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Trends and developments in vegetable research In India — a review

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Abstract

Vegetables are an integral component of horticulture sector, praying a pivotal role in the tapestry of Indian agriculture. Their substantial contributions extend to enhancing global food security and nutritional well-being. During 2021-22, India produced 204.84 million tonnes of vegetables, covering the area of 11.35 million hectares, with a fresh vegetable export value worth 865.24 USD millions. The AICRP on Vegetable Crops has forged a national network to test vegetable technologies in India. In the past five decades, 587 vegetable varieties, 442 production technologies, and 42 protection technologies have been developed through AICRP. The use of molecular markers has been proven promising in several vegetable crops, however only limited example of improvements are available from India. Through genetic engineering several biotic and abiotic stress resistant lines are developed. The genome editing has opened a new avenue in development of improved lines, however it is just gaining momentum in vegetable research in India.

Key words: Vegetables, Genome editing, Vegetable export, Breeding, Biotechnological approach, Biofortification

Vegetables play a crucial role in promoting human nutrition by serving as invaluable sources of essential nutrients, dietary fiber, vitamins, minerals, plant-based proteins, and antioxidants. Additionally, the presence of phytochemicals in vegetables has been scientifically linked to a reduction in the risk of non-communicable diseases (NCDs). These include some of the most prevalent and serious health concerns, such as certain forms of cancer, diabetes, gastric ulcers, stroke, and heart diseases (Dias, 2013). India has embraced a remarkable diversity in its vegetable consumption, with a repertoire that encompasses over 97 species of higher plants and among these, nearly 60 being cultivated on a commercial scale (Behera *et al*., 2021). Further. These vegetable crops span an impressive spectrum of 20 distinct plant families, with notable representatives from families such as Cucurbitaceae, Fabaceae, Brassicaceae, and Solanaceae, which together account for a rich tapestry of flavours, textures, and nutritional profiles.

The world's total vegetables production was estimated to be 1,154 million tonnes in 2021, China being at top position with a production of 600 million tonnes that accounts for 52.18% of the world. The top 5 countries (China, India, the United States of America, Turkey and Vietnam) account for 70.36% of total world's production (Statista, 2023). During 2021-22, India produced 204.84 million tonnes of vegetables covering the area of 11.35 million hectares, with average productivity of 18.05t/ha compared to area (2.84 million ha), production (16.5 million tonnes) and productivity (5.8 t/ha) of vegetables in 1950-51. Since 1951, there has been enhancement in area (4.0 fold), productivity (3.1 fold), production (12.41 fold) and per-capita availability (3.3 fold). Presently, India is the largest producer of ginger (2.23 mt) and okra (6.47 mt) in the world, while ranking second in the production of potatoes (54.23 mt), dry onions (26.64 mt)), cauliflowers and broccoli (9.25 mt), brinjal (12.87mt), and cabbage (9.56 mt) (FAO, 2020). The fresh vegetable export value was reported to be worth of 865.24 USD millions (APEDA, 2023).

In India, systematic vegetable improvement work was initiated in the 1960's. This transformative effort gained momentum through the establishment of several national research institutes and the implementation of All India Coordinated Research Project (AICRP) focusing on vegetables. These strategic initiatives have not only propelled significant advancements in vegetable production and productivity but have also positioned India as the second-largest global producer in this domain. As on date, a total of 553 vegetable varieties in 30 vegetables have been in public domain for cultivation in different agro climatic zones of India

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(Behera *et al.*, 2021). Vegetable breeding presents a distinct level of complexity and challenge when compared to grain crops, where the grain itself is the primary product. In the realm of vegetables, various plant components like leaves, stems, roots, flowers, and fruits are consumed. The region-specific demand for attributes such as colour, shape, nutrition, taste, and the optimal harvest stage, along with the need to address quality concerns, ensure a consistent year-round supply, and manage other intricate considerations, represents the requirement for a comprehensive and specialized approach to achieve the desired outcomes in crop improvement.

Vegetables, production and quality are significantly impacted by a multitude of pathogens and insects. The consequences of excessive pesticide and fungicide use, coupled with the presence of microbial contaminants, colorants, and heavy metals, pose notable environmental and health hazards. Among these concerns, the presence of pesticide residues emerges as a paramount food safety issue. Alarmingly, India contributes to 25% of global pesticide poisoning cases, and between 50-60% of vegetables harbour pesticide residues (Dhaliwal *et al.*, 2015). Further, vegetable crops are particularly sensitive to environmental extremes particularly elevated temperatures and inadequate soil moisture stand out as primary contributors to diminished yields in tropical regions, and these challenges are anticipated to intensify with the progression of climate change. To combat these problems a due focus is given on the resistance breeding for various biotic and abiotic stresses in each vegetable crop. A diverse array of vegetable crop varieties with increased productivity and other desirable attributes has already been attained through the implementation of conventional breeding techniques. However, this traditional approach to genetic enhancement is characterized by a gradual pace, involving numerous generations for genome refinement in an uncontrolled manner. Alongside conventional breeding, recently innovative genetic engineering techniques, including recombinant DNA technology, RNA interference (RNAi), and CRISPR-Cas9, has notably contributed to the genesis of novel crop varieties. This review provides an overview of the current state of vegetable cultivation, prevalent breeding techniques, focal traits of interest, utilization of wild genetic resources for biotic and abiotic stress resilience, as well as modern breeding methodologies encompassing biotechnological assisted strategies, gene editing, and the potential integration of artificial intelligence and machine learning techniques to advance and enhance vegetable production in India.

Network approach of research

The All India Coordinated Research Project (AICRP) on Vegetable Crops began during the IVth five-year plan in 1970-71, establishing a national network for testing vegetable technologies from diverse research institutions and state agricultural universities. Presently, the AICRP Vegetable Crops is a network of 36 regular and 18 voluntary centres and 26 co-operating centres, located in different agro climatic zones of the country with its headquarters at Indian Institute of Vegetable Research (IIVR) in Varanasi. The main function of AICRP-VC is to provide a national level platform for multi-location testing of the vegetable technologies developed by various research institutes and state agricultural universities to identify region specific recommendations. Over the period of last five decades, a total of 587 vegetable varieties in 28

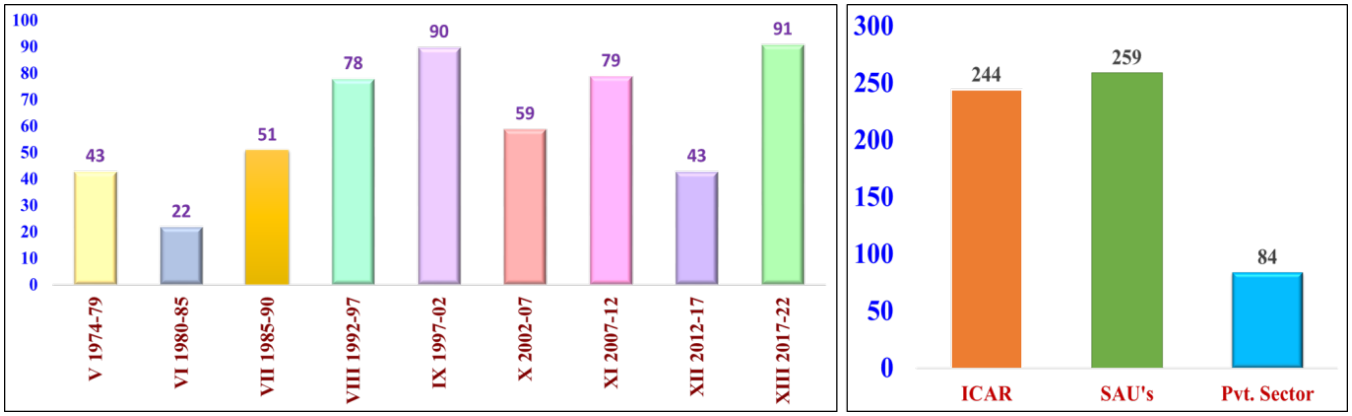

Fig. 1: Plan-wise varieties/hybrids developed and number of varieties/hybrids contributed by different sectors, identified through AICRP (VC) in last five decades

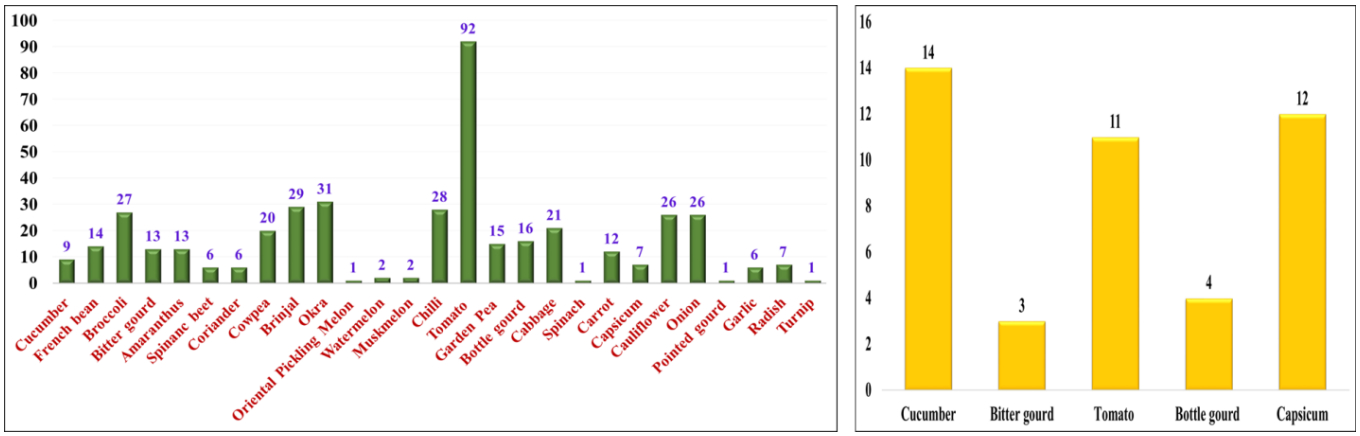

Fig. 2: Crop-wise production and protection technologies developed through AICRP (VC) during last five decades

vegetable crops have been recommended for cultivation in various agroclimatic zones of the country (Fig. 1). This includes 309 O.P. varieties, 163 hybrids and 54 O.P./ hybrids resistant to different biotic and abiotic stresses. During 2009 – 2019, a total of 126 varieties including 66 OPV, 50 F_1 hybrids and 10 resistant varieties have been identified and recommended by the AICRP (VC) in 24 vegetables.

Likewise, the centre has successfully developed 432 production technologies covering 27 distinct vegetables, complemented by an additional 46 protection technologies in 5 vegetables (Fig 2). It is worth noting that when it comes to protection technologies, cucumber takes the lead, closely followed by bitter gourd, tomato, bottle gourd, and capsicum.

Traditional breeding approaches and targeted traits

The traditional breeding methods, encompass prominent approaches such as introduction, pure line selection, pedigree method, bulk method, single seed descent, back cross method, heterosis, and mutation. As emphasized by Behera *et al.* (2023), the significant breeding objectives in various vegetables crops includes focus on high yields (Pandey *et al.* 2008), consumer liking, multiple diseases resistance, pest tolerance, processing quality and high Nutraceutical value (Pandey *et al.*, 2010). Singh *et al.* (2009) listed the available resistant cultivars, genotypes or wild species in various vegetables crops for various biotic stresses. The comprehensive listing of cultivars and hybrids developed to confer resistance against a myriad of biotic stresses across diverse vegetable crops is outside the purview of this review article. However, some of the most popular achievements have been mentioned with few examples as in case of brinjal (Pusa Vaibhav, resistant to *Fusarium* wilt, virus complex and little leaf under field condition; Arka Keshav: resistant to bacterial wilt); pea (Matar Ageta-7, resistant to rust & powdery mildew diseases; Kashi Samridhi: powdery mildew resistance), Okra (Kashi Chaman, resistant to YVMV & OLECV) etc. Similarly, due focus has been directed towards abiotic stresses and specific growth conditions. Some of landmarks varieties developed by the leading institutes across nation are summarized in table 1.

The significance of bioactive-rich and edible colour varieties cannot be ignored as they play a pivotal role in promoting both human health and culinary diversity. As stated in beginning, bioactive compounds, such as antioxidants, vitamins, and phytochemicals, present in these varieties offer a multitude health benefits, including bolstering the immune system, reducing the risk of chronic diseases, and supporting overall well-being. Moreover, the vibrant and diverse array of colours in these varieties not only enhances the visual appeal of dishes but also signifies the presence of different nutrients and phytochemicals. This is particularly important in a country like India, where traditional cuisine is deeply rooted and where the cultural significance of food is closely intertwined with its nutritional value. Table 2 listed out some of these varieties developed to cater to Indian consumers' preferences and nutritional needs.

Further, hybrid seed development stands as a pivotal factor in propelling the expansion of vegetable production on a global scale. This progress has been propelled by the strategic implementation of self-incompatibility (SI)

Table 1: Varieties for special growth conditions in some of crops

Crop	Special growth trait	Cultivars	Institute
Brinjal	Summer and autumn cultivation	Punjab Chamkila	PAU, Ludhiana
Brinjal	Summer and autumn cultivation	Pusa Purple Cluster	ICAR-IARI, New Delhi
Cabbage	Tolerance to high temperature	Green Express, Green Boy, KK Cross,	-
Cabbage	Tolerance to high temperature	Pusa Ageti	ICAR-IARI, New Delhi
Cabbage	Tolerance to high temperature (36°C)	Bajrang (F1 hybrid)	Bejo Sheetal Seeds Pvt. Ltd., Jalna
Cauliflower	Tolerant to heat	Garima	Golden Seeds
Chilli	Tolerant to moisture stress	Arka Lohit	IIHR, Bangalore
Chilli	Tolerant to salinity	Aparna (CA-1068)	APAU (Lam)
Cowpeas	Tolerant to heat and drought	Arka Garima	ICAR-IIHR, Bangalore
Cowpeas	Wider adaptability	Kashi Kanchan, Kashi Nidhi	ICAR-IIVR, Varanasi
Garlic	Tolerant against soil salinity	HG-6	CCSHAU, Hissar
Onion	Kharif season	Arka Kalyan,	ICAR-IIHR, Bangalore
Onion	Kharif season	N53, Agrifound Dark Red, Baswant 780	-
Pea	Wider adaptability	Kashi Udai, Kashi Nandini	ICAR-IIVR, Varanasi
Peas	High Temperature	Arka Tapas	ICAR-IIHR, Bangalore
Pointed gourd	Tolerant to moisture stress	Swarna Alaukik	CHES, Ranchi
Potato	Tolerant to frost	Kufri Navtal, Kufri Sheetman	ICAR- CPRI, Kufri, Shimla
Potato	High temperature tolerant	Kufri Surya	ICAR- CPRI, Kufri, Shimla
Radish	Year round cultivation	Pusa Chetki, Pusa Desi	ICAR-IARI, New Delhi
Radish	High temperature tolerant (up to 40°C)	Kashi Mooli-40	ICAR-IIVR, Varanasi
Tomato	High Temperature	Kashi Tapas, Kashi Adhbhut	ICAR-IIVR, Varanasi
Tomato	High Temperature	Pusa Hybrid 1 (28°C night temp)	ICAR-IARI, New Delhi
Tomato	Low temperature	Ostenkinskiz, Cold Set	-
Tomato	Low temperature	Pusa Sheetal (8°C)	ICAR-IARI, New Delhi
Tomato	Fruit set at low temperature	Hissar Arun	HAU, Hissar
Tomato	Tolerant to moisture stress	Arka Vikas	ICAR-IIHR, Bangalore
Watermelon	Resistant to drought	Sugar Baby	ICAR- IARI, New Delhi

Table 2: Varieties rich in bioactive and edible colour in India

Crop	Variety	Pigment
Amaranthus	Pusa Lal Chaulai	Anthocyanin
Basella	Kashi Poi-3	Betalain
Bitter gourd	Pusa Aushadi	Beta carotene
Bitter gourd	Pusa Vishesh	Ca & Fe
Bitter gourd	Pusa Hybrid -2	Ca & Fe
Carrot	Pusa Ashita	Anthocyanin
Carrot	Kashi Krishna	Anthocyanin
Carrot	Pusa Rudhira, Pusa Vrishti	Lycopene
Carrot	Pusa Yamdagini, Pusa Nayanjyoti	Carotene
Paprika	KTPL-19	Capsanthin
Pumpkin	Arka Chandan	Carotene
Purple headed Broccoli	Palam Vichitra	Anthocyanin
Radish	Pusa Jamuni, Kashi Lohit	Anthocyanin
Radish	Pusa Gulabi	Lycopene
Red cabbage	Red Acre	Anthocyanin
Tomato	Pusa Uphar, Pusa Rohini, Pusa Hybrid 2, Pusa Red Plum	Vitamin C & Lycopene

and male sterility (MS) mechanisms in the production of hybrid seeds for various vegetable crops, each with distinct advantages and drawbacks. The utilization of the SI system, primarily found in Brassica species like broccoli, cauliflower, and cabbage, has demonstrated its commercial viability, albeit with certain limitations. In contrast, the male sterility system has found its application across a wider spectrum of vegetables. This innovative approach has not only contributed to enhancing crop yields and quality but has also provided an avenue to target other specific traits to meet the demands of an ever-evolving agricultural landscape. Table 3, describes some of the example in which these mechanisms have been exploited for hybrid development in vegetable crops.

Biotechnological approaches for vegetable improvement

Numerous varieties have been developed through conventional breeding in vegetable crops in India, as discussed in the previous sections. The breeding through conventional breeding is random and it takes several generations, long time and financial resources to develop the desired combination of traits. The success of conventional breeding depends on the available variation and is associated with two major problems, i.e., linkage drag and the distant hybridization barrier. There are different biotechnological tools for vegetable improvement such as genome editing using marker-assisted selection (MAS), CRISPR/Cas9, RNA interference (RNAi), genetic engineering etc.

Marker-assisted Selection

The integration of molecular markers into traditional breeding methods has ushered in a transformative approach known as marker-assisted selection (MAS). Through the utilization of molecular markers, significant breakthroughs have been achieved in identifying key QTLs/genes associated with critical horticultural, quality, and processing traits. Over the course of time, this treasure trove of discovered QTLs/gene has been utilized by researchers and breeders for development of new cultivars and improved lines. By leveraging the intricate markers information, a new era of precision and efficiency has emerged in vegetable breeding, ultimately leading to more resilient, high-yielding, and desirable varieties (Pandey *et al.*, 2021). The term 'marker assisted selection' was first used by Bechmann and Soller (1986) but it gained popularity in reference to mapping and tagging genes with the help of molecular markers (Xu and Crouch, 2008). The first report of application of MAS in plant breeding was for soybean cyst nematode (*Heterodera glycines* Ichinohe) (Concibido *et al.*, 1996). Application of MAS in vegetable crops are still limited in India. Few studies related to MAS application in vegetable crops in India has been presented in Table 4. The use of marker assisted breeding to improve varieties of vegetable crops is necessary because it requires less time and efficient. With the help of marker assisted selection, plant breeder can identify the plants possessing gene of interest at seedling stage, it speeds up the whole process by reducing the load of the population carried to next generation and also reduce the burden of making unnecessary crosses in marker assisted backcross breeding (MABB), marker assisted recurrent selection (MARS) and pyramiding of genes. The MABB is most widely utilized for transfer of oligogenes into the background of a desirable recurrent background, it involves three basic steps; foreground selection, recombinant selection and background selection (Sagar *et al.* 2020)

Table 3: Harnessing genetic mechanisms to develop hybrids in select vegetable crops

Crop	Vegetable crop	Variety
Cabbage	KGMR-1(Pusa cabbage hybrid 1), KTCBH 51, KTCBH 81	Self-incompatibility
Cabbage	KCH-5, Hybrid 991-5, Hybrid 854-6	Cytoplasmic male sterility
Carrot	Pusa Nayanjyoti, Pusa Vasudha	Cytoplasmic male sterility
Cauliflower	Pusa Hybrid-2, Pusa Kartik Sankar	Self-incompatibility
Cauliflower	Hybrid 8401 ×31022	Cytoplasmic male sterility
Chilli	Arka Sweta, Arka Meghna, Arka Harita, Arka Khyati,Kashi Surkh, CH-1, CH-3	Cyto genic male Sterility and Genetic male sterility
Cucumber	Solan Khira Hybrid-1, Solan Khira Hybrid-2	Gynoecious based F_1 hybrids
Onion	Arka Kirthiman, Arka Lalima	Cytoplasmic male sterility

Table 4: Vegetable crops improved through marker assisted selection in India

Crop	Gene introgressed	References
Tomato	*Ty-2* and *Ty-3* for tomato leaf curl disease	Prasanna *et al.* 2015
Onion	Transfer male sterility to other onion lines or genotypes	Saini *et al.* 2015
Cauliflower	Downey mildew resistant gene *Ppa3* and black rot resistant gene *Xca1bo*	Saha *et al.* 2021
Bell pepper	Genetic male sterility gene *ms10* from hot pepper to heat tolerant bell pepper	Rani *et al.* 2021
Tomato	Gene pyramiding of *Ty-1, Ty-2, Ty-3* for tomato leaf curl resistance genes; *Ph-2* and *Ph-3* for late blight resistance genes; *Mi-1.2* for root not nematodes resistance	Kumar *et al.* 2019
Soybean	Kunitz trypsin inhibitor free soybean	Kumar *et al.* 2020
Tomato	Gene pyramiding of *ToLCV* gene for enhanced tomato leaf curl virus disease resistance	Kumar *et al.* 2014
Cauliflower	Introgression of *Or* gene for enhancing β-carotene content in cauliflower	Kalia *et al.* 2018
Tomato	*Ty-1/Ty-3, Ty-2, ty-5 and ty-6*	Prabhandakavi *et al.* 2021
Tomato	Stacking of *Ty*3, *Mi*1.2 and *Ph*3	Maurya *et al.* 2023
Tomato	Marker assisted selection for *Mi 1.2* gene and *Ph2* and *Ph3*.	Kaur *et al.* 2023

Genomes sequencing of vegetable crops

The era of plant genome sequencing started with the sequencing of model plant *Arabidopsis thaliana* genome in 2000 by using Sanger sequencing method (first generation sequencing). The second generation sequencing era started with the discovery of sequencing-by-synthesis technology in 2005 developed by 454 Life Sciences. The third generation sequencing also known as next generation sequencing (NGS) became popular among the researchers because it reduced the cost of sequencing, time saving, and high accuracy. The first sequenced vegetable crop plant was soybean (*Glycine max* L. Merr.) (Shultz *et al.*, 2006), belonging to Fabaceae family, having small genome size of 1.1-1.15 Gb. After soybean, cucumber (*Cucumis sativus*) genome has been sequenced by Huang *et al.* (2009) with the genome size 367 Mb. The size of genomes of various vegetable crops varies greatly. The Faba bean (*Vicia faba*) is possessing the largest genome of 13 Gb (Carrillo-Perdomo et al., 2020) among the sequenced vegetable crop while silver seed squash (*Cucurbita argyrosperma*) having 238 Mb (Barrera-Redondo J *et al.*, 2019).

As per available data, 45 vegetable crops have been sequenced till date (Chen *et al.*, 2019) and these sequenced genomes help researchers to better understand the domestication process. To procure the data of sequenced genomes, several databases have been developed, among them few are freely accessible while other requires user registration and a login to access the data (Chen *et al.*, 2019). The Sol Genomics Network (SGN), a database of Solanaceous crops; the Cucurbit Genomics Database (CuGenDB), provide genome sequences of Cucurbitaceous crop and the Brassica Database (BARD) provide information of Brassica species. Plant genome sequencing accelerates the genomic-assisted breeding by providing a reference genome for sequence analysis. Further, this can facilities marker assisted breeding, genomic selection and epigenetic approach to improve the various traits of vegetable crops. As India is the origin of several crops, the sequencing of several indigenous, underutilized vegetables are still awaited.

Genome editing in vegetable crops

The optimal production and productivity of vegetable crops hinge upon their ability to withstand a variety of challenges, encompassing both biotic and abiotic stresses. This underlines the critical importance of developing vegetable varieties that are either resilient or tolerant to these adversities. Beyond mere yield, aspects such as flavour, nutritional value, and post-harvest shelf life also stand as crucial attributes warranting improvement within vegetable crops. In the era of genomic advancements, the revolutionary CRISPR/Cas9 tool emerges as a pivotal instrument, enabling precision modification of genetic material at specifically designated loci. Stemming from the adaptive immune system of bacteria, this mechanism induces double-stranded breaks via endonucleases guided by single-guide RNAs. Its resounding success traverses various domains including field crops, horticultural crops, and model plants. An illustrative instance is the

development of a drought-tolerant soybean variant featuring elevated oil content in 2017 through CRISPR/Cas9 technology (Waltz, 2018), garnering FDA approval for market distribution in the United States. It is noteworthy that CRISPR-edited crops traverse distinct regulatory mechanism compared to transgenic GM crops. Recently, government of India has notified detailed guidelines for the generation and testing of SDN1 and SDN2 opening the avenues of opportunity for cultivation of genome edited products.

Table 5: List of sequenced genomes of major vegetables crops

Common name	Species	Family	References	Estimated genome size
Sugar beet	*Beta vulgaris*	Amaranthaceae	Arumuganathan and Earle (1991)	758 Mb
Soybean	*Glycine max*	Fabaceae	Shultz *et al.* (2006)	1.1–1.15 Gb
Cucumber	*Cucumis sativus*	Cucurbitaceae	Huang *et al.* (2009)	367Mb
Musk melon	*Cucumis melo*	Cucurbitaceae	Gonzalez *et al.*, (2010)	450 Mb
Potato	*Solanum tuberosum*	Solanaceae	The potato genome sequencing consortium (2011)	844 Mb
Chinese cabbage	*Brassica rapa*	Brassicaceae	Wang *et al.* (2011)	485 Mb
Tomato	*Solanum lycopersicum*	Solanaceae	The tomato genome consortium (2012)	900 Mb
Water melon	*Citrullus lanatus*	Cucurbitaceae	Guo *et al.* (2013)	425 Mb
Cabbage	*Brassica oleracea*	Brassicaceae	Liu *et al.* (2014)	630 Mb
Common bean	*Phaseolus vulgaris*	Fabaceae	Schmutz *et al.* (2014)	587 Mb
Eggplant	*Solanum melongena*	Solanaceae	Hirakawa *et al.* (2014)	1126 Mb
Moringa	*Moringa oleifera*	Moringaceae	Tian *et al.* (2015)	315 Mb
Pumpkin	*Cucurbita moschata*	Cucurbitaceae	Zhang *et al.* (2015)	271.4 Mb
Radish	*Raphanus sativus*	Brassicaceae	Mitsui *et al.* (2015)	383Mb
Adzuki bean	*Vigna angularis*	Fabaceae	Kang *et al.* (2015)	538 Mb
Carrot	*Daucus carota*	Apiaceae	Iorizzo *et al.* (2016)	473 Mb
Brown mustard	*Brassica juncea*	Brassicaceae	Yang *et al.* (2016)	316.1 Mb
Berry-like pepper	*Capsicum baccatum*	Solanaceae	Kim *et al.* (2017)	3.9 GB
Bonnet pepper	*Capsicum chinense*	Solanaceae	Kim *et al.* (2017)	3.2 GB
Bitter melon	*Momordica charantia*	Cucurbitaceae	Urasaki *et al.* (2017)	339 Mb
Bottle gourd	*Lagenaria siceraria*	Cucurbitaceae	Wu S *et al.* (2017)	313.4 Mb
Lettuce	*Lactuca sativa*	Asteraceae	Kozik *et al.* (2017)	2.5 GB
Garden asparagus	*Asparagus officinalis*	Asparagaceae	Harkess *et al.* (2017)	~1.3 Gb
Spinach	*Spinacia oleracea*	Amaranthaceae	Xu *et al.* (2017)	989 Mb
White Guinea yam	*Dioscorea rotundata*	Dioscoreaceae	Tamiru *et al.* (2017)	594 Mb
Winter squash	*Cucurbita maxima*	Cucurbitaceae	Sun H *et al.* (2017)	372.0 Mb
Spanish pepper	*Capsicum annuum*	Solanaceae	Hulse-Kemp *et al.* (2018)	~3.5 GB
Summer squash	*Cucurbita pepo*	Cucurbitaceae	Montero-Pau J *et al.* (2018)	263 Mb
Silver-seed gourd	*Cucurbita argyrosperma*	Cucurbitaceae	Barrera-Redondo J *et al.* (2019)	238 Mb
Fava bean	*Vicia faba*	Fabaceae	Carrillo-Perdomo *et al.* (2020)	~ 13 GB
Snake gourd	*Trichosanthes anguina*	Cucurbitaceae	Ma *et al.* (2020)	919.8 Mb
Chayote	*Sechium edule*	Cucurbitaceae	Fu *et al.* (2021)	606.42 Mb
Ash gourd	*Benincasa hispida*	Cucurbitaceae	Xie *et al.* (2019)	913 Mb

The genomes of several important vegetables have been edited by using CRISPR/Cas9 technology in various countries. CRISPR/Cas9 technology was first time utilized in tomato in 2014. The gene *ARONAUTE7 (SlAGO7)* was targeted which is involved in leaf development (Brooks *et al*., 2014). The scope broadened to encompass traits like root growth, fruit maturation, anthocyanin synthesis, parthenocarpy, and fruit pigmentation. These achievements were attained through precision targeting of genes such as SHORT-ROOT (*SHR*) (Ron et al., 2014), ripening inhibitor (*RIN*) (Ali *et al*., 2015), Anthocyanin 1 (*ANT1*) (Cermak *et al*., 2015), SIAGAMOUS-LIKE 6 (Klap *et al*., 2017), and PHYTOENE SYNTHASE (*PSY*1) (Hayut *et al*., 2017) in the tomato genome. Meanwhile, CRISPR/Cas9 efforts also bolstered starch quality in potatoes by modifying the granule-bound starch synthase (GBSS) gene (Andersson *et al*., 2017). In the dynamic landscape of agricultural innovation, India has emerged as a prominent player in the application of CRISPR/Cas9 technology, where substantial research endeavours are currently underway to harness the potential of genome editing across diverse vegetable crops such as tomato, potato, onion, cucumber, and chili pepper, much of this work remains in progress. In line with this trajectory, Indian Council of Agricultural Research, New Delhi is proactively establishing centre of excellence for genome editing of various crops including vegetable crops, where major challenges hampering the production and processing of will be addressed.

The successful example of genome editing is available in tomato, chilli and onion. In tomato, the cv. Arka Vikas was improved for resistance against RNA viruses through genome editing of eukaryotic translation initiation factor (*eIF*) gene family, including *eIF4E* and its paralogue *eIF(iso)4E* (Santosh, 2020). The *Capsicum annuum* (cv.) Arka Lohit was successfully improved against the anthracnose disease caused by *Colletotrichum truncatum*. The target was achieved by altering *CaERF*28 through CRISPR/Cas9-mediated genome editing. The developed mutants demonstrated enhanced resistance to anthracnose compared to wild type as demonstrated by reduced spore count and fungal growth as well as induced expression of defense-related genes (Mishra *et al*., 2021). In onion, where phytoene desaturase (*AcPDS*) gene was edited in the cultivar Bhima Super, and albino mutants were identified in the subsequent generations. This is the first time a CRISPR/Cas9-mediated genome editing protocol has been successfully established in onion, with the *AcPDS* gene serving as an example (Mainkar *et al*. 2023). These landmark accomplishments not only showcases the tangible progress made in genome editing but also underscores the potential for similar advancements across a spectrum of vegetable crops, with far-reaching implications for agriculture and sustainability.

Genetic engineering

In recent years, remarkable progress has been made in improving the introgression of quality traits, cultivating resistant cultivars, and synthesising industrial proteins in vegetable crops. New research highlights the viability of incorporating novel agronomic traits into these crops. This integration has been accomplished through the skilled application of genetic engineering techniques, allowing for the cultivation of vegetables with desired phenotypic characteristics derived from wild species gene reservoirs. Simultaneously, genetic engineering has demonstrated its effectiveness in reducing the expression of genes responsible for the production of naturally occurring toxic compounds that endanger human health when consumed.

Genetic manipulation, for example, has facilitated the incorporation of genes responsible for bolstering defence responses against plant-pathogen, as well as the activation of mechanisms to combat a variety of stressors such as heat, cold, drought, salinity, and low oxygen levels. These trailblazing achievements demonstrate the successful application of genetic engineering in reshaping the genetic landscape of vegetables, resulting in crops that are not only more resilient and adaptable, but also safer and more nutritious for human consumption.

