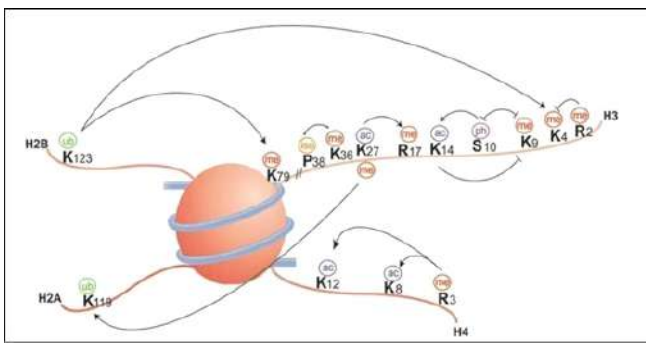

Fig.-10 : Histone modification crosstalk.

What is the relationship between DNA and Histone modification :

Co-operation between Histone modification and DNA methylation : There may also be cooperation between histone modifications and DNA methylation. For instance, the UHRF1 protein binds to nucleosomes bearing H3K9me3, but this binding is significantly enhanced when the nucleosomal DNA is CpG methylated. Conversely, DNA methylation can inhibit protein binding to specific histone modifications. A good example here is KDM2A, which only binds to nucleosomes bearing H3K9me3 when the DNA is not methylated.

How chromatin remodelling relates stress :

Clearly, at our current state of knowledge, the notion of 'active' or 'repressive' mark is not sufficient for identifying causal relationships between stress-induced changes of histone modifications and stress-induced changes of transcript levels.

Theoretically, chromatin modifications could be causally linked to transcriptional responses in a number of ways :

(1) The chromatin features are not themselves altered by the stress but their association with a particular gene before the stress may determine whether a stress-induced regulatory protein can exert its function or it may modulate its efficiency. An obvious, yet unproven case is a cell-type specific response where the action of a transcription factor depends on whether the target gene is transcriptionally competent in this cell-type or not. It is similarly plausible that this scenario enables responsiveness to depend on the physiological state of the plant at the time of stress experience. To prove this scenario, it would be important to compare the responsive- ness of a particular gene in different cell types or physiological states, and to relate any differences to cell- type/state specific chromatin modifications. (Fig.-11.)

(2) The chromatin is in fact the primary target of the stress signal. Changes of chromatin modifications would then cause (and be necessary) for downstream transcriptional regulation of the genes associated with the particular mark. This scenario is often implied when scientists report changes in histone modification profiles upon stress together with changes in gene expression. However, to prove this case, one would need to prevent the change in the histone mark, for example through knockout of the respective histone-modifying enzyme, and show that the transcriptional response no longer occurs. Optimally, impairment of the enzyme should be limited to the stress situation, for example through RNAi under the control of a stress-inducible promoter. (Fig.-11.)

(3) It describes a situation in which the primary target of the stress signal is a transcription factor and a change of chromatin properties is then part of the transcriptional regulation. For example, repressive transcription factors can recruit co-repressor proteins that are integral components of histone deacetylation complexes. Subsequent deacetylation of the histones associated with the target gene would then restrict access of the transcriptional machinery. To prove this case, binding regions of repressor or co-repressor could be altered, and this should prevent the stress-dependent down-regulation of the gene. Novel gene editing techniques offer an opportunity to carry out

such experiments without the need to over-express the mutant proteins. (Fig.-11.)

(4) Here, the stress alters chromatin features and transcription, but the two responses occur independently. To prove independence, one needs to show that each change can be eliminated without altering the other. For example, one should test whether knockout mutants for the transcription factor or the histone-modifying enzyme still produce a stress-induced change in the histone mark or the transcript, respectively. (Fig.-11.)

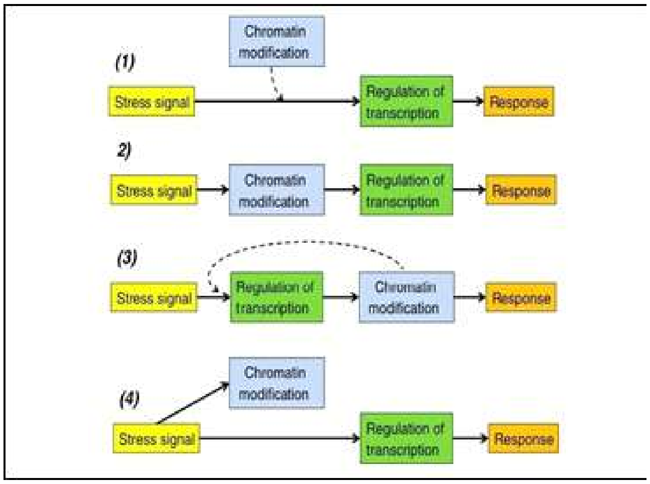

Fig.-11 : Causality scenarios for the role of chromatin modifications in transcriptional stress responses. (1) chromatin marks are not themselves altered by the stress but their association with the gene before the stress may determine whether a stress-induced regulatory protein can exert its function, or may modulate the strength of the response. **(2)** the mark is the primary target of the stress signal and its change causes downstream transcriptional regulation of the genes associated with the particular mark. **(3)** describes a situation where a change of chromatin is in fact part of the transcriptional regulation, acting downstream of a stress-inducible regulator. For example, a transcription factor may recruit a histone modifying enzyme which then enhances or represses transcription. **(4)**, the stress alters both, chromatin marks and gene transcription, but the two responses occur independently and the former is not necessary for the latter. The individual elements of the causal pathways may enhance or inhibit each other in feedback loops (e.g. (3) dotted line), and they may connect one scenario to another for different stresses or modifications.

Role of histone variants replacement in stress responses/Stress-dependent deposition of histone variants:

A. Here, the researchers used a mutant which is defective for H2A.Z variant. Mutants for H2A.Z were found to be less sensitive to temperature changes. When grown at cool temperatures (12–17°C) the mutant plants phenocopied wildtype plants grown at 27 °C and they displayed a constitutive high-temperature transcriptome. A genome-wide analysis of H2A.Z and transcript levels revealed that deposition of H2A.Z within gene bodies correlated not just with lower transcript levels but also with high variation of transcript levels across tissues and environmental conditions. In combination with the reported anti-correlation between H2A.Z and DNA methylation, this suggests that gene-body methylation may be a means to evict H2A.Z in order to constitutively maintain high expression levels. The obvious follow-on question is whether environmental stimuli actively alter H2A.Z disposition. Comparing H2A.Z profiles along temperature-responsive genes between Arabidopsis plants exposed to 17 °C or 27 °C revealed higher levels of H2A.Z at the low temperature. While this indicates temperature- dependent H2A.Z deposition the relation to the transcriptional response is unclear since the shift in H2A.Z level occurred irrespective of whether the genes were up-, down-, or unregulated by the temperature change. In the absence of a conclusive causal link the evidence available to date favors a model shown in Fig. 3A, in which the H2A.Z status prior to the stress determines stress responsiveness of individual genes, which is reminiscent of scenario 1 in above figure.

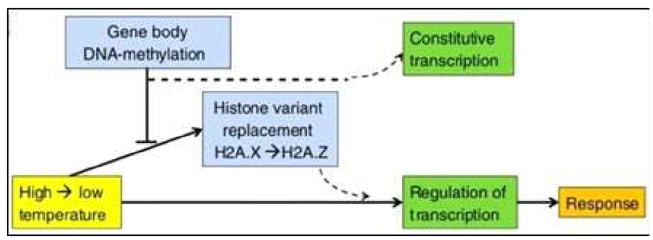

Fig.-12 : Histone 2 variants : The combined evidence available to date favors a model, in which the H2A.Z status determines whether a gene can be transcriptionally regulated or not. H2A.Z deposition is enhanced in the cold and increases the plant's sensitivity to the temperature change. Gene-body methylation may be a means to evict H2A.Z in order to maintain high expression levels of constitutively expressed genes. The exact molecular processes that mediate between H2A.Z deposition and transcriptional responses remain to be established.

B. Here, in this case researchers studied in detail about H1.3 histone variant. It was found that in unstressed conditions H1.3 was specifically expressed in guard cells. *h1.3* mutants displayed decreased stomatal density in young leaves, reduced CO_2 assimilation rate per plant and altered expression of genes with known function in guard cell development. These differences did not impact on plant growth under normal conditions or under drought in high light. However, when drought was combined with low light the *h1.3* plants had lower leaf number and weight. Indeed, H1.3 was strongly induced in all tissues by low light, with a synergistic effect to the previously shown induction by drought. The authors also determined histone mobility through Fluorescence Recovery After Photobleaching (FRAP) in plants expressing GFP-fusions of the different H1 variants. The measurements revealed that H1.3 has considerably higher mobility in the chromatin than the main variants H1.1. and H1.2, suggesting that under stress it could outcompete them. In accordance with this notion, an increase of DNA methylation (particularly in CHH context) upon combined low- light/drought stress was dependent on a functional H1.3. As summarized in figure below , the evidence to date favors a model in which H1.1/2 variants protect the DNA under normal conditions, but are replaced by the more mobile H1.3 under stress. This allows access of the DNA methylation machinery and hypermethylation. Comparison of DNA-methylation patterns between h1-variant mutants showed that H1.3-mediated DNA-methylation is slightly shifted from TE targets towards expressed genes. This observation indicates a potential effect of variant replacement on gene expression, the exact mechanistic link between stress-induced hypermethylation, transcriptional regulation and physiological responses remains to be established.

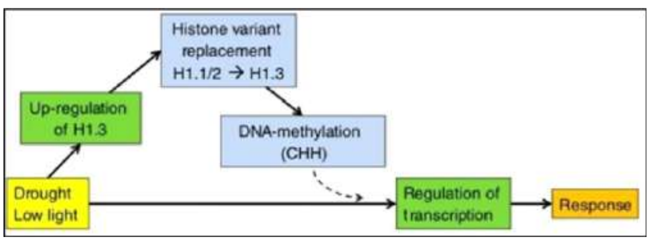

Fig.-13 : Histone 1 variants: Experimental research suggests a model in which the canonical H1 variants (H1.1, H1.2) prevent access of the DNA-methylation machinery to the DNA under normal conditions, but are replaced by the more mobile, smaller H1.3 variant under stress, thereby causing DNA hyper-methylation in CHH context. The observation that H1.3-mediated DNA-methylation is shifted towards expressed genes indicates a potential effect of variant replacement on gene expression, but the exact mechanistic link between stress-induced hyper-methylation, transcriptional regulation and physiological responses remains to be elucidated. For details and references see main text.

Future Perspective

Researchers have identified many histone modifications, but their functions are just beginning to be uncovered. Certainly, there will be more modifications to discover and need to identify the many biological functions they regulate. Perhaps most importantly, there are three areas of sketchy knowledge that need to be embellished in the future.

The first is the delivery and control of histone modifications by RNA. There is an emerging model that short and long RNAs can regulate the precise positioning of modifications and they can do so by interacting with the enzyme complexes that lay down these marks. Given the huge proportion of the genome that is converted into uncharacterized RNAs, there is little doubt that this form of regulation is far more prevalent than is currently considered.

The second emerging area of interest follows the finding that kinases receiving signals from external cues in the cytoplasm can transverse into the nucleus and modify histones. This direct communication between the extracellular environment and the regulation of gene function may well be more widespread. It could involve many of the kinases that are currently thought to regulate gene expression indirectly *via* signaling cascades. Such direct signaling to chromatin may change many of our assumptions about kinases, as drug targets and may rationalize even more the use of chromatin- modifying enzymes as targets.

The third and perhaps the most ill-defined process that will be of interest is that of epigenetic inheritance and the influence of the environment on this process. We know of many biological phenomena that are inherited from mother to daughter cell, but the precise mechanism of how this happens is unclear. Do histone modifications play an important role in this? The answer is yes, and as far as we know they are responsible for perpetuating these events. However, how does the epigenetic signal start off? Is the deposition of the modifications at the right place during replication enough to explain the process? Or is there a 'memory molecule', such a RNA, transmitted from mother to daughter cell, which can deliver histone modifications to the right place. These are fundamental questions at the heart of 'true' epigenetic research, and they will take us a while longer to answer.

Conclusion

It has become clear that it is crucial to understand how genomes are regulated in response to stress. To this end we need more genome-wide data to understand what the global changes induced by mutations in genes involved in chromatin remodelling are. It is not just about controlling the expression of a few genes, but about conditioning entire genomes for a fast and strong response to specific stresses.

References

1. Amtmann A. and Armengaud P. (2009). Effects of N,P,K and Son metabolism: new knowledge gained from multi-level analysis. *Curr. Opin. Plant Biol.*, 12: 275–283.

2. Baker N.R. (2008). Chlorophyll Fluorescence: A Probe of Photosynthesis In Vivo. *Annual Review of Plant Biology,* 59: 89–113.
3. Bannister A.J. and Kouzarides T. (2011). Regulation of chromatin by histone modifications, *Cell Res.*, 21: 381-395.
4. Bartke T., Vermeulen M., Xhemalce B., Robson S.C., Mann M. and Kouzarides T. (2010). Nucleosome-interacting proteins regulated by DNA and histone methylation. *Cell.* 143: 470- 484.
5. Boyer L.A., Latek R.R. and Peterson C.L. (2004). The SANT domain: a unique histone-tail- binding module. *Nat. Rev. Mol. Cell Biol.*, 5: 158–163.
6. Clapier C.R. and Cairns B.R. (2014). Fundamentals of Chromatin, *Springer,* 10*:* 69–146.
7. Clapier C.R. and Cairns B.R. (2012). Regulation of ISWI involves inhibitory modules antagonized by nucleosomal epitopes. *Nature,* 492: 280–284.
8. Clapier C.R., Iwasa J., Cairns B.R. and Peterson C.L. (2017). Mechanisms of action and regulation of ATP-dependent chromatin-remodelling complexes, *Nat. Rev. Mol. Cell Biol.*, 18(7): 407- 422.
9. Corona D.F. and Tamkun J.W. (2004). Multiple roles for ISWI in transcription, chromosome organization and DNA replication. *Biochem. Biophys. Acta*., 1677: 113–119.
10. Cuthbert G.L., Daujat S. and Snowden A.W. (20040. Histone deimination antagonizes arginine methylation. *Cell.* 118: 545-553.
11. Cutler S.R., Rodriguez P.L., Finkelstein R.R. and Abrams S.R. (2010). Abscisic acid: emergence of a core signaling network. *Annual Review of Plant Biology,* 61: 651–679.
12. Coleman-Derr D. and Zilberman D. (2012). Deposition of histone variant H2A.Z within gene bodies regulates responsive genes, *PLoS Genet*., 8- e1002988.
13. Dang W. and Bartholomew B. (2007), Domain architecture of the catalytic subunit in the ISW2-nucleosome complex. *Mol. Cell. Biol*., 27: 8306–8317.
14. Fabado M.A.A., Amtmann A. and Perrella G. (2016), Plant responses to abiotic stress: The chromatin context of transcriptional regulation, *Biochemica. Et. Biophysica. Acta.,* 1860: 106–122.
15. Hauk G., McKnight J.N., Nodelman I.M. and Bowman G.D. (2010). The chromodomains of the Chd1 chromatin remodeler regulate DNA access to the ATPase motor. *Mol. Cell.,* 39: 711- 723.
16. Jha S. and Dutta A. (2009). RVB1/RVB2: running rings around molecular biology. *Mol. Cell.,* 34: 521– 533.
17. Kasten M.M., Clapier C.R. and Cairns B.R. (2011). SnapShot: chromatin remodeling: SWI/SNF. *Cell.* 14: 310-318.
18. Kouzarides T. (2007), Chromatin modifications and their function. *Cell,* 128: 693-705.
19. Kunert N. and Brehm A. (2009). Novel Mi-2 related ATP-dependent chromatin remodelers. *Epigenetics,* 4: 209–211.
20. Lai A.Y. and Wade P.A. (2011). Cancer biology and NuRD: a multifaceted chromatin remodelling complex. *Nat. Rev. Cancer,* 11: 588–596.
21. Lan F. and Shi Y. (2009). Epigenetic regulation: methylation of histone and non-histone proteins. *Sci. China C. Life Sci.,* 52: 311-322.
22. Lee J.S., Shukla A. and Schneider J. (2007). Histone crosstalk be- tween H2B monoubiquitination and H3 methylation mediated by Compass. *Cell,* 131: 1084-1096.
23. Lusser A., Urwin D.L. and Kadonaga J.T. (2005). Distinct activities of CHD1 and ACF in ATP-dependent chromatin assembly. *Nat. Struct. Mol. Biol.*, 12: 160–166.
24. Mohrmann L. and Verrijzer C.P. (2005), Composition and functional specificity of SWI2/SNF2 class chromatin remodeling complexes. *Biochem. Biophys. Acta.*, 1681: 59–73.
25. Msanne J., Lin J., Stone J.M. and Awada T. (2011). Characterization of abiotic stress-responsive Arabidopsis thaliana RD29A and RD29B genes and evaluation of transgenes. *Planta*, 234: 97–107.
26. Murawska M. and Brehm A. (2011). CHD chromatin remodelers and the transcription cycle. *Transcription,* 2: 244–253.
27. Nelson C.J., Santos-Rosa H. and Kouzarides T. (2006). Proline isomerization of histone H3 regulates lysine methylation and gene expression. *Cell,* 126: 905-916.
28. Oki M., Aihara H. and Ito T. (2007). Role of histone phosphorylation in chromatin dynamics and its implications in diseases. *Subcell Biochem.,* 41: 319-336.
29. Paixao J.F.R., Gillet F.X., Ribeiro P.R., Bournaud C., Tessutti I.T.L., Noriega D.D., Melo, Papamichos-Chronakis M., Krebs J.E. and Peterson C.L. (2006). Interplay between Ino80 and Swr1chromatin remodeling enzymes regulates cell cycle checkpoint adaptation in response to DNA damage. *Genes Dev.*, 20; 2437–2449.
30. Papamichos-Chronakis M., Watanabe S., Rando O.J. and Peterson C.L. (2011). Global regulationof H2A. Z localization by the INO80 chromatin- remodeling enzyme is essential for genome integrity. *Cell,* 144: 200–213.
31. Phillips T. and Shaw K. (2008). Chromatin Remodeling in Eukaryotes. *Nature Education.,* 1(1): 209-2013.
32. Ramirez-Prado J.S., Piquerez S.J.M., Bendahmane A., Hirt H., Raynaud C. and Benhamed M. (20180.

Modify the Histone to Win the Battle: Chromatin Dynamics in Plant-Pathogen Interactions. *Front. Plant Sci.,* 19(9): 355-362.

33. Ryan D.P., Sundaramoorthy R., Martin D., Singh V. and Owen-Hughes T. (2011). The DNA- binding domain of the Chd1 chromatin-remodelling enzyme contains SANT and SLIDE domains. *EMBOJ*., 30: 2596–2609.
34. Kumar S.V. and Wigge P.A. (2010). H2A.Z-Containing Nucleosomes Mediate the Thermosensory Response in Arabidopsis, *Cell,* 140: 136–147.
35. Vermeulen M., Eberl H.C. and Matarese F. (2010). Quantitative interaction proteomics and genome-wide profiling of epigenetic histone marks and their readers. *Cell,* 142: 967-980.
36. Wang H., Wang L. and Erdjument-Bromage H. (2004). Role of histone H2A ubiquitination in Polycomb silencing. *Nature,* 431: 873-878.
37. Wang W.S., Pan Y.J., Zhao X.Q., Dwivedi D., Zhu L.H. and Ali J. (2011). Drought-induced site-specific DNA methylation and its association with drought tolerance in rice (*Oryza sativa* L.). *J. Exp. Bot.,* 62: 1951–1960.
38. Xhemalce B. and Kouzarides T. (2010). A chromodomain switch mediated by histone H3 Lys 4 acetylation regulates heterochromatin assembly. *Genes Dev.,* 24: 647-652.
39. Zhang X., Yazaki J., Sundaresan A., Cokus S., Chan S.W. and Chen H. (2006). Genome-wide high-resolution mapping and functional analysis of DNA methylation in Arabidopsis. *Cell,* 126: 1189–1201.
40. Zilberman D., Gehring M., Tran R.K., Ballinger T. and Henikoff S. (2007). Genome-wide analysis of Arabidopsis thaliana DNA methylation uncovers an interdependence between methylation and transcription. *Nat. Genet.*, 39: 61–69.

Website : www.asthafoundation.in
ICAAAS–An Edited Book (Volume-3)
ISBN : 978-81-958010-7-7
Published by : Astha Foundation, Meerut (U.P.) India
Edition-2024

Chapter 5

CONSERVATION OF PLANT GENETIC RESOURCES FOR FOOD AND NUTRITIONAL SECURITY

A.S. Jeena, Rohit, Tabassum and Ankit Kumar
Department of Genetics and Plant Breeding, G.B. Pant University of Agriculture and Technology, Pantnagar-263145 Uttarakhand

World population is expected to increase by 2.0 billion over the next 30 years, from 7.7 billion today to 9.7 billion in 2050. The world needs astonishing increase in food production to feed this population. Agriculture will be adversely affected by climate change in its manifold dimensions, but most significantly by the changes in rainfall pattern. The change in total precipitation as also the shift in time and distribution of rainfall will have pronounced effect on cropping pattern and overall productivity. The report of the IPCC indicates a probability of 10-40% loss in crop production in India and other countries of South Asia with increases in temperature by 2080-2100 and decrease in irrigation water (IPCC, 2007). India could lose 4-5 million tons of wheat production with every rise of 1°C temperature throughout the growing period even after considering carbon fertilization. In a study at the International Rice Research Institute, the yield of rice was observed to decrease by 10% for every 1°C increase in growing-season minimum temperature. Plant genetic resources (PGR) constitute the foundation upon which agriculture and world food securities are based and the genetic diversity in the germplasm collections is critical to the world's fight against hunger. They are the raw material for breeding new plant varieties and are a reservoir of genetic diversity. Human civilizations have benefited greatly from the domestication, conservation and use of plants species used for agriculture and food production. For thousands of years, farmers have used the genetic variation in wild and cultivated plants to develop their crops. Genetic diversity is the basic factor of evolution in species. It is the foundation of sustainability because it provides raw material for adaptation, evolution, and survival of species and individuals, especially under changed environmental, disease and social conditions and it will allow them to respond to the challenges of the next century (Hammer *et al.*, 1999). The future food supply of all societies depends on the exploitation of genetic recombination and allelic diversity for crop improvement, and many of the world's farmers depend directly on the harvests of the genetic diversity they sow for food and fodder as well as the next seasons seed (Smale*et al.*, 2004). The considerable genetic diversity of traditional varieties of crops is the most immediately useful and economically valuable part of global biodiversity.

Food and Nutrition Security

'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 (FAO definition 1996, 2009). Availability of food, Access to food, Utilization and food Stability are the four pillars of Food security. The term 'food security' does not clearly spell out the nutrition dimension of food. Over the time policy makers and practitioners combined both concepts linguistically and conceptually. Emphasizing to achieve both food security and nutrition security.The new proposed definition now is "Food and nutrition security exists when all people at all times have physical, social and economic access to food, which is consumed in sufficient quantity and quality to meet their dietary needs and food preferences, and is supported by an environment of adequate sanitation, health services and care, allowing for a healthy and active life."

Cited as : Singh S.P. (2024). ICAAAS : Conservation of plant genetic resources for food and nutritional security. *ICAAAS–An Edited Book.* Volume-3 : 44-49. Astha Foundation, Meerut (U.P.) India.

Food Security and Nutrition Scenario

The world population is growing steadily which is surely not doing any help to the Food Security and Nutrition of the World instead it is the major threat.Agricultural production in general and crop productionin particular, must increase substantially in order tomeet the rising food demand of a population thatis projected to expand by some 40 percent over theperiod from 2005 to 2050. Adding on to this climate change and increasing climate variability and extremes are affecting agricultural productivity, food production and natural resources, with impacts on food systems and rural livelihoods, including a decline in the number of farmers leading to major shifts in the way in which food is produced, distributed and consumed worldwide. According to the FAO, 2019 report more than 820 million people in the world are still hungry today, underscoring the immense challenge of achieving the Zero Hunger target by 2030. Another disturbing fact is that about 2 billion people in the world experience moderate or severe food insecurity.

India has nearly 195 million undernourished people, whichmake a quarter of the global hunger burden. Nearly 47 million or 4 out of 10 children in India are not meeting their full human potential because of chronic undernutrition or stunting. Since the independence India has no doubt some huge improvements and is committed for future also. Between 2006 and 2016, stunting in children below five years declined from 48% to 38%. Government of India has launched a number of programmes and schemes to farmers for doubling their income by the year 2022. They include: the National Food Security Mission, Rashtriya Krishi Vikas Yojana (RKVY), the Integrated Schemes on Oilseeds, Pulses, Palm oil and Maize (ISOPOM), Pradhan Mantri Fasal Bima Yojana, the e-marketplace, as well as a massive irrigation and soil and water harvesting programme to increase the country's gross irrigated area from 90 million hectares to 103 million hectares by 2017.The National Food Security Act (NFSA), 2013, aims to ensure food and nutrition security for the most vulnerable through its associated schemes and programmes, making access to food a legal right. The Act legally entitles upto 75% of the rural population and 50% of the urban population to receive subsidized foodgrains under Targeted Public Distribution System. About two thirds of the population therefore is covered under the Act to receive highly subsidized foodgrains (Department of Food and Public Distribution, Government of India).

Plant Genetic Resources

According to the revised International Undertaking 1983 of the FAO, plant genetic resources were defined as the entire generative and vegetative reproductive material of species with economical and/or social value, especially for the agriculture of the present and the future, with special emphasis on nutritional plants. In easier terms Plant genetic resources refer to the raw material that the breeders use to improve the productivity and quality of a crop species which can be any genetic material of plant origin acquiring some potential value for food and agriculture. The efficiency of global food production depends on the careful use and conservation of plant genetic resources to produce higher yielding, more nutritious, more stable and moreeco-efficient crop varieties.

PGR plays an important role in all aspects of life on earth from contributing in biodiversity for ecosystems to providing the genetic diversity to different researcher fields including plant breeders. Majorly it provides following vital services to the planet :

1. Provisioning services which includes the supply of products fromecosystems, such as food and genetic resources.

2. Regulating services, these arethe benefits, such as waterpurification obtained from the regulation ofecosystem processes.

3. Cultural services, it includes non-material benefits obtainedfrom ecosystems such as recreation, education and ecotourism.

4. Supporting services, these are needed for theproduction of all other ecosystem services.

PGR are a strategic resource and lie at the heart ofsustainable agriculture and food security of the world. The link between geneticdiversity and food security has two main dimensions:firstly the deployment of different crops and varietiesand the use of genetically heterogeneous varietiesand populations, can be adopted as a mechanism toreduce risk and increase overall production stability;and secondly, genetic diversity is the basis for breedingnew crop varieties to meet a variety of challenges.The struggle to obtain new plants for food and agriculture has beenone of the main motivations of human travel from the earliest times, and has oftenled to alliances and partnerships, but also to conflicts and wars between differentcivilizations and cultures. PGR was and will be the basis to shape humanity and mankind.

Conservation of Plant Genetic Resources

Plant genetic resources conservation strategies include *ex situ* conservation, in gene banks, field collections as seed and tissue samples and *in* *situ* conservation in protected areas under wild conditions. Most *in situ* conservation concerns crop wild relatives, an important source of genetic variation to crop breeding programs.Plant genetic resources that are conserved by any of these methods are often referred to as germplasm, which is a shorthand term meaning "any genetic materials".Nikolai I. Vavilovdedicated most of his life to the collection of plant germplasm resources; at his time, he organized more than one hundred expeditions to economically important plant regions around the world in an effort to resolve famine in Russia.The germplasm collection created from Vavilov's expeditions again saved Russia from starvation after the Great Patriotic War (June 1941 to May 1945).Vavilov collected more than 250,000 samples having estimated value at 8 trillion dollars.In the 1960s and 1970s,organizations such as the Rockefeller Foundation and the European Society of Breeding Research (EUCARPIA) emphasized more on the collection and conservation of plant genetic resources.

The core importance of PGR, for food and nutritional security of the world is well acknowledged now and constant efforts are made to promote and reward the farmers, researchers in the field of PGR conservation. International collaborations on PGR are made with major part of world now involved. A key event in the conservation of plant genetic resources was the establishment of the International Board for Plant Genetic Resources (IBPGR) in 1974. IBPGR promotes the global network of gene banks and assist in global efforts for conservation of PGR.

In 1979, during the 20thConference of FAO, international agreement was signed for an internationalagreement and the formation of a network of germplasm banks with internationalsovereignty, under the assumption that plant genetic resources are a heritage ofmankind and that a legal framework was needed to ensure its unrestricted availability.In 1983, first international agreement for the conservation and sustainable use ofagricultural biological diversity was resolved the Commission on Genetic Resources for Food and Agriculture was established, and the voluntary International Undertaking on Plant Genetic Resources was adopted by FAO. In 1991, the national sovereignty of plant genetic resources, plant breeders' rights and farmers' rights were recognized.In 1996, at the Leipzig International Technical Conference on Plant Genetic Resources Global Plan of Action was adopted. All these efforts eventually paved way for the historic adoption of the legally binding International Treaty on Plant Genetic Resources for Food and Agriculture (ITPGFRA) in 2001. The Treaty entered into force on 29 June 2004.

The International Treaty on Plant Genetic Resources for Food and Agriculture was adopted by the Thirty-First Session of the Conference of the Food and Agriculture Organization of the United Nations on 3 November 2001.

The Treaty aims at :

Recognizing the enormous contribution of farmers to the diversity of crops that feed the world.

Establishing a global system to provide farmers, plant breeders and scientists with access to plant genetic materials.

Ensuring that recipients share benefits they derive from the use of these genetic materials with the countries where they have been originated.

Conservation of Plant Genetic Resources in India

India has successfully taken strategic stepsfor conservation of plant genetic resources. For *ex-situ* conservation major activities are carried out under the Indian Council ofAgricultural Research (ICAR) by the National Bureau of Plant Genetic Resources(NBPGR), New Delhi, which is the nodal organization for ex situ managementof PGRFA. Additionally, several economically important plant species are also conserved in botanic gardens of various plant science-based institutes, most ofwhich come under the vigilance of the Botanical Survey of India (BSI), Ministryof Environment, Forests and Climate Change (MoEFCC).The exchange of PGRFA is crucial for crop improvement programmes andultimately the food and nutritional security of the world. India has contributedits share of genetic resources to the world through various national and internationalexchange programmes and would continue in the future also.Department of Agriculture & Cooperation, Ministry of Agriculture, declared all the crops listed in the Annex-I of ITPGRFA to be exempted from Section 3&4 of the Biological Diversity Act, 2002 (18 of 2003) for the purpose of utilization and conservation or research, breeding and training for food and agriculture. The exempted crops will be governed by the guidelines to facilitate the exchange of Plant Genetic Resources under the Multilateral System of ITPGRFA on 30.07.2014.

In India NBPGR also play most vital roles in food security through germplasm and gene conservation in following ways :

1. PGR acquisition through exploration and import.

2. Long term conservation in of accessions in National Genebanks and field repositories.

3. DNA fingerprinting for IPR protection and development of genomic resources.

4. Data base management and enhanced utilization.

5. Characterization and utilization of different yield related and physiological traits in collected germplasm.

6. Plant quarantine and health testing for pathogen, weed and pest free conservation.

The Contributions of Traditional Agriculture to Conserving Biodiversity

Traditional agriculture has adapted to a wide variety of local environments, producing diversity and reliable food supplies, reducing the incidence of disease and insect problems, using labour efficiently, intensifying production with limited resources, and earning maximum returns with low levels of technology. It utilizes a very wide range of species and land races which vary in their reaction to diseases and insect pests, and to different conditions of soil, rainfall and sunlight. It provides sustainable yields by drawing on centuries of accumulated experience by farmers who did not depend on scientific information, external inputs, capital, credit, or markets.

But with growing populations, steps need to be taken to enhance the productivity of lands under traditional agriculture. In the forested uplands, modern agricultural development should take existing systems as starting points and use modern agricultural science to improve on the productivity of the system. The essential element is the design of self-sustaining agroecosystems. These ensure the maintenance of local genetic diversity available to farmers, thereby enabling rural communities to manipulate production systems to best suit local conditions. In addition, the ability to maintain a stable and permanent system with forested land enables farmers to invest time and effort in other permanent assets like fruit trees, fenced gardens, terraces, and irrigation canals. Such mixed systems will often enable modern agricultural techniques to be wedded to traditional ones, and lead to the establishment of more permanent villages (McNeely,1989).

Agricultural ecologists have learned to respect the wisdom inherent in many traditional practices. If traditional farming is developed as part of an overall system of conservation-oriented management, it can continue to make a valuable input into the total agricultural productivity of a region and can contribute to the biological diversity of rural ecosystems. It should be noted that "protection" does not always lead to more biodiversity On the other hand, some conservation measures can help preserve traditional agroecosystems.

Role of Plant Genetic Resources for Food and Nutritional Security

In spite of advances in food production, food insecurity and malnutrition are still widespread, which is a consequence of the agricultural and industrial development and the progressive unification of cultural and eating habit or simply globalization. More people migrating towards cities the food choices are becoming narrower and hence triggered pressure on agricultural productivity as a result;the number of crops and the diversity within them has been progressively reduced. A large number of the country reports expressedconcern about the increasing use of genetically uniformvarieties and the trend for them to be grown on everlarger areas, resulting in increased genetic vulnerability.One aspect to counter is greater use ofgenetic diversity. The deployment ofdiversity at the farm and field level helps provide a bufferagainst the spread of new pests and diseases. Genetic diversity representsa 'treasure chest' of potentially valuable traits.PGR plays an important role in providing genetic resources, the raw materialfor improving the production of more and betterfood, either directly or indirectly throughlivestock. They are also important as the basis forimproving fibre, fuel or any other crop product.

This has led to a more intensive use of this germplasm in breeding and thereby yields of many crops increased dramatically. Some historical examples of utilization of germplasm for crop improvement are given below:

Wheat Improvement: Wheat is truly global, being one of the few crops grown over most of the world. There are hundreds of thousands of wild species, landraces, and local cultivars within the *Triticum* species that constitute the wheat of the world. Several specific genes that have made major impacts on wheat can be directly traced to contributions from genetic resources, such as dwarfing Genes*Rht1* and *Rht2*from ''Norin 10,'' a cultivar from Japan, resulted in the reduced height (or dwarf) in wheat. Norin 10, in turn, inherited these genes originally from ''Shiro Daruma,'' a Japanese landrace (Kihara, 1983). The incorporation of the *Rht1*and *Rht2* genes into the new varieties of wheat led to what is now been termed the ''Green Revolution''.

