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Management of abiotic stress in grapes (*Vitis vinifera*) - a review

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Abstract

Since viticulture is highly dependent on weather and climate, several climate change projections have been generated with the expectation that they may worsen the distribution of grape-growing regions in the years to come. Abiotic stress factors such as drought, salinity, temperature, hailstorm, and rainfall can restrict the growth and productivity of grapevines, as well as affect their quality and composition. Especially during critical developmental stages such as flowering, fruit set and ripening. This paper focused on review of current knowledge available on the effects of these stressors on grapevine physiology, development, and yield as well as the strategies and techniques to mitigate them. The paper provides a comprehensive overview of the management of abiotic stress in grapes and the challenges and opportunities for future research and grape growers can minimize the negative impacts of abiotic stresses.

Key words: Abiotic, Climate change, Mitigation, Stress, Salinity, Drought, Viticulture

Grape (*Vitis vinifera* L.) is a major horticultural crop grown on an area of 7.2 Mha, with the production of 27.9 million metric tonnes worldwide. Major grape producing countries are China, Italy, France, Spain, USA, Turkey, and India (OIV, 2024). According to II advance estimates of 2023, grape cultivation in India was on an area of 1,75,000 ha while production was 3896 thousand tons (Anonymous, 2024). Worldwide, grape is being grown mainly for wine, and less for fresh consumption, and juice. However, under Indian conditions, grape is cultivated mainly for table purpose and raisin making while minimum quantity is being consumed for wine and juice. Primarily, grape crop is from temperate region; however, it has been widely adopted in tropical and subtropical conditions. Indian viticulture thus has become unique as grape is now being grown from tropical to temperate climate.

Grape is a high value export-oriented fruit crop which has gained significance in tropical climatic conditions in the country due to location specific suitable modifications. However, during the last five years, it is seen that the grape industry is experiencing major setback due to changes in climatic conditions. The grapevine is facing the problems of unseasonal rains, hailstorm, cold waves during berry development stages and, high temperature during fruit bud development stage. Drought, salinity, temperature, unseasonal rains, flood are some of the major examples of abiotic stresses found around the world (Tester and Bacic, 2005). The global distribution of grapes is severely constrained by a variety of abiotic stresses. Only water deficiency has been successfully employed to the flavor and quality features of grape berries (Roby *et al.,* 2004, Chapman *et al.,* 2005). Reduced shoot vigor and competition for carbon resources (a change in the source to sink relationship) are two factors that contribute to this effect. Scientific evidence sharply states that climate change represents a dominant challenge for viticulture in the upcoming decades (Hannah *et al.,* 2013).

Summer stress generally refers to a variety of abiotic pressures that are exacerbated during the summer, such as water shortage, intense sunshine, and high temperatures (Cramer *et al.,* 2011). Given that many biochemical processes are light and temperature sensitive, it is crucial to understand the link between grape cluster temperature and solar exposure to understand grapevine metabolism (Spayd *et al.,* 2002). A severe drought causes a water deficit in the plant that lowers cell turgor, which causes stomata to close and cells to grow less, limiting leaf surface and photosynthesis per unit area. Understanding abiotic stress factors, it is essential to identify the specific factors that grapes are exposed to weather in a particular region.

This understanding will help in devising appropriate strategies for management. For instance, areas with high temperatures might require different strategies to overcome heat stress, while regions with poor soil quality might need nutrient management techniques. Extreme temperatures (both high and low) can impact grape production. Using strategies like shading, windbreaks, and selecting appropriate grape varieties for the local climate can mitigate temperature-related stress. In areas

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with saline soils, salinity stress can occur. Soil amendment techniques, proper irrigation scheduling, and salt-tolerant rootstocks can help to manage this stress. Choosing appropriate rootstocks that are tolerant to specific stress factors can enhance the plant's ability to cope with stress conditions. Grafting grapevines onto stress-tolerant rootstocks is a common practice. Proper canopy management during each season under tropical condition can ensures adequate light exposure, air circulation in the canopy, and reduction in disease incidence.

This review on management of abiotic stress in grape cultivation aims a holistic approach by implementing appropriate strategies and techniques. Grape growers can minimize the negative impacts of abiotic stressors leading to improved grape quality and overall vineyard productivity. The details outlines are as below.

Effect of high temperature

In India, grapes are mainly grown under tropical condition with high temperature reaching to 44^{0}C in some areas during fruit bud differentiation stage. During this stage, the high temperature affects basic physiological processes and growth of the grapevine. Although the grapevine needs a base temperature of 10°C to begin its vegetative cycle, it is also known that if the high-temperature threshold rises at crucial developmental stages the detrimental effects take place affecting the photosynthesis, berry size, sugar accumulation, and ripening. According to Kun, *et al.* (2018), 25 to 35°C is the ideal photosynthetic temperature for grapevines development. Above 40°C temperatures have an adverse impact on photosynthesis, mostly because they disturb the system that allows for photosynthesis.