Several successful genetic engineering applications has been recorded in the horticultural crops including vegetables. The first ever commercialized transgenic has been recorded in vegetable crop tomato for enhanced shelf-life trait 'Flavr-Savr' in USA in 1994. The major traits introduced through transgenics include insect-pest resistant (*Bt*. Toxin gene), virus resistance, male sterility, drought tolerance, etc. In India several examples are available where genetic engineering has been used for the improvement of vegetable crops. In potato the high nutritive value was achieved through expressing *AmA1* seed albumin gene derived from *Amaranthus hypochondriacus* in the potato tubers. The derived tubers were rich in the sulphur-containing amino acids such as methionine and cystine and essential amino acids lysine and tyrosine (Chakraborty

et al., 2000). Transgenic potato with enhanced vitamin E (α-tocopherol) was developed by over expressing *homogentisate-phytyltransferase* (*At-HPT*) and γ-tocopherol-*methyltransferase* (*At-γ-TMT*) genes isolated from *Arabidopsis* in potato, which was shown to combat with degenerative health problems, abating cancer risk and coronary heart diseases in humans (Upadhyaya *et al*., 2020). In carrots the transgenic plants overexpressing glycine betaine and betaine aldehyde dehydrogenase (BADH) in their plastids exhibited high tolerance to salinity (Kumar *et al*., 2004). In tomato the cultivar H-86 was transformed with *BcZAT*12 and the resulting plants were found to be tolerant to the heat stress through lowering the free radical formation, improved electrolyte leakae, relative water and chlorophyll content. Also, higher anti-oxidant activity related enzymes such as superoxide dismutase, catalase, ascorbate peroxidase and glutathione reductase were observed when exposed to HS (Shah *et al*., 2013). In tomato cv. Pusa Ruby, the boiling stable protein (*bspA*) gene from *Populus tremula* was over expressed to achieve moisture deficit tolerance. The boiling stable proteins plays role in desiccation tolerance by protecting the proteins in membrane and cytosols. The transgenic plants were having improved desiccation tolerance over the non-transgenic plants (Roy *et al*., 2006). The tomatoes are sensitive to chilling stress (0-12 °C), severely affecting growth and reproduction. In tomato, transgenic plants overexpressing *AtDREB1A* was found to show less sensitivity to the chilling stress. The cold stress induces ROS production, which is regulated by enhanced production of anti-oxidant enzymes (CAT), superoxide dismutase (SOD), and ascorbate, high relative water content, less electrolyte leakage and improved accumulation of proline and soluble sugars in transgenic plants (Karkute *et al*., 2019).

Generally vegetable crops lack resistance against the insect-pest, which is controlled through the application of chemical. Attempts have been made to utilize the *Bt* (*Cry*) gene isolated from a soil bacteria Bacillus thuringiensis for controlling the lepidopteran insects in number of crops. The *Bt*-cotton cultivation in India has been remarkably successful. Insect resistance was firstly reported in tomato using *Bt*. gene in 1987. Transgenic *Bt* tomato plants exhibited resistance against *Spodoptera litura* and *Heliothis virescens* (Fischhoff *et al*., 1987). Brinjal (*Solanum melongena*) cv. Pusa Purple Long was transformed with cry1Ab gene coding for an insecticidal crystal protein (ICP). The transgenic brinjal plants displayed significant differences in the insect mortality in fruit bioassays. Very high level of ICP in these plants are responsible for complete protection against the *Leucinodes orbonalis* (Kumar *et al*., 1998). The Cauliflower var. Pusa Snowball K-1 was transformed with a synthetic cryIA(b) showed effective resistance against infestation by diamondback moth (*Plutella xylostella*) larvae during insect bioassays (Chakrabarty *et al*. 2002). Paul *et al*. (2005) developed transgenic cabbage (*Brassica oleracea* var. capitata) line DTC 507 with a synthetic fusion gene of *B. thuringiensis* encoding a translational fusion product of *cry1B* and *cry1Ab* δ-endotoxins to confer resistant against diamondback moth (Plutella xylostella). In okra *(Abelmoschus esculentus) Cry1Ac* has been successfully transformed for incorporating resistance against the fruit and shoot borer (*Earias vittella*) of okra. The transgenic plants showed 100% larval mortality (Narendran *et al*., 2013).

Crops can now be genetically engineered to resist disease. Numerous genes, including chitinase, glucanase, osmotin, defensin, etc. are being inserted into different horticultural crops all over the world to confer resistance against bacterial and fungal diseases. According to Ceasar and Ignacimuthu (2012), a number of glycolytic enzymes, such as chitinase, glucanase, PR proteins, etc., are encoded by genes inside plant cells and have the ability to degrade cell walls. This property makes them attractive for use in the development of transgenic plants that incorporate resistance to fungal pathogens. The use of systemic acquired resistance (SAR)-related genes is one of the various approaches used in genetic engineering for disease resistance that is of utmost significance. According to Ryals *et al*. (1996), SAR is long-lasting and frequently accompanied by local and systemic accumulation of salicylic acid (SA) and induced expression of numerous genes, including pathogenesis-related (PR) genes. Girhepuje and Shinde (2011) created transgenic tomato plants overexpressing *chi*194, a wheat chitinase gene, under maize ubiquitin 1 promoter. Transgenic tomato lines with higher chitinase activity were highly resistant to Fusarium wilt caused by *Fusarium oxysporum f. sp. Lycopersici*.

Polyamines like putrescine, spermidine, and spermine help with biotic and abiotic stress tolerance. Hazarika and Rajam, (2011) transformed a human S-adenosyl methionine decarboxylase (*samdc*) gene to tomato cv. Pusa Ruby to biosynthesize spermidine and spermine. Transgenic tomato plants produced

more polyamines and were more resistant to *Fusarium oxysporum* and *Alternaria solani*, which cause wilt and early blight respectively. Transgenic lines also showed better tolerance to high temperature, drought, salinity, and chilling stress.

A bacterial mannitol-1-phosphate dehydrogenase (*mtl*D) gene driven by the constitutive cauliflower mosaic virus (CaMV) 35S promoter was transferred into tomato plants to improve abiotic stress tolerance (Khare *et al.* 2010). Transgenic lines tolerate abiotic stresses better than non-transformed plants in drought and salinity tests. Gangadhar *et al.* (2016) used *Agrobacterium tumefaciens* to transform a potato-derived gene *StnsLTP*1 into potato (*Solanum tuberosum* cv. Desiree) to make it tolerant to abiotic stresses. Transgenic potato lines reduced membrane lipid peroxidation activity and H_2O_2 content under stress, enhancing cell membrane integrity. Transgenic potato plants also had increased antioxidant enzyme activity, ascorbate accumulation, and stress-related gene upregulation, including *StAPX, StCAT*, *StSOD*, etc.

Subramanyam *et al.* (2011) could successfully improve the tolerance of chilli pepper (*Capsicum annum* L. cv. Aiswarya 2103) plants by the ectopic expression of tobacco osmotin gene via *Agrobacterium tumefaciens*-mediated gene transfer technique. T_2 generation of transgenic pepper plants revealed enhanced levels of chlorophyll, proline, glycine betaine, ascorbate peroxidase (APX), superoxide dismutase (SOD), glutathione reductase (GR) and relative water content (RWC) in biochemical analysis and survived in salinity level up to 300 mM NaCl concentration. Kaur *et al.* (2010) inserted a fruit-specific expansion gene, *LeEXP*1, into tomato cv. Pusa Uphar. The force required to rupture the fruit pericarp was higher in *LeEXP*1-overexpressed plants than in non-transgenic plants, and fruits were redder at different ripening stages.

Tomato Cv. H-88 was transformed with genes *AtDREB1* and BcZAT12 to generate double transgenics tomato plants. The developed transgenics showed improved tolerance against drought stress. Double transgenic plants showed increased activity of antioxidant enzymes, like catalase (CAT), superoxide dismutase (SOD), glutathione reductase (GR), ascorbate peroxidase (APX), dehydroascorbate reductase (DHAR), mono dehydroascorbate reductase (MDHAR) and guaiacol peroxidase (POD), and accumulation of non-enzymatic antioxidants like ascorbic acid, glutathione as compared to non-transgenic and single transgenic (Krishna *et al.*, 2021).

Bio-fortification in vegetables

Vitamins and micronutrients are vital element for human growth and development and deficiency of these components can cause "hidden hunger." Conventional way to deal with the problem of hidden hunger are supplementation or food fortification, but these methods have shortcoming of significant recurring cost and less extent of reach to rural areas. Vegetables are the cheapest and most readily available source of energy and nutrition. Vegetables, except for a few starchy ones, are rich in micronutrients compared to staple foods such as cereals (Singh *et al.*, 2022). The vegetables are inherently rich in minerals, antioxidants, and vitamins. These crops offer a wide range of variability in terms of the number of choices of crops to be grown across the seasons. Leafy vegetables are found to be one of the richest sources of iron and calcium. Coloured vegetables offer a wide choice to consumers along with anthocyanins, betalains and β-carotene. Demand for the natural products has led to the emergence of the science of biofortification by various means *i.e.* metabolic engineering (transgenic), agronomical biofortification, and genetic biofortification. Biofortification is the process of adding nutritional value to the crop. Biofortification is an economical and sustainable mode to improve the intake of vitamin and *mineral*, as micronutrients are breed into the crops.

Broccoli, spinach, carrot, squash, sweet potato, and pumpkin are rich in provitamin A carotenoids. Low levels of β-carotene were found in commonly grown cauliflower. A new orange cauliflower variety with 8-20 ppm β-carotene was developed through pure line selection (Kalia *et al.*, 2018). The Pusa Rudhira carrot variety contains β-carotene at 7.60 mg/100 g, β-carotene at 4.92 mg/100 g, and lycopene at 6.70 mg/100 g root. The pure line selection method was used to breed the sweet potato variety Bhu Sona. This variety has higher β-carotene (14 mg/100 g) content than other potato cultivars (Yadava *et al.* 2017). The 10-14 mg/100 FW carotene Sree Kanaka sweet potato was also released for cultivation. Another sweet potato Sree Vardhini rich with carotene (1200 IU carotene/100g). Sree Bhadra sweet potatoes have 972 IU/100g carotene and pink skin and flesh. Sree Rathna sweet potatoes, with purple skin and orange flesh, are now ready for cultivation. This variety contains 3500 IU/100g of carotene.

Table 6: Bio-fortified vegetable crops in India

Crop	Varieties	Characters	Year
Sweet potato	Sree Kanaka	Dark orange flesh colour, high beta carotene (ß-carotene 9-10 mg/100 g FW) content as compared to 2.0-3.0 mg/100 g β- carotene in popular varieties.	2017
	Bhu Sona	High β-carotene (14.0 mg/100 g) content	2017
	Bhu Krishna	High anthocyanin (90.0 mg/100g) content in comparison to popular varieties which have negligible anthocyanin content	2017
Potato	Kufri Neelkanth	Rich in anthocyanin (1.0 ppm) in comparison to negligible content in popular varieties	2020
	Kufri Manik	Rich in anthocyanin (0.68 ppm) in comparison to negligible content in popular varieties	2020
Okra	Kashi Lalima	Rich in anthocyanin and phenolics.	2019
Greater Yam	Sree Neelima	Rich in anthocyanin (50.0 mg/100g), crude protein (15.4 %) and zinc (49.8 ppm) in comparison to negligible anthocyanin, 2.7 % crude protein and 22-32 ppm zinc in popular varieties	2020
	Da 340	Rich in anthocyanin (141.4 mg/100g), iron (136.2 ppm) and calcium (1890 ppm) in comparison to negligible anthocyanin, 70-120 ppm iron and 800-1200 ppm calcium in popular varieties	2020
Carrot	Pusa Rudhira	Has higher level of Carotenoid (7.14mg) and Phenol (45.15mg)/ 100g	2008
	Pusa Asita	Rich source of anthocyanin.	2008
	Kashi Krishna	A black carrot variety is rich source of anthocyanin (285 mg/100 g FW carrot), 737 phenolics, and antioxidants.	2019
	Pusa Gulabi	First Pink fleshed variety High in total caroteniods, anthocyanin and ascorbic acid content.	2013
Radish	Pusa Jamuni	first purple fleshed nutritionally rich variety high in anthocyanin & ascorbic acid content.	2012
	Kashi Lohit	Red colour root and rich source of 740 antioxidants specially anthocyanin 80–100% higher than white radish	2019
Cauliflower	Pusa Beta Kesari 1	Contains high β-carotene (8.0-10.0 ppm) in comparison to negligible β-carotene content in popular varieties	2015
Cabbage	Kinner Red	Anthocyanin rich cultivar	2016
Brinjal	Pusa Safed Baigan 1	It has high total phenol content (31.21 mg GAE/100G) with high antioxidant activity.	2018
Soybean	NRC – 127	Free from Kuntiz Trypsin Inhibitor (30-40 mg/g of seed meal in popular varieties)	2018
	NRC – 132	Free from Lipooxigenase -2	2021
	NRC – 147	High Oleic acid (42%) as compare to popular cultivars (25%).	2021
Cowpea	Pant Lobia-1	high iron and zinc fortified variety 82 ppm Fe and 40ppm Zn	2008
	Pant Lobia-2	high iron and zinc fortified variety 100 ppm Fe and 37ppm Zn	2010
Poi/ Indian Spinach	Kashi Poi -3	excellent source of Carotenoids 635.9mg/100g FW with lower oxalate content (522.3 mg/100g FW)	2019
French bean	Kashi Baingani	Purple-coloured 750 French bean variety has high antioxidants and rich in anthocyanin	2020
Amaranth	Pusa Lal Chaulai	Red pigmented cultivar developed at IARI, yield 45-49 t/ha in 4 harvests	1991

Several anthocyanin rich varieties have been developed in vegetable crops. Anthocyanin rich Bhu Krishna sweet potatoes rich in anthocyanin (90 mg/100 g) has been released (Yadava *et al.* 2017). Kufri Neelkanth, the first purple-colored indigenous speciality potato variety, rich in antioxidants (anthocyanins > 100µg/100 g and carotenoids ~ 200µg/100 g). Anthocyanin rich black carrot variety Kashi Krishna (285 mg/100 g FW carrot) and Pusa Asita 520mg/100g has been released (Singh *et al.* 2019). Kashi Lohit, a red-root radish variety with 80-100% more anthocyanin than white radish, Pusa Jamuni and Pusa Gulabi are other radish varieties with anthocyanin and antioxidants (Singh *et al.* 2019). Kashi Lalima, a red/purple okra (*Abelmoschus esculentus* L.), has a high anthocyanin content (*Karmakar et al.*, 2022). French bean variety Kashi Baingani rich in antioxidants and anthocyanin recommended for cultivation.

Indian spinach (*Basella alba* L.) and amaranth (*Amaranthus tricolour* L.) have high betalain content in leaves, stems, and fruits (Sagar *et al.*, 2022). These two vegetables dominate national kitchen gardens. Many Amaranth varieties (Sagar *et al.*, 2021a) have been released, but few are available in Indian spinach (Sagar *et al.*, 2021b). Biofortified varieties of few vegetables crops has been developed in India are given in Table 5.

Pests and disease management

Cultivation of vegetable crops are suffered by several biotic stresses such as insect pests, pathogens and nematodes. It is highly essential to minimize the impact of pests and diseases in vegetable crops in order to obtain the economic yield by the resource poor farmers. In vegetables, insect pests and diseases cause huge loss as reflected in the table 6. If we could alleviate the losses due to plant diseases, we would be able to produce roughly 20% more food enough to feed predicted world population 9.1 billion by 2050 (Maxmen, 2013). In recent past, several insect pests and diseases are emerging into a major threat for the vegetable production system which were not previously reported in India. For example, tomato pin worm (*Tuta absoluta*) is one of the global destructive invasive pests of tomato with a potential to cause 100% yield loss was first time documented during 2014 in Maharashtra. From then, it has spread to different parts of the country including hilly regions (Sharma and Gavkare, 2017). Likewise, poleroviruses and criniviruses causing yellowing disease in cucurbits becomes a major constraint for its cultivation since 2018 (Nagendran *et al.*, 2023; Krishnan *et al.*, 2022; Kumari *et al.*, 2021).

For the management of these biotic stresses, farmers are relying on the chemical pesticides and fungicides. Ill effects of chemical insecticides are well known and therefore, researches are focusing on the management options with reduced application of chemicals in the vegetable crops. Crop protection measures include integrating different components of cultural, host plant resistance, chemical and biological measures. Several studies successfully demonstrated the integrated pest management (IPM) and Integrated disease management (IDM) modules for the management of pest and diseases of vegetable crops, respectively (Table 7). Integrated management of pests and diseases is a systematic approach for the control that syndicates biological, cultural, and other alternatives to chemicals with the sensible use of pesticides. The main aim of IPM is to maintain pest and disease levels below economic threshold levels through minimizing the use of chemical pesticides which pose harmful effects on human health and environment. IPM is a constantly evolving and dynamic system in which all the suitable control strategies are combined into a holistic management module along with the forecasting information for the use of farmer (Kumar *et al.*, 2022).

Activities of cultural practices includes deep summer ploughing, use of resistant cultivars, adjustment in the time of planting or sowing, intercropping with barrier crops, use of trap crops, mulching with black silver polythene sheet, etc. Similarly, the mechanical activities such as hand picking of larvae, installation of suction traps, light traps, yellow sticky and pheromone traps, trenching the field, proper disposal of infected plant parts, etc. In the management of insect pests, biocontrol agents such as predators, parasitoids, bacterial bioagents, fungal bioagents (including entomopathogenic fungus), viral bioagents and nematode bioagents (entomopathogenic nematodes) (Kumar *et al.*, 2022) were explored (Table 8).

Pathogens of vegetable crops including fungus, bacteria and viruses were demonstrated to be effectively managed by several biocontrol agents either through direct action (antibiosis) or indirect action (induced systemic resistance and growth promotion). Elanchezhiyan *et al.* (2018) and Manikandan *et al.* (2010) have efficiently demonstrated the management

of Fusarium wilt in tomato caused by the *Fusarium oxysporum* f. sp. *lycospersici* using the *Bacillus amyloliquefaciens* (FZB 24) and *Pseudomonas fluorescens* (PF1). Both the bioagents showed the growth promotional activity, increased activity of resistance mechanism in tomato crop ultimately resulted in the enhanced yield with reduced disease incidence. Severity of bud necrosis disease caused by the tospoviruses in tomato and watermelon has been found to be reduced upon treatment with the bioagents such as *Pseudomonas fluorescens* (Thiribhuvanamala *et al.*, 2013; Kandan *et al.*, 2005; Priyanka *et al.*, 2019). Culture filtrate of *Ganoderma lucidum* reduced the lesion numbers and inhibited the virus population build-up in tomato (Sangeetha *et al.*, 2020). With the help of *Trichoderm*a isolates (Nagendran *et al.*, 2016) has managed the wilt disease incidence in the chilli crop. Soil borne bacterial pathogen *Ralstonia solanacearum* causing wilt disease in brinjal crop has been suppressed by the *Bacillus* strains-based consortia upon applied with FYM in field conditions and enhanced yield (Sakthivel *et al.*, 2023). Similarly, several other works have demonstrated the management of diseases in vegetable crops through biological means.

Due to the instant result and easy availability of chemical pesticides, farmers prefer to use the chemicals for the pest and diseases management in

Table 7: Yield loss in vegetable crops due to different pests and diseases

Crop	Pest/disease	Yield loss (%)	References
Tomato	Fruit borer (*Helicoverpa armigera*)	24-65	
Chilli	Thrips (*Scirtothrips dorsalis*)	12-90	
Chilli	Mites (*Polyphagotarsonemus latus*)	34	
Brinjal	Fruit and shoot borer (*Leucinodes orbonalis*)	11-93	
Okra	Fruit borer (*H. armigera*)	22	
Okra	Leafhopper (*Amrasca biguttula biguttula*)	54-66	
Okra	Whitefly (*Bemisia tabaci*)	54	Rai *et al.* (2014)
Okra	Shoot and fruit borer (*Earias vittella*)	23-54	
Cabbage	Diamond back moth (*Plutella xylostella*)	17-99	
Cabbage	Caterpillar (*Pieris brassicae*)	69	
Cabbage	Leaf webber (*Crocidolomia binotalis*)	28-51	
Cabbage	Cabbage borer (*Hellula undalis*)	30-58	
Bitter gourd	Fruit fly (*Bactrocera cucurbitae*)	60-80	
Cucumber	Fruit fly (*Bactrocera cucurbitae*)	20-39	
Tomato	Root knot nematode (*Meloidogyne incognita*)	27.21	
Brinjal	Root knot nematode (*Meloidogyne incognita*)	16.67	
Chilli	Root knot nematode (*M. incognita*)	12.85	Gowda *et al.* (2019)
Okra	Root knot nematode (*M. incognita*)	14.10	
Cucurbits	Root knot nematode (*M. incognita*)	18.20	
Carrot	Root knot nematode (*M. incognita*)	10	
Tomato	Early blight (*Alternaria solani*)	36-47.9	Saha and Das, (2012)
Tomato	Septoria leaf spot (*Septoria lycopersici)*	50	Ferrandino and Elmer (1992)
Tomato	Fusarial wilt (*Fusarium oxysporum* f.sp. *lycopersici*)	60-70	Ravindra *et al.* (2015)
Tomato	Late blight (*Phytophthora infestans*)	12.84 - 79.47	Sandeep Kumar *et al.* (2022)
Brinjal	*Phomopsis vexans*	50	Rohini *et al.* (2023)
Chilli	Fusarium wilt	30-40	Wani and Najar (2012)
Cucurbits	Powdery mildew	50-70	Sitterly (1972)
Cowpea	Cercospora leaf spot	36 – 42	Schneider *et al.* (1976)
Tomato	Bacterial wilt	10.8 – 92.62	Ramkishun, (1987; Mishra *et al.* (1995)
Brinjal	Bacerial wilt	11.67 - 96.67	Bainsla *et al.* (2016)

Table 7 continued

Crop	Pest/disease	Yield loss (%)	References
Tomato	Leaf curl virus (Begomovirus)	>70	
Chilli	Leaf curl virus (Begomovirus)	>80	
Okra	yellow vein mosaic (Begomovirus)	>50-9	
Okra	Enation leaf curl (Begomovirus)	30-100	
Tomato	Bud necrosis (Groundnut bud necrosis virus)	80-100	
Watermelon	Bud necrosis (Watermelon bud necrosis virus)	60-100	Nagendran *et al.* (2017a)
Cucurbits	Green mottle mosaic (Cucumber green mottle mosaic virus)	10-15	
Watermelon	Green mottle mosaic (Tobamovirus)	11.4-47.6	
Cucurbits	Yellow mosaic virus (Potyvirus)	upto 95	
Cowpea	Mosaic (Cucumovirus)	14	
Tomato	Mosaic (Cucumovirus)	25	
Chayote	Mosaic (Tomato leaf curl New Delhi virus)	>60	Nagendran *et al.* (2017b)

Reference: Nagendran *et al.*, (2017b)

Table 8: Management modules developed against the pests and diseases of vegetables in India

Crop	Method	Target pests/ Diseases	References
Bitter gourd	Integrated	Fruit flies, cucumber moth, whiteflies and downy mildew	Halder *et al.* (2018)
Bottle gourd	Integrated	Fruit flies, plume moth, mirid bug, whiteflies and downy mildew	Halder et al. (2020)
Brinjal	Integrated	Shoot and fruit borer, whiteflies, hoppers, Phomopsis blight, Sclerotinia white rot and little leaf	Halder *et al.* (2022)
Bitter gourd	Integrated	downy mildew and mosaic disease	Nagendran *et al.* 2020a
Chilli	Integrated	Leaf curl disease	Nagendran *et al.* (2020b)
Tomato	Integrated	Fruit borer, leaf miner, leaf curl virus	Gajanana *et al.* (2006)
Watermelon	Integrated	Bud necrosis disease	Priyanka *et al.* (2019)
Cabbage	Integrated	Aphid and Diamond back moth	Tulsi *et al.* 2017
Okra	Integrated	Aphids, whiteflies, leafhoppers, leaf miners, nematodes, fruit borer, yellow vein mosaic virus and powdery mildew	Mohankumar *et al.* (2016)
Cucumber	Integrated	Nematode, mite, damping off, fusarial wilt	Sabir *et al.* (2011)
Chilli	Integrated	*Spodoptera litura* and die back	Reddy *et al.* (2011)

Table 9: List of bioagents used in the management of insect pest

Nature of bioagents	Bioagent	Target pests
Predators	Lady bird beetle (*Rodolia cardinalis* and *Coccinella* sp.)	Aphids, mealybugs and spider mites
Predators	Syrphid fly larvae	Aphids and mealybugs
Predators	Green lacewing larvae (*Chrysoperla carnea*)	Aphids, spider mites, thrips, leafhopper nymphs, and small caterpillar larvae
Predators	Damsel bug	Aphids, leafhoppers, mites and caterpillars
Predators (Bugs)	*Orius maxidentex* and *O. tantillus*	Thrips
Predators (mites)	*Amblyseius cucumeris, A. swirski* and *Stratiolaelaps scimitus*	Thrips
Parasitoids	*Trichogramma* wasp (Egg parasitoids)	Cutworms, corn borers, corn earworms, armyworms, codling moths, and cabbage moths

Table 9 continued

Nature of bioagents	Bioagent	Target pests
Parasitoids	*T. brasilensis*	Fruit borer
Parasitoids	*Cotesia plutellae, C. glomeratus*	Diamond back moth
Parasitoids	*C. plutellae*	*H. armigera*
Parasitoids	*Campoletus chloridae*	*H. armigera*
Parasitoids	*Telenomus remus*	*Spodoptera litura*
Parasitoids	*Phryxe vulgaris*	Caterpillars in cabbage and cauliflower
Parasitoids	*Ceranisus* sp. and *Thripobius* sp	Thrips
Entomopathogenic nematodes (EPN)	*Steinernema feltiae*	Thrips
Entomopathogenic fungi (EPF)	*Metarhizium anisopliae* and	Thrips, whitefly, Earias sp. brinjal fruit and shoot borer
Entomopathogenic fungi (EPF)	*Beauveria bassiana*	Thrips, whitefly, *Earias* sp., brinjal fruit and shoot borer
Entomopathogenic fungi (EPF)	*Nomuraea relyie*	*Earias* sp., brinjal fruit and shoot borer
Bacterial bioagent	*B. thuringienesis*	*L. orbonalis*, *Earias* sp., *Helicoverpa*, tomato fruit borer, diamond back moth
Viral bioagent	HNPV	Tomato fruit borer
Viral bioagent	SNPV	Tobacco caterpillar

vegetable crops. Nearly, 13-14% of the total pesticides are consumed in the vegetable crops against the 2.6% of cropped area of vegetables in India (Kumar *et al*., 2022). Since, indiscriminate use of chemical is not desirable in vegetable crops, IPM strategy will help to attain the goal of safe vegetable cultivation and consumption.

Conclusion

Vegetable crop improvement through plant breeding is critical for sustainable production of vegetable crops that contribute to healthful diets and enhanced quality of life for people around the world. Integrated management of pests and disease is a strategy, based on a systems approach that looks at the whole ecosystem and therefore, implementing management programme, growers should select ways to reduce overall pest and pesticide load and ensure that the management options are compatible with their other crop management strategies. Policymakers and investors have to turn their attention to enhanced funding for the vegetable sector, allowing farmers to compete with their products on a world market. Only then will the silent vegetable revolution currently underway benefiting poor farmers, consumers and industries.

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Research Article

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Effect of container size on yield and root morphology of different fruit crops

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Abstract

The experiment was conducted to standardize container gardening techniques for fruit crops to meet the nutritional requirement of city dwellers at ICAR-CISH, Lucknow, during 2017-20. The maximum average plant biomass (1072 g/plant) was noted in guava (*Psidium guajava.*) and minimum (423g) in pomegranate (*Punica granatum.*), maximum shoot biomass (1012.11g) was recorded in plant grown in 45 cm × 45 cm and minimum (402.78g/plant) in 30 cm × 30 cm container. Destructive method was used to extract the root mass for analysis. There was maximum root biomass (506.11g) in guava and minimum (239.86g) in pomegranate, however root biomass was recorded significantly maximum (509.78g) in 45 cm ×45 cm. Root to shoot ratio was recorded maximum (0.63) in Citrus lime (*Citrus aurantifolia swingle*). When the plant size is similar, high root to shoot biomass is preferred. The root shoot ratio had significant correlation with stem girth and negatively correlated with fruit weight, fruit yield and root hairs diameter. Collar diameter has significantly positive correlation with plant height, fruit weight and yield. The container size as well as growing media (substrate) influenced plant growth, root and shoot biomass, fruit yield and root morphology remarkably.

Key words: Container gardening, Lime, Pomegranate, Guava, Root morphology, Root:shoot ratio

Container farming is one of the micro model of farming where a family unit or household is producing fruits and vegetables in special containers for personal consumption to help improve the income, health and well –being. The container types and volume are most important characteristics because these factors have direct impact on plant quality and production cost. Different container size have direct impact on plant growth, fruiting behaviour and canopy forms. The growing media or substrate has direct impact on root morphology and topology. To examine impact of growing media/substrate on rooting behavior of different fruit crops an experiment was initiated to document rooting characters. Srivastava *et al.* (2019) reported that 45 cm × 45 cm and 45 cm × 60 cm of container top area and depth are most suitable to grow guava, lime and pomegranate. In western Australia black polythene containers of 150 mm high and 100 mm diameter (1500ml), with potting mixture sand: peat: perlite in the ratio of 3:2:2 for *S. album* production have been tried (Radomiljac, 1998). Root pruning in the base of container favors more fibrous root formation (Jinks, 1994). Increased in container size led increased in canopy growth (Keever and Cobb, 1987) in pear and peach, root coiling leads to canopy growth down. Therefore an experiment was conducted on container fruit growing to standardize production technology.

Materials and Methods

The experiment was conducted at ICAR-CISH, Lucknow, during 2017-20., including 03 kinds of fruits viz. guava, kagazi lime and pomegranate. Black color, UV stabilized plastic bag with 400 gauges thickness having 45 cm × 45 cm, 30 cm × 45 cm, and 30 cm × 30 cm container top diameter and depth, were utilized. Growing media comprised garden Soil, sand, FYM, vermicompost, neem cake, bone meal in definit proportion on the volume basis. All the four media components were properly mixed and sterilized through solarization process finally 400-500 g neem cake, 250 g bone meal also added. The media was filled in containers leaving 10 cm top for irrigation cup. For planting, wellfeathered grafted, healthy plants were selected from nursery. Before final planting in pot the earth ball of plants were dipped in carbendazim solution @2 g/liter-1 of water. Guava, pomegranate and Kagazi lime plants were planted in varying size containers during February - March, 2017. The plants were trained on small bush form, promoting scaffold branches after 8-10 cm, regular pruning, heading back and thinning out practiced to maintain the plants,

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Most of the fruit plants were pruned in December-January in guava. May pruning carried out to avoid fruiting of rainy season in guava. All the cultural operations were practised uniformly. Plant height and collar diameter were recorded during September October by digital Vernier caliper (Table 1). For root study, the poly bag was removed and plant along with media ball was kept in 100 liter capacity tub and filled with water, the media become loose and washed away earthball. The root biomass was measured after separation of shoot mass. Root hairs diameter was recorded by screw gauge. The experiment was laid out in Factorial RBD, replicated thrice with 04 plants per replication. Data on vegetative growth, fruit yield, tree spread, height, canopy spread, collar diameter, were recorded during Octber-November. During summer 6-8

Three years old Kagazi Lime

Collar diameter of Kagazi Lime

Kagazi Lime in full bearing

Rooting morphology in pomegranate

Rooting morphology in guava

liters of water/pot was needed every 2nd day, while as in autumn and winter 7-15 days interval.

