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Exploring potential of protected cultivation in India—a review

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Abstract

Protected cultivation has become an integral part of modern agriculture, significantly contributing to global food security and horticultural production. The diverse array of structures and crops grown under protection underscores the adaptability and versatility of these systems. As the world grapples with the challenges of feeding a growing population, protected cultivation is set to play an increasingly vital role in the future of agriculture, offering solutions to the problems of climate change, resource scarcity, and food quality. To realize the full potential of protected cultivation, governments, agricultural institutions, and private sector must work together to support and promote sustainable practices, ensure training and knowledge sharing, and create favourable policies for its continued growth. Looking to the future, the potential of protected cultivation is enormous. As global population growth and climate change continue to exert pressure on traditional agriculture, protected cultivation offers a sustainable solution to increase food production, ensure crop quality, and reduce the dependency on seasonal variations. Additionally, technological advancements in energy-efficient systems, renewable energy adoption, and integrated pest management are expected to make protected cultivation even more sustainable and economically viable.

With time it has been well proved that protected cultivation is a better technology to enhance productivity and quality of the crops by providing a logical and technical solution to manage the major and minor biotic and abiotic stresses encountered under open field cultivation of major horticultura lcrops. The effectiveness of the technology has also been observed in many parts of the world (Singh, 2013). Presently, the area under different forms of protected cultivation is around 4.5 million ha in the world. During the last two- and-a- half decades, the area under protected cultivation has increased exponentially in various countries and around Mediterranean sea.

In China, various kind of protected cultivation technologies like mulching, use of temporary plastic walls in open fields, plastic low tunnels, plastic covered walk-in-tunnels, high tunnels, temporary and permanent insect-proof net houses, shade net houses, rain shelters and different kinds of greenhouses etc are being adopted. Presently, China is the world leader in cultivating horticultural crops under different protected conditions, totalarea under protected cultivation being around 3.5 million ha. Out of this area, nearly 96 percent is being used for cultivation of commercial freshvegetables andtheir hybrid seed production. Simultaneously, growth in protected cultivation like China has also been observed in developing countries like Indian and African sub-continent.But the success rate varies significantly because of poor correlation between design of various protected structures and prevailing agroclimatic conditions of a region.

The experience of protected cultivation which emerged in Northern Europe, stimulated its development in other areas including the Mediterranean region, North America, Oceania, Asia and Africa, with various rates and degrees of success. It has been clearly established and proven that mere transportation or adoption of technology as such from Northern Europe to other parts of the world, irrespective of prevailing agroclimatic conditions was not a valid decision and step. Each region and area actually require further research, development, extension, training and new norms, procedures and methods of application of technology to meet the region-specific requirements for protected cultivation of horticultural crops (Singh, 2019).

Protected cultivation In India

India, with its vast and diverse agricultural landscape, has always been a significant contributor to the global agricultural market. The challenges of increasing population and changing dietary preferences have placed immense pressure on our country's food production systems. To meet the growing demands for fresh and nutritious produce, India must innovate and adopt

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modern techniques. Protected cultivation methods, including greenhouses, net-houses, high tunnels, and low tunnels, hold the key to increasing vegetable production and securing India's food future. India being a country with diverse climatic regions has shown an overall growth of around2.0 lakh ha area under protected cultivation in different states during the last two decades. The success rate of these technologies varied significantly depending upon the climatic conditions of various regions in India. In plains of Northern India, these technologies faced high challenges for making them successful against the harsh climatic conditions, whereas in mild climatic areas like Bengaluru and Pune, the success rate achieved has always been high.

Basically, the dismal growth of protected cultivation technology in the country happened mainly due to Government policies providing handsome subsidies under various schemes launched by the government of India under MIDH (NHM), TM, NHB, RKVY etc., and up to some extant due to the technical beauty of technology. The technical know-how for adoption of protected cultivation technology under Indian conditions was not to the level at the time of inception. With passage of time, research and developmental work carried out by various public sector institutions in collaboration with developed countries gradually reflected that technical designs of different protected structures needs modification suitable to the region-specific needs of prevailing climatic conditions and problems under open field cultivation.

During last few years, varieties& hybrids and production technology suitable for protected cultivation have beendeveloped by various public sector institutions in India. Further there are some most successful examples and models for adoption of this technology even under harsh climatic conditions like Bassi-JhajhraandBasari village, just 15 km away from Jobner (Jaipur), but this seems only in cluster approach. This most successful example in cluster approach clearly shows the potential of the technology expansion up to 15.0-17.0 lakh ha for growing horticultural crops in different states in India by the year 2050. Presently, the area under protected cultivation in India stands at a mere 2.0 lakh ha. In contrast our country produces 207.0 million tonnes of vegetables annually. Looking ahead to 2050, our nations vegetable requirement is expected to surge to 450.0 million tonnes. To bridge this massive gap, protected cultivation has the potential to play a pivotal role, offering a promising solution (Tuzel and Kacira, 2021).

Expansion of protected cultivation

Promotion and expansion of protected cultivation technology will not only be going to help for creation of huge self-employment for unemployed educated youths, but it will also increase the national economy by sale of quality healthy planting material, fresh horticultural produce for domestic and international markets. Under the era of FDI (Foreign Direct Investment) in retail, these kinds of models possess high potential for enhancing the income of farmers opting for quality and off- season vegetables and cut flowers cultivation through various protected cultivation technologies.

On one hand, production of vegetable and cut flower crops under protected conditions provides high-water and nutrient-use efficiency under varied agroclimatic conditions of the country. On the other, this technology has very good potential especially in peri-urban areas in cluster approach adjoining to major cities, a fast-growing market for fresh quality produce. Thus, it can be profitably used for growing high-value vegetables like, tomato, cherry tomato, coloured peppers, parthenocarpic cucumber and brinjal, cut flowers like roses, gerbera, carnation, chrysanthemum etc. and virus-free healthy seedlingsand planting material of horticultural crops in agro-entrepreneurial models.

But protected cultivation technologies require careful planning, attention adequate timing of production and moreover, harvesting time to coincide with high market prices, choice of varieties adopted to off-season environments, and able to produce economical yield of high-quality produce etc. Even though application of chemicals for controlling biotic stresses is also low under protected structures which gives a high-quality safe vegetables for human consumption. By using protected structures, it is also possible to raise off-season and long duration vegetable crops with high yield (3-5 fold as compared to open field cultivation) withquality. Vegetables and cut flowers farming in agro-entrepreneurial models targeting various niche markets of big cities is inviting regular attention of vegetable and flower growers for diversification from traditional ways of crop cultivation to the modern methods like protected cultivation of horticultural crops. (Singh *et al.* 2010).

Tips for protected cultivation

The basis behind the successful implementation of protected cultivation technology largely depends on selection of suitable designs with proper, crops, their varieties and adoption of successful cultivation are fundamental variables that may significantly affect success and economic return of the entire. A most successful example of protected cultivation in cluster approach is Bassi-Jhajhraand Basari village 15 km away from Jobner (Singh, 2023). The success of protected cultivation technology entirely depends upon four basic concepts, viz. what to produce, when to produce, how to produce and where to sell and where the export the high- quality produce.

The growers must know two basic options, i.e. choice of crop or variety for its high economic potential/ return and to develop most suitable production system in cluster approach. Crop should be selected based on existing structures, wide consumptionand good adoption to unsteady climatic conditions and suitable for long cultivation cycles. While adopting the protected cultivation technology, following most important points, viz. market requirement of the produce, distance from the market for the fresh produce, climatic conditions of the area, soil characteristics and quality of water, economic convenience, crop requirement, labour and skilled manpower requirement should be well considered in advance.(Singh,2005).

Major challenges in India

The major challenges are:

- Non-availability of region-specific designs of green houses and insect-proof net houses for varied agroclimatic conditions and regions.
- Fabrication of protected structure has come up as a big business, taking an opportunity small industry are sacrificing with quality of material to be used to gain more profit and also lack of understanding of designs of the protected structures for different regions and quality of basic steel and cladding material used for fabrication and installation of structures.
- Limited trainedskilled and professional manpower for designing, fabrication of protected structures and thereafter, maintenance of the structures and for protected cultivation of various high-value crops.
- Lack practical training institutions and advisory services in the area of protected cultivation of horticultural crops.
- Limited of availability of suitable crop varieties and planting material specific to protected cultivation, especifically with public sector institutions, its management practices etc. asplanting material/ seeds, cladding material, water- soluble fertilizers, etc. available with private sector companies andare too costly.
- Lack of demand-driven cultivation without proper marketing strategies several times creates problem for proper disposal of quality produce and sometime farmers are even not gettingreasonable price of their produce.
- Increasing threat of soil-born problems like root-knot nematodes and Fusarium for protected cultivation of horticultural crops and more specifically vegetable crops.
- Non-availability of virus-free healthy planting material in vegetables, fruits and ornamental crops.
- Poor power supply for dripirrigation is major challenge in protected cultivation.

Adoption of protected cultivation technologies

Protected cultivation technology for horticultural crops has tremendous potential for adoption under varied agroclimatic conditions of the country. The most potential areas where high scale interventions are required to be promoted are as under (Report of the Working Group, 2013).

- Use of plug tray nursery technology on commercial scale for raising virus free healthy vegetable and flower seedlings as Agri- business models.
- Large scale use of different designs of insect poof net houses with different designs for commercial vegetable cultivationand for hybrid seed production of vegetable crops.
- Use of modified naturally ventilated greenhouses equipped with mini sprinklers on the roof top area and zero energy consuming exhausts on gutters for continuous removal of greenhouse hot air forcultivation of vegetable and flower crops cultivation under harsh conditions of arid and semi-arid regions of the country.
- Use of naturally ventilated green house for hybrid seed production in vegetables for increasing the overall profitability of the farmers.
- Large scale use of plastic mulches for commercial vegetable cultivation under open fields and also under

Table 1: Expansion potential of protected cultivation technologies in different indian states by 2050

Protected structure	Suitable crops	States	Pace expected expansion
Low-cost playhous- es up to 50m^2- 250m^2 area	Several vegetable crops for protection against frost and pests and viruses	Uttarakhand, Himachal Pradesh, Tamil Nadu,- Jammu and Kashmir and all North East states	8-10% growth every year over the present level of this technology
Rain shelters-cum-insect proof net-houses	Several vegetables for protection against insect pests and viruses and continuous rains	All North East States, Bay Islands, Eastern Coastal Region, Western Coastal Region, Kerala etc	6-8% growth over the present level of use of the technol- ogy
Plastic low tunnel technology (but now needs replacement of Synthetic plastic with Non-woven material for covering the tunnels)	Mainly for off season cultivation of cucurbits during winter months	Punjab, Haryana, Rajasthan (parts adjoining to Haryana, Punjab), Uttar Pradesh	15-20% over the level of use in around 20,000-22,000 acres
Walk-in-tunnels	For off-season vegeta- ble cultivation during winter months	Foot Hills Uttarakhand, Himachal Pradesh, Jammu and Kashmir and North Eastern	8-10% over the present use of the technology
Insect-proof net houses	For protection of veg- etable and fruit crops like Papaya against viruses and Insect pests and up to some extent from frost	North Indian Plains, central India, western Parts like Rajasthan, Gujarat	15-20% over the present status of use in around 8000- 10000 ha
Naturally ventilated greenhouses	For large scale and year-round cultiva- tion vegetables viz. tomato, cherry tomato, Capsicum, seedless cucumber, eggplant, etc. and hybrid seed production of vegetable Large scale	Punjab, Haryana, Ra- jasthan, Uttar Pradesh, Madhya Pradesh, Guja- rat, Maharashtra, Ker- ela, Telengana, Orissa, Bihar, Jharkhand, Tamil Nadu, Andhra Pradesh	15-20% over and above the present use in around 1.20-1.30 lakh ha.
Semi-climate-con- trolled greenhouses	Nursery production and use for commercial vegetable cultivation and seed production of high value vegetable crops.	Rajasthan, Gujarat, Madhya Pradesh, Ma- harashtra, Arid Region and Semi-arid regions	8-10% over the present status of use in around area of 1500-2000 ha.
Shade net houses	For cultivation of leafy. Vegetables & herbs during peak summer months.	Arid and semi-arid regions of Madhya Pradesh, Rajasthan, Gujarat, Maharashtra, Andhra Pradesh., Tamil Nadu, etc.	10-12% over the present area in use around 12,000-14,000 ha
High tunnels	For off-season cultiva- tion of cucurbits and other vegetables during winter months + large-scale drying of chilli and pan methi	Rajasthan, Andhara Pradesh, Maharashtra, Madhya Pradesh, Gu- jarat and other arid and semi-arid regions	8-10% over and above the present level of use
Retractable green- houses	For cultivation of black berry and blue berries	Uttar Pradesh, Uttra- khand, Trait Region Madhya Pradesh, etc.	5-8% over the leaf level 20 -30 ha
Climate controlled greenhouse/glass- houses	For quality planting material production of Potato under aero- ponics systems and hydroponic system	Haryana, Punjab, Uttar Pradesh and Rajasthan	3-5% over the leaf level
Mulching (replace- ment of system- atic plastic with biodegradable or compostable plastic is needed or by organic mulch in fruit orchards	For cultivation of major vegetables, fruit crops, spices ornamental crops.	Across the country clubbed with raised beds and drip irrigation system	15-20% over the plant level of 50,000-60,000 ha

green houses and even under insect proof net houses under varied agro-climatic conditions but now the use of synthetic plastic needs replacement with biodegradable or organic mulch.

- Commercial application of micro-grafting technology for developing resistant plant material against soil borne problems.
- To promote cultivation of fruit crops like papaya, pomegranate under insect proof net houses for protection against biotic and abiotic stresses.
- Large scale application of low-pressure drip irrigation system for managing an area of 1000-2000 sq. mts. area for cultivation of different horticultural crops under protected structures.
- Commercial use of open roof type high tunnels in northern parts of the country and even under temperate conditions can be more rewarding.
- Large scale skill development of youth manpower in two ways following the Chinese model i.e., designing, fabrication and maintenance of protected structures and secondly the production management of crops under protected conditions
- Application of GAP procedures and standards for protected cultivation of high value vegetablecrops will help to catch international trade.
- Government support should be extended for self-fabrication mode of temporary low-cost structures like insect proof net houses, shade net houses, walk-in- tunnels and plastic low tunnels for the cultivation of suitable vegetable and flower crops.
- Promotion of protected cultivation technology for its sustainability in cluster approach especially in peri-urban areas of the country by following Bassi-Jhajhra village in Jobner.
- Government should also promote to develop input hubs for protected cultivation in multi-locations in PPP mode.
- Use of solar energy for running drip system and up to some extent for running heating and cooling devices of the protected structures should also be promoted.
- All the protected cultivation clusters must be mandatorily clubbed with rain water harvesting infrastructure facilities.
- Promotion of most suitable crop sequences for different protected structures and seasons based on research data.
- Promotion of large-scale mechanization in vegetable and flower cultivation by using raised bed makers, plastic laying machines, plastic low tunnel making machines, pipe bending machines for making walk-in-tunnels, drip lateral laying and binding machines
- To establish convergence and synergy among various on-going and planned government programmes in the field of protected cultivation development.
- To ensure adequate, appropriate, time bound and concurrent attention to all links in production under protected conditions, post production on-farm value addition, processing, consumption chainsand for export.
- Cluster approach for taking up protected cultivation as a whole is required and may be clubbed with processing industriesand export along with national high ways and dedicated freight corridors.

Benefits of protected cultivation

Protected cultivation provides a barrier against pests and diseases. The enclosed environment helps prevent the entry of harmful insects and pathogens, reducing the need for chemical pesticides. This contributes to a more environment-friendly and sustainable crop production systems.

The increased efficiency in resource utilization is another advantage. Controlled environments enable precise application of fertilizers and nutrients, minimizing waste and optimizing plant nutrition. This efficiency not only benefits the environment but also contributes to cost savings for farmers.

Protected cultivation also offers a range of benefits, including extended growing seasons, enhanced control over environmental factors, protection from adverse weather conditions, water conservation and pest and disease management. These advantages collectively contribute to higher agricultural productivity with better food quality, and increased sustainability in the face of evolving challenges in agriculture sector. (Singh, 2005).
Its versatility in adapting to diverse agroclimatic conditions. This technology allows year-round cultivation. It is beneficial for having with extreme climates. It supports sustainable crop diversification,enabling the cultivation of high-value crops such as fruits, vegetables, and flowers. Furthermore, it facilitates crop intensification by maximizing yields per unit area (Singh, 2011).

Addressing water scarcity

Water scarcity is a significant concern in many parts of India. Protected cultivation provides a means to optimize

water-use efficiency by controlling the microenvironment within the structure. Reduced water wastage and precise irrigation management are critical benefits, especially in areas struggling with water availability.

Product quality and safety

In an era of increasingly stringent market demands, standards, and regulations, product quality and safety are paramount. Protected cultivation allows for meticulous control of environmental factors such as temperature, humidity, and light, resulting in consistent and high-quality produce. Moreover, protection from external contaminants and pests minimizes the need for chemical interventions, aligning with the growing consumer preference for organic and safe products.

Cluster approach for success

The cluster approach has been instrumental in successful expansion of protected cultivation. Cluster of farmers adopt this technology in proximity benefit from shared knowledge, resources, and market access. This approach fosters collaboration, enhances economies of scale, and minimizes risks associated with technology adoption (Singh, 2023).

Multiple applications of protected cultivation

Protected cultivation technology finds diverse applications in Indian agriculture. Firstly, it plays a pivotal role in raising disease and virus-free healthy planting material. The controlled environment of greenhouses and polyhouses ensures that the initial crop material is of highest quality, contributing to the success of subsequent cultivation.

Secondly, it is instrumental in hybrid seed production, especially for vegetables. This technology enables the isolation and controlled pollination of different varieties, ensuring the purity and quality of hybrid seeds. (Singh and Tomar, 2015).

Thirdly, protected cultivation is central to the production of fresh food for better economic viability. The extended growing seasons and higher yields empower farmers to meet market demands consistently, enhancing their income.

Role of skilled manpower

For the sustained growth of protected cultivation, developing a skilled workforce is paramount. This involves training rural youth in two key areas: designing, fabricating, installing, and maintaining protected structures, and managing the entire crop production process under protected conditions. Skilled labour not only ensures the efficient operation of these systems but also opens up opportunities for employment and entrepreneurship in agricultural sector.

Expansion of protected cultivation in India

The future of protected cultivation technology in India is promising. It is envisioned that by 2050, the technology could be expanded to cover an estimated 15.0-17.0 lakh ha of agricultural land across the country. This expansion would offer solutions to the multifaceted challenges facing Indian agriculture, making it more resilient and sustainable in the face of changing climate patterns.

Gujarat

Gujarat has been a pioneer in greenhouse farming and is known for its successful adoption of protected cultivation techniques. The state's moderate climate and progressive government policies make it conducive for expansion. Vegetables, flowers, and export-oriented crops like capsicum, tomato, and seedless cucumbers are successfully being grown under protected conditions. The two sea ports for fast export of value-added options are the major ladder for the State of Gujarat for making fast progress in protected cultivation:

Maharashtra

Maharashtra, with its diverse agroclimatic zones, offers ample opportunities for protected cultivation. The state has seen increased adoption, especially in the Nashik region for grapes, Pune for floriculture, and areas around Mumbai for vegetables. The state government has also been encouraging farmers to invest in protected cultivation. Some of the areas have already come up as protected cultivation hubs around Pusa for cultivation of vegetable and ornamental crops. More areas in the State have potential for protected cultivation like Konkan region and areas which are boarding with Karnataka State.

Protected cultivation can be taken up on a large scale-seed production of vegetable crops.

Himachal Pradesh

The hilly terrain and cold climate in Himachal Pradesh make it suitable for high- value crops like strawberries, capsicum, cucumbers, tomatoes and cut flowers under protected cultivation. The state government has been promoting polyhouses for extending growing season and increasing yield. Seed production of vegetable crops can also be taken up in foothills of the State under low cost protected structures.

Karnataka

Karnataka, with its varied agroclimatic zones, is another state with immense potential for protected cultivation. Regions like Bengaluru, Mysore, and parts of North Karnataka have seen growth in greenhouse farming for vegetables, while the Coorg region is known for its floriculture. Seed production of vegetable crops can also be taken up in different regions of the state. Dharwad, Rani Benuer etc. are ideal for cut flower crops like gerbera, carnation or even roses. Protected cultivation of flowers can be taken up in large scale in different regions of State like Oaty hills, Coimbatore, Solem area, etc.

Tamil Nadu

Tamil Nadu's favourable climate allows for year-round cultivation of various crops. Protected cultivation is extensively used for vegetables, flowers, and even fruits. The state government has provided subsidies to encourage farmers to adopt these techniques. Protected cultivation of flowers can be taken up in large scale in different regions of State like Oaty Hills, Coimbatore, Salem areas, etc.

Punjab and Haryana

These states in northern India have adopted protected cultivation for vegetables and fruits, especially during the off-season. The region's extreme weather conditions make greenhouses and polyhouses vital for year-round production of high value vegetables, seed production of selected vegetables and large scale healthy nursery production. Protected cultivation can be taken up in cluster approach along with mega highways like NH 152D KMP, NH-1, etc. for cultivation of high value vegetables and nursery hubs can also be developed in these areas for fast transportation of the produce and planting material to far-flung areas of the country.

Rajasthan

Rajasthan's arid climate and extreme temperatures can be challenging, but protected cultivation, particularly shade net houses and polyhouses, have been adopted and can be further expended for growing fruits and vegetables like tomatoes, capsicum, cucumbers, and papaya. In Rajasthan, insect-proof net houses and shade-net houses can be used at large scale and Bassi-Jhajhara village model can be replicated in several other parts of Rajasthan and other states.

Andhra Pradesh and Telangana

These states have seen an increase in protected cultivation for export-oriented crops like flowers, vegetables, and fruits. The government has introduced subsidies to promote these practices. Seed production of vegetable crops can also be taken up to large scale in different regions mainly around Hyderabad.

Kerala

In Kerala, due to its humid tropical climate, protected cultivation is used for growing orchids, vanilla, and spices. Polyhouses and shade net houses have gained popularity and up to some extend vegetables like cucumbers and capsicum are being grown. There is a need to use protected conditions for large-scale healthy planting material production of spices like black pepper, cardamom, ginger, turmeric etc.

Uttarakhand

Uttarakhand's hilly terrain and cold climate provide opportunities for protected cultivation of high-value crops such as organic vegetables, medicinal herbs, and strawberries. Seed production of vegetable crops can also be taken up in foothills of the state.

Bihar and Jharkhand

Greenhouses and other low-cost protected structures in like insect-proof net houses, high tunnels, walking tunnels and shade net houses can be used at large-scale vegetable cultivation and also ten Gerbera, Carnation etc. Protected structures like greenhouses are required to be used at large scale for disease and virus-free planting material of different horticultural crops.

North-Eastern States

Low-cost protected structures like poly houses and rain shelter-cum insect-proof net houses can be used for cultivation of vegetable and ornamental crops. There is a need to use protected conditions for production of healthy planting material of different horticultural crops. In these states protected cultivation can be well linked with low-pressure drip irrigation system.

Orissa and West Bengal

Protected cultivation like greenhouses or net houses can be used for a large number of vegetable cultivation but in cyclone-prone coastal regions only low-cost protected structures are required to be used for cultivation of different horticultural crops.

Uttar Pradesh

In Uttar Pradesh, protected cultivation of vegetable and flower crops have very good potential. Same time, large scale planting material production can also be expanded along with national highways and in NCR region including Peri-urban areas of Lucknow, Prayagraj, Banaras, etc.

The expansion of protected cultivation in India also depends on market demand, access to technology, infrastructure development, and government incentives. Many state governments offer subsidies, technical assistance, and training programmes to encourage farmers to adopt these practices. With climate change affecting traditional agriculture, protected cultivation can play a crucial role in ensuring food security and income generation for farmers.

Diversified uses of protected structures

Post-harvest management: Plastic high tunnel can be used for better post-harvest drying, as it acts as a protected site under plastic and operates like a solar dryer with ventilation. The open sun drying under field reduces the face value of the produce by loss of excess moisture and discolouration besides chances of microbial contaminated if done on Kachcha platforms. Looking to the benefits of high tunnel, following are potential uses in arid/semi-arid regions (Singh, 2019).

Drying of Nagaurimethi: For drying of Nagaurimethi use of high tunnels can be very quick and clean process wherein the leaves can be dried 2-3 days earlier than sun drying. It is also safe from damage caused due to unusual weather situations like winter rains. This technology is more effective to have a clean and green produce of Nagaurimethi leaves especially for export purposes.

Drying of vegetable crops: Introduction of high tunnels is a cheap and clean process for drying vegetable like chilli, mint, spine gourd, ashwagandha etc. with maintaining quality for better consumer acceptability.

Drying of specific commodities: Some products like Panchkuta, kachri etc. which are unique to arid ecologies are sun dried by farmers. The use of high tunnel can be innovative approach in drying of these commodities for better quality and fast drying.

Drying of plantation crop products: In the region of Sojat and Paliregion cultivation of heena leaves holds special identity as a Geopgraphical Indicator. The drying of henna leaves under high tunnels will be very useful in producing better heena powder for local and international market.

Conclusion

There is a huge potential of expansion of the protected cultivation technology in India,in different states huge but highly dependent upon the technicality and recommendation of the technology implementation. The technology can be expended up to 15.0- 17.0 lakh by the year 2050. The cluster approachin it adoption can play crucial role in it successful expansion. The protected cultivation technology has to play a significant role under varied agroclimatic conditions of our country as a means for sustainable crop diversification, intensification, and for vertical growth of productivity of horticultural crops leading to optimization of water and fertilizer-use efficiency. In the near future, first and most important requirement of its is raising disease and virus-free healthy planting material of horticultural crops. The use of technology for hybrid seed production of vegetables and production of fresh food for better economic-viability are other uses. Further, sustainability of the technology is utmost important to develop a large skilled manpower in form of rural areas. There is a need to replace use of synthetic plastic mainly used for mulching purposes or as a covering plastic low tunnels either with the use of biodegradable or non-woven material.

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Induced mutation breeding in tuberose (*Polianthes tuberosa*) – a review

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Abstract

Tuberose (*Polianthes tuberosa Linn.*) is major bulb crop growing in both tropical and subtropical areas. The popularity of tuberose is due to as it occupies prime position in cut and loose flower, essential oils extraction and landscaping. The main problem in conventional tuberose breeding is lack of genetic variability, self-incompatibility and seed sterility. To achieve the rapid evaluation, induced mutation was opted. It is one of important pathway to find variability in vegetatively propagated species. So far 3,300 officially released mutants available in 170 different species from 60 countries. Mutation induction in tuberose was carried out by physical mutants like X-rays, Gamma Rays and chemical mutagens like EMS and DES. Till now two induced mutants namely, Rajat Rekha (Silver strip) and Swarna Rekha (Golden Strip) with leaf variation have been developed at CSIR-National Botanical Research Institute, Lucknow (Uttar Pradesh). More mutation works was also carried out through induced mutation. In future still there is wide scope opened for induction of different mutants like colour variation, change in petal shape, altered flower arrangement in spike, long and short spike mutants in tuberose.

Key words: Chemical mutagen, Dimethyl sulphate, Ethyl methane sulphonate, Fast neutron, Gamma rays, Induced mutation, Physical mutagen.

Commercially floriculture is a fast-emerging major venture in the world, growing at the rate of 10-15 per cent (Datta, 2019). Among different flower crops, ornamental bulbs are one of the most beautiful and variable group of geophytes, have been appreciated from ancient times. Tuberose (*Polianthes tuberosa Linn.*) is most important bulbous perennial flowering plant, belonging to monocots. It occupies second position in area and production after gladiolus in India. It is found to be originated at Mexico, it was placed under the family Agavaceae.

The most extensive contributions to new species of *Polianthes* were made by Some other important species of *Polianthes* are *P. palustris* (white), *P. durangensis* (purplish), *P. montana* (white), *P. longiflora* (whitish purple), P. plaitphylla (white tinged with red), *P. grandiflora* (deep red), *P. geminiflora* (light orange red), *P. gracillis* (white), *P. blissi*, *P. pringlie* (white), *P. sesiliflora* (white), *P. nelsonill* (white) and *P. graminiflora* (red). These species range in colour from white, orange red and red. All the species are wild with the exception of *P. tuberosa* which has never been found anywhere except under cultivation.

Tuberose (*Polianthes* tuberose Linn.) occupies a prime position owing to its popularity as a cut flower, loose flower and also raw material for extraction of the highly valued natural flower oil (Singh *et al.* 2021). The serene beauty of the flower is because of its tall and straight spikes which bear bright white florets which are loosely arranged on spike that can reach 2-4 feet in height. The flowers are bisexual, funnel shaped with waxy white and fragrant perianth tube. Perianth tube consists of six acute tepals. Stamens are six in number with the anthers dorsifixed in the middle of the tube. Gynoecium has a trilocular ovary with numerous ovules and the fruit is a capsule. Foliage is long, slender and grass-like with landscape value (Jyothi and Singh, 2016).

In India, tuberose is being commercially cultivated over 1435 ha area and the main growing states are Uttar Pradesh, Uttarakhand, Haryana, Telangana, West Bengal, Maharashtra, Karnataka, Tamil Nadu and Andhra Pradesh (NHB, 2018-19). The yield

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maximization and sustainable production was mainly dependent on integrated nutrient management (Bohra and Nautiyal 2019). There are about 20 cultivars available in India, which include Single type, Double type and Variegated ones. The main problem in tuberose breeding is lack of genetic variability. Only two cultivars 'Single' 'and 'Double' are popular among farmers and are being commercially cultivated. All the variegated cultivars are merely novelties and hence not cultivated commercially. All the available cultivars in India bear white colour flowers, Even though some of the cultivars bear flower buds which are tinged with pink blush and green tinge, the fully opened flowers are white in colour in all the cultivars. The genetic variability in tuberose is very limited and it has narrow genetic base.

Non-availability of genetic variability has become a major constraint in conventional breeding of tuberose. Genetic improvement of tuberose is hampered by meager genetic variability, self-incompatibility and seed sterility. Tuberose is highly heterozygous and hence variability can be created (Jyothi and Singh, 2015). In India, since not many improved cultivars have been developed in this crop, there is a great scope for mutation breeding in this crop. Tuberose has advantage of its vegetative mode of propagation through bulbs and bulblets. Once a superior genotype is identified it can be further multiplied by bulbs and bulblets (Jyothi and Singh, 2016).

Induced mutations should become increasingly important sources of genetic variability for plant improvement programme because (1) sources of natural genetic variability for some crop plants are at various stages of depletion or low and (2) induced mutations represent a new nearly untapped reserve of genetic variability (Datta, 2017).The history of mutation is as old as the science of modern genetics. Genetic variability, the raw product for evolution in plant species is replenished by spontaneous mutations. Plant breeding which is a controlled evolution was initially dependent on genetic variability from natural sources. Discovered that mutations could be induced artificially in plant by physical agent like X-rays. Since then, it appeared that the breeders possessed a new tool with which they could create variability at will.

Induction of mutation is an important pathway for the production of new genotypes in vegetatively propagated species and to enhance natural genetic resource. Induction of mutation in vegetatively propagated crops has attracted considerable attention because the selection of mutations of directly prescribed characteristics like colour, form or size, is generally not difficult. Mutation induction with radiation has been the most frequently used method to develop mutant cultivars, accounting for about 90% of obtained cultivars (64% with gamma-rays, 22% with X-rays. Physical mutagents like ionizing radiation (X-rays, gamma rays and neutrons) and UV light and also a series of chemical agents are common examples of mutagens that have high efficiency in generation of mutation in plants, animals as well as bacteria. Initial attempts to induce mutation in plants mostly used X-rays, later more and more gamma rays and also fast and thermal neutrons were used. The advantages of physical mutagens are accurate dosimetry and reasonable reproducibility and high and uniform penetration of multicellular system particularly by gamma rays. Gamma radiation has provided a large high number of useful mutants and is still showing a higher potential for improving vegetatively propagated plants.

Hernandez-Munoz *et al.* (2019) reported that mutagenesis is an important tool in the generation of ornamental plant varieties. By 2017 more than 700 varieties have been registered in the mutant variety database jointly administered by the Food and Agriculture Organization of the United Nations and the International Atomic Energy Agency. Among the main genera reported are *Chrysanthem, Rosa, Dahlia* and *Alstromeria*, with 283, 67, 35 and 35 registered varieties, respectively. From *Dahlia*, 18 varieties have been registered and a large number of mutant forms have been generated in Asia and Europe, while from *Polianthes* mutant forms have been developed in Iran and India and from *Helianthus* 569 mutant forms have been developed in Bulgaria. These not only increase biodiversity but also provide breeding material for conventional plant breeding, these mutant forms also have ornamental attributes that meet the quality standards demanded in the international market. Preliminary study on mutagenic effect of gamma radiation and chemical mutagens on tuberose was done.

Induced mutation

In tuberose, there is no record of spontaneous mutation but two induced mutants namely; Rajat Rekha from Mexican Single and Swarna Rekha from Pearl Double developed from CSIR-National Botanical Research Institute, Lucknow (Uttar Pradesh) with variegation in leaves was released. In tuberose so far there is no other flower/foliage variation has been observed.

Mutagenic agents

Yadav *et al.* (2022) stated that the agents used for induction of mutation are known as mutagens. The mutation type comprises of physical mutagents (X-rays, gamma rays, alpha particles and ultraviolet radiations) and chemical mutagents or DNA reactive chemicals (Nitrous acid, dimethyl sulphate (DMS), ethyl nitrosourea (ENU), methyl nitrosourea (MNU), ethyl methane sulfonate (EMS), ethyl ethane sulphonate (EES), base analogs (5-bromourcail and 5-chlorourcail), intercalating agents (acridine orange, ethidium bromide and proflavine) metals (arsenic, cadmium, chromium, nickel and biological agents (virus, transposonand bacteria.

Physical mutagens

Many mutant varieties have been created using X-rays and gamma rays. Gamma radiation in particular has been popular; approximately half of all mutant varieties registered in the FAO/IAEA mutant variety database were created using gamma rays. X-rays only account for about 17% of the registered varieties and chemical mutagenesis has been used for about 10% International Atomic Energy Agency (2021).

Mutation induced by fast neutrons and X-rays

Tuberose cvs Mexican Single and Pearl Double bulbs (small and large size) with 142, 284, 426, 568 and 710 rads fast neutron dose. They reported that Mexican Single cultivar flowered in about 10 weeks and bulb size difference did not delay significantly the flowering (Kaintura and Srivastava 2015 and Kaintura *et al.*, 2016). Studied the effect of X-rays treatment on vegetative and floral chracters of different cultivars of tuberose and isolation of promising mutants was done. The experimental material comprised of four tuberose cultivars, *viz.* Kalyani Single, Kalyani Double, Arka Suvasini and Arka Prajwal with two doses of X-rays (0.6 kr and 1.2 kr) along with untreated sample (control). The results indicated that higher dose was detrimental for vegetative and floral parameters. Six mutants were obtained exhibiting variation in plant height (cv. Arka Prajwal) increase in number of petals per floret (cv. Arka Prajwal) and presence of stamen in Arka Suvasini with bulb treatment with 1.2 kr X-rays.

Mutation induced by gamma irradiation

This type of ray is one of the most important mutagenic agents within ionizing radiation because they have been shown to be highly penetrating and potent in inducing variability in plants (Datta, 2017). Gamma rays are emitted in the disintegration process of the radioisotopes of carbon-14, cobalt-60, caesium-137 and to a lesser extent plutonium-239. Irradiation may be acute (short periods) or cronic (long periods). The efficiency of this radiation is because it has an energy level ranging from 10 keV to several hundred keV, which gives it greater penetration power than alpha and beta rays.

Two gamma rays induced variegated leaf mutants were developed and released under the name Rajat Rekha and Swaran Rekha. Rajat Rekha a single flowered tuberose mutant with white streaks along the middle of the blade, while Swaran Rekha a Double flowered mutant of tuberose with golden yellow streaks along the margins of blade. Tuberose cv. Mexican Single bulbs were irradiatd with 0.5 Kr, 1.5 kr, 2.5 kr and 3.5 kr with gamma rays and planted in beds. The gamma dose of 0.5 kr gave one desirable mutant with bolder flowers compared to the control and plants from bulbs treated with other doses.