According to Keller (2020), yield of grapevine depends on number of buds, bud fertility, number of berries per bunch and average berry weight. During the floral initiation period, high temperatures (>35^{0}C) was able to produce infertile buds (Keller, 2020). The mid-day temperature is high with temperatures ranging from 35 to 40^{0}C during blooming had a negative impact on fruit set and ovule fertility resulted in less berries per cluster (Greer and Weston, 2010). As per Pagay and Collins, (2017), extreme temperature (>35°C) during the flowering phase had a negative impact on fruit set (-48 to 38%) and eventual yield (-27%). Temperature variations have a significant impact on flowering and fruit set.

Continuous increase in temperature may result in peculiar development pattern of vines resulting in early flowering and berry softening.

This early season crop may lead towards the warmest period of season thus affecting grape yield and quality measured in terms of sugars, organic acids, phenolic compounds etc. (Keller *et al.,* 2010). Van Leeuwen and Destrac-Irvine (2017) observed that increase in temperature is predicted to diminish the acidity and increase the sugar content of grape berries, leading to unbalanced wine with greater alcohol content and lacking in freshness and aromatic complexity. High temperatures also tend to decrease anthocyanin content. During the maturation stage of most of the grape varieties, optimum temperature between 20-22^{0}C is ideal for formation of aroma compounds (Blancquaert, *et al.*, 2018). At temperatures above 30°C, colour formation is reduced, and above 37°C, grape colour is diminished and flavour element volatilization is increased (Neethling *et al.,* 2012). Anthocyanin is the main coloring compound found in grapes, during the high temperature condition reductions of delphinidins, anthocyanins, petunidin and peonidin-based anthocyanins in grapes is observed (Bernardo *et al.,* 2018).

High temperatures have an impact on the sugar-acid balance ratio as well. Increased temperatures have the potential to facilitate the buildup of sugars and the concurrent deterioration of organic acids, with the acidity being more severely impacted than the sugars. As a result, grapes cultivated in warmer climates have lower acidity for the same sugar level. The grape growing areas of Maharashtra and Karnataka experiences the high temperature during fruit bud differentiation after foundation pruning resulting into reduced fruitfulness of grapevine. During bunch development period after forward pruning, the high temperature hampers the berry development. In addition, it also reduces the quality as the berry colour changes from green to yellow which does not fit into the quality standard for export. Under the high temperature condition, total soluble solids increase at faster rate in grape berries.

Mitigations of high temperature stress

In grape vineyard of tropical region, the growth and developmental stages coincides with high temperature. Extreme high temperature leads to burning of shoot tips, scorching of leaf margins, leaf drying, etc. Reduction in internodal length thereby reducing the shoot vigor is some of the major effects leading to reduced storage of food material in the current seasons shoot. Crop load and leaf area influence the leaf to fruit ratio, we can lower this ratio by reducing leaf area through shoot pruning (Santesteban *et al.,* 2017). Leaf removal is a basic viticulture technique used for vineyard canopy control. Leaf removal is done on basal leaves to enhance cluster microclimate, increase fruit composition, and lower disease pressure (Smith and Centinari 2019).

Minimum pruning is a viticultural technique with a wide range of potential applications, especially in

warmer climates where one of its most notable effects is to delay berry ripening and create a cooler ripening environment for the grape development, which favours the accumulation of anthocyanins and preserves grape acidity. Minimum pruning is also a low-cost, time and money intensive method that produces high yields (Clingeleffer 2010). According to Keller, (2010) light is the most important part of photosynthesis, and the quantity and quality of light have an impact on the rate at which photosynthesis occurs. Novello and de Palma (2013) studied the shading nets over grapevines and concluded that shading nets decrease the amount of photosynthetic photon flux at the leaf surface that can be used for the photosynthetic process, which may delay fruit ripening. These effects are likely explained by the fact that the shade nets can reduce the temperature of the fruit and the canopy by up to 7^0C (Lobos *et al.,* 2015). Das and Raghavendra (1979) found that use of antitranspirants decreased transpiration losses, conserving water loss and by consequence, mitigating fruit shrinking.

Due to the impact of high temperatures and heat stress on canopy physiological processes, sunburn, yield, and berry quality, the use of this method in viticulture has recently increased (Frioni *et al.,* 2019a, 2019b). Canopy management practices, such as increasing leaf growth during hot period to provide shade for the fruit, removing leaves from the southeast or eastern side to capture morning sunlight, and positioning shoots on the northwest or western side to protect fruit from the intense afternoon heat, help reduce heat stress. Additionally, managing water to maintain varying levels of leaf cover plays a key role in preventing heat damage. Shade nets are also commonly used to minimize heat injury, particularly by growers of export-quality grapes (Sharma *et al*., 2013).

Effects of low temperature

Low temperature can reduce crop yields, by damaging the vine, the development of secondary issues like crown gall or even the complete death of the vine (Quamme, 1986). At temperatures of 4°C and below, roots are susceptible to freezing damage (Okamoto *et al.,* 2000). Deep soil freezing can occur because of factors such a lack of snow cover, extremely dry soil, and persistently low temperatures, which can also cause root damage. Root damage can also affect the trunk and canes, which can be seen during the growing season when the vine fails to grow or sometimes collapses. Wolfe (1991) reported that low temperatures additionally restrict plant species, but they may recover rather quickly once they return to warmer climates. According to Buttrose (1969), temperature drops severely inhibit grape shoot and root growth as well as fruiting yields.