Table A: Dimension of containers and media/substrate weight

Container size (cm)	Media (soil-FYM-vermi-sand) in equal proportion (Kg)
45*45	55.00
30*45	28.00
30*30	14.00

Results and Discussion

Analysis of variance showed that container sizes had significant effect on shoot weight of plants. Overall maximum average shoot biomass (1072 g/plant) was noted in guava followed by citrus (519.33 g) and in pomegranate (423g). Irrespective of fruit kind maximum shoot biomass (1012.11g) in plant grown in 45 cm × 45 cm and lowest (402.78g/plant) in 30 cm × 30 cm container size. Destructive method was used to extract the root mass from containerized plant, significant variation in root biomass was recorded, maximum (506.11g) in guava, followed by citrus (356.44g) and minimum (239.86g) in pomegranate, however, root biomass was recorded significantly maximum (509.78g) in 45 cm × 45 cm container followed by 327.67 g in 30 cm ×45 cm, while as minimum root biomass (264.97 g) was recorded in 30 cm × 30 cm container size. The data revealed that irrespective of fruit kind, root to shoot biomass ratio was recorded maximum (0.67) in 30 cm × 30 cm container plants while as minimum (0.52) in 45 cm × 45 cm container size. As for as fruit type concerned maximum root to shoot biomass (0.63) recorded in Citrus and minimum (0.55) in guava (Table 1). These results are in conformity with those of Niang Tian *et al* (2017). Fruit plants grown in larger container had more extended root system compared to smaller container. Significant variations in plant height was recorded in varied container size. Maximum plant height (117 cm) was noted in 45 cm × 45 cm container, followed by 30 cm × 45 cm, whereas lowest plant height (83.99 cm) noted in 30 cm × 30 cm container, however maximum average plant height (112.66 cm) in guava which was statically on par to pomegranate and minimum height (86 cm) noted in citrus, irrespective of container size (Table 2). Significantly maximum root hairs diameter (0.44 mm) were noted in 30 cm × 45 cm which was closely followed by root hairs diameter (0.39 mm) in 45 cm × 45 cm container size and minimum

Table 1. Effect of container size on media temperature and shoot and root weight in pomegranate, citrus and guava

Crop	Shoot biomass (g)				Root biomass (g)				Root:shoot ratio			
	Pot size											
	45×45	30×45	30×30	Mean	45×45	30×45	30×30	Mean	45×45	30×45	30×30	Mean
Pomegranate	486.00	401.33	381.67	423.00	287.33	209.67	222.57	239.86	0.59	0.52	0.58	0.57
Citrus	587.33	520.00	450.67	519.33	413.33	354.67	301.33	356.44	0.53	0.68	0.67	0.63
Guava	1963.00	878.00	376.00	1072.33	828.67	418.67	271.00	506.11	0.42	0.50	0.74	0.55
Mean	1012.11	599.78	402.78		509.78	327.67	264.97		0.52	0.56	0.67	
For comparing means			S.Em±	LSD0.05			S.Em±	LSD0.05		S.Em±	LSD0.05	
Variety			202.31	49.08			77.06	40.43		0.02	0.09	
Pot size			179.52	49.08			73.42	40.43		0.04	0.09	
Interaction (variety × pot size)			169.48	85.01			62.76	70.02		0.03	0.16	

Table 2. Effect of container size on root-shoot ratio, collar diameter and plant height in pomegranate, citrus and guava

Crop	stem girth (mm)				Collar diameter (mm)				Plant height (cm)			
	Pot size											
	45×45	30×45	30×30	Mean	45×45	30×30	Mean	45×45	30×45	30×30	Mean
Pomegranate	12.62	19.14	21.02	17.60	32.90	29.47	27.67	30.01	131.00	110.67	85.33	109.00
Citrus	13.12	18.10	21.00	17.41	35.18	29.16	29.47	31.27	105.00	96.33	56.67	86.00
Guava	22.92	20.22	14.27	19.14	38.42	32.10	20.28	30.27	115.00	113.00	109.97	112.66
Mean	16.22	19.15	18.76		35.50	30.24	25.81		117.00	106.67	83.99	
For comparing the means				S.Em±	LSD0.05	S.Em±	LSD0.05			S.Em±	LSD0.05	
variety				0.55	3.48	0.38	3.87			8.34	7.99	
Pot Size				0.92	3.48	2.80	3.87			9.75	7.99	
Interaction (variety × pot size)				1.27	6.02	1.70	6.71			7.11	13.84	

root hairs diameter (0.32 mm) in 30 cm × 30 cm container size. Irrespective of container size maximum root hair thickness (0.43 mm) was in pomegranate which was on a par in citrus (0.37 mm) and minimum (0.36 mm) in guava (Table 3). Positive effect of increased container size on plant growth was reported in many woody plant species. The plant height, root collar diameter and biomass increased with increase in container size for different plant species (Apko *et al,* 2014; Dumroese *et al.,* 2011; Vaknin *et al.,* 2009 & and Dominguez-Lerena *et al.,* 2006). The fruit yield was maximum (3.14 kg/plant) was noted in 30 cm × 45 cm container which was on par to 45 cm × 45 cm and 30 cm × 30 cm container size (Table 3).

The container type and growth medium significantly affected the growth biomass and root morphological characters. When plant size is similar, high root to shoot biomass is preferred. Haase (2007) also indicated that quality container seedlings must have shoot : root ratio of 2:1 or less. Brissette *et al* (1991) reported higher root to shoot biomass ratio.

Significantly positive correlation was recorded between container size and plant biomass (R= 0.996), root mass (R= 0.989), collar diameter(R= 0.959), plant height, plant girth, root hairs diameter, root length and fruit yield while as it was negatively with root shoot ratio. Similarly growing media weight has significantly positive correlation with shoot weight (R= 0.992), root weight, collar diameter, plant height, root hairs diameter and fruit yield. Significantly negative correlation between stem girth and plant root hairs diameter, root length and fruits yield. While plant height has significantly positive correlation with root hairs diameter and fruit yield.

Plant biomass has positive correlation with root weight (R= 0.999), collar diameter, plant height, and root hairs diameter and fruit yield (R= 0.992) while as it was negatively correlated with roots hoot ratio. Total root mass was significantly positive correlation with collar diameter, plant height, root hairs diameters and fruit yield. The root shoot ratio had significant correlation with stem girth and negatively correlated with fruit weight, fruit yield and root hairs diameter (R= -0.992).

Collar diameter has significantly positive correlation with plant height, fruit weight and yield (Table 4). Stem girth was negatively correlated with root hairs diameter, fruit weight and fruit yield. Similar correlation between shoot biomass and plant height was also reported by Apko *et al.* (2014), he observed that total seedling biomass having highest correlation with

Table 3: Effect of container size on plant girth, root hair diameter and root length in pomegranate, citrus and guava

Crop	Root hair diameter (mm)				Root length (cm)				Fruit yield (kg/plant)			
	45×45	30×45	30×30	Mean	45×45	30×45	30×30	Mean	45×45	30×45	30×30	Mean
Pomegranate	0.39	0.49	0.40	0.43	49.67	36.10	27.17	37.64	2.62	5.59	2.74	3.65
Citrus	0.42	0.42	0.28	0.37	56.47	35.50	40.17	44.04	1.53	1.45	0.90	1.29
Guava	0.37	0.40	0.29	0.36	51.67	56.00	35.33	47.67	1.85	2.39	3.19	2.48
Mean	0.39	0.44	0.32		52.60	42.53	34.22		2.00	3.14	2.27	
For comparing means of		S.Em±	LSD0.05			S.Em±	LSD0.05			S.Em±	LSD0.05	
Variety		0.02	0.07			2.93	10.96			0.68	0.95	
Pot size		0.03	0.07			5.31	10.96			0.34	0.95	
Interaction (variety × pot size)		0.02	0.12			3.52	18.98			0.46	1.65	

Table 4: Pearson correlation analysis between different parameters

	PS	SB	RB	RSR	CD	PH	SG	RHD	RL	NF	FW	FY
PS	1											
MW	1.000**											
MP	0.439											
SW	0.974	1										
RW	0.845	0.945	1									
RSR	0.245	0.46	0.725	1								
CD	.998*	0.986	0.877	0.306	1							
PH	0.984	0.918	0.737	0.069	0.971	1						
PG	-0.981	-.999*	-0.932	-0.427	-0.991	-0.932	1					
RHD	-0.204	-0.423	-0.696	-.999*	-0.266	-0.028	0.389	1				
RL	1.000**	0.974	0.847	0.248	.998*	0.984	-0.982	-0.208	1			
NF	0.157	-0.073	-0.396	-0.919	0.094	0.329	0.036	0.935	0.153	1		
FW	-0.633	-0.793	-0.949	-0.906	-0.68	-0.486	0.77	0.887	-0.636	0.665	1	
FY	-0.15	-0.372	-0.656	-0.995	-0.212	0.028	0.338	.998*	-0.154	0.953	0.86	1

Note: * Correlation is significant at 0.05 level (2-tailed); ** Correlation is significant at 0.01 level (2-tailed); n = 3. PS = Pot size, SB = Shoot biomass, RB= Root biomas, RSR = Root-shoot ratio, CD = Collar diameter, PH = Plant height, SG = stem girth, RHD = Root hair diameter, RL = Root length, NF = Number of fruits, FW = Average individual fruit weight, FY = Fruit yield.

plant height. Seedling root collar diameter and height were positively and significantly correlated with plant biomass (Ning Tian *et al.*, 2017).

Conclusion

Thus, it is concluded that container size as well as growing media (substrate) influenced the plant growth, root and shoot biomass and root morphology. Root and shoot biomass both were high in larger containers. Guava plants have high root and shoot biomass. Root:shoot ratio was higher in smaller-sized container but collar diameter was noted in larger container size. Fruit bearing in containers started early as compared to field planted saplings. The medium and large containers gave higher yield. Kagazi Lime, guava and pomegranate fruit crops do well in container. Correlation matrix showed that container size has highly significant and positive correlation with fruit yield, shoot and root biomass, collar diameter, plant height.

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Response of guava *(Psidium guajava)* genotypes to air-layering under sub-humid southern Rajasthan

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Abstract

The evaluation of genotypes of guava (*Psidium guajava* L.) for air-layering under sub- humid southern plains of Rajasthan conditions was done during July 2015-16 at RCA, MPUAT, Udaipur, Rajasthan. The study involved a diverse set of genotypes, including L-49, Allahabad Safeda, Lalit, Red Fleshed, Pant Prabhat, Safed Jam, Arka Amulya, Arka Mridula, MPUAT S-1, MPUAT S-2, Shweta, Burfkhan, Sarbati, RCGH-1, and One-Kg. The results revealed significant variation among the genotypes in terms of their rooting characteristics. The genotype Lalit stood out, exhibiting the earliest root initiation, the highest percentage of rooted air-layers, the greatest survival percentage, and the highest vigour index, while number of secondary roots was highest in L- 49 and root: shoot ratio in Shweta. On the other end of the spectrum, the genotype One-Kg showed a poor response to rooting, making it less ideal for air-layering propagation under the tested conditions. Thus, genotype Lalit is particularly well-suited for propagation through air-layering under sub-humid southern Rajasthan**.**

Key words: Chinese layering performance, Sub-humid condition, Red and white fleshed genotypes, Air-layering

Guava *(Psidium guajava* L.) is propagated by seeds and vegetative means. Seed propagated plants start bearing fruits in 6- 8 years with variation in fruit yield and quality, whereas vegetatively propagated ones are precocious in bearing (3- 4 years after planting) and produce uniform fruits (Bose *et al.,* 1986). Vegetative propagation in guava is done by layering, grafting and budding in different parts of India (ICAR-DKMA, 2001). Under Rajasthan conditions true-to- type saplings are produced through air and mound layering as well as inarching methods of propagation. The success of air-layering depends on variety, types of plant material and time of operation (Sharma *et al*., 1975, Dod *et al*., 1998 and Tomar, 2016). Since multiplication of desired genotype by air-layering under sub-humid southern plains of Rajasthan, is not done to meet the demand, an experiment was done.

Materials and Methods

The experiment was conducted during June- December at Rajasthan College of Agriculture, Udaipur, Rajasthan. The 15 genotypes, Allahabad Safeda, Arka Amulya, Arka Mridula, Burfkhan, L-49, Lalit, MPUAT S-1, MPUAT S-2, One-Kg, Pant Prabhat, RCGH-1, Red Fleshed, Safed Jam, Sarbati and Shweta were used. During July, 100 air-layering were performed on each genotype mother plant of 5-6 years old, with a total of 1,500 layers. One-year-old healthy shoots were selected and on each selected shoot a ring of bark about 1.5- 2 cm width between two nodes was removed carefully by giving two circular cuts with a sharp knife at 50-60 cm above from the tip of the shoots. This portion covered with a handful of moistened sphagnum moss which had been previously soaked in water for 2-3 hours. It was then wrapped with a piece of polyethylene sheet (150-gauges) to hold the moss in position around the operated portion and tied firmly with plastic strips at both the ends.

The layers were separated from the plant when roots were visible through the polythene sheet. After detachment of layers from plant the wrapped polythene sheet was removed and layers were then treated with COC (copper oxychloride) @ 3 g per litre and planted in polythene bag (10 cm × 15 cm) after shoot pruning. Observations were recorded on days taken for root initiation, percentage of air layers rooted, root characters (number of secondary roots, length of longest root, diameter of longest root, fresh weight and dry weight of roots), root/ shoot ratio (root: shoot ratio = averaged root length (cm)/ averaged shoot length (cm),

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vigour index {vigour index= averaged root length (cm) + averaged shoot length (cm) × survival percentage}, survival percentage after shifting in poly bags at 15 days and one month after shifting were recorded after shifting in poly bag survival percentage again recorded according to which remain 15 days after shifting.

Results and Discussion

The genotypes had a significant effect on days taken to rooting, per cent of rooting, root characters (number, length, diameter, fresh weight and dry weight of secondary roots), root: shoot ratio, survival percentage of rooted air layers and vigour index. Minimum days taken for root initiation was observed in Lalit (39 days), followed by Red Fleshed (40.60 days) and maximum days (50) taken for root initiation was in One-Kg. The probable reason might be due to genetic make-up of varieties (vigorous, dwarf and intermediate) and interaction with environmental factors (Manna *et al.,* 2001).

Maximum percentage of air layers rooted was recorded in Lalit (74.76 %), followed by Allahabad Safeda (71.19 %) and One-Kg (50.19 %). Lalit responded higher to air-layering due to genetic and physiological behaviour, better rooting occurs in layers when shoot is physiologically mature and is in active sap flow stage that varies with genotypes (Table 1). The results were found to be analogous with those of Sarkar and Ghosh (2006). Maximum number of secondary roots was recorded in L-49 (11.20), length of longest root in Lalit (7.12 cm), diameter of longest root in Pant Prabhat (1.11 mm), fresh weight (1508 mg) and dry weight (395 mg) in Lalit and minimum number of secondary roots (4.20), fresh weight (914 mg), dry weight (196 mg) in One-Kg, length of longest root (3.50 cm) in Sarbati and diameter (0.54 mm) in RCGH-1 (Table 2, Figs 1 and 2).

The possible reason for better root characters is due to difference in genetic make-up of genotypes either alone or in combination with environmental factors, that might contributed to higher carbohydrate supply to root, resulting in better vegetative growth as evident from our study. Similar results were also reported by Ramteke *et al.* (1998) and Tripathi *et al.* (2018).

Root: shoot ratio was significantly different among varieties. The maximum root: shoot ratio was noticed in Shweta (1.24), followed by Lalit (1.19) and One-Kg (0.97). The greater root: shoot ratio might be due to that Shweta recorded higher root growth that indirectly improved the root: shoot ratio. The study was close to that of Vaghela and Sharma (2015).

Table 1. Root initiation (days), rooted layers (%), secondary roots numbers and root: shoot of air-layers in genotypes.

Treatment	Genotypes	Days taken for root initiation	Air-layers rooted (%)	Number of secondary roots	Root: shoot ratio
T_1	L-49	42.40	67.20	11.20	1.12
T_2	Allahabad Safeda	41.40	71.19	8.80	1.10
T_3	Lalit	39.00	74.76	10.60	1.19
T_4	Red Fleshed	40.60	64.05	7.60	1.07
T_5	Pant Prabhat	42.20	64.05	7.20	1.13
T_6	Safed Jam	49.80	52.50	7.00	1.00
T_7	Arka Amulya	47.20	60.69	5.80	1.03
T_8	Arka mridula	44.20	61.53	6.40	1.07
T_9	MPUAT S-1	42.20	63.00	7.00	1.06
T_{10}	MPUAT S-2	49.80	55.65	4.80	1.03
T_{11}	Shweta	40.80	64.26	10.20	1.24
T_{12}	Burfkhan	42.80	62.37	5.20	1.03
T_{13}	Sarbati	43.80	61.95	6.60	1.02
T_{14}	RCGH-1	42.00	69.93	6.40	1.01
T_{15}	One Kg	50.00	50.19	4.20	0.97
SEm±		0.590	0.815	0.097	0.014
CD at 5%		1.706	2.353	0.280	0.041

each genotype 100 layers were attempted during 5-15 July and root: shoot was recorded after (15 days) shifting layers in poly bags.

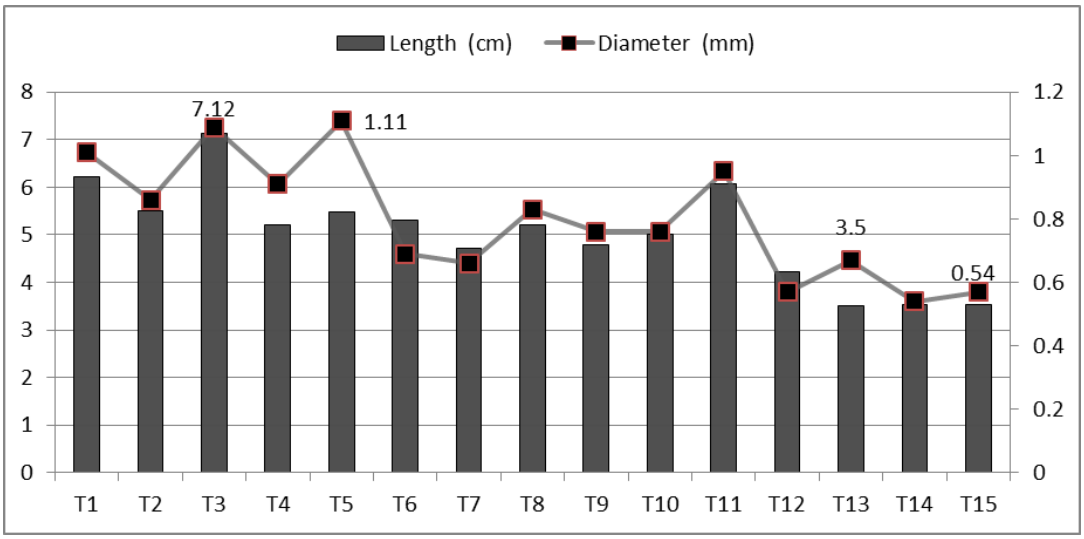

Fig. 1: Air-layer's secondary root length and diameter in different genotypes

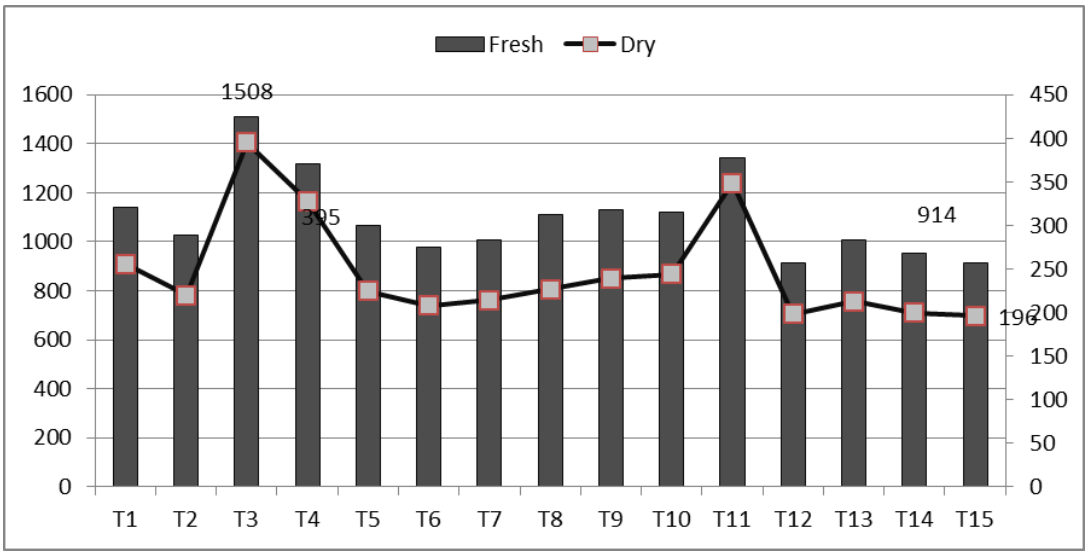

Fig. 2: Air-layer's root weight (mg) in different genotypes

The survival percentage of rooted air layers was maximum in Lalit (81.40 %), followed by Shweta (78.40 %) and One-Kg (47.80). Variety Lalit air layers had higher survivability which might be due to that healthy, stout and more number of secondary feeder roots production of layers not only support in uptake of water and nutrients from media but also more survival per cent (Table 2). Rehman *et al.* (2018) and Chand *et al.* (2018) also supported these findings. Genotypes Lalit recorded higher vigour index (838.42), followed closely by Red Fleshed (697.37). It might be due to difference in nature of varieties with respect to growth, development, survivability, root: shoot ratio and uptake of moisture play key role in enhancement of vigour index of poly bag shifted layers. This is in line with those of Ram and Majumdar (2000) and Tripathi *et al.* (2018).

Maximum success was observed in Lalit (91.00 %), followed by Shweta (88.00 %) and One-Kg (58.00 %). Direct reference is not available to support the present result, but probably due to Lalit recorded early root initiation, higher percentage of rooted air layers, higher root: shoot ratio and vigour index provides higher survival percentage of rooted air layers after shifting. Chand *et al.* (2018) and Rehman *et al.* (2013) supported our findings.

Table 2. Survival of rooted air layers (%), vigour index and success of layers in poly bag (%) of air layers.

Treatment	Genotypes	Survival of rooted air layers (%)	Vigour index	Success of layers in poly bag (one month after shifting) (%)
T_1	L-49	74.00	582.13	83.55
T_2	Allahabad Safeda	71.20	581.47	82.46
T_3	Lalit	81.40	838.42	91.00
T_4	Red Fleshed	77.20	697.37	86.00
T_5	Pant Prabhat	70.40	570.24	81.00
T_6	Safed Jam	50.80	318.35	61.00
T_7	Arka Amulya	53.80	394.53	64.00
T_8	Arka mridula	62.80	412.39	73.00
T_9	MPUAT S-1	66.20	494.29	76.00
T_{10}	MPUAT S-2	53.20	393.68	63.00
T_{11}	Shweta	78.40	663.79	88.00
T_{12}	Burfkhan	55.80	344.10	66.00
T_{13}	Sarbati	57.80	321.75	67.00
T_{14}	RCGH-1	58.40	336.77	68.00
T_{15}	One Kg	47.80	262.90	58.00
SEm±		0.881	9.347	0.933
CD at 5%		2.547	26.998	2.695

Survivability was recorded after (15 days) shifting of layers in poly bags

Conclusion

The early root initiation, percentage of rooted air layers, survival percentage and vigour index were maximum in Lalit, number of secondary roots highest in L- 49, root: shoot ratio maximum in Shweta and poor response observed in One-Kg. Response of guava genotypes to air layering exhibited overall trend, viz Lalit (better) > Red Fleshed> Shweta> L-49> Allahabad Safeda> Pant Prabhat> MPUAT S-1> Arka Mridula> Sarbati> RCGH-1> Burfkhan>Arka Amulya> MPUAT S-2> Safed Jam> One-Kg (poor).

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Evaluation of taro (*Colocasia esculenta*)-based cropping system for crop diversification under rainfed upland ecosystem of eastern India

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Abstract

A field experiment was conducted at the Regional Centre of ICAR-Central Tuber Crops Research Institute, Bhubaneswar, Odisha, India, during 2018-2020 on alfisols under rainfed conditions to identify most productive, resource use-efficient and remunerative taro-based cropping system. The experiment consisted of seven treatments, T_1- sole taro, T_2- sole maize, T_3- sole pigeonpea, T_4- taro+maize (5:1), T_5- taro+maize (5:2), T_6- taro+pigeonpea (5:1) and T_7- taro+pigeonpea (5:2). The results revealed that the cormel equivalent yield (CEY) was greater in T_1 and it was statistically on a par with T_4 and T_6. The LER of T_4, T_5, T_6 and T_7 were found >1. This indicated that all the above intercropping systems were biologically efficient. However, advantage of intercropping system was disappeared in T_5, T_6 and T_7, when evaluated via ATER concept. The treatment T_1 resulted in higher gross and net returns as well as B:C ratio however, it was statistically on a par with T_4 and T_6. Taro can be recommended for cultivation as a sole crop under upland ecosystem of eastern India. The treatment taro+maize (5:1) (T_4) can also be recommended for cultivation under rainfed conditions of eastern India for efficient use of resources, and optimum yield and returns. The intercropping system taro+pigeonpea (5:1) (T_6) can also be considered when more emphasis was given on soil health.

Key words: Area time equivalent ratio, Cormel equivalent yield, Gross and net returns, Land equivalent ratio

Taro [*Colocasia esculenta* (L.) Schott.], is capable of withstanding drought and flood. An annual rainfall of 900-1200 mm spread-over 5-6 months is required for its cultivation (Nedunchezhiyan and Sahoo 2019). High rainfall regions of eastern India are highly suitable for taro cultivation under rainfed conditions. As a sole crop, taro requires huge quantity of seed material (1.2 t/ha), causing very high initial investment. However, intercropping with cereals and pulses under replacement series will reduce seed cost of taro. Diversification with pulses not only provides food self-sufficiency but also contribute to nutritional adequacy (Rathore 2016).

Intercropping may be an alternate practice to overcome low productivity in case of low input and low output small scale farming (Dadabhau 2014). Maize+blackgram (*Vigna mungo* L.) intercropping is a viable agronomic means of risk minimizing farmers profit and subsistence oriented (Shilpa *et al.* 2019). The system productivity was higher in cropping systems through the inclusion of vegetables (Bhargavi *et al.* 2019a).

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The overall productivity increases (Singh *et al.* 2017). Inclusion of pulses and tuberous vegetables in cereal based cropping system improve the economic condition of small and marginal farmers owing to higher price and/or higher volume of their main and by products (Sharma *et al.* 2007; Nedunchezhiyan *et al.* 2022). Therefore, present investigation was carried out to find out resource-use efficiency of taro-based cropping system for yield and income under high rainfall upland ecosystem of eastern India.

Materials and Methods

A field experiment was conducted at the Regional Centre of ICAR-Central Tuber Crops Research Institute, Bhubaneswar, Odisha, India, during 2018-2020 on alfisols under rainfed conditions. The climate of location is hot and humid summer, and cool and dry winter. The experimental site soil (top 0.30 m) was having pH 5.7, organic carbon 0.37%, available N 205 kg/ha, available P 20.1 kg/ha and available K 252 kg/ha. The experiment was laid out in a randomized block design with three replications. The experiment consisted of seven treatments, T_1- sole taro, T_2- sole maize, T_3- sole pigeonpea, T_4- taro+maize (5:1), T_5-

taro+maize (5:2), T_6- taro+pigeonpea (5:1) and T_7- taro+pigeonpea (5:2).

All the crops in intercropping were planted at 45 cm × 30 cm spacing. Sole taro at 45 cm × 30 cm spacing, whereas sole maize and pigeonpea at 60 cm × 30 cm spacing. The variety Muktakeshi (taro), H 4226 (maize) and CORG 9701 (pigeonpea) were used. The recommended dose of fertilizers N-P-K 80-60-80, 80-40-40 and 20-40-20 kg/ha were applied for taro, maize and pigeonpea, respectively. In an intercropping, fertilizer dose of respective crops as per net sown area basis was applied.

Nitrogen (N), phosphorus (P) and potassium (K) were applied through urea, single super phosphate and muriate of potash, respectively. In all treatments, half dose of N and full doses of P and K were applied at the time of planting, while remaining N was applied 1 month after planting. The experiment was planted during second week of June in all the years. Maize was harvested 90 days after sowing, taro 165 days after planting and pigeonpea 200 days after sowing.

The average maximum and minimum temperature were 32.2 and 23.2°C, respectively. The total rainfall during crop growing period was 1568.2 mm with 74 rainy days. The cormel equivalent yield (CEY) data was computed taking into the consideration of selling price of taro corm and cormels, maize and pigeonpea seeds along with their yield.

$$\text{CEY (t/ha)} = \text{cormel yield (t/ha)} + \frac{\text{Corm/ maize/ pigeonpea yield (t/ha) x sale price of corm/ maize/ pigeonpea (₹/t)}}{\text{Sale price of cormel (₹/t)}}$$

The land equivalent ratio (LER) and area time equivalent ratio (ATER) were calculated as follows:

The land equivalent ratio (LER) and area time equivalent ratio (ATER) were calculated as follows:

$$\text{LER} = \frac{Ya}{Yaa} + \frac{Yb}{Ybb}$$

where, Ya = intercrop yield of crop 'a'

Yb = intercrop yield of crop 'b'

Yaa = pure stand yield of crop 'a'

Ybb = pure stand yield of crop 'b'

$$\text{ATER} = \frac{LA \times DA + LB \times LB}{T}$$

where, LA and LB are partial LERs of component crops A and B. DA and DB are duration of crops A and B, and T is the total duration of intercropping system.

The data were statistically analyzed and significance between mean differences among treatments for various parameters was analyzed using critical differences (CD) at 0.05 probability level.

Results and Discussion

Yield

The CEY computed revealed that T_1 recorded greater CEY (Table 1). This was due to higher genetic potential of higher tonnage yield as well as favourable rainfall during crop growing period. During all years average total rainfall received during crop growing period was 1568.2 mm with 74 rainy days, which was sufficient for raising sole taro crop. The CEY of T_4 and T_6 was statistically on par with T_1. But the CEY of T_5 and T_7 was significantly lower than T_1. This indicated that if one row of taro was replaced with maize or pigeonpea in an intercropping, they could compensate replaced taro population yield. Thokchom *et al.* (2016) reported that among taro intercropped treatments maximum taro yield was recorded in combination with single row of cowpea. The reduction in taro yield is compensated by intercrop (cowpea) yield in intercropping. If two rows of taro were replaced with maize or pigeonpea in an intercropping, they could not compensate replaced taro population yield (Table 1). Chhetri and Sinha (2020) also reported that maize+cowpea intercropping system 2:2 row ratio (replacement series) recorded higher maize equivalent yield than 2:4 row ratio. The CEY of T_2 and T_3 were significantly lowest. This was due to lower tonnage seed yield of maize and pigeonpea compared to taro. Inclusion of taro as an intercrop in maize and pigeonpea, the CEY of the intercropping treatments more than doubled.

The CEY of T_4 and T_5 was 248 and 212% higher respectively than T_2. The CEY of T_6 and T_7 was 138 and 105% higher respectively than T_3. The higher CEY in these treatments was due to higher tonnage taro yield as well as higher yield of maize and pigeonpea under intercropping than sole cropping on net area sown basis. Bhargavi *et al.* (2019b) also reported that the inclusion of high value crops, i.e. vegetables increased the system productivity.

Taro yield decreased under intercropping (Fig.1). The decrease in yield was due to decrease in taro population under intercropping. Taro corm yield was more affected than cormel yield under intercropping. The decrease of taro corm yield ranged from 17.1 to 41.9% under intercropping, whereas decrease of taro

cormel yield ranged from 16.1 to 38.0% (Fig. 1). The taro yield was also influenced by intercrops under intercropping. Pigeonpea reduced taro yield more than maize under intercropping (Fig. 1).

This was due to duration of interference of intercrop with main crop. Maize as an intercrop reduced taro corm yield 17.1-32.9% and cormel yield 16.1-29.0%, whereas pigeonpea as an intercrop reduced taro corm yield 26.6-41.9% and cormel yield 20.7-38% (Fig. 1). Increasing intercrop population resulted in decrease of taro yield, however it was not in linear. When one row of taro was replaced with maize (T_4), reduction in taro corm and cormel yield was 17.1 and 16.1%, respectively (Fig. 1). When two rows of taro were replaced with maize (T_5), the reduction in taro corm and cormel yield was 32.9 and 29.0%, respectively (Fig. 1). Similarly, one row of taro was replaced with pigeonpea (T_6), the reduction in taro corm and cormel yield was 26.6 and 20.7%, respectively. When two rows of taro were replaced with pigeonpea (T_7), the reduction in taro corm and cormel yield was 41.9 and 38.0%, respectively (Fig. 1).

Maize and pigeonpea as an intercrop recorded higher yield in intercropping than sole crops on net area sown basis (Fig. 1). Sowing of one row of maize/pigeonpea in treatments T_4/T_6 occupies 16.7% area, whereas sowing of two rows of maize/pigeonpea in T_5/T_7 occupies 28.6% area. One row of maize in T_4 recorded 27.6% of sole maize yield (T_2), whereas two rows of maize in T_5 recorded 43.6% of sole maize yield (T_2). Similarly, one row of pigeonpea in T_6 recorded 29.8% of sole pigeonpea yield (T_3), whereas two rows of pigeonpea in T_7 recorded 42.5% of sole pigeonpea yield (T_3).

The yield advantage of maize and pigeonpea in intercropping systems with taro probably occurred from the difference in timing of utilization of resources by different crops. Maize and pigeonpea are tall growing with deep root system, whereas taro is short height with shallow root system. Intercropping ensures efficient utilization of natural resources like light, nutrients, water and space but also conserve it by reducing soil erosion and lodging, suppresses weed growth thereby helps in yield increment (Shilpa *et al.* 2019). Under intercropping, taro recorded lower yield than sole crop on net area sown basis with pigeonpea, but no influence was found with maize (Fig. 1).

Sowing of five rows of taro in T_4 and T_6 occupies 83.3% area, whereas in T_5 and T_7 occupies 71.4% area. Taro yield in T_4 and T_5 (intercropping with maize) was found 83.7 and 70.1% of sole crop yield, respectively whereas, in T_6 and T_7 (intercropping with pigeonpea) was found 77.9 and 61.1% of sole crop yield, respectively. Thus, in T_4, taro yield recorded 83.7% of sole crop yield from 83.7% net sown area and in T_5, taro yield recorded 70.1% of sole crop yield from 71.4% net sown area. This showed that growing maize as an intercrop sown either one or two rows have not affected taro yield.