The higher doses like 2.5 Kr and 3.5 Kr proved to be more or less lethal for sprouting of bulbs. Irradiated bulbs with acute dose of gamma rays survived upto 2.5 kr. High sensitivity to bulbs to radiations particularly to gamma rays may be due to high moisture content of the buds in the bulb. In tuberose the number of leaves, plant height, number of plants flowered and survival decreased as the dose increased, i.e. 2.5 kr of gamma rays. When bulbs of both Mexican Single and Pearl Double cultivars of tuberose were exposed to 500, 1000 and 1500 rad of gamma rays for induction of genetic variability.

Different types of morphological abnormalities like shape, size, margin, apex, fission and fusion of leaves and chlorophyll variation in leaves were detected in treatment population. It was reported that morphological variants like chlorophyll mutants, non-flowering mutants and compact spike mutants were observed in tuberose cvs Mexican Single, Pearl Double, Arka Srinagar and Arka Suvasini treated with gamma rays (5.0 - 2.5 gy). The Rajat Rekha, mutant of Mexican Single tuberose gave maximum leaf length, leaf width, number of spikes per plant and number of florets per spike as compared to its control. While Swaran Rekha which is mutant of Pearl Double tuberose showed maximum plant height, number of florets per spike, floret length as well as length of spikes.

Majumdar *et al.* (2013) exposed tuberose cvs. Arka Prajwal and Arka Vaibhav bulbs to different doses of gamma radiation (2.5, 5.0, 7.5, 10.0 and 12.5 Gy) for induction of genetic variability. Bulb sprouting in cv. Arka Vaibhav was stimulated with lower dose (2.5 Gy) of irradiation. The number of leaf and its length, spike length and number of flowers reduced whereas, days to spike initiation increased with the increment of radiation doses in both the cultivars. The LD_{50} was found in higher dose (12.5 Gy) in both of them. Different types of morphological abnormalities like changes in shape, size, margin, apex fission and fusion of leaves and chlorophyll variegation in leaves were detected in the population. Frequency of morphological abnormalities and chromosomal abnormalities like bridge, fragments, early separation and clumbing increased with higher doses.

Pohare *et al.* (2013) carried out induction of genetic variability in in vitro regenerated *Polianthes tuberosa* in Local cultivar, with five different doses of gamma radiations (10, 20, 30, 40 and 50 Gy). Non-significant differences were observed in survival rates among the untreated (control) and treated plants with different doses of gamma irradiation. But significant differences were recorded in plant morphological characters upon gamma radiation treatments of 30 Gy in terms of plant height, number of leaves, leaf size and colour as compared to the control plant. Kainthura and Srivastava (2015) and Kainthura *et al.* 2016 treated four tuberose cvs. *viz.*, Kalyani Single, Kalyani Double, Arka Suvasini and Arka Prajwal with gamma rays (0.5 kr and 1.5 kr). The results indicated that mutagenic treatments at lower doses has significant simulative effect on some parameters i.e. sprouting percentage, days taken to sprouting whereas most of the parameters showed decrease from desired parameters i.e. survival rate, leaf length, number of spikes per plant, number of florets per spike, flowering duration and vase life. Higher dose was detrimental for vegetative and floral parameters.

Jyothi and Singh (2015) conducted a field trial in tuberose cvs Arka Prajwal and Phule Rajani with a view to evaluate the sensitivity, proper bulb stage and optimal gamma irradiation dose to induce mutant. Tuberose cvs Arka Prajwal and Phule Rajani with three different bulb stages, *viz.*, freshly harvested bulb, three weeks after uprooting and six weeks after uprooting were irradiated by 2.5 Gy, 5.0 Gy, 7.5 Gy, 10.0 Gy and 15.0 Gy of gamma rays and control untreated. Probable LD_{50} dose of gamma irradiation was between 10.0 Gy to 12.0 Gy for freshly harvested bulbs and bulbs after six weeks after uprooting in cv. Arka Prajwal and in all the bulb stags of cv. Phule Rajani. For bulbs after three weeks of uprooting probable LD_{50} dose was 3.25 Gy in cv. Arka Prajwal and 10.25 Gy in cv. Phule Rajani. Non sprouting of Arka Prajwal bulbs at three weeks after uprooting beyond 2.5 Gy was supported by histological results. All three stages of bulbs have showed different response over gamma irradiation. In general, sprouting and all vegetative parameters (plant height, number of tillers per clump, number of leaves per clump, length of leaves and width of leaves) decreased over increased irradiation level. Freshly harvested bulbs responded comparably high to the gamma irradiation doses followed by bulbs after six weeks of uprooting in both cultivars. It was concluded that gamma irradiation dose 7.5 Gy to 11.5 Gy could yield attractive and useful mutants in tuberose.

Furthermore, Jyothi and Singh (2017) with above experiment (Jyothi and Singh, 2015) assessed the effect of flower and bulb parameters in M_1 generation. They reported that with increase in doses of gamma irradiation, gradual reduction in number of spikes, flower number, number of bulb, weight of bulb and bulb diameter was observed. In some cases lower dose was found simulative, while higher dose had inhibitory effect on morphological variation. Various macro mutations were scored for uniform flowering, reduced number of bulbs and spike number in M_1 population.

The mutants of VM_1 generation not found stable in VM_2 generation, but some more mutants from the maintained gamma irradiation population of VM_1 generation related to change in flower shape. In general, freshly harvested bulbs responded more to gamma irradiation. From this study, it has found that gamma irradiation level 7.5 Gy and 10.0 Gy were found optimal for mutation in cvs Arka Prajwal and Phule Rajani. Furthermore, based on experiment conducted by Jyothi and Singh (2015), Jyothi *et al.* (2019) reported that gamma radiation affected the sprouting in cv. Arka Prajwal where above 2.5 Gy there was no bulb sprouting observed.

This was supported by the histological study were cells become bigger in size, deformed shape of cell, complete damage of outer epidermal layer and cells with more vacuolation was observed. New mutants were isolated from VM_1 generation *viz.*, tall flowering mutant, dwarf mutant, flower colour mutant, double spike head mutant, eventhough these mutants were novel but they were not found stable in next generation. In VM_1

populations mutants were derived from the primary gamma irradiated population which was maintained after observing the gamma irradiation effect of VM_1 generation *viz.*, flower shape mutant, tall mutant, flower colour mutant, mutant with higher rachis length and variegated leaf mutant. This study revealed that freshly harvested bulbs of cvs Arka Prajwal and Phule Rajani are highly suitable for mutation induction either in vivo and also in vitro condition.

Bulbs of tuberose cv. Arka Prajwal were subjected to treatments at different doses of gamma rays (0.5, 1.0, 1.5, 2.0, 2.5 and 3.0 KR). Leaf abnormalities (life texture and chlorophyll variation) were noticed in 1.0 KR and 1.5 KR treated bulbs. Gamma rays at 0.5 KR resulted in economic traits namely, number of spikes per plant (three number) and number of florets per spike (55 Nos.) as reported by Kayalvizhi *et al.* (2016a). Jyothi and Singh in 2016 concluded that freshly harvested bulbs of Prajwal Na Phule Rajani responded more to gamma irradiation. Gamma radiation at 7.5 Gy and 10.0 Gy. Optimal for mutation induction in these two studied cultivars. Based on this experiment Kayalvizhi *et al.* (2017b) also reported that in gamma rays 1.0 and 1.5 KR treated plants produced chlorophyll mutants such as Striata and also broad leaf mutants observed in 1.5 KR gamma ray dosages. Gamma ray treated plants produced branched spikes in tuberose.

An experiment was conducted by Sah *et al.* (2017) to observe the influence of gamma dose i.e. 2 KR and 4 KR alongwith untreated control in different cultivars of tuberose. 4 KR dose of gamma ray bulbs do not sprout due to lethal effect. Maximum sprouting percentage was recorded with control followed by 2 KR dose of gamma irradiation. Early flowering was noticed due to gamma irradiation dose at 2 KR which was significantly earlier than control. Maximum internodal length of spike, duration of flowering and weight of bulbs was recorded in control than treated bulbs.

Ghosh *et al.* (2017) treated tuberose cv. Calcutta Single loose flower with gamma irradiation (0.01, 0.02, 0.05, 0.10, 0.50, 1.0 and 2.5 KGY) and generally regarded as safe (GRAS) flower preservative solution for extending shelf life. The flowers were packed in low density polyethylene bags, heat sealed and stored at 23±2oC, 80% relative humidity (RH) and ±1oC, 40% RH, respectively. Flowers stored at these two temperature regimes were subjected to sensory evaluation and biochemical analysis. From these assessments, the longest shelf life of loose flowers was found to be 8 days at 23±2oC, 80% RH (compared to 4 days for control) and 24 days at 4±1oC, 40% RH (compared to 8 days for control) using combination treatment of low dose gamma irradiation (0.02 kGY) and preservative solutions (4% sucrose and 0.02% $CaCl_2$)

Singh and Sadhukhan (2019) carried out an investigation to isolate some putative mutants in tuberose cv. Calcutta Double. Different doses of 60 co gamma rays (to bulbs) were applied. Mutation having tall and branched spike and other almost one and half times taller (1.6 m) than the untreated control (1.01 m) could be scored from 10 KR gamma ray treatment. The third mutant scored from bulbs treated with 10 KR gamma ray was a unique chlorophyll variegated leaf mutant designated as Pranta Rekha that has green leaves with white margins. The branched mutant will provide the advantage of harvesting more number of flowers at a time than the leaf variegated mutant would have ornamental values. New mutant genes could be scored therefore form the mutagen treated population in tuberose.

Navabi *et al.* (2016) irradiated the mature bulbs of tuberose with gamma irradiation dose from 10 Gy to 400 Gy. The results showed that at the dose treatment of 10 Gy, all plants sprouted with a time delay, and at doses of 50 and 100 Gy, 57% and 29% of plants were sprouted and grew, respectively. Though, at dosages of 200 and 40 Gy, none of the plants survived. In this experiment, changes in plant morphology were observed according to the different treatments, but no changes were observed in flower colour.

Abhang Rao *et al.* (2019) treated tuberose cv. Phule Rajan bulb with five doses of 0.5 Kr, 1.0 Kr, 1.5 Kr, 2.0 Kr and 2.5 Kr alongwith untreated sample (control). The results indicated that the mutagenic treatment at lower doses had significant stimulative effect on some parameters that is, sprouting of bulb percentage, leaf length, chlorophyll content, rachis length, spike length, number of opened florets whereas most of the parameters have showed decreased at desired content, that is number of days for bulb sprouting, survival percentage, plant height, leaf area, stem diameter, number of unopened florets, weight of flower. Higher doses of mutagen were determental for growth parameters and lower doses of mutagen were beneficial for quality parameters. Seven mutants were obtained in VM_1 generation.

Sharavani *et al.* (2019) exposed tuberose cv. Hyderabad Single bulbs to different doses of gamma

rays *viz.*, 0, 5, 10, 15, 20, 25 and 30 Gy representing treatments. The results revealed that sprouting percentage was 100% for control and 5 Gy treatments. Maximum plant height, number of leaves, leaf width and number of tillers were recorded for bulbs treated with 5 Gy followed by control plants recorded maximum leaf area and chlorophyll content. All bulb parameter (bulb-weight, diameter, number) were recorded maximum in control. By increasing the dose of gamma rays from 10 Gy there was a significant reduction in vegetative growth parameters. Variegated leaves and albino mutants were recorded for bulbs treated with 20 Gy.

Further more (Sharavani *et al.*, 2019b), to avoid excessive loss of actual experimental materials, radio-sensitivity tests were conducted to determine LD_{50} doses before massive irradiation of similar material. Tuberose cv. Hyderabad Single bulbs were exposed to six doses of gamma radiation (5, 10, 15, 20, 25 and 30 Gy) and 0 as control. Significant reduction of in floral parameters was observed with increased dose of gamma irradiation. Bulbs treated with doses 5, 10, 15, 20 Gy and control plants have shown flowering Control plants recorded maximum values for all floral attributes followed by 5Gy. The probit analysis based on sprouting percentage and mortality values for bulbs exhibited that LD_{50} value of gamma irradiation for tuberose cv. Hyderabad single was 20 Gy.

Tuberose bulbs were subjected to gamma radiation in order to identify variants with altered scent profile. The results indicated that significantly decreased in plants sprouted from bulbs exposed to higher dose of gamma rays. Floral volatile emission rate was increased in the lowest dose (10 Gy) as compared to control plants. The phenomenon of hormesis was observed in the plants since bulbs exposed to lower dose (10 Gy) showed enhanced growth rate, higher volatile content in comparison with control plants. Plants sprouted from bulbs exposed to higher dose of radiation showed lethal effects. In order to study genetic variation among control and plants sprouted from irradiated bulbs, inter simple sequence repeat marker analysis was also carried out and it was observed that out of 74 loci, 67 were polymorphic (90.54%). The genetic similarity coefficient values were also calculated among control and variant lines thus validating morpho-physiological variation (Kutty *et al.*, 2020).

Regar *et al.* (2021) studied the response of gamma radiation (2.5, 5.0, 7.5, 10.0, 12.5, 15.0, 17.5 and 20.0 Gy) alongwith control (untreated) on bulb and bulblet parameters of tuberose cv. Arka Prajwal. The results revealed that lowest decline trends were observed on bulb per clump (2.73, 14.69), bulb fresh weight (68.67 g, 73.86 g), clump weight (275.06g, 574.90g) and propagation coefficient 507.91%, 673.68%) parameters at 2.5 Gy gamma irradiation in V_1M_1 and V_1M_2 generation respectively as compared to control.

Regar *et al.* (2021) Studied the effect of gamma irradiation on bulb and bulblet parameters of tuberose cv. Pearl double. They found that there was increased bulbs per clump which was directly correlated with the fresh weight of the bulb. Same trend was observed in number of bulblets obtained and fresh weight of it. Over all there was increased propagation ecoefficiency at 2.5 Gy. Gamma irradiation.

Regar *et al,* (2022) investigated the response of gamma irradiation on vegetative parameters of tuberose Cv. Pearl double. It has been observed that declining trend in 50% sprouting and sprouting percentage and also in plant survival. In the other way there was an increased in plant height from 35.53 cm to 44.30 cm was observed along with increased number of leaves, leaf length and leaf width at 2.5 Gy radiation. The growth parameters of Cv. Pearl double showed decline trend at 20 Gy. Gamma radiation.

In tuberose, genetic improvement techniques developed in Iran generated mutant forms for flower length and weight from irradiating mature tuberose bulbs with 10 Gy of 60 co gamma rays (Navabi *et al.*, 2016). In India two mutants namely Rajat Rekha and Swarn Rekha with leaf variegation were developed and released (Datta, 2019).

Mutation induction by chemical mutagens

Ethyl methane sulphonate ($CH_3SO_2OC_2H_5$, molecular weight 124.16) among chemical mutagents is the most potent mutagent. It acts as a selective mutagen and induces lethal mutations in lower frequency as compared to gamma rays. It produces random mutations in genetic material by nucleotide substitution, particularly by guanine alkylation (Kayalvizhi *et al.*, 2017). In tuberose, gamma rays were exhibiting more mutagenic efficiency than EMS (chemical mutagen) as far as commercial values are concern (Singh and Sadhukhan, 2019).

Bulbs of three cultivars i.e. Calcutta Double, Arka Prajwal and Arka Shringar of tuberose were subjected to mutagenic treatments with 0.5% and 0.25% of ethyl methane sulphate (EMS) for inducing mutations in quantitative and qualitative characters. Immediate effects of the mutagen were evident with respect to some

quantitative characters induced mutations leading to anatomical changes were evident in all three cultivars to untreated control variation was also exhibited in the structural organization of stomata (Singh and Sadhukhan 2013).

Singh *et al.* (2015) treated bulbs of three cultivars i.e. Calcutta Double, Arka Prajwal and Arka Shringar of tuberose with 0.25%, 0.50% and 1% (V/V) ethyl methane sulphate (EMS) concentrations. The results revealed that there was significant reduction observed for sprouting of bulbs, leaf area, spike length and diameter, flower size, number of florets per spike and flower fresh weight in all three cultivars treated with higher dose (1%) of EMS. However number of leaves was increased significantly in most of the EMS treatment and maximum number of leaves was found in 0.5% treatment as compared to their respective control. Minimum sprouting was noticed with higher dose (1%) treatment. Pollen sterility also increases with increasing dose of EMS in both Arka Prajwal and Arka Shringar. Among the cultivars Calcutta Double appeared to be more sensitive to EMS as compared to Arka Prajwal and Arka Shringar.

An investigation was carried out by Kayalvizhi *et al.* (2016b) on the induction of mutation in tuberose cv. Arka Prajwal with the objective of examining the effect of chemical mutagens *viz.*, diethyl sulphate (DES) @ 15, 20, 25 and 30 mM and ethyl methane sulphonate (EMS) @ 30, 45, 60 and 75 mM on bulb sprouting, survival percentage and growth parameters. The results revealed that lower doses (15 mM of DES and 30 mM of EMS) were found to favour bulb sprouting and growth parameters of plants. In general, variations in floral characters were observed invariably in all the treatments except control treatment. The LC_{50} values fixed for the chemical mutagens were 25 mM for DES and 60 mM for EMS. It was observed that lower doses of mutagents had recorded higher values for studied morphological parameters (plant height, number of leaves, leaf length and leaf width) and floral parameters (number of florets per spike) spike length, number of spikes per plant, floret length, floret diameter and single floret weight) than untreated control in M_1V_1 generation.

Kaintura *et al.* (2016) conducted an experiment on four cultivars of tuberose *viz.*, Kalyani Single, Kalyani Double, Arka Suvasini and Arka Prajwal to study the mutagen effectiveness of ethyl methane sulphate (EMS) by treating the healthy and uniform bulbs with different doses 0.1% and 0.2% alongwith untreated bulbs as control and evaluated for various vegetative and floral parameters. The findings of the experiment showed that the treatment of EMS at lower dose (0.1%) had significant simulative effect on vegetative parameters *viz.*, sprouting percentage, days to sprouting, while the parameters pertaining to survival rate, leaf length, number of spikes per plant, number of florets per spike, flowering duration and vase life were observed with decreasing trend. High doses had determental effect on studied vegetative and floral parameters.

Kayalvizhi *et al.* (2017b) carried out an experiment on the improvement of tuberose cv. Arka Prajwal through chemical mutagens. The bulbs were treated with diethyl sulphate (DES) ($C_2H_2O_2SO_2$) and ethyl methane sulphate (EMS). The treatment consisted on 15, 20, 25 and 30 mM of DES and 30, 45, 60 and 75 mM of EMS and control (untreated). The results revealed that in general, the treated population had mainifested reduced expression than the control (untreated population) for most of the morphological and floral characters. Higher the dose of mutagens, lower was the expressivity of the traits. Expression of the morphological characters namely, plant height, number of leaves, leaf length, leaf width and leaf thickness increased in the lower doses and decreased in the higher doses in M_1V_2 generation. As chimerism and genetic variability play a key role in the variation observed in mutation treated population, there is a need to identify solid mutants in the future generations. Kayalvizhi *et al.* (2017a) reported that tuberose cv. Arka Prajwal bulbs were treated with chemical mutagen DES at different doses. Nine tepal florets were observed in 30 mM of DES and eleven tepal floret was observed in 15 mM of DES.

Yadav *et al.* (2018) carried out a study in tuberose cv. Arka Prajwal with five treatments (concentrations) of ethyl methane sulphonate (0, 0.25, 0.50, 0.75 and 1.0%) and with three bulb dipping durations (5 min., 4 h and 8 h) resulting in 15 treatments. The results showed that with treatments of bulbs with EMS the number of days taken to initiation of sprouting, complete sprouting, days taken to spike emergence decreased at lower concentration of EMS (0.25%) but at higher doses they delayed the initiation parameters. The lower concentration of EMS (0.25%) also increased plant height, number of leaves, decreased length of leaves while higher doses increased length of leaves and reduced number of leaves and plant height. The dipping duration of 8h was reported effective to increase plant height, number of leaves and reduce length of leaves.

The interaction effect was found highest in treatment combination of 0.25% EMS with 8 h dipping duration for vegetative growth parameters. The interaction effect was non-significant for days to complete sprouting, spike emergence and plant height. With same treatments and treatment combinations (Yadav *et al.*, 2018) in tuberose cv. Arka Prajwal.

Yadav *et al.* (2022) reported that treatment of bulbs with EMS at 0.25% for 8h dipping duration was found best for increase in spike length, rachis length, spike weight, number of opened florets, number of unopened florets and number of spike per clump. Besides that earliness with respect to number of days taken for opening of first florets. Treatments of bulbs with 0.50% EMS for 4h dipping duration in EMS solution shows an increase in number of bulbs per clump, diameter of bulb and weight of bulb. Lower doses of EMS coupled with shorter dipping duration seems promising for extending the vase life of cut flower.

Mean lethal dose or mean reductive dose or median lethal dose-50 (LD_{50})

This dose is the one that reduces survival and growth to 50% in relation to the control treatment and is where most mutations are obtained. Some researchers recommend an interval of 20% higher and lower, while others state that the optimal dose should also lead to the survival of 40 to 60% of the treated material with respect to the untreated material.

According to Jyothi and Singh (2015) the total number of tuberose plants survived among the sprouted bulbs in each treatment was recorded. LD_{50} (Lethal dose-50) was determined on the basis of the plants survived in each treatment.

The survival percent of bulb was calculated using formula given below:

$$\text{Percent survival} = \frac{\text{Total number of bulbs survived}}{\text{Total number of bulbs planted}}$$

Datta (2017) has given LD_{50} value of gamma rays to tuberose (bulb) from 250 Krad to 8 Krad. Jyothi and Singh (2015) calculated the LD_{50} dose for freshly harvested bulbs of tuberose cvs. Arka Prajwal and Phule Rajani. The LD_{50} dose for freshly harvested bulbs of cv. Arka Prajwal was 10.25 Gy and for cv. Phule Rajani it was 11.25 Gy. In three weeks after uprooted bulbs LD_{50} dose was 3.25 Gy for cv. Arka Prajwal and 10.25 Gy for cv. Phule Rajani. The LD_{50} dose for six weeks after uprooted bulbs of cv. Arka Prajwal was 10.25 Gy and for cv. Phule Rajani it was 11.25 Gy. Kayalvizhi *et al.* (2016 b) fixed LD_{50} values for chemical mutagens 25 mM for DES and 60 mM for EMS in tuberose cv. Arka Prajwal. Also Kayalvizhi *et al.* (2016a) fixed LD_{50} value in tuberose cv. Arka Prajwal for gamma rays 2.13 kR (physical mutagen). By increasing the dose/concentration of physical and chemical mutagens beyond LD_{50}, decreased in sprouting percentage of bulbs, survival percentage, plant height and number of leaves per plant decreased. According to Sharavani *et al.* (2019b) the probit analysis based on sprouting percentage and mortality of treated bulbs exhibited that LD_{50} value of gamma irradiation for tuberose cv. Hyderabad single was 20 Gy.

Cytological studies in tuberose for realization of mutation

In one of the study it was reported that 1500 gamma radiations was found to be effective on chromosomal aberrations of root tip mitosis in tuberose cvs. Mexican Single and Pearl Double.

Conclusion

The uses of physical and chemical mutagens in tuberose (*Polianthes tuberosa* Linn.) have shown to be very effective under many qualitative and quantitative parameters. Therefore, mutation breeding has been regarded as a complementary or an alternative method to conventional breeding using physical and chemical mutagens. This has proved to an effective tool for enhancing genetic variability, thus creating grater chances for selection. Several factors should be considered when selecting mutagen treatment conditions. Although chemical mutagens are relatively inexpensive and require little sophisticated equipment, they are regarded as having inferior ability to penetrate deeply into plant tissues or thick seeds.

However, physical mutagens provide consistent treatments but require access to radiation sources, such as X-ray machines, gamma sources, particle accelerators, or nuclear reactors. Other advantages of physical mutagens include easy post-treatment handling of plant tissues or seeds, the ability to treat pollen grains and other fragile materials and the lack of toxic and carcinogenic waste. Another reasons why EMS or other chemicals may be tried in some cases is the fact that they mostly cause single base substitutions, possibly resulting in a series of phenotypically distrinct change of a function mutants for a particular trait. In contrast, physical mutagens usually cause deletions resulting in loss of function mutants. Previously reported experiences with tuberose are valuable

when starting mutation breeding for a new species or cultivar. Initial doses can be based on those experiences, thereafter, the treatment conditions may be fine-tuned because different mutagens have different mutagenic efficiencies.

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Research Article

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Ethno-botanical study of plants used by *Kodava* tribes in Kodagu district of Karnataka

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Abstract

The ethnic knowledge on medicinal value of major plants *viz. Justicia wynaadensis, Remusatia vivipara,* and *Bambusa bambos* consumed by *Kodava* tribes in Kodagu District of Karnataka, India was carried out to preserve the herbal/medicinal plant wealth and their proper usage, as there is a decline in human expertise to identify and recognize various medicinal plants. Data were documented using conventional ethnobotanical methods such as interviews and discussion with local populace of *Kodava* tribals (headmen, healers, and elderly persons) of the study area using a semi-structured questionnaire comprising information about plants and their local names, plant parts used, time of usage, method of sample collection and preparation of dishes, their nutritional and their use in traditional folk medicines, and any other specific comments. The study indicated that *J. wynaadensis,* locally known as *Maddh toppu* or *Kurinji Toppu* or *Aati soppu,* undergoes a mysterious transformation in terms of chemical constituents during wet and dark months of the monsoon, which is responsible for its medicinal values. During *Kakkada padinet*, *Kodava* people consume *Maddu Payassa* prepared from *J. wynaadensis* and believe that it generates heat and stabilizes the body temperature, and thus gives resistance against fever and cold during monsoon season. The *R. vivipara* is known as *Mara Kesa,* is used in folk medicine to cure inflammation, arthritis, to dispel worms and germs for disinfecting the genito-urinary tract. The consumption of newly emerged bamboo shoots (*B.bambos*) along with mushrooms is said to balance the body temperatures during heavy rainy days. In summary, the participants of the study underlined that these underutilized vegetables, major components in traditional dishes, offer enhanced nutritional and medicinal values when consumed especially during the monsoon season.

Key words: Ethnic knowledge, Folk medicine, Inflammation, Kodava tribes, Leafy vegetables, Medicinal value.

The interaction between human societies, particularly, tribals and aboriginals who are considered as primitive human societies with their surrounding flora was the core objective in ethnobotanical studies. As the Indian subcontinent is flourished with rich biodiversity (Zeven and de Wet, 1982; Arora, 1988) and vast heritage of about 705 diverse ethnic groups in different states of the country (Mamo, 2021), it is considered one of the major sites with ethnobotanical wealth in the world and attracts many researchers and environmentalists throughout the world. In the Indian subcontinent, about 5000 tribal-based villages are covering about 15% of the total geographical area. Ethnic communities residing in a particular region solely depend on natural resources available around them for their food, shelter, and traditional medicine.

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Of the endemic species, 1,600 are in the Western Ghats alone (Tripathi *et al*., 2018). Documentation of traditional knowledge is considered vital in order to preserve the herbal/medicinal plant wealth and their proper usage, as there is a decline in human expertise to identify and recognize various medicinal plants. The documentation of wild edible plants of Andaman and Nicobar islands by tribal population is essential for conservation and effective utilization of these plant genetic resources in future (Sharma *et al*., 2020).Though, literature is available on these crops pertaining to their medicinal values, ethnic knowledge on crops are scanty. To address this issue, study was carried out to collect the traditional knowledge of these herbs/plants which are consumed as a vegetable and have plenty of medical values.

Materials and Methods

Kodagu (Coorg) occupies a prominent position in humid tropical belt of Western Ghats and is situated to the South West in Karnataka on 12°26'

N latitude,75°47' E longitude covering an area of 4104 km^2 and altitude of 1525 MSL with an average rainfall of 2718 mm and the average temperature of 13 - 26 °C. Kodagu falls in high precipitation zone with picturesque topography. Major part of the year consists of rainy season starting in June till the end of September. Even in the post monsoon months of October and November, certain parts of the district receive a significant amount of rainfall. The district comprises three taluks, *viz.,* Madikeri, Somwarpet and Virajpet. The survey work was carried out to study the ethno-botany of three nutritionally rich medicinally important leafy vegetables (*Justicia wynaadensis, Remusatia vivipara* and *Bambusa bambos)* used by Kodavas in all three taluks, to ascertain the medicinal importance and other valuable information. Kodavas are the people from old civilization living in Kodagu with distict culture, heritage and life style of their own.

Data were collected from the local populace of *Kodava* tribals (headmen, healers, and elderly persons) and the persons having a thorough knowledge of different plants. A field survey was conducted in three Taluks (Madikeri, Somwarpet, and Virajpet) of Kodagu where the *Kodava* tribal community resides. For the collection and augmentation of data, conventional ethnobotanical methods endorsed by Botanical Survey of India were followed. The information about the three selected crops ((*Justicia wynaadensis, Remusatia vivipara* and *Bambusa bambos)* was collected through conducting interviews and discussion with knowledgeable elder people of the study area using semi-structured questionnaire comprising the information about plants and their local names, plant parts used, time of usage, method of sample collection and preparation of dishes, their nutritional and their use in traditional folk medicines, and any other specific comments. The specimens were collected and identified by referring to a standard flora (Murthy and Yoganarasimhan, 1990).

Results and Discussion

Justicia wynaadensis

The plant *Justicia wynaadensis* is locally known as *Maddh toppu* or *Kurinji Toppu* in *Kodava* parlance and as *Aati soppu* in Kannada. *J. wynaadensis* was reported as endemic to the rainforest region of the Western Ghats and Coorg. They are commonly found in wild throughout the district and some grow at home. It is highly believed that the wet, dark months of the monsoon bring about a mysterious transformation in terms of chemical constituents in the plant. These leaves are said to be replete with 18 types of medicinal values.

Justica is a small climbing herb, with a slender stem 2-3 m long with distant nodes (Fig. 1a). Leaves are 5-10 cm long, elliptic-lance in shape, long-pointed, base narrow, with 6-8 pairs of veins and oppositely arranged. Leaf petiole is 1-2 cm long. Flowers are borne in pairs on drooping spikes 5-10 cm long (Fig. 1b). Bracts are ovate, 3-5 mm long. Sepals are linear, stamens are 2 with dilated filaments. Style is thread-like, with two-parted stigma. The plant flowers during December-February.

Fresh leaves (Fig. 1c) with stem collected during 17th day of the *kakkada* month (first week of August every year)

The leaves are plucked and soaked (some boil it) in

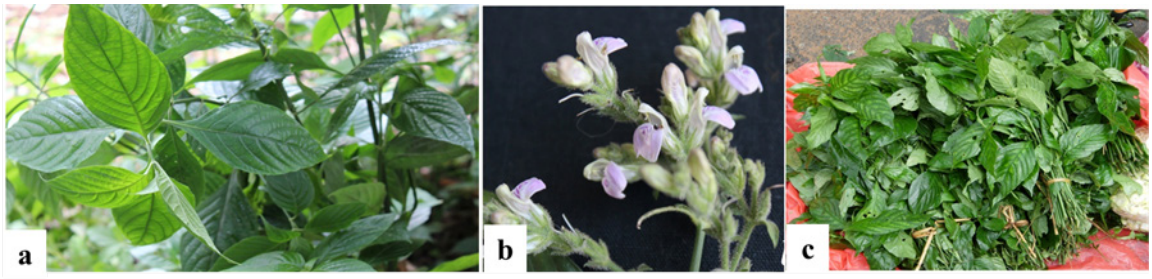

Fig. 1: (a) *Justicia wayanadensis* in Kodagu, Karnataka, India; (b) crop in flowering;(c) bundle of leaves sold in market of Madikeri, Kodagu, Karnataka

water overnight to extract the aromatic juice, which is thick and dark pinkish- violet in colour. Women make cakes or sweet porridge out of the mix, called "*Maddu Payasa,*" in households on the 18th day of the *Kakkada* month.

Collection of stem and leaves on the 17th day of kakkada month

(first week of August every year)

↓

Fill ¾th of a large vessel with the maddu thoppu (plucked stems and leaves) and soak with fresh water and cook on a very gentle heat for about 1 ½ to 2 hours

↓

the stem and leaves should be immersed in water at all times.

Keep the extract in the vessel overnight

↓

Strain and reserve the aromatic juice (extract), which is thick and dark pinkish- violet in colour and discard the stems and leaves

↓

The extract is used to prepare various dishes

("*Maddukuul*", which is simply rice cooked in to the extract,

"*Maddupayasa*", sweetened jaggery rice cooked into the extract,

"*Madduputtu*", an unsweetened rice cake prepared out of the extract

that is eaten with ghee and honey.)

Flow chart of preparation of delicious *Maddu Payasa*

In traditional functions of *Kakkada padinet*, local people mainly consume *Maddu Payassa* (Fig. 2.) prepared from *Maddh toppu*.

During the 18th Day of *Aati masa* (First week of August), Kodava people celebrate *Aati Padinema* (Dakshina Kannda) or *Kakkada Padinet* (Kodagu), which is the beginning of agricultural activities. On this particular day, people prepare a sweet and delicious

Fig. 2: Maddu payasa prepared from *aadi soppu (maddu soppu)*

dish from the leaves of *J. wynaadensis* and consume it.

A typical juice can be produced from all the parts of the plant *i.e* leaves, stems and twigs of *J. wynaadensis*. It generates heat and stabilizes the body temperature. This extract has the medicinal value, which gives resistance against fever and cold. Overnight preparation is given to the children at 5 o'clock in the early morning and it acts as deworming agent. *Aati soppu* has a great medicinal value in purifying blood as well. Person who is suffering from urinary tract infection is advised to consume one glass of the aati soppu juice, which helps in subsiding the infections. It is said that drinking *aati soppu* soup keeps urinary track clean *Kodavas* believe it as a herbal or ayurvedic tonic (Table 1). This traditional practice is believed to keep the people healthy throughout the year. Phyto-components presents in *J. wynaadensis* lend credence to its use by the local community as a plant with 'medicinal properties' and hold promise for the production of novel pharmaceuticals as well as a nutraceutical.

Remusatia vivipara

Remusatia vivipara (Roxb) Schott is an epiphytic species belongs to the family Araceae. It is one of the unexploited vegetable plants, used for its edible corms, stems and leaves. In India, it is distributed in the Himalayan region and the Western Ghats of central South India and Maharashtra region. In South India, it is commonly found in states of Kerala and Karnataka. In vernacular language it is known as *Mara Kesa*. The leaves and tubers are extensively used in folk medicine. This plant grows luxuriantly in the crevices and on tree tops (Fig. 3a,b) during monsoon season (June to September) .

Plants are small tuberous herbs, tuber up to 1 cm across, leaf solitary, 6-10 cm across, orbicular, peltate, membranous, rounded at apex, shallowly cordate at

Table 1. Traditional medicinal benefits of *Justicia wynaadensis* as described by *Kodavas*

Plant/herb	Habitat	Plant parts	Medicinal benefits
Justicia wynaadensis	Bushy shrub, shade loving	Leaves, stems and twigs Most effective on 18th day of *kakkada* month	• generates heat and stabilizes the body temperature • effective in treating cold, fever and headache • deworming agent • cleansing of the urinary track • blood purifier • restricted use for people suffering from gastric problem

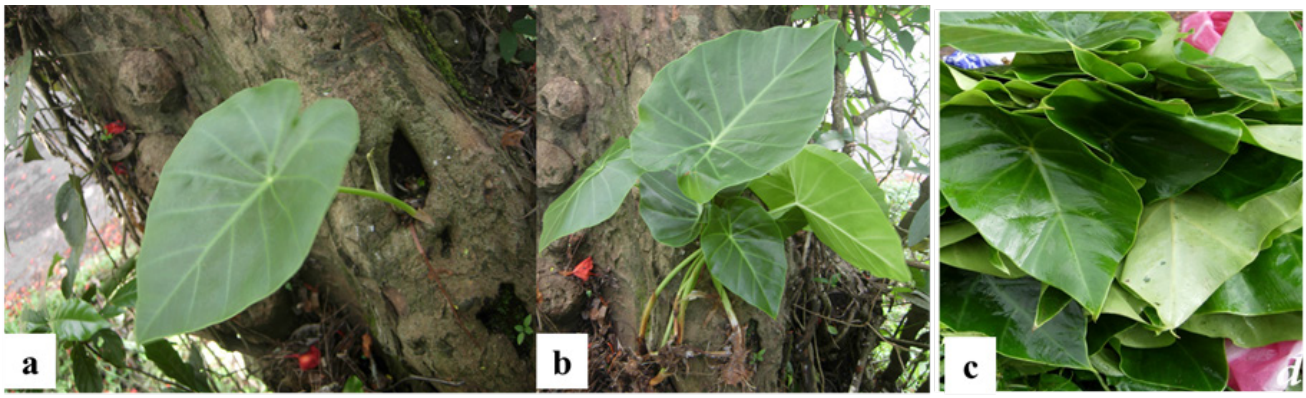

Fig. 3: (a, b) *Remusatia vivipara* grown in crevices on tree; (c) bundle of leaves sold in market of Madikeri, Kodagu, Karnataka

base, leaves dark green above and light green beneath, large arrowhead shaped leaves, petiole 6-11 cm long (Fig. 3c). Corms, stems and leaves are the edible parts.