Tomato: Domesticated tomato plants are commonly bred with wild tomatoes of a different species to introduce improved resistance to pathogens, nematodes and fungi. Resistance to at least 32 major tomato diseases have been discovered in wild relatives of the cultivated tomato. Genes responsible for promoting resistance to 16 of these have been bred into commercial cultivars, allowing tomato production in areas where they could not otherwise have grown

Sugarcane Improvement: Sugarcane, a multi species hybrid derivative, termed as*Saccharum* complex by Mukherjee (1957) included the genera *Saccharum*, *Erianthus*, *Sclerostachya*and *Narenga*constituted interbreeding group involved in the origin of modern sugarcane. In sub-tropical regions, low temperature, during December and January, is considered as growth limiting factor. Introgression of genes from *S. spontaneum, S. sinense*and*Erianthus*in sugarcane resulted in the growth of progenies during winter months. Uneven and unpredictable rainfall in the climate change regime is expected to result in frequent occurrence of drought in many part of India. Drought tolerance reported in many *Saccharum* species including *S. spontaneum*, *S. officinarum*and *S. barberi*and inthe genus *Erianthus*with a well-developed root system is generally perceived as useful for developing drought-tolerant varieties. Water logging is expected to be a big problem in sugarcane cultivation with the altered and unpredictable rainfall pattern. Clones with profuse fibrous floating roots and negatively geotropic roots with aerenchyma were found to be resistant to water logging (Srinivasan and Rao, 1960). However, tolerant to water logging on high water table is a trait present in *S. spontaneum*germplasm and the trait can be transmitted through crossing.

Use of Plant genetic resources in modern era

PGR provides the accessions having variability for enhancing the overall productivity of the crops this helps in development of high yielding varieties. This is most useful for the developing countries where the overall productivity is still low and there is a constant challenge of resources. One of the best examples for this is theNERICA rice. The term NERICA, means ‘New Rice for Africa’, is used to refer to the genetic material derived from the successful crossing by WARDA in the early 1990s, of the two species of cultivated rice, the African rice (*O. glaberrima*Steud.) and the Asian rice (*O. sativa* L.). The *O. glaberrima*accessions used in the breeding programme came from the WARDA genebank and simple biotechnological techniques were used to overcome sterility barriers with *O. sativa*.NERICA is a new group of rice varieties that adapt well to rainfed ecologies in Sub-Sahara Africa, where70 percent of smallholder farmers cultivate rice.

PGR are not only limited for providing increased total food productionbut also nutritional well-being. Normally the best way to healthy diet is ensuring anadequate intake of all the macro and micronutrientsneeded, which can be achieved by eating varied forms of fruits, nuts and other plant or animal based food. However, many poor people in the developing countries of Africa and Asia are unable to afford suchdiverse diet and have to rely heavily onjust a few staple food crops for most of their food. This is majorly responsible for nutrient deficiencies in these countries. Inrecognition of this, a number of breeding efforts areunderway to improve the nutritional quality of staplecrops, for example, by producing rice, maize, cassavaand sweet potato with higher levels of beta–carotene(the precursor of Vitamin A), pearl millet and beanswith higher levels of available iron and rice, wheat andbeans with higher levels of zinc. In India biofortified sorghum and pearl millet varieties and hybrids became a solution for malnutrition.ICRISAT developed high iron biofortified pearl millet variety ICTP 8203 Fe, released as Dhanshakti in Maharashtra, India, in 2013 and for all-India cultivation in 2014. Dhanshakti is the first iron biofortified crop cultivar to be officially released in India. It has been included in the Nutri-Farm Pilot Program launched by the Indian government.

Some recently biofortified varieties of crops are released by ICAR institutes in different crops are, rice (CR Dhan 310, DRR Dhan 45, DRR Dhan 49), wheat (HPBW 01,PusaTejas (HI 8759), PusaUjala (HI 1605), Maize (Pusa Vivek QPM9 improved, Pusa HM4 improved, Pusa HM8 improved, Pusa HM9 improved, Pearl millet(HHB 299,AHB 1200), lentil (Pusa Ageti Masoor, IPL 220), Mustard(Pusa Mustard 30,Pusa Double Zero Mustard 31), Soybean (NRC-127), Cauliflower (Pusa Beta Kesari 1) and Sweet potato (Bhu Sona, Bhu Krishna). These are majorly result of identification and induction of novel genes using PGR.

Millets : A solution to agrarian and nutritional challenges

Millets cultivation can keep dry lands productive and ensure future food and nutritional security. These contain good amounts of vitamins, minerals, essential fatty acids, phytochemicals and antioxidants that can help to fight against global nutritional challenges. As the climate change is expected to rise the global temperature which in turn will turn the agroclimatic conditions mostly in tropical and sub-tropical countries. This situation will demand sustainable crop substitutes and millets the best solution available. Therefore the germplasm conservation of millets holds the prime importance for now and near future. There are multiple benefits of millets that are recognized not only as a best substitute for changing ecological system but also health benefits. Millets are considered to impart role in lowering rate of fat absorption, slow release of sugars (low glycemic index) and thus reducing risk of heart disease, diabetes and high blood pressure. Millets fall under the group of C4 cereals. C4 cereals take more carbon dioxide from the atmosphere and convert it to oxygen, have high efficiency of water use, require low input and hence are more environment friendly. Thus, millets can help to phase out climatic uncertainties, reducing atmospheric carbon dioxide, and can contribute in mitigating the climate change (Kumar *et. al,* 2018). In the year 2018, India has proposed UN food and agriculture to declare 2023 as international year for millets. India enjoys the large diversity and cultural connection with all the millet crops from history.

Conclusion

Nowadays the utilization of the genebank holdings for crop improvement including abiotic stress tolerance is one of the main challenges. The successful exploitation of genetic resources requires (1) extensive characterization and evaluation and (2) genetic analysis and molecular mapping of the relevant traits. Detected loci determining abiotic stress tolerance at different developmental stages can be combined and transferred to modern cultivars via marker assisted selection. Plant genetic resources play a major role in incorporation of many useful genes including resistant to biotic stresses and tolerant to abiotic stresses. It is imperative that targeted exploration must be conducted to collect new germplasm, characterize for resistance/ tolerant to biotic and abiotic stresses and utilize them in pre-breeding activities. Convergence of conventional and biotechnological approaches is expected to bring greater breakthrough in introgression breeding programme to develop climate resilient genetic stocks for utilizing them in commercial breeding programme.

Website : www.asthafoundation.in
ICAAAS–An Edited Book (Volume-3)
ISBN : 978-81-958010-7-7
Published by : Astha Foundation, Meerut (U.P.) India
Edition-2024

Chapter 6

BREEDING STRATEGIES TO COMBAT ABIOTIC STRESS IN PULSES

S.P. Singh
CSAUAT-Agriculture Research Station, Kalai, Aligarh (U.P.) India
Email : dr.sp.singh24@gmail.com

Pulses are an important source of dietary protein especially for millions of vegetarians of India. The group comprises chickpea, pigeonpea, mungbean, urdbean, lentil, fieldpea, rajmash and grasspea besides several other grain legumes of local importance such as cowpea, mothbean, horsegram, fababean, ricebean, and the like. The dry grains of pulses are used mainly as 'dal' as a supplement to cereals, making the food as a perfect mix. However, in India and some parts of the world, immature seeds are also used as vegetables. Besides this, they also add significant amount of nitrogen to the soil by fixing atmospheric nitrogen in their root nodules.

In the developing countries like India, pulses are still crops of typically low input agriculture, which hardly receives better than average management practices. Such environments are prone to large errors, less differentiation between genotypes, and less repeatability across years. The prediction and management of such environments have become even more difficult under changing climatic scenario. Components of such environments largely include abiotic stresses such as extremes of moisture (water logging/drought) and temperature (high/low), salinity and mineral stresses (such as Al toxicity in acid soil). In low-input agriculture and/or low productivity environments in which most variables are unpredictable, high G-E interactions are observed. Consequently, identification of superior genotypes becomes very difficult. Before suggesting breeding strategies, it is pertinent to understand the nature and complexity of abiotic stresses.

The yield level of a crop reflects many facets of crop growth including environmental factors such as rainfall, temperature, sunlight and humidity and cultural factors such as planting date, row spacing, cultivar selection and tillage method. As a result, the interpretation of a relationship is difficult; however response is likely at low yields at high soil test values.

Nature of Abiotic Stresses in Pulses : Abiotic stress is deviation from optimum production condition arising due to non-living components of environment (such as high or low temperature and moisture, high salinity or acidity in soil, etc.) that adversely affect growth and reproduction of crop plants.

Soil degradation and related production constraints : Physical degradation like soil erosion, soil crusting and compaction, chemical degradation like loss of organic matter, soil fertility, multi nutrient depletion and deficiencies, salt accumulation, pollution, etc., are some of the major soil and management-related problems reported which account for nearly 60% (188 M.ha) of the total land area . Soil acidification is a natural soil-forming process accelerated by high rainfall, low evaporation, leaching of bases, and high oxidative biological activity that produces acid. The soil acidity plays major role in determining the nutrient availability to plants and in many instances by specific mineral stress problems. Production constraints are more intense on acid soils, which cover 30% of the world's land area. Acid soil infertility is a syndrome of problems that affect plant growth in soils with low pH. This complex of problems arises from toxicities and deficiencies in acid soils are related to :

Presence of the toxic concentration of Al and to a lesser extent Mn toxicity in many species,

Deficiency of bases (Ca, Mg, K) and their poor retention power,

Cited as : Singh S.P. (2024). ICAAAS : Breeding strategies to combat abiotic stress in pulses. *ICAAAS–An Edited Book.* Volume-3 : 50-56. Astha Foundation, Meerut (U.P.) India.

High P fixation capacity of soil caused by highly active Al and Fe surfaces, rendering it unavailable to plants,

Deficiency of Mo, especially for the growth of legumes,

Reduction of soil biological activities,

Impairment of N2-fixation by legumes caused by poor survival of microsymbiont and inhibition of nodulation, and

Fe and Mn toxicities.

Nutrient mining status : The soil fertility status of Indian soils has declined drastically over the years following the era of green revolution and is marked by a negative balance of 8-10 M. tons between nutrients removed by the crops and those added through manures and fertilizers leading to mining of soil nutrient capital and steady reduction in soil nutrient supplying capacity. The situation is further aggravated by the depletion of major soil nutrients like N and K in intensive cropping systems and emergence of wide spread deficiencies of secondary (S, Ca) and micronutrients (Zn, Fe, Mn, Cu and B). Soil test data available for major part of the country for the major nutrients (N, P, K) show that 89 and 80% of the soils are low to medium in N and P, and about 50% of the soils are responsive to K supply. District wise soil fertility status of Indian soils also indicates a similar trend.

The potential for developing new crop varieties by means of higher stress tolerance is promising, given recent advances in molecular biology and genomics, with implications of both conventional and transgenic breeding. A better scientific consideration is required of the yield restrictive practices to target future genetic and agronomic improvements and to evade the unnecessary use of inputs during those parts of the crop lifecycle that is not critical for crop growth and yield formation and are more affected by changing climate threats and can vary with countries and agro-climatic regions. Though, the long-term success in breeding crops adapted to climate change may be controlled by a potential loss of genetic diversity caused by temperature rise and shifts in precipitation that lead to range reduction or extinction of crop wild relatives. To counter this threat, maintenance is desired for policies that initiate defining the scope of the climate change risk to crop wild relatives, policies that engage local communities in their conservation, and the formulation of priority-determining mechanisms.

Farmers will need a diverse selection of improved crop varieties that are better adapted locally to ecologically based production practices and suited to resilient to climate change. The introduction of adapted and recognized crop varieties can potentially empower cropping systems by aggregate crop yields with building crop resilience to biotic and abiotic stresses in a sustainable way likewise by means of taking new market opportunities besides increasing crop productivity, quality, health and nutritional value which will help to make sure continuous improved agricultural production even at uncertainties about future climate change impacts and help to create eco-friendly sustainable environment. There are many crop varieties better adapt better to changing climatic parameters.

The topic of nutrient use efficiency has recently gained more attention with rising fertilizer costs and continued concern over environmental impairment. Nutrient or fertilizer use efficiency can be viewed from different perspectives based on yield, recovery or removal. Among the most common expressions of efficiency is the recovery efficiency (RE) of fertilizer nutrient, defined as the percentage of fertilizer recovered in aboveground plant biomass during the growing season. Fertilizer utilization rate (crop recovery efficiency) under favourable conditions for N is about 50-70%, 10-25% for P (15% average), and 50-60% for K. It was also suggested that efficiency of P and K over time (multiple growing seasons) could also be taken into account for realistic estimate. Nutrients that build-up in soil such as P and K, can certainly be viewed over the long term, while N efficiency is viewed on the short term because of its transient nature. Where there is potential for building soil C reserves, long term N efficiency is appropriate because soil C balance also affects N balance'

Reasons for low NUE :

Nutrient losses – Erosion, leaching, runoff, volatilization, denitrification etc.

Soil fixation of nutrients – P in deficient, highly weathered acid soils (Ultisols and Oxisols), K in highly illitic clay soils and Zn in high clay and calcareous soils.

Nutrient interactions - antagonistic interactions between P and Zn, Na and K, Mg and K, Ca and K, Ca and Fe etc.

Imbalanced fertilizer use - imbalanced use of a few straight fertilizers results in reduced availability of other nutrients there by reducing their use efficiency.

Soil related problems - acidity, salinity; alkalinity, calcareous, acid sulphate soils, poor drainage, texture etc. result in poor availability of nutrient elements.

Non – nutrient factors such as lodging, untimely planting, and pest / disease problems limit NUE.

Breeding for abiotic stress is considered more difficult because of: (a) complexity of conditions causing abiotic stresses, (b) complex nature of abiotic resistance in a variety, (c) occurrence of one stress more often in conjunction with the other, (d) low heritability of abiotic resistance, and (e) variable intensity of such stress under field condition. The actual mechanisms employed by individual crop plants vary greatly, and are not homogeneous. The tolerance to abiotic stress is often conditioned by quantitative trait loci with complex interactions. Besides these, high G×E interactions and lack of precise screening techniques make the task of breeder even more challenging.

Pulses encounter a number of abiotic stresses during various stages and phases of their life cycle. The nature of abiotic stresses may vary depending upon species, prevailing weather conditions and the type of soil. For example, winter grain legumes (cool season pulses) such as chickpea, lentil, peas and fababeans, which relatively tolerate low temperature, more often experiences terminal heat stress during their reproductive period. In low input agriculture, this condition is often intertwined with moisture stress. Warm (rainy) season pulses (e.g., pigeonpea, mungbean, urdbean, etc.,) often experience temporary waterlogging that may vary from hours to a few days. Although urdbean tolerates excess moisture to a greater extent, yield level is adversely affected in case excess water is not drained out after 2-3 days. This group of pulses also encounter moisture deficit owing to uneven rainfall pattern. Besides these, this group is relatively sensitive to low temperature stress. Pigeonpea, which is perennial by nature but is cultivated as a rainy season annual, encounter almost all such stresses such as waterlogging (during seedling stage) and drought and low temperature stresses(during reproductive stage). Depending upon the edaphic conditions, pulses may also face stresses imposed by salinity/alkalinity (high pH), Al toxicity and sodicity. Response of each grain legume to each stress may vary; the expression of stress (strain) may be manifested through effects on different traits. Consequently, different screening techniques and a different kind of breeding strategy is needed to mitigate abiotic stresses.

Screening Techniques and Marker Traits : Genetic variations have been noticed for almost all the abiotic stresses wherever a large number of genotypes have been screened. Marker traits conditioning tolerance to such stresses have also been identified. In the following section, we will discuss the specific screening techniques and the marker traits apt to differentiate genotypes for such a stress as:

Drought : The kind of drought that is of our interest is the *agricultural drought* that occurs where soil moisture and rainfall are inadequate during the growing season to support healthy crop growth to maturity and cause extreme crop stress and wilting of plants. A plant can resist drought condition through reduced water loss from aerial portions, increased water uptake from deep layers of the soil or by giving more yields at low water potentials. The maintenance of water uptake under drought condition is related to several properties concerning roots of plants such as root size and efficiency, root density, size of xylem vessel, and the like. Genotypic differences have been noted for all these attributes in almost all grain legumes. Several screening techniques including soil-based and field screening have been suggested to identify drought tolerant genotypes in grain legumes. Except field screening, these are almost exclusively based on identifying genotypes having long, dense and efficient root systems. Soil based screening techniques have been criticized as several constraints are encountered. To overcome these constraints, one novel screening technique "a new phenotyping technique to screen for drought tolerance in lentil", which is based on hydroponic system, has been recently suggested by. The new screening technique is based on seedling survivability, drought tolerance score, root and shoot length, and fresh and dry weight of roots and shoots. Three genotypes namely, ILL-10700, ILL-10823 and FLIP-96-51 showed the maximum seedling survivability and minimum reduction in the growth parameters with a drought score of 0.0–0.2, indicating higher tolerance to drought stress than other genotypes. The same technique with minor modifications has also been suggested to screen mungbean genotypes for drought tolerance. However, it appears that this technique is based on only partial component of even drought avoidance. Researchers have not corroborated the results of the hydroponic technique with the field level screening. Furthermore, it is also not clear whether the parameters (taken as the index of drought tolerance) confer only survival advantage to the surviving genotypes. Under field conditions, several variables interact to produce final outcome. Therefore, controlled field screening aided by rain-out shelter appears to be more reliable than simply soil or solution culture based screening techniques.

A number of morphological markers such as plant type (spreading or semi-spreading), morphology (leaf area index) and orientation of leaves (leaf angle), cuticular waxiness (which results in 2-50% reduction in transpiration), and leaf reflectance (up to 50% reduction in light absorption) are known to reduce water loss from aerial portion in grain legumes. Some physiological parameters such as water retention capacity of leaves (relative water content), osmotic adjustment, dehydration tolerance and stomatal regulation appear to be equally important in most of the legumes for combating moisture deficit condition. However, conclusive evidences that these parameters also confer reproductive advantages to the surviving genotypes are scanty. Agronomic traits such as pods/plant, seeds/pod, seed size and seed yield/plant under actual water deficit condition should be given much importance while breeding for drought resistance.

Waterlogging : Water logging refers to soil saturation with water. Some crop plants including rice tolerate this stress by virtue of their special character (presence of aerenchymatous cells). However, other crop plants are prone to waterlogging stress especially at seedling stage. Under waterlogged condition, oxygen diffusion rates in flooded soil is about 100 times lower than air, and respiration of plant roots, soil micro-flora and fauna leads to rapid exhaustion of soil oxygen, eventually causing anaerobiosis. However, proximate causes of plant injury can be oxygen deficit or mineral nutrient imbalances, a decrease in cytokinins or other hormones released from the roots, a decrease in available soil nitrogen and/or nitrogen uptake, an increase in toxic compounds in soil such as methane, ethylene, ferrous ions or manganese, an increase in toxic compounds (in the plant) such as ethanol or ethylene, and an increase in disease causing organisms.

Winter season grain legumes are sensitive to excess moisture compared to rainy season pulses. However, grasspea (*Lathyrus sativus*), a winter season annual that is often grown as a *paira* crop with rice in eastern India, is perhaps the most tolerant to waterlogging. This species needs to be fully investigated for the special attributes that confer upon it this peculiar adaptive advantage. Rainy season pulses such as pigeonpea, mungbean, urdbean, cowpea, and the like, more often encounter this stress owing to uneven pattern of monsoon rainfall. Urdbean, although relatively tolerant to excess soil moisture, may be damaged if there is prolonged waterlogging.

Screening techniques to discriminate tolerant and sensitive genotypes for waterlogging stress has been developed in pigeonpea. A set of test genotypes in 2-3 replications are grown in pots. These pots with two-three weeks' old seedlings are placed in a well-leveled tank and exposed to water treatments (partial submergence) for 6-8 days. After a fixed period of exposure to such stress, water is drained out completely. Data on plant density, chlorophyll content, oxygen content of water, pH of soil and other parameters are taken before and after water treatment. Agronomic data such as days to flowering, plant height, pods/plant, seeds/pod, yield/plant, maturity period, etc. are recorded on surviving genotypes in both treated and control treatments. This screening technique may be satisfactory. However, the timing of the experiment must be such that it mimics that of natural condition.

It has been observed that waterlogging can affect pigeonpea during germination, early and late seedling stages as these stages cover peak monsoon period. These three critical stages can be used for screening of tolerant genotypes. Waterlogging, in general, causes rapid senescence and drooping of the shoot tips of plants. In pigeonpea, it reduces plant height and delays flowering in surviving plants, resulting in the reduction in the number of pods, seeds/pod and seed yield. It has been observed that seed coat thickness, aerenchymatous cells, lenticels and adventitious roots also affect tolerance to waterlogging in pigeonpea. However, these traits need to be confirmed and re-validated before these can be used as selection criteria in crop plants.

The adoption of water saving technologies in general and breeding for aerobic and salt tolerant legumes in particular at the farm level will contribute to increasing water productivity, safe guarding food security, make use of salt affected land areas and alleviating poverty. Assuming an average farm size of 1 hectare, some 17 million farmers who face physical water scarcity and 22 million farmers who face economic water scarcity in 2025 will benefit from water saving technologies. A long chain of introduction, selection and recombination processes led to the development of improved salt tolerant materials which directly benefited the farmers by increasing their harvest in salt affected lands.

Extremes of temperature : In general, warm season grain legumes are relatively tolerant to heat stress and sensitive to low temperature. Winter season pulses, on the other hand, tolerate low temperature, but are sensitive to heat stress (>35°C). Amongst rainy season pulses, traditional pigeonpea encounters low temperature stress during winter months in North India. The stress adversely affects growth, survival and reproductive capacity of plants if the minimum temperature falls below 5°C. Genotypic variations for cold tolerance are well documented in pigeonpea especially for survival traits. Low temperature primarily affects development and growth and opening of flower buds. In some sensitive genotypes (IPA 209 and IPA 06-1), filaments of stamens fail to enlarge at low temperature and thus affect opening of flowers. Pollen dehiscence does not occur too, although pollens are fully fertile. As a consequence, unfertilized flowers wither and fall down, resulting in no pod formation in these genotypes under low temperature. It appears that formation of floral buds, no. of blossomed flowers and pod setting at low temperature can be used as selection criterion to identify tolerant genotypes in pigeonpea. These traits need to be investigated also in the wild relatives of pigeonpea to screen tolerant wild accessions as have been done in wild relatives.

Winter season pulses (chickpea, fieldpea and lentil) experience terminal heat stress especially during pod formation and grain-filling stages in North India. Screening techniques to identify heat tolerant chickpea genotypes have been developed. Genotypes are grown under late sown condition so that pod formation and grain filling stages (critical stages) coincide natural heat stress. The thermo-tolerance of the selected genotypes involved assessment of their pollen viability at 43°C, nondestructive assessment of photosynthetic ability through fluorescence imaging system and membrane injury test. Pollens of heat tolerant genotype 'ICCV 92944' were deeply stained at >40°C, while the sensitive genotypes 'ICC 14077' and 'PBG 5' showed non-viable pollen without taking stain. The increase in the non-viable pollen decreased fertility in these genotypes substantially at >40°C. Similar observations have been recorded for field pea and lentil. The biomass of lentil decreased significantly in all genotypes under late (January) sown condition compared to under normal (November) plantings. Therefore, lentil genotypes having relatively high biomass under heat stress would be desirable as there appears to be strong association of biomass and seed yield in lentil.

Salinity/alkalinity stress : Soil salinity is an ever increasing problem constraining production of both cool season and tropical and sub-tropical grain legumes in many parts of the world. Salinity of only 3 dS/m in field soils was the threshold for reduced shoot growth and yield in chickpea, although this exceeds the even lower salinity threshold (<1.3 dS/m) in some grain legumes like cowpea, soybean and pigeonpea. In chickpea, germination is less sensitive to salinity than early vegetative stage, and reproductive phase is considered to be even more sensitive than vegetative phase. However the chickpea is sensitive to salinity at both vegetative and reproductive phase, with pod formation being particularly sensitive. The sensitivity occurs even for a reputably tolerant cultivar 'JG 11' even at 20 and 40 mM NaCl levels that is considered relatively mild for many crops including modern wheat with which chickpea may be grown in rotation. In chickpea, 40 mM NaCl may be considered an optimum level to discriminate tolerant and sensitive genotypes. Upon removal of salinity (NaCl), which may hardly be a case under field condition, chickpea shows excellent recovery with substantial new shoot growth. This could happen presumably in almost all pulses as these are endowed with the unique adaptive advantage of having indeterminate growth habit.

Tissue ion regulation is a key trait for salt tolerance in plants, but whether Na or Cl 'exclusion' contributes to tolerance in chickpea remains uncertain. However the sensitivity during the reproductive phase was not caused by changes in pollen viability but was potentially due to toxic accumulation of Na and Cl in flowers, and possibly the sensitivity of pollen tube growth if NaCl entered the stigma. It therefore appears that in chickpea a combination of mechanisms, ion exclusion and tissue tolerance of excess ions are likely to contribute salt tolerance.

Under saline condition, symptoms of leaf necrosis, presumably related to the destruction of chlorophyll in leaf cells resulting from ion toxicity when Na^+ and/or Cl^- exceed threshold level in tissues have been observed; 'visual scores' of necrosis could be used as an index of salinity tolerance in chickpea. Salinity also causes physiological drought so that chickpea is unable to remove as much water from saline soil as from non-saline soil. Although chickpea shows osmotic adjustment, its role in salt-sensitive compared to salt resistant genotypes is not conclusive, and requires further study. Salinity has been shown to decrease number of pods/plant, seeds/pod and size of seeds; nevertheless, size is relatively less affected. No significant difference in seed size of salt-sensitive and salt resistant genotypes, indicating the possibility to develop salt resistant cultivars in the market-preferred seed size category. No consistency in performance was noticed when genotypes selected in seedling stage were brought to maturity under saline condition. It indicates that selections for salt resistance are required across the entire life cycle. Further, as genotypes differ in expression of resistance at different stages, it also provides an opportunity to combine sources of resistance for different stages from contrasting parents in chickpea.

In warm season pulses like pigeonpea, differential tolerance to salinity *vis-à-vis* pigeonpea maturity groups, like chickpea, no correlation was found between the tolerance at germination and later stages. However, percentage survival showed some association with seed yield under salinity. Low and high accumulation of Na and K, respectively in the roots and other plant parts (main stem, branches and leaves) perhaps helped salinity tolerance in pigeonpea. Wild relatives of pigeonpea including *C. scarabaeoides, C. albicans* and *C. platycarpus* have shown a wide range of variation in their salinity tolerance. Certain physiological attributes that confer salinity tolerance in these wild species include Na and Cl retention in the roots and limited translocation to the shoots, high K selectivity and maintenance of transpiration rate under saline conditions. NaCl treatment of 1.01 g/kg alfisol was suitable to salinity screening in pigeonpea, and large variations in the salinity susceptibility index and the percent relative reduction in both cultivated and wild accessions. The amount of Na accumulation in shoot showed that more tolerant genotypes accumulated less Na in the shoot except the wild species, which followed a different pattern compared to cultivated varieties. Overall, they found that *C. acutifolius, C. cajanifolius* and *C. lineata* were mostly sensitive, whereas *C. platycarpus, C. scarabaeoides* and *C. sericeus* provided good sources of tolerance. It was interesting to notice that *C. scarabaeoides* also provided a large range of sensitive materials.

In summary, grain legumes are sensitive to salinity stress. However, genotypic differences for salinity provide opportunity for selecting tolerant genotypes. The level of salt concentration to discriminate sensitive and tolerant genotypes may vary depending upon the species. There is no association of salinity tolerance between growth stages; therefore, screening needs to be performed from vegetative to reproductive stages. Salinity tends to interfere nutrient uptake (Ca, Fe, Mn and Mg), and usually favours accumulation of free proline in plant parts including pods. Ion exclusion (from root), tissue tolerance of toxic ions, and perhaps internal detoxification may be simultaneously operating to mitigate the effects of salinity stress.

Aluminum toxicity : Aluminum toxicity is a well known problem limiting crop production in 30% of arable lands. Considerable variation for tolerance to Al toxicity in plant species and genotypes within species has been reported. Both cool and warm season pulses are sensitive to Al toxicity. The work on screening for tolerance to Al toxicity in these grain legumes are only a few and limited to seedling screening.

However, due to operative simplicity, reliable and better precision and short test period, the hematoxylin staining at 30 ìg/ml Al concentrations was suggested as the best method to discriminate pigeonpea genotypes for Al tolerance. The same Al concentration (30 ìg/ml) has also been suggested for screening of other grain legumes including chickpea. However, the optimum level of concentration may vary in other legumes like lentil, mungbean, etc.

The better performance of tolerant genotypes could be ascribed to better regulation of ionic uptake and their distribution within the plants under different Al concentrations. The Al exclusion from root could be the possible mechanism for Al tolerance. However, internal detoxification in several other crops has also been reported as the possible mechanism of Al tolerance. Still in other cases, tissue tolerance to Al toxicity may also be possible.

Genetics of Marker Traits and Breeding Strategies : Escape mechanism has been invariably and widely utilized to mitigate the effects of abiotic stresses in almost all pulses. However, the same strategy cannot be applied for mineral stresses. It has been evident that during dry and wet years, specific gametic types are favoured separately. By extrapolation, grain legumes are likely to accumulate a specific combination of genes (alleles) if exposed separately to above-mentioned stresses. Therefore, a genotype showing tolerance to drought may react differently if exposed to water-logging and vice-versa. For example, JG-11–a leading chickpea variety of central and south zones in India, which is considered relatively tolerant to heat stress, is not a good performer in north India where atmospheric temperature is comparatively low during winter months (December-January). The best breeding strategy appears to be selection of superior genotypes of grain legumes under actual field condition. We are ultimately concerned with the yield (a measure of relative reproductive capacity) of genotypes. Therefore, selection should be based on yield and sometimes on its component traits. It is often argued that there may be temporal and spatial variation under field condition; therefore, screening should be done under controlled condition. However, under field conditions a number of variables interact to produce final outcome, thus field testing of genotypes cannot be ignored. Therefore, we suggest assessing genotypes for such abiotic stresses under actual field condition, and the results may be reconfirmed under controlled condition and vice versa. However, selection must finally be practiced for high yielding genotypes.

There are instances where traits in question are mono or oligogenic having high heritability (high regression of offspring on the parents). For example, Al tolerance has been shown to be dominant monogenic in chickpea and oligogenic in pigeonpea. Similarly, pollen dehiscence and pod setting under low temperature and waterlogging tolerance in pigeonpea, salinity tolerance in certain accessions of *Cajanus albicans*, a wild relative of pigeonpea, and winter hardiness in lentil (Frt gene) have also been reported as the dominant monogenic traits. Under such a situation, simple back cross breeding can be used to improve Al or other stress tolerance in pigeonpea or any other concerned grain legume. There are instances when even monogenic/oligogenic traits show high G×E interaction and low heritability. Such a situation calls for improving tolerance through marker assisted backcrossing, which generally involves transfer of a limited number of trait loci including transgenes from one genetic background (donor genotype) to the other genetic background (elite variety) using molecular markers.

However, resistance/tolerance to most abiotic stresses is quantitative in nature. For example, earliness, plant height, plant structure, growth habit and yield in lentil and root traits, drought tolerance score, canopy temperature differential and seed size in chickpea are controlled by several QTLs. The same holds true for yield and its component traits (seed number, seed weight), which should be given due importance while making final assessment of tolerance to such stresses. In such cases, retaining desirable gene combinations or pyramiding of several QTLs through marker-assisted backcross approach may be a challenging task. The best approach is to resort to marker-assisted recurrent selection. In some cases, superior alleles for a given trait (e.g., salinity tolerance in *C. albicans*) are identified and transferred from the wild species to a leading variety/cultivar. Under such situations, advanced backcross QTL approach for simultaneous discovery and transfer of superior alleles from wild species to develop improved lines may be followed as this approach facilitates efficient tracking for desired and non-desired alleles in breeding lines.

Website : www.asthafoundation.in
ICAAAS–An Edited Book (Volume-3)
ISBN : 978-81-958010-7-7
Published by : Astha Foundation, Meerut (U.P.) India
Edition-2024

Chapter 7

Exploring Lesser Utilizedor Underutilized Fruits for Product Developement

Purandar Mandal
OUAT-College of Horticulture, Chiplima, Sambalpur, Odisha-768025
Email : Purandar.mandal@gmail.com

Underutilized fruit crops can be defined as fruit crops which are have value but not widely grown, rarely found in the market and not cultivated commercially (Nilanthi Dahanayake, 2015). The underutilized foods can also be defined as the foods which are less available, less utilized or rarely used or region specific (Simrandeep Kour, 2018).

It is difficult to precisely define which attributes make a crop "underutilized", but often they display the following features :

Linkage with the cultural heritage of their places of origin

Local and traditional crops whose distribution, biology, cultivation and uses are poorly documented

Adaptation to specific agroecological niches and marginal land

Weak or no formal seed supply systems

Traditional uses in localized areas

Produced in traditional production systems with little or no external inputs

Receive little attention from research, extension services, policy and decision makers, donors, technology providers and consumers

May be highly nutritious and/or have medicinal properties or other multiple uses

India is home of world's most useful plants thriving in her diverse agro-ecological zones and altitudes. The varying weather conditions of this country provide suitable environment for growing variety of fruits. Nutritionists recommend that fruits must form an important constituent of the daily diet. Different fruits colour, varied aroma and taste make them palatable and freshen over mind and body. The importance of fruits lies not only in its nutritive value, but also in the fact that it can be consumed raw and at any time of the day. Utilization of fruits in India depends on its overall production and consumption by individuals and food industries. On the basis of these criteria, it appeared that even the most conventional fruits are under-utilized. These fruits are available in abundance and also in different seasons. This has resulted in limited scope for expansion of other minor fruits, though they are nutritious, and are the main source of livelihood for the poor.