There is no competition for above ground (light and space) and below ground (water and nutrients) resources in taro+maize intercropping systems (T_4 and T_5). Whereas, in T_6 taro yield recorded 77.9% of sole crop yield from 83.7% net sown area and in T_7, taro yield

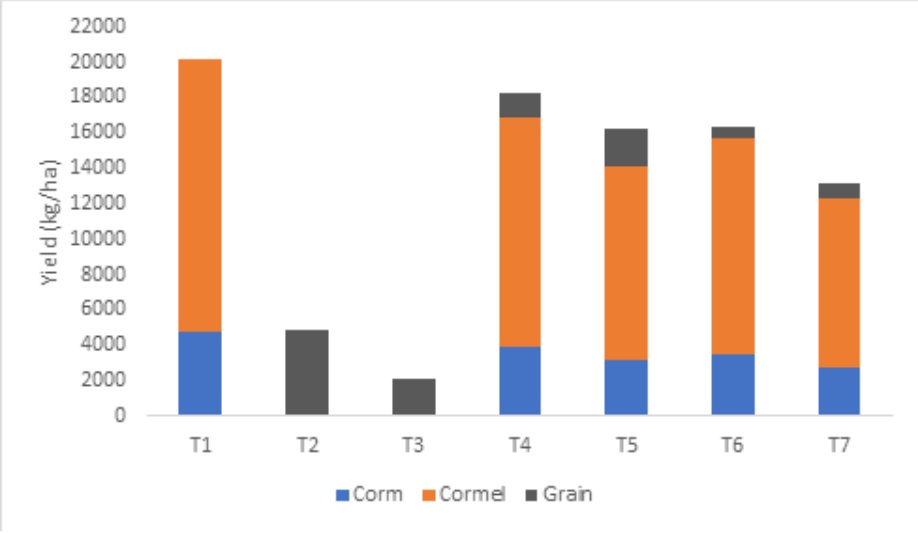

Fig. 1. Yield of taro, maize and pigeonpea in sole as well as in intercropping system

recorded 61.1% of sole crop yield from 71.4% net sown area. This showed that pigeonpea as an intercrop sown either one or two rows have affected taro yield. Pigeonpea was competing with taro for above ground (light and space) and below ground (water and nutrients) resources through-out the crop growing period.

Inclusion of maize and pigeonpea in taro, though the total yield was reduced compared to sole taro but it has advantage during aberrant weather conditions. These intercropping systems prevent total crop failure because maize and pigeonpea tap water and nutrients from deep layer due to their deep root-system (Behera *et al.* 2007; Dodiya *et al.*, 2018). Inclusion of pigeonpea as an intercrop with tuber crop supplies additional nutrient to crop plant by converting and fixing atmospheric nitrogen in available form through symbiosis with rhizobial strains (Geno and Geno 2001). Diversification with cereals, legumes and tuber crops not only provides food self-sufficiency but also contribute to nutritional adequacy (Singh *et al.* 2017; Suja and Nedunchezhiyan 2018).

Biological efficiency

The LER of T_4, T_5, T_6 and T_7 were found >1 (Fig. 2). This indicated that all the above intercropping systems were biologically efficient. Among all the intercropping systems, T_5 was found with highest LER and it was followed by T_4 (Fig. 2). Better LER in 2:2 row ratio of maize+cowpea intercropping system than other combination was reported by Chhetri and Sinha (2020). In this experiment, the duration of intercrops was widely varied. Hence, area time equivalent ratio (ATER) was used for assessing the intercropping efficiency.

The ATER of treatment T_4 was nearly one (0.99) and all other treatments were 0.94 and less. The resource use and resource complementarily between two species of high and low tonnage yielding crops was greater in T_4. The highest ATER in T4 indicated that growth requirement of both the component crops differs in time resulting in higher per day yield of the system due to temporal complementary effect. Thus, the advantage of intercropping system was disappeared in T_5, T_6 and T_7, when evaluated via ATER concept (Fig. 2). Similar findings in maize+black gram (Kheroar and Patra, 2014) and maize+cowpea (Chhetri and Sinha, 2020) were also reported.

Post-harvest soil nutrient status

The post-harvest soil nutrient status after three years of experimentation revealed that pH was increased in all the treatments over initial level (Table 2). Higher pH level was noticed in the treatment T_3 followed by T_7 and T_6. The organic carbon content in the post-harvest soil was found higher than initial level in all the treatments (Table 2). The treatment T_3 resulted in higher organic carbon level compared to other treatments. The next best treatments were T_6 and T_7. This may be due to large quantity of leaf shedding and organic exudates from the roots were added to the soil by pigeonpea compared to other crop species both sole as well as intercropping systems. Improved organic carbon aggregation in soil was noticed with the recycling of residues and mulches (Shukla *et al.*, 2020).

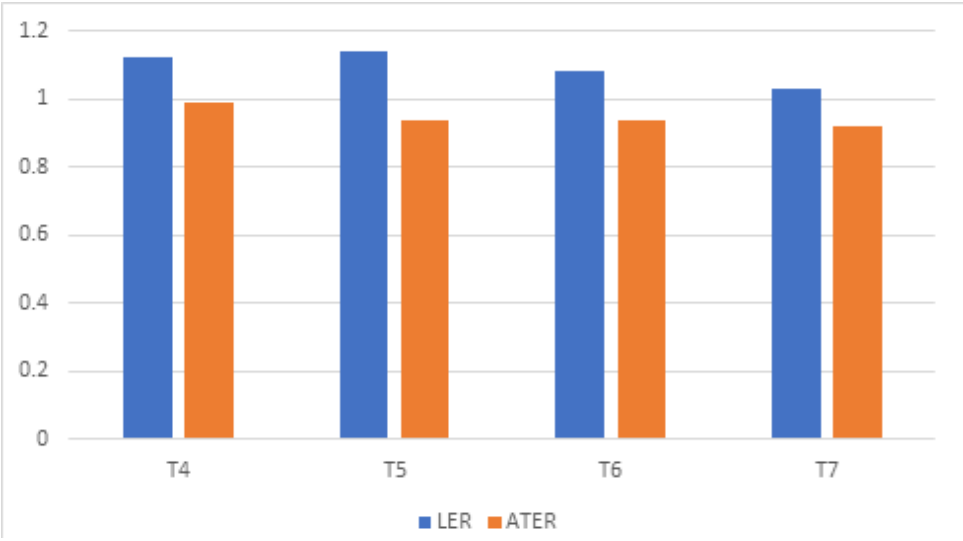

Fig. 2. LER and ATER of intercropping system

The post-harvest soil available N, P and K content were higher than initial levels (Table 2). The treatments T_7 and T_6 resulted in higher amount of post-harvest soil available N, P and K content and it was followed by T_3. This was due to application of recommended dose N, P and K, and contribution of decomposed organic matter from the crop plants. The higher build-up of soil nutrients caused by decomposition of above and below ground residues due to enhanced crop growth activities by application of recommended dose of manures and fertilizers was also reported by Sarangi *et al.* (2020) and Sharma *et al.* (2021).

Economics

The cost of cultivation was higher with taro either as a sole or as an intercrop (Table 1). The treatment T_1 resulted in highest cost of cultivation, followed by T_4 and T_6 (Table 1). This was mainly due to huge quantity of taro seed material required for cultivation as well as its cost. The treatment T_3 and T_2 recorded lower cost of cultivation due to lower seed cost as well as other input costs (fertilizers). The treatment T_1 registered with greater gross and net returns as well as B:C ratio (Table 1). This was mainly due to higher tonnage of taro yield. The gross and net returns as well as B:C ratio of T_4 and T_6 were statistically on a par with T_1 and were the next best treatments. The treatment T_2 and T_3 recorded lower gross and net returns as well as B:C ratio (Table 1). This was due to lower yield of maize and pigeonpea.

Conclusion

Considering yield and return, taro+maize intercropping system (5:1) can be recommended for cultivation as a

Table 1: Cormel equivalent yield and economics of taro, maize and pigeonpea involved intercropping systems

Treatment	Cormel equivalent yield (t/ha)	Cost of cultivation (₹/ha)	Gross return (₹/ha)	Net return (₹/ha)	B: C ratio
T_1	18.59	111400	278900	167500	2.50
T_2	4.86	55200	72900	17700	1.32
T_3	7.00	50600	105100	54500	2.07
T_4	16.90	105000	253500	148500	2.41
T_5	15.19	99900	227800	127900	2.28
T_6	16.64	104100	249700	145600	2.40
T_7	14.37	98800	215600	116800	2.18
SEm±	0.67	2700	10000	9000	0.09
CD (5%)	2.05	8200	30800	27800	0.27

Sale price of corm 10000 ₹/t; cormel 15000 ₹/t; maize 15000 ₹/t; pigeonpea 50000 ₹/t

Table 2: Post-harvest soil nutrient status of taro intercropping system

Treatment	pH	OC (%)	Available N (kg/ha)	Available P (kg/ha)	Available K (kg/ha)
T_1	5.8	0.39	212	21.2	261
T_2	6.0	0.43	216	22.1	266
T_3	6.3	0.48	230	23.4	276
T_4	5.8	0.40	218	22.2	268
T_5	5.9	0.42	222	23.2	272
T_6	6.1	0.44	232	24.4	280
T_7	6.2	0.46	236	24.9	282
SEm±	0.07	0.01	4.2	0.2	5.3
CD (5%)	0.2	0.03	13	2.6	16

crop diversification option under rainfed conditions of eastern India with lower risk. The intercropping system taro+pigeonpea (5:1) can also be considered when more emphasis was given on soil health.

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Impact of pre- harvest foliar spray of nutrients and agrochemicals on fruit yield and quality of ber (*Zizyphus mauritiana*)

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Abstract

A field experiment was conducted to find out the impact of pre- harvest foliar spray of nutrients and agrochemicals on fruit yield and quality parameters of ber (*Zizyphus mauritiana* Lamk) during 2022-23 and 2023-24 at SKN College of Agriculture, Jobner, Rajasthan. Among nutrients and agrochemicals, application of T_{11} ($ZnSO_4$ @ 4g/L + $CaCl_2$ @ 2g/L + chitosan @ 1.5g/L +salicylic acid @ 1g/L) to individual plants was significantly superior to all other treatments, but it was on a par with T_9 ($CaCl_2$ @ 2g/L + salicylic acid @ 1g/L), T_7 ($ZnSo_4$ @ 4g/L + salicylic acid @ 1g/L) and T_5 ($ZnSO_4$ @ 4g/L + $CaCl_2$ @ 2g/L). In treatment T_{11} ($ZnSo_4$ @ 4g/L + $CaCl_2$ @ 2g/L + chitosan @ 1.5g/L + salicylic acid @ 1g/L), an increase in days taken to first harvesting (137.00 days), days taken to complete harvesting (57.11 days), fruit weight (18.51 g), diameter of fruits (3.59 cm), fruit yield (38.01 kg/tree), fruit yield (105.68 q/ha), maximum TSS% (19.05 ^{0}Brix) and minimum titratable acidity (0.415 %) were recorded.

Key words: Agrochemicals, Nutrients, Spray, Fruit yield.

Indian jujube or ber (*Zizyphus mauritiana* Lamk) is one of the most common fruit, indigenous to an area joined from India to china. Cultivation of ber requires the least input and care (Pareek, 1983). It has a remarkable adaptability enabling it to grow in a wide range of agro-climatic situations and soils (Rana *et al.* 1979). Its fruits are palatable and delicious with a good amount of vitamin A, C, B complex and minerals (Pareek, 2002). In India, ber is being cultivated on an area of about 51.73 ha with a total production of 548.27 tonnes and productivity of 10.53 tonnes (MAFW, 2023-24). In Rajasthan, it is grown in an area of 11000 ha with a total production of 95900 tonnes and productivity of 8.71 tonnes (MAFW, 2023-24) in ber macro as well as micro nutrients improves the quality and quantity of production. Furthermore, zinc and calcium are very important nutrients required for its growth and development. The agrochemicals like chitosan and salicylic are needed for growth and development of plants, hence an experiment was conducted.

Materials and Methods

A field experiment was conducted at SKN College of Agriculture, Jobner, cv. Gola during 2022-23 and 2023-24. It consists of 12 nutrients and agrochemical treatments along with the control, T_0 (control), T_1 (zinc sulphate @ 4 g / L), T_2 (calcium chloride @ 2 g / L), T_3 (chitosan @ 1.5 g / L, T_4 salicylic acid @ 1 g / L), T_5 (zinc sulphate @ 4 g / L + calcium chloride @ 2 g / L), T_6 (zinc sulphate @ 4 g / L + chitosan @ 1.5 g / L), T_7 (zinc sulphate @ 4 g / L + salicylic acid @ 1 g / L), T_8 (calcium chloride @ 2 g / L + chitosan @ 1.5 g / L), T_9 (calcium chloride @ 2 g / L + salicylic acid @ 1 g / L), T_{10} (chitosan @ 1.5 g / L + salicylic acid @ 1 g / L) and T_{11} (zinc sulphate @ 4 g / L + calcium chloride @ 2 g / L + chitosan @ 1.5 g / L + salicylic acid @ 1 g / L) laid out in factorial randomized block design with three replications.

The treatments were applied during first week of November 2022-23 and 2023-24 after recording initial (base) yield attributing parameters of plants and observations were noted. For the measurement of number days taken to first harvesting of fruits was counted from the initiation of flowering to first harvesting of fruits and averages were computed. Days taken to complete harvesting the numbers of days taken from date of first harvesting of fruits to last date of harvesting of fruits constituted duration of harvesting. Number of days for each replication were recorded. Weight of fruit twenty fruits from each treatment were selected at random in each picking during both the years and weighed separately on electronic balance and average fruit weight in gram was calculated.

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The fruit diameter was measured at fruit maturity/ harvesting stage. The fruit size *i.e.* length and breadth were measured in centimeters with the help of calibrated Vernier Calipers. The volume of fruits was recorded by water displacement method with the help of measuring cylinder and volume of displaced water was expressed in cubic centimeter. The number of fruits/ plant were counted at each picking and total numbers of fruits were recorded for each treatment individually. Ripen fruits were harvested periodically and then weight was recorded with the help of single pan balance. Thereafter total fruit yield was calculated by summing up the total weight of fruits at different pickings obtained during harvesting period from each experimental plant.

$$\text{Yield (q/ha)} = \frac{\text{Yield/ plant (kg)}}{100} \times 278 \text{ (plant/ha)}$$

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

Results and Discussion

Application of nutrients and agrochemicals had significant effect on fruit yield and quality parameters of ber fruits. The earliest first harvesting (137.00 days after initiation of flowering) was recorded with the application of treatment T_{11} ($ZnSo_4$ @ 4g/L + $CaCl_2$ @ 2g/L + chitosan @ 1.5g/L + salicylic acid @ 1g/L), which was found significantly superior over rest of the treatments except treatments T_9 ($CaCl_2$ @ 2g/L + salicylic acid @ 1g/L), days, T_7 ($ZnSo_4$ @ 4g/L + salicylic acid @ 1g/L), days and T_5 ($ZnSo_4$ @ 4g/L + $CaCl_2$ @ 2g/L) days during both the years and pooled mean. However, maximum days taken to first harvesting after initiation of flowering (152.33 days) was noted under the control. Similarly, maximum days taken to complete harvesting (195.72) days after flowering was noted treatment T_{11} followed by T_9 (192.94) days, T_7 (191.33) days and T_5 (190.06) days minimum of (179.11) days taken to complete harvesting was noted under control T_0 treatment (Table 1).

The maximum fruit weight (18.51 g) was recorded with the application of treatment T_{11} ($ZnSo_4$ @ 4g/L + $CaCl_2$ @ 2g/L + chitosan @ 1.5g/L + salicylic acid @ 1g/L). This treatment was found statistically at par with treatment T_9 ($CaCl_2$ @ 2g/L + salicylic acid @ 1g/L 18.20 g), T_7 ($ZnSo_4$ @ 4g/L + salicylic acid @ 1g/L 18.02 g), T_5 ($ZnSo_4$ @ 4g/L + $CaCl_2$ @ 2g/L 17.85 g) and minimum fruit weight of (15.59g) was noted under the control. Maximum diameter of fruit of (3.63) was noted treatment T_{11} followed T_9 (3.55 cm), T_7 (3.49cm), T_5 (3.44cm) minimum diameter of fruit (2.83cm) was noted under control T_0 treatment (Table 2).

The highest volume of fruit of (18.83 cc) was recorded with the application of treatment T_{11} ($ZnSo_4$ @ 4g/L + $CaCl_2$ @ 2g/L + chitosan @ 1.5g/L + salicylic acid @ 1g/L). followed treatment T_9 ($CaCl_2$ @ 2g/L + salicylic acid @ 1g/L 18.54 cc), T_7 ($ZnSo_4$ @ 4g/L + salicylic acid @ 1g/L18.36cc), T_5 ($ZnSo_4$ @ 4g/L + $CaCl_2$ @ 2g/L18.18cc) and minimum volume of fruit (16.10cc) noted under the control. Similarly, treatment T_{11} ($ZnSo_4$ @ 4g/L + $CaCl_2$ @ 2g/L + chitosan @ 1.5g/L + salicylic acid @ 1g/L) registered maximum number of (2236.06 fruits/plant).

This treatment was found significantly superior over rest of the treatments except treatment T_9 (2214.10 fruits/plant), T_7 (2202.84 fruits/plant), T_5 ($ZnSo_4$ @ 4g/L + $CaCl_2$ @ 2g/L 2193.58 fruits/ plant) minimum number of (1822.13 fruits/ plant) were noted under the control treatment (Table 3). Maximum fruit yield (38.01 kg/tree) during both the years and pooled mean, respectively was recorded with the application of treatment T_{11} ($ZnSo_4$ @ 4g/L + $CaCl_2$ @ 2g/L + chitosan @ 1.5g/L + salicylic acid @ 1g/L). followed by this treatment T_9 ($CaCl_2$ @ 2g/L + salicylic acid @ 1g/L 37.12 kg/tree), T_7 ($ZnSo_4$ @ 4g/L + salicylic acid @ 1g/L 36.98 kg/tree), T_5 ($ZnSo_4$ @ 4g/L + $CaCl_2$ @ 2g/L 36.77 kg/tree) and minimum fruit yield of 31.28 kg/tree was noted under the control.

Treatment T_{11} was recorded maximum fruit yield q/ha of (105.68) q/ha during both the years and pooled mean, respectively, which was found statistically at par with T_9 (103.20 q/ha), T_7 (102.80 q/ha), T_5 (102.22 q/ha) and minimum fruit yield of (86.95 q/ha) were noted under the control (Table 1).

Maximum TSS content of (19.05^0 Brix) during both the years and pooled mean, respectively was recorded in fruits with treatment T_{11} ($ZnSo_4$ @ 4g/L + $CaCl_2$ @ 2g/L + chitosan @ 1.5g/L + salicylic acid @ 1g/L). This treatment was significantly superior over rest of the treatments except treatment T_9 ($CaCl_2$ @ 2g/L + salicylic acid @ 1g/L 18.90^0 Brix), T_7 ($ZnSo_4$ @ 4g/L +salicylic acid @ 1g/L 18.33 Brix), T_5 ($ZnSo_4$ @ 4g/L + $CaCl_2$ @ 2g/L 18.69^0 Brix and minimum TSS content (16.80^0 Brix)

Table 1. Effect of Pre-Harvest Foliar Spray of Nutrients and Agrochemicals on Days taken to First Harvesting and Days taken to Complete Harvesting of Ber fruits.

Treatment	Days taken to First Harvesting			Days taken to Complete Harvesting		
	2022-23	2023-24	Pooled	2022-23	2023-24	Pooled
Nutrients and agrochemicals						
T_0 Control	152.44	152.22	152.33	25.44	28.11	26.78
T_1 $ZnSO_4$	151.89	148.00	149.94	28.56	35.44	32.00
T_2 $CaCl_2$	149.33	147.89	148.61	29.89	34.33	32.11
T_3 Chitosan	146.89	146.22	146.56	28.33	34.22	31.28
T_4 Salicylic acid	146.33	145.44	145.89	34.00	37.89	35.94
T_5 $ZnSO_4$ + $CaCl_2$	142.33	141.22	141.78	45.11	51.44	48.28
T_6 $ZnSO_4$ + Chitosan	149.78	147.44	148.61	31.00	36.33	33.67
T_7 $ZnSO_4$ + Salicylic acid	139.44	139.44	139.44	49.44	54.33	51.89
T_8 $CaCl_2$ + Chitosan	145.00	144.22	144.61	35.11	38.89	37.00
T_9 $CaCl_2$ + Salicylic acid	138.89	137.89	138.39	52.11	57.00	54.56
T_{10} Chitosan+ Salicylic acid	148.00	147.11	147.56	35.56	39.44	37.50
T_{11} $ZnSO_4$ + $CaCl_2$ + Chitosan + SA	137.44	136.56	137.00	54.33	59.89	57.11
SEm±	**3.07**	**3.10**	**2.18**	**4.86**	**4.26**	**3.23**
CD (P = 0.05)	**8.65**	**8.73**	**6.09**	**13.72**	**12.01**	**9.04**
Different Stage of Foliar Spray						
S_1	144.86	144.14	144.50	41.61	43.42	42.51
S_2	150.47	148.31	149.39	27.94	34.78	31.36
S_3	141.61	140.97	141.29	42.67	48.64	45.65
SEm±	**1.53**	**1.55**	**1.09**	**2.43**	**2.13**	**1.62**
CD (P = 0.05)	**4.32**	**4.37**	**3.05**	**6.86**	**6.00**	**4.52**

was noted under control. However minimum acidity (0.415 %) was recorded under treatment T_{11} followed by this treatment T_9 (0.417%), T_7 (0.418), T_5 (0.421%) and maximum titratable acidity (0.469%) was recorded in control at the time of completion of experiment (Table 2).

Application of zinc sulphate, calcium chloride, salicylic acid and chitosan enhanced the yield and yield parameters of ber when applied either alone or in combinations. Zinc sulphate application reduced maturity duration could be attributed to enhancing effect of $ZnSO_4$ in enzymatic reaction, cell division as well as in growth (Supriya and Bhattacharya, 1993). The enhancement in weight, diameter and volume of fruits with foliar spray of salicylic acid may be due to the high content of starch and plant hormones, especially cytokines, which play a vital role in enhancing cell division and expansion, ultimately leading to increased volume (Uthairatanakij *et al.,* 2007). Application of salicylic acid at pea size stage showed a maximum increase in fruit weight, diameter and volume of fruits because at this time, stone fruit undergoes through the cell elongation stage (Kassem *et al.,* 2011). During this stage, cells absorb water from adjacent cells or xylem, which can cause turgidity of the cells and elongation of the fruit cells, activation of some essential enzymes and supply of more plant hormone for the growth and development of fruit which increases volume and diameter of fruits (Valero *et al.,* 2002).

The increase in number of ber fruits by application of foliar application of nutrients and agrochemicals (calcium, zinc, salicylic acid and chitosan) treatment

Table 2. Effect of Pre-Harvest Foliar Spray of Nutrients and Agrochemicals on fruit weight and diameter of fruits on ber fruit.

Treatments	Fruit weight			Diameter of fruits		
	2022-23	2023-24	Pooled	2022-23	2023-24	Pooled
Nutrients and agrochemicals						
T_0 Control	15.29	15.90	15.59	2.69	2.96	2.83
T_1 $ZnSO_4$	16.51	17.09	16.80	2.87	3.11	2.99
T_2 $CaCl_2$	16.48	17.15	16.82	2.80	3.07	2.94
T_3 Chitosan	16.46	17.07	16.77	2.74	3.02	2.88
T_4 Salicylic acid	16.42	17.03	16.73	2.87	3.11	2.99
T_5 $ZnSO_4$ + $CaCl_2$	17.54	18.15	17.85	3.40	3.50	3.45
T_6 $ZnSO_4$ + Chitosan	16.98	17.59	17.28	3.12	3.22	3.17
T_7 $ZnSO_4$ + Salicylic acid	17.71	18.32	18.02	3.41	3.56	3.49
T_8 $CaCl_2$ + Chitosan	16.92	17.53	17.22	3.26	3.29	3.27
T_9 $CaCl_2$ + Salicylic acid	17.89	18.50	18.20	3.46	3.64	3.55
T_{10} Chitosan+ Salicylic acid	16.89	17.50	17.19	3.31	3.42	3.36
T_{11} $ZnSO_4$ + $CaCl_2$ + Chitosan + SA	18.12	18.89	18.51	3.56	3.62	3.59
SEm±	**0.38**	**0.43**	**0.29**	**0.11**	**0.18**	**0.10**
CD (P = 0.05)	**1.09**	**1.21**	**0.80**	**0.30**	**0.49**	**0.29**
Different Stage of Foliar Spray						
S_1	17.03	17.66	17.35	3.14	3.32	3.23
S_2	16.48	17.04	16.76	2.97	3.06	3.01
S_3	17.29	17.99	17.64	3.27	3.50	3.38
SEm±	**0.19**	**0.21**	**0.14**	**0.05**	**0.09**	**0.05**
CD (P = 0.05)	**0.54**	**0.60**	**0.40**	**0.15**	**0.25**	**0.14**

may be due to increased fruit set and reduced fruit drop due to that these nutrients play important role in biosynthesis of IAA (Alloway, 2008). As a result of spray of these nutrients could give higher number of fruits and consequently yield. Further, increase in fruit yield in treated plant may be attributed to reason that plants remain physiologically more active to build up sufficient food stock for developing fruits ultimately leading the higher yield. The increase in percentage of total soluble solid when spraying calcium may be due to the role of these elements in increasing activity of vegetative growth, then absorb nutrients (Badway *et al.*, 2019).

An increase in TSS: acid ratio is due to increase in TSS content and the decreased acidity Abdelrhman *et al.,* (2017). The present results are in conformity with the findings of Singh and Maurya (2004) in mango, Singh *et al.* (2005) in papaya, Rajkumar *et al.* (2014) in guava, Goswami *et al.* (2014) in guava, Yadav *et al.* (2018) in guava, Yadav *et al.* (2018) in pomegranate, Ajender and Chawla (2019) in apple and Gami *et al.* (2019) in ber.

Conclusion

Thus, it may be concluded that application of T_{11} ($ZnSo_4$ @ 4g/L + $CaCl_2$ @ 2g/L + chitosan @ 1.5g/L + salicylic acid @ 1g/L).) had its better effect on fruit yield and quality of ber plants. The (($ZnSo_4$ @ 4g/L + $CaCl_2$ @ 2g/L + chitosan @ 1.5g/L + salicylic acid @ 1g/L) emerged better in its effectivity on fruit yield and quality attributes.

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Evaluation of *Trichoderma, Psedomonos* and biofertisol as foliar application on quality and yield of guava (*Psidium guajava*)

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Abstract

The experiment was designed in Randomized Block Design in four replications with seven treatments, i.e. T_1 - control (only water), T_2 –*Trichoderma viride* 5%, T_3-*Trichoderma viride* 10%, T_4 - *Pseudomonas* 5%, T_5 -*Pseudomonas* 10%, T_6 -biofertisol 5% and T_7 - biofertisol 10%, at Department of Horticulture, JNKVV, Jabalpur, in 8 year old guava (*Psidium guajava* L.) variety L 49, during 2020-21 and 2021-22. Foliar application of *Trichoderma* @ 10 % was most beneficial for growth, yield and quality parameters. *Trichoderma* @ 10 % recorded maximum increment in shoot length, plant height, canopy height, leaf chlorophyll Index, chlorophyll content index**,** LAI. Foliar application of 10% *Trichoderma was*also superior in yield parameter found maximum number of flowers shoot, fruit set percentage, fruit retention percentage, fruits/shoot, fruit/splant, yield/plant, fruit length, fruit width, fruit weight, fruit volume, pulp weight/fruit and pulp per cent. Total soluble solids, total sugar, and reducing sugar were recorded in *Trichoderma* 10% (T_7) and minimum acidity was recorded in foliar application of *Pseudomonas* 10% (T_5) .

Key words: Biofertilizer, Biofertisol, Pseudomonas, Trichoderma,

Guava (*Psidium guajava* L.) has gained tremendous popularity among fruit growers (Meena *et al*., 2020). The pre-harvest sprays of growth regulators and minerals are new practices adopted nowadays for higher fruit production and improved fruit quality (Dongre *et al*., 2021). Foliar nutrition coupled with growth hormone is still the way forward approach to produce nutrient dense fruit crops (Srivastava and Hota, 2020). By applying *Trichoderma* to the soil or as foliar sprays, farmers can promote healthier plant growth and reduce the need for chemical pesticides.

Similarly biofertisol is rich in nitrogen and is a source of several trace elements. Therefore, the effect of *Trichoderma,Psedomonos* and Biofertisol as foliar application on quality and yield parameters was carried out to assess the productivity of guava as influenced by foliar application of biofertilizers.

Material and Method

The Experiment was conducted at Department of Horticulture, JNKVV, Jabalpur, on 8 – year- old guava variety L 49, during 2020-21 and 2021-22. Jabalpur is situated in the "Kymore Plateau and Satpura Hills" agro climatic region of Madhya Pradesh. It falls on 23.9° North latitude and 79.58° East longitudes with an altitude of 411.8 m above the mean sea-level. The experiment was designed in randomized block design in four replications with seven treatments, i.e. T_1 - control (only water), T_2 –*Trichoderma viride* 5%, T_3-*Trichoderma viride* 10%, T_4 - Pseudomonas 5%, T_5 -Pseudomonas 10%, T_6 -biofertisol 5% and T_7 - biofertisol 10%.

Spraying was done on the tree canopy by foot sprayer. It was considered that one liter of solution is sufficient for a tree. Hence for making the one liter solution of required treatment, required quantities of biofertilizers were dissolved in water. All the treatments were sprayed at Pre-flowering and 30 days after fruit setting stage.

The data were recorded on physiological, biochemical, yield-attributing characters and economics of guava. The shoot length (cm), plant height (m), canopy height (m), chlorophyll content index, LAI and light transmission ratio (%), yield parameters (number of flowers / shoot, fruit setting (%), fruit retention (%), number of fruits / plant, yield (kg/plant), fruit length (cm), fruit width (cm), fruit weight (g), and pulp (%). TSS (°Brix), acidity (%), TSS acid ratio, ascorbic acid (mg per 100 g), total sugar (%),

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reducing sugar (%) and non-reducing sugar (%) were recorded.

The chlorophyll index (SPAD value) in leaves was recorded at harvesting stage. Leaf chlorophyll index was estimated by using SPAD chlorophyll meter by simple clamping the meter over leafy tissue. (Gardner *et al.* 1985

Total numbers of flowers/shoot were calculated regularly and average numbers of flowers were calculated. Total fruit settings (%) on tagged shoots were counted and subsequently total number of fruits was again counted at the time of fruit maturity. The percent (%) fruit retention was calculated. At each picking, number of fruits per plant was independently recorded. The pulp percent was calculated by deducting the weight of seed and peel from total weight of fruit. Pulp was calculated by total weight of pulp divided by total weight of fruit.

To record TSS, a few drops of extracted juice were put on the surface of the refract meter's prism with the assistance of a clean glass rod to determine TSS in °Brix. Acidity (%) TSS acid ratio, ascorbic acid (mg per 100 g), total sugar %, reducing sugar % and non-reducing sugar were determined using (AOAC 1970).

Result and Discussion

There wore maximum shoot length (50.13 cm), plant height (0.47 m), canopy height (0.37 m), chlorophyll content index (37.89), leaf area index (165.92), in foliar

Table 1: Effect of biofertilizers on growth parameter of guava (mean of two years data)

Treatment		Shoot length (cm)	Plant height (m)	Canopy height (m)	Chlorophyll content index	LAI	Light transmission ratio (%)
T_1	Control (water)	37.64	0.31	0.28	31.82	115.13	15.97
T_2	Biofertisol 5%	44.52	0.34	0.28	36.32	126.06	15.33
T_3	Biofertisol 10%	45.41	0.36	0.30	36.83	138.63	15.16
T_4	*Pseudomonas* 5%	43.94	0.32	0.27	35.38	116.11	15.57
T_5	*Pseudomonas* 10%	44.55	0.35	0.29	36.51	116.68	15.17
T_6	*Trichodermaviride* 5%	48.22	0.43	0.34	36.98	132.30	14.68
T_7	*Trichodermaviride* 10%	50.13	0.47	0.37	37.89	165.92	14.45
	SEm (±)	1.034	0.013	0.007	0.369	2.600	0.097
	CD (5%)	3.072	0.038	0.020	2.031	7.725	0.288

Table 2: Effect of Biofertilizers on quality parameter of guava (mean of two years data)

Treatment		TSS (Brix)	Acidity (%)	TSS: acid ratio	Ascorbic acid (mg per 100 g)	Total sugar (%)	Reducing sugar (%)	Non-reducing sugar (%)
T_1	Control (water)	10.93	0.379	27.61	177.31	8.60	4.66	3.94
T_2	Biofertisol 5%	11.01	0.358	31.27	196.64	8.73	4.92	3.80
T_3	Biofertisol 10%	11.61	0.346	33.21	209.93	9.27	5.24	4.02
T_4	*Pseudomonas* 5%	10.93	0.363	30.46	189.56	8.75	4.81	3.94
T_5	*Pseudomonas* 10%	11.12	0.311	31.04	200.82	9.06	5.01	4.05
T_6	*Trichodermaviride* 5%	11.69	0.343	32.13	219.21	9.34	5.48	3.86
T_7	*Trichodermaviride* 10%	12.32	0.338	33.49	235.43	9.53	5.73	3.80
	SEm (±)	0.181	0.007	0.685	4.893	0.128	0.089	0.123
	C.D. (5%)	0.538	0.019	2.035	14.536	0.379	0.265	0.366

application of *Trichoderma viride* @ 10% (T_7). All growth parameters are significantly influence by foliar application of *Trichoderma viride* @ 10% (Benítez *et al.*, 2004) and closely related to Pangtu *et al. (2024)*. Application of *Trichoderma* helps to promote growth, improve nutrient availability, and induce systemic resistance against diseases, mainly phytopathogenic fungi (Pascale *et al*., 2017). Result was closely confirmed by Syam *et al* (2021) and by Devarakonda *et al.* (2020).