Method of preparation

Usually the tender leaves are picked fresh for preparations. The strings from the stem are removed and cut it into small pieces for preparing dishes. Special types of dishes (*kaymbu* curry) are prepared out of its leaves and leaf petiole. Further, *Mara kaymbu* leaves are also used adjacent areas and favoured of patrode popular in Mangalorean and Konkani cuisine.

Leaves and tubers are the edible parts. It is consumed by the inhabitants of Kodagu as a source of food. It is rich in vitamins, sugars and quinines. The plant is used in folk medicine to cure inflammation, arthritis, to dispel worms and germs for disinfecting genito-urinary tract and for promoting conception, also used as an analgesic (Table 2). It has ayurvedic properties such as general debility and alleviating kapha and pitta. Apart from use as vegetable, the leaves are extensively used in local tribes for the treatment of inflammation, arthritis, analgesic, on the wound to dispel any worms and germs, for disinfecting genitourinary tract and for promoting conception, whooping cough and for the treatment of reddish boils.

Bambusa bambos

The edible bamboo shoot is locally called "*Watte baimbale*" (bamboo shoot) or *'Kanile'* and much loved and enjoyed delicacy of *Kodavas* during the monsoon season. Though most varieties of bamboo have edible shoots, the common ones in Kodagu is spiny or thorny bamboo (*Bambusa bambos* (Druce) / *B. arundinacea* (Retz.) Willd).

Bambusa bambos is a tall, bright-green colored spiny bamboo species, which grows in thickets consisting of a large number of heavily branched, closely growing culms (Fig. 4a). It grows up to the height of 10–35 m and is mainly distributed naturally in dry zones of forest. Each clump is characterized by stout and curved spined arms. They are bright green, turns brownish green upon drying, and the young shoots are deep purple. Internode length is 15–46 cm, and diameter is 3.0–20 cm. Culm walls are 2.5–5.0 cm thick. Nodes are prominent and rootstock is stout. Newly emerged shoot (Fig. 4b, 4c)

Newly emerged shoot are harvested from clumps during late May-August and processed by soaking in water for a minimum of 24 hours to get rid them of hydrocyanic acid. The shoots are then soaked in fresh water and allowed to undergo a light fermentation, which gives them an appealing tangy edge. Prepared shoots are eaten in curries and fries, pickled, or preserved in brine for later use. The slender shoots of watte baimbale

have a delicate, asparagus-like tenderness. They taste particularly good when cooked with minced meat. Tender bamboo shoot preparations are perfectly spiced for pairing with akki rottis and a touch of ghee

Time of use: During May-August, especially during the heavy rainy season.

According to the Kodava community, the consumption of bamboo shoots along with mushroom is said to balance the body temperatures during heavy rainy days. Consumption of dishes prepared out of bamboo shoots is preferred, when people fall sick to cold during monsoon season, and it is believed that these foods help to increase immunity. *Bambusa bambos* have been widely used in Indian folk medicine for anti-inflammatory, laxative, astringent, diuretic, anti-ulcer and anti-obesity activities (Table 3).

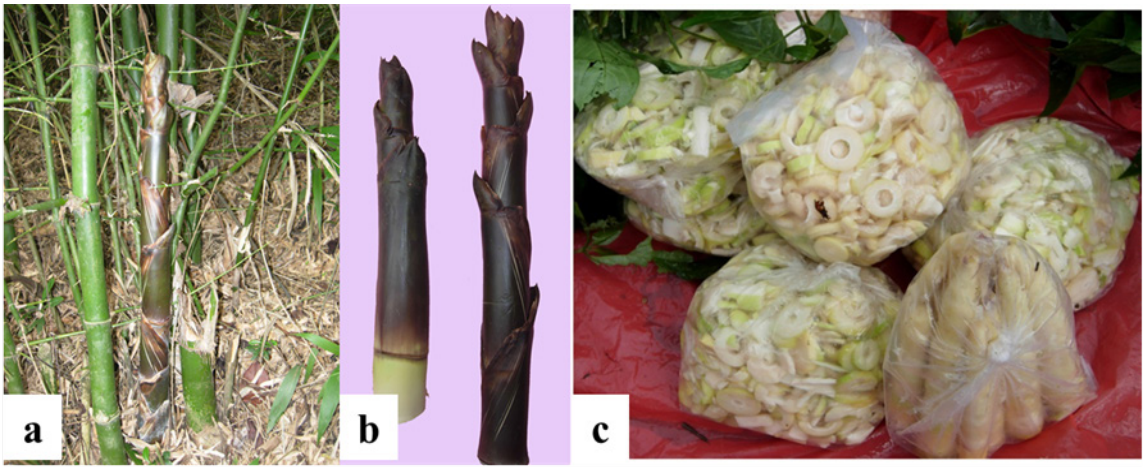

Fig. 4: (a) *Bambusa bambos*; (b) immature stems used as vegetable; (c) bundle of cut tender stems sold in market of Madikeri, Kodagu, Karnataka

Table 2: Traditional medicinal benefits of *Remusatia vivipara* as described by *Kodavas*

Plant/herb	Habitat	Plant parts	Medicinal benefits
Remusatia vivipara	Herb epiphytic species	Leaves and tubers	The leaves are extensively used in folk medicine for the treatment of • inflammation • arthritis • analgesic • on the wound to dispel any worms and germs • disinfecting genitourinary tract • conception • whooping cough • reddish boils The tubers are strongly poisonous but used externally to treat • breast mastitis • abscesses • ascariasis

Table 3: Traditional medicinal benefits of *Bambusa bambos* as described by *Kodavas*

Plant/herb	Habitat	Plant parts	Medicinal benefits
Bambusa bambos	Tree, tall, grows in thickets consisting closely growing culms	Newly emerged shoot	• balance the body temperatures during heavy rainy days • increase the overall immunity • anti-inflammatory • laxative • astringent • diuretic • anti-ulcer • anti-obesity activities.

Conclusion

This study revealed that knowledge on three leafy vegetable species is open to everybody, which helps to secure knowledge continuity and future development and conservation of plans. However, loss of indigenous knowledge on leafy vegetables may occur if the resources disappear from the landscape. Thus, documentation of traditional knowledge and conserve these wealth is important besides working towards minimizing the threatening factors for these species. Moreover, it is crucial to work towards developing technologies that increase the productivity of such crops with medicinal value considering farmers prioritized requirement.

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Efficient *in-vitro* regeneration protocol in chrysanthemum (*Chrysanthemum morifolium*) from ray florets

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Abstract

The experiment was conducted to standardize regeneration protocol from ray florets in chrysanthemum cv. Pusa Arunodaya (TQP-06). For callus induction, the highest callusing percent (82.67%) with a minimum number of days for callus initiation (10.87 days) was observed in MS medium supplemented with Kinetin (10 mg/l) + NAA (1.0 mg/l) in treatment (T_3). Highest shooting percent (69.33 %) with minimum number of days for shoot initiation (6.27 days) along with maximum number of shoots per explant (5.67 shoots) in MS medium supplemented with Kinetin (5.0 mg/l) + NAA (1.0 mg/l). In shoot proliferation, the highest number of shoots after 30 days (51.67), 60 days (72.00), and 90 days (98.67) in MS medium supplemented with Kinetin (5.0 mg/l) + NAA (1.0 mg/l). The highest rooting percent (85.00%) with least days for root initiation (7.00 days) along with maximum roots per shoot (8.00) and optimum root length (5.00 cm) in MS medium supplemented with IBA (0.2 mg/l). The rooted plants were successfully acclimatized in 3-4 weeks and survived under field conditions.

Key words: Chrysanthemum, *in-vitro,* ray florets, callus induction, regeneration, proliferation.

Chrysanthemum (*Chrysanthemum morifolium* Ramat) is vital cut flower in international markets and is placed in second place in the global cut flower trade (Datta and Gupta, 2012). It is from the Asteraceae family and is an important traditional flower that can be used as both loose and cut flowers (Lone and Shah, 2013).

India has commercially released 46 mutant cultivars of chrysanthemum (Verma and Prasad 2019). Micropropagation, an *in-vitro* method, has the ability to quickly produce a significant amount of healthy, disease-free and true-to-type stock (Karn *et al.* 2022). Different explants were used for shoot organogenesis and plant regeneration like petal, leaf and stem (Xue *et al.,* 2004; Nahid *et al.*, 2007) to improve the micropropagation rate. However, there are very few examples of new mutants being successfully established in chrysanthemums using irradiation and *in-vitro* regeneration techniques (Prasad *et al.*, 2008). Therefore, Pusa Arunodaya (TQP-06) which is a mutant developed by gamma irradiation from cv. Thai Chen Queen was used.

Materials and Methods

The explants were collected from fully mature flowers of Pusa Arunodaya (TQP-06) which were maintained at Research Farm of ICAR Directorate of Floriculture Research (DFR), Pune. The explants were washed with detergent (Tween 20) solution for 4-5 minutes, and washed with double distilled water 2-3 times then treated with fungicide (carbendazim) for 30 minutes, followed by 3-4 washings of double distilled water. During inoculation explants were surface sterilized with 0.1% $HgCl_2$ solution for 2-3 minutes and immediately rinsed with double distilled water 3 times to remove all traces of $HgCl_2$. The pH of medium was adjusted to 5.8 before autoclave (121^{0}C for 20 minutes) and the medium was solidified by the addition of agar (0.8%).

The surface sterilized ray florets were inoculated on MS medium supplemented with different concentrations of cytokinins, i.e. kinetin (7.5 and 10.0 mg/l) or BAP (2.0, 3.0 and 6.0 mg/l) along with NAA (0.1, 0.2, 0.5 and 1.0 mg/l) and 2, 4-D (1.0 mg/l). MS medium supplemented with different concentrations of cytokinins, i.e. kinetin (5.0 mg/l) or BAP (2.0 and 5.0 mg/l) along with NAA (0. 5 and 1.0 mg/l) was used for micro-shoots regeneration from ray florets and MS medium supplemented with different concentrations of cytokinins, i.e. kinetin (5.0 mg/l) or BAP (2.0 and 5.0 mg/l) along with NAA (0.5, and 1.0 mg/l) was used for shoot proliferation.

Half-strength and full-strength MS medium supplemented with different concentrations of auxins, indole butyric acid (IBA) (0.1 and 0.2 mg/l) were used

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for *in vitro* rooting to the well-developed and elongated shoots. The experiments were laid out in a completely randomized design (CRD). Each treatment had 15 units with three replications and rooting had 20 units with four replications. All the percentage values were arcsine transformed and counted data below 10 was square root transformed before calculating ANOVA. The data having common superscripts are statistically non-significant or otherwise significant.

Results and Discussion

Callus induction : The callusing (82.67 %) was observed after 10.87 days when the surface sterilized and pinched (wounded) ray florets were cultured on MS medium supplemented with Kinetin (10 mg/l) and NAA (1.0 mg/l) (T-3) as compared to those cultured on other media (Fig-1). Present findings are in line with those of Kumar *et al.* (2012). Kumar *et al.* (2017) and Verma and Prasad (2019) reported that wounded parts of ray florets showed faster callusing as compared to those inoculated without wounding (Table 1).

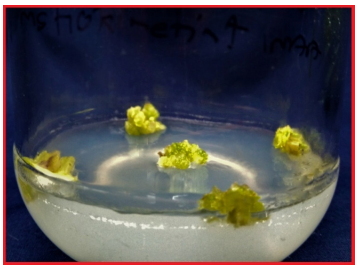

Fig. 1: Callus induction

According to Verma and Prasad (2019), kinetin and NAA in combination in the culture medium resulted in highest callus initiation with a good morphogenic response from nodal and ray floret explants in chrysanthemum. The present results on survival and callusing percentage confirm with earlier findings of Nahid *et al.* (2007) and Kumar *et al.* (2017).

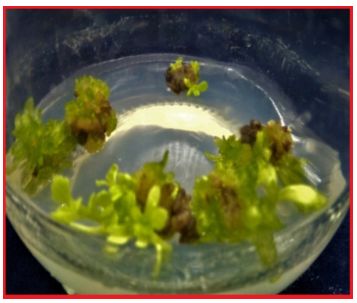

Fig. 2: Shoot regeneration

Micro-shoot regeneration and shoot proliferation: Data shows highest regeneration (69.33 %), maximum number of shoots/explant (5.67) in minimum days for shoot initiation (6.27 days) in ray florets cultured on MS medium supplemented with Kinetin (5.0 mg/l) and NAA (1.0 mg/l) as compared to those cultured on other media (Fig. 2 and Table 2). Similar results were obtained by other workers working on chrysanthemums (Kumar *et al.,* 2012, Kumar *et al.*, 2017 and Verma and Prasad 2019).

Table 1: Effect of BAP, Kinetin, 2, 4-D, and NAA on callus induction

Treatment	Medium	Callusing (%)	Days required for initiation
T_1	MS blank (control)	0.000 (0.00)	0.000
T_2	MS+ Kinetin (10 mg/l) + NAA (0.5 mg/l)	77.33^{cdc}(61.69)	12.53^{b}
T_3	MS + Kinetin (10 mg/l) + NAA (1.0 mg/l	82.67^{e} (65.40)	10.87^{a}
T_4	MS + Kinetin (7.5 mg/l) + NAA (0.5 mg/l)	72.00^{abc}(58.07)	13.27^{c}
T_5	MS + Kinetin (7.5 mg/l) + NAA (1.0 mg/l)	80.00^{de}(63.48)	12.47^{b}
T_6	MS + BAP (2.0 mg/l) + NAA (0.1 mg/l)	68.00^{a}(55.64)	13.73^{c}
T_7	MS + BAP (2.0 mg/l) + NAA (0.2 mg/l)	70.67^{ab}(57.26)	13.60^{c}
T_8	MS + BAP (3.0 mg/l) + 2, 4-D (1.0 mg/l)	74.67^{bcd}(59.98)	13.20^{c}
T_9	MS + BAP (6.0 mg/l) + 2, 4-D (1.0 mg/l)	81.33^{e}(64.48)	11.93^{b}
	C.D. @ 0.01	6.27	0.62
	S.E. (m) ±	2.10	0.21
	C.V. (%)	6.72	3.18

Table 2: Effect of BAP, Kinetin, and NAA on shoot regeneration

Treatment	Medium	Shoot Regeneration (%)	Days for initiation of shoots	Shoots/ explant
T_1	MS Blank (control)	0.00 (0.00)	0.000	0.000 (1.00)
T_2	MS + BAP (2.0 mg/l)	45.33^{a} (42.30)	10.07^{d}	2.47^{a} (1.90)
T_3	MS + BAP (2.0 mg/l) + Kinetin (1.0 mg/l)	48.00^{ab} (43.83)	9.80^{d}	2.73^{a} (1.93)
T_4	MS + BAP (2.0 mg/l) + Kinetin (0.5 mg/l)	49.33^{bc} (44.60)	9.73^{cd}	2.80^{a} (1.95)
T_5	MS + BAP (5.0 mg/l) + NAA (0.5 mg/l)	52.00^{cd} (46.13)	8.87^{c}	3.80^{b} (2.20)
T_6	MS + BAP (5.0 mg/l) + NAA (1.0 mg/l)	53.33^{d} (46.90)	7.33^{b}	4.20^{b} (2.28)
T_7	MS + Kinetin (5.0 mg/l) + NAA (0.5 mg/l)	57.33^{e} (49.20)	6.33^{a}	4.33^{b} (2.31)
T_8	MS + Kinetin (5.0 mg/l) + NAA (1.0 mg/l)	69.33^{f} (56.36)	6.27^{a}	5.67^{c} (2.60)
	C.D. @ 0.01	2.74	0.89	0.14
	S.E. (m) ±	0.91	0.29	0.05
	C.V. (%)	3.81	6.99	3.90

The direct adventitious micro-shoot regeneration begins with cells that are located either in the epidermis or just below the surface of explant which apparently originate from single cells. The data showed maximum number of shoots after 30 days (51.67), 60 days (72.00), and 90 days (98.67) in MS + Kinetin (5.0 mg/l) + NAA (1.0 mg/l) as compared to other treatment combinations (Table 3). These results lend support to the report of earlier workers (Liu and Gao 2007, Waseem *et al.* 2011, Kumar *et al.* 2012, Kumar *et al.* 2017 and Verma and Prasad 2019). Shoot proliferation might be due to the optimum doses of cytokinins and auxins, which enhances axillary branching.

Rooting and establishment of plantlets in greenhouse : The micro-shoots cultured on full-strength MS medium supplemented with 0.2 mg/l IBA took minimum days to root initiation (7.00 days) and produced maximum rooting (85 %), higher average number of roots/shoot (8.00) and optimum and manageable length of longest root (5.00 cm) (Table 4 and Fig. 3). These findings are in line with reports of Prasad *et al.* (2008), Waseem *et al.* (2011), Kumar *et al.* (2012), and Kumar *et al.* (2017).

Fig. 3: Rhizogenesis

Plantlets were successfully acclimatized by transferring them in pots each filled with sterilized coco peat devoid of any nutrients and frequent watering. After 3-4 weeks of acclimatization, the plants were transferred to open conditions. (Fig. 4). The mutant plants produced uniform bright pinkish colour flower as compared with the parent.

Fig. 4: Acclimatized plantlets in open conditions

Table 3: Effect of BAP, Kinetin, and NAA on shoot proliferation

Treatment	Medium	Number of shoots		
		after 30 days	after 60 days	after 90days
T_1	MS Blank (control)	0.00	0.00	0.00
T_2	MS + BAP (2.0 mg/l)	10.33[a]	19.33[a]	25.67[a]
T_3	MS + BAP (2.0 mg/l) + Kinetin (1.0 mg/l)	18.33[b]	24.00[b]	32.33[b]
T_4	MS + BAP (2.0 mg/l) + Kinetin (0.5 mg/l)	26.67[c]	30.67[c]	41.33[c]
T_5	MS + BAP (5.0 mg/l) + NAA (0.5 mg/l)	29.67[d]	38.33[d]	58.33[d]
T_6	MS + BAP (5.0 mg/l) + NAA (1.0 mg/l)	32.33[de]	49.33[e]	61.00[d]
T_7	MS + Kinetin (5.0 mg/l) + NAA (0.5 mg/l)	40.67[e]	58.00[f]	79.33[e]
T_8	MS + Kinetin (5.0 mg/l) + NAA (1.0 mg/l)	51.67[f]	72.00[g]	98.67[g]
	C.D. @ 0.01	2.92	2.98	3.32
	S.E. (m) ±	0.97	0.99	1.10
	C.V. (%)	6.38	4.68	3.84

Table 4: Effect of auxins on rooting of micro-shoots

Treatment	Medium	Rooting (%)	No. of days for root initiation	No. of roots/ shoot	Length of longest root (cm)
T_1	MS (1/2 strength) control	59.00[a] (50.17)	9.95[e]	1.90[a] (1.70)	6.20[e]
T_2	MS (1/2 strength) + IBA (0.1 mg/l)	79.00[b] (62.71)	8.25[d]	6.55[b] (2.75)	4.00[a]
T_3	MS (1/2 strength) + IBA (0.2 mg/l)	81.00[b] (64.21)	7.85[c]	6.78[c] (2.79)	4.40[b]
T_4	MS + IBA (0.1 mg/l)	82.00[c] (64.90)	7.50[b]	7.23[d] (2.87)	4.70[c]
T_5	MS + IBA (0.2 mg/l)	85.00[d] (67.22)	7.00[a]	8.00[e] (3.00)	5.00[d]
	C.D. @ 0.01	2.77	0.21	0.04	0.02
	S.E. (m) ±	0.91	0.07	0.01	0.01
	C.V. (%)	2.95	1.71	1.03	0.31

Conclusion

The best treatment for callus induction was MS medium with Kinetin (10 mg/L) with NAA (1.0 mg/L), for shoot regeneration and proliferation was Kinetin (5.0 mg/L) with NAA (1.0 mg/L) and for rooting was MS + IBA (0.2 mg/l). Therefore, these treatments can be recommended for large-scale multiplication of mutant plantlets.

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Morphological and physiological responses of CMD resistant cassava (*Manihot esculenta*) genotypes to nutrient regimes

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Abstract

The field studies were carried out on cassava (*Manihot esculenta* Crantz) varieties resistant to cassava mosaic disease (V_1-CR43-2, V_2-15 S 59, V_3-15 S 409 , V_4-15 S 154, V_5-CR43-7, V_6-8S 501-2, V_7-CR24-4, V_8- 15S-436) and three levels of nutrient doses (F_1-75:50:75, F_2- 100:50:100 and F_3- 125:50:125 kg NPK/ha) in spilt plot design during 2018-19 and 2019-20 to assess the response of varieties to nutrition. There was significant difference in morphological and physiological parameters among varieties, but not with different nutrient doses. The rate of leaf production was more 4-6 months after planting (34-40%) and percentage retention was less for first season crop (55.6-41.4%) compared to second season (77.2-52.5 %). Though not significant, higher nutrition levels recorded more number of green leaves as well as leaf area at most of the stages. Tuber bulking rate was 0.19 to 0.37 g/day during initial two months. The rate increased and maximum bulking was recorded between 4 and 8 months (2.15-6.71 g/day). Pooled analysis also showed a gradual increase in tuber yield with nutrient levels, but was not significant (7%). The varieties responded differently to nutrients with respect to tuber yield. F_3 recorded higher tuber yield (66.9 t/ha) than F_1 (45.7 t/ha) in V_7 and V_6 recorded highest tuber yield with F_2 level of nutrition (71.1 t/ha). F_1 was found optimum for rest of the varieties.

Key words: Leaf area index, Nutrition, Tuber bulking rate, Tuber yield, Varietal response

Cassava (*Manihot esculenta* Crantz) is the fourth most important food crop in the world. Its wide adaptability to various cropping and farming systems, high yield potential, and season insensitivity ensuring year-round availability, make it an ideal food security crop and versatile industrial raw material. Cassava is considered as a low-input crop, able to yield reasonably good under adverse environments with low fertility and acidic soils where other crops fail (El-Sharkawy *et al*., 2012). However, adequate supply of nitrogen and potassium is essential for high productivity and yield stability in cassava (Ezui *et al*., 2017). The total N, P and K uptake requirements for producing one ton of fresh cassava tuber ranged from 2.9 to 6.9 kg for N, 0.68 to 1.3 kg for P and 3.9 to 7.9 kg for K (Byju and Suja, 2020). Cassava mosaic disease (CMD) is prevalent in India, Africa and Sri Lanka. Different CMD resistant varieties were assessed for their morphological and physiological traits under different nutrient regimes and its relation to final tuber yield.

Materials and Methods

Field experiments were conducted during 2018-19 and 2019-20 at ICAR-CTCRI, Thiruvananthapuram, Kerala. The soil is deep, well-drained, sandy clay loam, moderately acidic. Split-plot design in a completely randomized block was used. All CMD resistant varieties were allocated to the main plots (V_1- Sree Sakthi, V_2-15 S 59, V_3-15 S 409, V_4-15 S 154, V_5-CR43-7, V_6- Sree Kaveri, V_7- Sree Reksha, V_8- 15S-436) and three fertilizer doses were allocated to sub-plots (F_1-75:50:75, F_2- 100:50:100 (present recommendation) and F_3- 125:50:125 NPK/ha). The crop was planted uniformly at a spacing of 90 cm x 90 cm with a gross plot size of 36 plants and a net plot size of 16 plants. The farm yard manure @ 12.5 t/ha and full dose of phosphorus were applied as basal. The N and K were applied in two equal splits, half as basal at planting and the rest half, 45 days after planting.

The morphological data on height, number of green and fallen leaves, leaf retention rate and leaf area were recorded at two months intervals. Destructive sampling was done to assess the biomass production and partitioning at two months intervals. Physiological parameters, viz., leaf area index (LAI), total dry-matter production (TDMP), tuber bulking rate (TBR), crop growth rate (CGR), relative growth rate (RGR), leaf area ratio (LAR), leaf area duration (LAD) and harvest index(HI) (Pandey *et al*., 2017) and finally the yield

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were estimated. All the data collected were analysed statistically for individual years and pooled.

Results and Discussion

During first season, height of plants varied significantly at 2 MAP, and also towards later stages after six months. V_8 recorded lowest values at all the stages. Though not statistically significant, F_2 level of fertilization resulted in taller plants. During second season, difference in height of plants could be noted only after six months, V_1, V_3, V_5, V_6 and V_7 were comparatively taller. The rate of increase in height was more during 2-8 MAP during the first season, whereas during second season, rate was more from 4 months.

The total leaf production was highest in V_2 during both the seasons. Total leaf production varied from 99.18 in V_7 to 151.11 in V_2 during first season (NS) and 171.22 in V_7 to 331.25 in V_2 during second season (p=0.05; LSD: 84.26). The rate of leaf production was more from 2-4 MAP (34%) and from 4-6 MAP (40%) during first and second seasons respectively. Though the effect was not significant, more number of leaves was produced under F_2 and F_3 level of nutrition. Rate of leaf retention was more during initial stages and gradually reduced towards maturity.

Percentage retention was less for first season crop and it varied from 55.6 to 41.4%. The value increased at 8 MAP due to rains received. Rate of leaf retention varied from 77.2 to 52.5 % during second season. Percentage of leaf retention was maximum for V_2 at all the stages during 2018-19 (45.96%). However, during 2019-20, it varied among varieties at different phases of growth, but values were higher compared to first season at all stages. Second crop retained 77.7 % leaves after 4 MAP and 64.2% after 6 MAP, but for first crop, retention percentage was less than 50% from 4 MAP. Consequently, number of green leaves was more during second season, compared to first season.

Green leaves were highest for V_2 from 4-10 MAP during first season, while during second season, V_1, V_2,V_4, V_6 and V_8 had more number of green leaves after 4 MAP and all values were on a par. Higher nutrition levels recorded more number of green leaves as well as leaf area at most of the stages. The leaf area differed significantly among varieties at 2 MAP (p=0.05; LSD: 2.02) and 10 MAP (p=0.05; LSD: 6.76) during first season. The value was maximum for V_6 at 2, 4,6 and 8 MAP and V_1 recorded maximum value at 10 MAP. During second season also V_6 recorded maximum leaf area at 2, 4 and 6 MAP, thereafter, V_8 recorded the maximum at 8 and 10 MAP and values statistically varied towards later stages.

Though cassava is grown mostly under rainfed conditions, supplementary irrigations during drought period could give higher dry-matter production, crop growth rate (CGR), tuber weight and yield (Sunitha *et al*., 2013; Sunitha *et al*.,2016). Cassava responds positively to management practices, it is sensitive to over fertilization, especially with N, which resulted in excessive leaf formation at the expense of root growth (Sagrilo et al., 2006). We also recorded more height, number of leaves and leaf area with higher nutrition, though difference was not significant. Dry period coincided with more leaf fall and less retention of green leaves and subsequent leaf area. Under water stress, cassava frequently sheds its leaves, resulting significantly in reduced productivity (El-Sharkawy, 2014; Daryanto *et al*., 2016).

All the growth indices were highly influenced by rainfall pattern received during both growing seasons. Leaf area index increased at a slow pace during establishment phase of initial 2 months in first season. It reached maximum at 4 months, and retained more or less the same value at 6 MAP, but decreased at 8 MAP, followed by a slight increase at 10 MAP during first season.

This is mainly because of rains received during later stage, ie., after 8 months, which triggered out- flux of starch from tubers to vegetative parts. During second season, LAI development was slow up to 4 months, reached peak at 6 and 8 MAP, then declined. During both seasons, leaf area indices were very much dependent on rainfall, temperature and leaf retention. Reduced leaf area represented dry periods of season, resulting in maximum leaf fall, thereby reducing the transpiration loss and above ground growth, which is a self-defending mechanism in cassava.

The pattern of leaf area development was more or less similar with all fertilizer regimes, higher levels resulted in higher values, but variation was not significant. This is in agreement with Mwamba (2021) and Sunitha *et al.* (2018), where cassava recorded less LAI with dry periods and an increase with resumption of rains, but more or less uniformly with different fertilization regimes. A similar trend was observed in harvest index values also which showed a decline from 6 MAP (0.55-0.71) to 10 MAP (0.53-0.65) during first season, but an increasing trend during second season (0.53-0.79).

The CGR expressed a steady increase from planting up to harvesting, during both seasons. Tuber development from 6 months at a faster rate caused a rapid increase in CGR from 6 MAP. The values ranged from 0.65 (V_8) to 2.83 g/day (V_3) during first two months and increased to 7.49 (V_2) to 21.56 g/day (V_1) from 8 to 10 months. Though vegetative growth was less, tuber development and maturity caused a significant increase in CGR towards later stages, after six months. However, relative growth rate (RGR) was comparatively higher during first two months in both seasons and the values ranged from 0.026 (V_8) to 0.037 g/g/ day (V_3). Leaf area duration expressed a progressive trend from planting to harvesting. The rate of increase was more from 6-8 MAP. Consequently leaf area ratio (LAR) showed a declining trend from planting to harvesting. The values ranged from 0.005 (V_3) to 0.014 (V_8) at 4 MAP and 0.0015 (V_3) to 0.0053 (V_8) at 10 MAP.

Tuber bulking rate was 0.19-0.37 g/day during initial two months as tuber initiation occurs only 40-45 days in cassava. Then rate increased and maximum bulking was recorded between 4 and 8 months (Fig.1). Once tuber bulking initiated, rate of increase in tuber dry-matter continued until, it is lower than other vegetative parts. This is mainly because, dry-matter accumulation in tubers occurs mainly by the translocation of starch assimilated from vegetative parts to storage roots and is not by formation of new tissues. This is in line with Adalton *et al.* (2017) which indicted that late application of potassium for second cycle growth of cassava encouraged fresh plant growth and storage yield.

Biomass partitioning at various stages of the crop was not affected by nutrient levels, but only with varieties, but in a similar trend. At 2 MAP, leaves and stem portion contributed a major share of biomass. Leaves accounted for 32.2% (V_3) to 63.6 % (V_6) of biomass in different varieties and stem accounted for 18.3 (V_6) to 56.1 % (V_2). Leaf biomass was reduced to 3.7-7.9% at 10 months, except in V_5 and V_8, where stem and leaves retained almost equal biomass, restricting the tuber biomass production after 8 months, as reported by Adalton *et al.* (2017). This is due to regrowth of stems and leaves at the expense of tubers with favourable soil moisture conditions. A major share of the tuber bulking occurred between 4-8 MAP in all the varieties except V_8 in both the seasons, where tuber bulking was more during 6 to 8 MAP.

There was a decrease in tuber biomass and increase in stem and leaf biomass during second season irrespective of the varieties. Intermittent rains received during summer season, just before harvesting triggered vegetative growth, even causing the reverse translocation of starch from tubers to vegetative parts because of excess soil moisture. During drought stress, LAI and dry matter partitioning to stems and leaves reduces rapidly as photo-assimilates are mostly channelled to growth of storage roots and only increase after resumption of rainfall as reported in some studies (Ezui *et al.*, 2015).

There was significant difference in tuber yield, only with varieties. During first season, a corresponding increase was noticed from F_1 to F_3, in second season the values were almost the same. Pooled analysis also showed a gradual increase in tuber yield with nutrient levels, but was not significant. F_3 level of nutrition resulted in only 7% increase in tuber yield compared

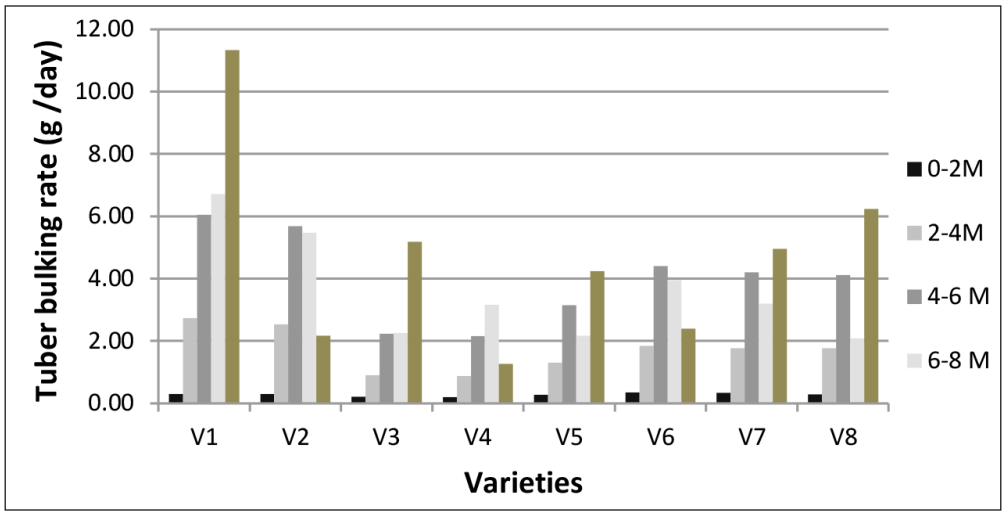

Fig. 1: Tuber bulking rate in different varieties from planting to harvesting (pooled means)

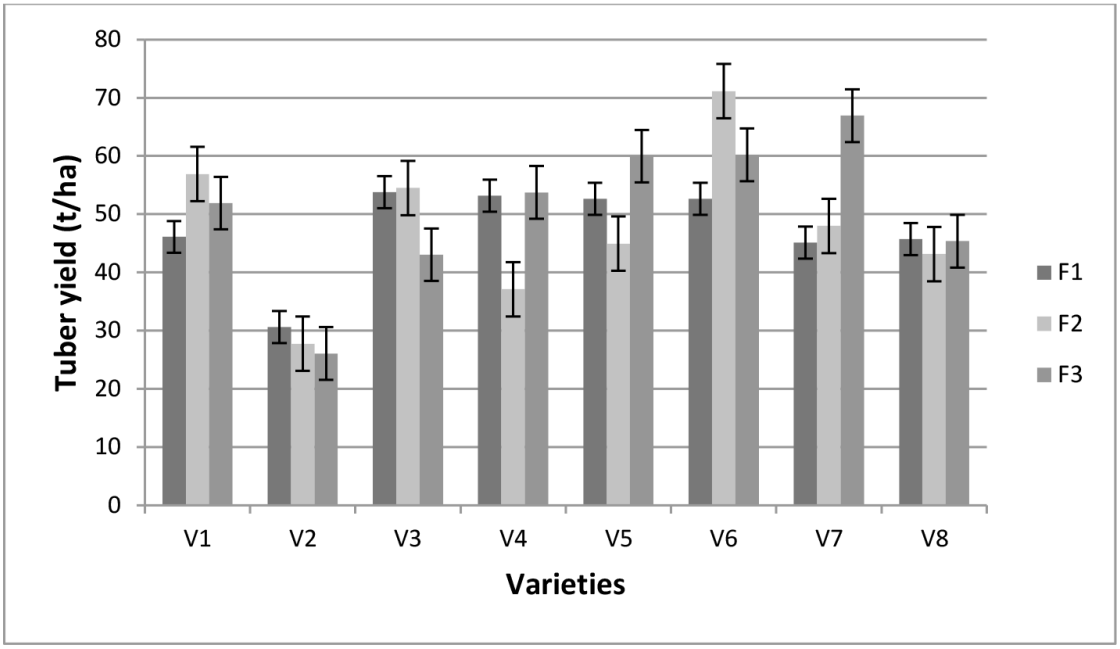

Fig. 2: Tuber yield of varieties under different nutrient doses (pooled means)

to F_1 based on pooled data analysis and the variation was not significant. Variable response of varieties in growth and yield attributes is reported in cassava (Nedunchezhiyan *et al.,* 2022) and potato (Jatav *et al.*, 2023).