Most of the underutilized fruits of the tropics are often available only in the local markets and are practically unknown in the other parts. A large number of these fruits can grow under adverse conditions and are also known for their therapeutic and nutritive value and can satisfy the demands of the health-conscious consumers (Ravani and Joshi, 2014).The underutilized fruit crops are the species that are traditionally used for their food, fiber, fodder, oil or medicinal properties. However, those species have under-exploited potential to ensure food security, nutrition, health, income generation and environmental services. The underutilized fruits like aonla, bael, jamun, karonda, passion fruit, Lassora, phalsa, tamarind, wood apple, cashew, custard apple, elephant apple, Ber, Fig, Carombola etc. are the main sources of livelihood for the poor and play an important role in overcoming the problem of malnutrition (Gajanana *et al.,* 2010). Underutilized fruit crops are mainly rich sources of antioxidants and minerals. Antioxidants are basically phytochemicals required in human diets, which neutralises harmful free radicals generated in the body.

Furthermore massive amounts of the perishable fruits produced during a particular season results in a

Cited as : Singh S.P. (2024). ICAAAS : Exploring lesser utilizedor underutilized fruits for product developement. *ICAAAS–An Edited Book.* Volume-3 : 57-64. Astha Foundation, Meerut (U.P.) India.

glut in the market and become scarce during other seasons. Food preservation has an important role in the conservation and better utilization of fruits in order to avoid the glut and utilize the surplus during the off-season. It is necessary to employ modern methods to extend storage life for better distribution and also processing techniques to preserve them for utilization in the offseason in both large and small scale (Bhattacharyya and Bhattacharjee, 2007; Jena , 2013).

However, some of these fruits are not acceptable in the market in fresh form due to their acidic nature ,unpleasent flavour,typical strong aroma, highly perishable nature , strong fruity aroma, sour sweet tastes, astringent taste, high percentage of tannin, presence of oily substance. , hardshell, mucilagenous texture , numerous seed , thickened, sour and glutinous sepals, Hence, there is a need to less-known/ under-utilized fruit species which have the potential for commercial exploitation are yet to be utilized to their potential. This, to some extent, can be achieved through developing suitable processing and marketing strategies for these underutilized fruits.There is an earnest need to concentrate on research efforts in diversification and popularization of such underutilized fruit crops, where it ensures fair returns to the growers to improve their economic condition. It also helps to mitigate the problem of under -employment during off-season in the agricultural sectors.There is a great scope of food processing and value addition to the underutilized fruits into a range of highly acceptable fruit products as mentioned in below table.

Aonla (*Emblica officinalis*)

Aonla : also known as Indian gooseberry belongs to family Euphorbiaceae. It occupies an important place among the indigenous fruits of India. Aonla tree thrives well throughout tropical and subtropical parts of India and is most in wild or cultivated form in the region extending from the base of the Himalaya to Srilanka and from Malaysia to South China. The tree is hardy in nature and can be successfully grown in variable agro-climatic and soil conditions.

It is one of the most important minor fruit which has some commercial importance. The plant is quite hardy and prolific bearer giving high profitable returns, although it is the most neglected crop. Fruits are rich source of vitamin 'C'. The stability of ascorbic acid and presence of astringency in aonla fruit is due to the presence of polyphenols (Sastry *et al.,* 1966). The fruit has also fair amount of iron, calcium and lysine . Aonla fruit is highly valued among indigenous medicines. It

Sl. No.	Underutilized fruits	Scientific name and Family	Value added products
1.	Aonla	*Emblica officinalis Euphorbiaceae*	Pulp, RTS, Nectar, Squash, Syrup, Herbal Syrup, Jam, Herbal Jam, Toffee, Sauce, Candy , Preserve, shreds, Pickle, Aonla sweets, Aonla powder, Diabetes powder, Trifla powder.
2.	Jackfruit	*Artocarpus heterophyllus Moraceae*	RTS, Squash, Jam, Jelly, Chutney, Chips, Nectar, Preserves, Confections, Green jackfruit utilized for making pickle in oil and pickle in vinegar, Canned vegetables, Papad, Leather, Jackflakes can be bottled ,Jackfruit seed can be processed in to flour.
3.	Jamun	*Syzygium Cuminii Myrtaceae*	RTS, Nectar, Squash, Syrup, Jelly, Vinegar.
4.	Karonda	*Carrisa carandus Apocynaceae*	Candy, Preserve, Pckle, Chutney, Jelly, Jam, RTS, Nectar, Squash, Syrup, dried raisins, tarts, sauces, carissa cream or jellied salad.
5.	Phalsa	*Grewia subinequalis Tiliaceae*	Juice, RTS, Nectar, Squash, Syrup, Crush.
6.	Bael	*Aegle marmelos Rutaceae*	RTS, Nectar, Squash, Syrup, Candy, Preserve, Jam, leather/slab, powder.
7.	Custard apple	*Annona squamosa Annonaceae*	RTS, Squash, Nectar, Syrup, Jam, Jelly, Fermentedalcoholic beverages, Custard apple milkshake, Natural ice cream ,pulp can be supplied to the ice cream industries.
8.	Lasoora	*Cordia myxa Boraginaceae*	Pickle, use as vegetable during off season.
9.	Ber	*Ziziphus mauritiana Rhamnaceae*	RTS, Nectar, Squash, Syrup, Ber candy, preserve, pickle, Carbonated beverages, dehydrated Ber products.
10.	Fig	*Ficus carica Moraceae*	Jam, Jelly, Pudding, Cakes, Dried, Preserved, Candied or Canned.
11.	Tamarind	*Tamarindus indica Fabaceae*	Edible pulp which is principle souring agent for Sauces, Chutney, Beverages and in general cooking.

is acrid, cooling, refrigerant, diuretic and laxative. Dried fruits have been reported to be useful in haemorrhages, diarrhoea, dysentery, anaemia, jaundice, dyspepsia and cough. Vishal Nath (2004) reported that Aonla fruits are not consumed as fresh because of its astringent taste. The excellent nutritive and therapeutic value of fruits offers great potential for processing into various value added products. It is also very important ingredient in the chyavanprash, and a constituent of triphala powder (Boora and Bons, 2015). Besides fruits, leaves, bark and even seeds are being used for various purposes.

However, aonla fruits are processed in to a number of fruit products likePulp, RTS, Nctar, Squash, Syrup, Herbalsyrup, Jam, Herbal Jam, Toffee, Sauce, Candy, preserve, shreds, pickle, Aonla sweets, Aonla powder, Diabetes powder, Trifla powder. (Tondan *et al.,* 2003; Jain *et al.,* 2006; Sagar and Kumar, 2006; Goyal *et al.,* 2008; Bhattacherjee *et al.,* 2011; Pandita *et al.,* 2017).

Jack fruit (*Artocarpus heterophyllus*)

World's largest fruit, belonging to the family Moraceae and is an important indigenous tropical fruit crop of India. It is very popular in Eastern and Southern parts of India. Botanically Jackfruit is monoecious, cross pollinated, medium sized tree of 8-10 m. tall having a dense irregular globose crown. The sap is milky white. The leaves are dark green, alternate, petiolated and ovate-oblong or obovate type. Ripe fruit is laxative, restorative, cooling, fattening and useful in treating biliousness (Singh *et al.,* 2000). The plant is reported to possess anti-bacterial, anti-inflammatory, anti-diabetic, antioxidant and immuno-modulatory properties (Prakash *et al.,* 2009). The ripe jackfruit consists of yellow flesh, pith and large number of bulbs inside the fruit that has carbohydrates, proteins and minerals in sufficient quantity. The ripe fruit also contains macro-nutrients such as vitamins, minerals and organic acids (Tiwari and Vidhyarthi, 2012). Jackfruit (Kathal) is an integral part of common Indian diet and is freely available in Indian and adjoining continents, its medicinal properties are also mentioned in Ayurveda. The poor people of jack fruit growing area, used to eat this fruit instead of rice, for one of the daily meals. Hence, jack fruit is called 'poor man's food'. People consumed it mostly as a fruit when ripe but also as a vegetable in the unripe stage. Both tender and ripe fruits as well as the seeds are rich in minerals and vitamins. It is grown and sold in the market almost whole the year in the country. However, the fruit is perishable and cannot be stored for long time because of its inherent compositional and textural characteristics (Molla *et al.,* 2008). Ripe fruit due to its typical strong aroma are not acceptable as table fruit by the majority of people. The fruit has not so far been fully exploited by the fruit preservation industry.

However, jackfruits are processed in to a number of fruit products like RTS, Squash, jam, jelly, chutney, chips, nectar, preserves, confections, green jackfruit utilized for making pickle in oil and pickle in vinegar, canned vegetables, papad, leather, jackflakes can be bottled. Jackfruit seed can be processed in to flour. Unripe green fruit employed like a vegetable in the preparation known as 'Kathal sabzi' insome north Indian states and 'Sayar nangka' in Indonesia (Loganathan *et al.,* 2017).

Jamun (*Syzygium cumini*)

Jamun: is an important indigenous fruits of India. It belongs to the family Myrtaceae. Jamun trees are found scattered throughout the tropical and subtropical regions but there is no organised orcharding of this fruit in the country. Fruit is a rich source of mineral constituent particularly iron, calcium and phosphorous. The ripe fruit is astringent, stomachic, carminative and antiscorbutic. All parts of the jamun can be used medicinally and it has a long tradition in alternative medicine. The plant has been viewed as an antidiabetic plant since it became commercially available several decades ago. The seeds have also shown anti-inflammatory effects in rats and antioxidant properties in diabeties. Jamun fruit is highly perishable and seasonal in nature. Considerable losses occur in this fruit during harvesting. It is popular as a desert fruit because of its slight astringent taste and big sized seeds.

However, Jamun are processed in to a number of fruit products like Processing of this fruit into quality beverages such as nectar, squash, syrup would be more nutritious than many of the synthetic drinks. Warrier *et al.* (1996) reported that the ripe fruits are used for health drinks, making preserves, squashes, jellies and wine. Lal *et al.* (1960) reported that good quality jamun juice is excellent for sherbet, syrup and squash. Miller *et al.* (1955) reported that white-fleshed jamun has adequate pectin and makes a very stiff jelly.

Karonda (*Carissa carandas*)

Karonda is a hardy, evergreen, spiny and indigenous shrub which thrives well as rainfed crop. The fruit belongs to the family Apocynaceae. Fruits, sour and astringent in taste, are a very rich in iron contains a good amount of vitamin C. They also contains protein, carbohydrates, fat, fibre and calcium. Fruits can also be used in dyeing and tanning industries. Karonda fruit is considered to be antiscorbutic and is also very useful in curing anaemia, stomach ache and is anthelmintic.

However, Karonda are processed in to a number of fruit products like Candy, preserve, Jam, RTS, Nectar, squash, syrup, tarts, the ripened fruits may be eaten as dessert or used for the preparation of jelly, sauce, carissa cream or jellied salad. Unripe fruits are used for making pickles, sauces and chutney. The dried fruits may act as a substitute for raisins (Cheema *et al.,* 1971). The wine prepared from ripe fruits contains about 14.5 to 15% alcohol and is very much liked by wine fanciers Nalawadi (1975).

Phalsa (*Grewia Subinequalis*)

Phalsa belongs to Tiliaceae family and native to India. Fruits of phalsa are acidic, good source of vitamin A, ascorbic acid and also rich in various other nutrients. Being highly perishable, the fruit must be utilized within 24 hours after picking. The popularity of phalsa fruit is due to its attractive colour ranging from crimson red to dark purple and its pleasing taste. The juice when extracted gives a deep crimson red to dark purple colour and is very popular. It is rated very high in indigenous system of medicine. The juice is extremely refreshing and is considered to have a cooling effect especially in hot summer. Fruits contain 50-60 per cent juice and edible part of the fruits varies from 69-93 per cent. Generally, its fruits are consumed fresh (Boora and Bons, 2015). The fruit is astringent and stomachic. It has been reported that when unripe, phalsa fruit alleviates inflammation, respiratory, cardiac and blood disorders, as well as in fever reduction (Singh *et al.,* 2009).

However, Karonda are processed in to a number of fruit products like fruits are used for making excellent juice, RTS ,nectar ,squash, syrup and crush having cooling effect on the body (Boora and Bons, 2015; Pangotra *et al.,* 2018).

Bael fruit (*Aegle Marmelos*)

Bael belongs to family Rutaceae is indigenous to India. The bael fruit is a hard shelled berry and the pulp contains tunnels which are filled with a mucilage. The fruit is very nutritive and contains fair amount of vitamin-A, vitamin-B, vitamin-C, minerals and high carbohydrates content. The fruit is very rich in Riboflavin (Vitamin B_2). Bael fruit is not popular as a desert fruit due to its hardshell, mucilagenous texture and numerous seed. It has good processing attributes such as excellent flavour, nutritive and therapeutic values. The different parts of Bael are used for various therapeutic purposes, such as for treatment of asthma, anaemia, fractures, healing of wounds, swollen joints, high blood pressure, jaundice, diarrhoea healthy mind and brain typhoid troubles during pregnancy (Sharma *et al.,* 2011). The unripe dried fruit is astringent, digestive, stomachic and used to cure diarrhea and dysentery. Sweet drink prepared from the pulp of fruits produce a soothing effect on the patients who have just recovered from bacillary dysentery. The ripe fruit is a good and simple cure for dyspepsia (Parichha, 2004, Chowdhury *et al.,* 2008).

However, Bael are processed in to a number of fruit products like RTS, Nectar, Squash, Syrup, candy, preserve, Jam, leather/slab, powder , Fresh bael fruit can be stored for 15 days at 30oC when harvested at full maturity, for 1 week at 30^{o}C when harvested ripe, for 3 months at 9^{o}C. fruit pulp can be stored for 6 months, when stord in heat-sealed containers. Fruit powder can be stored for a year when packed in 400 gauge polypropelene pouches and stored under dark, cool place, while fruit jam, squash and preserve can be stored for several months (ITDC, 2000). The bael fruit pulp contains many functional and bioactive compounds such as carotenoids, phenolics, alkaloids, coumarins, flavonoids, and terpenoids and has innumerable traditional medicinal uses (Karunanayake *et al.,* 1984; Singh 1986; Nagaraju and Rao, 1990).

Custard apple (*Annona Squamosa*)

Custard apple is one of the most delicious fruit plants of tropical and sub-tropical areas and belongs to Annonaceae family. In India, the fruits are eaten mainly by the lower and medium class people. Custard apple is harvested in several installments, but the best harvesting stage is when the firm fruit begins to develop colour. It is generally picked when it becomes creamy yellow between the segments and begins to crack slightly. The fruit has the tendency to burst open if kept on the tree for a long time. Custard apple is highly perishable and cannot be stored for long time. The ripe fruits are rich in sugar. Its pulp contains about 13 per cent moisture, 0.8-1.5 per cent and 14.5 per cent sugars, 0.3 per cent fat, 1.0 per cent iron and 0.7 per cent mineral matter. It is quite rich in calcium (0.02 per cent), phosphorus (0.04 per cent) and iron (1.0 per cent). The fruit is very sweet and delicious hence is used for table purpose. When fully ripe, it is soft to touch and easily pulled out. The flesh may be scooped from the skin and eaten as is or served with light cream and a springing of sugar.

However ,Custard apple can be processed into number of fruit products like shakes or smoothes or even into natural ice creams, RTS, Squash, nectar, Syrup, jam, jelly, fermentedalcoholic beverages, custard apple milkshake, natural ice cream, pulp can be supplied to the ice cream industries.

Lasoora (*Cordia myxa*)

Locally known as Gonda, Lasora or lehsua belongs to Boraginaceae family. It grows throughout India except in high hills and temperate climate. It is a perennial, medium sized tree with crooked stem. It bears small sized fruits in bunches, used in traditional vegetable and pickles. Being a multipurpose plant, it has long been associated with health, nutrition and other diversified uses in curing certain human ailments (Chandra and Pareek, 1992). Fruits are considered as one of richest natural sources of antioxidants i.e. carotenoids, ascorbic acid, phenols etc. Fruits are important sources of minerals, fiber and vitamins, which provides essential nutrients for the human health (Mala, 2009). The most important nutrients present in plants are carbohydrates, such as the starch and free sugars, oils, proteins, minerals, ascorbic acid, and the antioxidant phenols, such as chlorogenic acid and its polymers (Spiller, 2001).

However, lasoora are processed in to a number of fruit products like Immature green fruits are used as vegetable, Chutney and pickles. Sometime fruits are dehydrated after blanching for used as vegetable during off season (Singh, 2001).

Ber/Indian Jujube (*Ziziphus mauritiana*)

Ber belongs to the family Rhamnaceae, ideal fruit tree for arid and semi-arid regions which bear fruits of greenish yellow to reddish brown having high amount of vitamin C (85-95 mg per 100 g). More vitamin C was found in the fruit flesh near the seed rather than near the skin of the fruit (Krivencov *et al.,* 1970) . The decoction from root and bark is good for dysentery and diarrhoea and leaf decoction is useful as gargle in sore throat and in bleeding gums. The seed kernels are aphrodisiac.

However ber fruit are consumed as such or can be processed into different fruit products. Juicy varieties are better suited for pulp and juice extraction. The fully ripe, well-developed fruits are washed de-stoned and juicer extracts juice. Ber juice can be used for the preparation of ready-to-serve beverage, Nectar, Squash, Carbonated beverage of ber is highly acceptable and has excellent keeping quality. Dehydrated ber is prepared by treating ber fruits with sulphur dioxide at 3.5-10 g/kg for 3 hours followed by sun drying, or cabinet drying below 15% moisture. Ber can be utilized for candy, Preserve and ber pulp can be processed into wine.

Fig (*Ficus carica*)

Fig belongs to family moraceae ,is a gynodioecious ,deciduous tree, large shrub that grow up to 7-10 metres tall,with smooth, white bark .The fig fruit develops as a hollow, fleshy structure called the synconium that is lined internally with numerous unisexual flowers. The edible mature synconium stem develops into a fleshy false fruit bearing the numerous one-seeded fruits, which are technically druplets. It is a highly nutritious fruit consisting of 84% pulp and 16% skin. Besides, the fruit also contains protein, calcium, iron, vitamin A and thiamine at varying concentrations. The fruit is valued for its laxative property. It is applied for boils and other skin. The latex is used to coagulate milk and leaves are used medicinally as diuretic, demulcent, emollient and anthelmintic properties.

However, Fresh figs are nutritious and used as dessert or for making jam, jelly, pudding, cakes, dried, preserved, candied or canned.

Tamarind (*Tamarindus indica*)

Tamarind is native to Tropical Africa and belongs to the family Fabaceae. It is the ‘Indian date’ and is one of the most important fruits of India. In Tripura, it is locally called “tentul” (Das *et al.,* 2013) . It is a large sized, long-lived evergreen tall tree with a spreading crown. It is an excellent tree for social forestry and agro forestry. This crop is highly suitable for wastelands due to its multi ferrous uses and capacity to withstand adverse agro-climatic conditions.

The fruit of tamarind a pod 5 to 15 cm long, 3 to 10 seeds surrounded with edible pulp which is principal souring agent for sauces, chutney, in beverages and in general cooking. Pulp is carminative, laxative, given as infusion in biliousness and febrile conditions. The tartaric acid is extracted from unripe fruits. Besides, polyose obtained from the seed is good substitute for fruit pectin in the preparation of jam, jelly or marmalade. Tamarind balls are prepared after taking out seeds from the fruit. Tamarind paste and tamarind juice concentrate are the other commercial products. It is also used in drying and tanning and for polishing and cleaning metal ware. The polysaccharide (jellose) is extracted from seeds, which is used as a sizing material in the cotton and jute industries. The bark and leaves are used for tanning.

Passion fruit (*Passiflora edulis*)

Passion fruit belongs to family Passifloraceae is native to tropical America. It produces fruits with unique flavour and aroma for fresh eating and processing as well. Passion fruits are fair to good source of provitamin A, ascorbic acid, riboflavin and niacin and have a high mineral content. The pulp obtained after scooping from the fruits when cut in halves are added to fruit salads, ice-cream or fruit juice. Other processed products include juices, jelly, jam, squash, RTS, Nectar, Syrup etc. (Menzel 1985).

Wood apple (*Limonia acidissimia*)

This is also known by many different names such as kainth and monkey fruit. Its shape is pyriform, oval, oblong, 5-15 cm in diameter. The tree belongs to Rutacae family. The fruit is not under regular orcharding, however along the border of fields, roads, railways lines and as a roadside tree, near villages and banks of river are the most common places where the plants are found as stray plant. Plant seed are important unconventional sources of proteins which when incorporated in food products would improve the functional properties such as absorption of water or oil and also in the formation of stable foam. They are also good nutritional supplements. The fruit is amazingly hard rind which can be difficult to crack, security rind about 6mm thick, greyish-white, pulp is brown, odorous, mealy, resinous, astringent, acid or sweetish with numerous small, white seeds scattered through it. There are two forms, one with large sweet fruits and the other with small, acid fruits.

It is a climacteric fruit, ripening may also take place after fruit is harvested. It is well known for its quality and storage life, which helps avoiding the waste of raw material. The fruit contains a number of Phyto-constituents, which are the key factors in the medicinal values. Almost all parts of the plant such as leaf, fruit, seed, bark and root are used to cure a variety of disease.

Wood apple can be converted into value added products like jam, powder and fruit bar in order to avoid glut and utilize the surplus during the season, it is necessary to employ methods to extend storage life, for better distribution, to preserve them for utilization in the offseason both in large scale and home scale. Wood apple juice when mixed with other fruits can serve as an excellent beverage like RTS, Squash, Syrup. Realizing the importance of wood apple fruit as a significant contributor to human well being, as a cheaper and better source of protective foods; its perishable nature and seasonality in production calls for preservation of it to be supplied throughout the year for human consumption.

Cashew apple (*Anacardium occidentale*)

The cashew apple belongs to family Anacardiaceae, is a tropical evergreen tree ,that produces the cashew seed and the cashew apple.The tree can grow as high as 14 m , but the dwarf cultivars, growing up to 6 m (20 ft), prove more profitable, with earlier maturity and greater yields. Cashew apple juice without removal of tannin has been prescribed as a remedy for sorethroate and chronic dysentry. Cashewnut processing has assumed an important place inthe countries economy. Though we have made substaintial progress in the utilization and promotion of the nut ,vast tonnage of pseudo fruits ,the cashew apple which are quite rich in vitamin C and other minerals largely go to waste. Fresh cashew apples are very soft and are highly perishable. Varioues species of yeast and fungi cause spoilage and make it unfit for use within 8-24 houres of its plucking from the tree. The juice is astringent and some what acrid due to high percentage of tannin and presence of another oily substances. These are the reasons why this fruit has not become popular among consumers and processors.

Value added products : Methods have been standerdized for the preparation of RTS, squash, jam, pickle, chutney, vinegar etc. Cashew apple juice can also be blended with lime juice ,orange juice or pine apple juice on 75:25 basis and served. For preparation of any value added products tannin has to be removed.

The cashew seed is often considered a nut in the culinary sense; this cashew nut is eaten on its own, used in recipes, or processed into cashew cheese or cashew butter and the cashew apple is a light reddish to yellow fruit, whose pulp can be processed into a sweet, astringent fruit drink or fermented and distilled into liquor. The shell of the cashew seed yields derivatives that can be used in many applications including lubricants, waterproofing, paints.

Carambola (*Averrhoa carambola*)

Carambola belongs to the family Oxalidaceae. In India carambola is grown in the Western Coastal areas and at the Nilgiri hills up to an altitude of 1200 m. Two cultivars sour and sweet depending on their taste are grown in our country. The tree is medium sized, attractive and evergreen growing to about 10m (Bose and Mitra, 1990). The fruit of Carambola is a rich source of reducing sugars, ascorbic acid and minerals such as K, Ca, Mg and P. Oxalic acid and tannin are considered to influence taste strongly. Carambola fruit with its attractive appearance, oval shape and translucent skin is soft and juicy and is highly perishable. It has strong fruity aroma and sour sweet tastes. It is not a popular table fruit in India because of its Fruit and its juice is often traditionally recommended to cure many diseases as a heat reducer, diuretic expectorant, and to suppress cough, rich in bio-active health promoting factores.

However, Carambola are processed in to a number of fruit products like RTS, Nectar, Squash, Syrup, candy, preserve, The fruit can be eaten fresh and is often used in salads and as a Garnishing of cake due to its unique star shape. For making sweet-sour dishes, dalma and curry. Used for flavouring fish, used as vegetable, Can be used as pickle.

Elephant Apple (*Dillenia indica*)

Elephant apple belongs to family Dilleniaceae is indigenous to an area stretching from India to China. Elephant Apple is a deciduous tree of moderate size with a short but straight trunk and spreading branches forming a dense head. The narrow pointed leaves are set on short stalks near the ends of the branches. It bears a large and hard fruit of 3-5 inches in diameter consisting of 5 closely fitted imbricate sepals enclosing numerous seeds embedded in a glutinous pulp (Sastri, 1952). It is rich in protein, carbohydrate, fat and fibre with fairly high amount of calcium, phosphorus and energy value of 59 Kcal per 100g (Gopalan *et al* 1971). It is generally not popular because of its thickened, sour and glutinous sepals. It has good processing attributes because of its flavour, sourness, nutritive and therapeutic values. Fruit is the main usable part having many medicinal and nutritional uses. rich in vitamin-C, antioxidant, anti-inflammatory and anti- microbial compounds. It has several health benefits like cure diarrhoea and dysentery, Tonic and laxative, Fruit-juice : mixed with sugar, and water is used for fever, fits, cough, weakness.

However, Elephant apple are processed in to a number of fruit products like Pickles, sauces, jams, jelly & RTS beverages, Sweet-sour dishes, dalma and curry, Dried product, Residual Osmo-syrup, Osmo-dehydrated products, Used for flavouring fish.

Conclusion

Thus underutilized/minor fruits play in important role in food and nutritional security. These fruits are known for their typical flavour and taste and if properly utilized, a variety of processed products could be developed which can add to the product range. This can also help in increasing the capacity utilization in the fruit processing industry. Most of the minor fruits are enriched with nutritional and medicinal value, and can be grown even in wastelands without much care. Therefore, it is worthwhile to look into the organized cultivation and improvement of minor group of fruit crops like aonla, wood apple, bael, ber, phalsa, karonda, woodapple etc. so that their utilization can be maximized. There is always demand from consumers for new, delicious, nutritious and attractive fruit products. To satisfy this demand, there is a constant effort to develop products from diverse sources. The potentiality of processed products from some minor fruits in the country is still untapped. However, efforts have been made by various researchers for the development of value added products from underutilized fruits as explained above. It reflects the feasibility for the development of some diversified value added products from some of the minor fruit crops grown in India in order to minimize the wastage, to promote these products as export items and to uplift the nutritional and socio-economic status of the vulnerable communities of the country. Minor fruits are the future for horticulture of 21st century as this offer a variety of potential benefits in profitability, productivity, sustainability, crop quality, food safety, environmental protection and rural economic development. A large proportion of rural population depends on locally available fruits to meet their dietary requirements. These fruit crops have their own history of consumption, local people are well aware of their nutritional and medicinal properties. Most of them can be grown even in wastelands without much care. Therefore, it is worthwhile to look the organized cultivation and improvement of under-utilized crops like aonla, bael, karonda, phalsa, jackfruit, custard apple ,fig ,elephant apple ,passion fruit ,cashew apple ,tamairnd and lasora so that their utilization can be maximized and variety of value added products can also be prepared from them as explained above.

References

1. Bhattacharyya B.K. and Bhattacharjee D. (2007). Bactriocin: A biological food preservative. *Journal of Food Science and Technology,* 44(5): 459-464.
2. Boora R.S. and Bons H.K. (2015). The minor fruits-health treasure. *Kisan world,* 42(11): pp:32-33.
3. Bhattacharjee A.K., Tandon D.K., Dikshit A. and Kumar S. (2011). Effect of pasteurization temperature on quality of aonla juice during storage. *Journal of Food Science and Technology*, 48(3): 269-273.
4. Bose T.K. and Mitra S.K. (1990). Fruits : Tropical and subtropical. *Nayaprakashan, Bidhan Sarani*. Calcutta-6 India. P 785-794.
5. Cheema G.S. and Cheema B.K. (1971). *Farm Journal of Calcutta,* 12: 24.
6. Chowdhury M.G.F., Islam M.N., Islam M.S., Islam A.T. and Husain M.S. (2008). Study on preparation and shelflife of mixed juice based on wood apple and papaya. *J. Soil Nat.,* 2(3): 50-60.
7. Chandra A. and Pareek C.S. (1992). Lasoda (*Cordia myxa* L.) potential fruit crop in Jaisalmer district of western Rajasthan. *Agricultural Science Digest*, 12(1): 11-12.
8. Dahanayake N. (2015). Some neglected and underutilized fruit crops in Sri Lanka. *International Journal of Scientific and Research Publications*, 5(2): 116-120.
9. Das S.C., Prakash J., Deb A.K. and Biswas T. (2013). Medicinal Value of Underutilized Fruits in Hilly Tripura. *Acta Horticulture*, 972: 135-141.

10. Gajanana T.M., Gowda I.N.D. and Reddy B.M.C. (2010). Exploring market potential and developing linkages-A case of underutilized fruit products in India. *Agricultural Economics Research Review,* 23: 437-443.
11. Goyal R.T., Patil R.T., Kingsly A.R.P., Walia H. and Kumar P. (2008). Status of post harvest technology of aonla in India-A Review. *American Journal of Food Technology*, 3(1): 13-23.
12. Gopalan C., Ramasastri B.V. and Balasubramaniam S.C. (1971). Nutritive value of Indian Foods. *Indian Council of Medical Research*, New Delhi.
13. ITDC (2000). Processing of wild bael fruit for rural employment and income generation. *ITDC Food Chain*, 27: 15-17.
14. Jena S. (2013). Development of a preserved product from underutilized passion fruit and evaluation of consumer acceptance. *Journal of Food Research and Technology,* 1(1): 11-19
15. Jain V., Singh S. and Singh A.K. (2006). Screening of aonla cultivars for making squash. *Indian Journal of Arid horticulture*, 1(1): 44-46
16. Karunanayake E.H., Welihinda J., Sirimanne S.R. and Sinnadorai G. (1984). Oral hypoglycaemic activity of some medicinal plants of Srilanka. *Journal of Ethnopharmacology*, 11(2): 223-231.
17. Kour S. (2018). Strategies on Conservation, Improvement and Utilization of Underutilized Fruit Crops, *Int. J. Curr. Microbiol. App. Sci.,* 7(3): 638-650
18. Krivencov V.I., Karahanova S.V., Savina G.G., Bjull Gos. Nikitsk, Bot Sada (1970)2: 5759.
19. Loganathan P., Rajadurai A. and Malliga C. (2017). Jackfruit: Its medicinal uses and benefits. *Kisan World,* 44(6): 7-9.
20. Mala R. (2009). Nutrient content of important fruit trees from arid zone of Rajasthan. *Journal of Horticulture,* 1(7): 103-108.

Website : www.asthafoundation.in
ICAAAS–An Edited Book (Volume-3)
ISBN : 978-81-958010-7-7
Published by : Astha Foundation, Meerut (U.P.) India
Edition-2024

Chapter 8

Major Insects and Diseases of Blackgram Crop and Their Management

Harmeet Kaur* and Balbir Singh Khadda
GADVASU-Krishi Vigiyan Kendra, SAS Nagar, Mohali, Punjab
**Corresponding Author Email : harmeetkaur@gmail.com*

Abstract

Blackgram is an important pulse crop in India with high nutritive value. With the ability to improve soil fertility, it is also used as nutritive fodder for milch animals. The crop is mostly cultivated during kharif season. The insects and diseases are considered as one of the major constraints to obtain low yield in blackgram. It is obligatory to know the symptoms and management of these insects-pests for better crop production. Generally, number of insects including foliage feeders (hairy caterpillar, tobacco caterpillar, pod borer), sucking insects (whitefly, aphids, thrips), nematodes and various fungal (powdery mildew), bacterial (Xanthomonas spp) and viral diseases (yellow mosaic virus) were noticed in India on blackgram crop. In some areas they become serious pest whereas in other areas they got the status of minor pests. Pest attack was also noticed under storage conditions after crop harvest. Therefore, attempts were made to describe information regarding insect-pest attack in blackgram and their control tactics to harvest quality yield with high productivity.

Key words : *Blackgram, disease, India, insect, kharif, management, productivity, quality, yield.*

Introduction

Blackgram (*Vigna mungo* L.; Family: Fabaceae) also known as urdbean, mashbean, black lentil, mashkalai black mapte etc. is a rich source of proteins and carbohydrates. Primary origin of blackgram is India (Ali and Gupta, 2012) which is also its largest producer and consumer (Singh and Singh 1977). Its various recipes are being prepared during religious festivals in India. The crop is one of India's most treasured pulse with ability to improve the soil by fixing atmospheric nitrogen. Besides, it is also used as nutritive fodder, especially for milch animals. Mash crop thrives in a hot and humid season. With the exception of saline-alkaline and waterlogged soils, it may thrive on all types of soils from sandy loam to heavy clay. Maharashtra, Karnataka, Andhra Pradesh, Tamil Nadu, Madhya Pradesh and West Bengal are the primary blackgram-producing states in India.

The foremost issue known to restrict the yield of pulse crops is the incidence of insect pests. The blackgram crop is attacked by different insect-pests both in field (from sowing to harvest) and storage (Lal and Sachan, 1987). The annual yield loss due to such insect pests has been estimated at about 30 % in blackgram and mungbean (Gailce Leo Justin *et al.,* 2015). Insect-pest attack results into poor blackgram production in Rewa district, Madhya Pradesh including sucking insects such as whitefly (*Bemisia tabaci*), aphid (*Aphis craccivora*), jassid (*Empoasca* spp.) and green leaf hopper (*Nephotettix* spp.) and foliage feeders such as Grasshopper (*Atractomorpha* spp.), Leaf webber (*Grapholita critica*), Grey weevil (*Myllocerus* spp.), Tobacco caterpillar (*Spodoptera litura* Fabricius), Bihar hairy caterpillar (*Spilosoma obliqua*), Leaf miner (*Chromatomyia horticola*) and Epilachna beetle (*Epilachna* spp.) reported by Rajawat *et al.,* 2021. Thrips cause damage from flowering to

Cited as : Singh S.P. (2024). ICAAAS : Major insects and diseases of blackgram crop and their management. *ICAAAS–An Edited Book.* Volume-3 : 65-70. Astha Foundation, Meerut (U.P.) India.

pod filling stage in blackgram (Rajak and Chandra, 2004). Satyagopal *et al.,* (2014) provided detailed information regarding insect-pests, nematodes, diseases and weeds infesting blackgram and greengram crop along with their integrated management. Under Punjab conditions, bihar hairy caterpillar, whitefly, tobacco caterpillar, yellow mosaic virus are the major insects and disease problems prevalent in blackgram crop *during kharif* season (Anonymous, 2022).