Shukla *et. al*., 2014 also found that application of Azotobacter + PSM + *T. harzianum* + organic mulching significantly influenced plant height, stem girth, canopy spread in both directions, i.e. north–south and east–west. Sajeesh *et al.* (2015) found maximum plant height in potato and Uddin *et al.* (2015) by application of *Trichoderma* spp. Sani *et al.* (2020) reported that application of *Trichoderma* and biochar with half dose of N-P-K significantly resulted in greatest plant height, branches/plant, number of leaves, root and shoot dry matter weight in tomato.

Uddin *et al.* (2015) and Nagata *et al.* (2005) recorded maximum chlorophyll percentage in tomato by the application of *Trichoderma*. *Trichoderma* produced auxins that are able to stimulate plant growth and root development (Contreras-Cornejo *et al*., 2009). The increase in tree height might be due to production of more chlorophyll content with inoculation of nitrogen fixers. The reason of increase in growth characters is constituent of the protein which is essential for formation of protoplasm thus affecting cell division and cell elongation and thereby more vegetative growth (Dutta *et al*., 2009).

The maximum number of flower/shoot (5.49), fruit setting (68.22%) , fruit retention (71.77%), fruits/plant (98.95) , yield/plant (22.59 kg), maximum fruit length (6.87 cm), fruit width (7.12 cm), fruit weight (227.98 g, pulp weight/ fruit (219.75 g), pulp (96.39 %) were recorded under *Trichodermaviride* 10% (T_7) and it was significantly superior.

Numerous studies have shown that use of *Trichoderma* sp. may promote primary or secondary plant metabolism and boosts crop yield (Rouphael *et al*., 2017). The phyto-stimulatory effect of it has several direct and indirect impacts on plants, including release of substances with auxin activity, small peptides, organic acids, which appear to improve root system architecture and assimilation of nutrients, thereby improving plant growth and productivity (Hermosa *et al.,* 2012; and Rouphael *et al*., 2017). Application of it to plants activates secondary metabolites that help to promote growth, improve nutrient availability, and induce systemic resistance against diseases, mainly phytopathogenic fungi (Pascale *et al*., 2017). Molla *et al*., 2012 found *Trichoderma* improve the quality of tomato fruit.

The result partially supported to those of Uddian *et. al.* (2015). Shukla *et al.* (2014) summarized that application of Azotobacter + PSM + *T. harzianum*+ organic mulching significant increase in fruit yield, fruit weight, fruit length and fruit diameter. Biofertilizers as in (50% recommended dose of fertilizer + 25 kg FYM + 250 g *Trichoderma* + 250 g *Pseudomonas*) encouraged better growth and accumulated optimum dry matter with the induction of growth hormones, which stimulated cell division, cell elongation; activated photosynthesis process, as well as energy transformation which in turn caused increase in physical qualities of fruits. Sani *et.al.* (2020) found half dose of NPK with combined application of *Trichoderma* and biochar showed highest number of flower clusters /plant, number of fruit / cluster, number of fruit / plant, the weight of individual fruit and yield /plant.

The highest increase in TSS (12.32 °Brix), TSS:acid ratio (33.49), ascorbic acid (235.43 mg/100g), total sugar (9.53 %), reducing sugar (5.73%) were recorded in Trichoderma 10% (T_7). It was significantly superior over rest of the treatments. This finding supported Lal *et al.* (2017).

The foliar application of Pseudomonas 10% (T_5) recorded minimum acidity (0.311%) and maximum non-reducing sugar (4.05%) which was significant among all the treatments. Similar result were found by Singh *et. al*., (2020).

Conclusion

The foliar application of *Trichoderma* @ 10 % recorded maximum increment in shoot length, plant height, canopy height, leaf chlorophyll Index and chlorophyll content index**,** LAI. It also gave maximum number of flower/shoot, fruit setting (%), fruit retention (%), fruit /shoot , fruits / plant , yield / plant, fruit length, fruit width, fruit weight, fruit volume, pulp weight per fruit, pulp per cent.

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Effect of nano nitrogen and phosphorus on yield and quality of ber (*Ziziphus mauritiana*)

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Abstract

An experiment was conducted at Agricultural Research Station, Mandor, Jodhpur (Rajasthan) to find out the effects of nano nitrogen and phosphorus fertilizers on growth, yield and quality of ber (*Ziziphus mauritiana* Lam.) using factorial randomized block design with 5 replications during October 2021 to March 2022. There was maximum plant height (6.45 %, 79.17 cm), number of primary branches (14.72), secondary branches (22.09), chlorophyll contents (55.34 SPAD), fruit volume (20.63cm^3), specific gravity (0.95), fruit length (3.42 cm), fruit diameter (3.16 cm), pulp thickness (12.56 mm), pulp weight (15.79 g), pulp: stone ratio (19.20), fruit setting (6.92 %), average fruit weight (18.00 g), yield/ tree (64.57 kg), ascorbic acid (vitamin-C) (65.75 mg/100g pulp), total soluble solid (15.77°Brix), total sugar (9.20 %), reducing sugar (4.83 %), non-reducing sugar (4.37 %), fruit pH (5.50), whereas minimum stone weight (0.82 g) and fruit drop (49.38 %) were recorded with application of nano nitrogen @ 2 ml/ litter water + nano phosphorus @ 2 ml/ litter water spray over the control.

Key words- Ascorbic acid, Arid climate, Nano nitrogen, Nano Phosphorus, Total sugar

Ber (*Ziziphus mauritiana* Lam.), family Rhamanaceae is known as poor man's apple fruits (Majumder *et al*., 2017) and (Choudhary *et al*., 2017). Nano-fertilizers are non-toxic and less hazardous to humans and the environment than traditional fertilizers (Nongbet *et al*., 2022). They improve soil fertility, productivity, and crop quality while minimizing costs and increasing profit (Raj *et al*., 2021). They provide more surface for various metabolic reactions in the plant (Solanki *et al*., 2015). Nano-fertilizer can reduce the rate of nutrients loss through leaching and improves the nutrient-use efficiency of fruit plant (An *et al*., 2022). Nowadays nano-fertilizers are emerging as an alternative to conventional fertilizers (Veronica *et al*., 2014). The use of nano-fertilizers can improve crop production by up to 30 per cent compared with traditional chemical fertilizers (Kah *et al*., 2018). Nano nitrogen and phosphorus are important for improving plant growth and yield, enhance nutrient uptake, stimulate photosynthesis and get better water use efficiency (Gupta *et al*., 2022). Studies have shown their effectiveness in increasing crop productivity, as well as their potential in sustainable agriculture (Elnahal *et al*., 2022). Keeping in view, the study was carried out to determine the effect of nano fertilizers on growth, yield, and quality of fero.

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Materials and Methods

The field experiment was conducted during October, 2021 to March, 2022 at Agricultural Research Station Mandor, Jodhpur, on eight-year-old plant of Gola. Geographically, it is located between 26°30' N to 26°35' North latitude and 70°04' E to 73°15' East longitude at an altitude of 231 meter above mean sea-level, Arid Western Plains Zone of Rajasthan. The experiment was laid out in factorial randomized block design with five replications along with three treatments and each treatment consist with three randomly selected equal size plant block. Nano nitrogen @ 2 ml/ litter water, nano nitrogen @ 2 ml/ litter water + nano phosphorus @ 2 ml/ litter water first spray was applied at the pea size fruit and second spray is applied 25 days prior to harvest.

The treatments are denoted as nano nitrogen @ 2 ml/ litter water (N_1), nano nitrogen @ 2 ml/ litter water + nano phosphorus @ 2 ml/ litter water (N_2), whereas control (N_0) is without application any nano-fertilizers. Data were recorded on growth parameters *viz.* plant height (cm), number of primary and secondary branches

on selected shoots and chlorophyll contents in leaves (SPAD value). Fruit physical parameters, *viz.* fruit volume (cm^3), specific gravity, fruit length at harvest (cm), fruit diameter at harvest (cm), pulp thickness (mm), pulp weight (g), stone weight and pulp: stone ratio. Yield parameters, *viz.* fruit setting, fruit drop (%), average fruit weight (g) and yield/ tree. Quality parameters, *viz.* ascorbic acid (Vit-C) (mg/100g pulp), total soluble solid (°Brix), total sugar (%), reducing sugar (%), non-reducing sugar (%) and fruit pH was also observed standard methods.

Results and Discussion

The treatment N_2 was found best for plant growth, increased number of primary and secondary branches and chlorophyl content compared to other treatments (Table 1). The maximum increase in growth of plant (6.45%), number of primary branches (14.72), number of secondary branches (22.09) and chlorophyll content in leaves (55.34 SPAD value) were recorded with the application of N_2 treatment (Leghari *et al.*,2016). Nano fertilizers increased the availability of plant nutrients for a longer period and slow release with plant growth, which increased the composition of chlorophyll, photosynthesis, and dry matter production and, as a result, improved overall plant growth (Al-Juthery *et al.*, 2018). It may be due to role in various physiological processes and gives the green parts of plant the dark green colour (Yadegari *et al.,* 2013). It is also better for nutrient absorption, improving nitrogen-use efficiency and increase nitrogen contain in plant which resulted in enhances of plant growth (Sami *et al.,* 2019). The increases of chlorophyll is due to the role of nano particle in improvement of leaves photosynthesis and decreasing the respiration rate (Mahmoud *et al.*, 2019).

There were maximum fruit volume (20.63 cm^3), specific gravity (0.95), length of fruit (3.42 cm), fruit diameter (3.16 cm), pulp thickness (12.56 mm), pulp weight (15.79 g), and pulp: stone ratio (19.20), whereas minimum stone weight (0.83 g) was recorded in treatment N_2 (nano nitrogen @ 2 ml/ litter water + nano phosphorus @ 2 ml/ litter water), however minimum fruit volume (18.92 cm^3), specific gravity (0.93), fruit length (2.73 cm), fruit diameter (2.86 cm), pulp thickness (10.71 mm), pulp weight (12.93 g), and pulp: stone ratio (15.00) were recorded with the application of N_0 (control). The higher nitrogen-use efficiency and significantly lower nutrient losses of nano-fertilizers lead to higher productivity (6–17%) and nutritional

Table- 1: Effect of nano fertilizers on growth and physical attributes of ber

Treatment	Plant height (cm)	Number of primary branches	Number of secondary branches	Chlorophyll content in leaves (SPAD value)	Fruit volume (cm^3)	Specific gravity	Fruit length at harvest (cm)	Fruit diameter at harvest (cm)	Pulp thickness (mm)	Pulp weight (g)	Stone weight (g)	Pulp: stone ratio
N_0	74.37	12.50	19.53	50.72	18.92	0.93	2.73	2.86	10.71	12.93	0.86	15.00
N_1	76.67	14.03	20.98	53.91	19.90	0.94	3.26	3.04	12.31	14.82	0.85	17.53
N_2	79.17	14.72	22.09	55.34	20.63	0.95	3.42	3.16	12.56	15.79	0.83	19.20
SEm(±)	1.325	0.213	0.260	0.427	0.345	0.0043	0.058	0.057	0.202	0.261	0.0066	0.12
CD (P = 0.05)	**3.809**	**0.612**	**0.747**	**1.228**	**0.991**	**0.0139**	**0.167**	**0.163**	**0.580**	**0.750**	**0.0192**	**0.34**

quality of vegetable crops was reported (Zahedi *et al.,* 2020).

The application of nano-fertilizers increased fruit productivity, quality and shelf-life through their positive effects on anatomical, morphological, physiological, physico-chemical, gene expression, regulation and translocation for mitigating abiotic stresses and molecular traits (Sharma *et al.*, 2021). It increased cell division, cell elongation, photosynthetic activity, enhanced rapidly reactivity of nutrient in plant (Davarpanah *et al.*, 2017).

It is essential for formation of adenosine triphosphate (ATP), which is currency of plant cell and it is also necessary for development of strong root system which are critical for nutrient uptake and water absorption (Kazem *et al.*, 2021). Nano fertilizers activate enzyme that are responsible for breakdown of organic acid and converting into energy, this energy is used for fruit growth and development and it is crucial component of amino acid which are building of blocks of protein (Al-Juthery and Al-Shami, 2019).

There was maximum fruit setting (6.92 %), average fruit weight (18.00 g) and yield/tree (64.57 kg) and minimum fruit drop (49.38 %) N_2 treatment. The combination of nano fertilizers (nano nitrogen @ 2 ml/ litter water + nano phosphorus @ 2 ml/ litter water) increased fruit setting, fruit weight and yield. There was increase in fruit size (length and width), weight and volume and minimum fruit setting (5.76%), average fruit weight (14.08 g) and yield/ tree (57.90 kg), whereas maximum fruit drop (56.35%) was recorded in N_0 (control).

Yadegari *et al. (*2013) and Meghany *et al.* (2019) also supported this study. Nano fertilizer has unique properties due to its small surface area with high absorption, which increase in photosynthesis and leaves area (Sekhon, 2014). It improves yield and quality of fruits and increase average weight of fruits through optimum use of nutrients (Al-juthery *et al.*, 2018; Davarpanah *et al.*, 2017). The presence of these elements also reduce stomatal resistance and increase stomatal conductivity, which provides the plant with enough carbon dioxide and water to continue photosynthesis and withdraw nutrients from soil leading to an increase in yield (Sharma *et al.*, 2021). Additionally, it is increasing the activity of enzyme involved in photosynthesis, stimulate production of growth-promoting hormones and improve nutrient uptake by plants (Kazem *et al.*, 2021). They also helping reduce plant stress caused by environmental

Table- 2: Effect of nano fertilizers on yield and quality attributes of ber

Treatment	Fruit setting (%)	Fruit drop (%)	Average fruit weight (g)	Yields (kg\tree)	Ascorbic acid (Vit-C) (mg/100g Pulp)	Total soluble solid (°Brix)	Total sugar (%)	Reducing sugar (%)	Non-reducing sugar (%)	pH
N_0	5.76	56.35	14.08	57.90	59.75	15.05	7.74	4.08	3.66	5.28
N_1	6.44	50.65	16.73	61.77	63.71	15.62	8.37	4.45	3.92	5.39
N_2	6.92	49.38	18.00	64.57	65.75	15.77	9.20	4.83	4.37	5.50
SEm(±)	0.089	0.750	0.147	1.257	0.569	0.036	0.0521	0.037	0.020	0.013
CD (P = 0.05)	0.257	2.157	0.422	3.613	1.636	0.106	0.1498	0.108	0.050	0.0397

factor such as drought or high salinity (Sharma *et al*., 2022) (Table 2).

The maximum ascorbic acid (65.75mg/100g pulp), total soluble solid (15.77°Brix), total sugar (9.20 %), reducing sugar (4.83 %), non-reducing sugar (4.37 %) and pH (5.50) were significantly higher over the control (Table 2). Similar results were also reported by Yadegari *et al.* (2013), Sharma *et al.* (2021), Davarpanah *et al.* (2017) and Kazem *et al.* (2021). The application of nano nitrogen @ 2 ml/ litter water + nano phosphorus @ 2 ml/ litter water had a positive effect in improving the quality of ber fruits, and higher T.S.S. due to higher chlorophyll activities, which is responsible for accumulate more photosynthates and sugar in fruit tissue, leading to increase in T.S.S. (Mishra *et al*., 2020) and also increase in the maturity index, total sugars and total phenols (Davarpanah *et al*., 2016).

Conclusion

It can be inferred that the application of nano nitrogen @ 2 ml/ liter water + nano phosphorus @ 2 ml/ litter water could give maximum growth, yield and fruit quality.

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Effect of processing methods on cyanogenic compounds, protein, and minerals of cassava leaves

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Abstract

This study investigated the effects of boiling, drying, and ensiling on linamarin content, protein content, and mineral composition of cassava (*Manihot esculenta* Crantz) leaves. The drying was found effective method for reducing linamarin content in most genotypes. Boiling had variable effects, with some genotypes showing similar or slightly lower linamarin levels compared to fresh leaves. Ensiling significantly reduced linamarin content after 7 days, with the reduction remaining stable up to 20 days, indicating its effectiveness in reducing cyanogenic compounds. However, genotypes, H 1687 and Malayan 4, showed a decrease in protein content during ensilage, suggesting potential nutritional changes. The study also observed dynamic changes in mineral composition of cassava leaves, with copper, zinc, iron, and manganese varying over time. These findings highlight the impact of different processing methods on nutritional quality of cassava leaves, emphasizing the need to consider these factors when using cassava leaves as animal feed.

Key words: Cyanogenic compounds, Genotype, Linamarin, Processing methods, Leaves

Cassava (*Manihot esculenta* Crantz) is a crucial staple food crop, extensively cultivated for its starchy roots (Suchitra and Byju, 2015; Soman and Byju, 2017). However, increasing attention has been given to the nutritional value of cassava leaves. Despite their nutritional benefits, cassava leaves contain anti-nutritional cyanogens (Nedunchezhiyan *et al.,* 2022; Gundersen *et al.,* 2022). Studying the distribution and levels of linamarin, a primary cyanogenic glycoside in various cassava genotypes is essential for evaluating the potential health risks of consuming cassava products (Ndam *et al.,* 2019). This knowledge supports the development of breeding strategies and the selection of cassava genotypes with reduced linamarin content (Sayre, 2022). Urgent interventions and regulations are needed to raise awareness about the health risks associated with cyanogens in cassava leaves and to promote proper processing methods to mitigate these risks (Okareh *et al.,* 2021). Microbial enzymes play a crucial role in converting cyanogens into less toxic compounds, resulting in significantly lower cyanide levels (Mahendran *et al.,* 2020). This study investigates the potential of fermentation, boiling, and drying in reducing cyanogen levels in cassava leaves, aiming to enhance cassava-based foods' safety and nutritional value.

Materials and Methods

Ten genotypes of cassava leaves were chosen from the field of ICAR-CTCRI, Thiruvananthapuram, Kerala during 2018-19. They were H-226, Sree Athulya, Me-833, Quintal, M-4 (Malayan), Sree Jaya, Sree Vijaya, H-1687 (Sree Visakam), Sree Swarna, and Ci-848. First, a representative sample of cassava leaves was collected. The sample was then weighed using a digital balance, and the weight was recorded as the fresh weight. The fresh sample was then placed in an oven set at a specific temperature (70°C) and left to dry, and the weight was recorded as the dry weight.

For the preparation of cassava leaf silage, 5 kg of fresh cassava leaves from Malayan 4 and H-1687 varieties were collected. The leaves were allowed to wilt for 12 hours until they reached a moisture content of 70%. Subsequently, wilted leaves were chopped into 10 mm pieces using a hand-operated chopping machine. The chopped leaves were weighed and mixed thoroughly with 50 g of activated encapsulated yeast (*Saccharomyces cerevisiae*) in a concentrated sugar

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solution, along with the addition of 10 g of urea. The inclusion of sugar helps accelerate the fermentation process. The mixture was well-blended and packed tightly into polypropylene plastic bags measuring 60 cm in width and 100 cm in length, ensuring the expulsion of air from the bags. Rubber bands were used to secure the bags, which were then placed in anaerobic conditions for 3-4 weeks. The mineral and nutrient content of the silage was monitored during the first, second, and third weeks, and the quality of the silage was compared to that of the fresh leaves.

Linamarase, enzyme responsible for catalyzing the breakdown of linamarin in cassava, was isolated from cassava latex obtained from the cut end of cassava petioles. The isolation process involved acetone and ammonium sulfate precipitation. Two g of cassava latex were mixed with 50 ml of phosphate buffer (pH 6.0) and stirred for 30 minutes. The solution was then centrifuged at 10,000 × g for 30 minutes, and the clear supernatant was divided into two equal fractions. In one fraction, chilled acetone was added in three times the volume, and the solution was refrigerated overnight. The precipitated proteins were collected by centrifugation, dissolved in 10 ml of phosphate buffer (0.1 M, pH 6.0), and stored at 4°C for further use. The second fraction, after removing cell debris, was subjected to 60% saturation ammonium sulfate and kept at 4°C overnight. The resulting precipitate was dissolved in 10 ml of phosphate buffer, extensively dialyzed against diluted buffer, and used for enzyme activity assay.

Samples of fresh, boiled, dried, and ensiled leaves were obtained and weighed (2 g). The samples were then homogenized with 25 ml of orthophosphoric acid using a mortar and pestle. After centrifugation at 5000 rpm for 15 minutes, the supernatant was collected. The residue was subjected to an additional extraction in 25 ml of orthophosphoric acid, and the resulting supernatants were combined and adjusted to a final volume of 50 ml. In test tubes, 0.1 ml of the supernatant was mixed with 0.4 ml of phosphate buffer (0.1 M, pH 7.0) and 0.5 ml of phosphate buffer (pH 6.0), making a total volume of 1 ml. Then, 20µl of the linamarase enzyme was added to tubes, which were incubated at 30˚C for 15 minutes. The reaction was halted by adding 0.6 ml of 0.2N NaOH and thorough mixing. After 1 minute, 2.8 ml of phosphate buffer (pH 6.0) was added and shaken. To this mixture, 0.1 ml of chloramine T solution was added, followed by the addition of 0.6 ml of iso-nicotinic acid barbiturate coloring reagent. The resulting pink complex was incubated for 10 minutes and its absorbance was measured at 605 nm.

The protein estimation was performed using the Lowry method. A standard protein solution was prepared from bovine serum albumin (BSA) at 1 mg/ml concentration. Dilutions were made ranging from 0.05 to 1 mg/ml. Each protein solution (0.2 ml) was placed in separate tubes. An alkaline copper sulfate reagent was formed by combining 2% sodium carbonate and 0.1 N NaOH (solution A), along with 1.56% copper sulfate and 2.37% sodium potassium tartrate (solution B). These solutions were mixed to create the reagent. Tubes received 2 ml of the reagent and were incubated for 10 minutes. Following this, 0.2 ml of Folin-Ciocalteu solution (diluted from commercial reagent) was added to each tube and incubated for an additional 30 minutes. The resulting purple color's absorbance was measured at 660 nm using a UV-visible spectrophotometer. A calibration curve was constructed using absorbance values and known protein concentrations. The absorbance of an unknown sample, treated similarly, was measured at 660 nm to determine its protein concentration using the calibration curve. The protein content value is expressed on a dry weight basis.

For the analysis of mineral content, dried powdered leaf samples were used. In test tubes, 0.5 g of the samples were combined with 15 ml of a tri-acid mixture consisting of nitric acid (HNO_3), perchloric acid ($HClO_4$), and sulphuric acid (H_2SO_4) in a ratio of 10:4:1. The tubes were left overnight in a beaker containing a small amount of sulphuric acid for wet digestion. After wet digestion, the samples underwent hot digestion on a hot plate at 125° C for approximately 2 hours to ensure complete digestion. Following cooling, the clear sample digest was taken and diluted to a final volume of 100 ml using distilled water. The tri-acid digest, obtained from the sample, was utilized for the estimation of Ca, Mg, Fe, Mn, Zn, and Cu using an Atomic Absorption Spectrophotometer (AAS).

The phosphorous content in leaf samples was determined using a calorimetric method with a spectrophotometer (Double beam spectrophotometer 2202, Systronics). A volume of 5 ml of the tri-acid digest was transferred to a 25 ml standard flask. To this, 5 ml of Vanadomolybdate reagent was added, and the final volume was adjusted to 25 ml with distilled water. The resulting sample solution was allowed to sit for one hour to develop color. The yellow color that formed was then measured at a wavelength of 420 nm

using the spectrophotometer, and absorbance value was recorded. The potassium (K) content in leaf samples was determined using a flame photometer. For analysis, 1 ml of tri-acid digest was transferred to a standard flask and diluted to a final volume of 25 ml. The resulting extract was directly measured using a flame photometer (Systronics Flame Photometer Model No. 128), utilizing the appropriate filter for potassium.

To assess the quality of cassava leaf silage, samples from H 1687 and Malayan 4 varieties enriched on day 7 and day 20 were selected. The protein, linamarin, and mineral contents were the parameters measured in this study. The procedures mentioned earlier were followed to determine these parameters. The samples were dried in an oven and then transformed into a powdered form for analysis.

Results and Discussion

The variation in linamarin content was investigated in fresh, dry, and boiled cassava leaf samples (Fig.1). The linamarin content was analyzed in the fresh leaf tissue of various cassava genotypes and among the samples, Sree Jaya exhibited the lowest linamarin content, measuring at 0.75 ± 0.20 mg/g (Fig.1). Slightly higher linamarin levels were observed in H 226, Malayan 4 and Sree Vijaya, with values of 1.24 ± 0.1 mg/g, 1.32 ± 0.36 mg/g and, 1.72 ± 0.44 mg/g, respectively. The genotype Quintal displayed the highest linamarin content, recording a value of 6.04 ± 1.69 mg/g. Sree Athulya demonstrated the second-highest linamarin content among all genotypes tested, measuring at 4.40 ± 0.05 mg/g. Overall, the observations in fresh leaves demonstrated significant variance in linamarin content among the investigated cassava genotypes.

Boiling cassava generally resulted in a decrease in linamarin content (Fig.1), as observed in most genotypes compared to fresh leaves. Sree Jaya, Sree Vijaya, Malayan 4, H 226, Sree Athulya, Sree Swarna, and Ci 848 showed lower linamarin levels in boiled samples compared to the fresh ones. H 1687 and Me 833 exhibited a moderate decrease in linamarin content after boiling. Quintal and Me 833 displayed the highest linamarin levels among the genotypes, with values of 1.20 ± 0.06 mg/g and 1.077 ± 0.39 mg/g, respectively. On the other hand, Ci 848 and Sree Jaya exhibited the lowest linamarin content at 0.34 ± 0.01 mg/g and 0.39 ± 0.01 mg/g.

Drying had variable effects, with some genotypes showing similar or slightly lower linamarin levels in dried samples compared to the boiled ones (Fig.1). Among the genotypes tested, Sree Jaya, Sree Vijaya, Malayan 4, H 226, Sree Athulya, Quintal, Sree Swarna, and Ci 848 exhibited similar linamarin levels in the dried samples, ranging from 0.34 ± 0.02 mg/g to 0.41 ± 0.01 mg/g. The H 1687 and Me 833 genotypes showed a slightly higher linamarin content compared to the aforementioned genotypes, with a value of 0.51 ± 0.06 mg/g and 0.44 ± 0.06 mg/g, respectively. The linamarin

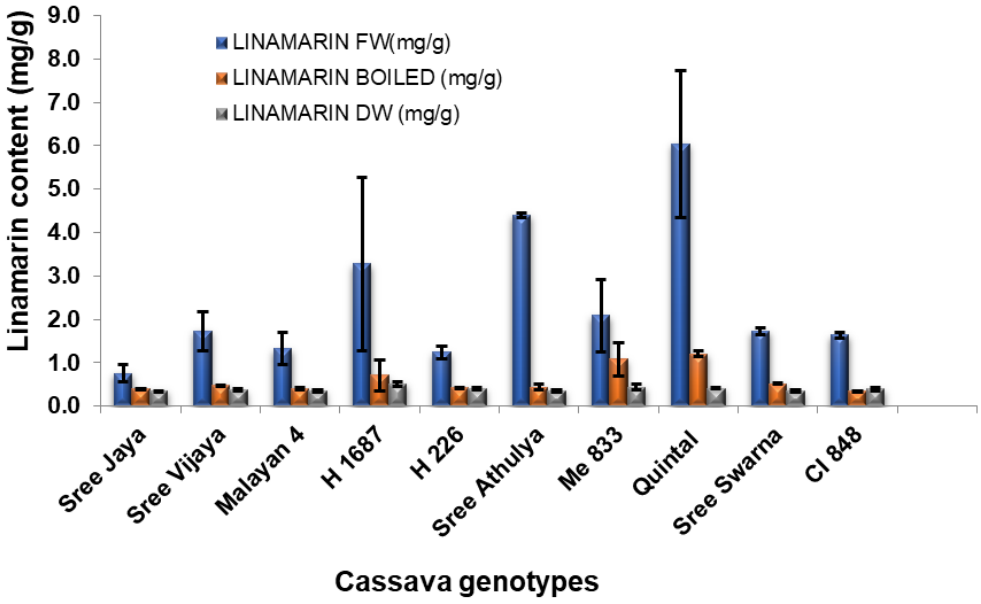

Fig. 1: Variation in linamarin content in fresh (FW), dried (DW), and boiled leaf samples of cassava genotypes

content was found lowest in Sree Swarna, Malayan 4 and Sree Athulya genotypes with the values 0.34 ± 0.02 mg/g, 0.35 ± 0.01 mg/g and 0.35 ± 0.02 mg/g, respectively. The analysis of linamarin content in various cassava genotypes revealed significant variation. These findings are consistent with previous studies that have highlighted the variability in cyanogenic potential among different cassava genotypes (Chaiareekitwat *et al.,* 2022) and useful for selection of best genotype for indeed applications (Swaroop *et al.,* 2019). Overall, drying was more effective in reducing linamarin content in cassava compared to boiling and fresh leaves samples. The drying and boiling effects on linamarin content in cassava have been widely studied. The drying cassava roots resulted in less linamarin breakdown compared to boiling (Ndubuisi and Chidiebere, 2018). However, other studies have shown that drying with higher moisture levels can enhance linamarin breakdown (Bolarinwa *et al.,* 2016). Drying at elevated temperatures has been found to promote linamarin degradation, leading to a decrease in linamarin content (Junior *et al.,* 2019). On the other hand, boiling cassava generally leads to a reduction in linamarin content, as observed in most genotypes (Panghal *et al.,* 2019). The high temperature during boiling treatment results in the inactivation of heat-sensitive enzymes such as linamarase, which is responsible for the degradation of linamarin (Panghal *et al.,* 2019). The boiling cassava roots at temperatures above the boiling point of HCN facilitates the release of HCN, contributing to linamarin degradation (Ndubuisi and Chidiebere, 2018). The formation of HCN during boiling might be attributed to the thermal degradation of cyanohydrins, which are intermediates in the breakdown of linamarin.

The linamarin contents of ensilaged leaf samples for genotypes H1687 and Malayan 4 were studied and analyzed on the 7th and 20th day of ensilage. The initial linamarin content (mg/g) of H1687 was 3.27 ± 1.99, while for Malayan 4, it was 1.32 ± 0.36 on day 0 (Table 1). However, after 7 days of ensilage, the linamarin content significantly decreased for both genotypes, with H1687 showing a content (mg/g) of 0.35 ± 0.001 and Malayan 4 exhibiting 0.36 ± 0.03. By the 20th day of ensilage, the linamarin content (mg/g) remained relatively stable, with H1687 measuring at 0.35 ± 0.01 and Malayan 4 at 0.36 ± 0.001. There was a decrease in linamarin content during the ensilage period for both genotypes, suggesting a potential reduction in cyanogenic compounds in the ensilaged leaf samples. These findings align with previous studies that have demonstrated the effectiveness of ensiling in reducing cyanogenic compounds in cassava biomass (Unigwe *et al.,* 2023). The observed decrease in linamarin content during ensilage highlights the hydrolysis process, wherein linamarin is converted into less toxic compounds. This outcome has important implications for the safety and utilization of cassava leaf biomass in monogastric animal diets. Thus, ensilage can be considered a viable method for reducing linamarin content and enhancing the safety of cassava leaf biomass for animal feed applications.

In addition, the genotypes were tested to find out more about the influence of ensilaged leaf samples on cassava nutrition. Both the H 1687 and Malayan 4 (M4) genotypes of cassava leaf ensilage experienced a reduction in protein content on both the 7th and 20th days (Table 1). Specifically, the protein content of H 1687 decreased from an initial value of 0.28 ± 0.02 g/g to 0.24 ± 0.018 g/g on the 7th day and further to 0.19 ± 0.012 g/g on the 20th day. Similarly, the protein content of Malayan 4 decreased from the initial value of 0.28 ± 0.019 g/g to 0.22 ± 0.017 g/g on the 7th day and then to 0.20 ± 0.01 g/g on the 20th day.