Mitigations of low temperature stress

In India, Nashik district of Maharashtra state has major grape cultivation used for export purpose. In this region, mainly white seedless grape varieties are grown. In some of the grape growing pocket of this district, the grape vineyard during berry development stage (10-14 mm berry size) faces low temperature thereby leading to drying of leaves, leaf scorching/burning, sunscald symptoms on developing berries, etc. This hampers the physiological processes of grapevine thereby reducing the crop yield. In addition, the hailstorm is also being experienced in these areas resulting into berry damage/ cracking. In these areas, use of plastic on the vineyard will help to increase canopy temperature as well as hail net so as to reduce the chances of crop losses. Removal of any barriers that may restrict airflow on frost-prone areas, such as shelterbelts and overgrown grass along fence lines can help (McCarthy, 1997).

According to Rahemi (2016), several cultural practices such as appropriate slope, good soil and drainage, cold air drainage, and site selection, may be able to shield vines against winter damage. While some farmers cover the crown and root sections of their planting rows with straw mulches, others cover every part of the vegetative parts of the planting rows with geotextile materials (white blanket). Depending on the kind of soil, the grape growers are either burying the entire vine with soils or hill the soils on planting rows to a height of 20 to 25 cm (to cover the graft unions and lower the trunk) before the soil freezes (re-hilling if the soil washed away by a severe storm). American grape varieties including *Vitis labrusca* L., *Vitis aestivalis* Michx., and *Vitis riparia* Michx. have several cold tolerance genes, and these species exhibit relatively stronger cold hardiness than *V. vinifera* (Fennell 2004).

Among these, the best approach to cultivate grapes in a cold climate is to select rootstocks with the right vine balance in addition to cold-hardy cultivars. Within cold climate rootstock breeding programs, one of the primary selection criteria is cold hardiness (Rahemi, 2016). A study conducted by Guo *et al.* (1987) reported taht in regions where soil temperatures drop significantly during the winter, grape rootstock can help prevent root cold injury. According to Rahemi *et al.* (2022) delayed pruning technique involves pruning in two stages: an initial lighter pruning when the vines are fully dormant followed by a final bud-count pruning after the risk of frost has completely passed is beneficial for cold injury.

Effects of drought

Under tropical conditions, the vine is pruned twice in a year (once for fruit bud differentiation and second

for fruits). Water requirement of a grapevine varies with the growth stages with minimum quantity requires during fruit bud differentiation stage (31 to 60 days after foundation pruning). Water deficiency has a several kinds of effects on vegetative and productive growth stages. Prior to slowing down the growth of the main shoot and controlling stomata opening, the initial physiological reaction to mild water deficiency stress is a reduction in shoot growth, which mostly affects lateral/secondary shoots (Lebon *et al.,* 2006; Pellegrino *et al.,* 2006). One of the earliest signs of water shortage is a reduction in early plant development. The physiological behavior of vines, as well as the quantity and quality of grapes and wines, are all significantly influenced by the plant water status (Baeza *et al.,* 2019).

Keller (2010) observed that when the water deficit increases, the vine begins to close its stomata (reduce stomatal conductance) to reduce water loss through transpiration which lowers photosynthesis. Apart from impairment of carbon metabolism, drought can also influence nitrogen metabolism and photosynthesis through reduced activity of nitrate reductase (Bertamini *et al.,* 2006). Insufficient irrigation water caused by a drought leads to decreased fruitfulness, consequently reducing the yield of table grapes (Somkuwar *et al.,* 2014). The berry quality of red grapes is improved by a mild water stress which decreases berry weight and titratable acidity while increasing TSS, total anthocyanin, and phenolic contents (Romero *et al.,* 2010). This reaction appears to be influenced by the rootstock/cultivar combination as well as by the soil and climatic conditions. Ojeda *et al.* (2002) subjected Shiraz grapevines to three levels of water deficit and found that the reduction in berry size resulted in an increase in the concentration of phenolic compounds in the berry skins. However, the timing and intensity of the stress could have a negative impact on the concentrations of phenolic compounds.

Hochberg *et al.* (2015) discovered that depending on the phenological stage, water stress altered the polyphenol metabolism of Shiraz and Cabernet Sauvignon, causing the buildup of stress-related metabolites including proline and ascorbate. A lot of research has been done to learn how water scarcity affected the physiology and quality of berries. According to Ojeda *et al.* (2001), the initial growth phase's early water deficits have the greatest effect on berry size and consequently the yield. It does not affect the rate of cell division but slows down cell expansion in the berry. Zhang *et al.* (2006) reported that the final berry size is less affected by water deficit throughout the ripening period, perhaps because of a change from symplastic to apoplastic osmotically driven sugar unloading via the phloem.