The interaction effects were significant, ie., varieties responded differently to nutrients with respect to tuber yield. Higher level of nutrition, F_3 recorded significantly higher yield in V_7 in both seasons and pooled performance. V_6 recorded highest tuber yield with F_2 level of nutrition. Rest of the varieties did not express any significant variation in yield with nutrition, ie., a lower level of nutrition, F_1 is found optimum for these varieties (Fig.2). In earlier study (Mutchima, 2018), it was observed that cassava starch waste at 12.5 t and 75 kg of N or 25 t of cassava starch waste and 25 kg N resulted in more harvest index and storage root yield in cassava compared to other higher levels of nutrition. It could be inferred that these treatments supplied a good balance between total production of carbohydrates by the plants and their distribution to the roots as reported in cassava through fertigation (Sunitha *et al.*, 2013; Sunitha *et al.*, 2018).

Significant variation was noted in tuber yield among varieties and in among seasons. First season crop which experienced a dry period during critical growth stage suffered yield loss compared to second season (61%). The first 3–5 MAP is a critical period for cassava (Turyagyenda *et al.*, 2013; Sunitha *et al.*, 2017). Moisture stress, during these first months of leaf formation, root initiation, and tuberization can reduce the yield of storage root by up to 60% . A 30% yield reduction of cassava cultivated in Kerala was observed due to late monsoons and planting followed by a period of drought. The study emphasized the need for timely planting of cassava, coinciding with initiation of monsoon season so that crop will get enough soil moisture during establishment and tuber bulking stages with subsequent monsoon rains or else need for supplementary irrigation to realise maximum tuber yield. Also the possibility of reducing fertilizer doses by 25% in medium fertile soils.

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Optimizing mulch thickness for enhanced vegetative growth of khirni (*Manilkara hexandra*)

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Abstract

A field experiment for optimizing mulch thickness for enhanced vegetative growth of khirni (*Manilkara hexandra* Roxb.) cv. Thar Rituraj was conducted during the 2019-20 at College of Horticulture and Forestry, Jhalawar, Rajasthan. Among different thicknesses application of T6-12 cm thickness of dry grass to individual plants was significantly superior to all other treatments, but it was on at par with T5-10 cm thickness of dry grass. In treatment T6, an increase in shoot and leaf parameters, such as rootstock girth (10.98%), scion girth (11.05%), plant height (32.61%), number of nodes/shoot (80.52%), number of internodes/shoot (94.33%), number of leaves/plant (39.94%), leaf length (13.45%) and leaf area index (1.50%), were recorded during February 2020.

Key words: Development, Growth, Mulching, Thickness, Vegetative growth

Khirni (*Manilkara hexandra* Roxb.) is one of the important underutilized fruit crop of tropical and sub-Tropical region of India. It belongs to family Sapotaceae with a somatic chromosome number, 2n= 26. Major *khirni* growing states are Madhya Pradesh, Gujarat, Rajasthan, Karnataka, Maharashtra and Tamil Nadu.

Mulching is an essential cultural technique which helps to produce healthier plants. Mulching conserve soil moisture by reducing water loss thorough evaporation, minimizing soil erosion, moderating soil temperature, inhibiting weed growth, encouraging the growth of beneficial soil microorganism and reducing the spread of soil-borne pathogen by preventing soil form splashing onto plants during rainstorms and watering. It can also be used as winter and summer protection, improving soil structure and quality, and returning nutrients to soil. No work has been carried out on the effect of mulching on *khirni* plants, hence an experiment was conducted.

Material and Methods

This field experiment was conducted at Department of Fruit Science, College of Horticulture and Forestry, Jhalarapatan, Jhalawar, in the newly established orchard of *khirni* cv. Thar Rituraj during 2019-20. It consists of six mulch treatments along with the control, T_0 (Control), T_1 (2 cm thickness of dry grass), T_2 (4 cm thickness of dry grass), T_3 (6 cm thickness of dry grass), T_4 (8 cm thickness of dry grass), T_5 (10 cm thickness of dry grass) and T_6 (12 cm thickness of dry grass) laid out in randomized block design with three replications. The treatments were applied during first week of March 2019 after recording initial (base) growth and development parameters of plants and observations were noted at 2 months interval for a total period of 12 months.

For the measurement of rootstock and scion girth of plant marked at a fix point with white paint and values were expressed in mm. The plant height was recorded from the base of soil to highest tip of the plant with the help of measuring scale and noted in centimeter (cm). The numbers of nodes and internodes/ shoot and number of leaves/plants were counted manually. For measuring leaf length, selected tagged leaves under various treatments of *Khirni* were measured in April, June, August, October, December and February. The average increase in leaf length was calculated on the basis of cumulative increase in initial value. The average increase in LAI was calculated on the basis of recorded values of leaf area and plant spread as per the given formula (Watson, 1947);

LAI = (Leaf area) / (ground area)

The data were statistically analyzed as per analysis of variance technique as suggested by Panse *et al.* (1995).

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The significance of the treatments was tested through F test at 5 per cent level of significance. The critical difference CD was calculated to assess the significance of difference among the different treatments.

Results and Discussion

Thickness of dry grass mulch significantly influenced growth of plants. The highest increase (10.98%) in rootstock girth was observed in T_6-12 cm thickness of dry grass and found at par with T_5 -10 cm thickness of dry grass (10.37%) (Table 1). The lowest increase (4.27%) in rootstock girth was noted in T_0- control. Similarly, maximum increase (11.05%) in scion girth was noted in T_6 followed with T_5 (10.48%) and minimum increase (4.55%) was observed in T_0 treatment (Table 2). Plant height maximum (32.61%) application of 12 cm thickness of dry grass followed with application of 10 cm thickness of dry grass (31.72%) and minimum increase with the control (11.22%) (Table 3). It apparently appears that maximum increase in number of nodes and internodes (80.52% and 94.33%, respectively) was observed with treatment T_6 and it was found at par with T_5 (76.70%, 89.14%, respectively). The lowest increase in number of nodes and internodes (50.00% and 58.33%, respectively) was recorded in control at the time of completion of experiment.

The shoot parameters were recorded comparatively better with T_6-12 cm thickness of dry grass treatment as compared to rest of treatments. Healthier shoot attributes observed under T_6 treatment may be due to relatively more amenable effect of this treatment in modification of microclimate, better improvement in texture of soil, conservation of soil moisture, improvement of fertility and control of weeds. This treatment might also influence hydrothermal regimes by changing radiation balance, rate of heat, water vapour transfer and minimized hit of soil with sun more effectively in comparison to other treatments. Effective prevention of moisture deficit leading to improved cell division and elongation, perhaps also led to better shoot parameters in T_6 (12 cm thickness of dry grass) treatments over other treatments evaluated. Similar effect of the mulching on the plant growth was reported by Chattopdhyay and Patra (1992), Borthakur and Bhattacharyya (1996), Mal *et al.* (2006). Ali and Gaur (2013).

The maximum increase of number of leaves/ plant (39.94%) was noted with treatment T_6 followed by treatment T_5 (38.23%) (Table 6). However, minimum increase (21.68%) of number of leaves was observed

Table 1: Effect of mulching on rootstock girth of *Khirni* during growth period

Treatment	Initial value (March)	Rootstock girth (mm)					
		April	June	August	October	December	February
T_0	7.02	7.05 (0.42)	7.09 (0.99)	7.19 (2.42)	7.26 (3.41)	7.29 (3.84)	7.32 (4.27)
T_1	6.14	6.21 (1.14)	6.27 (2.11)	6.46 (5.21)	6.52 (6.18)	6.56 (6.84)	6.59 (7.32)
T_2	6.18	6.26 (1.29)	6.34 (2.58)	6.54 (5.82)	6.59 (6.63)	6.63 (7.28)	6.68 (8.09)
T_3	6.49	6.60 (1.69)	6.67 (2.77)	6.89 (6.16)	6.95 (7.08)	7.01 (8.01)	7.05 (8.62)
T_4	6.99	7.11 (1.71)	7.20 (3.00)	7.45 (6.58)	7.53 (7.72)	7.59 (8.58)	7.63 (9.15)
T_5	6.65	6.79 (2.10)	6.88 (3.45)	7.13 (7.21)	7.20 (8.27)	7.26 (9.17)	7.34 (10.37)
T_6	6.28	6.43 (2.38)	6.53 (3.98)	6.80 (8.28)	6.88 (9.55)	6.91 (10.03)	6.97 (10.98)
SEm ±	-	0.04	0.05	0.12	0.13	0.14	0.23
CD (5%)	-	0.12	0.15	0.37	0.39	0.43	0.69

Data in parentheses indicate per cent increase in rootstock girth

CD has been calculated based on percentage value

Table 2: Effect of mulching on scion girth of *khirni* during growth period

Treatment	Initial value (March)	Scion girth (mm)					
		April	June	August	October	December	February
T_0	3.95	3.97 (0.50)	3.99 (1.01)	4.05 (2.53)	4.09 (3.54)	4.11 (4.05)	4.13 (4.55)
T_1	3.18	3.21 (0.94)	3.25 (2.20)	3.34 (5.03)	3.39 (6.60)	3.43 (7.86)	3.46 (8.80)
T_2	3.23	3.27 (1.23)	3.32 (2.78)	3.43 (6.19)	3.47 (7.43)	3.50 (8.35)	3.54 (9.59)
T_3	3.29	3.34 (1.51)	3.40 (3.34)	3.51 (6.68)	3.55 (7.90)	3.58 (8.81)	3.60 (9.42)
T_4	3.54	3.60 (1.69)	3.67 (3.67)	3.79 (7.06)	3.83 (8.19)	3.86 (9.03)	3.90 (10.16)
T_5	3.91	3.98 (1.79)	4.06 (3.83)	4.20 (7.41)	4.25 (8.69)	4.28 (9.46)	4.32 (10.48)
T_6	3.80	3.89 (2.36)	3.98 (4.73)	4.10 (7.89)	4.16 (9.47)	4.19 (10.26)	4.22 (11.05)
SEm ±	-	0.04	0.06	0.09	0.10	0.13	0.22
CD (5%)	-	0.12	0.18	0.28	0.30	0.39	0.67

Data in parentheses indicate per cent increase in scion girth

CD has been calculated based on percentage value

Table 3: Effect of mulching on height of plant during growth period

Treatment	Initial value (March)	Height of plant (cm)					
		April	June	August	October	December	February
T_0	72.80	73.25 (0.61)	74.69 (2.59)	78.68 (8.07)	79.67 (9.43)	80.10 (10.02)	80.97 (11.22)
T_1	70.45	71.57 (1.58)	73.24 (3.96)	76.87 (9.11)	78.74 (11.76)	80.13 (13.74)	81.42 (15.57)
T_2	71.24	72.45 (1.69)	74.31 (4.30)	77.98 (9.46)	81.12 (13.86)	82.87 (16.32)	84.51 (18.62)
T_3	71.66	73.12 (2.03)	74.84 (4.43)	78.68 (9.79)	81.98 (14.40)	84.35 (17.70)	86.81 (21.14)
T_4	73.54	75.13 (2.16)	77.23 (5.01)	82.26 (11.85)	85.91 (16.82)	87.75 (19.32)	90.32 (22.81)
T_5	68.14	70.12 (2.90)	72.35 (6.17)	78.61 (15.36)	83.02 (21.83)	86.14 (26.41)	89.76 (31.72)
T_6	72.60	74.86 (3.11)	77.32 (6.50)	85.42 (17.65)	89.12 (22.75)	93.05 (28.16)	96.28 (32.61)
SEm ±	-	0.02	0.02	0.07	0.09	0.12	0.30
CD (5%)	-	0.06	0.06	0.22	0.27	0.38	0.91

Data variation lying in the range of 11.22 to 32.61 per cent, they were subjected to Arc sine transformed values. The variation not varying between 0 to 30 or 70 to100 were subjected to Arc Sine transformation (Gomez and Gomez, 1984)

CD has been calculated based on percentage value

with the control. Leaf length and leaf area index were maximum *i.e.*, 13.45% and 1.50%, respectively with the application of 12cm thickness of dry grass. Whereas, lowest increase in leaf length (3.32%) and leaf area index (0.46%) was recorded in T_0-Control.

The effect of mulching on leaf parameters viz., number of leaves/ plants, leaf length and leaf area index observed maximum increase with T_6-12 cm thickness of dry grass. These results may be clarified in the light of improvement of physico-chemical properties of soil through comparatively better congenial environment in the root zone (Kumar *et al.* 2008, Singh *et al.* 2004 in plum and Helaly *et al.* 2017 in gooseberry).

Conclusion

Thus, it may be concluded that application of the treatment T_6 (12 cm thickness of dry grass) had its better effect on growth and development of *Khirni* plants. The (12 cm thickness of dry grass emerged better in its effectivity on growth and development.

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Impact of saline soils on grafted tomato (*Solanum lycoparsicon*) onto brinjal (*Solanum melongena*)

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Abstract

The experiment was conducted to evaluate the effect of salinity on horticultural traits of grafted tomato (*Solanum lycopersiocon* Mill.) onto brinjal (*Solanum melongena* L.) rootstock and to find out the best salt tolerance or resistant rootstock/graft combination during 2021-22 at ICAR-IIVR KVK, Bhadohi, Uttar Pradesh. Three rootstocks (IC-111056, IC-354557, and Surya) and graft between three different scions (Kashi Aman, Kashi Chayan and NS-4266) were compared with their scions. Among rootstock, IC-111056 and IC-354557 were observed highly salt tolerant to saline condition which could be used as rootstock for further crop production in saline conditions and its use in conventional breeding programme to develop salt tolerant/resistant variety.

Tomato (*Solanum lycopersiocon* Mill.) is most used vegetable crop. In eastern Uttar Pradesh, most of farmers prefer fertile land for cultivation of other crops. The high soil salinity renders the cultivation of vegetables in many areas prohibitive. Almost 20% of total arable land and 50% of irrigated land are deteriorated by salinity (Arzani, 2008), caused either by irrigation water or underground water of low quality. The grafting techniques is being employed as a means of assuaging the negative impacts of high salinity, by using rootstocks capable of getting over the problems induced by high concentrations of salts in the root environment (Yetisir and Uygur, 2010). Grafting has been demonstrated as a simple and cheap technique to improve adaptation of tomato plants to salt stress Colla *et al.*, 2010. Use of grafting techniques to overcomes many biotic and abiotic problems in cucurbits Holer, *et al.,* 2024. Therefore, an experiment was conducted to find out the effect of rootstock × scion combination on growth, development and yield of tomato grafted onto three rootstocks and themselves, and grown in under salt stress at outdoors environmental conditions.

Materials and Methods

The experiment was conducted at ICAR-IIVR Krishi Vigyan Kendra, Bejwan Bhadohi, during 2021-22. The samples were collected from ICAR-IIVR. Brinjal (*Solanum melongena* L.) rootstock was grafted onto tomato scion. Rootstock of three brinjal accessions (IC-354557, IC-111056 and Surya) were grafted with three tomato cultivars (Kashi Aman, Kashi Chayan and NS-4266) and compared with them. Graft combination details given (Table 1).

The experimental site is situated at 25.12° to 25.32° North Latitudes and 82.12° to 82.42° East Longitudes and at an elevation of 85 m above mean sea-level.

Table 1: Graft combination used

Rootstock	Scion	Graft combination
IC-111056	Kashi Aman	IC-111056 x Kashi Aman
	Kashi Chayan	IC-111056 x Kashi Chayan
	NS-4266	IC-111056 x NS-4266
IC-354557	Kashi Aman	IC-354557x Kashi Aman
	Kashi Chayan	IC-354557x Kashi Chayan
	NS-4266	IC-354557x NS-4266
Surya	Kashi Aman	Surya x Kashi Aman
	Kashi Chayan	Surya x Kashi Chayan
	NS-4266	Surya x NS-4266

This region is humid and sub-humid. The soil textural class was alluvial (Inceptisols) formed by deposition of sediments brought by the river Ganga. Soil samples were collected from five different locations of each bed at the depth of 15cm in zigzag pattern across the required areas. A composite sample of about 2 kg was taken through mixing of represented soil sample. These soils were first sieved by gyrator sieve shaker

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with approximately 2 mm spacing to remove the coarser particles and then allowed to dry in air for 1 hour. The proposed samples were analyzed for physico-chemical properties using standard procedures. The nutrient concentrations and physico-chemical parameters of soil samples are represented in Tables 2.

The experiment was laid out in RCBD with three replications. The net plot size was 1.40 m^2 with a spacing 70 cm row-to-row and 50 cm plant-to-plant. The recommended package of practices were followed to raise the crop. After eliminating the border plants, observations were recorded on five randomly chosen plants for 13 quantitative traits, viz. days to first fruit picking (days), number of branches, plant height (cm), fruit length (cm), fruit breadth (cm), average fruit weight (g), number of truss per plant, number of fruit/truss, number of fruits/plant, harvesting duration (days), marketable yield/plant (g), marketable yield per plot (kg) and self-life (days). The statistical analysis was carried out for each observed character under the study using MS-Excel, SPSS 16.0 and SPAR 2.0 packages. The mean values of data were subjected to analysis of variance and ANOVA was set as per Gomez and Gomez (1983) for randomized block design.

Results and Discussion

The nutrient status of plot falls under high soil pH means higher salt concentration, which increase higher osmotic potential in root zone resulting in water scarcity condition. Due to less absorption water, the plants are not able to absorb the essential plant nutrients, resulting is internodal length of plant, which becomes smaller. Due to reduced plant growth, flower become early, resulting in reduced yield. Due to formation of soils over basaltic parent material (calcium rich) and higher or moderately alkaline earth contents leads to neutral to alkaline conditions. Higher pH value in soils may be due to basalt as parent material, which is alkaline in nature (Chinchmalatpure *et al.*, 2000).

Higher amount of salts in soils restricts the nutrient uptake and thus affects plant growth. The electrical conductivity is show optimum level. The EC of surface soils was lower than that of subsurface soils and in general increased with depth. This may be due to leaching of salts from the surface to subsurface horizons through pedogenic processes. It contains, retains and supplies all essential plant nutrients and thus, asserts an abiding influence on sustenance of soil fertility. In addition, it also improves soil structure, infiltration rate, water and nutrient storage capacity and reduces soil erosion. The low level of organic carbon is found in plot due highly saline condition with sluggish rate of mineralization. Similar results were observed by Wiesmeier *et al.,* 2014.

The available P and K content, which denotes high level of P and Medium level of K present. Therefore, P availability in soils might have been favored by the warm climatic condition of study area along with the preferred pH range. Available P values declined with increasing depth which could be attributed to decrease in soil OC. Potassium removal from primary minerals requires hydronium ion, which dissociates from organic and inorganic acids in soil solution (Buol *et al.,* 2003). The supply of hydronium is relatively higher in surface horizon due to relatively higher contents of organic matter and root activities, which release CO_2. The dissolution of CO_2 forms H_2CO_3 and ultimately hydronium ion. This process might have resulted in higher available K in surface than subsurface layers (Table-2).

Table 2: Soil properties and nutrient status of research plots

Parameter	Mean value
Physical properties	
pH	9.0
EC (dSm^{-1})	0.09
OC (g/Kg^{-1})	0.37
Chemical Properties	
Major Nutrients (Kg/ha)	
N	175
P	27
K	158
Minor nutrients (Mg/ha)	
Fe	10.5
Mn	16.3
Cu	2.5
Zn	2.0

Relatively higher values of available micronutrients were expected under highly organic decomposed lands which are organic matter can find physical protection from microbial decomposition, which is a potential source of micronutrients. Under investigation, Fe, Mn, Cu and Zn were categories as a sufficient level. Similar results were reported by Jibhkate *et al.* (2009).

The mean sum square shows highly significant differences among graft combinations. Minimum days to first fruit picking was taken in IC-111056+ Kashi Aman, IC-111056+K. Chayan and non-grafted

NS-4266, while IC-111056+NS-4266 better performed from your non -grafted scion. However, minimum days promote earliness, IC-111056 promoted earliness on Kashi Aman and Kashi Chayan scion. Fruit length, fruit breadth, average fruit weight, marketing yield and total yield directly promoting economical yield of crops.

Maximum fruit length, fruit breadth and average fruit weight was recorded in IC-111056+ Kashi Aman, IC-111056+K. Chayan and IC-111056+NS-4266 compared to non-grafted scion. IC-111056 encourages economical yield in saline condition. Grafting tomato plant had a significant effect on plant vegetative growth (Table 3). The result showed a significant increase in plant height, number of branches, number of truss, number truss/cluster and number of fruit/plant was sequel with Karaca *et al.* (2012). Harvesting duration and selflife of grafted tomato on IC-111056 was found better than non-grafted tomato under saline condition. The IC-111056 was promoted harvesting duration of crops under salt condition as well as post-harvest life of tomato.

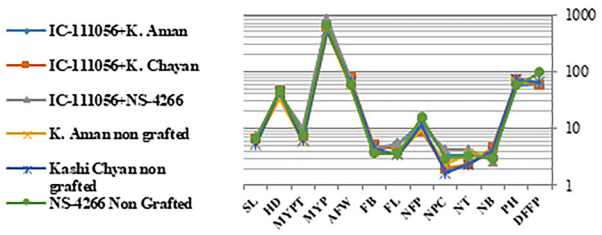

Fig. 1. Performance of rootstock IC-111056 on tomato

Minimum days to first fruit picking was taken in IC-354557+Kashi Aman, IC-354557+ Kashi Chyan and Kashi Aman non-grafted, while other graft combination non-significantly performed in saline conditions. Similarly, IC-354557 significantly promoted earliness on Kashi Aman and Kashi Chayan Scion. The result showed a significant increase fruit length, total yield / plant, yield/plot and selflife. The IC-354557+Kashi Aman, IC-354557+Kashi Chyan and IC 354557+NS-4266 compared to non-grafted plant in salty soils. While, maximum fruit breadth, average fruit weight and harvesting duration was found in Kashi Chyan non-grafted, IC-354557+Kashi Chyan and IC 354557+NS-4266 and compared to other graft combination.

They found that grafted tomato plants were encouraging the economical yield in salt condition. Similar results were reported by Turhan *et al.* (2011) and Echevarria *et al.* (2012) who found that grafting tomato plants improved yield and its components. Grafting tomato plants resulted had a significant effect on plant vegetative growth (Table 3). The result showed a significant increase in Plant height, number of branches, number of truss, number truss/cluster and number of fruit/plant was sequel with the observations Karaca *et al.* (2012). They found that grafted tomato plants were more vigorous than non-grafted plants.

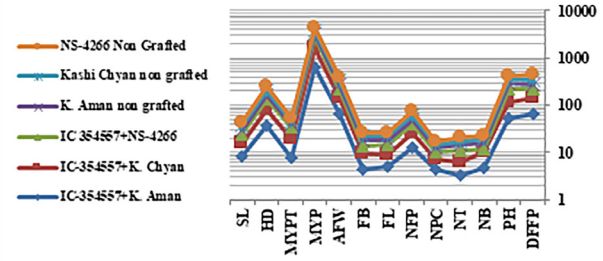

Fig. 2. Performance of Rootstock IC-354557 on tomato

The IC 354557 was found better than non-grafted tomato under saline condition. They observed that IC 354557 was promoted marketing yield as well as vegetative growth of crops under salt condition.

Minimum days to first fruit picking was taken in Surya+ Kashi Aman and Kashi Chayan non-grafted, whereas Surya + NS-4266 better performed their scion. However, Surya promoting on Kashi Aman is minimum days taken to harvesting. Fruit length, fruit breadth, average fruit weight, Marketing Yield/plant and total yield/plot directly promoting economical yield. Maximum fruit length, fruit breadth and average fruit weight was recorded in Surya+ Kashi Aman, Surya+Kashi Chayan and Surya+NS-4266 compared to non-grafted scion.

Surya also encourages the economical yield in salt condition. Grafting tomato plant had a significant effect on plant vegetative growth (Table 3). The result showed a significant increase in plant height, number of branches, number of truss, number truss/cluster and number of fruit/plant was sequel with the observations Iseri *et al.* (2015). They found that grafted tomato plants were more vigorous than non-grafted plants.

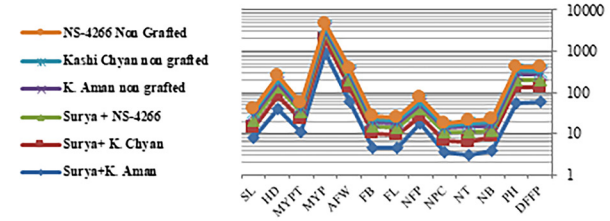

Fig. 3. Performance of Surya rootstock on tomato

Among rootstock, IC 354556 and IC-111056 comparatively better performed under saline condition.

Table 3: Mean performance of different rootstock on tomato

Treatment	DFFP	PH	NB	NT	NFC	NFP	FL	FB	AFW	MYP	MYPT	HD	SL
Performance of IC-111056													
IC-111056+K. Aman	59.57	57	3.67	3.33	3.33	12.33	5.47	4.1	69.57	788	9.46	36.78	6
IC-111056+K. Chayan	57.57	72.33	4.67	2.33	3.30	9	4.27	5.27	77.57	614.97	7.38	45.33	6.67
IC-111056+NS-4266	65.27	75.33	2.67	4.33	4.33	11	5.57	4.63	75.27	853.67	10.24	40.33	7.33
K. Aman non grafted	67.18	64.33	3.33	3.67	2.33	10	3.67	4.03	57.18	496.15	5.95	33	6
Kashi Chyan non grafted	64.53	72.67	4	2.33	1.67	11.67	3.43	4.63	64.53	518.97	6.23	43.67	5.33
NS-4266 Non Grafted	96.67	57	3	3.33	3	15.67	3.63	3.63	57.17	638.63	7.66	45	6.67
Performance of IC-354557													
IC-354557+K. Aman	64.07	51.67	4.67	3.33	4.33	13	4.97	4.27	64.07	660.73	7.93	37.67	8
IC-354557+K. Chyan	74.63	61.33	5.33	3	3	13.67	3.9	4.93	74.63	920.77	11.05	41.67	7.67
IC 354557+NS-4266	75.17	108	2	4.67	3	13.33	5.87	4.8	75.17	1204.17	14.45	52	8.67
K. Aman non grafted	57.18	64.33	3.33	3.67	2.33	10	3.67	4.03	57.18	496.15	5.95	33	6
Kashi Chyan non grafted	64.53	72.67	4	2.33	1.67	11.67	3.43	4.63	64.53	518.97	6.23	43.67	5.33
NS-4266 Non Grafted	96.67	57	3	3.33	3	15.67	3.63	3.63	57.17	638.63	7.66	45	6.67
Performance of Surya													
Surya+K. Aman	60.57	54.67	4	3	3.67	17.33	4.6	4.6	60.57	907.53	10.89	38.33	7.67
Surya+ K. Chyan	65.03	81.67	4.67	3.33	3.33	9.67	4.7	5.57	75.03	993.2	11.92	42.33	6.33
Surya + NS-4266	71.14	67.67	3.33	5	4.33	12.67	4.2	4.37	71.14	1021.24	12.25	55	7.67
K. Aman non grafted	67.18	64.33	3.33	3.67	2.33	10	3.67	4.03	57.18	496.15	5.95	33	6
Kashi Chyan non grafted	64.53	72.67	4	2.33	1.67	11.67	3.43	4.63	64.53	518.97	6.23	43.67	5.33
NS-4266 Non Grafted	96.67	57	3	3.33	3	15.67	3.63	3.63	57.17	638.63	7.66	45	6.67
SE(m)±	2.28	1.62	0.41	0.35	0.47	1.15	0.29	0.21	3.10	78.58	0.94	2.04	0.47
SE(d)±	3.23	2.29	0.58	0.49	0.66	1.63	0.41	0.30	4.39	111.13	1.33	2.89	0.67
Critical Difference	6.55	4.65	1.19	1.00	1.34	3.30	0.83	0.61	8.91	225.60	2.71	5.86	1.36
CV %	5.50	4.09	18.95	17.31	25.22	16.01	11.04	8.03	7.85	16.98	16.98	8.30	11.73

Whereas, DFFP=Days to first fruit picking, PH=Plant height (cm), NB=No. of branches, NT= No. of truss, NFC=No. fruit per truss**,** NFP= No. of fruit per plant, FL= fruit length (cm), FB=fruit breadth (cm), AFW= average fruit weight (gm), MYP= marketing yield/plant (gm), MYPT= Marketing yield per plot (kg), HD= harvesting duration (days) and SL= Self-Life (days),

It is enormous scope for use of usar soil for further cultivation. Similarly, Savvas *et al.* (2011) demonstrated that effect of grafting on tomato fruit yield depends on rootstock and level of salinity.

Similarly, Savvas *et al.* (2011) demonstrated that effect of grafting on tomato fruit yield depends on rootstock and level of salinity.

Conclusion

Thus, it was concluded that IC 354556 and IC-111056, followed by Surya and their scion under saline condition were found to be high salt tolerant. The salt tolerant brinjal rootstock identified for their field assessment. Such a tolerant rootstock can be utilized for further breeding superior variety/ used as rootstock to produce salt tolerant grafted plants under saline condition.

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Effect of fruit retention and days to fruit maturity on seed yield and quality of okra *(Abelmoschus esculentus)*

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Abstract

The experiment was conducted at Department of Seed Science and Technology, BACA, AAU, Anand, to find out the effect of fruit retention and days to fruit maturity on seed yield of okra *(Abelmoschus esculentus)*, during kharif season of 2021-22. The experiment consisted of twelve treatment combinations involving four different number of fruits retention, viz. R1: 10 fruits/plant, R2: 15 fruits/plant, R3: 20 fruits/plant and R4: all fruits/plant and three days to fruit maturity, viz. M1: 50 days after fruit formation, M2: 60 days after fruit formation and M3: 70 days after fruit formation. The 15 fruits retained/plant (R2) and 50 days after fruit formation (M1) gave significantly higher fruit yield, seed quality and seed vigour. The maximum weight of fruit (7.80 g), fruit length (17.77 cm), fruit girth (5.75 cm), number of seeds/fruit (47.01), 100-seed weight (6.893 g), germination (96.67 %), seedling root length (11.91 cm), seedling shoot length (18.68 cm), seedling length (30.58 cm), seedling fresh weight (4.810 g), seedling dry weight (0.1804 g), seedling vigour index-I (2955.96) and seedling vigour index-II (17.44) were noticed in 15 fruits/plant 50 days after fruit formation (R2M1). Whereas, lower (0.800) electrical conductivity was recorded with R2M2.

Key words: Fruit retention, Maturity, Seedling vigour index, Seedling shoot length

Okra (*Abelmoschus esculentus* L) is an economically important vegetable crop grown in tropical and sub tropical parts of world. It is widely consumed species of Malvaceae family. Farmers in India are still producing crops based on knowledge transmitted to them by their forefathers leading to grossly unscientific agronomic, nutrient management and pest management practices (Choudhary *et al.,* 2024). Seed harvesting when the fruits reach their maturity will produce plant with better vigour and seed storage ability. Seeds in their physiological maturity have complete food storage to support the growth of seedlings (Copeland and McDonald, 1985). The information on fruit retention, optimum stage of harvesting and seed vigour quality on okra is limited. Hence, an experiment was conducted.

Materials and Methods

The experiment was conducted at Main Vegetable Research Station, Anand and laboratory experiments were carried out at Department of Seed Science and Technology, BACA, Anand Agricultural University, Anand, during 2021-22. The seeds of Gujarat Anand Okra 8 (Anand Komal) were obtained from Main Vegetable Research Station. Two experiments were conducted. Both the field and laboratory experiment consisted of twelve treatment combinations involving four different number of fruits retention, *viz.* R_1: 10 fruits/plant, R_2: 15 fruits/plant, R_3: 20 fruits/plant and R_4: all fruits/plant and three days to fruit maturity, *viz.* M_1: 50 days after fruit formation, M_2: 60 days after fruit formation and M_3: 70 days after fruit formation. The experiments were conducted in randomized complete block design (factorial) and completely randomized design (factorial) in field and laboratory respectively with three repetitions.

The first fruit appearance node was counted from the ground level in five randomly tagged plants. The average first fruits appearance at node was computed. The matured fruits harvested from five tagged plants were collected randomly from each replication of all treatments, and length, girth and weight of fruits were recorded immediately after picking of fruits. From five matured fruits seeds of each fruit were extracted by manual method. The number of seeds/fruit was counted by computerized seed counting machine and average was recorded. One-hundred-seed weight was weighed separately by electronic weighing balance from each

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replication of treatment as per ISTA 2018.

The germination test was conducted by adopting "between Paper (BP)" method. The 100-seeds in four replications were taken at random from seed lot of each treatment and placed uniformly on germination paper. The rolled paper was kept in germinator at 25° C and relative humidity was maintained at 95 ± 1 per cent. The final count of germination percentage was recorded on 21st days of germination test. On final count ten normal seedlings were selected randomly and their root length, shoot length and seedling length were measured. To record seedling fresh weight, ten seedlings were counted and weighed while still moist and for seedling dry weight weighed seedlings were placed at 80° C in an oven for 24 hr for drying. Thereafter, seedlings were removed and cooled in desiccator for one hour before weighing on an electronic balance. The seedling vigour index I and II were calculated as per Abdul-Baki and Anderson (1973).

Speed of germination was calculated by counted number of germinated seed daily from first day and cumulative index made by the formula (Maguire, 1962). Dehydrogenase activity was estimated following method given by kittock and Law (1968). Twenty seeds for each replication were preconditioned and prepared before staining in 1% TZ solution (2, 3, 5 triphenyl tetrazolium chloride) for 5 hr in dark at 25° C. Excess solution was drained out and seeds were washed thoroughly, to stained seeds for 5 ml of methyl cello solve was added and left for 4-6 hr with occasional stirring to extract the red colour formazan. The red coloured formazan containing methyl cello solve is decanted into the test tubes. The intensity of decanted solution was read at 480 nm in a spectrophotometer (Beckmann DU-640, USA) using methyl cello solve as blank.

For paper piercing test seed were planted on moist sand layer of 2 cm taken in plastic box. It was then covered with selected dry filter paper. Boxes were then kept at 25° C for 21 days to take final count. The seedling which are able to penetrate the paper were considered vigorous [Fritz (1965)]. The accelerated ageing test was conducted according to the procedure given by Delouche and Baskin (1973). The 50-seeds from each of seed lot were drawn and spread out in thin layer in nylon net bag. These packets were kept in ageing chamber, subjecting the seeds to 40° C at 100% RH. Seeds were removed after 72 hr and germination test was carried out on 50 seeds of four replicates.

Seed which produce an identifiable seedling regardless of their size is counted as germinable one and per cent germination after accelerated ageing was calculated. The electrical conductivity of seeds is measured by soaking 50 harvested seeds of each treatment in 25 ml of distilled water for 24 hr at room temperature. Later seeds were decanted and volume was made up to 25 ml by adding distilled water. The EC of seed leachate was measured through electrical conductivity meter and is expressed in dS/m (Agrawal and Dadlani, 1992).

The data were analyzed through randomized complete block design (factorial) under field conditions and completely randomized design (factorial) under laboratory condition (Steel and Torrie, 1960) statistically for all the characters using ANOVA. The standard error of mean (S.Em) and critical difference (CD) at 5% level of probability were calculated.

Results and Discussion

The fruit retention and days to fruit maturity had significant effect on seed yield. Maximum weight of fruits (6.45 g) and 100-seed weight (6.501 g) were noticed in 15 fruit/plant (R_2). In fruit length, fruit girth and number of seeds/fruits, maximum value was recorded in 20 fruits/plant (R_3) which is 17.40 cm, 5.57 cm and 44.02 respectively. This might be due to that under low fruit load, competition for assimilates reduced (Ginoya et al., (2021). Significantly highest seed yield/plant (74.73 g) was noticed in all fruits retained per plant (R_4). It may be due to retention of more number of fruits/plant (Patil *et al.,* 2008). Maximum plant height and bulb yield was observed due to different planting dates (Sharma and Khadda, 2023).