The mineral analysis of cassava leaf genotypes, Malayan 4 and H 1687, on the 0th, 7th, and 20th day of enrichment revealed dynamic changes in copper (Cu), zinc (Zn), iron (Fe), and manganese (Mn) content (Fig.2). The copper content in Malayan 4 increased from 28.3 mg/l initially to 34.3 mg/l (7th day) and 44.6

Table. 1: Changes in linamarin and protein content of cassava leaf silage

Genotype	Days after treatment	Linamarin content (mg/g)	Protein content (g/g)
H1687	0	3.27 ± 1.99	0.28 ± 0.02
	7	0.35 ± 0.001	0.24 ± 0.018
	21	0.35 ± 0.01	0.19 ± 0.012
Malayan 4	0	1.32 ± 0.36	0.28 ± 0.019
	7	0.36 ± 0.03	0.22 ± 0.017
	21	0.36 ± 0.001	0.20 ± 0.01

mg/l (20th day), while H 1687 showed an increase from 28.5 mg/l to 46.2 mg/l (7th day) and then a decrease to 33.2 mg/l (20th day). Zinc content decreased over time for both genotypes, with Malayan 4 dropping from 176.2 mg/l to 167.2 mg/l (7th day) and 127 mg/l (20th day), and H 1687 decreasing from 230.9 mg/l to 166.1 mg/l (7th day) and 144.3 mg/l (20th day). Iron content was found 476.7 mg/l and 475.4 mg/l for Malayan 4 and H 1687, respectively on 0th day, the content decreased on the 7th day, reaching 397.1 mg/l (Malayan 4) and 379.7 mg/l (H 1687), followed by a slight increase to 433.4 mg/l (Malayan 4) and 394 mg/l (H 1687) on the 20th day. Manganese content decreased to 117.2 mg/l (Malayan 4) and 162.8 mg/l (H 1687) on the 7th day, and then increased to 160 mg/l (Malayan 4) and decreased to 104.2 mg/l (H 1687) on the 20th day. Initially the manganese content was observed as 311.5 mg/l and 222.7 mg/l for Malayan 4 and H 1687, respectively on 0th day. These results highlight the dynamic nature of mineral content during the enrichment process for these cassava genotypes. The phosphorus (P) content in the leaf samples was relatively low, with Malayan 4 and H 1687 exhibiting initial values of 2.467 mg/l and 2.577 mg/l, respectively. On the 7th day of enrichment, the phosphorus content increased to 2.913 mg/l (Malayan 4) and 2.241 mg/l (H 1687), and further 2.86 mg/l (Malayan 4) and 2.66 mg/l (H 1687) on the 20th day.

Changes in mineral content of potassium (K), calcium (Ca), and magnesium (Mg) in cassava leaf silage were also investigated (Fig.3). Regarding potassium content, Malayan 4 started with 14150 mg/l and decreased to 9075 mg/l (7th day) and then increased to 10600 mg/l (20th day), while H 1687 started with 19275 mg/l and decreased to 12025 mg/l (7th day) and 7650 mg/l (20th day). Calcium content showed a decrease for both genotypes, with Malayan 4 dropping from 9127.5 mg/l to 5765 mg/l (7th day) and then increased to 6630 mg/l (20th day), and H 1687 dropping from 8462.5 mg/l to 7532.5 mg/l (7th day) and 6465 mg/l (20th day). Similarly, magnesium content decreased for both genotypes, with Malayan 4 dropping from 6977.5 mg/l to 3952.5 mg/l (7th day) and increasing to 5290 mg/l (20th day), and H 1687 dropping from 6037.5 mg/l to 5135 mg/l (7th day) and 4472.5 mg/l (20th day).

Based on the provided results, the mineral content of cassava leaves, specifically copper, zinc, iron, manganese, phosphorus, potassium, calcium, and magnesium, exhibited dynamic changes during the enrichment process. These findings are consistent with previous studies on the mineral composition of cassava leaves, which have reported variations in mineral content at different growth stages and during maturity (Laya *et al.,* 2023). The observed changes in mineral content could be attributed to factors such as plant

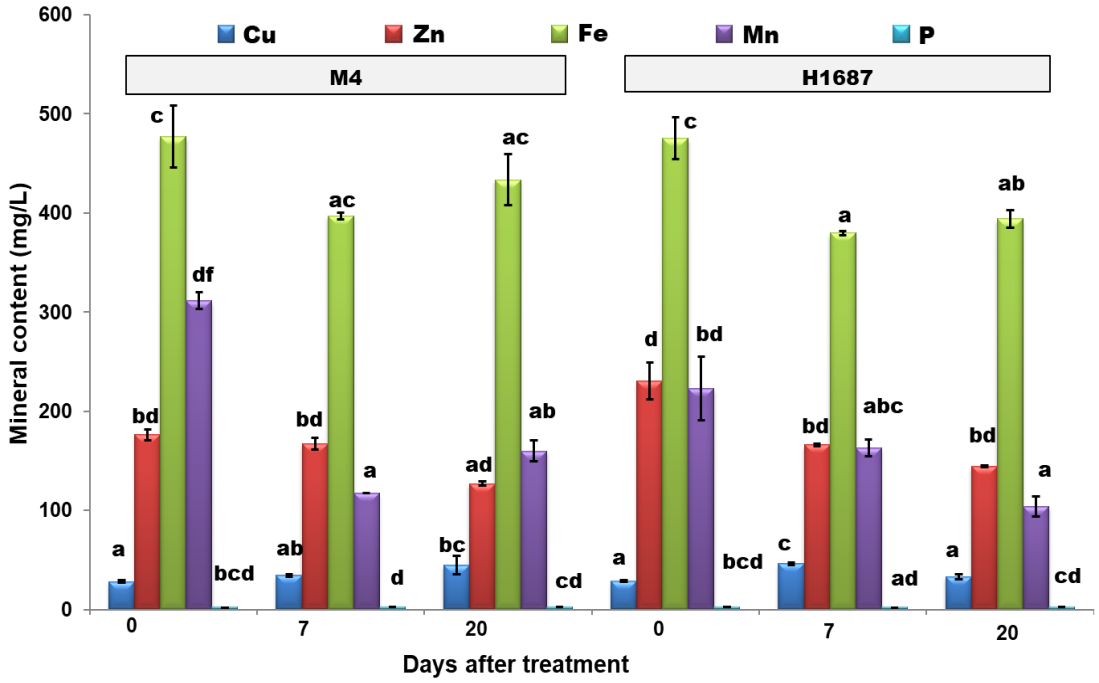

Fig. 2: Changes in mineral content (Cu, Zn, Fe, Mn and P) in cassava leaf silage

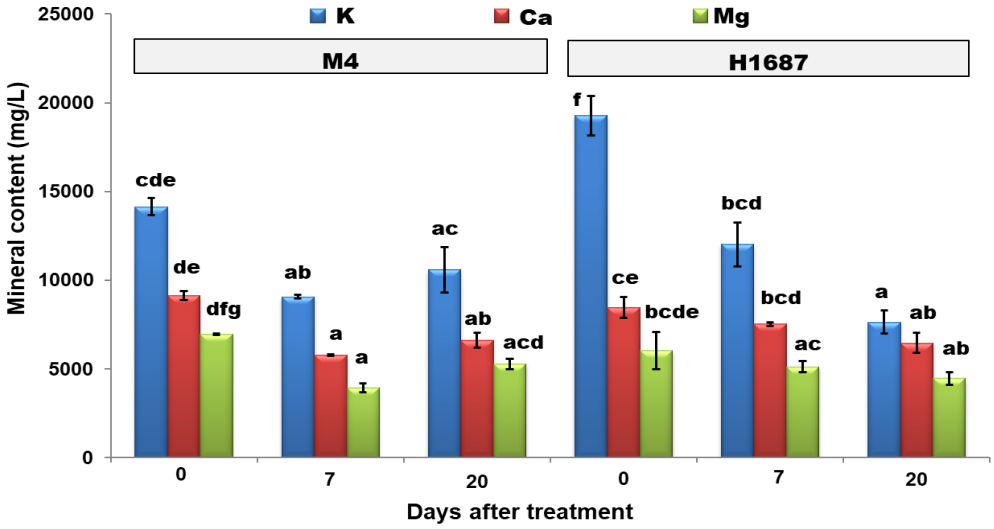

Fig. 3: Changes in mineral content (K, Ca, Mg) in cassava leaf silage

maturity, nutrient availability, and the physiological processes occurring during leaf development. Additionally, the use of ensilage techniques and additives, as highlighted in studies involving cassava (Oduguwa *et al.,* 2007), may have influenced the mineral content changes during the enrichment process. These results emphasize the importance of considering the mineral composition of cassava leaves and their variations over time when evaluating their nutritional value and potential utilization as animal feed (da Silva Santos *et al.,* 2020).

Conclusion

This study reveals that ensilage and drying cassava effectively reduces linamarin levels while boiling also contribute to the reduction of cyanogenic compounds. Protein content decreased during ensilage, indicating potential changes in nutritional value. The mineral composition of cassava leaves exhibited dynamic changes during the enrichment process, emphasizing the need to consider these variations when assessing their nutritional value. These findings provide valuable insights into the safe utilization of cassava leaves as animal feed, highlighting the importance of appropriate processing methods to enhance their safety and nutritional quality. Further research is warranted to explore additional processing techniques and their effects on cassava leaf composition.

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Response of packaging material and storage condition on postharvest quality of tuberose *(Polianthes tuberosa)* loose flowers

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Abstract

The study was carried out at ICAR-Indian Agricultural Research Institute, New Delhi, to study the response of packaging materials, *viz.* woven bag, high density polyethylene (HDPE) 51 micron , low-density polyethylene (LDPF) 25 micron, muslin cloth bag and bamboo basket (control, without packaging) and two storage conditions, *i.e.* ambient condition (22) and cold storage (or low temperature) condition (and 85-95% relative humidity) on keeping quality attributes of loose flowers of single petalled tuberose (*Polianthes tuberosa* Linn.) cv. Arka Prajwal. Fully developed unopened florets were harvested in early morning (before sunrise). The packaging and storage condition significantly influenced all parameters. Among all treatments, loose flowers packed in HDPE 51 micron bag and stored under cold storage recorded maximum flower diameter (8.99 mm), flower opening index (77.85%), colour (whiteness) index (89.13%) and shelf-life (6.00 day) of loose flowers under cold storage condition. On the other hand, in control treatment the above said parameters recorded were 6.98 mm, 50.00%, 54.10% and 3.50 day, respectively. Under ambient condition, maximum flower diameter (8.08 mm), flower opening index (66.00%), colour index (91.85%) and shelf-life (4.00 day) of flowers were recorded with HDPE 51 micron packaging. In control treatment, these parameters were 6.73 mm, 50.00%, 63.77% and 1.50 days, respectively. Thus, it can be concluded that among packaging materials HDPE 51-micron thickness bag was found to be the best for packing of loose flowers of tuberose cv. Arka Prajwal under both ambient and cold storage conditions.

Key words: High-density polyethylene, Loose flowers, Packaging material, *Polianthes tuberosa*, Storage condition

Tuberose **(***Polianthes tuberose* Linn.**)** belonging to the family Agavaceae, can be used as loose flower, cut flower, landscaping or bedding purposes and extraction of essential oils for perfume industry, etc. (Jain *et al,* 2015.). The major portion of tuberose flowers consumption is in form of loose flowers, followed by cut flowers and extraction of essential oils (Singh *et al.,* 2010). Postharvest technologies like packaging and storage of flowers are helpful to restrict the changes in metabolic activities. Packaging is a technique of protecting the flowers from physical damage, water loss and external conditions during transport and enhance the shelf-life of flowers (Majumdar *et al.,* 2014, Panwar *et al.*, 2020). However, very little information is available on the storability of loose flowers of tuberose. Keeping in view, present study was undertaken to find out suitable packaging material and storage condition for enhancing shelf-life and quality of loose flowers of single petalled tuberose cv. Arka Prajwal.

Materials and Methods

The experiment was conducted at ICAR-Indian Agriculture Research Institute, New Delhi, during 2020-2021. The unopened mature florets of Single petalled tuberose cv. Arka Prajwal were harvested during early morning hours. Five packaging materials and two storage conditions namely, P_1-woven bag, P_2-High density polyethylene, (HDPE) 51 micron () thick bag, P_3-low density polyethylene (LDPE) 25 micron () thick bag, P_4-muslin cloth bag and P_5-bamboo basket (control) and two storage conditions -S_1-ambient condition (22) and S_2-cold storage condition (or low temperature) condition -(with 5±1° and 85-95% relative humidity) were used. Mature unopened florets weighing 2 kg for each treatment were taken. Periodical observations on flower diameter (mm), flower opening index (%), colour (whiteness) index and shelf-life (days) were recorded. The flower diameter (mm) was measured with ten flowers at widest part by using Digital Vernier Calipers and then averaged. For recording the flower opening index (%) on each day of observation, number of opened flowers (whether

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fresh or wilted) were recorded and expressed as percentage. The colour (whiteness index, WI) used as an indicator of intensity of white colour was calculated by using numerical values of L*, a* and b*. As per the commission on Illumination (CIE) L* a* b* system of colour representation, L value corresponds to a dark-bright scale and represents the relative hue (colour). The a* and b* values extend from -60 to 60; a negative is for green a* positive is for red and b* negative is for blue and a positive for yellow.

The Whiteness index was calculated by using following formula: Whiteness index (WI) = 100 - [(100-L*) + (a^{*2} + b^{*2}) 1/2. The shelf-life of flowers was determined as the number of days taken from placing the mature flower buds till wilting/fading of petals and time taken for development of necrotic symptoms was recorded. The statistical design of experiment was followed factorial completely randomized design (FCRD) in which packaging materials and storage conditions were two factors and all treatments were replicated four times. Recorded data were subjected to statistical analyses. Complication of mean, standard error (SE) and critical difference (CD) was used for all comparisons where significance - probability () were found using OPSAT version 6.1 software for analysis of variance (ANOVA).

Results and Discussion

There was a significant difference among the packaging material, duration and their interaction on diameter of floret. Among five packaging materials, flowers packed in HDPE 51 micron recorded the maximum floret diameter, (8.08 mm) which was statistically higher with other treatments of packaging materials, whereas minimum floret diameter (6.73 mm) was recorded in control treatment (bamboo basket) (Table 1). The maximum floret diameter (8.00 mm) was recorded on fourth day which was statistically higher with other days, while minimum floret diameter (6.19 mm) was recorded on zero day, i.e. on initial day. The interaction effect of packaging material and duration indicates that the maximum floret diameter (8.83 mm) was recorded in loose flowers packed in HDPE 51 micron on fourth day, while the minimum floret diameter (5.30 mm) was recorded in control treatment on zero day.

Under cold storage condition, there was a significant difference among packaging material, duration and their interaction. (Table 1). The loose flowers packed in HDPF 51 micron recorded the maximum floret diameter (8.99 mm) which was higher with other packaging materials, whereas minimum floret diameter (6.98 mm) was observed under control treatment. The maximum mean of floret diameter (9.07 mm) was recorded on sixth day, which was higher with other days and at par with fifth day, while minimum floret diameter (6.13 mm) was observed on zero day. The interaction effect of packaging material and duration indicates that the maximum floret diameter (10.82 mm) was recorded in flowers packed in HDPE 51 micron on sixth day, which was statistically at par with P_2 treatment on fifth day, while minimum floret diameter (5.39 mm) was recorded on zero day, which was statistically at par with P_4 treatment (muslin cloth bag).

Loose flowers packed in HDPE 51 micron recorded maximum floret diameter and minimum floret diameter under control treatment (bamboo basket). This might be due to modified atmosphere conditions of high carbon dioxide, high relative humidity and low oxygen concentration within a package result in low respiration (Farber *et al.,* 2003) and helps in minimizing loss of carbohydrates as well as water by a process of respiration and transpiration, respectively (Zeltzer *et al.,* 2001) from the petal cells and increase floret opening results in increased floret diameter. Reduced floret diameter in control treatment was due to the inhibition of corolla growth and flower opening as a result of low water potential and low carbohydrates states in the petal cells (Viresh *et al.,* 2023). Our findings are in close agreement with the results obtained by Khongwir *et al.* (2017) in Single petalled tuberose cultivars.

There was a significant difference among the packaging material, duration and non-significant difference on their interaction on floret opening (Table 2). Among packaging material, loose flowers packed in HDPE 51 micron recorded the maximum mean of floret opening (66.00%) which was higher with other packaging materials, whereas the minimum flower opening (38.00%) was recorded under control treatment flowers. The maximum mean of flower opening (72.00%) was recorded on third and fourth day, which was higher with other days, while the minimum mean of flower opening (20.00%) was recorded on zero day i.e. on first day.

Under cold storage condition, there was a significant difference among packaging material, duration and non-significant difference on their interaction. Flowers packed in HDPE 51 micron observed the maximum mean of floret opening (77.85%) which was statistically higher with other packaging materials, whereas the minimum floret opening

(50.00%) was recorded in control treatment. The maximum flower opening (78.00%) was recorded on fifth and sixth day, which was statistically higher with other days, while the minimum mean of flower opening (23.00%) was recorded on zero day. In our study, loose flowers packed in HDPE recorded the maximum flower opening index. Flower opening associated with change in petal orientation. Osmotic changes in special cells, at petal base results in opening and closing movements in flowers. Metabolic activity in flowers are regulated by modified atmosphere condition created within the package (Goszezynska and Rudnicki, 1988) and maintenance of relative humidity may influence flower opening. Gladiolus spikes dry stored in polyethylene sleeves indicated considerable decline in post storage vase life and opening of florets, with an increase in storage duration (Jhanji and Dhatt 2017). Similar trend was observed in our study also where flower opening declined towards the end of storage duration. This might be due to a decline in stored food and water status in the petal cells with the advancement of storage duration (Khongwir *et al.,* 2017).

Under ambient conditions, a significant difference among packaging material, duration and their interaction was observed on colour index of loose flowers of tuberose. Among five packaging materials, flowers packed in HDPE 51 micron recorded the maximum white colour (91.85) which was statistically better with other packaging materials; whereas minimum white colour (79.19) was recorded in control treatment flowers. The maximum mean of white colour (99.19) was recorded on zero day, which was statistically superior with other days, while minimum mean of white colour (72.79) was recorded on fourth day. Interaction effect of packaging material and duration shows that the maximum white colour (99.82) was recorded in flowers packed in HDPE 51 micron on zero day, while minimum white colour (63.77) was recorded in control treatment flowers on sixth day.

There was a significant difference among packaging material, duration and their interaction. Flowers packed in HDPE 51 micron recorded the maximum white colour (89.13) which was statistically higher with other packaging materials, whereas the minimum white colour (77.79) was recorded in control treatment. The maximum mean of white colour (99.32) was recorded on zero day which was statistically superior with remaining days, while the minimum mean of white colour (65.70) was recorded on sixth day. Interaction response of packaging material and duration indicates that the maximum white colour (99.95) was recorded in flowers packed in HDPE 51 micron on zero day, while the minimum white colour (54.10) was recorded in control treatment on sixth day.

The flowers packed in HDPE 51 micron recorded maximum white colour retention on zero day under ambient (99.19) and cold storage (99.95) condition and the minimum white colour under ambient (63.77) and cold storage (54.10) conditions on sixth day. It might be due to cellular senescence process of loose flowers which proceeded even during cold storage and such senescence activities were carried out at the expense of stored food in flowers. Although, at low temperature it was possible to store the flowers for longer period, the white colour was reduced as compared to shorter period (Happy *et al.,* 2022). Higher relative humidity and lower temperature might have favoured more white colour in tuberose (Bhuvanesari and Sangama, 2017). Our results are also in close conformity with those of Sharma *et al.* (2021) and Choudhary *et al.* (2019).

There was a significant difference among different packaging materials on shelf-life of tuberose loose flowers. Among five packaging materials tested, flowers packed in HDPE 51 micron recorded maximum shelf-life (4.00 day) which was statistically higher with other packaging materials and at par with P_3 treatment (LDPE 25 micron) whereas the minimum shelf-life (1.5 day) was observed in control treatment (bamboo basket). Under cold storage condition, there was significant difference among packaging materials on shelf-life of flowers. Flowers packed in HDPE 51 micron recorded maximum shelf-life (6.00 day) which was statistically higher with other packaging materials and the minimum shelf-life (3.50 day) was recorded in control treatment (bamboo basket). The maximum shelf-life of flowers packed in polyethylene may be due to the reason that polyethylene sheet provide modified atmosphere, which increases carbon dioxide concentration as well as relative humidity and slows down the respiration process (Viresh *et al,* 2023). Furthermore, it might have more amount of carbohydrates and energy because of permeability of polyethylene sheet which may lead to increase in shelf-life of loose flowers. Our results are in close conformity with the results of Singh *et al.* (2023), (Varu and Barad, 2008); Majumdar *et al.* (2014) in tuberose and Sharma *et al.* (2021) Naveen *et al.,* (2024) in marigold flowers.

Conclusion

The high density polyethylene (HDPE) 51 micron bag was found to be the best packaging material. The maximum flower diameter, flower opening index, colour (whiteness) index and vase-life were recorded in loose flowers of tuberose cv. Arka Prajwal packed in 51 micron bag under both ambient and cold storage conditions. Tuberose flowers stored under low temperature condition recorded significantly higher flower diameter, flower opening index, colour (whiteness) index and shelf-life as compared to ambient conditions.

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Evaluation of grafted brinjal (*Solanum melongena*) for doubling yield in climate resilient condition

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Abstract

A field experiment on grafted brinjal *Solnum meloagena* L. was conducted at Agoor village, Villupuram district, Tamil Nadu, India, during November 2020-December 2021. Turkey berry (*Solanum torvum* Sw.) resistant to verticillium wilt and bacterial wilt (*Ralstonia solanacearum*), was used as rootstock for grafting of brinjal. Seeds of Turkey berry were soaked in water for 12,24 and 36 hours and sown in 98 cavity protrays containing well decomposed cocopeat and raised beds. The germination was significantly higher when Turkey berry seeds was soaked for 36 hours and sown in protrays. After 30 days of Turkey berry sowing, brinjal seeds were sown in 98 cavity protrays. The scion from 30-35 days old brinjal was grafted on 55-60 days old rootstock, Turkey berry using grafting clips and kept under shade net. The crop duration was significantly higher in grafted brinjal compared to seedlings. The grafted brinjal was maintained up to one year. The fruit yield was significantly higher in grafted brinjal (6.01 kg / plant and 60.6 t / ha) compared to seedlings (3.12 kg / plant and 30.14 t / ha). The gross income was significantly higher in grafted brinjal than seedlings. The net income of ₹.5,41,300/- was recorded with benefit cost ratio of 2.51 in grafted brinjal. Shoot-borer infestation was less and easily manageable in grafted brinjal. The fruit-borer infestation (11.70%) was lower in grafted brinjal than seedlings (21.55%). There was no wilt incidence in grafted brinjal.

Key words: Grafted brinjal, Turkey berry, Rootstock, Germination, Grafting, Shoot-borer, Fruit-borer, Wilt, Yield, Net income

Grafting enhances nutrient uptake (Santa-Cruz *et al.*, 2002), duration of harvesting and fruit quality (Colla *et al.*, 2006). Grafting enhances water and nutrient uptake and nutrient-use efficiency (Santa-Cruz *et al.*, 2002), to extend the duration of harvest time and to improve fruit quality (Colla *et al.*, 2006). Brinjal (*Solanum melongena* L.), is susceptible to many pests and diseases. The losses caused by shoot and fruit-borer (*Leucinodes orbonalis* Guenee) vary from season to season. Yield loss of brinjal is high due to shoot and fruit-borer (Jat and Pareek, 2003). Integrated pest management strategies were effective in controlling shoot and fruit borer in eggplant (Pandey *et al.*, 2016). Grafting with rootstocks can provide added vigour, fruit quality (Kumbar *et al.*, 2021) and resistance to abiotic stress, insect pests and diseases. Grafting reduces pesticides to manage soil-borne diseases (Bletsos *et al.*, 2003) and salinity (Singh *et al.*, 2024). Turkey berry (*Solanum torvum* Sw.) is resistant to verticillium wilt (Alconero *et al.*, 1988) and bacterial wilt (Yenare *et al.*, 2023) caused by *Ralstonia solanacearum* (Ramesh *et al.*, 2016) and used as rootstock (Bodakonda *et al.*, 2017) for grafting of brinjal. Graft compatibility and success was significantly influenced by scions and rootstocks (Deepa Adiveppa *et al.*, 2024). The survival rate of grafted plants using Turkey berry rootstock was good (Petran and Hoover, 2014). Keeping in view, technology demonstration of location-specific intervention was conducted at farmers fields in most vulnerable district to impart knowledge and provide confidence to cope up with adverse climate conditions.

Materials and Methods

Demonstration on cultivation of grafted brinjal was conducted at Agoor village, Tindivanam Taluk, Villupuram district, Tamil Nadu, India, during November 2020-December 2021. Seeds of Turkey berry (*Solanum torvum* Sw.) were soaked in water for 12, 24 and 36 hours and sown in raised beds and 98 cavity protrays containing well-decomposed cocopeat. Germination started from 15 days and continued up to 30 days. After attaining 2 - 3 leaf stage, Turkey berry seedlings were transplanted in 50 cavity protrays containing well-decomposed cocopeat. After 30 days of Turkey berry sowing, brinjal seeds were sown in 98 cavity protrays.

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The scion from 30 - 35 days old brinjal cultivar PLR 2 was grafted on 55 - 60 days old rootstock, Turkey berry using grafting clips and kept under shade net. After graft union was successful, brinjal grafts cultivar PLR 2 were distributed to farmers. The grafts were transplanted at a spacing of 0.8 m x 0.8 m. After establishment, data on yield, pest and diseases incidence was recorded. The data were subjected to statistical analysis (Panse and Sukhatme, 1985).

The incidence of shoot-borer, fruit-borer and wilt were recorded as %.

Shoot-borer (%) = number of shoot borer affected branches/total number of branches × 100

Fruit-borer (%) = number of fruit-borer infested fruits/total number of fruits × 100

Wilt = number of wilt affected branches/total number of plants × 100

Results and Discussion

The germination of Turkey berry seeds was significantly higher when seeds soaked for 36 hours and sown in protrays followed by sown in raised beds (Table 1). The germination was uniform in protrays. The higher germination recorded in seeds soaked for 36 hours might be due to leaching of germination inhibitors. The crop duration was significantly higher in grafted brinjal compared to seedlings. The grafted brinjal was maintained up to one year. Yield is significantly increased by manures and micronutrients (Jat *et al.*, 2023). The fruit yield was significantly higher in grafted brinjal (6.01 kg / plant and 60.6 t / ha) compared to seedlings (3.12 kg / plant and 30.14 t / ha).

The double yield was recorded in grafted brinjal compared to brinjal seedlings (Sudesh et al., 2021). The higher yield was recorded in grafted brinjal by Quamruzzaman *et al.*, 2018. The gross income was significantly higher in grafted brinjal than seedlings. The net income of ₹.5,41,300/- was recorded higher in grafted brinjal with benefit cost ratio of 2.51 compared to seedlings with benefit cost ratio of 1.34.

Shoot-borer (*Leucinodes orbonalis* Guenee) was less (9.34%) and easily manageable in grafted brinjal. The fruit-borer infestation (11.70%) was lower in grafted brinjal than seedlings (21.55%). Grafting of vegetables is an effective for managing pathogens and pests (Louws *et al.*, 2010). There was no wilt incidence in grafted brinjal while wilt incidence was recorded in seedlings (20.44%). The freshness of brinjal fruits harvested from grafted plants was also good after harvesting.

Conclusion

It is concluded that there is two-fold increase in yield in grafted brinjal over seedlings. The net income of ₹.5,41,300/- was recorded in grafted brinjal. The damage due to shoot-borer and fruit-borer was lower in grafted brinjal. There was no wilt incidence in grafted brinjal.

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Table 1: Germination percentage of Turkey berry seeds in raised beds and protrays

Treatment	Germination (%)
Turkey berry seeds sown in raised beds	-
Turkey berry seeds soaked in water for 12 hours and then sown in raised beds	2.39
Turkey berry seeds soaked in water for 24 hours and then sown in raised beds	35.92
Turkey berry seeds soaked in water for 36 hours and then sown in raised beds	64.78
Turkey berry seeds sown in protrays	-
Turkey berry seeds soaked in water for 12 hours and then sown in protrays	4.15
Turkey berry seeds soaked in water for 24 hours and then sown in protrays	50.23
Turkey berry seeds soaked in water for 36 hours and then sown in protrays	87.77
SEd	1.15
CD (0.05)	2.31

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Estimation of magnitude of heterosis for growth traits in onion (*Allium cepa*)

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Abstract

The experiment was conducted to estimate the magnitude of heterosis for growth traits in onion (*Allium cepa* L.) for 28 F_1s crosses at SKN College of Agriculture, Jobner, Rajasthan. These genotypes were planted in randomized block design with three replications under 3 date of sowing during *rabi* season,2022-23. The most heterotic crosses for growth contributing characters were RO-59 × Bhima Shakti, Pusa Shobha × Pusa Red, Bhima Shakti × Pusa Shobha RO-59 × Pusa Shobha, Kashi No. 1 × Pusa Red and RO-1 × Pusa Red. The crosses had significant heterobeltiosis for growth contributing characters RO-59 × Bhima Shakti, Bhima Shakti × Pusa Shobha, Pusa Shobha × Pusa Red RO-1 × Kashi No. 1, RO-1 × RO-59 and RO-1 × Pusa Madhavi. These crosses were considered promising for their use for growth improvement in onion.

Key words: Heterosis, Growth, Heterobeltiosis, Crosses, Improvement.

Onion (*Allium cepa* L.), 2n = 16, is a member of family Alliaceae. In India, onion is cultivated mainly in Maharashtra, Karnataka, Madhya Pradesh, Gujarat, Rajasthan and Bihar, occupying 1914 thousand ha with a total production of 31.12 million tonnes. In Rajasthan, it is grown extensively in Alwar, Ajmer, Jodhpur, Sikar, Nagaur, Jhunjhunu, Heterosis can be defined as superiority or inferiority of F_1 hybrid over its parents. It can be measured over mid-parent value (relative heterosis), better parent value (heterobeltiosis) and check parent (standard heterosis). Heterosis leads to superiority in adaptation, yield, quality, disease resistance, maturity and general vigour over its parents (Shull, 1914). The magnitude of heterosis depends on accumulation of favourable dominant alleles in F_1 population. If parental population differ from each other for more favourable alleles, magnitude of heterosis will also be proportionately higher. Heterosis helps to identify potential genotypes or crosses to develop high potential cultivars for growth traits in onion.

Materials and Methods

The experiment was conducted at Horticulture farm, SKN College of Agriculture, Jobner (Jaipur) (Rajasthan), during *rabi* season of 2022-23. Eight genetically diverse parents namely, RO-1, RO-59, Bhima Kiran, Bhima Shakti, Pusa Shobha, Pusa Madhavi, Kashi No. 1 and Pusa Red were crossed in diallel fashion excluding reciprocals. All the 28 F_1s were evaluated in a randomized block design with three replications under 3 different date of sowing. The seedlings were planted in row 15 cm apart by hand dibbling method with a row-to-row spacing of 10 cm. The standard cultural practices were followed to raise the crop. Five plants were randomly selected from each genotype. The observations were recorded on plant height, number of leaves, total chlorophyll content, number of days to 50% neckfall. Heterosis and heterobeltiosis were calculated as per the method of Shull (1914) and Fonseca and Patterson (1968).

Results and Discussion

The parents vs. crosses component of variance was significant for most of the characters in different environments as well as over environments, indicating presence of sufficient heterosis. Among crosses, wider range in heterosis over mid-parent was found for number of leaves (-21.63 to 37.22), followed by total chlorophyll content (-28.89 to 32.51), plant height (-20.93 to 31.35) and number of days to 50% neckfall (-8.36 to 6.08) in all environments. Maximum desirable heterosis over better parent (heterobeltiosis) was 33.04 (RO- 59 × Pusa Shobha in E_1) for number of leaves, followed by 25.99 (RO-59 × Bhima Shakti in E_1) for plant height, 25.85 (RO-1 × Pusa Shobha in E_2) for total chlorophyll content and -7.5 (RO-1 × RO-59 in E_2) for number of days to 50% neckfall in different environments.