Symptoms of pest attack and their management tactics in blackgram crop are mentioned below :

(A) Insect Pests

1. Sucking insects :

(a) Whitefly, *Bemicia tabaci* Gennadius (Aleyrodidae: Hemiptera)

(b) Jassid, ***Empoasca kerri* (Cicadellidae: Hemiptera)**

(c) Aphid, ***Aphis craccivora* (Aphididae: Hemiptera)**

Nymphs and adults of whitefly, aphids and jassids suck sap from the leaves, thus lowering the strength of the plants. The leaves become wrinkled, curled and twisted. Whiteflies emit honeydew, on which sooty mould grows resulting into blackening of leaves. The regular photosynthesis process declines in case of infected plants. In case of severely attacked crop, the leaves dry up and finally causes total crop failure. Whitefly is a vector of mungbean yellow mosaic virus.

Management

Rouge out virus-infected plants.

Rain and wind minimise sucking pest infestations.

Fix of yellow sticky traps (20cmX15cm size) at a rate of five per acre in crop field.

Natural enemies

Predators of whitefly, aphids and jassids: *Coccinella septumpunctata*, *Syrphus* sp., *Chrysoperla carnea*, Mirid bug, *Dicyphus hesperus*

Parasitoids of whitefly: *Encarsia formosa*, *Eretmocerus* sp

Parasitoid: *Aphidius colemani*, *Aphelinus* sp

(d) Thrips, *Megalurothrips usitatus* (Bagnall) (Thysanoptera: Thripidae)

The damage appears as silvery streaks or spots on the leaves giving shining appearance in the sunlight. In case of severe attack, major portion of plant leaves is covered by these tiny patches causing difficulty for the plant to properly photosynthesize. Through the damaged tissues, the plant loses more water than usual and plant pathogens can easily penetrate.

Management

Natural enemies

- Parsitoid: *Ceranisus menes*

- Predators: *Oligota* spp, *Orius* spp, hover fly, mirid bug etc

2. Bihar Hairy caterpillar, *Spilosoma obliqua* Walker (Erebidae: Lepidoptera)

The caterpillar also referred as defoliating pest, consumes the leaf's green tissue and only leaves midribs behind. Due to a heavy attack, the crop may be completely denuded. They are polyphagous in nature. Female lays masses of eggs on leaves. The larvae can be easily identified due to presence of yellow hairs all around the body.

Management :

Young larvae are social creatures which can be eliminated by digging up the larvae-infested plants and burying them underground.

Kill the adult caterpillars by crushing them under feet or by picking and dropping them into kerosene-water mixture. In case of heavy adult population, spray Ekalux 25 EC (quinalphos) @ 500 ml in 80-100 litres of water per acre area.

Natural enemies:

- Parasitoids: *Bracon* spp., *Trichogramma* spp.

- Predators: *Chrysoperla carnea*, ladybird beetle, spider, red ant, dragon fly, praying mantis, ground beetle, shield bugs.

3. Tobacco caterpillar, *Spodoptera litura* Fabricius (Noctuidae: Lepidoptera)

The caterpillar attacks on variety of crop plants and weeds. small larvae feed ravenously and skeletonize the vegetation. Later, the adult larvae feed singly. In addition to leaves, they harm buds, flowers and pods. The small larvae exhibit black colour whereas grown up larvae are dark green with black triangular spots on their body. On the underside of leaves, the moth deposits large quantities of eggs covered with brown hairs.

Management

Expose pupae to high temperature through deep ploughing and then destroy them.

Castor should be planted as a trap crop.

Collect the egg masses and growing larvae of tobacco caterpillar feeding gregariously along with leaves and kill them.

4. Pod borer, *Helicoverpa armigera* Hubner (Noctuidae: Lepidoptera)

The green part of the plant is consumed by small larvae. Full grown larvae consume almost all aerials parts of the plant including flower buds, flowers, leaves, pods and seeds within the pods, thus, greatly reducing crop yield. Circular bore holes on pulse pods blocked by the head of a larva. Caterpillar attack is favoured by warm weather conditions followed by light rains and dry spells. Before reaching maturity, a single larva may destroy thirty to forty pods. The larvae may exhibit different colours like pale green, yellow, chocolate brown or blackish. Plant damage and the presence of dark green faeces on the soil beneath the plants can both act as indicators of larval activity. If we shake the plants forcefully, the larvae fall on the ground. Pod borer is cosmopolitan pest with wide host range. More severe attack was noticed in chickpea, pigon pea, mungbean, urdbean, lentil, soybean, cowpea etc. It also causes damage in cotton, okra, maize, sorghum, berseem, sunflower, tomato and late sown wheat crop.

Management

Mixed intercropping should be preferred over sole crops with those host plants which are not preferred by the insect like barley, wheat, mustard, linseed.

Erection of bird perches.

Cultural practice of ridge planting combined with cover crops like moth bean, cowpea, and soybean works well.

Natural enemies :

- Parasitoids : *Trichogramma* spp., *Tetrastichus* spp., *Chelonus* spp., *Telenomus* spp., *Bracon* spp., *Ichneumon* spp., *Carcelia* spp., *Campoletis chlorideae*

- Predators : ladybird beetles, *Chrysoperla carnea*, red ants, spiders, dragon flies, robber flies, reduviid bugs, praying mantis, black drongo, wasps, common mynah, *Geocoris* bug, earwigs, ground beetles, pentatomid bugs etc.

5. Blister beetle, *Mylabris pustulata* (Meloidae: Coleopteran)

The peak incidence is typically seen during the blossoming period which can result in up to 95% floral damage. Adults feed on new leaves, flowers and tender pods resulting into poor crop yield. The beetles remain active during day time. There is presence of bright red and black stripes on the forewings of adult beetles. If we try to disturb the beetles, they release a fluid that contains cantharidin and produces blisters on human skin. The adult beetles cause damage on different pulses like arhar, moong, blackgram etc. The adult size is approximately 2.5 cm in length. The immature stages (larvae) of this beetle are beneficial which live in the soil and feed on eggs of grasshopper.

Management

Avoid excess use of nitrogen fertilizers.

Manual collection or collection of beetles with insect net and killing of adults in kerosenized water.

6. Dhora beetle, (*Callosobruchus* spp.): (Bruchidae: Coleoptera)

Dhora beetles are stored grain insects which attack the pulse grains after harvest. The female beetles lay eggs on grains. Small whitish grubs comes out of these eggs and get entry inside pulse grain. Development of all grub stages occurs inside the grain where the grubs eat all the inner content leaving only outer grain shell. The adults come out of the shell leaving behind round exit holes and again start egg laying after mating. Infested grains provide favourable conditions for development of foul-smelling fungus.

Management

Clean the metal bins and place them under sun for 2-3 days. Dry the pulse grains properly before storage into these metal bins.

In the godowns, seal all holes, cracks and crevices before storage.

Use fresh gunny bags for grain storage purpose.

Prior to storing the grains, disinfect empty godowns by fumigrating them with 25 aluminium phosphide tablets per 100 cum vacant space or by spraying 0.05 per cent malathion emulsion 50 EC @ 100 ml in ten litres of water on the floor, walls and ceiling. Give exposure of seven days. These are fatally dangerous, so they should only be used by trained individuals in airtight stores.

Cover the bulk-stored pulses with a seven cm layer of sand, sawdust or dung ash to protect them from dhora beetle.

7. Root-knot nematode: *Meloidogyne* spp.

Patches of infected plants might be seen in the field. On the root system of the host, galls formation occurs. From the gall tissue of roots, lot of branches occur resulting in a ‘beard root’ feature. Due to nematode infection, knobs and knots appear in the root system. The root’s ability to absorb and transmit water and nutrients is severely impeded. Plants wilt under dry conditions and frequently get stunted. Infection occurs due to presence of egg clumps in soil and infected plant debris. Secondary infection occurs through second stage juveniles which may disperse through water.

Management

Purchase the plants from nematode free reliable nurseries.

Intercropping with pigeonpea, marigold and castor along with the main crop helps to inhibit infestation by nematodes.

(B) Diseases

Plant diseases also play major role to hamper plant growth and development. In pulses including blackgram, lot of bacterial, fungal and viral diseases attack. Blackgram and greengram crops are attacked by several diseases such as powdery mildew, blight, root rot, anthracnose, leaf spot, rust, dry root rot, mungbean yellow mosaic disease, leaf crinkle disease, leaf curl, ascochyta leaf spot and bacterial blight (Khaire and Hake, 2018). We should take care about source of their primary and secondary infection for proper disease management. Commonly prevalent diseases of blackgram in India are mentioned below along with their control strategies :

1. Yellow mosaic virus :

Irregular yellow and green patches appear on the leaves of the infected plant. Diseased plants exhibit stunted growth. Very few flowers and pods develop on such plants. Whitefly and aphids act as vectors of this disease. Since these insects are more active in the warm summer months, a rise in their population will result in more viral dissemination and disease spread.

Management

Diseased plants should be removed early in the season.

Grow the blackgram varieties which can bear disease attack such as Mash 883, Mash 114 and Mash 338 are tolerant to yellow mosaic virus disease during *kharif* season under Punjab condition.

2. Cercospora leaf spot : Causal organism: *Cercospora cruenta* & *C. canescens*.

Due to disease infection, circular, brown, wet, necrotic disease spots appear initially on leaves. Later, these spots merge and cover a larger area and induce defoliation. In severe cases, these wet lesions also appear on stem and petioles. These lesions have light brown centres from which powdery growth of the fungus appear. The organism thrives well in infected plant debris, alternate hosts and on volunteer blackgram plants. The disease is favoured by intermittent rains, dense plant population and moist conditions.

Management

Remove and burn diseased plant material.

Maintain field drainage properly.

Sow disease resistant blackgram varieties, Mash 883, Mash 114 and Mash 338 during *kharif* season.

Spray of Mancozeb @ 800g/acre or Carbendazim @ 200 g/acre is effective against disease development.

3. Bacterial leaf spot: Causal organism: *Xanthomonas campestris pv. phaseoli*

Circular to irregular brown flecks/spots evolve on mash leaves which later enlarge and unite to form irregular brown patches. The seed borne pathogen is involved to initiate primary infection. Later, moist and cool conditions along with rains favour disease spread.

Management

Sow pathogen free seed.

Select immune mash varieties for sowing purpose such as Mash 883, Mash 114 and Mash 338 are fairly resistant or tolerant against disease during *kharif* season under Punjab conditions.

4. Powdery mildew : Causal organism : *Erysiphe polygoni*

With the onset of fungal disease, the above leaf surface is covered by small, erratic powdery patches. Sometimes infection occurs on both the leaf surfaces. During stage of flowering and pod development, severe attack can be noticed. The stem, leaves, petioles and pods are entirely covered with white powdery patches. Later, the leaves wilt and turn yellow. Frequently, pods deformed, remain small and sometimes contain few. Moist and warm weather favours disease spread.

Management

Diseased crop debris should be removed and destroyed.

Spray Wettable sulphur @ 800g or Carbendazim @ 200g/acre or Tridemorph @ 200 ml/acre at the time of onset of mildew. Second spray should be applied fifteen days after first spray.

5. Root rot : Causal organism-*Macrophomina phaseolina*

Due to disease attack, the leaves become yellow and droop down. Later, leaves fall and plant dies within six to seven days. Chocolate coloured lesions appear on the stem at ground level. We can pul such plants with little force from the soil. The disease perpetuate through this infected rotten portion present in the soil. Huge number of black sclerotia occurs from rotton tissues. The sclerotia in seed and plant debris cause primary infection. Secondary spread occurs through air or wind. Long dry periods with 30°C day temperature followed by irrigation are congenial conditions for disease development.

Management

Seed treatment with carbendazim + thiram @ 2 g per kg (1:1 ratio) or seed dressing with *Trichoderma viride* or *Pseudonomas fluorescens* @ 4 g per kg seed (106cfu/g) having bio-fungicidal properties against *M. phaseolina*.

Application of farmyard manure/green leaf manure (*Gliricidia maculata*) and neem cake @ 4 t/acre and 60 kg/acre, respectively.

6. Anthracnose : Causal organism-*Colletotrichum lindemuthianum*

The symptom can be seen at any stage of crop development. The above ground plant parts got effected. The fungus kills the seedlings by causing chocolate coloured to black lesions on the hypocotyl region. On leaves, little angular brown lesions occur between the veins and later develop into areas with a grey dots in the centre having dark brown, tanned or reddish edge. Leaf petioles and stem may exhibit the lesions. On blackgram pods, a small water soaked lesion appear which later turns brown and develop into a large depressed contusion. Its margins turn bright red or yellow. Numerous spots combine to form necrotic patches. The seeds from such infected pods got discoloured. The ideal environment for anthracnose development is 15-20° C temperature, high relative humidity (Above 90%), and rainy days. The primary infection occurs with fungus developed on infected seeds and plant debris in soil. Air or rain splash may result in secondary spread.

Management

Use disease free seed.

The disease may also develop due to presence of infected plant debris which should be removed timely from the field.

Apply Carbendazim @ 2 g/kg for seed treatment before crop sowing.

Spray Carbendazim @ 200g/acre or Mancozeb @ 800g/acre after the onset of anthracnose and another spray application should be given fifteen days after first spray.

7. Rust : Causal organism-*Uromyces phaseoli typica*

Usually, leaves are effected due to this disease whereas stem, petioles and pod are effected rarely. Small, spherical, reddish brown or cinnamon coloured rust spores appear named as uredosori on the lower leaf surface. They may show up in bunches, and a number of sori may combine to cover a sizable portion of the leaf. On leaves dark brownish teliosori Later in the growing season, dark brown teliosori evolve on the leaves. Due to severe infestation, the leaves dry out and loose the ability to photosynthesize. This disease is favoured by cloudy and moist weather with temperatures between 21 to 26 °C and nights along with heavy dews. The pathogen persists in agricultural plant debris and soil. The wind support secondary spread of rusts.

Management

Infected crop debris should be removed and destroyed.

Immediately after appearance of rust postules, spray Mancozeb 800g/acre or Carbendazim 200 g/acre or Propiconazole 400ml/acre. apply second spray after fifteen days of first spray.

8. Web blight : Causal organism-*Rhizoctonia solani*

The symptoms appear in the form of lesions on seedlings which later enlarge and cause death of seedlings. On the leaves, whitish webby growth occurs which is supported by wet and humid conditions. The plant tops show blightened appearance. Chocolate brown sclerotia appear on diseased tissue. Web blight occurs due to seed and soil borne pathogen. The further spread of fungus take place through wind.

Management

Keeping the field free of weeds will help to check the disease.

Conclusions

For proper management of different insect-pests in blackgram, it is important to find root cause behind pest attack. Farmers should be aware regarding life cycle of insects attacking their crop, most damaging crop stage and time of appearance of these insects, symptoms of insect damage on different plant parts. In addition, knowledge about the favorable conditions for disease development, primary and secondary source of infection and resistant crop varieties against particular disease is mandatory. With the help of such records, we can plan an effective management strategy against different pests. We should adopt different cultural, mechanical practices, crop rotation, intercropping, use of natural enemies before the use of pesticides. We should avoid the use of pesticides till the pest population reaches up to economic threshold level (ETL).

References

1. Ali M. and Gupta S. (2012). Carrying capacity of Indian agriculture Pulse crops. *Current Science*, 102(6): 874-88.
2. Anonymous (2022). Package of practices for (*Kharif*) crops of Punjab. Punjab Agricultural University, Ludhiana, 87-88 pp.
3. Gailce Leo Justin C., Anandhi P. and Jawahar D. (2015). Management of major insect pests of black gram under dryland conditions. *Journal of Entomology and Zoology Studies,* 3(1): 115-121.
4. Khaire P.B. and Hake L.G. (2018). Disease Management

of *Kharif* Green Gram and Black Gram. *Popular Kheti*, 6: 96-103.

5. Lal S.S. and Sachan (1987). Insect pests of mungbean, urdbean, cowpea and pea and their management Plant Protection in field crops (eds. Veerabadhara Rao M, Sithanantham S.). *Plant Protection Association of India*, Hyderabad, India 185-201.
6. Rajak U. and Chandra D.C. (2004). Studies on insect pests on urdbean (*Vigna mungo*). *Annals of Plant Protection Science,* 12: 213-214.
7. Rajawat I.S., Kumar A., Alam M.A., Tiwari R.K. and Pandey A.K. (2021). Insect pests of black gram (*Vigna mungo* L.) and their management in Vindhya Region. *Legume Research,* 44(2): 225-232.
8. Satyagopal K., Sushil S.N., Jeyakumar P., Shankar G., Sharma O.P., Sain S.K., Boina D.R., Lavanya N., Sunanda B.S., Ram Asre, Kapoor K.S., Arya S., Kumar S., Patni C.S., Dhanapal, Sabalpara A.N., Beura S.K., Biju C.N., Naik B.G., Mesta R.K., Jacob T.K., Sathyanarayana N. and Latha S. (2014). AESA based IPM package for Blackgram and Greengram. *National Institute of Plant Health Management,* Rajendranagar, Hyderabad pp 43.
9. Singh K.M. and Singh R.N. (1977). Succession of insect pests in green gram and black gram under dry land conditions at Delhi. *Indian Journal of Entomology,* 39(4): 365-370.

Website : www.asthafoundation.in
ICAAAS–An Edited Book (Volume-3)
ISBN : 978-81-958010-7-7
Published by : Astha Foundation, Meerut (U.P.) India
Edition-2024

Chapter 9

Genomic Assisted Breeding in Chickpea : Historical Overview, Current Progress and Future Prospects

Anil Kumar[1], Chandan Kishore[1], Harish Pal Bhati[2*], S.P. Singh[3], Archana Kushwaha[4] and Aradhana Suman[1]

[1]*Department of Plant Breeding and Genetics, DKAC, Arabari, Kishanganj, Bihar*

[2]*CCSU–Government College, Jewar, U.P.*

[3]*CSAUAT-Agriculture Research Station, Kalai, Aligarh, U.P.*

[4]*Department of Food and Nutrition, GBPUAT, Pantnagar, Uttarakhand*

**Corresponding Author Email : harishbhati21@gamil.com*

Abstract

The future of genomic assisted breeding in chickpea is poised to significantly improve the efficiency of breeding programs and facilitate the development of superior cultivars. By incorporating transcriptomes data, researchers can gain a deeper understanding of gene expression patterns, allowing for the creation of new varieties with enhanced traits. This is made possible by leveraging the wealth of genetic information obtained from the sequencing of the chickpea genome. Marker-assisted breeding methods play a crucial role in expediting the development of cultivars with desired characteristics. By using genetic markers associated with specific traits, breeders can more efficiently select and breed plants with the desired genetic makeup. Additionally, the availability of cost-effective genotyping platforms and high-resolution genetic mapping techniques further enhances the utilization of genomic resources in breeding programs. These tools enable breeders to make informed decisions based on genetic data, leading to more precise and effective breeding strategies. Overall, these advancements in genomic assisted breeding aim to accelerate the rate of genetic improvement in chickpea crops. By revolutionizing traditional breeding processes and harnessing the power of genomics, researchers can work towards developing chickpea varieties that exhibit enhanced traits such as yield, disease resistance, and stress tolerance. Ultimately, these efforts are expected to result in the creation of improved chickpea cultivars that meet the evolving needs of agriculture and contribute to global food security.

Introduction

The chickpea (*Cicer arietinum* L.), belonging to the Fabaceae family, is a significant rabi pulse crop in India, contributing to 20% of global pulse production. Known by various names such as chana, gram, chhola, and Bengal gram, it is a staple in many diets. The term Cicer is derived from the Greek word kiros, referring to the renowned Roman Cicero family. Arietinum, derived from Latin aries, refers to the ram head-like shape of the kabuli chickpea seed.With a genome size of 732 Mbp, the chickpea is a self-pollinated, diploid (2n = 2x = 16) cool-season pulse crop cultivated in over 44 countries across all continents under diverse agro-climatic conditions. It is a major dietary protein source for the agrarian population of the country. The presence of nitrogen-fixing bacteria in its roots enhances soil fertility, and its deep roots improve soil aeration, promoting better root development and

Cited as : Singh S.P. (2024). ICAAAS : Genomic assisted breeding in chickpea : Historical overview, current progress and future prospects. *ICAAAS–An Edited Book*. Volume-3 : 71-82. Astha Foundation, Meerut (U.P.) India.

microbial activities. It is consumed in various forms: green leaves and tender branches as vegetables, immature grains as salad or vegetables, matured grains as split cotyledons (dal), parched or roasted grains, and flour for making sweets or salted snacks. The straw or green leaves and stem portions also serve as cattle feed.

Chickpea is the largest produced food legume in South Asia and the third globally, after common bean (*Phaseolus vulgaris* L.) and field pea (*Pisum sativum* L.). It is grown in more than 50 countries, with India being the largest producer, accounting for 64% of global chickpea production. Over the past three decades, there has been a significant shift in the growing environment from the cooler, long-season environments of northern India to the warmer, short-season environments of central and southern India. This shift is due to the inclusion of chickpea in new cropping systems and intense sequential cropping practices, leading to prolonged exposure of chickpea to high temperatures. Heat stress is a serious constraint to chickpea production in northern and central India, particularly affecting the reproductive stages (flowering and podding).

India is the largest chickpea producer, accounting for about 67% of global chickpea production. In Bihar, the area of chickpea cultivation is 60 thousand hectares with a productivity of 958 kg/ha. However, the area of chickpea cultivation in Bihar has declined from 2.45 lakh in 1975-76 to 0.56 lakh hectares in 2010-11, although productivity has increased from 550 kg/ha to 1000 kg/ha during the same period. The highest productivity of 1430 kg/ha was recorded in Bihar state in 2012-2013.

Genetic crop improvement relies on the exploitation of trait diversity available in the gene pool, providing useful information for parent selection and further utilization through plant breeding approaches. Diversified germplasm is a source that may have genes of biotic and abiotic stress resistance for future breeding programs. However, recent plant breeding practices have narrowed the genetic base of cultivated chickpea. Characterization of newly developed genotypes for economic traits will assist in the development of superior cultivars.

Chickpea is an affordable source of protein for people in developing countries, especially in South Asia, who are largely vegetarian either by choice or due to economic reasons. Additionally, chickpea is rich in minerals (phosphorus, calcium, magnesium, iron, and zinc), fiber, unsaturated fatty acids, and -carotene. Chickpea also improves soil fertility by fixing atmospheric nitrogen, meeting up to 80% of its nitrogen (N) requirement from symbiotic nitrogen fixation. Chickpea returns a significant amount of residual nitrogen to the soil and adds organic matter, improving soil health and fertility. Due to its deep tap root system, chickpea can withstand drought conditions by extracting water from deeper layers in the soil profile.

Chickpea Varieties : A Scientific Overview

Chickpea is classified into two primary types :

1. Desi Chickpea : This variety is characterized by a thick, colored seed coat, with colors ranging from various shades of brown, yellow, green, and black. The seeds are typically small, angular, and have a rough surface. The flowers are usually pink, and the plants exhibit varying degrees of anthocyanin pigmentation, although some desi types have white flowers and lack anthocyanin pigmentation on the stem. Desi types constitute 80-85% of the chickpea cultivation area. Products such as split cotyledons (dal) and flour (besan) are predominantly made from this type.

2. Kabuli Chickpea : Kabuli chickpeas are distinguished by their white or beige-colored seeds, which have a ram's head shape, thin seed coat, and smooth seed surface. The flowers are white, and there is an absence of anthocyanin pigmentation on the stem. Compared to desi types, kabuli types contain higher levels of sucrose and lower levels of fiber. Kabuli types generally have larger seeds and command a higher market price than desi types, with the price premium increasing as the seed size increases.

Chickpea Research Evolution

The journey of chickpea research in India commenced in 1905 with the then Imperial Agricultural Research Institute, Pusa (now Indian Agricultural Research Institute (IARI)), initiating breeding work on chickpea. The All India Coordinated Pulses Improvement Project (AICPIP) established in 1967 marked the beginning of systematic chickpea research. In 1972, the international organization CGIAR founded ICRISAT to globally enhance the improvement of select dryland crops, including chickpea. ICRISAT collaborated with ICAR and other Indian partners for global operations. Recognizing the significance of chickpea, ICAR instituted a dedicated All India Coordinated Research Project (AICRP) on Chickpea in 1993. Over 190 chickpea varieties with key traits have been released in India (Chaturvedi *et al.* 2016).

To accelerate genetic gains, the availability and application of genomic resources in breeding programs is essential. Despite chickpea's initial status as an "orphan legume", global research efforts have enriched it with genomics resources. Thousands of molecular markers (Nayak *et al*. 2010), high-density genetic maps (Thudi *et al*. 2011; Gujaria *et al.* 2011; Jaganathan *et al.* 2014; Kale *et al.* 2015), transcriptomic resources (Varshney *et al.* 2009; Hiremath *et al.* 2012; Kudapa *et al.* 2014), and a physical map (Varshney *et al.* 2014a) are now available for trait dissection and crop enhancement.

Recent years have seen advancements in understanding the genetics of complex abiotic stresses like drought (Varshney *et al.,* 2014; Kale *et al.* 2015), heat (Paul et al., 2018), salinity (Vadez et al. 2012; Pushpavalli *et al.* 2016), and biotic stresses like Fusarium wilt, Ascochyta blight (Sabbavarapu *et al.* 2013). Genomic regions/QTLs have been identified, and several functional genomics approaches such as RNA-seq, Massive Analysis of cDNA Ends (MACE) with parental genotypes of mapping populations as well as near isogenic lines (NILs) have provided candidate genes for drought tolerance that are being validated through genetic, genomic, and/or TILLING approaches.

In 2013, the International Chickpea Genome Sequencing Consortium, co-led by ICRISAT, University of California-Davis (USA), and BGI-Shenzhen (China), assembled the draft genome of kabuli chickpea genotype CDC Frontier, while the Next Generation Challenge Programme on Chickpea Genomics (NGCPCG), India assembled the genome sequence of desi genotype ICC 4958. Post-assembly, efforts were initiated to exploit next-generation sequencing (NGS) technology to understand chickpea's genome architecture. NGS-based whole-genome re-sequencing (WGRS) of chickpea parental lines led to the identification of 2 million Single Nucleotide Polymorphisms (SNPs) and over 290K Indels (Thudi *et al.* 2016a).

NGS-based WGRS was also used to understand the impact of breeding on genetic diversity and temporal diversity trends in chickpea. More than 100 chickpea varieties released over the last five decades were re-sequenced, identifying 1.2 million SNPs. These SNPs were used to identify genomic changes during the history of chickpea breeding, suggesting an increase in diversity in the primary gene pool as a result of recent chickpea breeding programs (Thudi *et al.* 2016b).

In addition to parental lines and varieties, a chickpea reference set (comprising 300 accessions) was also re-sequenced using the WGRS approach, leading to the identification of 4.9 million SNPs. These SNPs are being used for genome-wide association study (GWAS) to identify markers associated with traits of interest and to understand domestication and post-domestication divergence in chickpea.

Global gene banks store a vast germplasm wealth that has the potential to significantly contribute towards enhancing the rate of genetic gain. The Chickpea Genome Sequencing Initiative re-sequenced 3000 lines from the Global Chickpea Composite Collection (Varshney, 2016). This marked the first time in chickpea research history that 3000 lines were evaluated at six different locations in India for two seasons for several traits of agronomic importance. The generated genomic resources have been successfully deployed for developing superior lines for different traits of interest.

Advancements in Chickpea Trait Mapping and Molecular Breeding

Trait mapping and molecular breeding methodologies, such as Marker Assisted Backcrossing (MABC), Marker-Assisted Recurrent Selection (MARS), and Advanced Backcross Quantitative Trait Loci (AB-QTL) analysis, which are standard practices in major crop breeding programs, have been incorporated into chickpea research. For instance, superior chickpea lines with improved drought tolerance (Varshney *et al.* 2013b), and resistance to Fusarium wilt and Ascochyta blight (Varshney *et al.* 2014c) have been developed.

The introgression of the "QTL-hotspot" into several elite varieties in India, Kenya, and Ethiopia has resulted in the development of superior lines exhibiting enhanced drought tolerance and increased yield under both rainfed and irrigated conditions, irrespective of the genetic background. Furthermore, the available genomic resources have facilitated the successful implementation of modern breeding approaches like genomic selection for accelerated genetic gains (Roorkiwal *et al.* 2016).

For the effective application of the available genomic resources in crop improvement, cost-effective genotyping platforms play a crucial role. In this regard, cost-effective SNP genotyping assays such as VeraCode assays (Roorkiwal *et al.* 2014) and KASPar assays (Hiremath *et al.* 2012) have been developed. Recently, a precise and cost-effective SNP genotyping platform, featuring 50,590 high-quality non-redundant SNPs on the Affymetrix Axiom® Cicer SNP array, has been developed and is being utilized for high-resolution genetic mapping (Roorkiwal et al., 2018). This array will also be beneficial for fingerprinting the released varieties and evaluating their adoption, in addition to its applications in genetics and breeding.

Over the past 12 years, significant progress has been made in developing genomic resources, and these resources have been effectively employed to achieve faster genetic gains in chickpea.

Aims of Chickpea Genetic Improvement

Yield Enhancement : The cardinal aim is to augment and ensure consistency in grain yield.

Seed Quality Improvement : An additional objective is the generation of cultivars with larger seeds.

Biotic Stress Resistance : The program aims to incorporate resistance to major biotic stresses, with a continuous progression towards multi-resistance.

Adaptability to Adverse Conditions : The breeding program also emphasizes increased resilience to unfavorable environmental conditions, specifically drought, salinity, and thermal stress.

Development of Short-Duration Genotypes : The creation of short-duration genotypes suitable for non-traditional areas is another significant objective.

Methods for Crop Enhancement 4.1 Traditional Strategies

The chickpea, primarily a self-pollinating crop, has breeding programs aimed at developing homozygous genotypes with desirable traits. The breeding process can be divided into three key stages:

1. Generation of Genetic Diversity : This is the cornerstone of a breeding program. The success of such a program hinges on the type and degree of variability.

2. Selection within the Created Diversity : This involves choosing the most promising variants from the generated diversity.

3. Assessment of Selected Lines : This step involves evaluating the performance of the selected lines.

The creation of genetic diversity is crucial for a robust and successful breeding program, which can be achieved through :

1. Introduction of Cultivars : This involves acquiring and evaluating genotypes from both within and outside the country, and identifying a desirable genotype that is adapted to the local environment with high productivity or any other specific desired trait. The success of plant introduction depends on the nature of the introduced material. Generally, material introduced from locations with similar soil characteristics and climatic conditions is expected to be successful. Introduction is generally facilitated by:

Exchanging material with fellow plant breeders

Exploring areas showing rich variation of the species

Obtaining generic resources from international institutes/organizations

The introduced material may be homozygous and stable like pure lines, or it may be heterogeneous mixed with landraces or heterozygous segregating populations. If the introduced material is a pure line, it will be immediately accepted as it shows good adaptability. But with mixtures (landraces) or segregating material, it will be necessary to identify either a productive line or a line with a specific desirable trait that will be useful in a recombination breeding program. Although plant introduction is employed at the beginning of a breeding program, it is nevertheless a continuous process. It is the cheapest and fastest way of developing cultivars. Therefore, it becomes an important breeding procedure in a country where there is financial constraint or lack of trained staff, and also in those countries where the area under the crop is relatively small. There are several examples of successful introduction in chickpea. A bruchid resistant line (G109-1) is a selection from an exotic variety introduced to India from Turkey.

2. Pure Line Selection : With the increase in local landraces and exotic germplasm, systematic purification and evaluation were initiated. These landraces exhibited variability, and purification was achieved through selection.

3. Hybridization : The goal of hybridization is to amalgamate desirable traits from multiple parents into a single cultivar. This is undertaken once the existing natural variation is depleted. The success of a hybridization program largely depends on the appropriate selection of parents. When the objective is to supersede the existing variety with a superior one, the existing variety, which is adapted to the local environment, is a logical choice as one parent. The second parent should be chosen such that it complements the first parent. If the objective is to create variation for the desired traits or to broaden the genetic base, then diverse parents are selected. Evaluation reports of the germplasm from national gene banks, such as the National Bureau of Plant Genetic Resources (NBPGR) in India, international institutes, and other national research reports, as well as periodicals, serve as valuable resources to select parents for a crossing program based on specific objectives. Biometrical approaches are employed to analyze diversity and the combining ability of genotypes involved in hybridization.

Crossing Techniques

Crossing in chickpea is a laborious task, and the success of artificial hybridization ranges from 10% to 50%, depending on the weather, particularly temperature and humidity, in addition to the genotypes involved. Since chickpea flowers are small and delicate, emasculation and pollination often cause damage to the floral parts, thus reducing the success rate.

Hybridization Involves :

Single Crosses

These are extensively used in chickpea to develop new cultivars. Through single crosses, efforts were made to select superior recombinants than the parents used in the cross.

Three-way Crosses

These involve three different parents, each possessing a specific desirable trait, with the aim of recombining the traits together in a new cultivar.

Multiple Crosses

In these, more than three parents are involved, which are crossed in various ways. These crosses are used to broaden the genetic base and to enhance the opportunities for recombination.

Handling of Segregating Populations

It is always desirable to attempt well-planned crosses based on diversity and combining ability of parents. Since heterosis of F1 hybrids has been shown to be correlated well with the performance of the segregating populations later, poor-performing F1 crosses can be rejected which enables handling of few but promising hybrids so that sufficiently large populations of F2 from selected F1 populations can be handled for achieving better results.

Selection Methods

Pedigree Method

This is the most widely used method of handling segregating population in self-pollinated crops.

Bulk Method

This method of breeding is advantageous for the development of high-yielding and short-duration varieties.

Backcross Method

This method is used for interspecific hybridization and limited backcross for desi × Kabuli introgression and resistance breeding.

Recent Advancements in Plant Breeding Techniques

Hybridization is the primary technique used for developing recent varieties. Depending on the breeding program's objective, single, three-way, or multiple crosses are utilized.

Backcross breeding is frequently employed to integrate one or a few traits from a germplasm line or a wild species into a well-adapted variety.

To manage segregating generations, pedigree, bulk, or various modifications of these methods are used (Refer to Table-4).

There is a necessity to improve the precision and efficiency of selections in segregating generations for higher and quicker genetic gains.

The precision in selection for resistance/tolerance to stresses can be enhanced by screening under controlled environmental conditions or at hot spot locations.