The maximum weight of fruits (6.69 g), fruit length (17.41 cm), fruit girth (5.64 cm), number of seeds/fruit (45.44), seed yield (54.01 g) and 100-seed weight (6.58 g) were recorded in 50 days after fruit formation (M_1). These might be due to fruits after attaining a maximum growth in initial stages, its weight decreased towards later stages. This loss in weight of fruits in later stages was associated with changes in moisture content in maturing fruits. These results are in conformity with those of Dhobi et al. (2015). Significantly maximum weight of fruit (7.80 g), fruit length (17.77 cm), fruit girth (5.75 cm), number of seeds/fruits (47.01) and 100-seed weight (6.893 g) were recorded in 15 fruits/plant with 50 days after fruit formation (R_2M_1). Seed yield/plant (77.87 g) was significantly higher in R_4M_2 (Table 1).

Table 1: Effect of number of fruits retention and days to fruit maturity on seed yield and seed vigour test of okra

Treatment	Seed Yield Attributes							Seed vigour test				
	Weight of fruit (g)	First fruit appearance at node	Fruit length (cm)	Fruit girth (cm)	Number of seeds/ fruit	Seed yield/ plant (g)	100-seed weight (g)	Speed of germination	Dehydro-genase test	Paper piercing test	Accelerated ageing test	Electrical conductivity test
Number of fruits retention/plant (R)												
R_1- 10 fruits	6.05	2.67	16.86	5.49	43.17	28.62	6.427	9.31	86.67	17.78	24.11	0.873
R_2- 15 fruits	6.45	2.89	17.20	5.56	42.66	42.41	6.501	11.39	90.00	36.67	32.78	0.825
R_3- 20 fruits	6.28	2.78	17.40	5.57	44.02	59.34	6.487	11.18	88.33	20.00	24.67	0.837
R_4- all fruits	5.71	2.89	16.67	5.43	42.09	74.73	6.133	10.65	82.22	26.11	19.56	0.890
S.Em±	0.12	0.21	0.16	0.04	0.47	1.41	0.096	0.14	1.11	0.56	0.42	0.004
CD @ 5%	0.35	NA	0.46	0.11	1.38	4.14	0.283	0.40	3.24	1.62	1.22	0.012
Days to maturity (M)												
M_1- 50 days	6.69	2.67	17.41	5.64	45.44	54.01	6.588	10.44	84.58	22.50	22.83	0.870
M_2- 60 days	5.99	3.00	16.67	5.48	43.27	51.40	6.320	10.55	87.08	24.58	24.92	0.855
M_3- 70 days	5.68	2.75	16.72	5.43	40.24	48.41	6.254	10.90	88.75	28.33	28.08	0.844
S.Em±	0.10	0.18	0.14	0.03	0.40	1.22	0.083	0.12	0.96	0.48	0.36	0.004
CD @ 5%	0.30	NA	0.39	0.09	1.19	3.59	0.245	0.35	2.81	1.40	1.06	0.011
Interaction (R × M)												
$T_1 = R_1M_1$	6.61	2.33	17.72	5.73	46.64	29.05	6.387	7.88	86.67	15.00	14.00	0.880
$T_2 = R_1M_2$	5.81	2.67	16.64	5.41	42.81	28.03	6.343	9.60	86.67	15.00	24.00	0.866
$T_3 = R_1M_3$	5.73	3.00	16.22	5.33	40.05	28.77	6.553	10.45	86.67	23.33	34.33	0.873
$T_4 = R_2M_1$	7.80	2.67	17.77	5.75	47.01	50.19	6.893	11.60	86.67	35.00	31.00	0.806
$T_5 = R_2M_2$	6.75	3.33	17.67	5.63	45.12	37.40	6.237	11.10	93.33	35.00	33.33	0.800
$T_6 = R_2M_3$	4.79	2.67	16.16	5.31	35.84	39.63	6.373	11.46	90.00	40.00	34.00	0.870
$T_7 = R_3M_1$	6.37	2.33	17.65	5.59	44.65	61.26	6.570	11.82	85.00	20.00	30.33	0.870
$T_8 = R_3M_2$	6.10	3.33	17.16	5.57	43.67	62.31	6.290	10.95	85.00	18.33	16.33	0.816
$T_9 = R_3M_3$	6.36	2.67	17.36	5.56	43.74	54.44	6.603	10.76	95.00	21.67	27.33	0.826
$T_{10} = R_4M_1$	5.96	3.33	16.50	5.49	43.45	75.52	6.503	10.47	80.00	20.00	16.00	0.923
$T_{11} = R_4M_2$	5.31	2.67	16.42	5.29	41.48	77.87	6.410	10.55	83.33	30.00	26.00	0.940
$T_{12} = R_4M_3$	5.85	2.67	17.10	5.50	41.34	70.80	5.487	10.93	83.33	28.33	16.67	0.806
S.Em±	0.20	0.36	0.27	0.07	0.81	2.44	0.166	0.24	1.92	0.96	0.73	0.007
CD @ 5%	0.60	NA	0.79	0.19	2.37	7.17	0.491	0.69	5.62	2.81	2.12	0.021
CV %	5.81	22.30	2.76	2.10	3.26	8.26	4.510	3.89	3.84	6.63	4.98	1.48

The seed quality attributes showed significant differences for number of fruits retention and days to fruit maturity. The 15 fruits/plant (R_2) recorded significantly higher germination (90.89 %) (Fig. 1), seedling root length (10.67 cm), seedling shoot length (17.89 cm), seedling length (28.56 cm), seedling fresh weight (4.740 g), seedling dry weight (0.1768 g) seedling vigour index-I (2601.28) and seedling vigour index-II (16.08). This may be due to less competition among fruits in 15 fruits retention treatment and higher competition for metabolites among fruits that retained all, due to less availability of photosynthates to individual seed for development that the resulted in the low quality of seeds (Kumar *et al.,* 2016).

The 70 days after fruit formation (M_3) recorded maximum germination (90.67 %) and seedling vigour index-II (15.61). Significantly maximum germination (96.67 %), seedling root length (11.91 cm), seedling shoot length (18.68 cm), seedling length (30.58 cm), seedling fresh weight (4.810 g), seedling dry weight (0.1804 g), seedling vigour index-I (2955.96) and seedling vigour index-II (17.44) were found in 15 fruits/plant with 50 days after fruit formation (R_2M_1) (Table 2).

The 15 fruits/plant recorded maximum speed of germination (11.39), dehydrogenase test (90.00), paper piercing test (36.67), accelerated ageing test (32.78) and lowest electrical conductivity (0.825 ds/m) due to lesser number of fruits absorbed more nutrients and minerals as compared to retaining all fruits/plant (Sharma *et al.,* 2020). Days to fruit maturity showed significant effect on seed vigour. The maximum speed

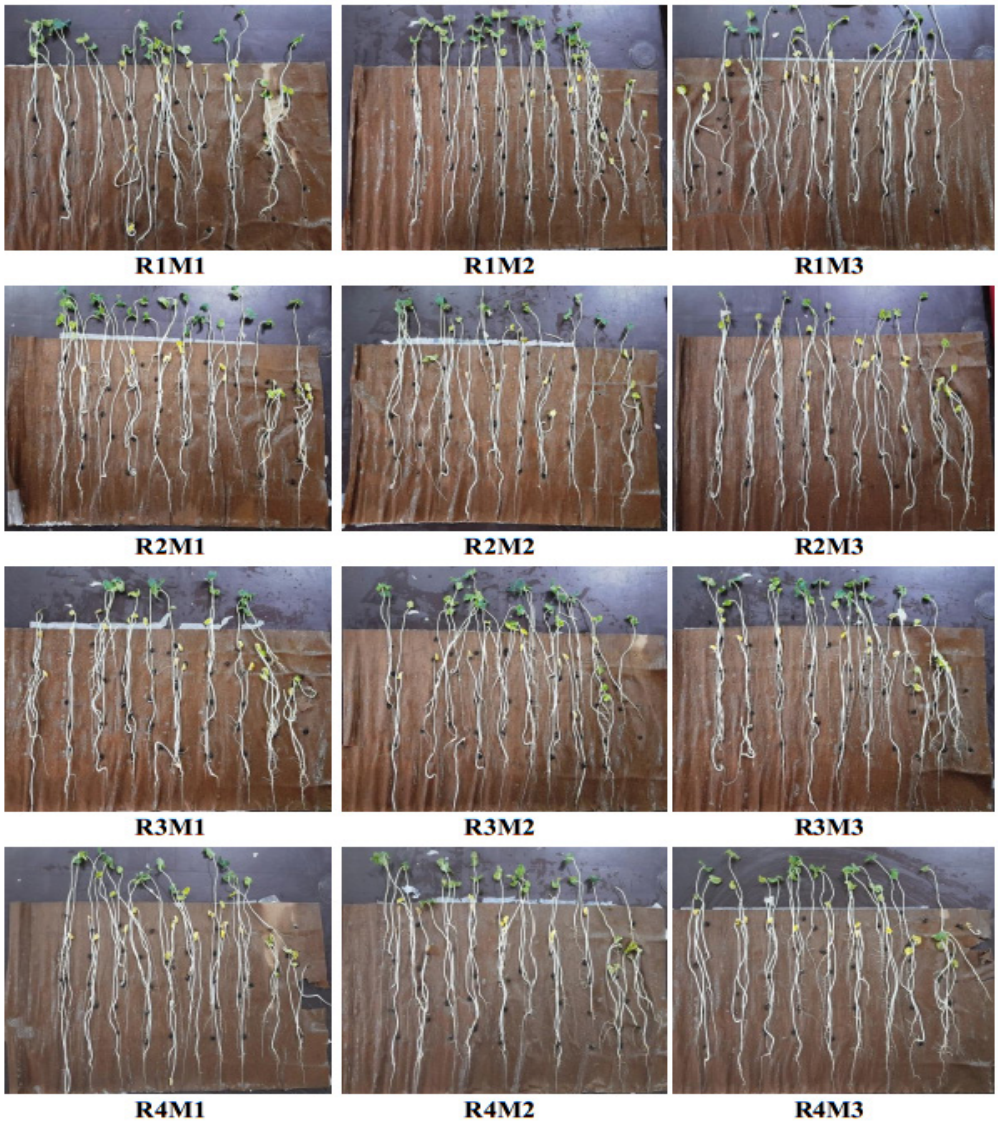

Fig. 1. Effect of number of fruits retention and days to fruit maturity on germination (%)

Table 2: Effect of number of fruits retention and days to fruit maturity on seed quality parameters of okra

Treatment	Seed Quality Parameters							
	Germination (%)	Seedling root length (cm)	Seedling shoot length (cm)	Seedling length (cm)	Seedling fresh weight (g)	Seedling dry weight (g)	Seedling vigour index-I	Seedling vigour index-II
Number of fruits retention/plant (R)								
R_1- 10 fruits	88.22	8.68	17.11	25.79	4.518	0.1709	2274.21	15.07
R_2- 15 fruits	90.89	10.67	17.89	28.56	4.740	0.1768	2601.28	16.08
R_3- 20 fruits	88.22	9.92	16.49	26.41	4.524	0.1716	2329.21	15.11
R_4- all fruits	85.11	9.11	16.31	25.42	4.416	0.1693	2162.39	14.42
S.Em±	1.24	0.26	0.39	0.46	0.041	0.0017	50.72	0.22
CD @ 5%	3.61	0.76	1.17	1.34	0.120	0.0050	148.94	0.67
Days to maturity (M)								
M_1- 50 days	87.00	9.54	16.95	26.49	4.485	0.1704	2315.28	14.85
M_2- 60 days	86.67	10.05	16.73	26.78	4.557	0.1737	2322.86	15.05
M_3- 70 days	90.67	9.20	17.17	26.37	4.606	0.1723	2387.17	15.61
S.Em±	1.07	0.23	0.35	0.40	0.036	0.0015	43.93	0.190
CD @ 5%	3.13	0.66	NA	NA	NA	NA	NA	0.580
Interaction (R × M)								
$T_1 = R_1M_1$	82.67	8.12	17.30	25.42	4.483	0.1705	2097.86	14.10
$T_2 = R_1M_2$	88.00	9.39	17.55	26.95	4.613	0.1735	2374.44	15.27
$T_3 = R_1M_3$	94.00	8.52	16.48	25.00	4.460	0.1687	2350.31	15.86
$T_4 = R_2M_1$	96.67	11.91	18.68	30.58	4.810	0.1804	2955.96	17.44
$T_5 = R_2M_2$	86.00	10.56	17.52	28.08	4.706	0.1753	2417.94	15.08
$T_6 = R_2M_3$	90.00	9.55	17.48	27.03	4.703	0.1746	2429.93	15.72
$T_7 = R_3M_1$	89.33	9.09	14.80	23.89	4.143	0.1602	2138.88	14.30
$T_8 = R_3M_2$	87.33	11.05	17.08	28.14	4.730	0.1802	2456.29	15.72
$T_9 = R_3M_3$	88.00	9.62	17.59	27.12	4.700	0.1744	2392.47	15.31
$T_{10} = R_4M_1$	79.33	9.03	17.04	26.06	4.506	0.1708	2068.44	13.56
$T_{11} = R_4M_2$	85.33	9.19	14.76	23.95	4.180	0.1658	2042.79	14.16
$T_{12} = R_4M_3$	90.67	9.12	17.12	26.24	4.563	0.1715	2375.97	15.55
S.Em±	2.14	0.45	0.69	0.79	0.071	0.0030	87.86	0.19
CD @ 5%	6.25	1.32	2.02	2.33	0.208	0.0087	257.98	0.58
CV %	4.21	8.17	7.07	5.22	2.710	3.030	6.49	4.50

of germination (10.90), dehydrogenase test (88.75), paper piercing test (28.33) and accelerated ageing test (28.08) were recorded in 70 days after fruit formation (M_3). Significantly lower electrical conductivity (0.844 ds/m) was recorded 70 days after fruit formation (M_3). It may be due to high accumulation of photo assimilates in seeds harvested 70 days to fruit maturity, in comparison to seeds obtained at 50 days to fruit maturity. The results are in conformity with Vidyadhar et al. (2014). Interaction between fruit retention and fruit maturity (R × M) showed significant effect on seed vigour test. The highest speed of germination (11.82), dehydrogenase test (95.00), paper piercing test (40.00) and accelerated ageing test (34.33) were recorded in R_3M_1, R_3M_3, R_2M_3 and R_1M_3 respectively. Whereas, lower (0.800 ds/m) electrical conductivity was recorded with R_2M_2 (Table 3).

Conclusion

Seed production of okra variety GAO 8 can be practised at 15 fruits/plant (R_2) which resulted in higher seed yield and quality parameters. The 50 days after fruit formation (M_1) proved to be more effective for obtaining higher seed yield and better quality of seeds. Therefore, 15 fruits/plant (R_2) at 50 days after fruit formation (M_1) may be used for higher seed yield, quality and vigorous seed of okra var. GAO 8.

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Evaluation of high temperature tolerant longmelon (*Cucumis melo)* cultivar

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Abstract

Longmelon (*Cucumis melo* L. var. *utilissimus*), a warm season crop, can be grown in tropical and subtropical regions. The cv. AHLM-2 (Thar Sheetal) has been developed to produce early fruiting with quality fruits free from bitterness coupled with tolerance to high temperature. Varieties developed by the private sector are used by the farmers and their seed are expensive. The release of Thar Sheetal, an open-pollinated cultivar with better fruit length (27.62 cm) and fruit weight (81.82 g) is a prolific bearer (18.20-21.87 marketable fruits/ plant). Thar Sheetal has high yield potential of 136.31 q/ has under hot arid conditions, which is 22.11% higher than the control 'Punjab Longmelon-1'. It bears tender, attractive, light green fruits which are not bitter. Thar Sheetal can withstand high temperature and is able to set fruits up to 42° C under hot arid conditions.

Key words: Abiotic, Biotic, Hot arid, High temperature, Variability, Yield

Longmelon (*Cucumis melo* L. var. *utilissimus*) with tender fruit is used as a salad, pickle or cooked as a vegetable. India being the centre of diversity provides a wide range of variation for genetic improvement of melons (Pandey *et al.*, 2005). The persistence of large variability ensures better chances to select new genotypes having resistance/ tolerance against biotic and abiotic stress (Choudhary *et al.*, 2016 and Saroj and Choudhary, 2020). Therefore, evaluation of the variability is prerequisite in crop improvement programme.

Materials and Methods

The Thar Sheetal was evaluated during 2015 to 2017 (Choudhary and Saroj, 2018 and Choudhary *et al.*, 2018a). The experiment was conducted during summer season at ICAR-CIAH, Bikaner, Rajasthan. The soil of experimental field was loamy sand with a pH of 8.7, EC 0.20 dS/m and organic carbon 0.07%. The experiment comprised seven lines of longmelon including control in randomized block Design replicated thrice.

The data were recorded on five randomly selected plants from each replication for days taken to produce 50% pistillate flowering, fruit length (cm), fruit diameter (cm), fruit weight (g), number of marketable fruits/ plant, marketable fruit yield/ plant (kg) and fruit yield (q/ ha). Fruit length, fruit diameter and fruit weight were recorded at marketable stage. Diameter of fruits was measured with the help of Digital Vernier Caliper (MITU-TOYO, 300 mm, 0.01 mm reading capacity). Fruits were tested at tender stage for bitterness.

The number of fruit fly infested fruits and marketable fruits from five selected plants were counted separately from all pickings and calculated the per cent fruit fly infestation. The genotypes were categorised adopting the rating system proposed by Nath (1966) for fruit infestation as: immune (no damage), highly resistant (1–10%), resistant (11–20%), moderately resistant (21–50%), susceptible (51–75%) and highly susceptible (76–100%).

The pooled data of 03 years were statistically analysed online using http://dsdhakre.in/pooled.html. The data on percentage fruit fly infestation were analyzed through one-way ANOVA using SPSS 16 software (O'Connor, 2000). The DNA fingerprinting was done by using PCR profiling of 15 ISSR, 10 ScoT (start codon targeted polymorphism) and 10 CBDP (CAAT box-derived polymorphism) markers using Punjab Longmelon-1 cultivar as comparative control to assess the fidelity of varietal-specific bands.

The trials were conducted adopting recommended cultural practices (Choudhary *et al.*, 2018b). The field was prepared through disc harrow twice followed by planking to make the soil friable. The well-decomposed FYM (200 q/ ha) was applied at last ploughing. Seed treatment was

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done with Thiram @ 2 g/ kg seed. The crop was established from seed sown in the field during second fortnight of February on drip system of irrigation installed maintaining 2.0 m space between rows and 60 cm from plant-to-plant. The 60 kg N, 80 kg P_2O_5 and 60 kg K_2O was applied with urea, DAP and muriate of potash, respectively. The half dose of nitrogen and full of phosphorus and potassium was applied before sowing in the marked area only.

The remaining dose of N was divided in two equal parts and applied at the time of vine growth and full blooming stage. Fertigation with water-soluble NPK 19:19:19 @ 10 kg/ ha was done at vine development and fruiting stage. Foliar spray of Boron @ 25 ppm at 2-4 true leaf stage and flower initiation stage was done. The crop was irrigated at 2-3 days interval for 1-1.5 hour through drip system having in-line drippers of 4 litre/ hour capacity. Weed control was done manually by performing 2 hand weeding at 15-20 days after sowing and again at 35-40 days after sowing.

The white fly, leaf miner and aphid were controlled by spraying Imidacloprid 17.8% SL @ 0.3 ml/ litre of water. Mite was controlled by need based spray of Propargite @ 2 ml per litre of water. To manage fruit fly, 12 Cue-lure traps were installed in one hectare field. Spinosad 45% SC (0.4 ml per litre of water) was also sprayed to control fruit fly (Haldhar *et al.*, 2014). Mencozeb @ 2 g per litre of water was sprayed to manage the *Alternaria* leaf blight disease. Drenching with Carbendazim @ 2 g per litre of water was carried out to manage the Fusarium wilt (Maheshwari *et al.*, 2022).

Results and Discussion

Fruit yield of 'Thar Sheetal' was higher than other genotypes and the control (Table 1). The increase in fruit yield of 'Thar Sheetal' was up to 43.20% over AHLM-5, followed by AHLM-1 (35.63%). Thar Sheetal recorded 22.11% higher yield over the control (Punjab Longmelon-1) during summer seasons at Bikaner. Fruit length varied from are 25.83-29.67 cm which is acceptable by consumersand a single plant produced 18.20-22.20 marketable fruits/plant under hot arid conditions.

The plants of Thar Sheetal have vine length of 2.15-2.38 m at last fruit harvest and produced profuse branching. It produced pistillate flowers on lower nodes (6.80-7.60). Thar Sheetal bears light green coloured, attractive and tender fruits at edible stage which are free from bitter principle at high temperature conditions (Choudhary *et al.*, 2018a). Thar Sheetal is capable to withstand high temperature and able to set fruits up to 42°C during April-May months under hot arid conditions of Rajasthan.

The melon fruit fly (*Bactrocera cucurbitae*) is a serious pest of longmelon and its outbreak cause substantial loss (30-100%) to growers. Therefore, Thar Sheetal was screened against melon fruit fly during 2015 and 2016. It was found moderately resistant

Table 1. On-station performance of longmelon lines for fruits/ plant[z] and marketable fruit yield (2015-17)

Line	Number of marketable fruits/ plant		Marketable fruit yield (kg/ plant)		Fruit yield (q/ ha)		Increase in fruit yield (%)
AHLM-1	14.18		1.03		100.50		+35.63
AHLM-2 (Thar Sheetal)	20.76		1.70		136.31		-
AHLM-3	15.24		1.09		104.56		+30.36
AHLM-4	15.25		1.08		102.38		+33.15
AHLM-5	15.00		1.03		95.19		+43.20
AHLM-6	16.82		1.23		114.88		+18.66
Punjab Longmelon-1 (C)	17.51		1.15		111.63		+22.11
	SE	CD (0.05)	SE	CD (0.05)	SE	CD (0.05)	
Location	0.34	0.68	0.03	0.07	2.70	5.47	
Treatment	0.52	1.05	0.05	0.11	4.12	8.35	
Treatment × location	0.89	1.81	0.09	0.19	7.13	14.47	
CV (%)	6.67		9.51		7.99		

[z]Varietal trials conducted in a randomized block design with three replications.

LSD: Least significant difference, SE: Standard error, Values within columns with different letters (superscript) are significantly different according to Duncan's test at P=0.05.

against melon fruit fly under field conditions. The fruit infestation varied from 29% (2015) to 30.67% (2016) under field conditions (Table 2).

Table 2. Reaction to per cent fruit infestation by melon fruit fly under field conditions

Line	Fruit infestation (%)	Category
AHLM-1	37.358	Moderately resistant (MR)
AHLM-2 (Thar Sheetal)	33.574	MR
AHLM-3	47.865	Susceptible (S)
AHLM-4	38.074	MR
AHLM-5	47.852	S
AHLM-6	42.109	MR
Punjab Longmelon-1 (C)	52.19	S
SEm+	2.068	
CD (0.05)	6.443	
CV (%)	8.386	

*Values in parentheses are angular-transformed.

SEm: Standard error of mean, CD: Critical difference, CV: Coefficient of variation

Based on the performance of Thar Sheetal at station trials, it was proposed for adaptive trials and conducted the experiment at Adaptive Trial Centre (ATC), Jodhpur, Rajasthan during summer 2018 along with the control. It gave fruit yield of 170.30 q/ ha which was 17.04% higher over check *i.e.* Punjab Longmelon-1. Further, Thar Sheetal was also evaluated at KVK, Fatehpur and KVK Pali during summer season of 2018. It was found suitable for cultivation in different agroclimatic conditions of Rajasthan and produced fruit yield of 165.0 q/ ha at KVK, Fatehpur and 178.0 q/ ha at KVK, Pali. In adaptive trial, Thar Sheetal took 46 days for first fruit harvesting which produced 32.60 cm long fruits weighing 110.16 g and yielded 3.70 kg marketable fruits/ plant.

The DNA fingerprinting of Thar Sheetal was done by using PCR profiling of 15 ISSR, 10 ScoT (start codon targeted polymorphism) and 10 CBDP (CAAT box-derived polymorphism) markers. Punjab Longmelon-1 cultivar was used as comparative control to assess the fidelity of varietal-specific bands. Ten ISSR markers, three ScoT and seven CBDP markers produced specific bands which differentiated Thar Sheetal from Punjab Longmelon-1.

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Variability in different isolates of *Penicillium italicum* causing blue mould rot in orange (*Citrus reticulata*)

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Abstract

Seven isolates of blue mould fungi (*Penicillium italicum*), causing blue mould rot on orange (*Citrus reticulata Blanco*) isolated from Jobner region exhibited variable growth on artificial culture media (PDA). The PI-1 appeared as dark green centre with white periphery. The other isolates had different colony characters with green to light blue centre surrounded by cottony to profuse colony peripheries. The disease intensities of blue mould isolates were also variable. The PI-1, PI-2 and PI-3 were at par, while maximum intensity (57.76 %) was recorded in PI-1 and minimum (21.12 %) in PI-7.

Key words: Morphological, Pathological, Isolates, Blue mould rot, Cultural variability

Orange (*Citrus reticulata* Blanco) is most common citrus fruit grown in India. In Rajasthan, area under orange is 23,188 ha with a total production on 3,17,679 tonnes and productivity of 13.70 tonnes/ha (2017-18). The major constraint is post-harvest spoilage, caused by green and blur moulds. The *Penicillium digitatum* and *P. italicum* causes 80 per cent losses in mediterranean conditions (Embaby *et al.*, 2013). Primarily consumed as fresh fruits and also processed mainly to prepare squash, juice, marmalade and pickles (Tripathi *et al.*, 2018). An experiment conducted to improve quality and yield of Nagpur mandarin by using foliar application of GA3 with urea to delay the senescence of tissues and maintain their firmness (Kalapatti *et al.*, 2022).

Materials and Methods

Seven locations in Rajasthan, viz. Jaipur, Chaumu, Sikar, Ajmer, Alwar, Jhalawar and Jaipur were surveyed for the fungus. The diseased sample were collected, from markets, the pathogen was isolated, brought to pure cultures and cultural, morphological and pathogenic differences were studied. Small bits of infected rind of orange fruits adjoining with some healthy area were surface sterilized in 1 per cent Naocl, followed by three washings with sterilized water and transferred to petridishes at 25+1oC in BOD incubator for seven days. The culture was purified by preparing a spore suspension in distilled water with a dilution of 25-30 spores under 10x magnification and transferred to plain agar medium (2.0%).

After 24 hours, germinating spores were located, cut by a dummy objective, transferred to PDA slants and incubated at 25+1oC for 6-7 days. Pathogenicity tests were carried out through standard technique. To investigate the cultural and morphological variability, single spore culture of seven isolates (PI-1 to PI-7) were established and maintained on PDA and radial growth of fungal mycelium, colony characters and sporulation. Each treatment was quadruplicated. In order to test the pathogenic variability among isolates, orange fruits were inoculated with seven days old culture of fungus. Severity of fruit rot was recorded with each treatment replicated 4 times, having three orange fruits in each replication.

Results and Discussion

The cultural and morphological characteristics such as colour and appearance of mycelial growth of different isolates of *Penicillium italicum* were recorded by growing them on artificial culture medium. The results clearly reveal that there were marked variations in colony characters and growth rates among seven isolates of fungus measured at seven-day-old inoculation (Table 1) The colony growth rate of these isolates arranged in descending order showed maximum growth in PI-1 (65.60 mm) followed by PI-3 (63.80 mm), PI-4

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(62.60 mm), PI-2 (61.50 mm), PI-5 (59.70 mm), PI-6 (56.50 mm) and PI-7 (55.75 mm). Based on the colony appearance PI-1 characterized as green centre with white periphery whereas PI-2, PI-5 and PI-6 were of green colour without dominant green centre and had white periphery. The PI-3 colony had light green colour, surrounded by a white cottony growth, whereas PI-4 was of green centre with profuse cottony growth and PI-7 was of light bluish colour with cottony periphery (Fig. 1).

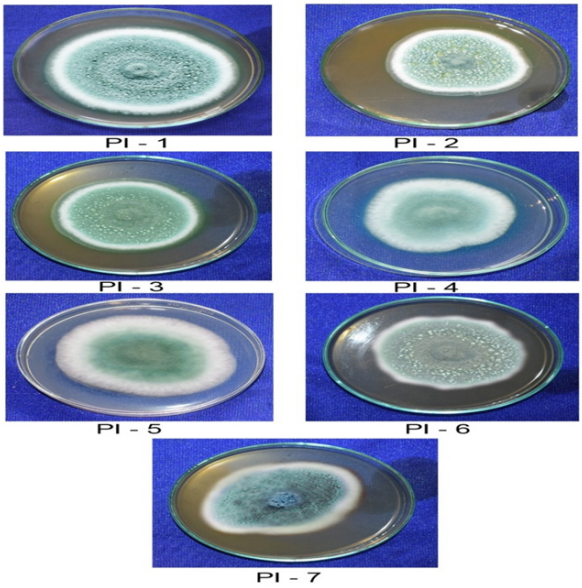

Fig. 1: Cultural and morphological variability in different isolates of *Penicillium italicum*

Table 1: Cultural and morphological variability in different isolates of *Penicillium italicum* at 7th day of incubation

Isolate	Colony characters	Colony diameter (mm)*
PI-1	Green centre with whitish periphery	65.60
PI-2	Medium green and cottony periphery	61.50
PI-3	Light green surrounded by cottony growth	63.80
PI-4	Green centre with profuse cottony growth	62.60
PI-5	Greenish growth with white periphery	59.70
PI-6	Light green with dark centre surrounded by white periphery	56.10
PI-7	Light bluish with cottony periphery	56.75

*Average of four replications

Morphological characteristics of Penicillin italicum and P. digitalum have been described by Subramanian (1971) and Kumari (2005). Our findings of present investigation are in close confirmation of Zhao *et al.* (2016) and Yin *et al.* (2016).

The morphological behavior of different isolates of *Penicillium italicum* has also been reflected in their pathogenic variability on orange fruit. All the seven isolates were tested under favourable conditions of the pathogen. The results showed maximum disease intensity (57.76%) with PI-1 isolate, followed by PI-3 (54.11%), whereas lowest disease intensity (21.12%) was recorded with PI-7. The remaining isolates were intermediate in disease intensity percentage. The PI -1, PI-2 and PI-3 were statistically at par with each other and PI-4 and PI-7 were also statistically similar (Table 1). Different levels of disease incidence have been reported by earlier workers. Disease incidence was reported between 17.6 to 48.6 per cent on wholesale and retail markets of Madhya Pradesh, caused by Pencillium of orange fruits, whereas average disease severity 49.63 per cent was recorded under ambient conditions (Alam *et al.* 2016).

Table 2: Pathogenic variability in different isolates of *Penicillium italicum* at 7th day of incubation

Isolate	Intensity
PI-1	57.76 (49.46)
PI-2	44.62 (41.91)
PI-3	54.11 (47.36)
PI-4	53.21 (46.84)
PI-5	43.23 (41.11)
PI-6	37.80 (37.94)
PI-7	21.12 (27.36)
SEm±	1.55
CD (p=0.05)	4.77

Figures in parentheses are angular transformed values

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Integrated protocol for value-addition in strawberry *(Fragaria x ananassa)*

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Abstract

An integrated protocol was standardized for production of diversified products from strawberry (*Fragaria x ananassa*). The fresh fruits were subjected to lactic acid fermentation using *Lactobacillus* sp. The prepared probiotic drink was collected and left over fruits were utilized for preparation of other products, viz. candy, squash, jelly and wine. Candy was prepared by incubating whole fruits in subsequently increasing concentrations of sugar syrup and then drying at 60 °C temperature in electric dehydrator to an intermediate moisture level of around 12%. The sugar syrup thus left had attractive red color due to anthocyanins extracted from the fruits. It was used for preparation of squash, jelly and wine. The strawberry probiotic drink contained 2.2 °B TSS, 0.17% acidity, 2.1 mg/100ml vitamin-C, 37.1 mg/100ml phenolics and 2.36 mg/100ml anthocyanins. During ambient storage of probiotic drink up to 30 days, vitamin-C, phenolics and anthocyanin contents decreased while reducing sugars increased. Quality analysis of strawberry products revealed that candy contained highest amounts of phenolics and anthocyanins followed by jam, jellly and squash and least in wine. The vitamin-C content ranged between 1.6 to 14.8 mg/100 g or ml, being highest in jelly while least in wine. The ethanol content in wine was found to be 11.7 per cent. All the strawberry products were highly acceptable during sensory evaluation scoring above 7.0 out of total 9.0. It may be concluded that a variety of processed products could be prepared from same raw material by using the integrated protocol for strawberry products.

Key words: Strawberry, Probiotic, Fermentation, *Lactobacillus,* Anthocyanins

Strawberry (*Fragaria x ananassa*) is one of the richest sources of natural antioxidants among fruits (Wang *et al.,* 1996, Wang and Zheng, 2001). In addition to usual nutrients, such as vitamins and minerals, strawberries are also rich in anthocyanins, flavonoids and phenolic compounds (Heinonen *et al.*, 1998). The fruit contains ellagic acid, ellagitannins, gallotannins, proanthocyanidins, quercetin, catechin, ascorbic acid, folic acid and minerals (Karaaslana and Yamanb, 2017). A number of strawberry products like juice, jam, jelly, squash, etc. were prepared by many workers (Ayub *et al*., 2010; Khan *et al*, 2012; Islam *et al*, 2012; Kefayatullah *et al*., 2019) but their studies were limited only to preparation of single product from single raw material. A concept of multiple product development from single source with complete utilization of left over materials has been worked out. An integrated protocol has been developed for production of diversified products, viz. probiotic drink, sqaush, jam, jelly, candy and wine.

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Materials and Methods

Healthy, mature, ripe fruits of strawberry were brought from Institute's orchard and washed thoroughly with tap water. The probiotic drink was prepared as per the method developed by Garg *et al.* (2015) for cucumber probiotic drink. The fruits were subjected to lactic acid fermentation in brine solution using *Lactobacillus plantarum* culture maintained in Microbiology Laboratory. After achieving desired level of lactic acid content in solution, it was collected as probiotic drink after separating the fruits (Fig. 1). The drink was filled in bottles and stored under ambient conditions. It was analyzed for biochemical, sensory and microbial parameters enlisted in next paragraph.

The fruits obtained were divided into two batches. One batch of fruits was subjected to jam preparation by pulping and heating of pulp with required amount of sugar and acid using protocol described by Srivastava and Kumar (2002). The second batch of strawberries was utilized for preparation of candy as per the method Tandon *et al.*

(2004) for making aonla candy. The strawberries were incubated for two successive overnights in increasing concentrations of sugar syrup at 50 and 60 °Brix. The fruits were then separated, rinsed with warm water and dried in electric dehydrator at 60° C to an intermediate moisture level of around 12 percent. The prepared candy was packed in small jars. The attractive red colored left-over sugar syrup was then utilized for three kinds of products. Two non-fermented products, viz. squash and jelly were prepared by mixing sugar and other additives using methods of Srivastava and Kumar (2002). The fermented product, strawberry wine was prepared through alcoholic fermentation applying lab culture of *Saccharomyce cerevisiaes* as per the protocol developed by Garg *et al.* (2014) for bael wine.

The prepared strawberry products were analyzed for physico-chemical attributes. The TSS was recorded by using hand refractometer (Erma, Japan). Titratable acidity, ascorbic acid, and total phenolics were determined as per the methods described by Ranganna (2000). The acidity of products was estimated by titrating the samples against 0.1 N sodium hydroxide solution using phenolphthalein as indicator. The acidity of probiotic drink was calculated in terms of lactic acid while it was in terms of citric acid in case other products. Ascorbic acid content of beverage was measured by titrating samples against 2, 6-dichloro phenol indophenol dye solution, while phenolic content was estimated by using Folin and Ciocalteu's reagent. Total anthocyanins were determined by the ethanol extraction method developed by Fuleki and Francis (1968). The concentration of ethanol in strawberry wine was measured spectrophotometrically using potassium dichromate-sulphuric acid mixture as per the method of Caputi *et al.* (1968).