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Table 1 : Estimates of per cent heterosis over mid parent and better parent in individual environment

Character	Env.	Heterosis	%	Heterobeltiosis	%
Plant height (cm)	E_1	RO-59 × Bhima Shakti	31.35**	RO-59 × Bhima Shakti	25.99**
		Pusa Shobha × Pusa Red	26.8**	RO-1 × RO-59	17.42**
		Bhima Shakti × Pusa Shobha	22.19**	Pusa Shobha × Pusa Red	16.04**
	E_2	Pusa Shobha × Pusa Red	26.53**	RO-59 × Bhima Shakti	22.29**
		RO-59 × Bhima Shakti	26.03**	Bhima Shakti × Pusa Shobha	20.17**
		RO-1 × Pusa Shobha	22.39**	Pusa Shobha × Pusa Red	20.08**
	E_3	Kashi No. 1 × Pusa Red	25.92**	RO-59 × Bhima Shakti	19.24**
		RO-1 × Kashi No. 1	22.62**	RO-1 × Kashi No. 1	18.56**
		RO-59 × Bhima Shakti	19.38**	RO-1 × RO-59	17.39**
Number of leaves/ plant	E_1	RO-59 × Pusa Shobha	37.22**	RO-59 × Pusa Shobha	33.04**
		Kashi No. 1 × Pusa Red	27.8**	Kashi No. 1 × Pusa Red	25.96**
		RO-59 × Bhima Shakti	26.92**	Bhima Shakti × Kashi No. 1	19.8**
	E_2	RO-59 × Pusa Shobha	23.92**	Pusa Madhavi × Pusa Red	17.16**
		Pusa Madhavi × Pusa Red	21.24**	RO-1 × Kashi No. 1	16.28**
		RO-1 × RO-59	19.69**	RO-59 × Bhima Shakti	15.45*
	E_3	RO-59 × Pusa Shobha	32.63**	RO-59 × Pusa Shobha	28.57**
		Bhima Shakti × Kashi No. 1	32.29**	Kashi No. 1 × Pusa Red	17.59**
		Kashi No. 1 × Pusa Red	24.62**	RO-1 × RO-59	17.48**
Total chlorophyll Content (mg/g)	E_1	RO-1 × RO-59	19.04**	RO-1 × Pusa Madhavi	14.97**
		Pusa Shobha × Pusa Red	16.98**	Pusa Shobha × Pusa Red	14.79**
		RO-1 × Pusa Madhavi	16.3**	RO-1 × Pusa Shobha	14.34**
	E_2	RO-1 × Pusa Madhavi	32.51**	RO-1 × Pusa Shobha	25.85**
		Pusa Shobha × Pusa Red	30.75**	RO-1 × Pusa Madhavi	20.97**
		RO-1 × Pusa Shobha	27.59**	RO-1 × Kashi No. 1	17.82**
	E_3	Bhima Shakti × Kashi No. 1	23.21**	Kashi No. 1 × Pusa Red	18.53**
		RO-1 × Kashi No. 1	22.64**	RO-1 × Kashi No. 1	15.68**
		Kashi No. 1× Pusa Red	22.11**	Bhima Shakti × Kashi No. 1	14.45**
Number of days to 50% neckfall	E_1	RO- 1 × Pusa Madhavi	-7.86**	RO-1 × Pusa Red	-7.05**
		RO-1 × Pusa Red	-7.71**	RO- 1 × RO-59	-6.11**
		Pusa Madhavi × Pusa Red	-7.29**	Pusa Madhavi × Pusa Red	-5.52**
	E_2	RO- 1 × RO-59	-7.81**	RO- 1 × RO- 59	-7.5**
		Pusa Madhavi × Pusa Red	-7.52**	RO- 1 × Pusa Shobha	-5.66**
		RO- 1 × Pusa Madhavi	-6.35**	Pusa Shobha × Pusa Red	-5.08**
	E_3	RO-1 × Kashi No. 1	-8.36**	Kashi No. 1 × Pusa Red	-7.31**
		Kashi No. 1 × Pusa Red	-7.67**	RO-1 × Kashi No. 1	-5.49*
		RO- 1 × RO-59	-7.21**	Bhima Shakti × Kashi No. 1	-5.22*

* and ** significant at 5 and 1 per cent level of significance, respectively

Out of a total 28 cross combinations, 6 crosses indicated significant heterosis in more than one environment for growth characters. Such cross combinations were RO-59 × Bhima Shakti, Pusa Shobha x Pusa Red, Bhima Shakti × Pusa Shobha RO-59 × Pusa Shobha, Kashi No. 1 × Pusa Red and RO-1 × Pusa Red. [Table 1]. These crosses were considered promising for use for growth improvement because of having high heterotic effect for yield as well some component characters. Similar results in varying environments for different characters were reported by Mallikarjun (2006), Evoor *et al.* (2007), Ambresh and Gowda (2013), Gowda and Ambresh (2014), Satyanarayan (2014), Quartiero *et al.* (2014), Chaudhary *et al.* (2017), Popat *et al.* (2020).

Out of 28 cross combinations, 7 crosses exhibited significant heterobeltiosis in more than one environments, showing significant heterobeltiosis for growth. Such cross combinations were RO-59 × Bhima Shakti, Bhima Shakti × Pusa Shobha, Pusa Shobha × Pusa Red, RO-1 × Kashi No. 1, RO-1 × RO-59 and RO-1 × Pusa Madhavi. [Table 1]. These crosses were considered promising for their use for growth improvement. Highly variable heterosis and heterobeltiosis for growth and associated characters were also reported Evoor *et al.* (2007), Ambresh and Gowda (2013), Gowda and Ambresh (2014), Satyanarayan (2014), Quartiero *et al.* (2014), Tripathi *et al.* (2018), Popat *et al.* (2020), Ara and Deb (2021), Sharma (2022) and Gangadhara (2023b).

Conclusion

The most heterotic crosses for growth contributing characters were RO-59 x Bhima Shakti, Pusa Shobha x Pusa Red, Bhima Shakti x Pusa Shobha RO-59 x Pusa Shobha, Kashi No. 1 x Pusa Red and RO-1 × Pusa Red. The crosses having significant heterobeltiosis for growth contributing characters were RO-59 x Bhima Shakti, Bhima Shakti x Pusa Shobha, Pusa Shobha x Pusa Red RO-1 x Kashi No. 1, RO-1 x RO-59 and RO-1 × Pusa Madhavi. These crosses were considered promising.

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Relationship analysis among intergeneric hybrids of *Ascocentrum* based on floral characters

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Abstract

A study was undertaken for characterizing 30 intergeneric hybrids of *Ascocentrum* orchid based on floral characters and cluster analysis. The results showed that variety V25 (*Mokara* Syam *Ascocenda* Doung Porn) produced more number of spikes/plant/year (7.86), whereas, variety V11 (*Vascostylis* Blue Bay White) produced more number of florets/spike (40.67). Hybrid V3 (*Ascocenda* Kultana × *Vanda* Bitzs Heartthrob) had highest length (9.33 cm) and width (9.00 cm) of flower. Cluster analysis with 14 floral characters was done by classifying hybrids/varieties into 12 groups. Cluster 2 and 5 had five members, whereas, cluster 11 and 12 with only one member each. The cluster 2 and cluster 5 were less similar to each other with an inter-cluster distance 6.27,whereas highest inter-cluster distance was observed in cluster 6 and cluster 10 (41.47). Cluster 10 had high mean values for spike length (51.12 cm), flower length (7.94 cm) and width of flowers (7.50 cm). whereas cluster 6 which included V6 (*Ascocenda* Sirichi Fragrance) and V11 (*Vascostylis* Blue Bay White) had lowest internodal length with the highest value for number of florets/ spike. This cluster also observed to have low flower length and width (2.52 cm and 2.42 cm, respectively). This indicated that these varieties produce flowers in the dense bunch.

Key words: Floral character, Intergeneric hybrid, Cluster analysis, *Ascocentrum, Mokara, Ascocenda, Vascostylis, Kagawara*

Monopodials have recently gained popularity due to the availability of a large number of varieties and hybrids involving intergeneric ones that show a wide range of variability in floral characters. *Ascocentrum* is a small flowered monopodial, vandaceous orchid having erect inflorescence and lasting flower. Vanda gained more popularity through the bigeneric hybrid *Ascocenda* (*Ascocentrum* × *Vanda*); the bright orange flowers, more number of florets and longevity are contributed by *Ascocentrum*. This was subsequently used for the production of multi-generic vandaceous hybrids, *viz*., *Mokara, Kagawara, Vascostylis, etc*. and many other bigeneric and multigeneric hybrids have been evolved in *Ascocentrum* alliance. The species and cultivars/ hybrids are visually differentiated on the basis of colour and size of flowers.

Material and Methods

The study was carried out at College of Horticulture, Kerala Agricultural University, Thrissur during 2016-2018. Thirty *Ascocentrum* varieties/hybrids were used. The characterisation was done in selected healthy and insect-free varieties of intergeneric hybrids, *viz Ascocenda*, *Vascostylis*, *Mokara*, and *Kagawara,* where in one of the parents was *Ascocentrum.* The thirty selected varieties (Table 1) were grown in even slope span rain shelter having 200 micron UV film and 25 % UV stabilised shade net. Two to three years old, fully grown flower-bearing plants, 5 each of 30 varieties, were arranged in completely randomised design with three replications. The observations on floral characters were made by measuring and counting floral parts as required. Number of spikes produced per year in each variety/hybrid was noted. Other floral parameters such as length of spike, length of rachis, length of floral stalk (length of peduncle), girth of spike at base, intermodal length, length of pedicel (pedicel of single floret), length of flower and width, length of labellum (lip length) and width of labellum (lip width) length of column and length of spur were measured in centimetres. The data collected on these characters were subjected to one way ANOVA using OPSTAT (online based software developed by CCS HAU, Hisar) and cluster analysis was performed using Minitab Version-18.

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Table 1: Intergeneric hybrids of Ascocentrum selected for field evaluation

Variety No.	Varieties
V_1	*Ascocenda* Udomochai
V_2	*Ascocenda* Kraillerk White × *Vanda* Sanderiana
V_3	*Ascocenda* Kultana × *Vanda* Bitzs Heartthrob
V_4	*Ascocenda* Yip Sum Wah × *Vanda* Josephine Van Brero
V_5	*Ascocenda* Suksamran Sunlight
V_6	*Ascocenda* Sirichi Fragrance
V_7	*Vascostylis* Pine River Blue
V_8	*Vascostylis* Pine River Pink
V_9	*Vascostylis* Aroonsri Beauty
V_{10}	*Vascostylis* Pine Rivers Fuchsia Delight
V_{11}	*Vascostylis* Blue Bay White
V_{12}	*Mokara* Walter Oumae Pink
V_{13}	*Mokara* Calypso × *Vanda* Doctor Anek
V_{14}	*Mokara* Rassmatozz
V_{15}	*Mokara* Khaw Piak Suan × *Ascocenda* Bicentennial Yellow Spot
V_{16}	*Mokara* Khaw Piak Suan × *Ascocenda* Jiraprapra
V_{17}	*Mokara* Sayan × *Ascocenda* Bangkuntein Gold
V_{18}	*Mokara* Calypso Pink
V_{19}	*Mokara* Calypso Jumbo
V_{20}	*Mokara* Chao Praya Sunset Yellow Spot
V_{21}	*Mokara* Chao Praya Sunset Orange
V_{22}	*Mokara* Sunspot Orange
V_{23}	*Mokara* Omayaiy Yellow
V_{24}	*Mokara* Omayaiy Orange
V_{25}	*Mokara* Syam *Ascocenda* Doung Porn
V_{26}	*Mokara* Chark Han Pink
V_{27}	*Kagawara* Youthong Beauty
V_{28}	*Kagawara* Cristae Low
V_{29}	*Kagawara* Boon Rub
V_{30}	*Kagawara* Samrong

Results and Discussion

High variation was observed in all the varieties and hybrids on spike characters (Table 2). Variety V_{25} (7.86) to produced more number of spikes/plant/year which was on a par with V_{23} (6.33) and V_{27} (6.00). Whereas, V_{16} (1.00) produced least number of spike/plant/year which was on apar with V_1, V_2, V_3, V_{10}, V_{11}, V_{12}, V_{13}, V_{17}, V_{19}, V_{20}, V_{21}, V_{22}, V_{26}, V_{28} and V_{30}. In spike length, variety V_{23} (54.70 cm) recorded maximum value which was on a par with V_{24} (47.53 cm). Whereas, V_9 (17.33 cm) recorded minimum spike length which was on a par with V_1, V_2, V_3, V_6, V_7, V_{11}, V_{12}, V_{13}, V_{15}, V_{16} and V_{17}. Rachis length was higher in V_{30} (28.80 cm) It was on a par with V_8, V_{10}, V_{18}, V_{19}, V_{21}, V_{23}, V_{24}, V_{25}, V_{26}, V_{27}, V_{28} and V_{29}. However, it was low in V_{16} (8.67 cm) which on par with V_1, V_2, V_3, V_5, V_7, V_9, V_{12}, V_{13}, V_{15} and V_{17}. In case of peduncle length, again V_{23} (27.60 cm) had higher value on a par with V_{25} (24.40 cm) and V_{24} (23.47 cm). Regarding peduncle length, V_3 (8.47 cm) had highest value followed by V_2 (6.63 cm), V_{24} (6.53 cm), V_{23} (6.43 cm) and V_{25} (6.10 cm). In girth, V_3 (8.47 cm) had highest value, followed by V_2 (6.63 cm), V_{24} (6.53 cm), V_{23} (6.43 cm) and V_{25} (6.10 cm). V_6 (2.80 cm) had a minimum value and it was on par with V_8 (2.73 cm), V_{10} (2.53cm) V_7 (2.40 cm) and V_{11}. The varieties The *Mokara* is the trigeneric hybrid with the parents *Ascocentrum*, *Arachnis* and *Vanda* (Lee 1994). *Arachnis* a tall, climbing and epiphytic orchid (Tan 1976), being one of the parents of *Mokara,* it might have contributed the higher values in the inflorescence characters.

The *Ascocentrum* varieties/hybrids also exhibited considerable variation for flower characters. Variety V_{11} (40.67) produced more numbers florets / spike, whereas, V_{15} (5.67) produced least number of florets/spike, and was on apar with V_2, V_3, V_4, V_{12}, V_{13}, V_{14}, V_{16}, V_{18}, V_{20}, V_{21}, V_{24} and V_{26}. The intermodal length was highest in V_5 (5.00 cm) and low in V_{11} (0.70 cm) which was on par with V_{10} (1.07 cm). Hybrid V_3 (8.47 cm) had highest pedicel length, whereas, it was low in V_{11} (2.23 cm). Hybrid V_3 (8.47 cm) also recorded highest length of flower (9.33 cm) and width of flower (9.00 cm), whereas lowest length and width of flower (2.27 cm and 2.13 cm, respectively) was observed in V_{11}. The lip length and lip width, and less variation were observed as many of hybrids/ varieties had near to similar lip length and width. Lip length ranged from 1.80 cm (V_{10}) to 4.80 cm (V_3), and lip width from 3.77 cm (V_3) to 1.20 cm (V_9). Variety V_{18} (1.17 cm) and V_{21} (1.17 cm) had high column length. The V_{29} (0.43 cm) and V_{30} (0.43 cm) had less column length. The spur length, high variation was observed. Hybrid V_3 (0.90 cm) and V_{27} (0.90 cm) had high value for spur length, whereas, it was low in V_{12} (0.23 cm) and V_{30} (0.23) The variations in flower characters of *Ascocentrum* varieties and hybrids have been reported (Rajkumar

Table 2: Floral characters of *Ascocentrum* hybrids /varieties during 2016-18

Variety no.	Spike characters							Flower characters						
	No. of spikes/ year/ plant	Spike length (cm)	Rachis length (cm)	Peduncle length (cm)	Spike girth (cm)	No. of florets/ spike	Internodal length (cm)	Pedicel length (cm)	Length of flower (cm)	Width of flower (cm)	Lip length (cm)	Lip width (cm)	Column length (cm)	Spur length (cm)
V_1	3.00	24.33	12.17	12.17	1.80	20.67	1.73	3.23	3.70	3.47	2.33	1.77	0.50	0.60
	(1.99)	(5.02)	(3.62)	(3.62)	(1.67)	(4.63)	(1.65)	(2.06)	(2.17)	(2.11)	(1.83)	(1.66)	(1.22)	(1.26)
V_2	2.00	25.00	12.50	12.50	2.57	9.67	1.50	6.63	6.67	6.33	3.43	3.20	0.70	0.53
	(1.72)	(5.08)	(3.66)	(3.66)	(1.89)	(3.26)	(1.58)	(2.76)	(2.77)	(2.71)	(2.11)	(2.05)	(1.3)	(1.24)
V_3	2.67	22.50	10.87	11.63	2.50	8.00	2.17	8.47	9.33	9.00	4.80	3.77	1.10	0.90
	(1.88)	(4.81)	(3.43)	(3.51)	(1.87)	(2.99)	(1.78)	(3.08)	(3.21)	(3.16)	(2.41)	(2.03)	(1.45)	(1.38)
V_4	3.00	31.87	15.00	16.87	2.17	9.00	1.80	5.73	6.30	5.90	2.37	2.50	0.57	0.80
	(1.99)	(5.73)	(4.00)	(4.22)	(1.78)	(3.16)	(1.67)	(2.59)	(2.70)	(2.63)	(1.84)	(1.87)	(1.25)	(1.33)
V_5	3.00	27.33	12.33	15.00	2.20	16.67	5.00	3.37	6.43	6.23	2.53	1.37	0.97	0.80
	(1.99)	(5.32)	(3.64)	(4.00)	(1.79)	(4.20)	(2.44)	(2.09)	(2.73)	(2.69)	(1.88)	(1.54)	(1.4)	(1.34)
V_6	5.00	24.40	14.50	9.90	1.40	37.67	1.27	2.80	2.77	2.70	3.10	2.17	0.90	0.73
	(2.45)	(5.03)	(3.94)	(3.28)	(1.55)	(6.21)	(1.51)	(1.95)	(1.94)	(1.92)	(2.03)	(1.78)	(1.38)	(1.32)
V_7	2.67	22.67	14.00	8.67	1.57	14.67	1.47	2.40	2.53	2.43	2.63	1.63	0.60	0.53
	(1.91)	(4.86)	(3.86)	(3.11)	(1.60)	(3.96)	(1.57)	(1.84)	(1.88)	(1.85)	(1.91)	(1.62)	(1.26)	(1.24)
V_8	3.67	30.00	17.50	12.50	1.67	33.33	1.37	2.73	2.77	2.70	2.63	1.53	0.50	0.63
	(2.16)	(5.56)	(4.25)	(3.66)	(1.63)	(5.85)	(1.54)	(1.93)	(1.94)	(1.92)	(1.91)	(1.59)	(1.22)	(1.28)
V_9	3.00	17.33	11.60	5.73	1.30	17.00	1.33	3.00	2.80	2.53	2.57	1.20	0.53	0.57
	(1.99)	(4.28)	(3.55)	(2.59)	(1.52)	(4.23)	(1.53)	(2.00)	(1.95)	(1.88)	(1.89)	(1.48)	(1.24)	(1.25)
V_{10}	2.33	34.33	23.00	11.33	1.40	32.67	1.07	2.53	2.73	2.37	1.80	1.33	0.70	0.43
	(1.82)	(5.93)	(4.89)	(3.49)	(1.55)	(5.78)	(1.44)	(1.88)	(1.93)	(1.83)	(1.67)	(1.53)	(1.30)	(1.20)
V_{11}	3.00	24.33	15.50	8.83	1.17	40.67	0.70	2.23	2.27	2.13	2.43	1.87	0.60	0.37
	(1.99)	(5.03)	(4.06)	(3.13)	(1.47)	(6.45)	(1.30)	(1.80)	(1.81)	(1.77)	(1.85)	(1.69)	(1.26)	(1.17)

Table 2 (continued)

V_{12}	2.33	25.00	12.00	13.00	1.97	8.33	1.77	3.70	6.83	5.67	2.90	1.23	0.67	0.23
	(1.82)	(5.09)	(3.60)	(3.74)	(1.72)	(3.05)	(1.66)	(2.17)	(2.80)	(2.58)	(1.97)	(1.49)	(1.29)	(1.11)
V_{13}	2.33	24.80	11.97	12.83	2.10	10.67	1.97	3.67	5.83	5.80	3.17	1.53	0.67	0.30
	(1.81)	(5.07)	(3.59)	(3.72)	(1.76)	(3.41)	(1.72)	(2.16)	(2.61)	(2.60)	(2.04)	(1.59)	(1.29)	(1.14)
V_{14}	4.33	29.20	14.43	14.77	2.10	7.00	1.90	5.00	6.60	6.47	2.37	1.60	0.80	0.33
	(2.29)	(5.50)	(3.93)	(3.97)	(1.76)	(2.83)	(1.70)	(2.45)	(2.76)	(2.73)	(1.84)	(1.61)	(1.34)	(1.16)
V_{15}	3.67	24.33	11.33	13.00	1.63	5.67	2.77	3.80	6.40	6.30	2.60	1.30	1.00	0.73
	(2.14)	(5.00)	(3.49)	(3.72)	(1.62)	(2.56)	(1.94)	(2.19)	(2.72)	(2.70)	(1.90)	(1.52)	(1.41)	(1.32)
V_{16}	1.00	20.00	8.67	11.33	2.30	7.00	2.67	4.87	5.70	5.23	1.83	1.23	0.80	0.57
	(1.41)	(4.58)	(3.09)	(3.51)	(1.82)	(2.83)	(1.91)	(2.42)	(2.59)	(2.50)	(1.68)	(1.49)	(1.33)	(1.25)
V_{17}	3.00	24.00	13.00	11.00	1.67	13.67	1.83	3.77	7.47	6.23	2.70	1.90	1.07	0.63
	(1.99)	(5.00)	(3.74)	(3.46)	(1.63)	(3.83)	(1.68)	(2.18)	(2.91)	(2.69)	(1.92)	(1.70)	(1.44)	(1.28)
V_{18}	4.00	28.00	17.60	10.40	2.00	11.33	2.63	4.47	4.93	4.83	2.73	2.33	1.17	0.30
	(2.23)	(5.39)	(4.31)	(3.38)	(1.73)	(3.51)	(1.91)	(2.34)	(2.44)	(2.41)	(1.93)	(1.83)	(1.47)	(1.14)
V_{19}	1.63	35.53	19.03	16.50	2.70	24.33	2.53	5.97	6.73	6.33	2.90	2.70	1.10	0.67
	(1.62)	(6.03)	(4.46)	(4.18)	(1.92)	(5.01)	(1.88)	(2.64)	(2.78)	(2.71)	(1.98)	(1.92)	(1.45)	(1.29)
V_{20}	2.33	33.97	16.03	17.93	2.33	10.67	2.37	5.90	5.70	6.50	2.30	2.00	0.87	0.63
	(1.82)	(5.89)	(4.12)	(4.32)	(1.83)	(3.40)	(1.84)	(2.63)	(2.59)	(2.74)	(1.82)	(1.73)	(1.37)	(1.28)
V_{21}	1.27	35.43	19.00	16.43	2.80	10.43	2.57	5.57	7.57	7.37	3.20	2.73	1.17	0.40
	(1.50)	(6.00)	(4.45)	(4.15)	(1.95)	(3.38)	(1.89)	(2.56)	(2.93)	(2.89)	(2.05)	(1.93)	(1.47)	(1.18)
V_{22}	2.87	34.00	16.03	17.97	2.50	13.77	1.87	4.67	6.60	6.20	2.53	1.53	0.80	0.50
	(1.95)	(5.89)	(4.12)	(4.34)	(1.87)	(3.83)	(1.69)	(2.38)	(2.76)	(2.68)	(1.88)	(1.59)	(1.34)	(1.22)
V_{23}	6.33	54.70	27.10	27.60	2.57	19.33	2.87	6.43	8.10	7.57	2.63	1.67	0.73	0.63
	(2.70)	(7.45)	(5.29)	(5.33)	(1.89)	(4.49)	(1.97)	(2.72)	(3.02)	(2.93)	(1.91)	(1.63)	(1.32)	(1.28)
V_{24}	5.00	47.53	24.07	23.47	2.73	12.10	3.67	6.53	7.77	7.43	2.40	1.70	1.03	0.50
	(2.43)	(6.96)	(5.00)	(4.92)	(1.93)	(3.62)	(2.16)	(2.74)	(2.96)	(2.90)	(1.84)	(1.64)	(1.43)	(1.22)
V_{25}	7.87	42.60	18.20	24.40	2.73	28.73	3.77	6.10	7.00	6.73	2.40	2.70	0.70	0.43
	(2.97)	(6.60)	(4.38)	(5.04)	(1.93)	(5.44)	(2.18)	(2.66)	(2.83)	(2.78)	(1.84)	(1.92)	(1.30)	(1.20)

Table 2 (continued)

	1.33	35.17	18.27	16.90	2.40	7.87	2.33	5.83	7.00	6.67	2.40	1.50	0.90	0.57
V_{26}	(1.52)	(6.00)	(4.39)	(4.18)	(1.84)	(2.97)	(1.83)	(2.61)	(2.83)	(2.77)	(1.84)	(1.58)	(1.38)	(1.25)
	6.00	39.50	24.37	15.13	2.03	18.43	2.67	5.87	6.23	6.30	2.20	1.50	0.70	1.10
V_{27}	(2.62)	(6.34)	(5.03)	(3.96)	(1.74)	(4.38)	(1.92)	(2.62)	(2.69)	(2.70)	(1.79)	(1.58)	(1.3)	(1.44)
	3.10	42.87	25.53	17.33	1.90	24.20	1.93	4.60	3.80	3.93	2.63	1.50	0.60	0.50
V_{28}	(2.02)	(6.62)	(5.14)	(4.24)	(1.70)	(5.01)	(1.71)	(2.37)	(2.19)	(2.22)	(1.91)	(1.58)	(1.26)	(1.22)
	3.33	28.87	17.10	11.77	1.67	20.53	1.73	4.33	3.43	3.33	2.37	1.30	0.43	0.73
V_{29}	(2.08)	(5.46)	(4.25)	(3.57)	(1.63)	(4.64)	(1.65)	(2.31)	(2.11)	(2.08)	(1.84)	(1.51)	(1.20)	(1.32)
	2.00	40.87	28.80	12.07	1.67	30.07	1.47	3.60	3.33	3.13	1.87	1.87	0.43	0.23
V_{30}	(1.72)	(6.47)	(5.46)	(3.61)	(1.63)	(5.57)	(1.57)	(2.14)	(2.08)	(2.03)	(1.69)	(1.69)	(1.20)	(1.11)
C.D.@5%	0.418	0.712	0.547	0.715	0.071	0.60	0.133	0.125	0.106	0.117	0.097	0.303	0.084	0.073
SE(m)±	0.147	0.251	0.193	0.252	0.025	0.211	0.047	0.044	0.037	0.041	0.034	0.107	0.03	0.026
C.V.	12.654	7.762	8.029	11.339	2.497	8.828	4.613	3.256	2.577	2.891	3.111	11.025	3.855	3.552

The data in parenthesis indicate square root transformed values

and Sharma, 2010; De *et al*., 2015; Deepa, 2017; Kasutjianingati and Firgiyanto, 2018).

Cluster analysis with 14 different floral characters revealed 12 clusters at 75 % similarity (Table 3 and Fig. 1). Cluster 2 and 5 had five members, whereas cluster 11 and 12 with only one member The cluster 2 and cluster 5 were less similar with each other with inter-cluster distance of 6.27, whereas, the highest inter-cluster distance was observed in cluster 6 and cluster 10 (41.47) (Table 4).

Cluster 10 had high mean values for spike length (51.12 cm), flower length (7.94 cm) and width of flower (7.50 cm). Cluster 11 had high mean values for a number of spikes/plant/year, intermodal length (3.77 cm) and had high flower length (7.00 cm) and width of flower (6.73 cm) next to cluster 10. Whereas, cluster 6 including V_6 (*Ascda* Sirichi Fragrance) and V_{11} (*Vasco* Blue Bay White) had lowest internodal length with the highest value for number of florets/spike. This cluster also had low flower length and width (2.52 cm and 2.42 cm, respectively).This indicates that these varieties produce flowers in the dense bunch.

Conclusion

It can be concluded that selection based on these traits would be most effective for plant breeders in developing new *Ascocentrum* orchid varieties.

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Table 3: Inter cluster distance among 12 clusters in *Ascocentrum* hybrids /varieties

	Cluster 1	Cluster 2	Cluster 3	Cluster 4	Cluster 5	Cluster 6	Cluster 7	Cluster 8	Cluster 9	Cluster 10	Cluster 11	Cluster 12
Cluster1	0.00											
Cluster2	13.28	0.00										
Cluster3	16.32	6.24	0.00									
Cluster4	14.77	10.63	16.11	0.00								
Cluster5	7.80	6.27	10.18	10.47	0.00							
Cluster6	19.04	31.85	33.42	32.24	26.16	0.00						
Cluster7	9.78	12.56	12.79	19.71	10.06	23.98	0.00					
Cluster8	14.81	27.35	30.74	24.47	21.50	11.61	22.82	0.00				
Cluster9	16.33	22.53	27.47	14.60	18.26	25.50	25.11	14.86	0.00			
Cluster10	31.33	32.32	37.73	21.93	30.62	41.47	39.35	30.84	17.08	0.00		
Cluster11	23.34	29.91	34.43	22.35	25.99	27.47	32.91	19.15	12.89	17.45	0.00	
Cluster12	22.27	31.58	36.11	25.14	26.49	23.68	30.35	12.67	11.57	23.87	18.53	0.00

Table 4: Mean values of floral characters for clusters in *Ascocentrum* hybrids /varieties

Variable	Cluster1	Cluster2	Cluster3	Cluster4	Cluster5	Cluster6	Cluster7	Cluster8	Cluster9	Cluster10	Cluster11	Cluster12
No. of spikes/ year/ plant	3.17	2.93	1.84	2.16	3.33	4.00	2.84	3.00	3.58	5.67	7.87	2.00
Spike length (cm)	26.60	25.67	21.25	34.09	26.44	24.37	20.00	32.17	39.30	51.12	42.60	40.87
Rachis length (cm)	14.64	12.45	9.77	16.87	14.31	15.00	12.80	20.25	22.98	25.59	18.20	28.80
Peduncle length (cm)	11.97	13.22	11.48	17.22	12.13	9.37	7.20	11.92	16.32	25.54	24.40	12.07
Spike girth (cm)	1.74	2.07	2.40	2.44	1.96	1.29	1.44	1.54	2.21	2.65	2.73	1.67
No. of florets / spike	20.60	8.27	7.50	10.35	13.89	39.17	15.84	33.00	22.32	15.72	28.73	30.07
Internodal length (cm)	1.73	1.98	2.42	2.19	3.15	0.99	1.40	1.22	2.38	3.27	3.77	1.47
Pedicel length (cm)	3.78	4.56	6.67	5.54	3.87	2.52	2.70	2.63	5.48	6.48	6.10	3.60
Length of flower (cm)	3.57	6.47	7.52	6.63	6.28	2.52	2.67	2.75	5.59	7.94	7.00	3.33
Width of flower (cm)	3.40	6.11	7.12	6.53	5.76	2.42	2.48	2.54	5.52	7.50	6.73	3.13
Lip length (cm)	2.35	2.89	3.32	2.56	2.65	2.77	2.60	2.22	2.58	2.52	2.40	1.87
Lip width (cm)	1.54	1.67	2.22	2.05	1.87	2.02	1.42	1.43	2.66	1.69	1.50	1.87
Column length (cm)	0.47	0.77	0.95	0.86	1.07	0.75	0.57	0.60	0.80	0.88	0.70	0.43
Spur length (cm)	0.45	0.42	0.74	0.58	0.72	0.55	0.55	0.53	0.76	0.57	0.43	0.23

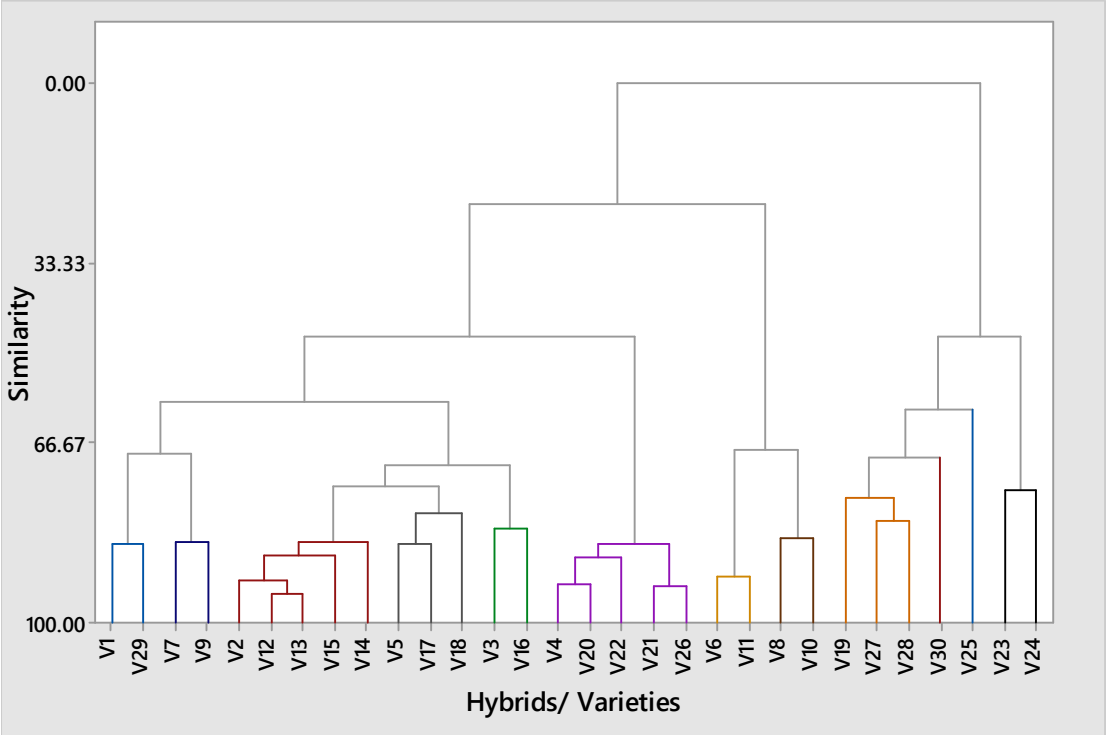

Fig. 1: Dendrogram showing clustering of 30 hybrids/ varieties of *Ascocentrum*

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Effect of foliar application of organic liquids on yield and quality of garlic (*Allium sativum*)

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Abstract

The effect of foliar application of organic liquids on growth, yield and quality of garlic (*Allium sativum* L.) cv. Yamuna Safed-3" was studied at Regional Horticultural Research Station, ASPEE College of Horticulture and Forestry, Navsari Agricultural University, Navsari, Gujarat during *rabi* season (2019-20). The experiment was laid out in randomized block design with three replications and nine treatments, *viz. Panchagavya,* novel plus, *Jeevamrut* and cow urine at each of 1% and 2% concentration and the control (no spray). The foliar application of *Panchagavya* @ 2 % (T_2) gave significantly maximum plant height (55.05 and 60.61 cm at 75 and 90 DAP, respectively), whereas maximum number of leaves/plant (7.0 and 8.13 at 75 and 90 DAP, respectively) and minimum days to maturity (127.37 days) were also reported in novel plus @ 2 % (T_4). The novel plus @ 2 % (T_4) recorded significantly maximum fresh weight of bulbs (24.79 g), dry weight of bulbs (16.73 g), diameter of bulb (3.75 cm), number of cloves/ bulb (18.60), weight of clove (2.16 g), length of clove (3.48 cm) and yield of bulbs (3.97 kg/plot and 7.87 t/ha). The plants sprayed with novel plus @ 2 % (T_4) recorded higher total soluble solids (16.87 and 22.43 ^{0}Brix at 2 and 4 MAH, respectively), ascorbic acid content (20.30, 18.30 and 15.97 mg at 2, 4 and 6 MAH, respectively) with maximum storage life of 219.67 days at room temperature. However, maximum net income of ₹2,36,012/ha with a benefit: cost ratio of 3.00 was recorded in foliar spray of Novel plus @ 2 % (T_4) as compared to rest of the treatments.