Singh (1987) summarized the utility of different breeding methods for specific traits in chickpea as follows :

The pedigree method is used for resistance breeding (disease, insect, nematode).

The modified bulk method is used for stress characters (drought, heat, cold, iron deficiency).

The backcross method is used for interspecific hybridization.

Limited backcross is used for Desi x Kabuli introgression and resistance breeding.

The bulk pedigree method is used for traits such as winter hardiness and drought tolerance.

5. Mutational Breeding

Prolonged use of conventional breeding methods may have led to a reduction in genetic variability. To further enhance a crop species, it is essential to increase this novel genetic variability. In this context, mutations can be beneficial for plant-breeding programs (Micke, 1988a,b).

The concept of mutation dates back to 1900, introduced by de Vries (1901) in "Die Mutations theory". The earliest record of spontaneous mutants dates back to around 300 BC in China, particularly in cereal crops, as described in the ancient book, Lulan (van Harten, 1998).

Induced mutations were first discovered in the fruit fly (Drosophila melanogaster L.) by Muller (1927). Following the discovery of x-ray-induced mutations, Stadler (1928) validated the ability of x-rays to induce mutation and demonstrated its application to barley (*Hordeum vulgare* L.).

Despite the initial success of induced

mutations by numerous scientists worldwide, the work on mutations gradually declined towards the 1960s due to its various adverse effects (Allard, 1960).

In 1964, with the establishment of the Food and Agricultural Organization/International Atomic Energy Agency (FAO/IAEA) Division of Nuclear Techniques in Food and Agriculture, plant breeders were motivated to utilize mutation techniques for beneficial purposes.

Toker *et al.* (2005) developed a straight forward and reliable method to detect gamma-irradiated Cicer seeds, including C. bijugum P.H. Rech. and C. reticulatum Ladiz.

Recently, mutagenesis has garnered significant attention as a promising new technique known as 'targeting induced local lesions in genomes' (TILLING).

Molecular Strategies for Chickpea Enhancement

The advent of molecular markers and the ability to map genes/QTL of interest have paved the way for genomics-assisted breeding in chickpea. The integration of genomics tools and the creation of markers have expedited the chickpea breeding process. The following molecular techniques can be employed for the enhancement of chickpea :

1. Marker-Assisted Backcrossing (MABC) : This technique leverages molecular markers to identify and select genes of interest/QTL, accelerating the breeding process.

2. Marker-Assisted Recurrent Selection (MARS) : MARS is a method that uses molecular markers to select superior recombinants from a breeding population.

3. Gene(s) and QTL Identification for Introgression Programme : This involves the identification of beneficial genes and QTL for integration into the chickpea genome.

4. Genome Wide Selection (GWS) : GWS is a technique that uses markers distributed throughout the genome for selection.

5. Next-Generation Genotyping and Sequencing Technologies : These advanced technologies allow for high-throughput genotyping and sequencing, providing detailed genetic information for breeding programs.

1. Marker-Assisted Backcrossing (MABC)

MABC is a potent technique that utilizes molecular markers to identify and select genes that confer resistance to various factors. It is employed to integrate genes of interest or QTL from a less desirable source (donor parent) into a chosen cultivar or breeding line (recipient parent), eliminating any linkage drag from the donor parent. This technique is particularly useful for enhancing cultivars already favored by farmers.

Selection in MABC can be categorized into :

Foreground Selection (FS) : FS employs two flanking markers to select a specific gene or a QTL.

Background Selection (BS) : BS uses multiple markers not linked with the desirable QTL/gene to select backcross progeny with the highest proportion of the recipient parent's genome.

Key advantages of MABC over traditional breeding include :

FS can be used to select heterozygous plants at the seedling stage.

Recessive alleles can be identified in MABC selection.

MABC can be used to develop near-isogenic lines (NILs), which are often used for genomic analysis.

Linkage drag (binding of undesirable genes) can be minimized through MABC.

2. Marker-Assisted Recurrent Selection (MARS)

MARS is an innovative approach where individuals for intercrossing are selected using a selection index constructed based on QTL-associated molecular markers. This method is expected to yield higher gains from selection than phenotypic selection used in conventional recurrent selection methods. MARS could be useful in pyramiding genes involved in complex traits, like drought, in chickpea breeding.

3. Identification of Gene(s) and QTL for Introgression Programme

Molecular markers have been instrumental in establishing linkage maps for many crop species and determining gene numbers for specific traits and gene tagging. Many crucial biotic and abiotic resistance genes have been mapped and tagged in chickpea using marker approaches. With rapid advancements in genomics, it is now feasible to transfer the favorable alleles into an elite germplasm more efficiently. Therefore, wild species can significantly contribute to varietal development by being excellent sources of resistance/tolerance to biotic and abiotic stresses that can be utilized in breeding programs.

Gene Introgression Approaches

Several strategies have been employed for the introgression of genes from wild species, including the creation of introgression libraries and the use of advanced-backcross QTL (AB-QTL).

1. Introgression Libraries

These are generated through successive backcrossing to the recurrent parent, typically over three to four generations, resulting in introgression lines (ILs). Molecular markers are utilized to track the introgressed fragments. The entire donor genome is represented by a collection of small, overlapping fragments. Such ILs have found application in various crops including rice, tomato, soybean, and groundnut.

2. Advanced-Backcross QTL (AB-QTL)

This approach, proposed by Tanksley and Nelson in 1996, is capable of detecting additive, dominant, partially dominant, and over-dominant QTL. It involves repeated backcrossing with the elite parent. Both phenotyping and genotyping (with polymorphic markers) are performed on the segregating BC_2F_2 or BC_2F_3 population produced during backcrossing, followed by QTL analysis.

These methods offer a precise and efficient way to incorporate beneficial traits from wild species into cultivated varieties.

Genome-Wide Selection (GWS)

Genomic selection (GS) is an innovative method that employs genetic markers dispersed across the entire genome, ensuring that all quantitative trait loci (QTL) are in linkage disequilibrium with at least one marker. This approach leverages both phenotypic and genotypic data to compute genomic estimated breeding values (GEBVs) for offspring.

Key points

1. GEBVs : These values represent the cumulative effects of all QTL throughout the genome, thereby harnessing all genetic variation for a specific trait.

2. Integration of Data : The amalgamation of comprehensive sequence information with precise phenotypic variation enables the identification of accessions with rare variants that could be responsible for key phenotypes such as yield components, tolerance to abiotic stress, or disease resistance.

3. GBS Approach : This method has been employed to detect genome-wide single nucleotide polymorphisms (SNPs) in chickpea.

Next-Generation Genotyping and Sequencing Technologies

Next-Generation Sequencing (NGS) technology, specifically the Sequence-based Genotyping (SbG) method, has emerged as a preferred technique for deciphering the genetics of complex traits in both flora and fauna. The applications of SbG technologies are extensive and include:

1. Genetic Mapping : It aids in the creation of genetic maps, which are crucial for understanding the genetic architecture of species.

2. Purity Testing : It ensures the genetic purity of a species or variety, which is vital for maintaining the integrity of breeding programs.

3. Marker-Trait Associations : It helps establish associations between genetic markers and traits, facilitating the identification of genes responsible for specific traits.

4. Marker-Assisted Selection (MAS) : It accelerates the process of selecting individuals with desirable traits in breeding programs.

5. Genomic Selection (GS) : It enhances crop improvement efforts by enabling the selection of individuals based on their genomic estimated breeding values.

The NGS approach has also been employed by the International Chickpea Genome Sequencing Consortium (ICGSC) for sequencing the genome of CDC Frontier, a variety of kabuli chickpea. The desi chickpea genotype ICC4958 was targeted for generating a draft genome assembly using NGS platforms, BAC end sequences, and a genetic map. An enhanced version of the desi chickpea cultivar ICC4958 was reported, which exhibited a 2.7-fold increase in the length of pseudomolecules. This improved assembly could bridge the gaps in the existing genome assembly and predicted the existence of over 30,000 protein-coding genes.

Advancements in Chickpea Breeding Using Molecular Methods

Conventional breeding based solely on phenotypic selection remains common in legume breeding programs. However, molecular methods aim to accelerate genetic gain by increasing efficiency and reducing time and cost. Several challenges exist in this context:

Limited Predictive Molecular Markers : Availability of predictive markers for target traits is restricted.

Access to Marker Technologies : Limited access to marker technologies poses a challenge.

Precise Phenotyping Platforms : High-throughput, cost-effective, and precise phenotyping platforms are not widely available.

Cost-effective sequencing technologies have revolutionized genomics and breeding. By identifying genes responsible for specific phenotypes, these methods allow selection based on genotyping information. Marker-assisted backcrossing (MABC) significantly shortens breeding time compared to conventional methods. Notably, chickpea lines with enhanced resistance to Fusarium wilt (FW) and Ascochyta blight (AB) have been successfully developed using MABC. Over the past 12 years, significant progress has been made in developing genomic resources, which play a crucial role in achieving faster genetic gains in chickpea.

Future Prospects and Conclusion in Chickpea Breeding

Significant strides have been made in the development of genetic and genomic resources for chickpea over the past few decades. Key advancements include :

1. **Molecular Markers and Genetic Maps**

   Availability of numerous molecular markers and dense genetic maps.

   Markers associated with specific traits facilitate targeted breeding efforts.

2. **Transcriptomics Resources**

   Integration of transcriptomics data enhances our understanding of gene expression.

   Enables trait dissection and identification of candidate genes.

3. **Draft Genome Sequencing**

   The chickpea genome has been sequenced, unlocking genetic potential.

   Breeders and biotechnologists can develop new varieties with enhanced resistance and yield.

4. **Marker-Assisted Breeding Methods**

   Marker-assisted backcrossing (MABC) and marker-assisted recurrent selection (MARS) are being integrated into chickpea breeding programs.

   These methods accelerate cultivar development by leveraging genotyping information.

In summary, the integration of genomic technologies holds great promise for improving breeding efficiency and developing superior chickpea cultivars in less time.

References

1. Ahloowalia B.S., Maluszynski M. and Nichterlein K. (2004). Global impact of mutation-derived varieties. *Euphytica* 135: 187–204.
2. Allard R.W. (1960) *Principles of Plant Breeding*. Wiley, New York.
3. Arora P.P. and Singh I.S. (1990). Crossing without emasculation in chickpea. *International Chickpea Newsletter* 23: 11.
4. Auckland A.K. and van der Maesen L.J.G. (1980). Chickpea. In: Fehr W.R. andHadely H.H. (eds) *Hybridization of Crop Plants*. *American Society of Agronomy*, Madison, Wisconsin, pp. 249–259.
5. Bahl P.N. (1981). Yield potential of improvedcultivar and plant type concept in chickpea. In: *Proceedings of the FAI Group Discussion on Increasing Pulse and Oilseed Production in India*. New Delhi, pp. 32–40.
6. Bahl P.N. and Gowda C.L.L. (1975). Pod setting in crosses of Bengal gram. *IndianJournal of Genetics,* 35: 13–16.
7. Bahl P.N., Salimath P.M., Malik B.A., Dahiya B.S., Deshmukh R.B. and Rangaswamy P. (1990). New approaches in chickpea breeding and prospects in the nineties. In: *Chickpea in the Nineties: Proceedings of the 2nd International Workshop on Chickpea Improvement*. 4–8 December1989. ICRISAT, Hyderabad, India, pp.225–232.
8. Bahl P.N., Singh S.P., Hayat R., Raju D.B. and Jain H.K. (1979). Breeding for improved plant architecture and high protein yields. *FAO/IAEA International Symposium on Seed Improvement in Cereals and Grain Legumes*. Vienna, Austria, pp. 297–307.
9. Basu U., Srivastava R., Bajaj D., Thakro V., Daware A., Malik N., Upadhyaya H.D. and Parida S.K. (2018). Genome-wide generation and genotyping of informative SNPs to scan molecular signatures for seed yield in chickpea. *Sci. Rep.,* 8: 13240
10. Bejiga G. and Tessema T. (1981). Identification on the optimum time of emasculation and pollination to increase percentage of hybrid seed set in chickpea. *Journal of Agricultural Sciences,* 3: 129–134.
11. Bernardo R. (2010). Genome wide selection with minimal selection in self-pollinated crops. *Crop Sci*., 117-125.
12. Bernardo R. (2010). Potential and practicality of genome wide selection in plants. In Proceedings of the Plant and Animal Genomes XVIII Conference, San Diego, CA, USA, 9–13 January 2010.
13. Bernardo R. and Charcosset A. (2006). Usefulness of gene information in marker-assisted recurrent selection: A simulation appraisal. *Crop Sci*., 46: 614–621.
14. Bernardo R. and Yu J. (2007). Prospects for genome-wide selection for quantitative traits in maize. *Crop Sci*., 47: 1082–1090.
15. Bhatia C.R., Maluszynski M., Nichterlein K. and van Zanten L. (2001a). Grain Legume cultivars derived

from induced mutations, and mutation affecting nodulation. *Mutation Breeding,* 13: 1–44.

16. Bhatia C.R., Nichterlein K. and Maluszynski M. (2001c). Mutation affecting nodulationin grain legumes and their potential in sustainable cropping systems. *Euphytica,* 120: 415–432.
17. Bhatnagar C.P., Handa D.K. and Misra A. (1985). Prospects of utilizing mutation breeding in inducing nematode resistance in chickpea. *International Chickpea Newsletter,* 12: 5–7.
18. Bisen M.S., Singh S.P. and Rao S.K. (1985). Effectiveness of selection methods in chickpea *Cicer arietinum* L. under different environments. *Theoretical and Applied Genetics,* 70(6) : 661–666.
19. Byth D.E., Green J.M. and Hawtin G.C. (1980). ICRISAT/ICARDA chickpea breeding strategies. In: *Proceedings of the International Workshop on Chickpea Improvement*. 28 February–2 March 1979. ICRISAT, Hyderabad, India, pp. 11–27.
20. Cagirgan M.I. and Toker C. (2004). Selection of chickpea mutants for cold tolerance and ascochyta blight resistance. *International Chickpea and Pigeonpea Newsletter* 11: 14–16.
21. Canci H., Toker C. and Cagirgan M.I. (2004b). Preliminary screening for nodulation in chickpea mutants. *International Chickpeaand Pigeonpea Newsletter,* 11: 13–14.
22. Chakraborty K. and Devakumar C. (2006). Chemical hybridizing agents for chickpea (*Cicer arietinum* L.): leads from QSAR analysis of ethyl ozanilates and pyridones.*Journal of Agricultural and Food Chemistry,* 54(5): 1868–1873.
23. Chaky J.M., Specht J.E. and Cregan P.B. (2004). Advanced backcross QTL analysis in a mating between*Glycine max* and *Glycine soja*. In *Proceedings of the Plant and Animal Genome XII Conference Abstracts*, San Diego, CA, USA, 10–14 January 2004; pp. 545.
24. Charcosset A. and Moreau L. (2004). Use of molecular markers for the development of new cultivars and the evaluation of genetic diversity. *Euphytica*, 137: 81–94.
25. Chaudhary M.S., Chandra S. and Tomar Y.S. (1970). Genetical studies on a variant form in Bengal gram (*Cicer arietinum*). *Indian Journal of Heredity,* 2: 133–138.
26. Clegg M.T., Allard R.W. and Kahlar A.L. (1972). Is the gene unit of selection?Evidence from two experimental plantpopulations. *Proceedings of the NationalAcademy of Sciences of the United States of America,* 19: 2474–2478.
27. Cobos M.J., Rubio J., Fernández-Romero M.D., Garza R., Moreno M.T., Millán T. and Gil J. (2007). Genetic analysis of seed size, yield and days to flowering in a chickpea recombinant inbred line population derived from a Kabuli × Desi cross. *Annals of Applied Biology*, 151(1): 33-42.
28. Cobos M.J., Rubio J., Strange R.N., Moreno M.T., Gil J. and Millan T. (2006). A new QTL for Ascochyta blight resistance in an RIL population derived from an interspecific cross in chickpea. *Euphytica*, 149: 105–111.
29. Cobos M.J., Winter P., Kharrat M., Cubero J.I., Gil J., Millan T. and Rubio J. (2009). Genetic analysis of Agronomic traits in a wide cross of chickpea. *Field Crops Res.*, 111: 130–136.
30. Concibido V.C., La Vallee B., Mclaird P., Pineda N., Meyer J., Hummel L., Yang J., Wu K. and Delannay X. (2003). Introgression of a quantitative trait locus for yield from *Glycine soja* into commercial soybean cultivars. *Theor. Appl. Genet.*, 106: 575–582.
31. Conger B.V., Konzak C.F. and Nilan R.A. (1977). Radiation sensitivity and modifying factors. *Manual on Mutation Breeding*, 2nd edn. Technical reports series No.119. *International Atomic Energy Agency*, Vienna, Austria, pp. 40–50.
32. Croser J.S., Ahmad F., Clarke H.J. and Siddique K.H.M. (2003). Utilization of wild *Cicer* in chickpea improvement–progress, constraints, and prospects. *Australian Journal of Agricultural Research,* 54: 429–444.
33. Dahiya B.S. (1974). Crossing without emasculation in chickpea. *Indian Journal of Genetics,* 34: 206–207.
34. Dahiya B.S., Lather V.S. and Kumar R. (1990). A brachytic mutant of chickpea. *International Chickpea Newsletter,* 22: 42.
35. Dahiya B.S., Lather V.S., Solanki I.S. and Kumar R. (1984a). Useful spontaneous mutants in chickpea. *International Chickpea Newsletter,* 11: 4–7.
36. Das S., Upadhyaya H.D., Bajaj D., Kujur A., Badoni S., Laxmi K.V., Tripathi S., Gowda C.L.L., Sharma S., Singh S., Tyagi A.K. and Parida S.K. (2015). Deploying QTL-seq for rapid delineation of a potential candidate gene underlying major trait-associated QTL in chickpea. *DNA Res.,* 22: 193–203
37. Dua R.P., Chaturvedi S.K. and Shiv Sewak (2001). Reference Varieties of chickpea for IPR Regime. IIPR, Kanpur.
38. Flandez-Galvez H., Ades P.K., Ford R., Pang E.C.K., Taylor P.W.J. (2003). QTL analysis for ascochyta blight resistance in an intraspecific population of chickpea (*Cicer arietinum* L.). *Theor. Appl. Genet.*, 107: 1257–1265.
39. Frisch M., Bohn M. and Melchinger A.E. (1999). Minimum sample size and optimal positioning of

flanking markers in marker assisted backcrossing for transfer of a target gene. *Crop Sci.*, 39: 967–975.

40. Gupta P.K., Kumar J., Mir R.R. and Kumar A. (2010). Marker assisted selection as a component of conventional plant breeding. *Plant Breed. Rev.*, 33: 145–217.
41. Gupta P.K., Langridge P. and Mir R.R. (2010). Marker-assisted wheat breeding: present status and future possibilities. *Mol. Breed.*, 26: 145–161.
42. Heffner E.L., Sorrells M.E. and Jannink J.L. (2009). Genomic selection for crop improvement. *Crop Sci.*, 49: 1–12.
43. Hospital F. (2005). Selection in backcross programmes. *Philos. Trans. R. Soc. B*, 360: 1503–1511.
44. Jannink J.L., Lorenz A.J. and Iwata H. (2010). Genomic selection in plant breeding: from theory topractice. *Brief. Funct. Genomics Proteom.*, 9: 166–177.
45. Kale S.M., Jaganathan D., Ruperao P., Chen C., Punna R., Kudapa H. and Garg V. (2015). Prioritization of candidate genes in "QTL-hotspot" region for drought tolerance in chickpea (*Cicer arietinum* L.). *Scientific reports,* 5: 15296.
46. Kharkwal M.C., Nagar J.P. and Kala Y.K. (2005). BGM 547–A high yielding chickpea (*Cicer arietinum* L.) mutant variety for late sown conditions of North Western Plains Zone of India. *Indian J Genet.*, 65: 229–230.
47. Kharkwal M.C., Pandey R.N. and Pawar S.E. (2004). Mutation Breeding for Crop Improvement. In: Jain, H.K. and Kharkwal, M.C. (ed.) *Plant Breeding–Mendelian to Molecular Approaches.*, New Delhi, 601–645.
48. Li B., Zhang N., Wang Y.G., George A.W., Reverter A. and Li Y. (2018). Genomic prediction of breeding values using a subset of SNPs identified by three machine learning methods. *Front. Genet.,* 9: 237
49. Madrid E., Rubiales D., Moral A., Moreno M.T., Millan T., Gil J. and Rubio J. (2008). Mechanism and molecular markers associated with rust resistance in a chickpea interspecific cross (*Cicerarietinum* × *Cicer reticulatum*). *Eur. J. Plant Path.*, 121: 45–53.
50. Micke A. and Donini B. (1993). Induced mutations. In: Hayward, M.D., Bosemark, N.O. and Romagosa, I. (eds) *Plant Breeding:Principles and Prospects*. Chapman and Hall, London, pp. 53–62.
51. Moose S. and Mumm R.H. (2008). Molecular plant breeding as the foundation for 21st century crop improvement. *Plant Physiol.*, 147: 969–977.
52. Nanda G.S., Singh G. and Gill K.S. (1990). Efficiency of intermating in F_2 generation of an intervarietal cross in bread wheat.*Indian Journal of Genetics and Plant Breeding,* 50(4): 364–368.
53. Parween S., Nawaz K., Roy R., Pole A.K., Venkata Suresh B. and Misra G. (2015). An advanced draft genome assembly of a desi type chickpea (*Cicer arietinum* L.). *Sci. Rep.,* 5: 12806. Doi: 10.1038/srep12806
54. Paul P.J., Samineni S., Thudi M., Sajja S.B., Rathore A., Das R.R. and Gaur P.M. (2018). Molecular mapping of QTLs for heat tolerance in chickpea. *International journal of molecular sciences*, 19(8): 2166.
55. Pratap A., Chaturvedi S.K., Tomar R., Rajan N., Malviya N., Thudi M., Saabale P.R., Prajapati U., Varshney R.K. and Singh N.P. (2017). Marker assisted introgression of resistance to fusarium wilt race 2 in Pusa 256, an elite cultivar of desi chickpea. *Mol. Gen. Genomics,* 293: 1237–1245
56. Pundir R.P.S. and Reddy G.V. (1989). Induction, genetics and possible use of glabrousness in chickpea. *Euphytica,* 42: 141–144.
57. Pundir R.P.S. and Reddy K.N. (1984). Comparison of cross-pollination methods in chickpea. *International Chickpea Newsletter,* 11: 9–11.
58. Rahman M.A. and Bahl P.N. (1985). Comparison of single seed descent, mass selection and random bulk methods in chickpea. *Indian Journal of Genetics,* 45(2): 186–193.
59. Retig G. (1971). Hybridization method in chickpea (*Cicer arietinum* L.). II. Crossing without emasculation. *Israel Journal of Agricultural Research,* 21(3): 113.
60. Ribaut J.M., de Vicente M.C. and Delannay X. (2010). Molecular breeding in developing countries: Challenges and perspectives. *Curr. Opin. Plant Biol.*, 13: 1–6.
61. Ribaut J.M. and Hoisington D. (1998). Marker-assisted selection: New tools and strategies. *Trends Plant Sci.*, 3: 236–239.
62. Roorkiwal M., Bharadwaj C., Barmukh R., Dixit G.P., Thudi M., Gaur P.M. and Varshney R.K. (2020). Integrating genomics for chickpea improvement: achievements and opportunities. *Theoretical and Applied Genetics,* 133(5): 1703-1720.
63. Rupela O.P. (1992). Natural occurrence and salient characters of non-nodulating chickpea plants. *Crop Science,* 32: 349–352.
64. Salimath P.M. and Bahl P.N. (1985b). Early generation selection in chickpea. III Predicted and realized gains. *Experimental Genetics,* 1(2): 59–62.
65. Sandhu J.S., Brar H.S. and Verma M.M. (1990). Inheritance of plant type mutant and its utilization in chickpea. *Euphytica,* 48: 111–112.
66. Saxena H.P. and Raina A.K. (1970). A bruchid resistant strain of Bengal gram. *Current Science,* 39: 189–190.
67. Shaikh M.A.Q. (1977). Grain legumes in Bangladesh. In: Induced Mutations for the Improvement of Grain Legumes in South East Asia (1975), IAEA-203.

International Atomic Energy Agency, Vienna, Austria, pp. 61–70.

68. Sharma B. and Kharkwal M.C. (1982). Induced mutations in grain legumes. In: *Induced Mutations for the Improvement of Grain Legumes Production II, IAEA-TECDOC-260. International Atomic Energy Agency*, Vienna, Austria, pp. 59–64.
69. Sharma K.D., Winter P., Kahl G. and Muehlbauer F.J. (2004). Molecular mapping of *Fusarium oxysporum* f. sp. *ciceris* race 3 resistance gene in chickpea. *Theor. Appl. Genet.*, 108: 1243–1248.
70. Sindhu J.S., Lal S.B. and Singh R.P. (1981). Studies on the factors determining crossing success in chickpea (*Cicer arietinum*). *Pulse Crops Newsletter,* 1: 21–22.
71. Singh B.D. (2005). Mutations in crop improvement. In: Singh, B.D. (ed.) *Plant Breeding, Principles and Methods*. *Kalyani Publishers,* Ludhiana, India, pp. 698–731.
72. Singh D. and Shyam R. (1958) Sterility in gram (*Cicer arietinum*). *Current Science,* 27: 491–492.
73. Singh H. and Dahiya B.S. (1974). Note on inheritance of bushy mutant in chickpea. *Current Science,* 43: 731–732.
74. Singh I. and Waldia R.S. (1994). Comparison of selection methods in chickpea under late sown condition, *Crop Research, Hissar,* 8(3): 508–511.
75. Singh K.B. (1987). Chickpea breeding. In: Saxena, M.C. and Singh, K.B. (eds) *The Chickpea*. *CAB International*, Wallingford, UK, pp. 127–162.
76. Singh K.B. (1997). Chickpea (*Cicer arietinum*L.). *Field Crops Research,* 53: 161–170.
77. Singh K.B. and Auckland A.K. (1975). Chickpea breeding at ICRISAT. In: *Proceedings of the International Workshop on Grain legumes*. ICRISAT, Hyderabad, India, pp. 3–17.
78. Singh K.B., Ocampo B. and Robertson L.D. (1998). Diversity for abiotic and biotic stress resistance in the wild annual *Cicer* species. *Genetic Resources and Crop Evolution,* 45: 9–17.
79. Singh N. (2001). Crossing technique without emasculation in chickpea. *Indian Journal of Genetics,* 61(4): 366.
80. Singh O. and Rupela O.P. (1991). Genetic relationship among the newly identified nonnodulating chickpea lines. *International Chickpea Newsletter,* 25: 11–12.
81. Singh O. and Rupela O.P. (1998). A new gene that controls root nodulation in chickpea. *Crop Science,* 38: 360–362.
82. Singh O., Rupela O.P. and van Rheenen H.A. (1992a). Genetics of non-nodulation in chickpea. *International Chickpea Newsletter,* 15: 5–6.
83. Singh O., van Rheenen H.A. and Rupela O.P. (1992b). Inheritance of a new non-nodulation gene in chickpea. *Crop Science,* 32: 41–43.
84. Smartt J. (1976). Comparative evolution of pulse crops. *Euphytica,* 25: 139–143.
85. Smithson J.B., Thompson J.A. and Summerfield R.J. (1985). Chickpea (*Cicer arietinum*) In: R.J. Summer field and E.H. Roberts (eds) *Grain Legume Crops*. Collins, London, UK. pp. 312–390.
86. Stadler L.J. (1928). Mutations in barley induced byx-rays and radium. *Science,* 68: 186–187.
87. Stam P. (1994). Marker-Assisted Breeding. In *Proceedings of the IX Meeting of EUCARPIA Section on Biometrics in Plant Breeding*, Wageningen, the Netherlands,; pp. 32–44.
88. Streeck T.S. and Piepho H.P. (2010). Genome-wide selection by mixed model ridge regression and extensions based on geo statistical models. *BMC Proc.*, 4: S1–S8
89. Tanksley S.D. and Nelson J.C. (1996). Advanced backcross QTL analysis: a method of the simultaneous discovery and transfer of valuable QTLs from unadapted germplasm into elite breeding lines. *Theor. Appl. Genet.*, 92: 191–203.
90. Tekeoglu M., Rajesh, P.N., Muehlbauer F.J. (2002). Integration of sequence tagged microsatellite sites to the chickpea genetic map. *Theor. Appl. Genet.*, 105: 847–854.
91. Tester M. and Langridge P. (2010). Breeding technologies to increase crop production in a changing world. *Science*, 327: 818–822.
92. Toker C. (2005). Preliminary screening and selection for cold tolerance in annual wild *Cicer* species. *Genetic Resources and Crop Evolution,* 52: 1–5.
93. Toker C. and Cagirgan M.I. (2004). Spectrum and frequency of induced mutations in Chickpea. *International Chickpea and Pigeonpea Newsletter,* 11: 8–10.
94. Toker C., Uzun B., Canci H. and Ceylan F.O. (2005). Effects of gamma irradiation on the shoot length of *Cicer* seeds. *Radiation Physics and Chemistry,* 73: 265–367.
95. Turano M.J., Baird L.M. and Webster B.D. (1983). Characteristics of the stigma of chickpea. *Crop Science,* 23: 1033–1036.
96. Udupa S.M. and Baum M. (2003). Genetic dissection of pathotype-specific resistance to ascochyta blight disease in chickpea (*Cicer arietinum* L.) using microsatellite markers. *Theor. Appl. Genet.*, 106: 1196–1202.
97. Upadhyaya H.D., Bajaj D., Das S., Kumar V., Gowda C.L.L., Sharma S., Tyagi A.K. and Parida S.K. (2016). Genetic dissection of seed-iron and zinc concentrations in chickpea. *Sci. Rep.,* 6: 24050

98. Vadez V., Krishnamurthy L., Thudi M., Anuradha C., Colmer T., Turner N., Siddique K., Gaur P. and Varshney R.K. (2012). Assessment of ICCV 2 × JG 62 chickpea progenies shows sensitivity of reproduction to salt stress and reveals QTL for seed yield and yield components. *Mol. Breed.*, 30: 9–21.

99. Van der Maesen L.J.G. (1972). Cicer L. A Monograph of the Genes, with Special Reference to the Chickpea (*Cicer arietinum*), Its Ecology and Cultivation. Mededlingen Landbouwhoge School (Communication Agricultural University), Wageningen, The Netherlands.

100. Van Harten A.M. (1998). *Mutation Breeding : Theory and Practical Applications*. Cambridge University Press, Cambridge.

101. Van Rheenen H.A. (1996). Determinate growth in chickpea. *International Chickpea and Pigeonpea Newsletter,* 3: 18.

102. Van Rheenen H.A., Pundir R.P.S. and Miranda J.H. (1994). Induction and inheritance of determinate growth habit in chickpea (*Cicer arietinum* L.). *Euphytica* 78: 137–141.

103. Varshney R.K., Gaur P.M., Chamarthi S.K., Krishnamurthy L., Tripathi S., Kashiwagi J., Samineni S., Singh V.K., Thudi M. and Jaganathan D. (2013b). Fast-track introgression of "QTL-hotspot" for root traits and other drought tolerance traits in JG 11, an elite and leading variety of chickpea. *Plant Genome,* 6: 1–9

104. Varshney R.K., Thudi M., Nayak S.N., Gaur P.M., Kashiwagi J., Krishnamurthy L. and Rathore A. (2014). Genetic dissection of drought tolerance in chickpea (*Cicer arietinum* L.). *Theoretical and Applied Genetics,* 127(2): 445-462.

105. Varshney R.K., Hiremath P.J., Lekha P., Kashiwagi J., Balaji J., Deokar A.A., Vadez V., Xiao Y., Srinivasan R. and Gaur P.M. (2009). A comprehensive resource of drought- and salinity-responsive ESTs for gene discovery and marker development in chickpea (*Cicer arietinum* L.). *BMC Genomics*, 10: 523.

106. Varshney R.K., Terauchi R. and McCouch S.R. (2014b). Harvesting the promising Fruits of genomics applying genome sequencing technologies to crop breeding. *PLoS Biol.,* 12: e1001883. doi:10.1371/journal.pbio.10 01883.

107. Varshney R.K., Mohan S.M., Gaur P.M., Chamarthi S.K., Singh V.K., Srinivasan S., Swapna N., Sharma M., Singh S., Kaur L., Pande S. (2014). Marker-assisted backcrossing to introgress resistance to Fusarium wilt (FW) race 1 and Ascochyta blight (AB) in C 214, an elite cultivar of chickpea, *Plant Genome* 7 (1): 568-572.

108. Winter P., Benko-Iseppon A.M., Hüttel B., Ratnaparkhe M., Tullu A., Sonnante G., Pfaff T., Tekeoglu M., Santra D., Sant V.J., Rajesh P.N., Kahl G. and Muehlbauer F.J. (2000). A linkage map ofthe chickpea (*Cicer arietinum* L.) genome based on the recombinant inbred lines from *C. arietinum* × *C. reticulatum* cross: Localization of resistance genes for *Fusarium* races 4 and 5. *Theor. Appl. Genet.*, 101: 1155–1163.

109. Zamir D. (2001). Improving plant breeding with exotic genetic libraries. *Nature Rev. Genet.*, 2: 983–989.

Website : www.asthafoundation.in
ICAAAS–An Edited Book (Volume-3)
ISBN : 978-81-958010-7-7
Published by : Astha Foundation, Meerut (U.P.) India
Edition-2024

Chapter 10

Cover Crop and Live Mulch–A Weed Control Strategy in Direct Seeded Rice

Pratik Sanodiya* Manoj Kumar Singh, Nikhil Kumar Singh, Sudhir Kumar Rajpoot, Sanjeev Kumar and Neelkamal Mishra

Department of Agronomy, Institute of Agricultural Sciences, Banaras Hindu University, Varanasi-221005

**Email : prsanodiya10@gmail.com*

Abstract

Weed is a major pest of direct seeded rice in rice growing belts of India which competes for sunlight, nutrient, water and space during critical growth stages of crop. Weed reduces growth and development of main crop by suppressing them. Most of the weeds have more than one or two species which can identify with their distinct characteristics in rice. Weed growth occurs fast and vigorous in rainy season with many flushes due to favorable climatic conditions and causes nutrient depletion in large quantity besides of causing economic losses. Critical period of crop weed completion is a very crucial phase in controlling various species of grasses, broad leaved weeds and sedges for enhancing rice growth and productivity, nutrient balance in soil and profitability in direct seeded rice. Therefore, selection of appropriate weed control practice takes place an important role for minimizing weed infestation and increasing yield amongst rice growers. Integrated weed management practices has been also reported suitable and compatible practice in DSR rice cultivation by various researcher and farmers groups.