Mitigations of water stress

Since the water deficit is the main limiting factor, increasing water use efficiency, survival potential, growth capacity, and scion tolerance to stress conditions, rootstocks might play a significant role in preventing crop loss (Meggio *et al.,* 2014). According to Flexas *et al.* (2009), the rootstocks Lider 116-60, Ramsey, 1103 Paulsen, 140 Ruggeri, Kober 5BB, and Richter 110 confer to scion increased drought tolerance. Galmés *et al.* (2007) also showed that the expression of the aquaporins genes in 110 R differs between the leaves and the roots. Specifically, they showed that the expression of aquaporins upon water stress was low in the leaves to reduce transpiration and increased in the roots to increase water uptake. In times of water stress, stomata also play a crucial role in controlling water loss, and stomatal closure is one of the first reactions to a water shortage (Damour *et al.,* 2010).

Phytohormone accumulation is one of the factors that cause stomatal closure. One of the most researched hormones in plants that respond to water stress is abscisic acid (ABA) and its synthesis is one of the quickest abiotic stress responses in plants. Its buildup in leaves is associated with stomatal closure, which eventually limits cellular growth by reducing water loss (Serra *et al.,* 2014). To improve production efficiency and profitability while minimizing the negative effects of global warming, many precision viticulture tools can integrate cutting-edge techniques like artificial intelligence, sensors, decision support systems, etc. with the findings of field and laboratory studies. Thermal imaging using remote sensing can be a helpful technique for estimating variations in water status throughout vineyards, due to its capacity to measure canopy temperature, which in turn affects transpiration and ultimately plant water status (Santesteban *et al.* 2016).

Low planting density could be one of the strategies to improve drought tolerance and reduce vine competition. Pieri *et al.* (2012) established a model of the water balance and suggested that an ideal low-density system designed to adapt to future water scarcity. One strategy to deal with future temperature change may be changing the orientation of rows. In most of the tropical and subtropical conditions, different irrigation techniques are being used such as partial root zone drying technique, sub-surface irrigations, and regulated deficit irrigation improved water used efficiency without affecting productivity and quality. According to Upadhyay *et al.* (2006), application of mulches and antitranspirants (anti-stress agents) led to 25% water savings in surface drip-irrigated vines. Likewise, utilizing mulching and an anti-stress (acrylic polymer) can also achieve 25% reduction in water use

for surface drip-irrigated vines. Alguacil *et al.* (2009) suggested that subsurface irrigation is beneficial in water scarcity regions, which can improve yield and quality of fruits and reduces the cost of cultivation. Use of mulches on bunds can help to reduce the evaporation losses from soil. Organic as well as inorganic mulch will be useful under specific condition. However, the availability of salts in irrigation water may affect the vegetative growth. In addition, the water loss from leaf through transpiration is more during high temperature. Under such conditions, the spray of antitranspirants at different vegetative growth stage may help to reduce the losses.

Effects of flood

The grape vineyard established in low lying areas may suffer the yield losses due to flood. Flooding can result from intense localized rainfall or a gradual flow of flood waters across the terrain, or a combination of both factors. Regardless of the cause, it is crucial to consider the duration and timing of the flooding. When flooding occurs in well-drained soil types, where water typically recedes within one or two days, it typically has minimal impact on vine growth. However, in areas where flood waters take longer to recede, either due to soil characteristics or the volume of water, certain problems may arise.

Flooding certainly has adverse impacts on plant structure, function, and chemical processes. It can lead to damage of roots and result in a decrease in fruit yield (Jogaiah, 2023). The primary issue plants face during flooding is a lack of oxygen (O_2). Waterlogging significantly reduces oxygen availability, which disrupts plant metabolism, ultimately impacting growth and productivity. The response of grapevines (*Vitis* spp.) to waterlogging remains unclear, and the molecular and metabolic reactions of grapevine roots to low oxygen levels (hypoxia) have not been fully explored. Since cultivated grapevines are hybrids formed by combining different rootstocks and scions, the complex interactions between various genotypes and environmental factors make it difficult to completely understand the mechanisms behind flooding tolerance (Ruperti *et al*., 2019).

Flooding has various effects on grapevines. It can lead to desiccation of the shoot apex, flagging of leaves, necrotic areas on leaves, senescence of basal leaves, and regeneration of roots near the water surface (Striegler *et al.,*1993). It can also affect the growth and development of grape berries and wine production, resulting in a reduction in quantity and quality (Sophie *et al*.,2015).

Mitigation of flood

The problem of flooding in grapevines can be mitigated through various strategies. One of the major approaches is to implement physiologically based water-saving irrigation methods, such as deficit irrigation and regulated deficit irrigation, which can improve water use efficiency and berry quality (Myburgh *et al.,* 2003). Another method is to shelter grapevines from rainfall, which reduces the severity of grape diseases and increases yields (Iduna *et al.,* 2019). Proper drainage in the vineyard will also help to safeguard the root system during berry development stage. By implementing these techniques, grape growers can mitigate the negative effects of flooding and ensure the long-term productivity of their vineyards.