Key words: Garlic, *Panchagavya,* Novel plus, *Jeevamrut,* Cow urine and Foliar application

Garlic (*Allium sativum* L.) belongs to the family Amaryllidaceae. In Gujarat. it is cultivated in an area of 13,320 hectares with production of 105,160 tonnes (DAC&FW, 2020). Foliar fertilization or foliar feeding entails the supply of nutrients, plant hormones, stimulants and other beneficial substances in liquid form to plant through leaves and stems and other sites to realize enhanced yield. The advantage of organic liquid manure is that they disperse in water and it is rapidly taken by plants compared to solid organic fertilizers, helping in overcoming temporary, acute nutrient shortages in crops (Dhanoji *et al.*, 2018). *Panchagavya* and *Jeevamrut* are the organic inputs, which can act as a growth stimulant and immunity booster. Novel plus is a banana pseudostem based organic liquid nutrients. Therefore, the experiment was conducted to study the effect of foliar application of organic liquid sources on growth, yield and quality of garlic cv. Yamuna Safed-3".

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Materials and methods

The field experiment was conducted at Regional Horticultural Research Station, ASPEE College of Horticulture and Forestry, Navsari Agricultural University, Navsari (Gujarat), during *rabi* season (2019-20) to evaluate the effect of foliar application of organic liquids on, yield and quality of garlic cv. Yamuna Safed-3". The soil of experimental plot was clay with pH of 7.9 and 8.1 at 0-15 cm and 15-30 cm depths, respectively. The fertility of soil was relatively low in available N (220-240 kg/ha) and medium in available P_2O_5 (95-101 kg/ha) and rich in K_2O (270-280 kg/ha). The Randomized Block Design with three replications and nine treatments comprising *Panchagavya* @ 1% (T_1) and 2% (T_2), novel plus @ 1% (T_3) and 2% (T_4), *Jeevamrut* @ 1% (T_5) and 2% (T_6), cow urine @ 1% (T_7) and 2% (T_8) and control (T_9) was used.

The experimental plots were prepared by one deep ploughing, followed by one harrowing. Healthy bulbs of cv. Yamuna Safed-3 were collected from NHRDF, Rajkot, Gujarat and cloves were planted on raised beds of 110cm at a spacing of 20cm × 10cm during second

week of December 2019. The above said solutions were given as foliar spray at 30 and 60 DAP to the respective treatments. The observations on growth and yield attributes were recorded at 45, 75 and 90 DAP from ten selected plants per plot which were tagged with labels, whereas, quality parameters were recorded 2, 4 and 6 months after harvesting of bulbs.

Results and Discussion

Foliar application of organic liquid sources gave significant growth attributes of (Table 1). The plant height at 45 days after planting was found to be non-significant. However, plant height was significantly affected at 75 and 90 DAP. The maximum plant height was reported with *Panchagavya* 2% (T_2) treatment, *i.e.* 55.05 cm at 75 DAP and 60.61 cm at 90 DAP. The plant height might be increased due to application of *Panchagavya* which contains nitrogen, phosphorus, potassium, micro nutrients and growth hormones. The biofertilizers in liquid formulation which might have favored rapid cell division and elongation resulted in enhanced growth rate of plants (Ranpariya *et al.,* 2020).

Besides Indole Acetic Acid and gibberellic acid have also been reported in *Panchagavya* (Perumal *et al.,* 2006) which might have accelerated the mobility of photosynthates. The number of leaves/plant was not influenced significantly at 45 DAP. However, it was maximum in T_4 *i.e.* novel plus @ 2% (7.0 at 75 DAP and 8.13 at 90 DAP). This might be due to nitrogen content of novel plus which proliferated rate of vegetative development, resulted in maximum number of leaves. Moreover, nitrogen increases the cation exchange capacity of plant roots and makes them potent in absorbing other nutrients. To add on, nitrogen present in novel plus is responsible for formation, growth and development of cells and accelerating the formation of meristematic tissues. The plants sprayed with novel plus @ 2 % matured early (127.37 days). This might be due to hormones and nutrients which are present in novel plus may enhanced early maturity of bulbs. Another reason might be attributed to nitrogen availability which is one of the major and indispensable constituents of proteins and nucleic acid molecules, which ultimately trigger rate of photosynthesis (Pooja Rani *et al.*, 2015) results in early completion of vegetative growth.

The maximum fresh weight and dry weight of bulbs was noticed in T_4 (novel plus @ 2%), *i.e.,* 24.79 g and 16.73 g, respectively (Table 1). This is due to the nutrients which are present in novel plus might

Table 1: Effect of organic liquid sources on growth and yield attributes of garlic cv. Yamuna Safed-3

Treatment	Plant height (cm)			Number of leaves/ plant			Days to maturity	Fresh weight (g)	Dry weight (g)	Bulb diameter (cm)	No. of cloves per bulb	Weight of clove (g)	Length of cloves (cm)	Yield (t/ha)
	45 DAP	75 DAP	90 DAP	45 DAP	75 DAP	90 DAP								
T_1: *Panchagavya* @ 1%	39.67	51.17	58.08	4.23	5.20	6.53	131.23	20.46	14.64	3.34	15.30	1.63	2.86	6.59
T_2: *Panchagavya* @ 2%	40.53	55.05	60.61	4.33	6.00	7.03	129.40	21.61	15.44	3.53	16.00	1.91	3.20	7.24
T_3: Novel plus @ 1%	39.07	50.04	54.80	4.30	5.43	7.00	130.30	21.52	14.98	3.43	15.60	1.74	3.16	6.98
T_4: Novel plus @ 2%	40.08	53.13	58.83	4.43	7.00	8.13	127.37	24.79	16.73	3.75	18.60	2.16	3.48	7.87
T_5: *Jeevamrut* @ 1%	38.83	50.10	53.02	4.00	4.83	6.10	133.33	19.33	13.29	3.06	14.00	1.45	2.42	6.18
T_6: *Jeevamrut* @ 2%	39.03	50.83	56.47	4.20	5.03	6.57	132.67	20.37	14.61	3.29	14.57	1.51	2.61	6.53
T_7: Cow urine @ 1%	38.73	45.11	52.37	3.87	4.50	6.00	135.40	18.50	12.41	2.81	13.33	1.18	2.32	6.40
T_8: Cow urine @ 2%	38.83	48.27	53.02	4.13	4.63	6.07	134.40	19.60	13.23	3.15	14.40	1.23	2.35	6.04
T_9: Control (No spray)	36.83	44.00	48.03	3.87	4.20	5.47	136.37	17.50	12.15	2.70	13.03	0.90	2.26	5.90
S.Em.±	1.68	1.53	2.09	0.17	0.20	0.28	1.11	1.07	0.72	0.12	0.62	0.09	0.13	0.28
CD (5%)	NS	4.63	6.33	NS	0.60	0.85	3.36	3.23	2.19	0.34	1.88	0.26	0.41	0.83
CV (%)	7.45	5.33	6.60	7.14	6.51	7.47	1.46	9.07	8.84	6.01	7.22	9.86	8.50	7.24

have increased the growth character by cell division, cell elongation and cell enlargement coupled with increase in photosynthesis rate which leads to better accumulation of food material in plants that might have ultimately increased the weight of bulbs (fresh and dry) and cloves (Govind *et al.*, 2015).

It might be due to increased number of leaves with spray of novel plus which helps in accumulation of photosynthates and their utilization for build-up of new cells, resulting in increased dry matter production (Singh *et al.*, 2013 and Umamaheswarappa *et al.*, 2014). The maximum diameter of bulb (3.75 cm), number of cloves/bulb (18.60), clove weight (2.16 g), clove length (3.48 cm) and yield (3.97 kg/plot) were recorded in T_4, *i.e.*, novel plus @ 2%. This might be due to novel plus consisting of lavish amount of macro and micronutrients which ameliorate photosynthetic activity leads to augment in production and allocation of carbohydrates and photosynthesis which ultimately increases the yield and yield attributing characters (Singhal *et al.*, 2015).

The nutrients N and K at higher rate exerted a significant positive influence on yield attributes. The other bio-parameters which could have helped in increase of yield were synthesis of carbohydrates and their translocation to the potential storage organs (Kalariya *et al.*, 2018). Moreover, maximum number of leaves and leaf length might have influenced yield attributes as they have physiological capacity to mobilize and translocation of photosynthates to organ of economic value which in turn might have increased bulb yield (Nandini *et al.*, 2018).

There were significant difference in total soluble solids content of bulbs at 2 and 4 MAH. Whereas, it was found non-significant at 6 MAH. The maximum TSS value (16.87°Brix, 22.43°Brix at 2 and 4 MAH, respectively) with ascorbic acid content (20.30 mg, 18.30 mg, 15.97 mg at 2, 4 and 6 MAH respectively) and storage life of bulbs (219.67 days) at room temperature was reported in T_4 (novel plus @ 2%). The spray of organic liquid nutrients has no significant effect on physiological loss in weight after 2, 4 and 6 months of storage. However, minimum physiological loss in weight was observed in T_4 (novel plus @ 2%) *i.e.* 12.32, 22.17 and 29.67 % at 2, 4 and 6 MAH, respectively.

The results showed that plants sprayed with novel plus @ 2% (T_4) have significantly maximum TSS, ascorbic acid content with storage life of bulbs. This might be due to the nutrients present in novel plus which

Table 2: Effect of organic liquid sources on quality and economics of garlic cv. Yamuna Safed-3

Treatment	TSS (°Brix)			Ascorbic acid (mg/100g)			PLW (%)			Marketable yield (t/ha)	Cost of cultivation (₹/ha)	Treatment cost (₹/ha)	Fixed cost (₹/ha)	Gross income (₹/ha)	Net income (₹/ha)	BCR
	2 MAH	4 MAH	6 MAH	2 MAH	4 MAH	6 MAH	2 MAH	4 MAH	6 MAH							
T_1	16.10	21.07	31.63	19.37	17.70	14.83	14.83	24.87	33.33	6.59	55,273	2,740	16,475	2,63,600	1,89,112	2.54
T_2	16.43	22.23	32.10	19.90	18.23	15.80	13.83	24.41	32.60	7.24	55,273	4,240	18,100	2,89,600	2,11,987	2.73
T_3	16.30	21.57	31.83	19.63	18.20	15.23	14.30	24.83	33.18	6.98	55,273	2,540	17,450	2,79,200	2,03,937	2.71
T_4	16.87	22.43	33.97	20.30	18.30	15.97	12.32	22.17	29.67	7.87	55,273	3,840	19,675	3,14,800	2,36,012	3.00
T_5	14.10	20.50	31.17	18.63	16.27	13.63	17.33	27.00	34.00	6.18	55,273	2,040	15,450	2,47,200	1,74,437	2.40
T_6	14.43	20.53	31.20	19.03	17.20	14.10	16.98	26.27	36.27	6.53	55,273	2,840	16,325	2,61,200	1,86,762	2.51
T_7	16.07	21.00	31.33	18.30	16.07	13.23	16.33	26.67	34.80	6.40	55,273	1,640	16,000	2,56,000	1,83,087	2.51
T_8	14.17	20.77	26.20	18.43	16.63	13.87	17.10	25.17	33.83	6.04	55,273	2,040	15,100	2,41,600	1,69,187	2.34
T_9	12.07	20.10	28.53	18.20	15.83	13.17	20.27	30.00	43.00	5.90	55,273	0	14,750	2,36,000	1,65,977	2.37
S. Em.±	0.18	0.28	1.98	0.20	0.14	0.16	1.56	1.87	2.27	6.59	55,273	2,740	16,475	2,63,600	1,89,112	2.54
C.D. at 5%	0.53	0.84	NS	0.60	0.42	0.49	NS	NS	NS	7.24	55,273	4,240	18,100	2,89,600	2,11,987	2.73
C.V. %	2.02	2.31	11.12	1.80	1.41	1.96	16.97	12.62	11.38	6.98	55,273	2,540	17,450	2,79,200	2,03,937	2.71

Selling price of garlic: ₹ 40/kg

are involved in carbohydrate synthesis, breakdown and translocation of starch, synthesis of protein and neutralization of physiologically important organic acids (Gajjela and Chatterjee, 2019). The increase in total sugars may also be attributed to adequate supply of macro and micro nutrients with 2 sprays of 2% novel plus that might synthesize and accumulate total sugars in bulbs (Shah *et al*., 2019).

The cost of cultivation, gross return, net return and B:C ratios were worked out for different treatments (Table 2). The higher net realization and maximum benefit cost ratio *i.e.* ₹2,36,012/hectare and 3.00, respectively was recorded under 2% novel plus (T_4). This might be due to the investment cost was less and yield was higher in this treatment which gives higher benefit cost ratio. This finding is in agreement with Parikh *et al.* (2020).

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Short Communication

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Study on underground storage of potato (*Solanum tuberosum*) during winter in Ladakh

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The passive underground storage of potato (*Solanum tuberosum*) was designed and potato tubers of Kufri Jyoti, Kufri Himalini and Kufri Girdhari were stored in passive underground storage during November 2022 - April 2023 at Defense Institute of High-Altitude Research, Leh Ladakh. Of three cultivars, tubers of Kufri Girdhari showed lowest total weight loss as compared to other varieties.

Potato is most valued non cereal crop in Ladakh. It is consumed by the locals as well as the army deployed here, all through the season. The crop is multiplied vegetatively using tuber as seed material usually (Paul *et.al.,* 2022). The crop is cultivated in May and harvested in September. During the harsh cold winter, continuous supply of fresh vegetables is not possible as the region remains landlocked during November - May. Transport of vegetables through air route is expensive as it charges around Rs 130/kg. In such cases, storage of potato for long period of winter becomes essential (Singh and Srivastava ,2012). Moreover, to address food insecurity, it is crucial to boost productivity and expand the area dedicated to potato production (Jatav *et.al.,* 2023)

The study was carried out in underground passive storage located at Leh (77.57298° E; 34.13298° N; elevation 11482 ft) during November - April (Fig 1). Potato tubers of Kufri Jyoti, Kufri Himalini and Kufri Girdhari were used for study. Potatoes were properly cured, free from damages and stored in perforated leno bags (35kg each). The observation for weight loss and rotting were done monthly. Temperature and humidity were also recorded during the storage period with testo 175 H1 data logger.

In potato tubers, physiological processes such as respiration and transpiration occur even after harvesting. These processes cause physiological changes and leads to water loss. The process of heat transfer is dependent on various factors such as temperature, humidity, and physical properties of tuber (GolMohammadi and Sayyah,2013). The temperature and humidity recorded during the storage period is given in Table 1. The temperature in storage fluctuates with fluctuation in ambient temperature. During the storage period maximum ambient temperature was recorded as 22.6° C, whereas maximum temperature in underground passive storage was 7.60° C. Also, it was observed that during peak January when minimum temperature 4.05° C was recorded inside the underground passive storage while the ambient temperature was -21.1° C.

Fig 1: Underground passive storage of potato.

Evaporation losses from tuber surface (skin) leads to reduction in weight of tubers which is considered as physiological weight loss. Excessive evaporative losses not only cause reduction in weight but also cause shrinkage on tuber skin and consequently affect the market value of tubers (Sudha *et al*., 2017). At the end of storage period, it was observed that physiological weight loss was observed as 1.88%, 2.35% and 2.04 % in Kufri Jyoti, Kufri Himalini and Kufri Girdhari respectively (Table 2). The minimum weight loss was recorded in Kufri Jyoti (1.88%) and maximum weight loss in Kufri Himalini (2.35%). The difference in weight losses may be due to variable respiration and transpiration processes occurring in the different cultivars. Also, continuous physiological process of respiration and transpiration after harvesting of tubers leads to dehydration and leads to weight loss (Ozturk and Polat, 2016). The weight loss is related with periderm thickness, number of cell layers

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Table 1: Monthly average maximum and minimum temperature of underground passive storage

Month	Maximum		Minimum		Humidity (%)	
	Open	Store	Open	Store	Open	Store
November	22.6° C	7.60° C	13.7° C	6.6° C	30.5	80
December	5.40° C	5.90° C	-18.90° C	5.20° C	32.10	76.27
January	0.12° C	5.58° C	-21.1° C	4.05° C	46.74	84.67
February	3.58° C	5.54° C	-19.5° C	4.00° C	47.99	86.73
March	22.4° C	8.16° C	-8.3° C	5.65° C	40.46	81.78
April	20.4° C	10.50° C	-6.90° C	8.23° C	26.51	66.94

Table 2: Physiological weight loss and percentage loss due to rottage and total weight loss of different potato cultivar in underground passive storage

Variety	Physiological weight loss (%)	Loss due to rottage (%)	Total weight loss (%)
Kufri Jyoti	1.88	8.49	10.37
Kufri Himalini	2.35	5.98	8.33
Kufri Girdhari	2.04	5.74	7.78

in periderm and number of lenticels on tuber surface (Ezekiel *et al*., 2004).

The percentage loss due to rottage in underground passive storage was observed as 8.49 %, 5.98% and 5.74% in Kufri Jyoti, Kufri Girdhari and Kufri Himalini respectively (Table 2). Minimum percentage loss due to rottage was observed in Kufri Girdhari (5.74%) and maximum was observed in Kufri Jyoti (8.49 %). The lower rate of rotten percentage of potato tubers is influenced by the environment, under which genotypes were grown and stored (Bhutani and Khurana, 2005).

Total weight loss in potato varieties determines the longevity of their storage and their shelf- life. Total weight loss (including physiological weight loss and weight loss due to rottage) at 180 days of storage showed large variation between varieties in the study. Total weight loss was lowest in Kufri Girdhari (7.78%) and highest in Kufri Jyoti (10.37 %). Sudha *et al.* (2017) studied the storage behaviour of 5 different potato cultivars under ambient storage conditions of Nigiri region and reported lowest total weight loss observed in Kufri Girdhari (15%) as compared to other varieties. Based on the findings, it can be concluded that Kufri Girdhari is the best variety for storage at high altitude. Also, the underground passive storage provides a favourable environment for potato storage during the peak winter month.

Thus, it is concluded that potato tubers were found suitable for consumption at the end of storage period demonstrating that potatoes can be stored successfully during winter period in passive underground store in Ladakh.

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Assessment of suitable variety of marigold (*Tagetes erecta*) for northern dry zone condition

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This field experiment was laid out by adopting F test at farmers' fields of marigold (*Tagetes* species Linn.) at Mutkod and Kellur village of Jewargi taluk during 2018-19. Totally 3 treatments were considered by three different varieties, Arka Agni and Arka Bangara 2 from IIHR, Bengaluru and local variety from Jewargi. The mean value of plant height was highest in Arka Agni (40.16 cm), followed by local variety (35.6 cm) Arka Bangara 2(33.6 cm). The variation in plant height due to genotypic differences in phenotypic expression of plant height is due to genotype-environmental interaction effects on plant height.

Similar results were reported by Rao *et al.* (2005), Singh and Singh (2006) and Mahantesh *et al.* (2018). The mean value of plant spread showed highly significant difference among varieties. The highest plant spread (41.30 cm) was recorded in Arka Bangara 2. However, lowest (37.30) was recorded in the control at 60 DAT. The mean value at 90 DAT was highest in Arka Bangara 2 (46.52 cm), followed by Arka Agni (45.55 cm) and lowest in the control (42.50 cm). Considering the values for plant spread all the varieties shown significant difference similar results were observed and documented by Narsude *et al.* (2010) and Raghuvanshi and Sharma (2011).

The genotypes showed significant by number of primary branches/plant. The highest number of primary branches was recorded in Arka Agni (8.3), lowest in the control at 30 DAT. At 60 DAT, it was highest in Arka Bangara 2 (11.3), followed by Arka Agni (10.1) and the control (8). At 90 DAT, highest branches were recorded in Arka Bangara 2 (12.5), followed by Arka Agni (11.3) and the control (9.3). Similar results were observed by Mahantesh *et al.* (2018).

The highest number of secondary branches were in Arka Bangara 2 (9.1), followed by Arka Agni (8.25) and the control (7.1) at 30 DAT. The highest number of secondary branches was observed in Arka Bangara 2 (14.6), followed by Arka Agni (12) and the control (9.1) at 60 DAT. The highest number of secondary branches were observed in Arka Bangara 2 (17.2), followed by Arka Agni (15.9) and the control (14.5) at 90 DAT. The increased number of branches in some genotypes may be attributed to genetic make up of cultivars, Supported by Naik *et al.* (2005), Singh *et al.* (2008) and Mahantesh *et al.* (2018).

The genotypes were non-significant in number of days taken for first flower bud appearance. The earliest days (48.2) was recorded in Arka Bangara 2. Maximum number of days to first flowering (51.5) was recorded in Arka Agni. This is also recorded by Palthe *et al* (2019) and Rao *et al.* (2005).

The genotypes differed significantly in flower size and weight of flowers. Highest flower size with diameter 4.8 cm and flower weight (5.4 g) were recorded in Arka Bangara 2, followed by Arka Agni and the control. These results are in conformity with those of Singh *et al.*, 2008 and Mahantesh *et al.,* 2018.

The longest flower duration (62.6) was recorded in Arka Agni and lowest in the control. The genetic control of these character and modification in their expression due to environmental factors might be possible causes of observed variation. Similar findings have been also reported by Raghuvanshi and Sharma (2011), Palthe *et al.* 2019 and Shubhashish *et al* (2023).

The genotypes differed significantly in flower yield/plant. The maximum (0.44 kg) flower yield was recorded in Arka Bangara 2. However, lowest (0.32 kg) was recorded in the control. This clearly indicates that there is an existence of relationship between number of flowers/plant and flower yield/plant. The maximum

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Table 1: Mean performances of African marigold genotypes

Variety	Plant height(cm)		No. of primary branches/plant		Flower diameter (cm)	Weight of single flower (g)	Flower yield (Kg/Plant)	Flower yield (tonnes/ha)
	60 days	90 days	60 days	90 days				
Arka agni	60.55	73.23	10.1	11.3	4.2	5.2	0.36	11.70
Arka bangara 2	55.32	70.65	11.3	12.5	4.8	5.4	0.41	13.32
Control	58.50	73.00	8.0	9.3	4.1	5.1	0.32	10.40

(13.33 t/ha) flowers yield was recorded in Arka Bangara 2. However, it was the lowest (10.40 t/ha) in the control. The flower yield per plant and population of plants were directly proportional to flower yield per hectare. Flower yield exhibited highly positive correlation with number of flowers/plant, flower diameter and flower weight. These similar results were reported by Narsude *et al.* (2010 a), Beniwal and Dahiya (2012), Mahantesh *et al.* (2018) and Palthe *et al.* (2019). Thus, it is concluded that Arka Bangara 2 was better than Arka Agni and local type during *Kharif* season.

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Effect of seed soaking and growing media on seedling vigour and economics of acid lime (*Citrus aurantifolia*)

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Acid lime (*Citrus aurantifolia* Swingle) is the most commercially important fruit crops of India. Seeds of acid lime are soaked with plant growth regulator such as gibbrellic acid (GA_3) as well as with organic substance such as cow urine, cow dung slurry and water for better seed germination. GA_3 controls mobilization of starch which acts as a respiratory substrate leading to immediate enhancement in cell elongation (Meghwal *et al.* 2021). Cow dung slurry also contains some growth promoting substances N, P, K, micronutrients and biodigestable enzymes which cause for softening of seed coat, enhancing seed germination and growth of seedlings (Raj *et al.* 2014). Water soaking of seeds is done to modify hard seed coats, remove inhibitors, soften seeds and reduce the time of germination. Media must also have good water holding capacity, drainage, physical and chemical properties for growth of seedlings (Solanki *et al.* 2023). Keeping in view, an experiment was conducted.

The experiment comprised six levels of seed soaking, *viz.,* S_1 (water), S_2 (GA_3 @ 50 ppm), S_3 (GA_3 @ 100 ppm), S_4 (cow urine @ 25 %), S_5 (cow urine @ 50 %) and S_6 (cow dung slurry; 1:1 w/w) and four levels of different growing media, *viz.,* G_1 (sand + vermicompost), G_2 (sand + FYM), G_3 (sand + vermicompost + cocopeat) and G_4 (sand + FYM + cocopeat) which were used in 1:1 proportion on volume basis. The poly bags were used in FCRD, which included 24 treatments with 3 replications. They were soaked before sowing in different seed soaking treatments for 12 hr in beaker. The seeds were dried for 10 minutes in shade after soaking. The dried seeds were immediately sown in polythene bags at 1.2 cm depth. Irrigation was given immediately by watering cane. Observations were recorded by using standard procedure and statistically analyzed.

The seedling vigor index I was calculated by adding the values of root length and shoot length 150 days after sowing. These were randomly selected and multiplied with their corresponding germination percentage.

Seedling vigor index I = germination percentage x total length of seedling (cm)

The seedling vigor index II was calculated by multiplying dry weight of seedlings with their corresponding germination percentage.

Seedling vigor index I= germination percentage x dry weight of seedlings (g)

The survival percentage of each treatment was recorded at 150 DAS, as per using following formula:

$$\text{Survival (\%)} = \frac{\text{No. of survived seedlings}}{\text{Total no. of seedling}} \times 100$$

The interaction effect of seed soaking and growing media was significant with respect to seedling vigour index I. Freshly extracted acid lime seeds treated with GA_3 100 ppm and sown in growing media [sand + vermicompost + cocopeat (1:1:1)] showed maximum seedling vigour index I (4355.44 cm). It might be due to increased germination and seedling height which has contributed to higher vigour index– I (Table 1) Ramteke *et al.* (2015) reported similar results. Media combination could have provided better condition like aeration and porosity for proper growth and development of seedlings which leads to increase seed vigour index- I. These results were in close agreement with Ramteke *et al.* (2015).

The interaction effect of seed soaking and growing media was found significant with respect to seedling vigour index II. Freshly extracted acid lime seeds treated with GA_3 100 ppm and sown in growing media [sand + vermicompost + cocopeat (1:1:1)] showed maximum seedling vigour index II (360 gm). It might be due to increased germination and seedling weight which have contributed to higher vigour index –II. The

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results were in close agreement with these Ramteke *et al.* (2015). It might be due to increased á-amylase activity for breaking the starch stored in seeds by growth regulators and increasing metabolic activities in seeds, which resulted in higher seed vigour were obtained by Pangtu *et al.* (2024). This might be due to favourable media for better growth and development of the seedlings. The similar results were reported by Bhardwaj (2014).

The interaction effect of seed soaking and growing media was significant with respect to survival percentage at 150 DAS (Table 1). Freshly extracted

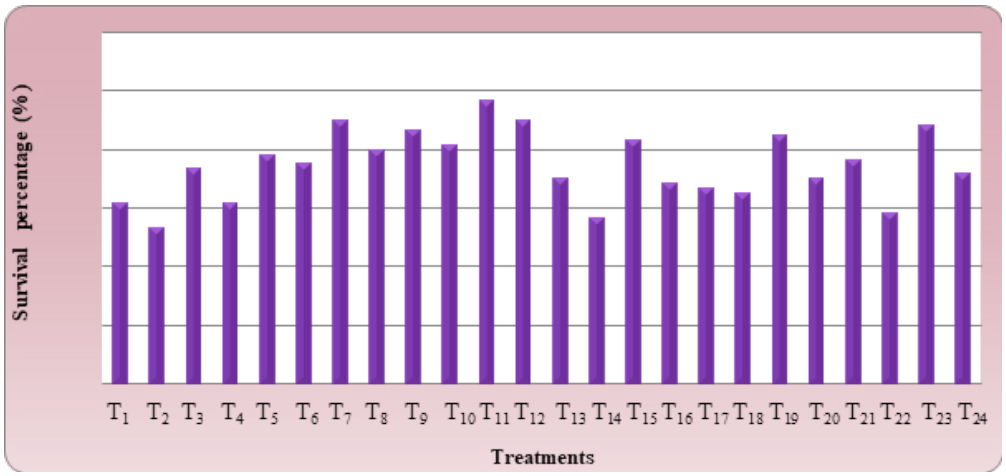

Fig. 1: Effect of seed soaking and growing media on survival percentage of acid lime

Table 1: Effect of seed soaking and growing media on economics of acid lime seedling

Treatment combinations	Plant survived	Fixed cost (₹)	Variable Cost(₹)	Total Cost (₹)	Gross realization(₹)	Net return (₹)	B: C ratio
s_1g_1	37/60	313.58	229	543	740	197	1.36
s_1g_2	32/60	313.58	106	420	640	220	1.52
s_1g_3	44/60	313.58	453	767	880	113	1.15
s_1g_4	37/60	313.58	371	685	740	55	1.08
s_2g_1	47/60	313.58	228	542	940	398	1.73
s_2g_2	45/60	313.58	105	419	900	481	2.15
s_2g_3	54/60	313.58	452	766	1080	314	1.41
s_2g_4	48/60	313.58	370	684	960	276	1.40
s_3g_1	47/60	313.58	229	543	940	397	1.73
s_3g_2	46/60	313.58	106	420	920	500	2.19
s_3g_3	58/60	313.58	453	767	1160	393	1.51
s_3g_4	54/60	313.58	371	685	1080	395	1.58
s_4g_1	42/60	313.58	228	542	840	298	1.55
s_4g_2	34/60	313.58	105	419	680	261	1.62
s_4g_3	50/60	313.58	452	766	1000	234	1.31
s_4g_4	41/60	313.58	370	684	820	136	1.20
s_5g_1	40/60	313.58	228	542	800	258	1.48
s_5g_2	39/60	313.58	105	419	780	361	1.86
s_5g_3	51/60	313.58	452	766	1020	254	1.33
s_5g_4	42/60	313.58	370	684	840	156	1.23
s_6g_1	46/60	313.58	228	542	920	378	1.70
s_6g_2	35/60	313.58	105	419	700	281	1.67
s_6g_3	53/60	313.58	452	766	1060	294	1.38
s_6g_4	43/60	313.58	370	684	860	176	1.26

seeds treated with GA_3 100 ppm and sown in growing media [sand + vermicompost + cocopeat (1:1:1)] gave maximum survival percentage (96.67 %) at 150 DAS. Higher survival percentage might be due to optimum application of GA_3 helps in cell expansion and its elongation resulting better root and shoot growth (Patel *et al.,* 2018), which supports and encourage better survival of the seedlings (Rahangdale 2019 and Lunagariya *et al.,* 2022) and media containing vermicompost and cocopeat as most of the constituents provided a start for establishment of seedlings which further got supplemented by PGPR's. Good physical and biological conditions in media combination had positive effect on root and shoot growth which also helps in better survival. Similar results were obtained by Ramteke *et al.* (2015). These findings are in agreement with these of Gupta (1989), Khatana *et al.* (2015) and Patel *et al.* (2016).

The findings indicate thatthe highest gross return (₹ 1,160) was recorded in treatment s_3g_3 [GA_3 @ 100 ppm + sand + vermicompost + cocopeat (1:1:1 v/v/v)]. Whereas, highest net return (₹ 500) and benefit cost ratio (2.19) were recorded in treatment s_3g_2 [GA_3 @ 100 ppm + sand + FYM (1:1 v/v).

The highest gross return obtained from s_3g_3 [GA_3 @ 100 ppm + sand + vermicompost + cocopeat (1:1:1 v/v/v)] might be due to maximum survival percentage of acid lime seedlings as compared to other treatments. Maximum net return and benefit cost ratio were due to comparatively less cost of the treatment.

Conclusion

It could be concluded that GA_3 @ 100 ppm and sand + vermicompost + cocopeat (1:1:1 v/v/v) were found to be superior for enhancing the seedling vigour with maximum gross return under shade net house condition.

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