The sensory evaluation of products was carried out by a panel of semi-skilled judges on composite scoring (Amerine *et al.*, 1965) based on colour, aroma and taste of samples. The microbial counts for bacteria, yeast and mould were observed as per Speck (1984) method. The samples were analyzed in three replicates and data was presented in tabular form. It was analyzed statistically for mean value and standard deviation using microsoft excel.

Results and Discussion

The prepared probiotic drink was subjected to total microbial count and was found to have more than 10^6 counts of *Lactobacillus* bacteria. The total soluble solid of the drink was 2.2 °B at zero day which remained almost unchanged during storage up to one month (Table 1). The acidity of drink was observed to be 0.17

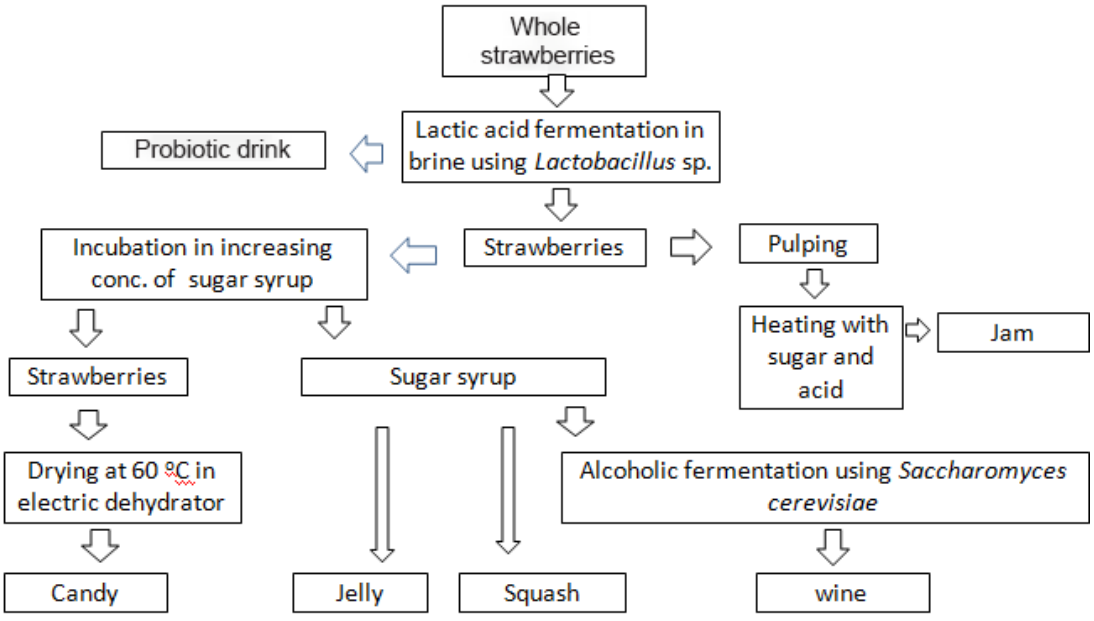

Fig. 1: Flow diagram of integrated protocol for strawberry value-addition.

per cent as lactic acid. It remained unchanged up to 20 days of storage but decreased thereafter to 0.12 per cent at 30 days (Table 1). The product had little amount of vitamin C (2.1 mg/100 ml) which further declined to negligible amount (0.8 mg/100 ml) after one month (Table 1).

This reduction might be due to oxidation of ascorbic acid into dehydroascorbic acid by oxygen (Sethi *et al.,* 1980). The probiotic drink contained good amount of phenolic compounds (37.1 mg/100ml) initially which decreased continuously with the storage period (Table 1). After 30 days, the total phenolic content was found to be 25.1 mg/100ml. The decrease in phenolic compounds may be attributed to break down of these compounds during storage. Raj *et al.* (2011) also reported gradual decline in polyphenol contents in sand pear and pear-apple juice beverage during storage.

The product had attractive purple colour due to presence of anthocyanins. The level of anthocyanin pigment was 2.36 mg/100ml initially which fell to a final level of 1.33 mg/100ml after one month, showing regular decrease throughout storage (Table 1). The fall in anthocyanins during storage might be due to oxidation of pigment. Muche *et al* (2018) also reported reduction in anthocyanin content during storage. Reducing sugars content depicted increasing trend during storage. It increased from an initial value of 0.48 per cent to 1.03 per cent at the end of storage.

The increase is attributable to the hydrolysis of sucrose in glucose and fructose by the acid present in the beverages or gradual inversion of non-reducing sugars into reducing sugars in acidic medium (Malav *et al.*, 2014). During sensory evaluation on the basis of appearance, aroma and taste, the probiotic drink obtained high organoleptic score (8.1 out of 9.0) at zero day which though declined but retained within good acceptable range till the end of storage (Table 1).

The prepared products, viz. squash, jelly, jam, candy and wine were also evaluated for different biochemical parameters (Table 2). The vitamin-C content in squash, jelly, jam and candy ranged from a lowest of 11.6 mg/100 g in squash to a highest of 14.8 mg/100 g in jelly. Candy was found to contain maximum phenolic (198.0 mg/100 g) and anthocyanin contents (20.4 mg/100 g), followed by jam, jelly and squash. The strawberry wine was found to contain 11.7 per cent ethanol apart from 1.6 mg/100 ml vitamin-C, 22.5 mg/100 ml phenolics and 3.7 mg/100 ml anthocyanin content after 45 days of ageing under refrigerated condition. All the products had good acceptable sensory qualities.

Table 1: Changes in chemical attributes of strawberry probiotic drink during storage

Parameters	Period of storage (Days)			
	0	10	20	30
Total soluble solids (^{O}B)	2.2±0.11	2.2±0.11	2.2±0.11	2.0±0.11
Acidity as lactic acid (%)	0.17±0.01	0.17±0.01	0.17±0.01	0.12±0.01
Vitamin-C (mg/100ml)	2.1±0.05	1.9±0.05	1.1±0.05	0.8±0.05
Total phenolics (mg/100ml)	37.1±0.11	34.9±0.89	28.4±0.25	25.1±0.90
Total anthocyanins (mg/100ml)	2.36±0.05	1.97±0.03	1.60±0.04	1.33±0.01
Reducing sugars (%)	0.48±0.01	0.51±0.01	0.58±0.01	1.03±0.01
Sensory scores (out of 9)	8.1±0.26	7.7±0.68	7.5±0.52	7.0±0.29

Mean Value ± Standard Deviation

Table 2: Biochemical characteristics of strawberry products

Product	Total soluble solids (OB)	Acidity (%)	Vitamin C (mg/100 g or ml)	Total phenolics (mg/100 g or ml)	Total anthocyanins (mg/100 g or ml)
Squash	55.0±0.11	0.69±0.05	11.6±0.06	30.6±0.75	4.7±0.06
Jelly	78.0±0.11	1.15±0.06	14.8±0.35	130.5±2.25	8.6±0.05
Jam	72.0±0.11	0.77±0.05	13.1±0.35	167.1±16.4	12.4±0.20
Candy	68.0±0.11	0.97±0.05	13.1±0.35	198.0±6.7	20.4±0.11
Wine	8.6±0.11	0.49±0.01	1.6±0.06	22.5±2.3	3.7±0.11

Mean Value ± Standard Deviation

Conclusion

The protocol followed for strawberry value addition resulted in obtaining multiple diversified products (main product and co-products) from a single starting raw material. After obtaining probiotic drink, fruits separated were used for preparation of candy or jam while byproduct, i.e. sugar syrup was used for squash, jelly or wine. Thus, depending upon the resources available, the processing economics can be improved to a significant extent. The technology leaves no waste and hence highly viable economically as well as ecologically.

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Effect of zinc and corm size on growth and corm yield in gladiolus (*Gladiolus* spp.)

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Abstract

An experiment was conducted at Banaras Hindu University, Varanasi, Uttar Pradesh, to find the effect of soil application of zinc sulphate and corm size on growth and corm parameters in gladiolus cv. Malaviya Kundan during 2018-19. The experiment was laid out in randomized block design replicated 4 times where mother corms of seven different sizes and zinc sulphate at three different levels were used. The largest-sized corm (4.0 cm) was found to be the best in growth characters like leaf length, scape width and number of leaves/plant. Application of zinc at various doses also provided positive response in days to sprouting and leaf length. Bigger- sized corms (3.0-4.0 cm) produced more no. of corms and cormels/hill, increased diameter and weight of corms compared to small size of mother corms (1.0-2.5 cm). All the doses of zinc sulphate failed to exert any significant effect on production of corms and cormels.

Key words: Corm grades, Zinc sulphate, Soil application, Plant growth, Corm, Yield.

Gladiolus (*Gladiolus* spp.), as a cut flower, is becoming popular day-by-day because of its magnificent inflorescence and availability of a wide range of colours (Singh, 2006, Swaroop *et al.*, 2019). Production of good quality floral spikes depends on vigorous vegetative growth and it is believed to be affected by the presence of micronutrients in soil in an ample quantity (Somkuwar *et al.*, 2023). Among all micronutrients, zinc (Zn) the meticulously regulates various metabolic processes in plants which helps to enhance growth (Hembrom and Singh, 2015), flower (Saeed *et al.*, 2013) and corm production (Singh and Singh, 2000). Application of ZnSO4 at 0.4% enhanced length and width of longest leaf and also improved weight of corms and cormels produced per hill with improved corm diameter in gladiolus (Hembrom *et al.*, 2015, Rocktim and Sunil, 2022). Application of zinc in gladiolus resulted in maximum number of cormels per hill whose weight was also influenced with the same (Singh *et al.*, 2015b). In the areas of Varanasi district, 46% of the soil was found deficient to zinc and higher content zinc found only in 17% soils (Singh *et al.*, 2013). In India, very little work has been done on soil application of zinc with the use of varying plant propagules in gladiolus. Keeping in view, a field trial was conducted to investigate the effect of zinc sulphate and corm grades on growth and corm yield in gladiolus cv. Malaviya Kundan.

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Materials and Methods

The experiment was conducted at Banaras Hindu University, Varanasi, Uttar Pradesh, India, during 2018-19. The experimental site is located around the centre of North- Gangetic alluvial plain at 25°15' north latitude, 83°03' east longitude and has an elevation of 129.23 metres above mean sea-level. The climate of Varanasi is humid-subtropical having dry summers as well as cold winters with the temperature ranging 22 to 46°C and annual rainfall around 998 mm per annum. Diseased-free and healthy corms of gladiolus cv. Malaviya Kundan of varying sizes, i.e. 1.0 cm, 1.5 cm, 2.0 cm, 2.5 cm, 3.0 cm, 3.5 cm and 4.0 cm were planted in beds sizing 3m × 2m with row-to-row 30 cm and corm-to-corm 20 cm during mid- November. Zinc sulphate (ZnSO4) was used at three different levels, i.e. control (no zinc), 15 kg/ha and 30 kg/ha and were incorporated in soil at the time of field preparation.

There were total 21 treatment combinations between corm grades and zinc sulphate. These treatments were replicated four times in randomized block design. The irrigation, weeding, earthing-up, plant- protection and staking were done whenever needed. The observations were recorded on growth and corm characters. Studied growth parameters were days taken to 50, 75 and 100% sprouting, leaf length, scape width, number of leaves/plant, whereas, yield/corm was counted as number of corms/hill, diameter of corms, weight of corms, number of cormels/

Table 1: Effect of corm grades and zinc sulphate on growth parameters such as days to sprouting, leaf length, scape width and number of leaves/plant in gladiolus var. Malaviya Kundan.

Treatment	Days to sprouting			Leaf length (cm)			Scape width (cm)			No. of leaves/plant		
	50%	75%	100%	40th DAP	60th DAP	80th DAP	40th DAP	60th DAP	80th DAP	40th DAP	60th DAP	80th DAP
Corm grades												
4.0 cm	10.63	11.62	16.66	34.83	36.92	41.37	1.91	2.72	2.88	4.02	7.47	7.47
3.5 cm	10.24	11.11	13.00	31.55	35.71	40.12	1.83	2.62	2.96	3.00	5.75	5.75
3.0 cm	9.93	11.52	17.33	26.79	31.03	36.99	1.73	2.52	2.97	2.79	5.58	5.58
2.5 cm	10.16	11.66	21.33	24.32	28.90	36.79	1.57	2.42	2.62	2.29	4.66	4.66
2.0 cm	11.70	14.00	22.33	23.82	27.01	33.61	1.64	2.80	2.91	2.06	4.12	4.12
1.5 cm	11.21	13.16	21.00	25.60	25.64	32.00	1.21	2.39	2.58	2.04	3.70	3.70
1.0 cm	12.94	14.02	15.36	20.96	24.67	26.35	0.60	1.38	1.49	1.14	2.39	2.39
C.D. (5%)	0.008	0.009	0.02	1.84	1.45	1.46	0.13	0.20	0.20	0.33	0.45	0.45
Zinc doses												
0 kg/ha (Control)	10.79	12.70	18.71	26.40	29.58	35.56	1.47	2.48	2.70	2.49	4.90	4.90
15 kg/ha	10.88	12.02	18.58	27.35	30.73	35.07	1.47	2.43	2.59	2.46	4.71	4.71
30 kg/ha	11.25	12.60	17.15	26.77	29.63	35.33	1.55	2.32	2.61	2.48	4.83	4.83
C.D. (5%)	0.005	0.006	0.01	NS	0.95	NS	NS	NS	NS	NS	NS	NS
Interaction (corm grade × zinc dose)												
4.0 cm × 0 kg/ha (Control)	10.56	11.00	13.00	35.45	37.12	41.30	1.89	2.66	2.72	3.87	7.56	7.56
4.0 cm × 15 kg/ha	10.85	13.00	20.00	35.59	37.01	41.53	1.97	2.77	2.89	3.93	7.25	7.25
4.0 cm × 30 kg/ha	10.50	10.86	17.00	33.46	36.63	41.28	1.87	2.74	3.02	4.25	7.62	7.62
3.5 cm × 0 kg/ha (Control)	10.90	11.79	14.00	30.14	35.46	40.72	1.85	2.61	3.00	3.18	6.06	6.06
3.5 cm × 15 kg/ha	10.83	11.25	12.00	34.28	37.07	39.16	1.79	2.64	3.05	3.06	5.62	5.62
3.5 cm × 30 kg/ha	9.00	10.30	13.00	30.24	34.60	40.46	1.86	2.62	2.85	2.75	5.56	5.56
3.0 cm × 0 kg/ha (Control)	10.30	11.57	19.00	25.37	29.83	37.57	1.74	2.49	3.01	2.75	5.93	5.93
3.0 cm × 15 kg/ha	9.00	11.00	18.00	26.92	33.84	36.45	1.71	2.65	2.78	2.56	5.37	5.37
3.0 cm × 30 kg/ha	10.50	12.00	15.00	28.09	29.42	36.94	1.73	2.42	3.13	3.06	5.43	5.43
2.5 cm × 0 kg/ha (Control)	8.80	11.00	22.00	25.40	29.47	37.52	1.57	2.60	2.73	2.50	4.62	4.62
2.5 cm × 15 kg/ha	10.00	11.00	20.00	24.03	27.53	35.76	1.56	2.64	2.69	2.25	4.62	4.62
2.5 cm × 30 kg/ha	11.70	13.00	22.00	23.54	29.71	37.07	1.57	2.02	2.44	2.12	4.75	4.75
2.0 cm × 0 kg/ha (Control)	12.00	15.00	23.00	23.49	25.84	33.04	1.36	3.10	3.22	2.06	4.06	4.06
2.0 cm × 15 kg/ha	10.80	12.00	20.00	25.43	28.24	33.91	1.50	2.54	2.66	2.00	4.06	4.06
2.0 cm × 30 kg/ha	12.30	15.00	24.00	22.56	26.95	33.88	2.06	2.76	2.85	2.12	4.25	4.25
1.5 cm × 0 kg/ha (Control)	11.00	15.00	25.00	23.11	23.76	31.29	1.39	2.41	2.71	1.81	3.56	3.56
1.5 cm × 15 kg/ha	10.88	11.50	23.00	26.07	25.91	33.09	1.16	2.44	2.54	2.31	3.81	3.81
1.5 cm × 30 kg/ha	11.75	13.00	15.00	27.62	27.25	31.62	1.09	2.33	2.49	2.00	3.75	3.75
1.0 cm × 0 kg/ha (Control)	12.00	13.60	15.00	21.85	25.57	27.46	0.51	1.47	1.50	1.25	2.50	2.50
1.0 cm × 15 kg/ha	13.80	14.40	17.00	19.11	25.56	25.56	0.61	1.32	1.49	1.12	2.25	2.25
1.0 cm × 30 kg/ha	13.00	14.00	14.00	21.91	22.89	26.05	0.69	1.36	1.47	1.06	2.43	2.43
C.D. (5%)	0.014	0.03	0.03	3.19	2.51	NS	0.22	NS	NS	NS	NS	NS

hill, weight of cormels/hill. The statistical analysis (ANOVA) was performed as per Assaad *et al.* (2014).

Results and Discussion

Various growth characters were significantly influenced by the corm grades and soil application of zinc in gladiolus (Table 1). Minimum days required for 50% sprouting was found with corm grade 3.0 cm (9.93 days), zinc at 0 kg/ha, i.e., control (10.79 days) as well as in interaction between grade 2.5 cm × $ZnSO_4$ 0 kg/ha (8.80 days). The 75% and 100% sprouting were achieved earliest in corm grade 3.5 cm (11.11 and 13 days respectively). Whereas, $ZnSO_4$ application at 15 kg/ha and the interaction of grade 4.0 cm × $ZnSO_4$ 0 kg/ha showed the earliest 75% sprouting in the field.

The application of $ZnSO_4$ at 30 kg/ha took minimum days to 100% sprouting (17.14 days). Leaf length was maximum in largest corm grade used for planting which was statistically at par with grade 3.5 cm. Whereas, among zinc doses lower dose, i.e., 15 kg/ha showed maximum leaf length at 60 days after planting (DAP) (30.73 cm). Corm grade 4.0 cm was responsible for maximum scape width at 40 DAP (1.91 cm) and 60 DAP (2.72 cm) which is also statistically at par with grade 3.5 cm. Effect of zinc sulphate was non-significant on this growth parameter.

Among interaction effects, grade 2.0 cm × $ZnSO_4$ 30 kg/ha was the best over other interactions. Total number of leaves/plant was maximum in largest corm grade (4.0 cm) at all 40, 60 and 80 DAP (4.02, 7.47 and 7.47 cm, respectively), whereas, it was minimum in smallest corm grade (1.0 cm) used for planting (Table 1). The effect of zinc was non-significant on the same. The improvement in growth might be due to the presence of micronutrient (zinc) which activates several enzymes in plants which ultimately regulates various metabolic and physiological processes. These findings are in agreement with those of Singh *et al.* (2012), Singh *et al.* (2015a) and Hembrom *et al.* (2015). The application of $ZnSO_4$ at 0.5% enhanced growth parameters (Devi *et al.*, 2017).

Ara *et al.* (2015) and Singh *et al.* (2017) also found similar results with the application of zinc in gladiolus and obtained positive response to plant height, number of leaves/plant. The positive effect of corm grades on growth of plants might be due to amount of food/carbohydrate stored in mother corms. In larger corm, more amount of carbohydrate is stored, hence, the larger-sized corm might have provided maximum vegetative growth as compared to smaller grades. Present findings are in line with those of Bhande *et al.* (2015).

The response of various corm grade was observed to assess corm attributes under uniform management

Table 2: Effect of corm grades and zinc sulphate on corm parameters such as number of corms, cormels/hills, diameter of corm, weight of corm and weight of cormels in gladiolus var. Malaviya Kundan.

Treatment	No. of corms/ hill	No. of cormels/ hill	Diameter of corm (cm)	Weight of corm (g)	Weight of cormels/hill (g)
Corm grades					
4.0 cm	1.89	42.16	35.48	16.68	0.15
3.5 cm	1.18	46.13	39.65	24.70	0.18
3.0 cm	1.06	52.72	39.81	22.05	0.15
2.5 cm	1.11	38.65	39.05	19.81	0.16
2.0 cm	1.00	27.17	32.83	13.04	0.20
1.5 cm	1.00	23.62	30.73	11.49	0.16
1.0 cm	1.00	18.71	23.93	7.50	0.15
C.D. (5%)	0.21	9.47	3.66	3.32	NS
Zinc doses					
0 kg/ha (Control)	1.20	33.04	33.59	15.47	0.16
15 kg/ha	1.12	37.86	36.08	17.54	0.17
30 kg/ha	1.21	35.88	33.82	16.39	0.17
C.D. (5%)	NS	NS	NS	NS	NS

situation. Maximum number of corms/hill (1.89) was produced from a single mother corm was highest in largest corm grade (4.0 cm). Cormels produced per plant was maximum in corm grade 3.0 cm (52.72). Whereas, number of corms and cormels were minimum in small-sized grades. Diameter of corm was maximum in corm grade 3.0 cm (39.81 cm) and it was also statistically at par with grade 3.5 and 2.5 cm. Weight of corm was maximum in grade 3.5 cm (24.70 g) which is also statistically at par with grade 3.0 cm (22.05 g). Effect of zinc sulphate on all the corm parameters was found non-significant. These findings are in close conformity with those of Memon *et al.* (2009) and Kamal *et al.* (2013). Joshi *et al.* (2011) also found similar results in which largest-sized corms performed better with respect to number of corms and cormels produced from a single mother corm of gladiolus.

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Effect of copper and zinc as a supplement fertilizer on growth of radish *(Raphanus sativus)* root and foliage

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Abstract

The foliar spray of copper (0.3%) and znc (0.4%) solution at 15 and 25 days of growth improved the plant height, fresh weight and root size of radish (*Raphanus* sativus L.). The application of copper and zinc along with N, P, K fertilizers improved crop growth more than the control. The concentration of 0.6% copper and 0.8% sinc showed some toxic effect and reduced growth of leaves and root but was better than the no application of Cu and Zn elements.

Key words: Copper, Zinc, growth, toxic, vitamins.

Radish (*Raphanus sativus* L.) crop is not given as much attention as other vegetable crops. Farmers do not apply even the major nutrients like N, P, K to their radish crop fields. Reports on use of micronutrient by the researcher are also scanty in India as well as abroad. People have choosen mostly tomato, potato, okra in their research projects. Particularly the farmers in Meerut region are not aware and habitual of applying micronutrient in radish crop. Many of the radish growers even do not provide major nutrients (N, P, K) in their fields. Looking at the importance of micronutrients, we decided to find out the effect of micronutrients particularly copper and zinc in the study.

Materials and Methods

Meerut region is situated in Western Uttar Pradesh with tropical climate, semi-arid conditions with extremes of weathers. Most of the rainfalls between June and September. Summers are hot and winters are cold with frost. Temperature ranges 8.9°C to 27.2°C from December to January. During the experiment temperature ranges are 7.5°C to 14.5°C. Relative humidity remains from 70-90%. Experimental plot soils are sandy loam. The soil pH was found to be 8.0. Before sowing the experiment the plots were manured with farm yard manure, urea and superphosphate . Farm yard mannure was mixed well before the sowing.

Radish variety Pusa Rashmi was sown on October 9. The micronutrient copper and zinc were used in following combinations in triplicate fields of random plot design of 3.0 × 1.35 m area. Cu_0 = 0.0%, Cu_1 = 0.3%, Cu_2 = 0.6%, Zn_0 = 0.0%, Zn_1= 0.4%, Zn_2 = 0.8% Cu as $CuSO_4$ and Zn as $ZnSO_4$ was used. The Cu_0Zn_0, Cu_0Zn_1, Cu_0Zn_2, Cu_1Zn_0, Cu_1Zn_1, Cu_1Zn_2, Cu_2Zn_0, Cu_2Zn_1, Cu_2Zn_2.

Micronutrients were applied on folige after 15 and 25 days of sowing the seeds. The observations of leaf and radish root parameters were taken at 15, 25 and 35 days after sowing. Required plants were collected from three beds separately and observation data and average of triplicate samples were recorded. Fresh weight of leaves (g), total dry weight of whole plant (g), total plant height including roots (cm), root weight (g), and root length (cm) were considered in this experiment. Yield of radish crop was also recorded. Statistical analysis of the observed data was done by the technique of "Analysis of variance" and significance was tested by 'F' test by the following formula.

Critical Difference (C.D.) = $\sqrt{\frac{ErrorVariance}{n}\times t}$ at 5% level of probability.

$$SEM \pm = \sqrt{\frac{ErrorVariance}{n}}$$

Results and Discussion

Data-showed that combination of Cu_1, Zn_1 doses produced the maximum height of radish plant at 15 days growth (39.0 cm) against the control treatment Zn_0Cu_0 (38.3 cm). The results were statistically singnificant as the SEm± found to be 0.7 and C.D. at 5% level was 2.1. The increase in Zn or Cu concentration to Zn_1 level increased the plant height to 33.1 cm over control 23.3 cm, but Zn_2 level further decreased the height than control value 19.7 cm). Similarly Cu application was also effective at

Cu_1 level. Higher dose of Cu_2 inhibited the growth (Table -1). The effect of Zn and Cu concentrations showed the similar behaviour of plant growth at 25 days of growth. Zn_1Cu_1 dose was found to be better 50.2 cm height and statistically significant (SEM± 0.07, C.D. at 5% - 2.01). The observations recorded at 35 days growth were also better at Zn_1 Cu_1 level than other doses (55.3 cm height) and statistically significant (SEM± 0.72, C.D. at 5% 2.10) (Table 1).

The spray of copper and zinc combination (Cu_1 Zn_1) on 15 day produced longest sized root (21.6 cm), where as minimum length observed was 10.6 cm at Cu_2 Zn_2 concentrations. Results obtained at 25 days growth were similar to 15 day growth as Cu_1Zn_1 produced longest root (70.0) and smallest at Cu_2Zn_1 (33.8 cm). Data obtained at both intervals were statistically significant. Observations on day 35 were not recorded.

The average plant dry weight at 15, 25 and 35 days of growth. At 15th day plant dry weight was maximum (15 g) at Cu_1Zn_1 and minimum at Cu_2Zn_2 levels (0.06 g). Similar observations were recorded at 25 day growth where Cu_1Zn_1 dose produced maximum plant dry weight (4.9g) and Cu_2Zn_2 produced minimum (2.3 g). Dry weight recorded at 35 days were like earlier growth period. Maximum dry weight recorded was at Cu_1Zn_1 dose (11.5g) and minimum at Cu_2Zn_2 (5.8g). All above observations were statistically significant.

The Zn and Cu combination sprayed on radish crop increased the leaf yield per plant over the control value of 10.0 g to 13.9 g with Zn_1Cu_1 concentration on 15ty day growth. Minimum leaf weight observed was 8.8g at Zn_2Cu_2 concentration. Data recorded were significant with SEM± 0.09 and C.D. at 5% is 0.28.

The observations at 25th and 35th day growth were similar to 15th day growth such that maximum leaf weight was 49.0 g at 25th day and 101.2 g at 35th day at Cu_1Zn_1 concentrations and minimum weight was 19.7 g and 52.3g at 25th and 35th day respectively. Statistical significant of data was also seen at these intervals.

We then measured the length of radish root to asses the growth of crop on application of Zn and Cu concentration at 15day growth. The maximum root length observed was 19.0 cm at Cu_1Zn_1 treatment and minimum (4.3 cm) at Cu_2Zn_2 combination even lower than control value of 9.0 g. Similarly Cu_1Zn_1 combination increase the root length to 26.5 cm at 25th day and minimum was 19.2 cm. Both these observations were statistically significant data for 35th day were not recorded.

Another growth parameter measured was the fresh weight of radish root. The observations were recorded in (Table 2). In this case the Zn_1Cu_1 combination gave better results than other. The length root was 9.6 cm on 15th day, 28.3 cm on 25th day and 74.3 cm on 35th day growth. Minimum values for root growth were 4.3, 14.3 and 31.3 cm respectively on 15th, 25th and 35th days of growth. As the observations were statistically significant for this parameter also.

Micronutrients when supplied to radish crop along with manure, N, P and K, it affected the plant growth as a whole as compared to control. Maximum growth observed was at 0.4% Zn in combination with Cu at 0.3%. It may be possible that Zn induces the synthesis of tryplophan, an amino acid, which is the processor of IAA. IAA stimulates the plant growth and

Table 2: Yield (q/ha) of radish crop at harvest stage in response to Cu and Zn application.

Cu, Zn levels	Cu_0	Cu_1	Cu_2
Zn_0	260.96	264.96	249.03
Zn_1	266.40	274.01	257.37
Zn_2	253.80	258.43	241.37
SEm±	-	0.59	-
C.D. at 5%	-	1.67	-

Table 1: Cu and Zn application effect on fresh weight (g) of radish root at 15, 25 and 35 days of growth

Cu, Zn levels	After 15 days			After 25 days			After 35 days		
	Cu_0	Cu_1	Cu_2	Cu_0	Cu_1	Cu_2	Cu_0	Cu_1	Cu_2
Zn_0	5.9	7.5	4.6	20.8	26.2	17.1	43.6	67.8	37.3
Zn_1	8.0	9.6	6.0	26.0	28.2	24.6	64.6	74.3	60.3
Zn_2	4.9	6.7	4.3	16.0	24.1	14.3	33.0	53.1	34.3
SEm±	-	0.16	-	-	0.29	-	-	1.42	-
C.D. (5%)	-	0.50	-	-	0.88	-	-	4.09	-

act as plant hormone. The results obtained at different growth stages were similar and statistically significant. The doses of both Cu and Zn reduced the crop growth causing adverse effect. Copper also improves plant metabolism by activating the enzymes of lipid, lignin and synthesis of other compounds. Copper increase chlorplast synthesis. Deficiency of copper results in chlorosis and some other diseases.

These effects of Cu and Zn were reflected for the all parameter of radish crop under study in our experiments of the same levels of Zn_1Cu_1. The higher dose like Zn_2 and Cu_2 in combined form were found to be toxic and resulted poor growth even than control plot yield. These minerals also serves as the cofactors of different matabolic enzymes in radish and also in other plants. Copper is a cofactor of cytochrome oxidase an enzyme involved in energy production.

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Application of microwave oven technology for dehydration of ornamental leaves

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Abstract

The standardization of microwave oven drying technology for dehydration of ornamental leaves was done. The embedding of leaves in silica gel and microwave oven drying (720 micro power, i.e. medium high) for 2 min was suitable technique for dehydration of ornamental leaves of *Swietenia mahagoni, Acacia auriculiformis* and *Hamelia patens* leaves. The time of 2.5 min was appropriate for leaves of *Alstonia scholaris*, *Rosa spp.*, *Hibiscus rosa-sinensis* and *Bougainvillea glabra*, 3 min for *Lagerstroemia speciosa* and 3.5 min for *Polyalthia longifolia* and *Ixora chinensis.*

Key words: Microwave oven, Dehydration, Technology, Ornamental leaves, Eco-friendly

The demand for natural, eco-friendly and biodegradable flower products is increasing rapidly throughout the world compared to artificial/synthetic flowers. Different decorative floral crafts/items can be prepared from dried flowers, which in turn add value and also generate employment (Datta and Roy, 2011). Indian entrepreneurs have a lot of opportunities to go into international floricultural trade as demand for dry flower industry is escalating at a remarkable rate of 8-10 % per annum (Singh, 2009). The country enjoys the benefit of cheap labour and favourable climate as against other countries. Lack of awareness regarding dry flowers, non-availability of dry flower products and of information has been foremost constraint in encouragement of dry flower production in India (Biswas and Dhua, 2010). Therefore, an experiment was set up with an objective to standardize the microwave oven drying technique for dehydration of ornamental leaves.

Materials and Methods

The experiment was conducted at Dry Flower Laboratory at Department of Floriculture and Landscape Architecture, Faculty of Horticulture, Bidhan Chandra Krishi Viswavidyalaya, Mohanpur, Nadia (District), West Bengal during 2018 to 2019. Fresh matured leaves free from blemishes, pest and disease were collected in morning after dew/moisture evaporation from university campus. Experiment was laid out in CRD (factorial) with five replications and 8 different treatment combinations with sand and silica as embedding media. After embedding, embedded glass containers were placed in the electrically operated microwave oven at fixed micro power of 720 power, i.e. medium high. Treatments were set based on trial-and-error method for 10 different foliages and dried samples were given subjective scores on average 10 points scale with reference to ornamental values, viz., colour, texture, brittleness and appearance/shape retention. Based on cumulative score, ranks were given and the best treatment combinations were worked out (Raj and Gupta, 2005).

Results and Discussion

In *Alstonia scholaris* leaves silica gel (M_2) as drying media recorded significantly maximum moisture loss (54.98 %) and sensory attribute scores, for colour (7.0) and appearance (6.65) compared to sand (M_1) but sand noted highest score for brittleness (7.85) in contrast to silica gel. Among drying durations D_4 recorded greatest moisture loss (61.48 %), which is statistically far with D1 (28.99 %). In Swietenia mahagoni, principal moisture loss (42.72 %) and sensory score for colour (7.10) and appearance (7.13) noted in silica gel (M_2), which are significantly far with sand (M_1) in microwave oven dried mahagoni tree leaves (Table 1). Extreme moisture loss was recorded in D_4 (47.16 %), which is statistically far with D_1 (27.76 %) among drying duration.