Effect of salinity stress

Salinity is becoming a bigger issue for viticulture production, according to major grape-growing nations, especially in some parts of Australia, Greece, Italy, India, Iran, Spain, Turkey, and the USA (Baneh *et al.*, 2014). Grape output reduced by 10% in soil with an EC of 1.5–2.5 dS m–1, by 10-15% in soil with an EC of 2.5–4.0 dS m–1, and by 20–25% in soil with an EC of 4.7 dS m–1 as reported by Ayers and West cot (1985). Growing grapes may be seriously threatened by rising soil salinization because dissolved salts in irrigation water put most irrigated vineyards especially those that are deficit-irrigated at risk (Keller, 2010).

According to Marschner (1986), plant growth is negatively impacted by salinity due to two main effects: a toxic effect whereby the concentrations of the beneficial element sodium and the micronutrient chloride in the plant's tissue reach toxic levels and an osmotic effect whereby the plant experiences an osmotic drought because of the soil solution increases soluble salt concentration. Osmotic stress caused by excessive salt exposure affects grapevine roots, reducing the plant's ability to obtain water. Moreover, the buildup of Na+ and Ci- ions in plant tissues can lead vines to display phytotoxicity. If the concentration of these ions is beyond a threshold, this might cause cellular metabolism to cease (Chaves *et al.,* 2010). Reduced stomatal conductance and photosynthesis as well as leaf burn are signs of salt stress in grapevines and are typically linked to an increase in shoot Ci- rather than Na+ concentration in plant tissues (Walker *et al.,* 1997). The physiology of grapevines is negatively impacted by salt stress. It results in long-lasting drought conditions and makes it challenging for roots to take up and transfer nutrients from the soil to other areas (Jellouli *et al.,* 2010). Grattan and Grieve (1998) stated that plant growth and development are gradually restricted by salinity because it increases intracellular ionic concentrations and reduces the ability of plants to absorb essential nutrients. Salinity generally causes lower rates of CO_2 fixation, decreased dry matter accumulation,

less number of bunches, smaller berries, lower yields, and decreased overall growth in grapevines (Downton *et al.,* 1990; Walker *et al.,* 2008).

There are various reasons when the yield may have decreased, including a decrease in berry size or shoot length resulting from an imbalance in the source-sink relationship, among other direct and indirect impacts (Stevens and Walker, 2002). Wine with high amounts of Na, K, and Cl has been linked to salinity derived characteristics, such as "soapy," "sea water like," and "brackish," which are viewed negatively from a sensory perspective (Mira de Orduña, 2010). High salt concentrations have an impact on several physiological functions, including lipid metabolism, protein synthesis, and photosynthetic processes (Parida and Das, 2002). Due to salt stress increase in the concentration of sodium and chloride in the leaves, as well as a decrease in the rates of leaf area expansion, dry weight of the plant and pigment contents is observed. The investigation carried out by Seemann and Critchley (1985) agreed with the leaf-area expansion rates of grapevines under salt stress.

Mitigations of Salt Stress

Many cultural practices, particularly significant water deficiency combined with salt, can be employed as coping mechanisms for changing climatic conditions. In the world's major grape-growing regions, using salt-tolerant rootstocks has been shown to mitigate the potential negative effects of salinity stress (Walker *et al.,* 2002). According to Jogaiah (2023), using resistant rootstocks that can withstand salt, such as 110R, 140 Ru, 101-14 Mgt, 1103P, etc., is another tactic to lessen the negative impacts over time. Farmers using Dogridge rootstocks as a means of overcoming abiotic challenges such as salinity and drought in majority of the grape growing regions (Somkuwar *et al.,* 2023).

The cv. Thompson Seedless, which is widely cultivated in India for both local and export markets, demonstrated reduced sodium ion accumulation and maintained yield over time when grafted on 110R (*Vitis berlandieri* x *Vitis rupestris*) rootstock (Satisha *et al.* 2010; Sharma and Upadhyay, 2008). However, Mullins *et al.,* (1996) stated the capacity of various cultivars, rootstocks, and their compatibility as well as different stock-scion combinations to limit Na or Cl entry into the shoot has been primarily attributed to salt tolerance. Inducing salt stress tolerance by lowering stress ethylene levels through the synthesis of 1-aminocyclopropane-1-carboxylate (ACC) deaminase which may enhance root growth and nutrient uptake is one way that plant growth-promoting bacterial strains can help plants.

The growth of plants can be mediated by plant growth promoting bacteria (PGPB) through many direct and indirect methods, such as enhanced nutrient availability and defense against pests and diseases. Compost, straw, green manure, organic manure, humic compounds, and biochar are examples of materials that are considered organic. To enhance soil quality and health and enable higher crop yields, these organic components can be added to saline soils. Organic acids, hydrogen ions (H+), and carbon dioxide (CO_2) are released when soil organic additions decompose (Kitila *et al.,* 2020). Suleiman *et al.,* (2021) stated that applying gypsum to crops improves their resistance to salinity stress by controlling several physiological and biochemical processes, including photosynthesis, water status, reactive oxygen species, the Na+ balance, and phytohormone levels. In addition to promoting the production, transport and secretion of proteins, antioxidants, and polyamines, sulphur also enhances a crop's response to salt stress by up-regulating genes that are very effective in mitigating a variety of abiotic stresses. During abiotic conditions like drought and salinity, some growth regulators support the maintenance of the water balance and chlorophyll content (Jogaiah, 2023).