Key Words : *DSR (Direct seeded rice), Sesbania, Sunhemp, Weed control efficiency, Weed index.*

Introduction

Rice (*Oryza sativa* L.) is the staple food of more than 60 per cent of world population, which is grown in 114 countries across the world on an area about 160 million hectares with annual production of 494.3 million tonnes, and total supply of 711.5 million tonnes. It is consumed mostly in Asia (90%) and rest (10%) in America, Africa, Australia and Europe. Globally, total rice consumption was recorded 491.5 million metric tonnes in 2014-15 (Anonymous 2016). Living mulches are plants grown with a cash crop. They are usually not grown for harvest or direct profit but, instead, to provide ecological including protecting soils from erosion, improving soil fertility, providing traffic lanes, suppressing weeds and reducing pest populations (Hartwig and Ammon, 2002). *Sesbania* is a legume used as a green manure in rice cultivation either as pre-rice or inter or mixed crop with rice. It is sown at 25 kg/ha together with rice. After 25-30 days of growth, when *Sesbania* is about 30-40 cm tall, it is killed with 2, 4-D ester at 0.50 kg/ha. This coculture technology can reduce the weed population by nearly half without any adverse effect on rice yield (Singh *et al.,* 2009b). Singh *et al.,* (2007) reported that *Sesbania* coculture reduced broadleaf and grass weed density by 76-83% and 20-33%, respectively, and total weed biomass by 37-80 % compared with a sole rice crop. Intercropping *dhaincha* exclusively for *in situ* green manuring recorded a higher grain yield of rice (with green manure) than sole rice. (Anbumani *et al.*, 2003). Teasdale and Daughty (1993) suggested that weed and living mulch plants compete for the same resources, weeds can be suppressed by the introduction of living mulches into cropping system and if a cover crop becomes established before the emergence of weeds, then the presence of green vegetation covering the soil

Cited as : Singh S.P. (2024). ICAAAS : Cover crop and live mulch–A weed control strategy in direct seeded rice. *ICAAAS–An Edited Book.* Volume-3 : 83-89. Astha Foundation, Meerut (U.P.) India.

creates a radiation environment that is unfavourable for weed germination, emergence and growth. Sowing of live mulches, cover crops followed by herbicide application is very important tool for managing weeds in direct seeded rice. Keeping above reviews in view the present study has been discussed which is useful in Indian subcontinent.

Losses caused by weeds

Rainfed upland direct seeded rice

According to Elliot *et al.,* (1984), aerobic soil, dry-tillage and alternate wetting and drying conditions, on the other hand, are conducive to the germination and growth of weeds causing grain yield losses of 50-91%. Paradkar *et al.,* (1997) found that the major impediment in the successful cultivation of direct-seeded rice in tropical countries is heavy infestation of weeds which often range from 50-91%. Weeds are one of the limiting factors in direct seeded rice which reduced the yield up to 50-97% in rainfed uplands (Kurchania *et al.* 1992, Singh *et al.* 1996).

Dry direct seeded rice

Weeds present the main biological constraint to the success of DSR (Chauhan, 2012), and failure to control weeds result in yield losses ranging from 50 to 90% (Chauhan and Johnson, 2011; Chauhan and Opena, 2012). Season-long weed competition in direct-seeded rice caused yield reduction up to 80% (Sunil *et al*. 2010). Rao *et al.,* (2007) observed that more than 50 weed species infest direct-seeded rice, causing major losses to rice production worldwide. Yield reduction due to weeds is more critical in direct seeded rice (Karim *et al.,* 2004). Ranjit (2007) observed that weeds caused yield loss in direct seeded rice ranging from 14-93 %. The grain yield decreased by 79.7% due to season long weed crop competition in direct seeded rice (Gopinath and Kundu, 2008).

Wet direct seeded rice

Weed menace is greater in wet seeded rice to the extent of 50 to 60% and even a complete crop failure at times (Govindarasu *et al.,* 1998). Maity and Mukerjee (2008) recorded that the uncontrolled weeds reduce the grain yield by 61% in wet direct seeded rice. Yield losses in wet seeded rice due to weed infestation up to 74% (Ramzan, 2003).

Critical period of crop-weed competition

The critical period for weed control is defined as the time period in the crop growth cycle, during which weeds must be controlled to prevent unacceptable yield loss (Dogan *et al.,* 2004). It is the time interval between two components of weed interference namely, the critical weed interference and critical weed free periods. Isik *et al.,* (2006) revealed that critical weed interference period is the maximum lengths of time during which weeds emerging soon after crop planting can co-exist with the crop without causing unacceptable yield loss. On the contrary, the critical weed free period is the minimum length of time required for the crop to be maintained weed free before yield loss caused by late-emerging weeds is no longer a concern.

Effect of cover crops and live mulches on weed

1. Cover crops on weed

Cover crops and mulches are a suitable choice for sustainable agriculture because they improve weed control and crop performance. Cover crops are planted to provide a soil cover, improve soil fertility and produce food and feed. They are normally grown during the dry season or as intercrops. They may be allowed to grow throughout the cropping season, or they may be killed and left on the soil surface as mulch. Rapid development and dense ground covering by the crop will suppress weeds (Nelson *et al.,* 1991). Growing cover crops, have potential as an important component of a system oriented ecological weed management strategy for sustainable agriculture (Kruidhof *et al.,* 2008), because it conserve soil and moisture, enhancing soil nutrient status (Malviya and Singh, 2007), total biomass production. The inclusion of cover crops in the rotation at a time when land might otherwise lie uncropped will suppress weed development, yet maintain soil fertility and prevent erosion (Liebman and Davis, 2000). The use of cover crops and mulches can reduce the germination and the development of the weed seeds (Weston, 1996; Ohno *et al.,* 2000) through allelopathic (Kruidhof *et al.,* 2008b) and mechanical effects (Den Hollander *et al.,* 2007a), and the competition between the cover crops and the weeds for limited resources such as light, water and nutrients (Kruidhof *et al.,* 2008a). Hussain *et al.,* (1991) reported that intercropping also smothers weed stand composed of *Echinochloa colona, Panicum* spp. *Ischaemum rugosum*, *Cyanotis* spp. and *Eclipta prostrata.* Rice may be successfully intercropped with legumes, such as *Crotalaria juncea, Vigna sinensis, Glycine max* and *Sesbania rostrata* (Sattar and Biswas 1991). Torres *et al.,* (1995) found that *Sesbania* being an aquatic plant can also be grown together with rice to suppress weeds. Allelopathic ability may also play a part in reducing weed development, but it is the weed suppression caused by competition for growth factors that is the main effect of a cover crop (Grundy *et al.,* 1999). Rajendran *et al*., (2002) reported that weeds were controlled by adoption of concurrent growing of

Table-1 : Common weed flora in direct seeded rice in India.

Weeds	Botanical Name	Family	English Name	Local name	Habitat
Grasses	*Echinochloa colona* (L.) Link	Poaceae	Jungli rice	*Dhenhari*	Annual
	Echinochloa crus-galli (L.) Beauv	Poaceae	Barnyard grass	*Shyma ghas*	Annual
	Cynodon dactylon (L.) Pers	Poaceae	Barmuda grass	*Doob grass*	Perennial
Sedges	*Cyperus iria* Linn	Cyperaceae	Yellow nut sedge	*Bhada*	Annual
	Cyperus difformis Linn	Cyperaceae	Small flower umbrella plant	*Jhirua*	Annual
	Fimbristylis miliacea (L.) Vahl.	Cyperaceae	Grass like fimbristylis	*Banchitra*	Annual
Broad leaved weeds	*Ammannia baccifera* (L.) Roxb	Lythraceae	Red stem	*Jangli mehandi*	Annual
	Caesulia axillaris (L.) Rottb	Compositae	Pink node flower	*Gathila*	Annual
Miscellaneous weeds	*Phyllanthus fraternus* Linn	Euphorbiacea	Gulf Leaf-Flower	*Bhuinanvalah*	Annual
	Commelina benghalensis Linn	Commelinaceae	Day flower	*Kankauwa*	Annual
	Ludwigia parviflora Linn	Onagraceae	Water purslane	*Water Primrose*	Annual
	Eclipta alba L. Hask	Compositae	Bhringraj	*False daisy*	Annual

dhaincha and rice using rice cum green manure seeder and the subsequent incorporation of dhaincha by using cono weeder. Subramanian *et al.,* (2005) revealed that intercropping of *Sesbania aculeata* and dual cropping of azolla with rice resulted in reduced density and dry weight of weeds. The impact of dhaincha intercropping in reducing weed density and dry weight were also reported by Ravisankar (2002). Singh *et al.,* (2009) observed that the minimum density and dry weight of *Echinochloa* were recorded due to intercropping of *Sesbania fb* spray of 2, 4-D without any adverse effect on rice.

2. Live mulches on weed

Living mulch consists of a dense stand of low-growing species, established before or after the crop. Annual weeds themselves could provide a natural ground cover if managed properly (Anaya *et al.,* 1988). Living soil cover between crop plants (living mulches) has been proposed as an environmentally sound option for suppressing weeds (Liebman and Dyck, 1993; Teasdale, 1996). However, successful suppression of weeds depends not only on the cover crop, but also on the composition of the weed population. In terms of weed control such plants must be easy to control and less competitive than weeds in relation to the main crop. One of the important factors of weed suppression mechanisms of living mulch is light interception. Because plants need light to develop and living mulches are blocking sunlight reaching the weeds, weed species, especially decumbent weeds, cannot get enough light for germination and growth. Teasdale and Daughty (1993) revealed that weed and living mulch plants compete for the same resources, weeds can be suppressed by the introduction of living mulches into cropping system and if a cover crop becomes established before the emergence of weeds, then the presence of green vegetation covering the soil creates a radiation environment that is unfavourable for weed germination, emergence and growth. Several requirements for breaking dormancy and promoting germination of weed seeds in soil (light with a high red to far red ratio and high daily soil temperature amplitude) are reduced more by living mulches than by desiccated residue. More weeds will emerge in low levels of cover crop residue (1-2 Mg/ha) than in uncovered control plots hence low level of residue are not sufficient to inhibit weeds from emerging but can create an environment more favorable for germination and emergence (Mohler and Teasdale, 1993; Teasdale and Mohler, 2000).

According to Singh *et al.,* (2006) amongst the weed control treatments, broadcasting of *Sesbania* knocked down by the application of 2, 4-D at 30 days after sowing recorded lowest weed dry weight. Co-culture of *Sesbania* in rice and its subsequent knock down by 2, 4-D ester reduced the weed population by nearly half without any adverse effect on rice yield (Gupta *et al*., 2006). Nalini *et al.,* (2008), the maximum reduction in weed density and dry matter was achieved under paired row sowing (PRS) of rice with *Sesbania aculeata* under weed free conditions. PRS of rice with *Sesbania aculeata* under weed free condition recorded the lesser weed index, higher weed control and weed smothering efficiencies. Weed control efficiency was higher in paired row sowing of rice + dhaincha under weed free condition. Intercropping not only suppress weeds but also reduce weeding cost. Dual crop reduced the weed density compared to sole rice. The vigorous growth and better canopy coverage of intercrop, biologically suppressed the growth of grasses and broad-leaved weeds. Among the weed control methods, paired row sowing of rice with dhaincha recorded lesser density of weed at all the stages of observation, since dhaincha intercropping suppressed the weed infestation due to faster canopy cover.

According to Chongtham *et al.,* (2016) found that integration of brown manuring practices (knock down of *Sesbania* at 25 day after sowing by 2, 4-D 0.5 kg/ha) with bispyribac-sodium 0.025 kg/ha was significantly superior in suppressing weed infestations with lesser weed index and higher weed control efficiency. *Sesbania* coculture reduced broadleaf and grass weed density by 76-83% and 20-33% respectively, and total weed biomass by 37-80 % compared with a sole rice crop (Singh *et al.,* 2007). Anitha *et al.,* (2012) reported that application of 2, 4–D resulted in maximum reduction of weeds without any adverse effect on rice. Incorporation of *dhaincha* by spraying 2, 4-D resulted in 78% reduction in total weed count and 59 % in weed dry matter production. Application of 2, 4-D for incorporation of *dhaincha* controlled broad-leaved weeds and sedges substantially because 2, 4-D is a selective herbicide recommended against broad-leaved weeds and sedges in rice.

Effect of cover crops and live mulches in DSR

1. DSR crop growth

Majhi *et al.,* (2009) showed that *Sesbania* intercropped and incorporated at 4 weeks after sowing + pendimethalin 1.0 kg/ha recorded higher leaf area index, crop growth rate and effective tillers ($124/m^2$). As regards to biomass production rate, *Sesbania* (intercropped and incorporated at 4 WAS) + pendimethalin 1.0 kg/ha had significantly higher biomass production rate (51.1 kg/ha/day) than all other integrated weed managements except 2 hand weedings 4 and 6 weeks after sowing (51.8 kg/ha/day). *Sesbania* is a legume used as a green manure in rice cultivation either as pre-rice or inter or mixed crop with rice. It is sown at 25 kg/ha together with rice. After 25-30 days of growth, when *Sesbania* is about 30-40 cm tall, it is killed with 2, 4-D ester at 0.50 kg/ha. This coculture technology can reduce the weed population by nearly half without any adverse effect on rice yield (Singh *et al.,* 2009b).

2. DSR yield and yield attributes

According to Subramanian *et al.,* (2005) stated that the favorable influence of higher level of N (100%) through organic and inorganic (*Sesbania* and azolla) means could be observed by higher number of panicles. Growing *Sesbania* and azolla as intercrop followed by mechanical incorporation created a conducive atmosphere in terms of weed-free condition. All these attributes had a positive influence on the yield components viz., panicles/m^2, panicle length and filled grains per panicle. Majhi *et al.,* (2009) revealed that *Sesbania* might have supplied sufficient nutrients in soil after decomposition coupled with smothering effect on weeds and increasing grains/panicle (77) and bolder 1000-grain (24.3g) which resulted in increased crop growth and yield during the crop period. Subramanian *et al.,* (2005) reported that the application of 100% N + *Sesbania* intercropping + azolla dual cropping produced higher grain yield of 5798 and 5502 kg/ha during *Kharif a*nd rabi seasons, respectively. Application of 100% N + *Sesbania* intercropping was the second best treatment in terms of grain yield when compared to 100% N alone treatment. The treatments that included intercropping or dual cropping recorded higher grain yield. Majhi *et al.,* (2009) found that *Sesbania* (intercropped and incorporated at 4 weeks after sowing) + pendimethalin 1.0 kg/ha produced higher grain yield (2091 kg/ha) and grain production rate (66.0 kg/ha/day) of direct seeded upland rice in comparison to other integrated weed management treatments.

According to Nalini *et al.,* (2008), the higher yield (3528 kg/ha) was achieved with paired row sowing of rice with *Sesbania aculeata* under weed free condition but it was comparable with normal sowing of rice with pendimethalin 1.0 kg/ha at 3 days after sowing followed by two hand weeding on 30 and 60 DAS. This was due to effective suppression of weeds, restricting the nutrient drain by weeds and nutrient addition due to incorporation of dual crop. Dhyani *et al.,* (2009) suggested that highest grain yield was obtained in *Sesbania* (RS) + pendimethalin + 2, 4-D (0.3 kg) 25 DAS + hand weeding where *Sesbania* was row seeded with direct seeded rice and 2, 4-D was applied at 0.3 kg/ha to kill during first year and during second year it was weed free which resulted in maximum yield. Slightly higher yield in *Sesbania* (RS) + pendimethalin + 2, 4-D (0.3 kg) 25 DAS + hand weeding may be due to some additional nitrogen added in the field through green biomass than weed free during first year.

Brown manuring

Application of 2, 4-D on standing *Sesbania* and sunhemp is having a very helpful technique of weed control in direct seeded rice besides adding organic matter in soil. Initially live mulches inhibit germination of weed seeds through their allelopathic effects and after three weeks broad leaved weed killer herbicides control remained dicot weeds alongwith live mulches.

Profitability

Anitha *et al.,* (2012) reported that concurrent growing of dhaincha and its incorporation at 30 DAS resulted in yield enhancement to the tune of 0.84 t/ha and profitability of 12520/ha. Concurrent growing of dhaincha and its incorporation using 2, 4-D is a low-cost weed management alternative for wet seeded rice. According to Chongtham *et al.* (2016), the economic evolution of the weed- management practices revealed the higher net returns and benefit: cost ratios were recorded under application of pendimethalin followed by brown manuring than the other weed-management practices. This could be attributed to higher grain yield of rice along with the low cost of *Sesbania* seed and herbicides (pendimethalin and 2, 4-D) in direct seeded rice.

Summary

Weeds are one of the limiting factors in direct seeded rice which reduced the yield weeds caused yield loss in direct seeded rice ranging from 14-93 % Ranjit (2007). Subramanian *et al.,* (2005) reported that the application of 100% N + *Sesbania* intercropping + azolla dual cropping produced higher grain yield of 5798 and 5502 kg/ha during *Kharif a*nd rabi seasons, respectively. *Sesbania* is a legume used as a green manure in rice cultivation either as pre-rice or inter or mixed crop with rice. This coculture technology can reduce the weed population by nearly half without any adverse effect on rice yield (Singh *et al.,* 2009b). Cover crops and mulches reduce the germination and the development of the weed seeds through allelopathic and mechanical effects and the competition between the cover crops and the weeds for limited resources such as light, water and nutrients. It also conserves soil moisture, enhancing soil nutrient status and total biomass production. living mulches block sunlight reaching the weeds, weed species, especially decumbent weeds, cannot get enough light for germination and growth. The presence of green vegetation covering the soil creates a radiation environment that is unfavourable for weed emergence, germination and growth. Therefore, cover crop and live mulch is an efficient strategy for weed control in direct seeded rice.

References

1. Anaya A.L., Gliessman S.R., Ortega R.C., Rosado-May R. and Rodriguez V.N. (1988). Effects of allelopathic weeds used as cover crops on the oristic potential of soils, In: Proceedings 6th International Conference IFOAM 1986, *Global Perspectives on Agroecological and Sustainable Agricultural Systems,* Santa Cruz, California, USA, 607-624.
2. Anbumani S., Chandrasekaran B., Nadanassababady T. and Rajendran P. (20030. Split strategies and intercropping dhaincha for *in situ* green manuring and seed production in wet-seeded rice. *Acta Agronomica Hungarica,* **51**(2): 173-179.
3. Anitha S., Mathew J. and Abraham C.T. (2012). Concurrent growing of green manure with wet-seeded rice for cost-effective weed management. *Indian Journal of Weed Science,* **44**(1): 34–37.
4. Anonymous (2016). Agricultural statistical data, Department of Agriculture and Cooperation, Government of India.
5. Anonymous (2016). Agricultural statistical data, Department of Agriculture and Cooperation, Government of India.
6. Chauhan B.S. (2012). Weed ecology and weed management strategies for dry seeded rice in Asia. *Weed Technology,* **26**: 1-13.
7. Chauhan B.S. and Johnson D.E. (2011). Growth response of direct seeded rice to oxadiazon and bispyribac-sodium in aerobic and saturated soils. *Weed Sciences,* **59**: 119-122.
8. Chauhan B.S. and Opena J. (2012). Effect of tillage systems and herbicides on weed emergence, weed growth and grain yield in dry-seeded rice systems. *Field Crops Research,* **137**: 56-69.
9. Chongtham S.K., Singh R.P. and Singh R.K. (2016). Effect of crop establishment methods and weed management practices on weed flora and yield of direct seeded rice (*Oryza sativa*). *Indian Journal of Agronomy,* **61**(1): 33-36.
10. Den Hollander N.G., Bastiaans L. and Kropff M.J. (2007a). Clover as a cover crop for weed suppression in an intercropping design, Characteristics of several clovers species. *European Journal of Agronomy,* **26**: 92–103.
11. Dhyani V.C., Singh V.P., Singh S.P., Kumar A. and Tripathi N. (2009). Impact of Sesbania brown manuring on weeds and performance of direct seeded rice, *Indian Journal of Weed Science*, 41, (3&4) : 157-159.
12. Doðan M.N., Ünay A., Boz O. and Albay F. (2004). Determination of optimum weed control timing in maize. *Turkish Journal of Agriculture and Forestry,* **28**: 349-354.
13. Elliot P.C., Navarez D.C., Estario D.B. and Moody K. (1984). Determining suitable weed control practices for dry-seeded rice. *Philippines Journal of Weed Sciences,* **11**: 70-82.
14. Gopinath K.S. and Kundu A. (2008). Evaluation of metsulfuron methyl and chlorimuron ethyl for weed control in direct seeded rice (*Oryza sativa*). *Indian Journal of Agricultural Sciences,* **78**(5): 466-469.
15. Govindarasu R., Rammohan J., Ramamoorthi N., and

Hanifa A.M. (19980. Direct seeding a best substitute for transplanted rice cultivation in future. *Kisan World* **25**: 20-21.

16. Grundy A.C., Bond W., Burston S. and Jackson L. (1999). Weed suppression by crops. In: Proceedings 1999 Brighton Conference Weeds Brighton UK 957-962.
17. Gupta R., Jat M.L., Singh S., Singh V.P. and Sharma R.K. (2006). Resource conservation technologies for rice production, *Indian Farming,* 56(7): 42-45, 2006.
18. Hartwig N.L. and Ammon H.U. (2002). Cover crops and living mulches. *Weed Sciences,* **50**: 688-699.
19. Hussain F.S., Shukat I. and Qureshi M.Z. (19910. Note on the Germination Behavior of Dodonaea viscosa. *Sciences Khy,* **4**(1) 45-49.
20. Isik D., Mennan H., Bukun B., Oz A. and Ngouajio M. (20060. The critical period for weed control in corn in Turkey. *Weed Technology,* **20**: 867-872.
21. Karim S.M.R., Man A.B. and Sahid I.B. (2004). Weed problems and their management in rice fields of Malaysia: An overview. *Weed Biology and Management,* **4**: 177-186.
22. Kruidhof H., Bastiaans M.L. and Kropff M.J. (2008). Ecological weed management by cover cropping: effects on weed growth in autumn and weed establishment in spring. *Weed Research,* **48**: 492-502.
23. Kruidhof H.M., Bastiaans L. and Kropff M.J. (2008a). Ecological weed management by cover cropping: effects on weed growth in autumn and weed establishment in spring. *Weed Research,* **48**: 492–502.
24. Kruidhof H.M., Bastiaans L. and Kropff M.J. (2008b). Cover crop residue management for optimizing weed control. *Plant Soil,* doi:10.1007/s11104-008-9827-6.
25. Kurchania S.P. and Samaiya K.K. (19920. Herbicide and fertililzer compatibility under drilling and lehi method of sowing in rice at different levels of nitrogen. *In: Abstract Annual Weed Science Conference, Hissar, 3–4 March* pp. 37-38.
26. Liebman M. and Dyck E. (1993). Crop rotation and intercropping strategies for weed management, *Ecological Applications*, 3(10): 92-122.
27. Liebman M. and Davis A.S. (2000). Integration of soil, crop and weed management in low-external-input farming systems. *Weed Research,* **40**: 27-47.
28. Maity S.K. and Mukerjee P.K. (2008). Integrated weed management in dry-seeded rice (*Oryza sativa*). *Indian Journal of Agronomy,* **53**(2): 116-120.
29. Majhi S., Thakur R., Upasani R.R., Singh M.K. and Pal S.K. (2009). Growth and productivity of direct seeded upland rainfed rice as influenced by integrated weed management. *Indian Journal of Weed Science,* **41**(3&4): 160-162.
30. Malviya A. and Singh B. (20070. Weed dynamics, productivity and economics of maize as affected by integrated weed management under rainfed condition. *Indian Journal of Agronomy*, **52**(4): 321-24.
31. Nalini K., Jayanthi C. and Vennila C. (2008). Weed management through dual cropping of green manure in semi-dry rice. *Indian Journal of Weed Science,* **40**(1&2): 50-51.
32. Nelson W.A., Kahn B.A. and Roberts B.W. (1991). Screening cover crops for use in conservation tillage systems for vegetables following spring plowing. *Hortscience,* **26**: 860-862.
33. Ohno T., Doolan K., Zibilske L.M., Liebman M., Gallandt E.R. and Berube C. (2000). Phytotoxic effects of red clover amended soils on wild mustard seedling growth. *Agriculture, Ecosystems & Environment,* **78**: 187–192.
34. Paradkar M.R., Kurchania S.P. and Tiwari J.P. (1997). Chemical control of *Parthenium hysterophorus* and other associated weeds in upland drilled rice. *Indian Journal of Weed Science,* **29**: 151-154.
35. Rajendran P., Tajuddin A. and Nadanassababady T. (2002). Seeder developed for direct sowing of rice (*Oryza sativa*) and green manure under puddle soil surface, 383-384. *In: Extended Summaries Vol.1, Second International Agronomy Congress,* 26-30 November 2002, Indian Council of Agricultural Research, New Delhi.
36. Ramzan M. (2003). Evaluation of various planting methods in rice-wheat cropping system, Punjab, Pakistan. *Rice Crop Report,* pp. 4-5.
37. Ranjit K. (2007). Weeds Associated with different crops, *Paper presented to Training on Weed management in rice*. April 25-27, NARC.
38. Rao A.N., Johnson D.E., Sivaprasad B., Ladha J.K. and Mortimer A.M. (2007). Weed management in direct-seeded rice. *Advances in Agronomy,* **93:** 153–255.
39. Ravisankar N. (2002). Efficacy of seeding methods, *in situ* incorporation of dhaincha and application time of pretilachlor plus on weed management and productivity of wet seeded rice. *Ph.D. thesis Tamil Nadu Agric. Univ.*, Coimbatore India.
40. Sattar S.A. and Biswas J.C. (1991). Intercropping a green manure with direct seeded rice. *International Rice Research Newsletter,* **16**(1): 23.
41. Singh A.N., Singh S., Bhan V.M. and Singh S. (1996). Effect of herbicides in direct-sown drilled rice (*Oryza sativa* L.) and associated weeds. *Indian Journal of Agronomy,* **41**(2): 233–236.
42. Singh S., Chhokar R.S., Gopal R., Ladha J.K., Gupta R.K., Kumar V. and Singh M. (2009b). Integrated weed management, A key for to success for direct seeded rice in Indo-Gangetic Plains. *International*

Rice Research Institute Los Banos Phillipines, Pp, 261-278.

43. Singh S., Ladha J.K., Gupta R.K., Bhushan L., Rao A.N., Sivaprasad B. and Singh P.P. (2007). Evalution of mulching, intercropping with Sesbania and herbicide use for weed management in dry-seeded rice (*Oryza sativa* L.). *Crop Protection,* **26**: 518-524.
44. Singh U.P., Singh R.P. and Singh Y. (2006). Integrated weed management in direct dry seeded rainfed lowland rice. *Indian Journal of Weed Science,* **38**(1&2): 49-53.
45. Singh V.P., Singh S.P., Dhayani V.C., Tripathi N., Kumar A. and Singh M.K. (2009). Bioefficacy of azimsulfuron against sedges in direct seeded rice. *Indian Journal of Weed Science,* **41**(1&2): 96-99.
46. Subramanian E., Martin G.J. and Ramasamy S. (2005). Effect of weed and nitrogen management on weed control and productivity of wet seeded rice. *Indian Journal of Weed Science,* 37(1&2): 61-64.
47. Sunil C.M., Shekara B.G., Kalyanamurthy K.N. and Shankaralingappa B.C. (2010). Growth and yield of aerobic rice as influenced by integrated weed management practices. *Indian Journal of Weed Science,* 42(3&4): 180-183.
48. Teasdale J.R. and Daughty C.S.T. (1993). Weed suppression by live and desiccated hairy vetch. *Weed Science,* **41**: 207-212.
49. Teasdale J.R. and Mohler C.L. (1993). Light transmittance, soil temperature and soil moisture under residue of hairy vetch and rye. *Agronomy Journal,* **85**: 673-680.
50. Teasdale J.R. and Mohler C.L. (20000. The quantitative relationship between weed emergence and the physical properties of mulches. *Weed Science,* **48**: 385-392.
51. Teasdale J.R. and Daughty C.S.T. (1993). Weed suppression by live and desiccated hairy vetch, *Weed Science*, 41: 207-212.
52. Teasdale J.R. and Mohler C.L. (1993). Light transmittance, soil temperature and soil moisture under residue of hairy vetch and rye. *Agronomy Journal,* 85: 673-680.
53. Teasdale J.R. (1996). Contribution of cover crops to weed management in Sustainable Agricultural Systems, *ACSESS* , 9(4) : 475-479.
54. Torres R.O., Pareek R.P., Ladha J.K. and Garrity D.P. (19950. Stem nodulating legumes as relay cropped or intercropped green manures for lowland rice. *Field Crops Research,* **42**: 39-47.
55. Weston L.A. (1996). Utilization of allelopathy for weed management in agroecosystems. *Agronomy Journal,* **88**: 860–866.

Website : www.asthafoundation.in
ICAAAS–An Edited Book (Volume-3)
ISBN : 978-81-958010-7-7
Published by : Astha Foundation, Meerut (U.P.) India
Edition-2024

Chapter 11

Advancements in Pigeon Pea Breeding

Anil Kumar[1*], Chandan Kishore[1], Harish Pal Bhati[2], S.P. Singh[3], Archana Kushwaha[4] and Aradhana Suman[1]

[1]Department of Plant Breeding and Genetics, DKAC, Arabari, Kishanganj, Bihar

[2]CCSU–Government College, Jewar, U.P.

[3]CSAUAT-Agriculture Research Station, Kalai, Aligarh, U.P.

[4]Department of Food and Nutrition, GBPUAT, Pantnagar, Uttarakhand

**Corresponding Author Email : dranilbau@gmail.com*

Abstract

This chapter provides a comprehensive overview of the challenges and opportunities related to pigeon pea cultivation in India, particularly focusing on Bihar. It discusses the historical perspectives of pigeon pea breeding in India, starting from the early 20th century and the breeding approaches that were initially employed to select against wild traits. The document highlights the challenges faced post-adoption of Integrated Pest Management (IPM) and Integrated Disease Management (IDM) practices, labor-intensive operations required for harvesting and threshing pigeon pea crops, and issues related to post-harvest losses due to inadequate storage practices. Furthermore, the chapter sheds light on infrastructure limitations, drainage disruptions leading to water logging, and the slow adoption of advanced agricultural technologies in pigeon pea cultivation. It also addresses the issue of price volatility impacting farmers' decisions. The significance of pigeon pea as a vital grain legume crop globally, especially in India, is underscored, with India being the primary producer of pigeon pea and accounting for a substantial portion of global production. Additionally, the chapter discusses the decline in pigeon pea cultivation in Bihar over the years, attributing it to various factors such as inadequate seed supply, challenges with bio-fertilizers, and biotic and abiotic stresses affecting crop productivity. Despite these challenges, pigeon pea productivity in Bihar has exceeded the national average, showcasing the crop's potential in the region. The chapter also touches upon the status of pulse production in India, highlighting the country's significant growth in pulse production, productivity, and area under cultivation. Overall, the chapter provides a detailed insight into the challenges faced by pigeon pea cultivation in India, the historical background of pigeon pea breeding, the current status of pulse production in the country, and the opportunities for enhancing sustainable production and nutritional security through the cultivation of pulses like pigeon pea.

Introduction

Pulses are essential for overcoming protein and micronutrient malnutrition due to their high dietary protein content (19-25%) and rich mineral and vitamin content. Pulse crops contribute to soil fertility through biological nitrogen fixation and organic matter addition. In Bihar, where people primarily follow a vegetarian diet, pulses are crucial for dietary protein. Despite population growth, pulse production has not kept pace, leading to decreased per capita availability. Promoting legume-based cropping systems can enhance sustainable production and nutritional security in Bihar. India is the world's largest pulse producer,

Cited as : Singh S.P. (2024). ICAAAS : Advancements in pigeon pea preeding. *ICAAAS–An Edited Book.* Volume-3 : 90-96. Astha Foundation, Meerut (U.P.) India.

with significant growth in area, production, and productivity. Pigeon pea (*Cajanus cajan* L. Millsp) is a vital grain legume crop globally, especially in India. Pigeon pea is grown in various Indian states, with Maharashtra, Uttar Pradesh, and Madhya Pradesh being major producers. Intercropping with short-term crops is common due to pigeon pea 's long growth cycle.

Status of pulse production in India

India is the largest pulse-producing country globally, cultivating over 29 million hectares of pulses. In 2017-18, India achieved a significant increase in productivity, reaching 835 kg/ha, surpassing the Eleventh and Twelfth plans' levels (662 kg/ha and 745 kg/ha, respectively). Despite consecutive drought years in 2014-15 and 2015-16, the XIIth Plan (2012-13 to 2016-17) recorded substantial growth in pulse area, production, and productivity. Notably, during 2016-17 and 2017-18, pulse production reached 23 million metric tons (Mt) and 25.23 Mt, respectively. The productivity of pulses increased by 13%, reaching 841 kg/ha in 2017-18, compared to 743 kg/ha in 2014-15.This growth represents a remarkable success story, with a production increase of 43%. In the year 2021-22, the estimated production of pulses was 26.96 million tonnes and it is projected to reach about 39 million tonnes by 2050, necessitating an annual growth to meet this target.

Pigeon pea (*Cajanus cajan* L. Millsp) is a crucial grain legume crop in tropical and subtropical regions, supporting small-scale farmers across Asia, Eastern Africa, and Southern Africa. Globally, it covers 5.32 million hectares, with India being the primary pigeon pea -growing country. Pigeon pea is the world's most important grain legume and India's second most significant pulse crop. While it is grown in Southeast Asia, Africa, and the Americas, India accounts for 90% of global pigeon pea production. Major Indian states for pigeon pea cultivation include Maharashtra, Uttar Pradesh, Madhya Pradesh, Karnataka, Gujarat, and Andhra Pradesh. Pigeon pea is often intercropped with other crops like cotton, sorghum, and maize due to its long growth cycle. Short-term pigeon pea varieties (100-160 days) allow single-crop cultivation, followed by timely wheat sowing.