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Table-1: Effect of drying media (M), duration (D) and their interaction on micro oven dried devils tree and mahogany tree leaves

	Alstonia scholaris							*Swietenia mahagoni*						
Treatments	FW (g)	DW (g)	ML (%)	Colour	Texture	Brittleness	Appearance	FW (g)	DW (g)	ML (%)	Colour	Texture	Brittleness	Appearance
M_1	1.30	0.74	42.94	6.20	6.15	7.85	5.55	0.73	0.46	37.22	5.78	5.98	7.33	6.10
M_2	1.21	0.56	54.98	7.00	6.70	6.40	6.65	0.73	0.42	42.72	7.10	6.10	6.95	7.13
S.Em **(±)**	0.01	0.00	0.28	0.04	0.03	0.03	0.03	0.00	0.00	0.00	0.03	0.03	0.03	0.03
CD at 5 %	0.02	0.01	0.82	0.10	0.10	0.09	0.09	N/A	0.01	0.00	0.10	0.08	0.09	0.10
D_1	1.31	0.93	28.99	4.20	4.30	8.60	4.50	0.68	0.49	27.76	5.15	4.95	7.55	5.40
D_2	1.25	0.69	45.55	6.80	6.50	8.10	6.50	0.75	0.44	40.94	6.70	7.15	7.80	7.10
D_3	1.22	0.49	59.82	7.70	7.80	6.60	7.00	0.70	0.39	44.02	6.95	6.95	7.55	7.05
D_4	1.23	0.48	61.48	7.70	7.10	5.20	6.40	0.80	0.42	47.16	6.95	5.10	5.65	6.90
S.Em **(±)**	0.01	0.00	0.40	0.05	0.05	0.04	0.05	0.01	0.00	0.00	0.05	0.04	0.05	0.05
CD at 5 %	0.03	0.01	1.16	0.15	0.14	0.13	0.13	0.02	0.01	0.01	0.14	0.11	0.13	0.14
M_1D_1	1.28	0.95	26.05	4.00	4.00	8.60	4.40	0.67	0.50	26.37	4.50	4.60	7.70	4.90
M_1D_2	1.33	0.84	36.50	5.40	4.60	8.40	5.40	0.75	0.49	35.11	4.90	6.80	7.30	5.70
M_1D_3	1.26	0.59	53.26	7.60	8.20	7.60	7.00	0.74	0.44	40.51	6.40	7.30	7.80	6.40
M_1D_4	1.31	0.58	55.94	7.80	7.80	6.80	5.40	0.76	0.40	46.90	7.30	5.20	6.50	7.40
M_2D_1	1.34	0.91	31.92	4.40	4.60	8.60	4.60	0.69	0.49	29.15	5.80	5.30	7.40	5.90
M_2D_2	1.18	0.53	54.59	8.20	8.40	7.80	7.60	0.74	0.39	46.76	8.50	7.50	8.30	8.50
M_2D_3	1.18	0.40	66.38	7.80	7.40	5.60	7.00	0.66	0.35	47.42	7.50	6.60	7.30	7.70
M_2D_4	1.15	0.38	67.01	7.60	6.40	3.60	7.40	0.83	0.44	47.53	6.60	5.00	4.80	6.40
S.Em **(±)**	0.01	0.01	0.57	0.07	0.07	0.06	0.06	0.01	0.00	0.00	0.07	0.06	0.06	0.07
CD at 5 %	0.04	0.02	1.65	0.21	0.20	0.18	0.18	0.02	0.01	0.01	0.19	0.16	0.18	0.19

{M_1- Sand, M_2- Silica gel (D_1- 1.5 min, D_2- 2.5 min, D_3- 3.5 min, D_4- 4.5 min), (D_1- 1 min, D_2- 2 min, D_3- 3 min, D_4- 4 min)}

Table-2: Effect of drying media (M), duration (D) and their interaction on micro oven dried pride of India tree and ashoka tree leaves

	Lagerstroemia speciosa							*Polyalthia longifolia*						
Treatments	FW (g)	DW (g)	ML (%)	Colour	Texture	Brittleness	Appearance	FW (g)	DW (g)	ML (%)	Colour	Texture	Brittleness	Appearance
M_1	1.18	0.53	54.27	4.10	4.65	7.00	4.50	0.62	0.33	45.81	3.30	5.33	5.88	3.90
M_2	1.19	0.49	58.32	5.80	6.25	7.45	5.55	0.51	0.20	62.23	6.35	6.68	6.85	7.05
S.Em **(±)**	0.01	0.00	0.29	0.03	0.03	0.03	0.03	0.00	0.00	0.34	0.03	0.03	0.03	0.03
CD at 5 %	N/A	0.01	0.84	0.07	0.09	0.09	0.07	0.01	0.01	0.98	0.07	0.09	0.09	0.09
D_1	1.02	0.52	49.04	3.90	4.50	8.10	4.30	0.58	0.33	40.97	3.75	5.65	6.70	5.05
D_2	1.14	0.51	55.74	5.20	5.00	7.70	5.50	0.59	0.31	49.18	4.70	5.55	5.95	4.45
D_3	1.25	0.51	59.32	5.40	5.90	7.40	5.10	0.53	0.21	60.97	6.05	6.45	6.65	5.65
D_4	1.33	0.52	61.06	5.30	6.40	5.70	5.20	0.55	0.20	64.96	4.80	6.35	6.15	6.75
S.Em **(±)**	0.01	0.00	0.41	0.04	0.04	0.05	0.04	0.00	0.00	0.48	0.04	0.04	0.04	0.04
CD at 5 %	0.03	N/A	1.18	0.10	0.12	0.13	0.10	0.01	0.01	1.38	0.10	0.13	0.13	0.13
M_1D_1	0.94	0.50	46.61	2.80	3.60	7.80	4.00	0.50	0.40	21.67	2.40	4.90	6.40	3.70
M_1D_2	1.21	0.57	52.73	3.80	4.40	7.60	4.00	0.68	0.43	37.72	1.80	4.50	4.60	1.80
M_1D_3	1.33	0.56	58.07	4.40	5.00	7.20	4.60	0.65	0.26	59.26	4.00	5.20	5.60	3.20
M_1D_4	1.22	0.49	59.65	5.40	5.60	5.40	5.40	0.63	0.22	64.59	5.00	6.70	6.90	6.90
M_2D_1	1.10	0.53	51.46	5.00	5.40	8.40	4.60	0.66	0.26	60.27	5.10	6.40	7.00	6.40
M_2D_2	1.06	0.44	58.75	6.60	5.60	7.80	7.00	0.50	0.20	60.64	7.60	6.60	7.30	7.10
M_2D_3	1.17	0.46	60.58	6.40	6.80	7.60	5.60	0.42	0.16	62.68	8.10	7.70	7.70	8.10
M_2D_4	1.43	0.54	62.46	5.20	7.20	6.00	5.00	0.48	0.17	65.32	4.60	6.00	5.40	6.60
S.Em **(±)**	0.01	0.01	0.58	0.05	0.06	0.06	0.05	0.01	0.00	0.68	0.05	0.06	0.06	0.06
CD at 5 %	0.04	0.02	1.67	0.15	0.17	0.19	0.15	0.02	0.01	1.96	0.15	0.18	0.18	0.18

{M_1- Sand, M_2- Silica gel (D_1- 2 min, D_2- 3 min, D_3- 4 min, D_4- 5 min), (D_1- 1.5 min, D_2- 2.5 min, D_3- 3.5 min, D_4- 4.5 min)}

In *Lagerstroemia speciosa*, silica gel (M_2) recorded significantly maximum moisture loss (58.32 %) and sensory scores, i.e. for colour (5.80), texture (6.25) and appearance (5.55) compared to sand (M_1) in microwave oven dried pride of India tree (Table 2). Between drying duration, moisture loss varied significantly from 49.04 % (D_1) to 61.06 % (D_4). In *Polyalthia longifolia*, application of silica gel (M_2) as embedding media recorded maximum of moisture loss (62.23 %) and sensory attribute scores, i.e. for colour (6.35), texture (6.68), brittleness (6.85) and appearance (7.05), which are statistically far with sand (M_1). Between drying duration, moisture loss noted highest in D4 (64.96 %), which is significantly far with D_1 (40.97 %). In *Rosa spp*., chief moisture loss (50.92 %) was recorded in silica gel (M_2), which is significantly far with sand (M_1) (41.90 %) in microwave oven dried rose leaves (Table-3). Colour and texture score found insignificant among drying media. Between drying duration, maximum moisture loss was observed in D4 (52.46 %) and highest score for texture and brittleness was recorded in D1 (8.0, 8.40) respectively.

In *Acacia auriculiformis* maximum moisture loss percent (51.28 %) was noted in silica gel (M_2), whereas colour, texture and appearance scores were insignificant among drying media. Drying duration D_4 recorded supreme moisture loss (59.05 %), which is statistically far with D_1 (26.71 %). In *Hamelia patens*, silica gel (M_2) as drying media noted maximum moisture loss percent (69.99 %) and highest quality parameter scores i.e. for colour (7.0), texture (6.20) and appearance (7.25), whereas brittleness score (7.25) found maximum in sand (M1). Drying duration D_4 (68.10 %) recorded extreme moisture loss, which is significantly far with D_1 (54.38 %). In *Ixora chinensis*, moisture loss and brittleness score were insignificant among media, whereas colour (5.13), texture (6.18) and appearance (6.30) score recorded significantly higher in silica gel (M2) compared to sand (M_1) in microwave oven dried ixora leaves.

Among drying duration, moisture loss varied significantly from 51.92 % (D_1) to 58.17 % (D_4). In *Hibiscus rosa-sinensis*, moisture loss (69.04 %) and quality parameter score, i.e. for colour (7.56), texture (7.25) and appearance (7.68) were recorded highest in silica gel (M_2) compared to sand (M_1) in microwave oven dried hibiscus leaves (Table-5). Among drying duration, moisture loss varied from 62.21 % (D_1) to 67.88 % (D_4). In *Bougainvillea glabra*, silica gel (M_2) as drying media noted highest moisture loss (65.93 %) and sensory attribute score, i.e. for colour (7.58), texture (7.43) and appearance (7.40), which are significantly far with sand (M1) in micro oven dried bougainvillea leaves. Moisture loss percent found highly significant among drying duration as it varied from 37.96 % (D_1) to 71.0 % (D_4), whereas quality parameter scores found insignificant.

Among interactions, greatest moisture loss was recorded in M_2D_4 and least was noted in M_1D_1, i.e. 67.01 % and 26.05 % in *Alstonia scholaris*, 47.53 % and 26.37 % in *Swietenia mahagoni*, 62.46 % and 46.61 % in *Lagerstroemia speciosa*, 65.32 % and 21.67 % in *Polyalthia longifolia*, 56.10 % and 34.45 % in *Rosa spp*., 62.16 % and 21.85 % (M_2D_1) in *Acacia auriculiformis*, 73.24 % and 43.67 % in *Hamelia patens*, 58.57 % and 51.70 % (M_2D_1) in *Ixora chinensis*, 71.01 % and 56.72 % in *Hibiscus rosa-sinensis,* 74.13 % and 24.88 % in *Bougainvillea glabra*.

As the drying duration increased, moisture loss was also increased rapidly; it might be due to long-term exposure of plant material to microwaves, which in turn agitated the water molecules in living plant cells. Loss of moisture was very fast in silica gel (M_2) compared to sand (M_1), it might be due to light weight, hygroscopic nature and particle density of it, which helped microwaves to penetrated through media easily and removed the moisture. These results are in accordance with Ranjan and Misra (2002), Raghupathi and Gantait (2020), Hemant *et al.*, (2016), Aravinda and Jayanthi (2004), Biswas and Dhua (2010).

Uppermost sensory score for colour, i.e. 8.50 in Devils tree, 8.50 in Mahagany, 6.60 in Pride of India, 7.80 in Rosa, 8.60 in Acacia, 7.60 in Hamelia was observed in M2D2, whereas M2D3 recorded highest score, i.e. 8.10 in Ashok tree, 6.70 in Ixora, 8.50 in Hibiscus and 8.50 in Bougainvillea. Colour is an important quality parameter criterion for any final product marketing as its appearance matters for customers. Improper moisture loss resulted in poor scoring for colour and high moisture loss also adversely affected colour pigments in dried leaves.

Similar results were also reported by White *et al.*, (2002) and Mishra *et al.* (2014). Chief texture score, i.e. 8.40 in Devils tree, 7.50 in Mahagany, 8.50 in Acacia, 7.60 in Hamelia, 8.50 in Hibiscus was recorded in interaction M2D2, whereas M2D3 recorded 7.70 in Ashok tree, 7.20 in Ixora, 8.40 in Bougainvillea and M_2D_4 (7.20) in Pride of India and M2D1 (8.40) in Rose. These results are in confirmation with findings of Kumari *et al.*, (2018) and Bhalla *et al.*, (2006). Maximum score for brittleness, i.e. 8.60 in Devils tree, 8.80 in Rose, 8.60 in Acacia, 8.0 in Hamelia and 7.80 in Bougainvillea was recorded in M_1D_1,

while 8.30 in Mahagany was noted in M_2D_2 and 8.40 in Pride of India, 7.70 in Ixora was observed in M_2D_1, 7.70 in Ashok tree was noted in M_2D_3 and 8.40 in Hibiscus was recorded in M_1D_2.

As the drying duration increased, brittleness score decreased, which is directly proportional to moisture loss in the plant cells. Low moisture loss also resulted in poor brittleness score. The results are in line with Renuka *et al.*, (2017) and Jawaharlal *et al.*, (2013). Highest score for appearance i.e. 7.60 in Devils tree, 8.50 in Mahagany, 7.0 in Pride of India, 8.20 in Rose was observed in M2D2, whereas 8.10 in Ashok tree, 7.60 in Hamelia, 7.60 in Ixora, 8.10 in Hibiscus and 8.30 in Bougainvillea was recorded in Interaction M_2D_3. Appearance is the overall acceptance of final dried product including its texture, colour and brittleness. Silica gel recorded better appearance scores compared to sand due to rapid evaporation of moisture. This result was in confirmation with the finding of Mathapati *et al.*, (2015) and Renuka *et al.*, (2016).

Conclusion

It can be concluded that embedding in silica gel and microwave oven drying (720 micro power, i.e. medium high) for 2 min was suitable technique for dehydration of hamelia and mahogany tree leaves, 2.5 min was suitable for dehydration of rose, hibiscus, bougainvillea and devils tree leaves, 3 min was ideal for lagerstroemia tree leaves and 3.5 min for dehydration of ixora and ashoka leaves.

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Response of integrated nutrient management and micronutrients on quality, nutrient content, uptake and soil of tomato (*Solanum lycopersicum*)

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Abstract

The experiment was conducted to find out the response of integrated nutrient management and micronutrients on quality, nutrient content, nutrient uptake and soil parameters of tomato at College of Agriculture, Anand Agricultural University, Vaso, during *rabi* season in 2019-20 and 2020-21. The randomized block design with factorial concept having 14 treatment combinations with three replications comprising two factors having two levels of micronutrients and seven levels of INM was used. Different treatments of INM and micronutrients improved the quality, nutrient uptake and soil parameters. The maximum titrable acidity (0.92%) recorded with M_1: zinc @ 100 & N_6: 50% RDF + 50% N from vermicompost + bio NPK, while maximum TSS (5.38 °Brix), lycopene (3.08 mg/100 g) and vitamin-C (34.93 mg/100 g) recorded with N_6. For nutrient uptake, M_1: zinc @ 100 ppm recorded maximum nitrogen uptake by plant (119.71 kg/ha). In INM, treatment N_5 recorded maximum nitrogen content (1.72%), phosphorus (0.68%), potash (1.38%), nitrogen uptake (125.75 kg/ha), phosphorus uptake (44.42 kg/ha) and potash uptake (54.95 kg/ha). The INM treatment N_5: 50% RDF + 50% N from FYM + Bio NPK recorded maximum microbial count (6.2×10^7 and 7.5×10^7) during 2019-20 and 2020-21, respectively and also maximum available N_2O (271.77 kg/ha), available P_2O_5 (51.08 kg/ha), available K_2O (257.13 kg/ha), organic carbon (0.45%), minimum electrical conductivity (1.13 dS/m) and pH (7.76).

Key words: INM, Micronutrients, Quality, Nutrient uptake, Soil parameters

Tomato (*Solanum lycopersicum* Mill.) is the most popular vegetable crops grown all over the world. The judicious integrated use of both nutrient sources provides an ideal environmental conditions for its crop, as the organic source improves soil properties and enhance the activity of soil microbes, immobilize nutrients and slowly releases them, while inorganic sources made available nutrients immediately, avoiding nutrient depression periods and hastens the decomposition of organic material. Besides sustainable agricultural production, all round improvement in physical, chemical and biological make up of soils is main aim of INM (Chadha, 2002). Zinc has important role in metal component of different enzymes (Marschner, 1995) and essential trace element like increases the rate of chlorophyll, antioxidant enzymes and essential component of many proteins. Therefore, a constant and continuous supply of zinc is needed for optimum growth and maximum yield. Boron plays an important role in flowering and fruit formation (Nonnecke, 1989).

Materials and Methods

A field experiment was conducted during *rabi* season of 2019-20 and 2020-21 at College of Agriculture, Anand Agricultural University, Vaso. The seedlings of tomato cv. Gujarat Anand Tomato-5 were transplanted during 1st week of November. Two factors, *viz.* (1) INM which consisted 7 levels, i.e N_1: 100% RDF (100:50:50 NPK kg/ha.), N_2: 75% RDF + 25% N from FYM + Bio NPK, N_3: 75% RDF + 25% N from vermicompost + Bio NPK, N_4: 75% RDF + 25% N from castor cake + Bio NPK, N_5: 50% RDF + 50% N from FYM + Bio NPK, N_6: 50% RDF + 50% N from vermicompost + Bio NPK, N_7: 50% RDF + 50% N from castor cake + Bio NPK and (2) micronutrients which consisted 2 levels, i.e. M_1: zinc @ 100 ppm and M_2: boron @ 100 ppm were used.

There were 14 treatment combinations. The Randomised Block Design with factorial concept was used. Bio NPK consortium was collected from the Department of Agricultural Microbiology, Anand Agricultural University, Anand. Bio-NPK is liquid biofertilizer consists of nitrogen fixers (*Azotobacter* and *Azospirillum*) + PSB and KMB (3 different *Bacillus* sp.). Bio NPK consortium was applied by dipping seedlings before transplanting in Bio NPK @ 5 ml/litre of water and mixing with organic manures @1 litre/60 kg of manures.

Zinc and boron were applied as a foliar spray @ 100 ppm three times at 10 days interval starting from 30 days

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after transplanting. The observations were recorded by average of five randomly selected plants and analysed. Titrable acidity was measured by method described by Ranganna (1979). The TSS in of tomato was recorded by using hand refractometer. Titrimetric method described by Ranganna (1979) was adopted for estimation of ascorbic acid and acetone extraction method given by Ranganna (1986) was used for estimation of lycopene content in tomato. Nutrient uptake of N, P and K was calculated by formula:

$$\text{Uptake of Nutrients (kg/ha)} = \frac{\text{dry matter yield (kg/ha) x nutrient content (\%)}}{100}$$

Results and Discussion

Titrable acidity influenced significantly by different treatment of INM. Maximum titrable acidity (0.94%) was recorded with N_6 (50% RDF + 50% N from vermicompost + Bio NPK) which was at par with N_5 (50% RDF + 50% N from FYM + Bio NPK). This might be due to increased available nutrients and growth promoting substances in the soil by application of vermicompost with Bio-NPK which results in more absorbance of macro and micro nutrients. Among them, potash is also absorbed in optimum quantity which is responsible for increasing in titrable acidity. These results were coincide with Avhad *et.al.* (2016), Gosavi *et.al.* (2010), Laxmi *et.al.* (2015). Among micronutrients, maximum titrable acidity (0.92%) was recorded with M_1 (Zinc @ 100 ppm) which was at par with M_2 (Boron @ 100 ppm). Zinc increases titrable acidity due to more profusing growth by zinc application as well as it enhances metabolic and enzymatic activities especially for enzyme acetone which is responsible for increasing titrable acidity. Similar result found by Mallick *et.al.* (2021) in tomato. (Table 1)

Maximum TSS (5.38 °Brix) was recorded with N_6 (50% RDF + 50% N from Vermicompost + Bio NPK) during which was at par with N_5 (50% RDF + 50% N from FYM + Bio NPK). Improvement in TSS content of tomato fruits with application of vermicompost might be due to increased photosynthetic activity and exhibited regulatory role on absorption and translocation of various metabolites, resulted improved quality parameter. Same result was reported by Avhad *et.al.* (2016), Gosavi *et.al.* (2010), Kumar *et.al.* (2017). Laxmi *et.al.* (2015) in tomato. TSS remained non-significant with micronutrients. (Table 1)

Maximum vitamin-C (34.93 mg/100 g) was recorded with N_6 (50% RDF + 50% N from Vermicompost + Bio NPK). Increase in vitamin-C might be due to application of vermicompost with Bio-NPK could be attributed by enhanced photosynthetic and metabolic activities, which resulted in the synthesis of higher amount of acids, metabolites and glucose. These assimilates might have contributed to synthesis of vitamin-C. Similar result was obtained by Avhad *et,al.* (2016), Gosavi *et,al.* (2010), Kumar *et,al.* (2017). Singh *et,al.* (2015) in tomato. vitamin-C remained non-significant with micronutrients. (Table 1)

Treatment of INM, N_6 (50% RDF + 50% N from Vermicompost + Bio NPK) recorded maximum lycopene (3.08 mg/100 g) which was at par with N_3 (75% RDF + 25% N from Vermicompost + Bio NPK). The reason behind increasing lycopene content with application of vermicompost might be addition of plant growth promoters from vermicompost and micro and macro nutrients available in optimum quantity. Same result was found by Kumar *et al.* (2017) in tomato. Same result is reported by Avhad *et.al.* (2016), Gosavi *et.al.* (2010), Kumar *et.al.* (2017) in tomato. Lycopene remained non-significant with micronutrients. (Table 1). Interaction effect of different treatments of INM and micronutrients remained non-significant for quality parameters of tomato.

Maximum nitrogen uptake by plant (125.75 kg/ha) was recorded with N_5 (50% RDF + 50% N from FYM + Bio NPK). This might be due to application of FYM with Bio-NPK which increased nutrient absorbance by making more available nutrients in the soil. More nutrient content is responsible for higher rate of photosynthesis which increased dry matter of the plant and finally nutrient uptake is increased. Same result obtained by Avhad *et,al.* (2016), Kumari and Tripathi (2018), Tekale *et,al.* (2017) in tomato. Among micronutrients, maximum nitrogen uptake by plant (119.71 kg/ha) was recorded with M_1 (Zinc @ 100 ppm). Application of zinc attributed to improvement in photosynthesis efficiency, metabolism of plant, physiological functions and hormones synthesis which resulted in more shoot and root growth which finally increased uptake of nitrogen in plant. Nitrogen uptake by plant remained non-significant with micronutrients (Table 2).

Maximum phosphorus uptake by plant (44.42 kg/ha) was recorded with N_5 (50% RDF + 50% N from FYM + Bio NPK) which was at par with N_6 (50%

Table 1: Effect of INM and micronutrients on quality and yield of tomato (Pooled of two years)

Code	Treatment	Titrable acidity (%)	TSS (oBrix)	Vitamin-C (mg/100g)	Lycopene (mg/100g)	Fruit yield per hectare (t)
Micronutrient (M)						
M_1	Zinc @100 ppm	0.92	5.18	32.19	2.85	35.68
M_2	Boron @ 100 ppm	0.91	5.20	32.40	2.89	39.55
	S.Em.±	0.01	0.03	0.33	0.03	0.62
	CD at 5 %	0.01	NS	NS	NS	1.77
INM (N)						
N_1	100% RDF	0.89	4.91	30.58	2.64	32.14
N_2	75% RDF + 25% N from FYM + Bio NPK	0.92	5.15	32.59	2.79	36.33
N_3	75% RDF + 25% N from Vermicompost + Bio NPK	0.91	5.17	32.68	2.96	37.65
N_4	75% RDF + 25% N from Castor cake + Bio NPK	0.91	5.15	31.25	2.83	36.41
N_5	50% RDF + 50% N from FYM + Bio NPK	0.93	5.30	32.22	2.93	42.57
N_6	50% RDF + 50% N from Vermicompost + Bio NPK	0.94	5.38	34.93	3.08	39.75
N_7	50% RDF + 50% N from Castor cake + Bio NPK	0.92	5.27	31.81	2.85	38.47
	S.Em.±	0.00	0.06	0.62	0.05	1.17
	CD at 5 %	0.01	0.17	1.76	0.14	3.31
	Year	Sig.	NS	Sig.	NS	Sig.
	Sig. interaction	-	-	-	-	-
	CV %	1.10	3.94	6.65	5.89	10.74

RDF + 50% N from Vermicompost + Bio NPK). This might be due to application of FYM with Bio-NPK which increased nutrient absorbance by making more available nutrients in the soil. More nutrient content is responsible for higher rate of photosynthesis which increased dry matter of the plant and finally nutrient uptake is increased. Same result obtained by Avhad *et,al.* (2016), Kumari and Tripathi (2018), Tekale *et,al.* (2017). Phosphorus uptake by plant remained non-significant with micronutrients (Table 2).

Potash uptake by plant was influenced significantly by different treatment of INM. Maximum potash uptake by plant (54.95 kg/ha) was recorded with N_5 (50% RDF + 50% N from FYM + Bio NPK). This might be due to application of FYM with Bio-NPK which increased nutrient absorbance by making more available nutrients in the soil. More nutrient content is responsible for higher rate of photosynthesis which increased dry matter of the plant and finally nutrient uptake is increased. Same result obtained by Avhad *et.al.* (2016), Kumari and Tripathi (2018), Tekale *et,al.* (2017) in tomato. Potash uptake by plant remained non-significant with micronutrients (Table 2). Interaction effect of different treatments of INM and micronutrients remained non-significant for nutrient uptake by plant of tomato.

The data in table 5 clearly indicated that the treatment combination M_1N_5 *i.e.* Zinc @ 100 ppm and 50% RDF + 50% N from FYM + Bio NPK recorded maximum microbial count (6.2×10^7 and 7.5×10^7) while the lowest microbial count (4.9×10^6 and 5.3×10^6) recorded with M_2N_1 *i.e.* Boron @ 100 ppm and 100% RDF.

Maximum available N_2O (271.77 kg/ha) was recorded with N_5 (50% RDF + 50% N from FYM + Bio NPK). Maximum available P_2O_5 (51.08 kg/ha) found with treatment N5 (50% RDF + 50% N from FYM + Bio NPK). Maximum available K_2O (257.13 kg/ha) found with treatment N_5 (50% RDF + 50% N from FYM + Bio NPK). Maximum organic carbon (0.45%) found with treatment N_5 (50% RDF + 50% N from FYM + Bio NPK). Minimum electrical conductivity (1.13 dS/m) found with treatment N_5 (50% RDF + 50% N from Vermicompost + Bio NPK) and N_2 (75% RDF + 25% N from FYM + Bio NPK). Minimum pH (7.76) found with

Table 2: Effect of INM and micronutrients on nutrient content and uptake by plant of tomato (Pooled of two years)

Code	Treatment	N content in plant (%)	P content in plant (%)	Kcontent in plant (%)	Nitrogen uptake by plant (kg/ha)	Phosphorus uptake by plant (kg/ha)	Potash uptake by plant (kg/ha)
Micronutrient (M)							
M_1	Zinc @100 ppm	1.64	0.65	1.32	119.71	39.90	45.94
M_2	Boron @ 100 ppm	1.65	0.63	1.32	117.55	38.38	47.22
	S.Em.±	0.01	0.01	0.01	0.56	0.57	0.48
	CD at 5 %	NS	NS	NS	1.60	NS	NS
INM (N)							
N1	100% RDF	1.59	0.60	1.24	109.00	34.75	38.68
N2	75% RDF + 25% N from FYM + Bio NPK	1.61	0.65	1.34	121.67	40.50	47.79
N3	75% RDF + 25% N from Vermicompost + Bio NPK	1.63	0.65	1.34	120.33	37.58	44.93
N4	75% RDF + 25% N from Castor cake + Bio NPK	1.62	0.63	1.31	115.33	36.17	42.26
N5	50% RDF + 50% N from FYM + Bio NPK	1.72	0.68	1.38	125.75	44.42	54.95
N6	50% RDF + 50% N from Vermicompost + Bio NPK	1.68	0.65	1.33	119.50	42.25	50.06
N7	50% RDF + 50% N from Castor cake + Bio NPK	1.65	0.63	1.32	118.83	38.33	47.38
	S.Em.±	0.01	0.01	0.01	1.05	1.06	0.89
	CD at 5 %	0.02	0.04	0.03	2.99	3.02	2.54
	Year	Sig.	Sig.	Sig.	Sig.	Sig.	Sig.
	Sig. interaction	-	-	-	-	-	-
	CV %	1.84	7.71	2.36	3.08	9.40	6.65

treatment N_5 (50% RDF + 50% N from Vermicompost + Bio NPK). Improvement in soil parameters might be due to application of organic manures with Bio-NPK which makes more nutrients available and also improve soil physical and chemical properties.

Conclusion

Thus it can be concluded that application of INM treatments, i.e. N_6 (50% RDF + 50% N from vermicompost + Bio NPK) improved TSS, lycopene, Vitamin-C and titrable acidity while zinc and boron do not affect quality parameters except titrable acidity. Further, N_5 (50% RDF + 50% N from FYM + Bio NPK) recorded maximum N, P and K uptake by plant. This treatment improved soil parameters and microbial count. Interaction effect found non-significant for quality parameters, nutrient uptake and soil parameters.

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Response of different fertigation levels and cultivars of strawberry (*Fragaria × ananassa*) on yield and economic benefit

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Abstract

A field study was conducted to evaluate the "response of different fertigation levels and cultivars of strawberry (*Fragaria* × *ananassa* Duch.) on yield and economic benefit" at the Department of Horticulture, Dr. K.S.G.A. College of Agriculture, Eternal University, Baru Sahib (HP) during 2021-2022. The experiment was set up using a Factorial Randomized Complete Block Design with 12 treatment combinations, which included four levels of fertigation (0%, 50%, 75%, and 100%) and three cultivars (Camarosa, Chandler, and Winter Dawn) and replicated thrice. The maximum value of fruit setting (99.21 %), number of flowers/plant (20.36), yield/plant (425.27 g) and yield/plot (5.10 kg) were noted in fertigation level F_3 (100% recommended dose of NPK). The highest fruit setting (96.58 %), number of flowers/plant (19.14), yield/plant (381.31 g), yield/plot (4.57 kg) were recorded under "Chandler" cultivar whereas, maximum fruit setting (98.91 %), yield/plant (442.18 g) and yield/plot (5.30 kg) were obtained with treatment combination T_{12} (Camarosa+100% RDF dose of NPK through drip) as compared to other treatments. The maximum Cost: benefit ratio (3.31) was observed in treatment combination T_{12} (camarosa with 100% recommended dose of NPK through drip).

Key words: Chandler, Camarosa, Fertigation, Winter Dawn

Strawberry (*Fragaria* × *ananassa* Duch.), a member of the Rosaceae family, has a unique place among cultivated worldwide for its berry fruits (Kachwaya *et al.,* 2016). This is one of the few fruit crops that offer faster returns (Gaikwad *et al.,* 2018; Rathod *et al.,* 2021). The fruit's increasing market demand, ability to grow in different agro-climatic conditions, and short harvesting period make it attractive to farmers as reported by Brym *et al.* (2022). Adoption of drip irrigation and fertigation, enhance nutrient consumption, while using the least quantity of water and fertilizer, is crucial to lowering the cost of irrigation and fertilizers (Pervin *et al.,* 2014). The fertigation becomes prerogative for enhancing yield under drip irrigation as reported by Pervin *et al.* (2014). Therefore, a proper nutrition programme for strawberries that includes NPK is crucial in terms of productivity and fruit quality (Kachwaya *et al.,* 2015). Therefore, an experiment was conducted.

Materials and Methods

The experiment was conducted at Dr Khem Singh Gill, Akal College of Agriculture, Eternal University, Baru Sahib, located at geo-graphically situated at 30.73° latitude in the North and 77.31° longitudes in the East at an elevation of 898 m above mean sea-level. Three cultivars, viz, Camarosa, Chandler and Winter Dawn and four fertigation levels were used. The healthy sapling of uniform growth without any diseases and injuries were selected. All the plants were maintained under uniform cultural practices during the entire course of experimentation.

The Randomized Block Design (RBD) with three replications of each of the twelve treatment combinations were used. The treatments were randomized in each replication. Twelve plants were planted in each treatment of experimental plot. The runners of all cultivars were transplanted into a matted row at spacing of 90 cm ×30 cm row to row and plant to plant during first week of October 2021-22. Two different factors were used i.e. four fertigation levels (control, 50%, 75% and 100%) and three strawberry cultivars (Camarosa, Chandler and Winter Dawn). The different treatment combinations were used T_1 (Chandler + Control), T_2 (Chandler + 50% RDF dose of NPK through

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drip (75,50,60 kg/ha), T_3 (Chandler + 75% RDF dose of NPK through drip (112,75,90 kg/ha), T_4 (Chandler +100% RDF dose of NPK through drip (150,100,120 kg/ha), T_5 (Winter Dawn + Control), T_6 (Winter Dawn + 50% RDF dose of NPK through drip (75,50,60 kg/ha), T_7 (Winter Dawn+75% RDF dose of NPK through drip (112,75,90 kg/ha), T_8 (Winter Dawn+100% RDF dose of NPK through drip (150,100,120 kg/ha), T_9 (Camarosa + Control), T_{10} (Camarosa + 50% RDF dose of NPK through drip (75,50,60 kg/ha), T_{11} (Camarosa + 75% RDF dose of NPK through drip (112,75,90 kg/ha), T_{12} (Camarosa+100% RDF dose of NPK through drip (150, 100, 120 kg/ha). The number of flowers is counted from the beginning of the initial blossoming until the end of full bloom, were visually recorded and the average was computed. Fruit sets and the percentage of those set was then reported using the formula below:

$$\text{Fruit set}(\%) = \frac{\text{Total number of fruit set}}{\text{Total number of flower appered}} \times 100$$

The average yield per plant was derived by summing the total fruit yield of all the tagged plants with the use of a digital analytical balance. B: C ratio of each module in each replication was calculated by following method.

$$\text{Net return} = \frac{\text{Gross return} - \text{Cost of cultivation (₹)}}{\text{Cost of cultivation (₹)}}$$

The average of whole season price of produce was considered for this purpose.

The mean, standard deviation and analysis of variance (ANOVA) of the data obtained from the experiment was subjected to Statistical Package and Social Science (SPSS) var. B. Mean were separated using least significant difference (LSD) at $p<0.05$.

Results and discussion

During the investigation period, data were collected on various yield parameters of strawberry, such as the number of flowers/plant, fruit setting (%), yield/plant (g) and the yield/plot (kg), which are presented in Table 1 and Table 2. The significant variation in yield characteristics among different cultivars of strawberry was attributed to the significant influence of varying fertigation levels. The maximum number of flower/plant (20.36), fruit setting (99.21%), yield/plant (425.27g), and yield/plot (5.10kg) were recorded under fertigation level F_3 (100% recommended dose of NPK) whereas minimum number of flower/plant (15.78), fruit setting (90.18%), yield/plant (264.94g), and yield/plot (3.10kg) were observed in fertigation level F_0 (0% recommended dose of NPK).

The application of NPK fertilizer at the recommended dosage of 100% through fertigation resulted in a significant enhancement of yield parameters. This improvement can be attributed to the increased vegetative growth of the plants and the optimized utilization of nutrients compared to soil fertilization. Furthermore, the fertilizer was applied in divided doses through fertigation, resulting in fragmented supplies that could meet the nutritional requirements of strawberries at various developmental stages. This approach resulted in improved fruit set, increased yield/plant and ultimately, higher overall yield, as reported by Kachwaya *et al.* (2016), Reddy *et al.* (2010) and Martinsson *et al.* (2012).

The increased absorption of nitrogen, phosphorus, and potassium by strawberry plants throughout the growing season, facilitated by the recommended dosage of NPK fertilizer applied through fertigation, may have significantly contributed to the improvement in yield parameters. This process, coupled with the synthesis of carbohydrates in the leaves, may have resulted in the formation of essential compounds such as amino acids, proteins, and chlorophyll. These biochemical changes are known to increase plant photosynthetic activity and carbohydrate synthesis, which helps new tissue grow and support various metabolic processes. Therefore, this fosters overall plant growth and enhances strawberry production characteristics. These findings are in line with previous research on strawberries conducted by Rathod *et al.* (2021), Kumar *et al.* (2009) and Jat & Kachha (2014).

Furthermore, among the various cultivars, the Camarosa cultivar (V_3) exhibited the highest yield parameters, including the number of flowers/plant (19.14), fruit setting (96.58%), yield/plant (381.31g) and yield/plot (4.57kg) while minimum number of flowers/plant (18.50), fruit setting (96.06%), yield/plant (359.49g) and yield/plot (4.31kg) were observed in Winter Dawn cultivar (V_2). The higher yield parameters observed could be due to the different genetic makeup of the genotypes. This study confirms the findings of Singh *et al.* (2020) and Neetu and Sharma (2018) in strawberry respectively. These results are further supported by the research of Ram and Yadav (2006), Singh *et al.* (2008) and Kumar *et al.* (2020).

Besides, among the various treatment combinations, the treatment T_{12} (Camarosa + 100% RDF of NPK) exhibited the highest yield parameters, such as number of flowers/plant (20.47), fruit setting (98.91%), yield/plant (442.18g) and yield/plot (5.30kg) while minimum

number of flowers/plant (16.07), fruit setting (90.36%), yield/plant (265.04g) and yield/plot (3.18kg) were obtained in treatment T_0 (Control). The combined effect of Camarosa cultivar + 100% recommended dose of NPK fertilizer indicates that proper amount of nitrogen, phosphorus and potassium within the plant system plays crucial role in the improvement of plant growth and genetic makeup of variety with appropriate climatic conditions which improves number of flower/ plant, fruit setting (%), and finally increased yield parameters of strawberry. These results are confirmed by the findings of Singh *et al.* (2020), Lakshmi *et al.* (2020), Choudhary *et al.* (2020) and Reddy *et al.* (2010).