Effect of rainfall

Indian viticulture has already been shown to be impacted by climate change. The main abiotic stressors for vineyards are unseasonal rain and hailstorms as they lead to bunch rot and berry cracking, which both lower grape quality (Kochewad *et al.,* 2021). Rainfall during flowering and fruiting is harmful. Rain during flowering causes the pollen grain to be washed away, reducing the fruit set while during pre-bloom stage it causes inflorescence rot and the incidence of diseases like anthracnose, downy mildew and bacterial blight thereby devastating the crop in the pre-bloom stage itself. Rainfall during the later stages of fruit development may wipe off a significant amount of the harvest due to the shifting climate. Fruit quality and appearance can be negatively impacted by variations in rainfall patterns. Prolonged rainfall causes an increase in humidity, which renders fruits insipid and causes skin cracking (Singh and Chhabra, 2019).

Mitigation of rainfall

Mitigation of unseasonal rains in grape vineyard can be achieved through various techniques. One such approach is to shelter the grapevines from rainfall, which has been found to reduce the severity of grape diseases and increase grape yields and farmers' income (Fei Du *et al.,* 2015). Another method is the use of a cover system that can be opened and closed automatically in response to

undesirable natural events such as rain (Oana *et al.,* 2023). Additionally, irrigation, canopy shading, water nebulization, and kaolin coating have been studied as techniques to mitigate the effects of adverse weather conditions on grape yield and wine quality (Oliveira, 2018). Finally, adaptation measures such as changes in crop-management practices and varietal and land allocation changes may be necessary in the long term to mitigate the impacts of climate change on grapevines (Helder *et al.,* 2012).

Effect of hailstorm

Depending on the severity, size and timing of the hailfall, vineyards may sustain damage from hailstorms that compromise grape production each year and may even have an impact on the next season's harvest (Teodor, 2018). Hail typically severely damages leaves, branches, inflorescences, clusters, and berries, but at higher intensities, it may also injure the stems and cordons of grapevines (Dry, 1986). Hail frequently damages the entire leaf area of the vine plant, which lead to looser, smaller, and lighter clusters as well as decreased sugar and total phenolic reserves in the grapes. In addition, hail-damaged vines displayed a higher accumulation of total soluble solids (TSS) and a bigger leaf area on the lateral branches; however, there were no negative impacts on photosynthesis, berry mass, grape acidity, or fertility in the subsequent year (Petoumenou *et al.,* 2019).

According to Vinet (2001), the damage caused by hail is much more severe if it occurs during the ripening stage, when cell division is at its peak, as grapevines are not capable of healing. However, if hail falls during fruit set, when cell division is occurring inside the plant, damage caused by hail can be healed. With the hails, the microclimate in the canopy increases thereby leading to incidence of fungal diseases. There has been a significant loss of fruits and flowers due to hail damage (Bal *et al.,* 2014). Hail can cause damage to branches of scaffolds, shatter, or break shoots, and inflict injuries on fruits some of which may fall to the ground. As evidenced by grape vines where badly damaged vines did not sprout after pruning during the next season, hail damage can have a serious negative impact on a vine's health (Jogaiah, 2023). It is important to know how to take care of hail-damaged plants and try to get them back into production after a severe hailstorm.

Mitigation of hailstorm

Shoot pinching just below the hail damage and treat the plant with copper oxychloride @ 2.0 g/L water if grapes suffer hailstorm damage right after backup pruning. Mulch with antistress products increase abiotic stress tolerance, whereas subsurface irrigation reduces the amount of water needed. It is possible to shield grapes from hailstorms and other biotic pressures by cultivating them in plastic covering. Anti-hail nets have been employed as a protective tool for crops to minimize hailstorm losses, but their potential to change the tree microclimate may potentially affect the growth and quality of trees (Manja and Aoun, 2019). Shade nets might be a useful alternative in locations where hailstorms are more likely to occur. Crops protected by nylon nets against bird damage are also shielded against hail damage (Bal *et al.,* 2014).

The application of bio-stimulants exogenously through various mechanisms not only enhances plant growth and productivity but also improves yield and yield nutritional quality (Ali *et al.,* 2020). According to Petcu *et al.,* (2007), the incorporation of fertilizers containing amino acids facilitates a smoother adaptation to plant stressors induced by severe occurrences like low temperatures, hail, and water stress.

CONCLUSION

The management of abiotic stress in grapes, focusing on the effects and mitigations of abiotic stress. Abiotic stress affects the physiological processes, growth, quality, and productivity of grapevines, especially during crucial developmental stages such as flowering and ripening. This paper emphasizes the need for a wide approach to manage abiotic stress in grape cultivation, considering the local climate and soil conditions, and aiming to improve grape quality and vineyard productivity. The successful management of abiotic stress in grapes requires a multifaceted approach that integrates agronomic practices, technological advancements, and ongoing research. By combining these strategies, grape growers can enhance the resilience of vineyards, optimize grape quality, and ensure the long-term sustainability of grape cultivation in the face of environmental challenges.