Pigeon Pea (*Cajanus cajan* L. Millsp) Profile in Bihar

Pigeon pea, a favored pulse crop in Bihar, has witnessed a decline in both area and production. In 2013-14, the cultivated area was 21.9 thousand hectares, with a production of 36.5 tonnes, compared to 172 thousand hectares and 147.8 thousand tonnes in 1965-66. Over subsequent decades, the area and production steadily decreased: 150.3 ('000 ha) and 147.8 ('000 tonnes) in 1970-71, 93.7 ('000 ha) and 91 ('000 tonnes) in 1980-81, 66.2 ('000 ha) and 82.3 ('000 tonnes) in 1990-91, and 43.7 ('000 ha) and 58.9 ('000 tonnes) in 2000-01.

Despite this decline, pigeon pea productivity in Bihar consistently exceeds the national average. The highest yield recorded was 1147 kg/ha in 2013-14. However, few farmers opt for pigeon pea cultivation due to its long duration and maximum field occupancy. Traditional long-duration varieties (>200 days) are photoperiod-sensitive, taking approximately 40 weeks to mature. Consequently, the crop faces terminal drought stress and frost damage almost every year, resulting in lower yields and poor-quality seeds.

Major constraints faced by pigeon pea cultivation in Bihar :

1. **Inadequate Seed Supply and Slow Replacement Rate**

   Insufficient availability of quality seeds for improved pigeon pea varieties.

   Slow adoption of seed replacement practices.
2. **Challenges with Bio-Fertilizers**

   Limited supply and poor adoption of quality bio-fertilizers containing efficient strains of Rhizobia and PSB (phosphorus-solubilizing bacteria).
3. **Biotic and Abiotic Stresses**

   Biotic stresses, primarily caused by fungal diseases and insect pests.

   Abiotic stresses such as drought, cold, and heat affecting pigeon pea growth.
4. **Post-IPM and IDM Adoption**

   Challenges arising after the adoption of Integrated Pest Management (IPM) and Integrated Disease Management (IDM) practices.
5. **Labor-Intensive Operations**

   Harvesting and threshing of pigeon pea crops require significant manual labor.
6. **Post-Harvest Issues**

   Enormous grain losses due to faulty storage practices and inadequate processing methods.
7. **Infrastructure Limitations**

   Lack of well-developed facilities, including covered threshing floors, roads, and godowns.
8. **Drainage Disruptions**

   Water logging caused by disruptions in the drainage system across the state.
9. **Awareness Gap**

   Slow awareness and adoption of advanced

agricultural technologies related to pigeon pea cultivation.

10. **Price Volatility**

Fluctuating prices of pulses impacting farmers' decisions.

Historical Perspectives on Pigeon pea Breeding in India

Pigeon pea breeding in India began in the early 20th century, notably with the establishment of the Imperial Agricultural Research Institute at Pusa in 1910. The primary breeding approach involved selecting against wild traits that had been naturally favored and preserved during evolution. These traits included indeterminate growth habit, non-synchronous maturity, pod shattering, seed dormancy, photothermal sensitivity, spreading habits, and seed color.

Initially, numerous pure line varieties were developed based on their performance at specific locations under particular climatic conditions. However, their adaptability to other regions remained uncertain due to limited multi-location testing. The momentum in pigeon pea breeding increased with the approval of ad hoc research schemes by the Indian Council of Agricultural Research (ICAR) in various states, starting in 1929. Between 1943 and 1953, several pure line varieties were developed and released across different states.

A significant milestone occurred in 1967 with the establishment of the All India Coordinated Pulses Improvement Project (AICPIP). AICPIP facilitated the infusion of new variability into breeding programs through hybridization and innovative breeding methods, all aimed at achieving specific breeding objectives.

Breeding Objectives

1. **High-Yielding Varieties with Grain Quality and Stability**

Develop pigeon pea varieties that exhibit high yield while maintaining acceptable grain quality.

Incorporate resistance or tolerance to major insect pests (such as pod borers and podflies), diseases (wilt, sterility mosaic, Phytophthora stem blight, and Alternaria blight), and abiotic stresses (waterlogging, drought, acidity, salinity, and extreme temperatures).

2. **Adaptation to Different Cropping Systems**

Breed short-duration varieties or hybrids suitable for multiple cropping systems.

Create efficient hybrids tailored to regions with adequate resources and effective management practices.

3. **Photoperiod and Thermo-Insensitive Varieties**

Develop pigeon pea varieties that are relatively insensitive to photoperiod and temperature variations.

Enable cultivation during non-traditional seasons, such as Kharif (rainy season) in the western region and Rabi (winter season) in the eastern region.

4. **Versatility in Cropping Systems**

Design genotypes adaptable to various cropping systems, including pure cropping, mixed or intercropping, alley cropping, multiple cropping, and ratoonability (multiple harvests).

5. **Specialized Varieties for Specific Uses**

Create pigeon pea varieties for specialized purposes, such as fodder, agro-forestry, vegetable production, and lac insect rearing.

Breeding Methods for Pigeon pea Improvement

To achieve the stated breeding objectives, various methods have been employed for developing early, medium, and late-maturing pigeon pea varieties. These methods include :

1. **Plant Introduction**

This method involves introducing pigeon pea varieties from other countries or regions.

The introduced varieties are acclimatized to local conditions and evaluated for suitability.

Notably, exotic lines like Hy 3C (derived from PI2817-2) and Brazil 1-1 have contributed to early maturing varieties (e.g., Mukta, Sharad, and Pusa Ageti) when combined with specific local lines (NP [WR] 15, NP41, and NP69).

2. **Pure Line Selection**

Pure line selection involves choosing superior individuals from genetically diverse populations and land races.

Selection focuses on standardized morphological and phenological traits, such as height, maturity, and seed color.

Disease and insect outbreaks provide strong selection pressure, leading to the production of disease-resistant varieties through direct selection.

Notable pigeon pea cultivars resulting from this method include T 7, UPAS 120, Bahar, BDN 2, C11, No.148, T 15-15, LRG 30, Hy 3C, Narendra Arhar-1, and Maruthi (ICPL 8863).

3. Recombination Breeding

Recombination breeding involves controlled crosses between selected parents, followed by pedigree selection or its modifications in segregating generations.

Yield-related traits, such as pods per plant and seed weight, are indirectly selected for higher productivity.

This method has been successful for highly heritable traits like disease resistance, seed size, growth habit, and seed number per pod.

While bulk population and single seed descent are better for breeding high-yielding varieties, recurrent selection and population improvement methods are also recommended for accumulating desirable genes and breaking linkages in pigeon pea.

4. Genetic Male Sterility and Recombination Populations

The identification of genetic male sterility in pigeon pea has led to the creation of populations through intermating numerous genotypes.

These populations, developed at the International Crops Research Institute for Semi-Arid Tropics (ICARISAT) since 1976, aim to increase the frequency of desirable recombinants.

They serve as valuable source material for selecting desirable parents in breeding programs.

5. Mutation Breeding

Mutation breeding, initiated in the mid-fifties, generates additional variability.

Initial experiments focused on observing morphological variations induced by mutagenesis.

Somatic mutations offer potential variability in Cajanus cajan.

Further studies explored the effectiveness and efficiency of various physical and chemical mutagens.

Economically useful mutants—both induced and spontaneous—have been documented, including disease tolerance, male sterility, altered plant forms, seed size, and plant height.

Some mutants have been released as varieties (e.g., TAT 10), while others serve as trait donors (e.g., TT 6, a bold-seeded variety resulting from gamma ray irradiation of T 21 seeds)

6. Wide Hybridization in Pigeon pea : Expanding Genetic Diversity

Wild species serve as valuable reservoirs of genetic variability for essential traits in pigeon pea . Inter-specific crosses have been conducted with the aim of broadening the genetic base of cultivated germplasm. These hybridization efforts focus on incorporating desirable traits related to biotic and abiotic stress tolerance, higher protein content, and the development of cytoplasmic genetic male sterile lines.

Key points from the literature include :

1. Early Observations:

Deodikar and Thakur (1936) were among the first to suggest the possibility of hybridization between *Cajanus cajan* (pigeon pea) and its wild relatives.

Kumar et al. (1958) successfully obtained hybrids by crossing *C. cajan* (female) with *C. lineata* (male), although these hybrids exhibited partial sterility and meiotic irregularities.

2. Species Crosses

Pundir and Singh (1983) explored crosses between C. cajan and several wild species, including *C. albicans, C. cajanifolia, C. lineata, C. scarabaeoides*, and *C. trinervia*.

C. scarabaeoides was found to possess both physical and antibiosis resistance to pod borers (Verulkar *et al.,* 1997).

Other wild species, such as *C. sericeus and C. albicans*, are rich in protein content, while *C. reticulatus* var. Grandifolius exhibits hardiness and fire tolerance (Akinola *et al.,* 1975).

C. albicans also shows tolerance to soil salinity.

3. Male Sterile Lines

Male sterile plants were isolated from segregating populations resulting from hybridization between cultivated pigeon pea and wild relatives.

Specific examples include crossing *C. sericeus* with *C. cajan* (Ariyanayangam *et al.,* 1995) and developing a cytoplasmic male sterile line (GT 288 A) using *C. scarabaeoides* cytoplasm (Tikka *et al.,* 1997).

Saxena and Kumar (2003) created a cytoplasmic nuclear male sterile line (CMS 88039A) by combining *C. scarabaeoides* (ICPW 89) with an early maturing line of *C. cajan* (ICPL 88039).

7. Heterosis Breeding in Pigeon pea : Leveraging Hybrid Vigor and Genetic Male Sterility

Heterosis, or hybrid vigor, has proven effective in breaking yield limitations across various crops. Pigeon pea (*Cajanus cajan*) exhibits the highest out-crossing rate among pulses, ranging from 20% to 25%, influenced by environmental factors. The discovery of stable genetic male sterility, coupled with pigeon pea 's cross-pollination behavior, has facilitated the exploitation of heterosis.

Six hybrids—ICPH 8, PPH 4, CoPH 1, CoPH 2, AKPH 4101, and AKPH 2022—were developed using genetic male sterility and released for cultivation in diverse agro-ecological zones. Despite their clear yield superiority over varieties, these hybrids faced limited adoption due to inherent challenges associated with the genetic male sterility system in seed production. Rogue fertile segregants within female rows increased seed production costs, while imperfect elimination of fertile siblings impacted hybrid seed quality.

To address these issues, the development of a cytoplasmic male sterility system (CMS), specifically GTH-1, has been achieved through CMS-based hybridization in pigeon pea.

For the production of cytoplasmic genetic male sterility in pigeon pea, two methods are employed:

1. **Mutagenesis** :

   Mutagens induce genetic variability.

   Interspecific hybridization with wild relatives such as *C. scarabaeoides, C. sericeus, C. cajanifolius,* and *C. volubilis* has yielded some success.

   However, stable cytosterility remains challenging.

2. **CMS Lines**

   Over time and across locations, two CMS lines—GT 288A and 67A—have been identified as fully sterile.

   Efforts continue to purify and test other CMS lines, including ICRISAT CMS and AKCMS 1A.

   Fertility restoration was observed in fertile derivatives of the inter-specific cross between *C. scarabaeoides* and *C. cajan*

8. Markers Assisted Selection in Pigeon pea : Leveraging Molecular Tools

DNA markers play a crucial role in various aspects of pigeon pea research and breeding. Here are the key points :

1. **Marker Types**

   Molecular markers, such as RFLP (Restriction Fragment Length Polymorphism), RAPD (Random Amplified Polymorphic DNA), AFLP (Amplified Fragment Length Polymorphism), and microsatellites, are essential tools.

   They allow precise study of geographical distribution, cultivar identification, genetic diversity, linkage analysis, gene tagging, marker-assisted selection, and association mapping.

2. **Applications**

   Molecular markers help locate genes of interest and facilitate their precise transfer through marker-aided selection.

   They aid in characterizing genetic variability, identifying cultivars and germplasm, and establishing relationships among pigeon pea species.

   Genes controlling resistance to diseases, insect pests, salt tolerance, drought, extreme temperatures, and day length responses can be identified using marker technology.

3. **RAPD for Cultivar Identification**

   Random Amplified Polymorphic DNA (RAPD) markers have been used to identify pigeon pea cultivars and related wild species.

   By using single primers with arbitrary nucleotide sequences, unique DNA fragments specific to individual accessions are amplified.

   Wild species exhibit high polymorphism, while within *C. cajan* accessions, polymorphism is limited.

   RAPD provides immense potential for DNA fingerprinting in pigeon pea.

4. **Mitochondrial DNA Variation in Cytoplasmic Male Sterile (CMS) Progenies**

   Researchers compared total DNA using Restricted Fragment Length Polymorphism (RFLP) patterns in three putative CMS progenies.

   These progenies resulted from crosses between wild species (*C. sericeus*) and cultivated species (seven *C. cajan* accessions, including two genetic male sterile lines).

   Maize mitochondrial DNA (mtDNA) specific probes were used.

   The hybridization patterns of putative CMS progenies (CMS 7-1, CMS 12-3, and CMS 33-1) resembled those of *C. sericeus*.

   Genetic male sterile lines (MS Prabhat and QMS-1) showed distinct hybridization patterns.

   Cluster analysis revealed mitochondrial genome variation even among cultivated species.

5. **Quantitative Trait Loci (QTL) Investigation Using RAPD Markers**

   RAPD markers were employed to study QTLs in two pigeon pea strains and their F_1 and F_2 progenies.

   DNA was extracted from young leaves and amplified via polymerase chain reaction (PCR).

   Single primers with arbitrary nucleotide sequences selectively amplified unique DNA fragments specific to parents, F_1, and F_2 progenies.

   While parents exhibited low polymorphism, F_1 was intermediate, and F_2 showed minimal variation at the DNA level.

6. **Genomic Project and Molecular Markers**

   The pigeon pea genomic project focused on developing robust molecular markers.

   Microsatellites, single nucleotide polymorphisms (SNPs), and diversity array technology markers were key areas of interest.

   Researchers generated microsatellite markers from BAC-end sequences and enriched libraries.

   Sequence data from Fusarium wilt (FW) and sterility mosaic (SM) samples resulted in 4,557 unigenes.

   Intra-specific genetic maps were developed, and QTLs for sterility mosaic disease resistance were identified.

   Comparative analysis revealed higher molecular diversity in wild related species than in cultivated germplasm.

   The draft sequence of pigeon pea (48,680 genes) contributed to understanding drought tolerance, domestication, and evolution.

Achievements

1. **Achievements in Pigeon pea Breeding**

   Pigeon pea has made significant strides in minimizing the impact of biotic stresses.

   Breeding efforts have focused on integrating resistance to major diseases, enhancing productivity, reducing crop duration, and improving seed size.

   Despite being grown in marginal environments, pigeon pea production has stabilized.

   Researchers have evaluated advanced breeding lines across diverse locations, resulting in the identification of over 100 high-yielding and stable varieties.

   Hybridization among diverse parents has been attempted to accumulate high-yielding genes and desirable traits.

   Notable high-yielding varieties include UPAS 120, Manak, Pusa 84, BDN 2, Maruthi, and others.

2. **Broadening the Genetic Base**

   Although wild species of pigeon pea offer high resistance levels, they are underutilized in breeding programs due to linkage drag and incompatibility barriers.

   Pre-breeding provides an opportunity to expand the primary gene pool by exploiting genetic variability from wild species and cultivated germplasm.

   This approach ensures a continuous supply of new and useful genetic diversity for developing cultivars with high resistance levels and a broad genetic base.

3. **Breeding for Disease Resistance in Pigeon pea**

Three economically significant diseases—Fusarium wilt, sterility mosaic, and Phytophthora stem blight—cause substantial yield losses in pigeon pea. Some accessions of *C. scarabaeoides* exhibit multiple disease resistances. These resistant lines can be strategically incorporated into hybridization programs to transfer resistance against major diseases and insect pests.

Future thrust for pigeon pea breeding

1. **Heterosis and CGMS-Based Hybrids**

   Exploit heterosis (hybrid vigor) and develop commercial cytoplasmic genetic male sterile (CGMS) hybrids.

   These hybrids can enhance yield potential and stability.

2. **Improved Varieties with Biotic and Abiotic Resistance**

   Focus on developing improved pigeon pea varieties resistant to major diseases (e.g., pod borer, Fusarium wilt, sterility mosaic disease, and Phytophthora blight) and abiotic stresses (e.g., drought, soil salinity, and waterlogging).

   Pre-breeding efforts should extend the genetic base by incorporating traits from secondary and tertiary gene pools.

3. **Early Maturing Varieties and Pod Fly Resistance**

   Develop early maturing pigeon pea varieties that are resilient to pod fly damage.

4. **Screening Germplasm for Desirable Traits**

   Systematically screen germplasm for high protein content and their response to major biotic and abiotic stresses.

Identify suitable donors for potential breeding programs.

5. Genomic Resources and Molecular Markers

Invest in genomic resources and genome-wide markers to facilitate molecular marker-assisted gene introgression and breeding.

References

1. Akinola J.O., Whiteman P.C. and Wallis E.S. (1975). The Agronomy of Pigeon pea. *Review series* no. 1/1975. CAB International, Wallingford, UK.
2. Ariyanayagam R.P. and Singh N.B. (1994). Pigeon pea breeding: Accomplishments and challenges. *Plant Breeding Abstract* 64(6): 773-782.
3. Ariyanayagam R.P., Rao A.N. and Zaveri P.P. (1995). Cytoplasmic genic male sterility in interspecific mating of Cajanus. *Crop Science*, 35: 981-985.
4. Dubey A., Penmetsa V., Saxena R.K., Farmer A.D. and Raju N.L. (2009). Developing genetic and genomic resources for pigeon pea to improve its crop productivity. *Plant and Animal Genomes* XVII Conference, January 10-14, San Diego, CA, USA.
5. Faris D.G. (1985). Pigeon pea population breeding at ICRISAT. *Paper presented at AICPIP Kharif Pulses Workshop*, 16-19 May 1985, Tamil Nadu Agricultural University, Coimbatore, India.
6. Mohar S., Narinder K.G., Mukesh K.R., Om P.D. and Dutta M. (2014). Pigeon pea Genetic Resources and its Utilization in India, Current Status and Future Prospects. *Journal of Plant Science Research* 1(2): 107.
7. Moss J.P., Singh A.K., Sastri D.C. and Dundas I.S. (1988). "Wide hybridization in legumes at ICRISAT." Proceedings of the International Workshop on Biotechnology in Tropical Crop Improvement, 12-15 January 1987, *International Crops Research Institute for the Semi-Arid Tropics* (ICARISAT), Patancheru, India.
8. Pundir R.P.S. and Singh R.B. (1987). Possibility of genetic improvement of pigeon pea (*Cajanus cajan* (L.) Millsp.) utilizing wild gene sources. *Euphytica,* 36: 33-37.
9. Ratnaparkhe M.B., Gupta V.S., Murthy R.M.V. and Ranjekar P.K. (1995). Genetic fingerprinting of pigeon pea (*Cajanus cajan* (L.) Millsp.) and its wild relatives using RAPD markers. *Theoretical and Applied Genetics* 91: 893-898.
10. Saxena K.B. and Kumar R.V. (2003). "Development of a cytoplasmic nuclear male-sterility system in pigeon pea using *C. scarabaeoides* (L.) Thours. *Indian Journal of Genetics and Plant Breeding,* 63(3): 225-229.
11. Sharma S. and Upadhyaya H.D. (2016). Pre-breeding to expand primary gene pool through introgression of genes from wild *Cajanus* species for pigeon pea improvement. *Legume Perspectives,* 11: 17-20
12. Singh D.P. (1997). Tailoring the plant types in pulse crop. *Plant Breeding Abstract* 67: 1213-1220.
13. Sivaramakrishnan S., Seetha K., Rao A.N. and Singh L. (1997). RFLP analysis of cytoplasmic male sterile lines of pigeon pea (*Cajanus cajan* (L.) Millsp.) developed by interspecific crosses. *Euphytica*, 93: 307-312.
14. Tikka S.B.S., Parmar L.D. and Chauhan R.M. (1997). First record of cytoplasmic genic male sterility system in pigeon pea (*Cajanus cajan* (L.) Millsp.). *GAU Research Journal* 22: 160-162.
15. Tyagi A.P. (1997). Investigation of quantitative trait loci (QTLs) in two diverse strains of pigeon pea (*Cajanus cajan*) using RAPD markers. *Journal of South-Pacific Agriculture,* 4(1-2): 92-98.
16. Varshney R.K., Chen W.L.Y., Bharti A.K. and Saxena R.K. (20120. Draft genome sequence of pigeon pea (*Cajanus cajan*), an orphan legume crop of resource-poor farmers. *Nature Biotechnology,* 30: 838.

Website : www.asthafoundation.in
ICAAAS–An Edited Book (Volume-3)
ISBN : 978-81-958010-7-7
Published by : Astha Foundation, Meerut (U.P.) India
Edition-2024

Chapter 12

Avenue of Agri-Business Entrepreneurship in India

Ranjith P.C., Deekshith M.[2], Murulidhar M. Venkannanavara* and Geeta Gadekar
C.C.S. National Institute of Agricultural Marketing, Jaipur, Rajasthan, India
*Email : assistant.prof-iev2@ccsniam.ac.in/murulidharmv@gmail.com

Introduction

Agriculture is principle economic activities in India that essentially strives to reduce poverty and bring rural prosperity. It is pertinent to note that one percent growth in agriculture is 2-3 times effective in reducing poverty than a similar growth in any other sector. In fact, in every two Indian directly depend on agriculture for livelihood. Thus, growth in agriculture directly have bearing on most of the pressing socioeconomic problem. Despite COVID-19Indian agriculture has contributes about 20 percent to Gross National Product (GDP) and providing livelihood opportunity to more than 50 percent of population. Although all other sectors of the economy showed a negative growth in the last fiscal (FY 21) agriculture displayed a positive growth of 3.4 percent and emerged as a key sector for economic revival during natural disaster (Economic Survey 2020-21). Studies have highlighted that during an economic crisis and global financial turbulence entrepreneurship have brought considerable economic healing by rekindling virtual cycle of investment, employment and income. As per NABARD 42 percent of workforce engaged in agriculture and allied sector in India. Given these facts encouraging entrepreneurship in agriculture and allied sector is key for bringing economy back on track. Moreover, it helps to effectively leverage existing demographic dividend which is expected to peak by 2041 (Economic survey 2018-19) and share of working age (20-59 years), hit 59% of population. Also, entrepreneurship development in rural industries seems to be the best way forward to create in-situ employment opportunities while adequately addressing the issues arising from migration. Therefore, on the backdrop of economic hardship met under the guise of Covid-19 encouraging entrepreneurship is the key to unleash growth potential. This article deeply delves to unveil existing avenues for agri-business entrepreneurship in India.

Main problems solved from Agri-business entrepreneurship

- Agrarian distress and existing burden originating from price, market and storage
- Fostering rural development and employment generation for youth
- Limiting migration from Rural to urban areas and
- Rise in contribution to GDP and wealth creation

Avenues for Agri-Business entrepreneurship

The feasible ventures in agri-business

Farm level : An individual family farm producer is treated as ventures and production is enhanced to avail benefits of market, possession and consumer demand.

Service oriented : Farm business that involves input borrowing and distribution, hiring of equipment like tractors, sprayers, seed drills, threshers, harvesters `dryers and scientific services such as setting up of irrigation amenities, weed curb, plant security, yielding, threshing, conveyance, warehouse, etc. related opportunities exist in the livestock husbandry sector for providing breeding, immunization, disease diagnostic and treatment services, apart from allocation of cattle feed, mineral combination, forage grains, etc.

Processing and Value addition : The process may be kindled by gross root organization, cooperatives, registered societies, joint stock companies by focusing on specialized products based on consumer and market demand.

Cited as : Singh S.P. (2024). ICAAAS : Avenue of agri-business entrepreneurship in India. *ICAAAS–An Edited Book.* Volume-3 : 97-101. Astha Foundation, Meerut (U.P.) India.

Sectoral avenues in agribusiness entrepreneurship.

Sectors	Trusted avenues
Agriculture	· Quality seed/planting material production and marketing · Quality input production and supply chain · Food grain marketing and export (Rice) · Pulse and oilseeds post-harvest and processing · Organic agriculture and processing · Value addition · Agro based Industry viz, medium, Small and micro-enterprises · Quality certification · Farm mechanisation · Application of ICT tools, IoT, Artificial intelligence and blockchain technology
Horticulture · Fruits · Vegetables · Flowers · Aromatic and Herbal plants	· Contract farming and organic farming · Modern techniques viz, hydroponics, Aeroponics etc · Commercial production of fruits and vegetables and marketing · Cold/ Bulk storage and modern/ smart warehouse development · Mega food parks and regional food units · Processing, value addition, packaging and shelf life enhancement · Common facility centres and custom hiring · Micro and mass propagation of planting material · Off-Season vegetable and quality flower production under low cost poly house for commercial purpose · Commercial flower production for export · Application of ICT tools, IoT, Artificial intelligence and block chain technology
Animal Husbandry and Veterinary	· Working with producer organisation and cooperatives · Dairy product procession · Meat processing · Broiler and Egg Production and Marketing · Value addition, packaging and storage · Product marketing and services · Livestock feed and nutrition related · Livestock vaccine / drug production / diagnosis / clinics · Supply chain management · Application of ICT tools, IoT, Artificial intelligence and block chain technology
Fishery	· Scientific and commercial Production fish · Integrated and intensive Farming · Carp hatchery · Organic farming · Processing and value addition · Ornamental fish, pearl farming · Fish feed, nutrition and health and diagnostic services · Fish based plastic gadgets, fish waste bio fertilizers · Aqua filed schools · Application of ICT tools, IoT, Artificial intelligence and block chain technology
Sericulture	· Silkworm Rearing Technology · Silk Yarn Production · Value addition · Handloom and textile / garment design · Marketing and exports · Application of ICT tools, IoT, Artificial intelligence and block chain technology
Others	· Mass production of bio pesticides and preparation plant-based pesticides · Bio-fertilizers production and marketing · Farm machinery production and marketing and service industry · Mushroom production · Vermi compost · Bee Keeping and Honey Marketing

Institutional support agribusiness entrepreneurship

From the last several years government is trying to empaneled various central government and state government institution to convergently work for providing various kinds of support and facilities for the development of Agribusiness-entrepreneurship. Some of the support structures are drawn here.

Dedicated institution for imparting training and human resource development

National Institutes of ICAR and Government of India :_ICAR with its 4 deemed universities, 65 research institutes, 14 National Research centres, 6 National Bureaux and 13 project directorate fostering the process of agribusiness entrepreneurship through technology validation, training and capacity building. While institutes such as NIAM, MANAGE, NAARM imparts agribusiness programme with broad focus to promote agribusiness entrepreneurship among farm graduates.

Agri-busines and Agri Clinic centres : The educated individuals of such programmes include agri-graduates, post graduates and diploma holders in agriculture and allied fields who can set up their Agri-Clinics and Agri Business Centers and offer professional extension services to farmers. There is also specialized training is provided at fee of cost. Centre for Entrepreneurship Development, (CED) Hyderabad is one of the recognized Nodal Training Institutes to provide two months Training Programme.

RKVY – RAFTAAR Agri Business Incubator (R-ABI) : A total of 24 R-ABIs and 5 Knowledge Partners (KP) are catering to the needs of agribusiness entrepreneurships with the objective of a) ensuring timely support to deserving incubates, b) enabling and handholding for translation of minimum viable product (MVP) to marketable stage and scale up the product and business, c)provide a platform for faster experimentation and modification in their approaches or minimum viable product (MVP) based on innovative solutions/ processes / products/ services/ business models etc. for scaling up. Under ICAR -Indian Agricultural Research Institute (IARI) total of 9 R-ABIs are working to assist the incubatees to launch their products/ services/ business platforms etc. into the market and help them to scale up their operations as well as to attain business viability at a faster pace.

Enabling interventions of ZTM and BPD Unit under RKVY-RAFTAAR fostering agribusiness entrepreneurship

Agri India Hackathon : is the largest virtual gathering to create dialogues, and accelerate innovations in agriculture with fresh perspectives, disruptive approaches, and cutting-edge research & knowledge. Agri India Hackathon seeks to create an impact in 5 interconnected areas to provide a roadmap for the future. 24 best innovations from different focus areas will be awarded a cash prize of INR 1,00,000 each. Also, the winning innovations will get an exclusive preference for incubation support, pre-seed & seed-stage funding of 5 Lakhs & 25 Lakhs respectively at any one of the 29 RABIs, subject to assessment by the independent RABI. Further the winning innovations will have the opportunity of field trial and also access technology validation from our network of institutions (if they opt for incubation support)

UPJA : Up to 25 lakh Grant-in-aid with opportunity to technology validation and backstopping, pilot opportunities and institutional network, access to cutting-edge infrastructure Business Mentoring from Industry Leaders and Market Linkages & Investor’s Connect

ARISE : Up to 5 lakh Grant-in-aid with opportunity to technology validation and backstopping, pilot opportunities, Business Mentoring from Industry Leaders and Market Linkages & Investor’s Connect.

Others

SAMARTH : A train the trainer initiative, SAMARTH is an incubator management program for new incubators and incubation managers. This program has been launched to impart best practices to manage Startups & Innovation, Business development & management, incubation and entrepreneurship development in the field of agricultural

MAITRI : Six months Programme and 15 days’ workshop for fostering relations between India and Brazil in the area of agribusiness entrepreneurship.

ABIC : The programme offers startups an opportunity to technology validation and backstopping, IP related facilitation, pilot opportunities, Business Mentoring from Industry Leaders and Market Linkages & Investor’s Connect.

(i) Agribusiness Incubators : The agri-business incubation (ABI) program launched in 2003. It is ajoint venture of the International Crops Research Institute for the Semi-Arid Tropics (ICRISAT) and India’s Department of Science and Technology (DST). It sponsors agricultural technologies developed by ICRISAT, other R&D centers of excellence, universities and other institutions.

(ii) State Agricultural Universities (SAUs) :

Almost all states SAUs started Agribusiness education and they promote the agripreneurship development among the graduate and post graduate students. Also, various training programmes and new degree courses (bot at UG and PG level) have been introduced to strengthen the agribusiness education and entrepreneurship development.

(iii) Agriculture Technology Management Agency (ATMA) : The existing network of ATMA encourages specific agri-business enterprises and various provisions have also been made to foster collective farming, group farming, value addition and marketing.

(iv) Krishi Vigyan Kendra (KVKs): The network of over 722 KVKs conducting various vocational training programme with broad objective of promoting agripreneurship among farm youth in rural and semi-urban areas. Some of the programes viz., Introduction of organic products and organic inputs, Special packaged foods for Sugar patient, Heart patient, packaged flower for special occasion and season promotes business entrepreneurship.

(v) Entrepreneurship Development Cell (EDC) : SAUs and even traditional Universities started functioning entrepreneurship Development cell to promote entrepreneurship among students.

(vi) Domestic and Export Market Intelligence Cell (DEMIC) : This indirectly support business entrepreneurship skills and decision 17 making skills of agri-entrepreneurs. In addition, it also performs function of forecasting of prices of commodities.

(vii) National Institute of Entrepreneurship and small business development (NISEBUD) : This institute in functioning at New Delhi. It imparts specialized training to various categories of entrepreneurs. It establishes a forum between various agencies involved in ED activities.

(viii) National Institute of small Industries Extension Training (NISIET) : It is functioning at Hyderabad. It gives training to entrepreneurs of small-scale industries. Apart from this it also supports the research on development of SSI. It also extends its consultancy services to SSI.

(ix) RUDSETI (Rural development for self-employment and training Institute) : This organization is being promoted by Syndicate Bank. It operates the training institutes at Mangalore and Kannur. It conducts a residential entrepreneurial development programme for rural unemployed youths.

(x) ITC- e-choupal : It empowers farmers knowledge about weather and price, provide direct linkage between business objectives and societal goals and provide expertise on business skills and entrepreneurship skills.

Available infrastructure support for agribusiness entrepreneurship

APEDA (Agriculture and Processed Food Products Export Development Authority) : Specialised institute to enhance agri export and maximise foreign exchange. Creation of employment through value addition.

Special Economic Zones (SEZ) : Over 328 SEZs were notified and 265 are operational in 24 states. While 4 dedicated Agro and Food Processing SEZs are also operational and 4 are notified earlier.

Agri Export Zone (AEZ) : Total 60 AEZs were notified in 60 farm commodities in 20 states catering to the needs of agri exports

Institutional Finance toagribusiness entrepreneurship

Commercial Banks

National Agricultural Bank for Rural Development

Industrial development banks of India (IDBI)

Industrial Finance Corporation of India (IFCI)

Industrial Credit and Investment Corporation of India (ICICI)

State financial corporations

State Industrial Development Corporations (SIDC)

Small Industries Development Bank of India (SIDBI)

Export-Import Bank of India (EXIM Bank)

YES Bank (Agri business)

Conclusion and policy implications

For promoting more attractive and profitable business enterprise in agriculture and allied Agri-entrepreneurship is the need of the hour. There is lot of untapped hidden potential agriculture in terms of effective management of soil, seed, water and market needs and agri-entrepreneurship is great scope to harness. As agriculture growth and development has direct bearing on reducing poverty, it is indeed essential drive the spirit of entrepreneurship among the youth. Essentially entrepreneurial actions associated with agriculture generate innovative practical solution for aid in increasing farm income, employment and rural prosperity. Further the right mix of managerial skills and entrepreneurial expertise imparted through various institutions and interventions would facilitate accomplishment of the growing needs of agri-business.

References

1. Economic Survey 208-19, Ministry of Finance, GoI
2. Economic Survey 2020-21, Ministry of Finance, GoI
3. https://www.manage.gov.in/pgdaem/studymaterial/aem202.pdf
4. https://www.researchgate.net/publication/295393711_Avenues_for_entrepreneurship_development_through_agri-
5.https://www.researchgate.net/publication/324586058_Entrepreneurial_Avenues_for_Enhancing_Farmers%27_Income horti_ecosystem_for_farmers_and_rural_youth/citations
6. https://pib.gov.in/newsite/PrintRelease.aspx?relid=186993
7. http://www.pusakrishi.in/index.php
8. https://www.startupindia.gov.in/
9. http://nmoop.gov.in/conference/docs/Background_Paper_Agri_Startups.pdf
10. https://icar.org.in/sites/default/files/Proceedings-UPAYA-2020.pdf
11. https://www.researchgate.net/publication/295393711_Avenues_for_entrepreneurship_development_through_agri-horti_ecosystem_for_farmers_and_rural_youth
12. http://researchjournal.co.in/online/RKE/RKE%2013(1)/13_69-72.pdf

Website : www.asthafoundation.in
ICAAAS–An Edited Book (Volume-3)
ISBN : 978-81-958010-7-7
Published by : Astha Foundation, Meerut (U.P.) India
Edition-2024

Chapter 13

Necessity of Organic Farming in Modern Times

Deekshith M., Ranjith P.C., Murulidhar M. Venkannanavara* and Geeta Gadekar
CCS National Institute of Agricultural Marketing, Jaipur, Rajasthan, India
*Email : assistant.prof-iev2@ccsniam.ac.in, murulidharmv@gmail.com

The indiscriminate use of chemicals in modern agriculture not only harms the environment but also leads to soil fertility degradation, adversely affecting human health. With a growing concern for health, people are increasingly seeking out nutritious food options. Those tired of consuming chemically-laden produce and facing hefty medical bills are turning to organic products, free from harmful chemicals.