The benefit cost ratio for different treatment was computed and shown in table 3. Maximum cost of cultivation (12, 30,300) was calculated in treatment T_8 (Winter Dawn+100% RDF dose of NPK through drip). However, minimum (12, 20,000) cost of cultivation was calculated in treatment T_5 (Winter Dawn with control). Maximum gross return (53, 06,196) was calculated in the treatment T_{12} (Camarosa+100% RDF dose of NPK through drip), whereas minimum

Table 1: Effect of different fertigation levels and cultivars on number of flowers, fruit set percent, yield per plant and yield per plot of strawberry

Treatment	Number of flowers/plant	Fruit set (%)	Yield/plant (g)	Yield/plot (kg)
V_1	18.97	96.42	373.79	4.49
V_2	18.50	96.06	359.49	4.31
V_3	19.14	96.58	381.31	4.57
$CD_{0.05}$	0.19	1.21	7.06	0.08
SEm±	0.06	0.42	2.39	0.03
F_0	15.78	90.18	264.94	3.18
F_1	19.19	97.78	377.62	4.53
F_2	20.14	99.01	418.29	5.02
F_3	20.36	99.21	425.27	5.10
$CD_{0.05}$	0.22	1.42	8.15	0.10
SEm±	0.07	0.48	2.76	0.03

*V_1= Chandler, V_2= Winter Dawn, V_3= Camarosa, F_0= Control, F_1= 50% through fertigation, F_2=75 % through fertigation, F_3=100 % through fertigation

Table 2: Effect of different treatment combinations on number of flowers, fruit set percent, yield per plant and yield per plot of strawberry

Treatment combinations	Number of flowers/plant	Fruit set (%)	Yield/ plant (g)	Yield/plot (kg)
T_1	16.07	90.36	265.04	3.18
T_2	18.73	97.90	373.30	4.48
T_3	20.36	98.58	422.77	5.07
T_4	20.70	98.81	434.04	5.21
T_5	15.57	89.73	259.31	3.11
T_6	19.40	97.28	375.30	4.51
T_7	19.58	98.78	403.49	4.84
T_8	19.42	98.46	399.58	4.80
T_9	15.69	90.45	270.46	3.25
T_{10}	19.45	98.15	383.99	4.61
T_{11}	20.47	98.80	428.59	5.14
T_{12}	20.96	98.91	442.18	5.30
$CD_{0.05}$	0.38	1.83	14.12	0.17
SEm ±	0.12	0.83	4.79	0.06

Table 3: Effect of different fertigation levels and cultivars on benefit cost ratio of strawberry

Treatment Combination	Total Cost of Cultivation (₹)	Gross Return (₹)	Net Return (₹)	B:C Ratio
T_1	1220000	3180474.4	1960474.4	1.61
T_2	1225150	4479536.8	3254386.8	2.66
T_3	1227725	5073234.4	3845509.4	3.13
T_4	1230300	5208492	3978192	3.23
T_5	1220000	3111707.2	1891707.2	1.55
T_6	1225150	4506982.8	3281832.8	2.68
T_7	1227725	4841908	3614183	2.94
T_8	1230300	4794937.6	3564637.6	2.90
T_9	1220000	3245509.6	2025509.6	1.66
T_{10}	1225150	4607873.6	3382723.6	2.76
T_{11}	1227725	5143119.2	3915394.2	3.19
T_{12}	1230300	5306196	4075896	3.31

gross return (31, 11,707.2) was calculated in treatment T_5 (Winter Dawn with control). Maximum net return (40, 75,896) was calculated in the treatment T_{12} (Camarosa+100% RDF dose of NPK through drip). However, minimum net return (18, 91,707.2) was calculated in treatment T_5 (Winter Dawn with control). Maximum B: C ratio (3.31) was calculated in the treatment T_{12} (Camarosa+100% RDF dose of NPK through drip), whereas minimum B: C ratio (1.55) was calculated in treatment T_5 (Winter Dawn with control). These results are in agreement with the findings of Nedunchezhiyan *et al.* (2023), Parmar *et al.* (2020); Chauhan and Chandel (2008), Bhattacharya (2010), Patel *et al.* (2010) and Ramana *et al.* (2014) observed that fertigation significantly increased the economics as compare to application of fertilizers through soil.

Conclusion

The fertigation improved yield by encouraging proper fertilizer nutrient use, lower labour cost and increasing productivity. The saving of about 33 per cent irrigation water and 20 per cent fertilizer, along with a 30 per cent increase in fruit yield, could be achieved through fertigation compared to conventional practices. Hence application of treatment T_{12} (Camarosa cultivar + 100% recommended dose of NPK through drip) is highly recommended to improve in terms of vegetative growth, yield and quality fruits.

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Genetic variability and character association for growth and yield characters in Dolichos bean (*Lablab purpureus var. typicus*) under rainfed semi-arid conditions

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Abstract

The genetic variability and character association were studied in 60 genotypes of dolichos bean (*Lablab purpureus var. typicus* L.) during 2018-2023 at Central Horticultural Experiment Station (ICAR- CIAH), Panchmahals (Godhra), Gujarat. A degree of variation was observed for all characters. High Phenotypic Co-efficient of Variation (PCV) and Genotypic Co-efficient of Variation (GCV) were recorded for primary branches/plant, number of pods/plant, Pod length, pod weight and pod yield/plant. The high PCV and GCV were recorded for primary branches/plant, number of pods/plant, pod length, pod weight and pod yield/plant indicated maximum variability in the genotypes. High heritability coupled with high genetic advance as per cent mean was observed for plant height, number of primary branches/plant, number of pods/plant, pod length, pod girth, pod weight and pod yield/plant indicating that these characters are controlled by additive gene action. Thus, selection for these characters will improve the yield. Pod yield/plant exhibited positive and highly significant correlation with number of branches, number of pods/plant, pod length, pod girth, pod weight at both genotypic and phenotypic levels. Hence these traits should be considered as important selection criteria for improvement of pod yield/plant.

Key words: GCV, PCV, Heritability, Association, Genotype

Dolichos bean (*Lablab purpureus* L) 2n=22, family of Fabaceae and is an ancient and important cultivated leguminous vegetable crop (Raghu *et al.,* 2018). There are two types of Dolichos bean have been recognized (Gangadhara *et al.,* 2023c) *Lablab purpureus* var. *typicus* which is a garden type bean having soft edible pods with less fiber content in pod walls. The second type is *Lablab purpureus* var. *lignosus*, is a field bean grown for dry seeds as a pulse.

The fresh pod contains 86.1% moisture, 3.8% protein, 6.7% carbohydrates, 0.7% fat, 0.9% minerals and 312 I.U, Vitamin-A (Singh *et al.,* 2004), while mature dry seeds contain 23% protein, 62% carbohydrates and 340 calories per 100g of edible portion (Tindall, 1983; Shulee *et al.,* 2021). Improvement in yield is possible only through selection for desired characters. Hence knowledge of association between yield and its component characters is essential for yield improvement through selection programme.

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Material and Methods

The study was carried out to assess the variability and character association in 60 diverse genotypes of dolichos bean at ICAR- CHES, Vejalpur, Panchmahals (Godhra), Gujarat. These genotypes were grown in a RCBD with three replications during the year 2018. 2019, 2020, 2021, 2022 and 2023 and four locations ((CHES,Vejalpur, Godhra, Gujarat, KVK-Panchmahal, Gujarat, CIAH, Bikaner, Rajasthan and ICAR-KVK, Kalaburagi-II, Karnataka) to evaluate for their growth, yield, quality and insect pest and disease incidence. The experimental site was located at (22° 41" 38" N latitude and 73° 33'38" E longitude at an altitude of 113 to 115 m above mean sea level which is characterized by semi-arid hot climatic conditions. The seeds were dibbled in ridges and furrows at a distance of 1m × 1.5m and the recommended dose of FYM (10-15t/ha) and fertilizers N.P.K. (25:75:60kg/ha) was also applied. The variance components and coefficients of variation were computed (Burten, 1952). The heritability in broad sense and expected genetic advance were determined by using the formula (Johnson *et al.*, 1955). The correlation

co-efficient among all possible character combinations at phenotypic and genotypic level were estimated by employing formula (Al-Jibouri *et al.,* 1958).

Results And Discussion

The analysis of variance for different quantitative characters for 60 genotypes indicated highly significant (P=0.01) difference among all genotypes for all characters. This indicated the presence of high degree of variation within the genotypes. Range of variation for various genetic parameters was observed for all traits indicated the presence of sufficient variation among the genotypes for all the nine characters (Table 1).

The high PCV and GCV were recorded for primary branches/plant (21.13 and20.51), number of pods/plant (86.21 and 85.62), pod length (29.05 and 28.86), pod weight (33.96 and33.61) and pod yield/plant (84.15and 83.66) respectively. The characters recorded for high PCV and GCV indicated maximum variability present in the germplasm for these characters. Moderate PCV and GCV were recorded for plant height (11.14 and10.34) and pod girth (14.46 and 13.61), whereas, low PCV and GCV were recorded for days to first flowering (5.28 and 5.26) and days to first harvesting (4.36 and 4.30) respectively, indicating the existence of limited variability in the germplasm. The higher estimates of PCV than GCV indicated towards the environmental influence in the expression of all the characteristics (Chaudary *et al.,* 2017; Gangadhara *et al.,* 2018; Gangadhara *et al.,* 2023c; Singh *et al.*, 2023).

High heritability in broad sense is useful in identifying appropriate character for selection and enables the breeder to select superior genotypes on the basis of phenotypic expression of quantitative traits. In our study, heritability ranged from 86.10% (plant height) to 99.0% (days to first flowering). High heritability was noticed for plant height (86.10%), number of primary branches/plant (94.10%), number of pods/plant (98.60%), pod length (98.70%), pod girth (88.60%), pod weight (97.90%), days to first flowering (99.0%), days to first harvesting (97.0%) and pod yield/plant (98.80%), indicating that these characters are less influenced by environmental factors and are under the control of additive gene effect and selection for improvement of such characters would be rewarding. Burten (1952) suggested that, GCV along with heritability estimates would provide a better picture of the amount of advance expected by phenotypic selection. Heritability estimates in conjunction with genetic gains are more effective and dependable in predicting the improvement through selection (Johnson *et al* 1955). High genetic advance as per cent mean was observed for plant height (20.17%), number of primary branches/plant (40.99%), number of pods/plant (175.16%), pod length (59.08%), pod girth (26.39%), pod weight (68.53%) and pod yield/plant (171.35%), indicating that these characters are controlled by additive gene action. Thus, selection for these characters will improve the yield. The similar results were reported by Chaudary *et al.* (2017), Gangadhara *et al.*(2018),Tripathi *et al.*(2018) and Singh *et al.* (2023).

The estimates of phenotypic and genotypic correlation coefficients among different characters of dolichos bean genotypes are presented in (Table 2). The Plant height exerted positive and highly significant

Table 1: Estimates of genetic parameters for various characters in dolichos bean

Character	Range		Mean	GCV	PCV	h^2	GA	GAM
	Min.	Max.						
Plant height(m)	2.72	4.88	3.90	10.34	11.14	86.1	0.77	20.17
Primary branches/plant	3.02	6.85	4.31	20.51	21.13	94.1	1.76	40.99
Number of pods/plant	59.91	1550.00	206.42	85.62	86.21	98.6	325.45	175.16
Pod length(cm)	5.43	17.50	11.05	28.86	29.05	98.7	6.53	59.08
Pod girth(cm)	3.30	6.13	4.36	13.61	14.46	88.6	1.15	26.39
Pod weight(g)	3.73	15.20	7.63	33.61	33.96	97.9	5.24	68.53
Days to first flowering	69.82	87.57	80.56	5.26	5.28	99	8.67	10.77
Days to first harvest	90.21	111.35	100.23	4.30	4.36	97	8.73	8.72
Pod yield/plant(kg)	1.02	9.80	2.72	83.66	84.15	98.8	2.29	171.35

GCV- Genotypic co-efficient of variation, **PCV**- Phenotypic co-efficient of variation,

h^2- Heritability (broad sense), **GA**- Genetic advance, **GAM-** Genetic advance as % mean

Table 2: Genotypic and phenotypic correlation (association) for growth and yield characters in dolichos bean

Character	Plant height(m)	Number of branches	Number of pods/plant	Pod length(cm)	Pod girth(cm)	Pod weight(g)	Days to first flowering	Days to first harvest	Pod yield/ plant(kg)
Plant height(m)	**1**	0.5622**	0.0541	0.0868	0.1102	0.0813	0.2210**	0.2130**	0.1194
Number of branches	0.5173**	**1**	0.4775**	0.3171**	0.2666**	0.2959**	0.0991	0.0413	0.5489**
Number of pods/plant	0.0477	0.4630**	**1**	0.1729*	0.2118**	0.1642*	0.0033	-0.1037	0.9443**
Pod length (cm)	0.0799	0.3073**	0.1693*	**1**	0.2009	0.8522**	0.1622*	0.1331	0.4196**
Pod girth (cm)	0.0899	0.2437**	0.1971**	0.1884*	**1**	0.4253**	0.2383**	0.1126	0.3333**
Pod weight (g)	0.0774	0.2905**	0.1615*	0.8388**	0.3944**	**1**	0.2401**	0.1600*	0.4408**
Days to first flowering	0.2093**	0.0980	0.0030	0.1590*	0.2224*	0.2362**	**1**	0.8581**	0.0808
Days to first harvest	0.2058**	0.0463	-0.1017	0.1293	0.0953	0.1588*	0.8498**	**1**	-0.0211
Pod yield/ plant(kg)	0.1145	0.5359**	0.9351**	0.4149**	0.3069**	0.4401**	0.0794	-0.0201	**1**

Above diagonal indicates genotypic correlations below phenotypic correlations. **Significant at 5% and * Significant at 1%

correlation with number of branches (r_g= 0.5422 and r_p= 0.5173), days to first flowering (r_g= 0.2210 and r_p= 0.2093), days to first harvesting (r_g= 0.2130 and r_p= 0.2058) at both genotypic and phenotypic level. Number of branches showed highly significant and positive association with number of pods/ plant (r_g= 0.4775 and r_p= 0.4630), pod length (r_g= 0.3171 and r_p= 0.3073), pod girth (r_g= 0.2666 and r_p= 0.2437), pod weight (r_g= 0.2959 and r_p= 0.2905) and pod yield/plant (r_g= 0.5489 and r_p= 0.5359) at both genotypic and phenotypic levels (Table 2). Number of pods/plant had positive and highly significant with pod girth (r_g= 0.2118 and r_p= 0.1971) and pod yield/plant (r_g= 0.9443 and r_p= 0.9351) at genotypic and phenotypic levels, whereas, it showed positive and significant correlation with pod length (r_g= 0.1729 and r_p= 0.1693) and pod weight (r_g= 0.1642 and r_p= 0.1615) at both levels. Pod length showed highly significant and positive correlation with pod weight (r_g= 0.8522 and r_p= 0.8388), pod yield/ plant (r_g= 0.4196 and r_p= 0.4149) at both levels while, it showed highly significant and positive correlation with pod girth (r_g= 0.2009 and r_p= 0.1884) at genotypic level only but significant and positive correlation at phenotypic level whereas, it had positive and significant correlation with days to first flowering (r_g= 0.1622 and r_p= 0.1590) at both levels. Pod girth recorded highly significant and positive association with pod weight (r_g= 0.4253 and r_p= 0.3944), days to first flowering (r_g= 0.2383 and r_p= 0.2224), pod yield/plant (r_g= 0.3333 and r_p= 0.3069) at genotypic and phenotypic level. Pod weight exhibited positive and highly significant correlation with, days to first flowering (r_g= 0.2401 and r_p= 0.2362), pod yield/ plant (r_g= 0.4408 and r_p= 0.4401) at genotypic and phenotypic level. Positive and significant correlation was recorded with days to first harvesting (r_g= 0.1600 and r_p= 0.1588) at both the level. Hence pod weight should be considered as important selection criteria for the improvement of pod yield/plant. Days to first flowering showed highly significant and positive correlation with days to harvesting (r_g= 0.8581 and r_p= 0.8498) at genotypic and phenotypic level. Days to first harvest recorded negative and non significant correlation with pod yield/plant (r_g= -0.0211 and r_p= -0.0201) at genotypic and phenotypic level which indicates the earliness.

Pod yield/plant exhibited positive and highly significant correlation with, number of branches (r_g= 0.5489 and r_p= 0.5359), number of pods/plant (r_g= 0.9443 and r_p= 0.9351), pod length (r_g= 0.4196 and r_p= 0.4149), pod girth (r_g= 0.3333 and r_p= 0.3069), pod weight (r_g= 0.4408 and r_p= 0.4401) while, non-significant negative correlation was recorded for days to first harvesting (r_g= -0.0211 and r_p= -0.0201) at both genotypic and phenotypic level. These results are in accordance with (Gangadhara *et al.,* 2023a; Gangadhara *et al.,* 2023b; Gangadhara *et al.,* 2023d; Singh *et al.*, 2023).

Hence these traits should be considered as important selection criteria for the improvement of pod yield/plant. Thus, trait pairs recorded higher values of genotypic correlations than their corresponding phenotypic correlations. This indicated that there was high degree of association between two variables at genotypic level; its phenotypic expression was deflated by the influence of environmental factors. The results on correlation coefficients revealed that number of branches, number of pods/ plant, pod length, pod girth and pod weight were most important traits and may contribute considerably towards higher pod yield/plant. The interrelationship among pod yield/plant components traits would help in future breeding programmes for increasing the pod yield in dolichos bean.

Highly diverse lines of dolichos bean: Highly promising and productive lines were identified during 2018-2023 based on different horticultural traits indicating ideal for four locations *viz.,* CHES,Vejalpur, Godhra, Gujarat, KVK-Panchmahal, Gujarat, CIAH, Bikaner, Rajasthan and ICAR-KVK, Kalaburagi-II, Karnataka.

CHESDB-7 (Thar Kiran): It is a high yielding with purple red pods and anthocyanin rich (190 mg/100g) variety. The plants have purple pigmentation in their stems, petioles, flowers, leaf veins and pods. The number of pods/plant varies for 1100 to1600/plant with an average yield of 7-9 kg/plant. It is resistance to dolichos bean yellow mosaic virus (DYMV) disease under field conditions.

CHESDB-50 (Thar Ganga): This variety has attractive and shining long green pods. The pods are very long with pod length (17.5cm), pod girth (5.21cm) and pod weight (15.2g). The fresh pods are harvested 98-110 days after sowing. The number of pods/plant varies for 800 to 1200/plant with an average yield of 8-10 kg pods/plant. It is moderately resistance to dolichos bean yellow mosaic virus (DYMV) disease under field conditions.

CHESDB-31(IC-631578): This genotype has whitish green pod colour with slender pod shape with cluster pod bearing in nature and produces 12-15pods/ cluster and it has got whitish colour matured seeds. Pods are long with pod length (14.23cm), pod girth (4.21cm) and pod weight (8.50g). It takes 98-100 days for first flowering and fresh pods are harvested at 115 and 120 days after sowing. It gives 900-1250 pods with a yield potential of 6–7 kg/plant. The whole pods are rich in proteins (4.20g/100g), other vitamins and minerals. It is moderately tolerant to dolichos bean yellow mosaic virus (DYMV) disease under field conditions.

CHESDB-40(IC-631579): It is a pole type genotype having light purple red colour and sickle shaped pods which are rich in anthocyanins (180mg/100g) and highly field resistant to dolichos bean yellow mosaic virus disease. It has pod length of 15.50cm pod girth (4.0cm) and pod weight (7-7.5g). The fresh pods are harvested at 95-97 days after sowing. It gives 900-1400 fresh pods with yield potential of 7.0 to 8.0 kg/plant.

CHESDB-10 (IC-631577): This genotype has unique broad pod shape with 6.20cm of girth, pods are long and creamy whitish green in colour. It is a prolific pod bearer and moderately field resistant to dolichos bean yellow mosaic virus disease. The pods are broad and long with length (16.00cm), pod girth (6.20cm) and pod weight (11.50g). It takes 98-100 days for first flowering and fresh pods are harvested at 115-120 days after sowing. It bears 750-900 pod/plant with a yield of 7.0–7.8 kg/plant which are rich in proteins (5.0g/100g), other vitamins and minerals.

CHESDB-01(IC-631574): It is a pole type genotype having long flat and medium sized and green pods. It has average pod length of 14.50cm with girth of 5.50cm and pod weight of 10.60g. It takes 78 days for first flower and fresh green pods are harvested at 90-95 days after sowing. It produces 750-800 pods/plant with a yield of 5.5-6.5 kg/plant of fresh pods.

Conclusion

The characters recorded for high PCV and GCV indicated wide variability present in germplasm. High heritability coupled with high genetic advance as per cent mean was observed for most of the characters, indicating that these characters are controlled by additive gene action. Thus, selection for these characters will improve the yield. Pod yield/plant exhibited positive and highly significant correlation with, number of branches, number of pods/plant, pod length, pod girth, pod weight at both genotypic and phenotypic level. Hence these traits should be considered as important selection criteria for improvement of pod yield/plant.

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Short Communication

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Ramification of post-harvest thermal disinfestation technology for mango fruit flies [*Bactrocera* spp. (Diptera: Tephritidae)] across India

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Mango (*Mangifera indica*) is the most important fruit crop of India with high potential in export and foreign exchange. An impediment in mango fruits export has been the infestation by *Bactrocera dorsalis* (Hendel) and *B. zonata* (Saunders). The adoption of pre-harvest Integrated Pest Management (IPM) developed by ICAR-Indian Institute of Horticultural Research (IIHR) reduced infestation by 95% (Stonehouse *et al*., 2005, Verghese *et al*., 2002). Subsequent improvement of pre-harvest control using ovipositional deterrence gave more than 98% control (Verghese *et al*., 2020). However, for exports, 100% disinfestation is mandatory. For the most part, postharvest pest control is focused on trade and exports. In order to achieve safe post-harvest disinfestation several experiments and studies were conducted on main commercial varieties using hot water (45°C to 48°C), for different lengths of time to standardize the thermal disinfestation protocol which is internationally acceptable (Yahia and Campos, 20.

All the studies were conducted at ICAR-IIHR where orchards of major export mango varieties are available. The entomology division here has an excellent fruit fly breeding laboratory and cultures. The Institute also built a prototype of the thermal disinfestation tank (Fig. 1) which all helped in developing a thermal disinfestation technology by 2011 (Verghese *et al*., 2011). This was adopted by Directorate of Plant Protection, Quarantine and Storage (DPPQS) and included under National Standards and Phytosanitary Measures (NSPM-15) on guidelines for certification of Hot Water Immersion Treatment (thermal disinfestation) facilities for mango fruits (DPPPQS, 2023).

During 2011 only two facilities had registered and established. However, during 2014 the European Union (EU) banned import of mangoes from India because of fruit fly infestation (PIB, GoI, 2015). This prompted the establishment of 11 thermal disinfestation facilitates in 2015 by DPPQS[6]. After this there was a steady increase in the establishment of thermal disinfestation facilitates from 13 to 52 as of 2023 (Fig. 1 and 4; Table 1). On 12th February 2015 EU lifted the ban on mango imports and till today there has been no reports of fruit fly infestation in the mango consignments (PIB, GoI, 2015).

The thermal disinfestation technology was a culmination of researches in varietal selection, insect behavioral studies, mortality assessment due to hot water on eggs and first instar larvae, standardizing of thermal tank with appropriate thermostat and post-harvest organoleptic tests (Verghese *et al*., 2011, Verghese and Rashmi, 2014).

Further the protocol consisted of a thermostat-controlled metal hot water bath (Fig. 2), the size of which can vary with volume of fruits, in which fruits harvested are submerged at 48°C (maintained thermostatically) (Fig. 3), for 60 to 75 minutes (depending on size and variety of mango) to disinfest eggs and 1st instar of fruit flies which are not easily discernable at harvest. The prototype was suitably scaled up by DPPQS to treat large volumes of mangoes where baskets of freshly harvested fruits are lowered into the hot water bath. The fruits are held at the prescribed temperature and length of time, then taken out, by an overhead hoist. The technology has ramified to 52 registered thermal water treatment plants in India (Fig. 4) (DPPPQS, 2023). Today this technology has helped in exporting mango varieties to countries where thermal disinfestation is mandatory: all European Union countries, Switzerland, Iran, South Korea and Mauritius (APEDA, 2023). India has exported 22963.76 MT of fresh mangoes worth of Rs. 378.49 crores/ 48.53 USD millions during the year 2022-23 (APEDA, 2023).

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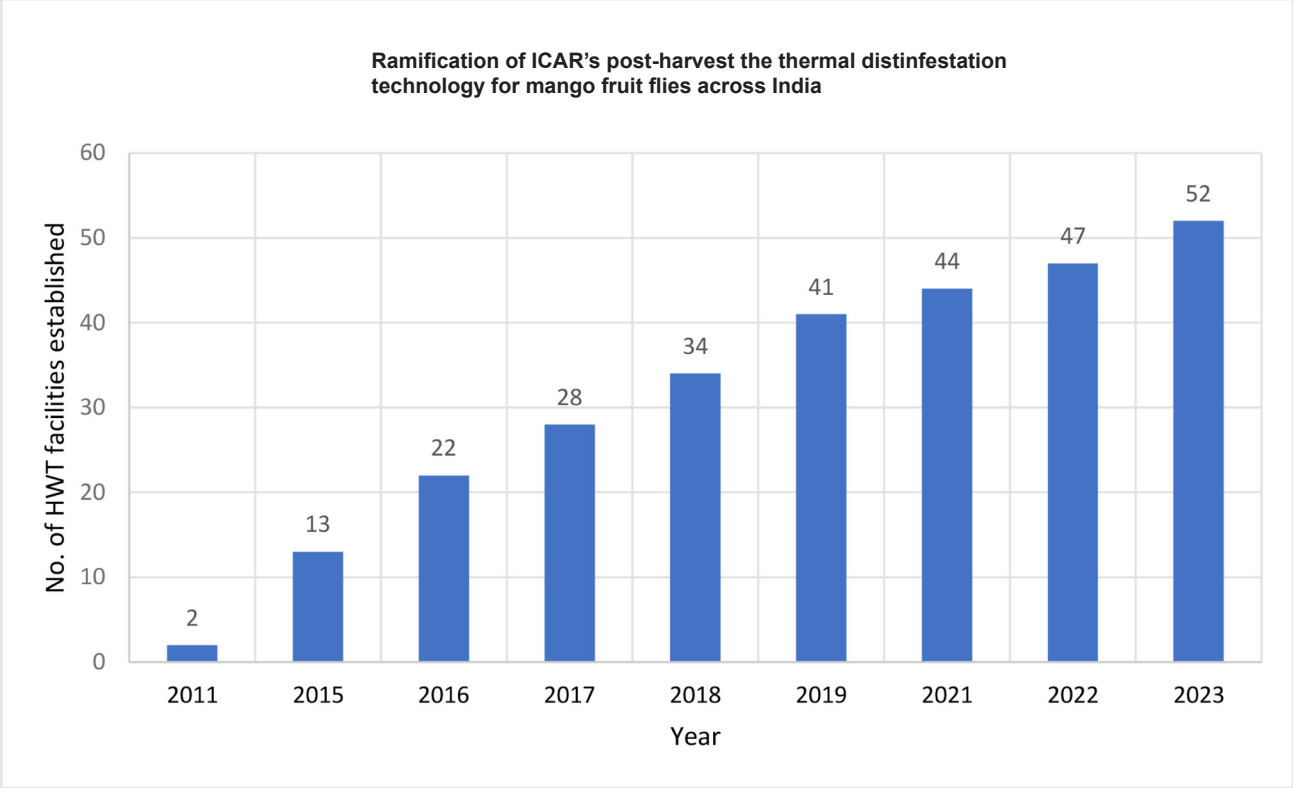

Fig. 1: Number of post-harvest thermal disinfestation technology across India from 2011 to 2023 (*Source:* DPPQS, GoI).

Fig. 2: Prototype of thermal disinfestation treatment developed at ICAR-IIHR during 2011 (In picture Dr. Amrik Singh Sidhu the then Director ICAR-IIHR with Dr Abraham Verghese)

Fig. 3: Thermal disinfestation immersion treatment process at a registered facility

Fig. 4: Map showing registered thermal disinfestation treatment facilities in India [6](as per NSPM – 15) https://pqms.cgg.gov.in/c5c4e81d-1670-4135-b66f-4ace5aed276f

It is interesting to note that these thermal water plants are concentrated around major mango marketing belts of India, 18 facilities in Maharashtra, 14 in Gujarat followed by other states as given in Table 1 (DPPPQS, 2023). These facilities are accredited by DPPQS and Agriculture Products Export Development Authority (APEDA). Export farmers can make use of these facilities after following the required formalities. The scope for enhancing exports is dependent on further ramification of the technology.

Table.1: Spread of the post-harvest thermal disinfestation technology across different states in India up to 2023 (*Source:* DPPQS, GoI, 2023).

State	No. of thermal disinfestation facilities
Maharashtra	18
Gujarat	14
Karnataka	5
Uttar Pradesh	4
West Bengal	3
Andhra Pradesh	2
Tamil Nadu	2
Telangana	2
Delhi	1
Kerala	1
Punjab	1
Total	**52**

The ramification of a single technology to 52 centers across different states of the country (Table 1) is a success story of interdisciplinary sciences leading to an adoptable viable technology especially because it has boosted exports, commerce and higher income to farmers (APEDA, 2023) and has provided environment-friendly and residue-free fruits (Verghese and Rashmi, 2014). Many other such ICAR technologies and varieties developed have helped the growth of agriculture and economy in India (ICAR, 2023).

Therefore, translating knowledge and research into adoptable technologies only will serve to contribute to the country's horticultural and economic growth.

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New varieties of arid fruits

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Bael Thar Bhavya: Its yield is 97.18 kg/plant in 10th year,each fruit weighing 0.65-0.78 kg, fruit size 11.15 cm × 10.24 cm, fruit girth 37.43-39.25 cm, shell thickness 0.16-0.18 cm, total number of seeds 56.25, fibre weight 38.00g, shell weight 97.17-105.00g, locules in cross section 14-16, pulp TSS 32.47-34.15°Brix, TSS mucilage 45.12-49.50°Brix, acidity 0.31-0.33% and vitamin C 19.24-21.63 mg/100g pulp. It is mid maturing variety (4th week of April). Compact canopy, short in stature and semi-spreading growth habit, highly suitable for high density (5m × 5m) planting. The fruits have very good shelf life (10-15days) and suitable for *sherbet* and slice. It is highly suitable for nuclear family.

Bael Thar Gauri: It yields per plant 133.70 kg/plant in 11th year, heavy yielding with fruit weight of 1.37-1.45 kg, fruit size 14.31 cm x 13.33 cm, fruit girth 41.73.00cm, shell thickness 0.23-0.24 cm, total number of seeds 59.13-62.00, total seed weight 27.54- 29.59g, fibre weight 43.23-49.70g, shell weight 190.23-1201.54g, locules in cross section 15-17, TSS pulp 41.85-43.25°Brix, TSS mucilage 45.00-50.12°Brix, acidity (0.34-0.38%) and vitamin C 22.40-24.07 mg/100g pulp. It is mid maturing variety (4th week of April), heavy yielder, compact canopy, cluster bearing, deep yellow colour of fruit. It is having excellent shelf life (15-20 days) and suitable for pickle, candy and powder and *ayurvedic* formulations.

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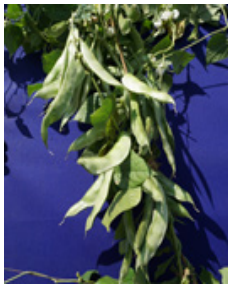
Drumstick Thar Tejas: It grows 2.74 m in plant height, yields 245 pods/plant, 218 g each pod weight, fruit length 45-48 cm, 9-10 seeds/pod and more flesh under rainfed semi-arid conditions. It is a comparatively early flowering and matures during January-March.It gives highest protein, potassium, iron and zinc in dry pod powder and highest dry matter, protein, calcium, magnesium, iron, manganese and zinc in dry leaves powder.

Spine gourd Thar Varsha: Its fruitweigh 15.4-20.6 g, seeds 16-20, high yield potential (1.6-2.8 kg/plant) with dark-green and round fruits along with small spines attributing to consumer preference. The fruits are rich in ascorbic acid (423.7 mg/100 g). Its vine is thin and spreading which grows very well on 4-line wire-trellis system. Its fruits are 3.5-5.7 cm long and 9.1-9.6 cm diameter with total yield of 5.50 t/ha at spacing of 2 m × 2 m. The plant produces 104-134 fruits in full cropping season (112-118 days) with sufficient pollinators.

Indian bean Thar Vinaya: It has attractive long, light green colour pods. It is pole type Indian bean variety with cluster pod bearing in nature. The plants have climbing growth habit and grow up to 4.0-4.6m. Pods are long (14 cm), girth (4.20 cm) with pod weight (8.5g). It takes 90-91 days for first flowering and 102-105 days after sowing for first harvest. Itr yields 1000-1265 fresh pods/ plant with yield 6.5-7.5 kg/plant and 50t/ha of fresh tender pods. It is moderately

resistant to dolichos bean yellow mosaic virus disease under field conditions.

Indian bean Thar Lakshmi: It is a pole type variety having long flat and medium sized green colour pods. Length of pod 14 cm, girth 5.5 cm and weight 10 g. First harvesting offresh pods starts at 90-95 days after sowing. Total of 800-1240 pods/plant with on an average yield of 6.5-6.7 kg/plant and 45-50t/ha of fresh pods can be obtained under rainfed conditions. This is moderately resistant to dolichos bean yellow mosaic virus disease under field conditions.



Yardlongbean Thar Prateeksha: It has attractive long light green colour pods. It is an early flowering (38-40 days) and early maturing (45-48 days) variety with 66.00 cm pod length, 3.4 cm pod girth and 32.0g

pod weight. It bears 120-150 pods/plant with an average yield of 3.0kg/plant of fresh pods. This variety is moderately resistant to cowpea mosaic virus disease under field conditions.

Yard long bean Thar Surya: It is an anthocyanin rich (190-200mg/100g) variety (pole type) having attractive

long & dark purple red colour pods**.** It is an early flowering and early maturing genotype. It takes 35-36 days for first flowering and 44-46 days after sowing for first harvesting of fresh tender pods. The pods have 52.50cm length, 2.5cm girth and 23.0g pod weight. The total number of pods per plant varies 180-200 pods/ plant with an average yield of 2.5 to 3.0kg/plant of fresh pods. This variety is moderately resistant to cowpea mosaic virus disease under field conditions.

Yardlomg bean Thar Deeksha: It is an early flowering and early maturing variety (Pole type) which has attractive long and light green colour pods. It takes 29-30days for first flowering and 36-38 days after sowing for

first harvesting of fresh tender pods. The pods have 52.0-54.0cm length, 3.30cm girth and 28.0-30.0g pod weight. It bears 150-180 pods/plant with an average yield of 3.0kg/plant of fresh pods. This is moderately resistant to cowpea mosaic virus disease under field conditions.

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Promising Dragon fruit varieties

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The systematic work of dragon fruit improvement was initiated at ICAR- IIHR, Bengaluru. Four varieties viz., CHESH-D1, CHESH-D2, CHESH-D3, CHESH-DE were identified.

CHESH- D1

Selection was made from open-pollinated progeny of Hiryur Red cultivar. The time taken between bud initiation and anthesis is 23 days and anthesis to maturity is 34 days. Fruits are round with red pulp, having dense bracts with medium apical bract length (5.70 cm). The individual fruit weight is striking character ranging from 507.71 g with pulp weight of 404.52 g and TSS 14.50 °Brix. The betalain content is 20.4 mg BCE and antioxidant potential was 467 ± 32 µmol TE. It is photo insensitive with average of 39.50 kg/pole.

CHESH-D1

CHESH- D2

It is an open pollinated variety of Vietnam Red, yielding oval fruits with red pulp. It takes 22 days from bud initiation to anthesis and 33 days from anthesis to maturity. Individual fruit weighs 442.25 g having pulp weight of 353.74 g with pH -5.04 and TSS of 15.35 °Brix. The highest total sugar content is 5.95 g. The betalain content in fruits is 21.2 mg BCE with an average fruit yield of 19 kg/pole.

CHESH-D2

CHESH-D3

It is selection from open-pollinated variety of Vietnam Pink cultivar. Fruits are round with pink pulp; medium dense bracts on surface; average individual fruit weighs 422.00 g with yield per pole 22 kg. Fruits have TSS of 14 °Brix. The pH of fruit juice is 5.32, total sugar content 5.45 g and the reducing sugar 4.21 g. The pulp is pink with betalain content of 19.00 mg BCE.

CHESH-D3

CHESH - DE

The seeds of dragon fruit cultivar Hirehalli Red were treated with 2.5 % EMS (Ethyl Methane Sulfonate). The mutant progeny of M2 generation was evaluated for its morphological and yield traits. Fruits have less to medium number of bracts with smooth surface, round shape. It bears fruits of pale pulp with pink blush. The average fruit weight is 379.18 g with pulp weight of 260.11 g and TSS of 14.80 °Brix. The total sugar content is 5.75 g and the reducing sugar is 4.66 g. The intensity of seeds is medium.

CHESH-DE

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