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Utilization of wild germplasm for vegetable improvement: a review

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Abstract

About 400 species constitute the total diversity in vegetable crops across the globe. Among the diversity rich regions of the world that represent the centers of origin and /or diversity as well the regions possessing maximum diversity are the tropical American, Tropical Asian and the Mediterranean region. In the tropical Asian region, both India and China hold maximum diversity. Nearly 80 species of major vegetables, apart from several wild/undomesticated types are native to Indian region and are mentioned under "Hindustani Centre". India has a long history of vegetable cultivation and Sanskrit equivalents are available for introduced vegetable crops indicating exchange of plant material with other countries well before the Christian Era e.g. bottle gourd and watermelon from Africa, and onion from Central Asia. Other species, having wide distribution in India are, *Trichosanthes, Momordica, Coccinia and Canavalia* etc. Overall, 20-25 vegetable crops are commercially important and these include both the indigenous and exotic species.

Germplasm acquisition from within and outside country is the first step in germplasm management programme. A large germplasm representing a broad spectrum of genetic diversity has been introduced from other countries. Several introduced varieties have been used directly for large-scale cultivation. Many introductions in vegetable crops have also been used as parents to develop new cultivars. Germplasm of wild species of crops like brinjal (47), chilli (87), okra (82), tomato (385), water melon (18) have been introduced by NBPGR from abroad in the past few years. Besides identifying donors form cultivated form, their wild allies called CWR does have valuable genes with immense value for crop improvement and adaptation to changing environmental conditions. Utilization of CWR has enjoyed a great success in few crops like okra, tomato, potato, cucumber.

Key words: Will germplasm, Vegetables, Relatives, Diversity, Environmental conditions

Global food security is increasingly threatened by a range of challenges, including population growth, habitat destruction, climate change, water scarcity, limited arable land, and soil degradation (Godfray & Garnett, 2014; Hengyou *et al*., 2015). Over the past five decades, human activities have drastically reduced biodiversity, accelerating genetic erosion in crops and their wild relatives. The Food and Agriculture Organization (FAO, 2010) estimates that nearly 75% of crop genetic diversity has already been lost, posing a serious risk to agricultural resilience and long-term sustainability. Ongoing habitat destruction further exacerbates this issue by diminishing the genetic resources essential for food production and adaptation to shifting environmental conditions. Addressing these challenges is imperative to ensuring a secure and sustainable global food supply.

Present day's vegetable crops have evolved from its wild progenitors known as crop wild relatives (CWRs). These hidden reservoirs of valuable genes are crucial for developing resilient, climate-smart vegetable crop varieties, making them essential for global food security (Castaneda *et al*., 2016; Singh *et al*., 2018). The potential of CWRs as gene donors for crop improvement was first recognized by renowned Russian plant geneticist Nicolai Vavilov in 1920s and 1930s (Vavilov, 1926). the CWRs share a common ancestry with domesticated species and serve as sources of beneficial alleles for key nutritional and agronomic traits (Tanksley and McCouch, 1997; Guarino and Lobell, 2011; Fielder *et al*., 2015). These wild relatives of vegetable crops enhance the adaptive capacity of agricultural systems worldwide due to their natural resilience to local environmental conditions. The use of CWRs for introducing genes conferring disease and pest resistance, as well as tolerance to abiotic stresses, dates back more than 60 years (Hajjar and Hodgkin, 2007). unfortunately, many CWRs of vegetable crops remain underutilized in breeding programs. It is, therefore, imperative to prioritize their conservation, particularly through *in-situ* preservation, allowing them to continue evolving and developing valuable adaptations for future agricultural challenges.

Over the past decade, international initiatives like the FAO treaty and UN programs have advanced efforts to conserve and share wild plant genetic resources. Key strategies, including the Global Strategy for Plant Conservation (CBD, 2010b) and the Aichi Biodiversity Targets (CBD, 2010a), emphasize comprehensive conservation. In India, the ICAR-NBPGR plays a vital role in collecting, conserving, evaluating, and sharing plant genetic resources with crop breeders for its utilization in crop improvement programmes.

The Indian subcontinent is rich in wild vegetable plant species with high nutritional, traditional, and social value. Collecting and characterizing wild vegetable

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species is crucial for identifying useful traits and conserving them for future breeding programs (Hajjar and Hodgkin, 2007 and Teso *et al.*, 2018). Advances in genomic tools, particularly high-density SNP markers, have transformed how breeders utilize genetic diversity, aiding in the discovery of valuable genes (Tanksley and McCouch, 1997 and Gayle and Christopher, 2011). Crop wild relatives (CWRs) play a key role in developing climate-smart genotypes with better adaptation, higher nutrition, and greater ecological flexibility. This review paper emphasizes the need for prioritizing, conserving and utilization of wild vegetable species in Indian gene banks to enhance food and nutritional security.