Farmers are also embracing the principles of organic farming, abandoning chemical-based practices that degrade the land. Organic farming emerges as a solution to the health challenges confronting humanity today. Its roots stretch back thousands of years, evolving alongside human civilization. This time-tested agricultural approach offers a remedy for contemporary health and environmental woes.

Organic farming entails cultivating crops without the use of chemical additives in the soil, instead utilizing natural waste and materials found in nature. This approach preserves soil quality, while promoting environmental sustainability. Grains, fruits and vegetables grown through organic methods are abundant in natural nutrients. Given the pressing need for environmentally friendly and pollution-free agricultural practices, organic farming has become increasingly vital in contemporary times. Here are some fundamental principles that organic farmers should embrace.

Crop Diversification : Poly culture or the cultivation of multiple crops on the same land, has gained popularity in recent times. Unlike mixed cropping, poly culture involves growing two or more crops together, a practice rooted in traditional agricultural wisdom. However, monoculture has dominated modern farming practices, overshadowing the benefits of diversification. Embracing multi-cropping or mixed cropping is a crucial aspect of organic farming, emphasizing the cultivation of diverse crops on a single piece of land.

Soil Management : The soil serves as the foundation of agriculture, being the source of sustenance for all living organisms. Therefore, it is imperative for farmers to safeguard the soil. In organic farming, priority is given to the natural preservation of soil properties and quality without the use of chemicals. Bio-fertilizers are solutions that enhance soil life are utilized to ensure soil fertility is maintained.

Weed Utilization as Green Manure : Weeds are pervasive in agricultural fields, seemingly intertwining with crops effortlessly. However, savvy organic farmers employ a strategy of converting weeds into green manure. Plants such as Dianch, velvet beans and flax are cultivated, and once they reach a certain stage of growth, they are cut (mulched) and transformed into green manure. This practice not only helps manage weed growth but also enhances soil fertility.

Control of Harmful Organisms : In agricultural ecosystems, alongside beneficial organisms, harmful pests lurk in the soil, posing a silent threat to crops. While conventional farming relies on chemical sprays to tackle such pests, organic farming necessitates alternative approaches. Organic methods offer various remedies to manage these pests without compromising soil health. Medicinal solutions such as neemasta, dashaparni, agni asta, and neem root decoction, derived from leaves and nuts of trees, effectively combat pests without causing harm to the environment. Controlling crop diseases and pests through organic

Cited as : Singh S.P. (2024). ICAAAS : Necessity of organic farming in modern times.
ICAAAS–An Edited Book. Volume-3 : 102-104. Astha Foundation, Meerut (U.P.) India.

means stands as a fundamental principle of organic farming.

Livestock Integration : Livestock, particularly indigenous breeds like desi cattle, play an integral role in organic farming. The organic farming system hinges upon the utilization of these animals. Farmyard manure, desi cow dung, cow urine, sheep, and chicken manure contribute to soil enrichment and provide essential nutrients to crops in organic farming. Additionally, in a practice complementing organic farming, a flock of sheep is allowed to graze on the farmland for a few days before sowing, further enhancing soil fertility.

Utilization of Natural Resources : Organic farming advocates for the exclusive use of natural resources. Farming practices should prioritize natural methods whenever feasible. This includes employing wooden ploughs for tillage, minimizing repeated ploughing after sowing, and utilizing traditional tools like swords and sickles for cutting overgrown weeds. Additionally, the use of tractors and other machinery should be minimized, only resorting to them when absolutely necessary.

First Steps in Organic Farming

The initial step towards adopting organic farming involves utilizing various types of organic, eco-friendly fertilizers as detailed below. These fertilizers aim to enhance soil fertility while improving its structure and texture.

Barn Manure (Dung Manure) : This fertilizer comprises dung from cows, buffaloes, oxen, calves, as well as sheep and goats. It serves as the fundamental organic fertilizer for augmenting soil fertility on the farm. The presence of cows and calves on a farmer's land is akin to having children in a household. Agriculture and animal husbandry are intertwined, as these animals not only provide valuable manure but also offer nutritious products such as milk, yogurt, butter, ghee and buttermilk. Cow dung holds immense value for farmers, akin to gold, as it serves various purposes including ploughing, spreading, harrowing, and sowing the land, particularly beneficial for smallholder farmers.

Earthworm Manure (Vermicompost) : Vermicompost can be prepared using readily available farm/vegetable waste materials. To create it, these materials should be finely chopped, powdered, and mixed with cow dung waste, then introduced to earthworms. This process yields an outstanding fertilizer that every farmer should master the art of producing.

Amrita Manure : This fertilizer fosters environmental sustainability and promotes high fertility through a blend of organic ingredients outlined below:

One basket of barnyard manure + Half a basket of earthworm compost + Half a basket of sand

+ Half a basket of red soil + A quarter basket of cow manure + A quarter basket of fish manure

+ One bunch of neem (100 gm) + 100 gm of bone meal + 100 gm of rock phosphate + 1 to 5 kg of ash

Combining these fertilizers in the correct proportions yields Amrita Manure. The following are the benefits of using these environmentally friendly organic fertilizers :

Improvement in soil particle structure and texture.

Availability of all necessary nutrients for crops, thereby enhancing soil fertility.

Increased water-holding capacity of the soil.

Enhanced fruit quality with softer and looser texture, facilitating better aeration around the roots.

Promotion of growth by fostering the proliferation of millions of beneficial organisms in the soil.

Animal Organic Fertilizers

Goat and Sheep Manure : This potent manure was traditionally utilized by experienced farmers before the advent of chemical fertilizers. Allowing sheep and goats to graze on farmland during fallow periods ensured their dung and urine enriched the soil, significantly enhancing its fertility. It is advisable to continue this practice, particularly in dry farming areas where crops are not cultivated year-round.

Manure from Horses, Chickens and other Animals : The manure from various animals such as horses, chickens, camels, elephants, donkeys and pigs can also contribute to increasing soil fertility. Each of these animal faeces holds its own unique fertilizing properties.

Fish Manure : Procuring high-quality fish manure is essential, and thorough testing should precede any purchase to ensure its efficacy. Fish manure, though valuable, may be scarce. Therefore, it is imperative to acquire and utilize trustworthy sources to maximize its benefits.

Animal Bone Manure : The use of manure derived from animal bone powder enriches the soil with additional phosphorus nutrition, thereby enhancing its fertility.

Bio fertilizers : Bio fertilizers play a crucial role in nitrogen fixation and phosphorus solubilisation, contributing significantly to soil fertility. These eco-friendly fertilizers can be applied scientifically at minimal cost, typically ranging from 15 to 20 rupees per acre. Leveraging the properties of beneficial organisms, nitrogen and phosphorus can be efficiently delivered to the soil, further augmenting its fertility.

Panchagavya - An Ancient Organic Plant Pesticide

An exploration of ancient agricultural practices in India reveals valuable insights utilized by many farmers of yore. One such practice is the preparation and application of Panchagavya, a solution derived from Panchamrita ingredients, with additional components contributing to its efficacy. Farmers have reported favourable outcomes from using Panchagavya, which can be easily prepared by individuals from readily available household ingredients. The process is straightforward and cost-effective. Panchamrita, a liquid concoction made from the following materials:

Desi cow's milk, Desi cow's curd, Desi cow's ghee, Honey, Sugarcane milk or Jaggery.

These five substances, used for abhisheka during worship, are augmented with three additional ingredients: Banana juice, Tender coconut water, Wood-apple.This blend is thoroughly mixed to create Panchagavya. The mixture is then sealed in an earthen pot, tightly covered with cloth, and left undisturbed for 7-21 days until a distinct odor develops. Once this aroma emerges, the Panchagavya is transferred to another earthen pot. Approximately 2 liters of the Panchagavya solution should be diluted with 5 litres of water and filtered through cloth. This prepared Panchagavya is then applied by sprinkling onto the leaves, stems, and roots of plants.

Some Important Benefits of Organic Farming

Organic farming promotes healthy agricultural production with relatively high-quality outcomes, while also being environmentally friendly. This is achieved through the enhancement of soil fertility, enabling the repeated use of certain lands for agricultural purposes. The organic farming system presents an opportunity for farmers to attain higher profits due to the increased market demand and prices for organic produce.

Consistent adherence to organic farming methods enables farmers to maintain a steady and equitable balance in crop yields, thereby safeguarding the environment and enhancing soil fertility. Organic farming serves as an effective measure in preventing pollution.

Today, the world's population has experienced significant growth, exemplified by India's population reaching 1.39 billion. Despite agricultural production increasing three to fourfold, there remains a shortage of food grains, pulses, oilseeds, fruits, and milk. If production fails to keep pace with population growth, there's a risk that future generations may face food scarcity, presenting a daunting dilemma.

The green revolution in India during the 1960s and 1970s was driven by several factors :

Research into hybrid and high-yielding, short-duration breeds.

Utilization of chemical fertilizers.

Adoption of chemical pesticides.

Expansion of irrigation facilities.

This revolution resulted in a substantial increase in agricultural production, reaching up to 8-10 tonnes per acre on individual farms, often through the implementation of multi-cropping schemes. However, it also led to a prominent reliance on chemical fertilizers, which gradually introduced toxins into the human body through food consumption.

To mitigate environmental damage, judicious water usage is crucial. Additionally, incorporating organic fertilizers such as cow dung, compost manure, ash, along with earthworm compost, at the appropriate times and in proper quantities, can significantly boost agricultural production without harming the earth.

India, predominantly an agrarian nation, sees about 70% of its population dependent on agriculture for livelihood, rendering much of the rural populace susceptible to poverty. Organic farming offers a solution by increasing production while eliminating the need for costly fertilizers, reducing diseases, and bolstering savings. The tangible benefits of organic farming directly contribute to the country's progress.

Governments and international communities are providing financial assistance to promote organic farming, which aids in preserving the agro-ecosystem and biodiversity. Farmers and agripreneur should seize this opportunity. Organic farming not only helps reduce pollutions and improve soil fertility but also diminishes the use of toxic chemicals and artificial additives in the food.

Website : www.asthafoundation.in
ICAAAS–An Edited Book (Volume-3)
ISBN : 978-81-958010-7-7
Published by : Astha Foundation, Meerut (U.P.) India
Edition-2024

Chapter 14

PARTICIPATORY TECHNOLOGY DEVELOPMENT THROUGH KRISHI VIGYAN KENDRAS : OPPORTUNITY AND STRATEGY

Netrapal Malik
CSAUAT-Krishi Vigyan Kendra, Aligarh-202122, Uttar Pradesh

KVK is the ambitious Agricultural extension endures of ICAR. Government of India is paying special attention towards KVKs and seeing these as an agency striving for holistic development of the farming community.

The first KVK was established in 1974 at Pondicherry under the administrative control of the Tamil Nadu Agricultural University, Coimbatore. Till then during each five year plan new KVKs were established. With the target of establishing one KVK in all the districts of the country by the end of 2012 total 631 KVKs are functional in different districts of the country with following mandates-

1Conducting 'on-farm testing' for identifying technologies in terms of location specific sustainable land use system.

2Organize training to update the extension personnel with emerging advances in agricultural research on regular basis.

3Organize short and long-term vocational training courses in agriculture and allied vocations for the farmers and rural youths with emphasis on 'learning by doing' for higher production on farms and generating self employment.

4Organize frontline demonstrations on various crops to generate production data and feedback information.(Choudhary,1999)

In the present context KVK may be defined as an institutional approach for technology assessment and refinement through On Farm Testing /Trials and demonstration of technology/products and its dissemination through training of farmers and extension personnel. Special features of KVK are as follows :

1. Need based in approach
2. Skill based vocational training
3. Comprehensive in activities
4. Farm based support
5. Inbuilt research-extension linkage
6. Participatory management
7. Multi-disciplinary team of scientist and
8. Mechanism for both feed back and feed forward

The greatest strength of KVK is its proximity to the farming community. KVK organize front line demonstrations and on-farm testing to asses and refine technologies generally generated by the host institute and other research institutions. The technology generated at research organizations is generally of complex nature. The farming community faces difficulty in understanding the practical utility of such a technology. It requires appropriate treatment to the best requirement of farmers. These farmers are human beings of different socio-economic domains. There is need to tailored the technology as per the system of the farming community (Verma, 1988). KVK can accomplish this task through Participatory Technology Development (PTD) and can enhance the acceptance of the technology.

What is Participatory Technology Development (PTD)?

Participatory Technology Development (PTD) can be defined as 'an approach, that links participatory research with extension, that bases on the promotion of internal capacity of rural communities to find out innovations in agriculture and natural resources management which meet the desires of farmers and suit

Cited as : Singh S.P. (2024). ICAAAS : Participatory technology development through krishi vigyan kendras : Opportunity and strategy. *ICAAAS–An Edited Book.* Volume-3 : 105-108. Astha Foundation, Meerut (U.P.) India.

strengths and weaknesses of households and communities'. It can be understood as a cooperative process of combining local knowledge and scientific knowledge, in which local knowledge is considered as important as any of scientific knowledge. PTD stimulates this creative combination to mobilize internal resources of farmers in order improve production and natural resources management in rural areas.

Special features of PTD

(a) PTD bases on needs and conditions of farmers. It meets expectation of farmers while considering feasibility, practicality and conditions of farmers to select appropriate solutions. Therefore, they are either not technical solutions that are over capacity of villages nor technologies transferred from outside that do not meet needs of farmers.

(b) In PTD, knowledge of farmers, researchers and extensionists is equally considered. Farmers are an equal partner in development and application of new technologies which are appropriate for agricultural and forestry production (Huy et.al, 2002).

Benefits of PTD

Participatory approaches to technology development are becoming widely adopted as the best way forward in developing agricultural technologies with resource poor farmers. This comes from a general acknowledgement that PTD has several distinct advantages over the traditional approaches to technology development. There are two main benefits of PTD over technologies developed in research organizations :

1. Experimenting by Farmers : PTD takes advantage of the ability of farmers to experiment and solve problems on their own farms. Unlike the relatively modern field of scientific research, farmers have been conducting experiments for thousands of years. Often all they lack to solve their problems is access to information and new technologies to test.

2. Improved Technology Adoption : PTD improves the chances of wider adoption of agricultural technologies. Any new technology developed and expanded by farmers themselves has a better chance of wider adoption than technology developed solely on research stations for extension to farmers.

Steps of Participatory Technology Development through KVKs

KVK must follow following steps for Participatory Technology Development.

Step-I : Problem Diagnosis

The first step we usually take when starting participatory technology development in a new area is problem diagnosis. It is similar to Participatory Rural Appraisal (PRA). Researchers work with a representative group of farmers to gain a greater understanding of their agricultural and livelihood systems.

The farmers :

Identify the problems that are of most concern within their agricultural and livelihood systems;

Identify causal links between these problems;

Describe what actions they have taken in the past to minimize each problem;

Decide which of the problems have the highest priority; and

Discuss what actions they would like to take to solve these problems in future.

If diagnosis identifies problems that the farmers want to try to resolve, and there are technologies with the potential to resolve those problems, researchers and farmers can together test these technologies.

Step-II: Experimentation

In PTD, the stage of Experimentation can take two forms; formal and informal experimentation. In formal experimentation, farmers conduct formal and statistically valid experiments in their own fields. There are two problems with this approach:

On-farm trials frequently have very variable results, *and*

Researchers want to control how trials are carried out, since they are more concerned with statistical validity than with encouraging farmers to innovate.

Overcoming these problems KVK's Subject Matter Specialists (SMSs) must allow farmers to test the technology on their farms in whatever way they want. At the same time, they must be informed about the experiences of other farmers and SMSs with the technology. When farmers develop promising technologies of their own, controlled experiments can then be conducted, to validate and quantify the farmers' experiences.

Step-III: Evaluation

Once farmers have begun testing the technologies, and have selected the most promising, then evaluation starts, in which farmers describe which of the technologies they like and why. They also explain which technologies they do not like, and why, and what characteristics of the preferred technologies could be improved. Evaluation not only indicates which technologies are showing promise for extension to other farmers, but also provides insights into farmers' criteria for judging research.

Principles of Participatory Technology Development

The key principle of PTD is active decision making involvement of farmers at all stages of technology development. Besides this KVK's SMSs must keep in mind following points:

1. Selection of sites and farmers is critical, and is often not given the attention it requires. Following approaches should be taken as guiding principles while selecting sites and farmers :

(i) Identify villages or communes where the farmers appear to have a real need that can be addressed by the particular technology. This may be achieved by using secondary information, consisting of both data and, key information and observations. Selected group of farmers must be representative of the farmers those are facing the problem.

(ii) At each selected site, KVK's SMSs must confirm that there is a genuine problem as identified in the secondary information.

2. SMSs of the KVK must confirm that

farmers regard the problem and want to work to solve it,

many farmers share the problem. The problem must not only address the interests of resource rich farmers.

that they have possible and appropriate solutions.

3. SMSs of the KVK must try to identify innovative farmers who can take the lead in testing the technology, expanding promising ones, and supporting neighbors who want to develop these technologies themselves.

4. SMSs of KVK must have empathy for working with farmers, and a willingness to spend long periods of time in villages. The early stages of technology development require regular visits to each farmer to overcome initial problems, answer questions and encourage the process of PTD. This takes time, energy and commitment.

5. Basic communication skills are more important than the tools of PTD. The skills of listening to farmers (not just hearing), using probing questions to gain deeper understanding of farmers' needs, working in partnership with farmers to solve their problems and providing information in a neutral manner are the most important aspects of PTD. Flexibility is also essential. We cannot use these tools like a recipe to get an end result. These skills are not obtained overnight or from formal training courses, but from field experience. Without these skills, the PTD tools e.g. matrix ranking and participatory evaluation are useless.

6. PTD is an ongoing process that starts with only a superficial understanding of technologies that may solve farmers' problems.

7. There should be no time lag between planning and working with farmers. It is observed that farmers want quick action following problem diagnosis. Frequently, it is experienced by the farmers that outsiders who come to them to develop their agricultural systems are quick in collecting information, but slow to provide new technologies in return. For farmers to realize that there is commitment from the KVK, SMSs must start the execution of further steps of PTD immediately.

8. Working in partnership with line departments and non-governmental organizations is essential to achieve sustainable results through institutional change. This requires compromises, commitment and time.

9. Allow farmers to learn and choose what to do with the technologies. This will result novel technologies appropriate for each situation. Farmers are not always right. PTD often encourages people to believe that farmers always know what is best. Researchers and farmers each have knowledge to contribute.

10. Researchers must contribute their knowledge and experiences. The challenge is to give farmers all relevant information, so that they can make an informed decision, without telling them what they should do.

11. Regular visits to collaborating farmers and informal "farmer training" are crucial for successful participatory technology development.

12. Not all of our technology development activities need to be participatory. Some activities are necessarily not participatory for example, PTD has no chance of success if there are no potential technologies to offer, and new technologies are usually generated by researchers on research stations (Horne and Stur, 1999).

The institution of Krishi Vigyan Kendra, since its very beginning in 1974, has proven to be an important mechanism in the process of technology dissemination from research laboratories to the farmers and end users. The KVK can be an effective mechanism for technology assessment, technology refinement and technology dissemination keeping in mind its relevance to the needs and resource endowments of the farming community. Application of principles of Participatory Technology Development (PTD) may enhance the quality of services being providing by KVKs.

References

1. Bao Huy, Vo Hung and Hoang Huu Cai (2002). Handbook of Participatory Technology Development. https://assets.helvetas.ch/downloads/ptd_participatory_technology_development_handbook_en.pdf. website visited on September, 09, 2013
2. Choudhary B.N. (1999). Krishi Vigyan Kendra (Agricultural Science Centre) A Guide for the KVK Managers. Division of Agricultural Extension, Indian Council of Agricultural Research, Krishi Anusandhan Bhawan, Pusa, New Delhi.
3. Horne Peter and Stur Werner (1998). Participatory Approaches to Agricultural Technology Development in Sloping Lands. http://www.agnet.org/. website visited on February 22, 2012.
4. Verma O.S. (1988). Editorial. *Journal of Extension System*. 4(1) http://www.jesonline.org/. website visited on February 22, 2012.

Website : www.asthafoundation.in
ICAAAS–An Edited Book (Volume-3)
ISBN : 978-81-958010-7-7
Published by : Astha Foundation, Meerut (U.P.) India
Edition-2024

Chapter 15

Precision Dairy Farming : Revolutionizing Dairy Management through Technology

Jyoti Srivastav* and Tushar Saxena
Department of Livestock Production Management, Sri Ganganagar Veterinary College, Tantia University, Sri Ganganagar, Rajasthan
**Email : srivastavajyoti228@gmail.com*

Introduction

The dairy industry faces increasing pressure to enhance productivity and sustainability while ensuring animal welfare. Precision Dairy Farming, a subset of precision agriculture, leverages modern technologies to address these challenges. Precision Dairy Farming (PDF) integrates advanced technologies into dairy management to optimize production, health, and welfare of dairy cattle. By employing tools like automated milking systems, wearable sensors, and data analytics, PDF allows for real-time monitoring and decision-making, leading to improved efficiency, productivity, and sustainability precision dairy farming utilizes data from various sources to make informed decisions, enhancing the overall management of dairy farms.

Key Technologies in Precision Dairy Farming

(1) Automated Milking Systems (AMS) : Automated Milking Systems, commonly known as robotic milkers, represent a cornerstone of PDF. These systems offer numerous advantages over traditional milking methods.

Components and Operation : AMS consists of several components :

Milking Robots : Perform the milking process, including udder cleaning, teat cup attachment, and milk extraction.

Barn cleaning robots : These robots maintain cleanliness in barns, reducing the risk of disease and improving animal comfort.

Sensors : Monitor milk quality and yield, detecting anomalies such as mastitis.

Data Management Systems : Collect and analyze data, providing insights into milk production patterns and cow heat.

Benefits of Precision Dairy Farming

(a) Enhanced Productivity : Precision dairy farming technologies enable farmers to monitor and manage each cow individually, optimizing milk production and improving overall farm productivity. Early disease detection and timely interventions prevent production losses and ensure consistent milk quality.

Milk Yield

Optimized Feeding : Precision feeding strategies ensure cows receive balanced nutrition, maximizing milk production.

Milking Efficiency : Automated milking systems allow for more frequent and consistent milking, increasing yield.

Reproductive Efficiency

Accurate Estrus Detection:

Wearable sensors accurately detect estrus, improving breeding success rates.

Timely Interventions :

Early detection of reproductive issues allows for prompt treatment, enhancing fertility.

Cited as : Singh S.P. (2024). ICAAAS : Precision dairy farming : Revolutionizing dairy management through technology. *ICAAAS–An Edited Book.* Volume-3 : 109-111. Astha Foundation, Meerut (U.P.) India.

(b) Improved Animal Health and Welfare

Continuous monitoring and early intervention improve animal health and welfare, leading to better overall herd performance.

Health Monitoring : Wearable sensors can detect deviations from normal behavior or physiological parameters, indicating potential health issues such as lameness, mastitis, or metabolic disorder. Early intervention can prevent more serious health problems and reduce veterinary costs.

Early Disease Detection : Identifying health issues early reduces the severity and duration of illnesses.

Preventive Care : Regular monitoring supports preventive health measures, reducing the incidence of diseases.

(c) Welfare Enhancements

Behavioral Insights : Understanding cow behavior allows for improvements in housing, feeding, and milking practices, reducing stress and enhancing welfare.

Customized Care : Individualized attention to each cow's needs improves overall well-being.

(d) Environmental Sustainability

Precision dairy farming promotes sustainable farming practices by optimizing resource use and reducing environmental impact.

Resource Efficiency

Precision Feeding : Tailored feeding strategies minimize waste and optimize nutrient utilization.

Water Management : Efficient water use through real-time monitoring and automated systems.

Environmental Impact

Reduced Emissions : Improved manure management and optimized feeding reduce greenhouse gas emissions.

Sustainable Practices : Enhanced efficiency in resource use supports long-term sustainability goals.

Challenges and Limitations

High Initial Costs

The investment required for installing advanced technologies can be a significant barrier for small and medium-sized farms. Cost-benefit analysis and financial support mechanisms are essential to encourage adoption.

Economic Viability

While the long-term benefits of PDF can outweigh the initial costs, the upfront investment is substantial. Government subsidies, loans, and grants can help mitigate these financial barriers.

Data Management and Integration

Handling and integrating large data from various sources can be complex. Effective data management systems and interoperability standards are crucial for seamless operation.

Data Security

Ensuring data privacy and security is paramount, as farms handle sensitive information. Robust cyber security measures and data governance frameworks are necessary to protect data integrity and confidentiality.

Technological Reliability

Ensuring the reliability and robustness of technologies in various farm conditions is vital. Regular maintenance and updates are necessary to prevent system failures and data inaccuracies.

System Failures

Technology malfunctions can disrupt farm operations and affect animal welfare. Establishing reliable technical support and maintenance services is essential to minimize downtime and ensure continuous operation.

Future Prospects

The future of Precision Dairy Farming lies in continued technological advancements and increased integration of AI and machine learning. Developing more affordable and user-friendly solutions will enhance adoption rates, especially among smaller farms. Moreover, greater emphasis on data security and privacy will be essential as data sharing becomes more prevalent.

(a) Technological Innovations : Ongoing research and development in sensor technology, AI, and robotics will drive the next generation of PDF tools. Innovations such as non-invasive health monitoring and autonomous feeding systems hold promise for further enhancing farm efficiency and animal welfare.

(b) Policy and Regulation : Supportive policies and regulations can encourage the adoption of PDF. Governments and industry bodies need to collaborate to create frameworks that promote innovation while ensuring ethical standards and environmental sustainability.

(c) Industry Collaboration : Collaboration between technology providers, researchers, and farmers is crucial for the successful implementation of PDF. Industry partnerships can facilitate the exchange of knowledge and best practices, driving continuous improvement in dairy farming.

Conclusions

Precision Dairy Farming represents a significant advancement in dairy management, offering substantial benefits in terms of productivity, animal welfare, and environmental sustainability. Despite challenges such as high initial costs and data management complexities, continued evolution of precision dairy farming technologies promises to revolutionize the dairy industry. As technology becomes more affordable and integrated, and as data security measures are enhanced, PDF will play an increasingly vital role in shaping the future of dairy farming, making it more efficient, sustainable, and humane.

References

1. Bewley J.M. (2010). Precision dairy farming: advanced analysis solutions for future profitability. *Proceedings of the Western Dairy Management Conference*.
2. DeVries T.J. and von Keyserlingk M.A.G. (2009). Short communication: Associations of cow behavior, barn design, and management with resting behavior and leg injuries of dairy cattle. *Journal of Dairy Science,* 92(5): 2597-2604.
3. Eastwood C. and Kenny S. (2009). Precision dairy farming in practice: a study of adoption and adaptation of sensor technologies. *Computers and Electronics in Agriculture,* 62(2): 139-143.
4. Rutten C.J., Velthuis A.G.J., Steeneveld W. and Hogeveen H. (2013). Invited review: Sensors to support health management on dairy farms. *Journal of Dairy Science,* 96(4): 1928-1953.
5. Steeneveld W. and Hogeveen H. (2015). Characterization of Dutch dairy farms using sensor systems for cow management. *Journal of Dairy Science,* 98(7): 4448-4456.

Our Conference Memory

About the Chief Editor

Chief Editor

Dr. S.P. Singh, born in Village Jevri, Post Rajbun, District Meerut (U.P.), in 1970 and Graduated in Agriculture with Honors from G.M.V., Rampur Maniharan, Saharanpur (U.P.). He did his Post Graduation in Agricultural Botany, Institute of Advance Studies, Meerut University Campus, Meerut and Doctorate in the same discipline (Ag. Bot.) from C.S.J.M. University, Kanpur. Presently, he is working as Scientist (Plant Breeding) at C.S.A. University of Agriculture and Technology, Zonal Agriculture Research Station, Kalai, Aligarh (U.P.). Dr. Singh is a fellow of SRDA, and member of many other professional Societies, having 21 years of experience in Research and Extension Education Works. He authored many books such as Plant Breeding, Agriculture at a Glance, Hand Book of Agriculture (Hindi), Crop Physiology (Hindi & English), College Botany, Environmental Science & Agroecology, Concepts of Ecology etc. He is well recognized Scientist and having more than 300 publications in reputed National and International Journals. Dr. S.P. Singh is also Editor-in-Chief, Progressive Research-An International Journal & Frontiers in Crop Improvement (both Journals are NAAS recognized), Secretary, Society for Scientific Development in Agriculture & Technology and also Chief Managing Director, Astha Foundation, Meerut, working in the field of Science & Education.

He has been awarded as Best Editor and Writer Award-2006, Young Scientist Award-2007, Dr. M.S. Swaminathan Young Scientist Award-2009, Distinguished Scientist Award-2014, Scientific Initiator Award-2014 from Directorate of Rice Research, Hyderabad, Science Leader Award-2015 From RVSKVV, Gwalior, Outstanding Scientist in Agriculture Award-2016, Outstanding Achievement Award-2016, Excellence in Research Award-2017, Innovative Scientist of the Year Award-2017 Outstanding Scientist in Agriculture Award-2018 Before this International conference, Dr. S.P. Singh has already organized five conference at different corner of country, first conference was National symposium on "Achieving Millennium Development Goal : Problems & Prospects" at Bundelkhand University, Jhansi (UP) during October 25-26, 2009 under the umbrella of SSDAT, Meerut, Dr. Singh has been acted as an Organizing Secretary. The second was National conference on Emerging Problems and Recent Advances in Applied Sciences : Basic to molecular Approaches (EPRAAS-2014) during February 08-09, 2014 at Ch. Charan Singh University, Meerut (UP) again by SSDAT, Meerut in which Dr. S.P. Singh has played his role as an Organizing Chairman. The Third, Conference was Organized by SSDAT, Meerut and Astha Foundation, Meerut at Directorate of Rice Research, Hyderabad on Emerging Challenges and opportunities in Biotic and Abiotic Stress Management (ECOBASM-2014) during December 13-14, 2014. Fourth Conference organized by Astha Foundation, Meerut & SSDAT, Meerut at RVSKVV, Gwalior on Global Research Initiatives for Sustainable Agriculture & Allied Sciences (GRISAAS-2015). Fifth Conference was jointly organized by SSDAT, Meerut & Astha Foundation, Meerut at PJTSAU, Rajendranagar, Hyderabad, Telangana State on Innovative and Current Advances in Agriculture & Allied Sciences (ICAAAS-2016) during December 10-11, 2016. Sixth Conference organized by Astha Foundation, Meerut in collaboration with SSDAT, Meerut, MPUAT, Udaipur; CSAUAT, Kanpur; UAS, Raichur at MPUAT, Udaipur, Rajasthan on Global Research Initiatives for Sustainable Agriculture & Allied Sciences (GRISAAS-2017). Seventh Conference organized by Astha Foundation, Meerut in collaboration with SSDAT, Meerut, CSAUAT, Kanpur; IGKV, Raipur; BAU, Sabour; MPKV, Rahuri; RARI, Durgapura, Jaipur; Global Research Initiatives for Sustainable Agriculture & Allied Sciences (GRISAAS-2018). Eight Conference organized by Astha Foundation, Meerut in collaboration with SSDAT, Meerut, CSAUAT, Kanpur; IGKV, Raipur; BAU, Sabour; MPKV, Rahuri; UAHS, Shivamogga, Global Research Initiatives for Sustainable Agriculture & Allied Sciences (GRISAAS-2019). Ninth Conference organized by SSDAT, Meerut in collaboration with Astha Foundation, Meerut, Innovative and Current Advances in Agriculture & Allied Sciences (ICAAAS-2020) at Bangkok, Thailand. Tenth International Web Conference organized by Astha Foundation, Meerut in collaboration with SSDAT, Meerut, CSAUAT, Kanpur; IGKV, Raipur; BAU, Sabour; MPKV, Rahuri; BAU Rachi and UAHS, Shivamogga on Global Research Initiatives for Sustainable Agriculture & Allied Sciences (GRISAAS-2020). Eleventh International Web Conference organized by SSDAT, Meerut in collaboration with Astha Foundation, Meerut, CSAUAT, Kanpur; IGKV, Raipur; MPKV, Rahuri; BAU Rachi and UAHS, Shivamogga on Innovative and Current Advances in Agriculture & Allied Sciences (ICAAAS-2021). Twelth International Web Conference organized by Astha Foundation, Meerut in collaboration with SSDAT, Meerut, CSAUAT, Kanpur; IGKV, Raipur; BAU, Sabour; MPKV, Rahuri; BAU Ranchi and UAHS, Shivamogga on Global Research Initiatives for Sustainable Agriculture & Allied Sciences (GRISAAS-2021). Thirteen International Conference in Hybrid Mode organized by SSDAT, Meerut in collaboration with Astha Foundation, Meerut, CSAUAT, Kanpur; HPU, Shimla; BAU Ranchi, HFRI, Shimla and HNBGU, Srinagar on Innovative and Current Advances in Agriculture & Allied Sciences (ICAAAS-2022). Fourteen International Conference organized by Astha Foundation, Meerut in collaboration with SSDAT, Meerut, CSAUAT, Kanpur; BAU Ranchi; RLBCAU, Jhansi; SKRAU, Bikaner; ICAR-CIFE, Mumbai; AFU, Rampur, Chitwan, Nepal; NPU, Palamu and RK (P.G.) College, Shamli on Global Research Initiatives for Sustainable Agriculture & Allied Sciences (GRISAAS-2022).

Glimpse of SSDAT & Astha Foundation's Conferences

Published By :

Astha Foundation, Meerut

Suman Villa, 85, Phool Bagh Colony, Main Road, Meerut-250002

Mob. : 08273775051, 09450068438

ISBN : 978-81-958010-7-7