Gene pool

Wild relatives of crop plants constitute a part of the crop gene pool. The crop gene pool concept developed by Harlan and de Wet (1971) is used to classify genetic relationship between crops and related taxa (Fig.1). In crops where categorization of CWR into gene pools has not been done as per their crossability relationship, taxonomic classification can be useful. This method of classification is referred to as taxon group concept (Maxted et al., 2006). In brinjal, the primary gene pool (GP1) consists of cultivated and its wild ancestor (Fig.2) *Solanum insanum* L. (Ranil *et al.,* 2017) which can be crossed easily and produce normal fertile hybrids (Plazas *et al.*, 2016). The secondary gene pool (GP2) includes a large number (over 40) of *Solanum* species that can be crossed or are phylogenetically close to brinjal, but the success of the crosses and viability of the hybrids with

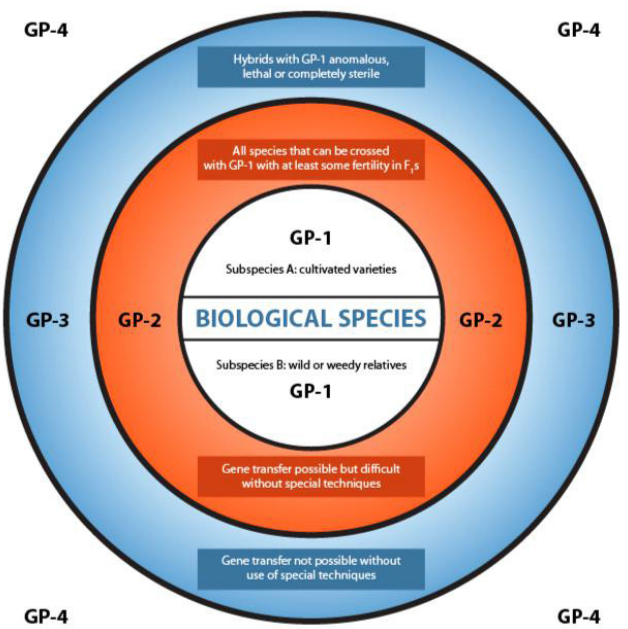

Fig 1: The modified "gene pool concept" adapted from Harlan and de Wet (1971)

Brinjal (*Solanum melongena* L.) may be reduced. For example, some interspecific hybrids derived from GP2 are partly sterile or weak due to reproductive barriers such as with *S. dasyphyllum, S. linnaeanum* Hepper and P.-M. L. Jaeger or *S. tomentosum* L. (Rotino *et al.*, 2014 and Kouassi *et al.*, 2016). The tertiary gene pool (GP3) of brinjal includes more widely related New World species which are used in its improvement programs for the transfer of resistance traits. For making successful crosses between these species, there is a need of follow specific breeding tools (e.g., *S. torvum* Sw., *S. elaeagnifolium* Cav., and *S. sisymbriifolium* Lam.; Kouassi *et al.*, 2016; Plazas *et al.*, 2016; Syfert *et al.*, 2016).

Genus *Pisum* is comprises of mainly three species i.e. *P. sativum* L. with subsp. *sativum* (includes var. *sativum* and var. *arvense*), ssp. *elatius*, *P. fulvum* and *P. abyssinicum*. The widely used classification is given by Maxted and Ambrose, 2001 to which *Vavilovia formosa* was added to group four species (Smýkal *et al.* 2011). In pea, primary gene pool consists of *Pisum sativum* including wild *Pisum sativum* ssp. *elatius*, the secondary gene pool is composed of *Pisum fulvum* and the tertiary gene pool consisting only of *Vavilovia formosa*. This is the closest species to whole tribe Fabeae that holds significant interest and breeding value in leguminous crops in the world. Gepts and Papa (2003) modified the gene pool concept and gave an additional gene pool level known as quaternary gene pool which takes into account the biotechnological advances such as plant transformation and genomics. It harness the genes from wild species which otherwise are sexually incompatible with crop species. This type of gene pool can also contain synthetic nucleotide sequence that does not occur in nature.

Diversity in vegetable crops

Plant genetic resources of wild relatives of vegetable crops are important components of agro- biodiversity, therefore extremely useful for present and future generations. Characterization of genetic diversity of wild collections exhibit evidence of historical demography and natural selection (Gayle and Christopher, 2011). India is the primary centre of diversity for brinjal, Smooth gourd (*Luffa cylindrica* (L.) *M. Roem.* (*M.J. Roem.*)), ridge gourd (*Luffa acutangula* (L.) Roxb. Roxburgh (Roxb.)), bitter gourd (*Momordica charantia* L.), spine gourd (*Momordica dioica* Roxb), Sweet gourd (*Momordica cochinchinensis*) and cucumber (*Cucumis sativus* L..), and the secondary centre for cowpea (*Vigna unguiculata* (L.) Walp), okra (*Abelmoschus esculentus* (L.) *Moench*), chillies (*Capsicum annuum* and *Capsicum frutescens*), melons (*Cucumis melo* L), pumpkin (*Cucurbita moschata*), cluster bean (*Cyamopsis tetragonoloba*) and members of brassicaceae

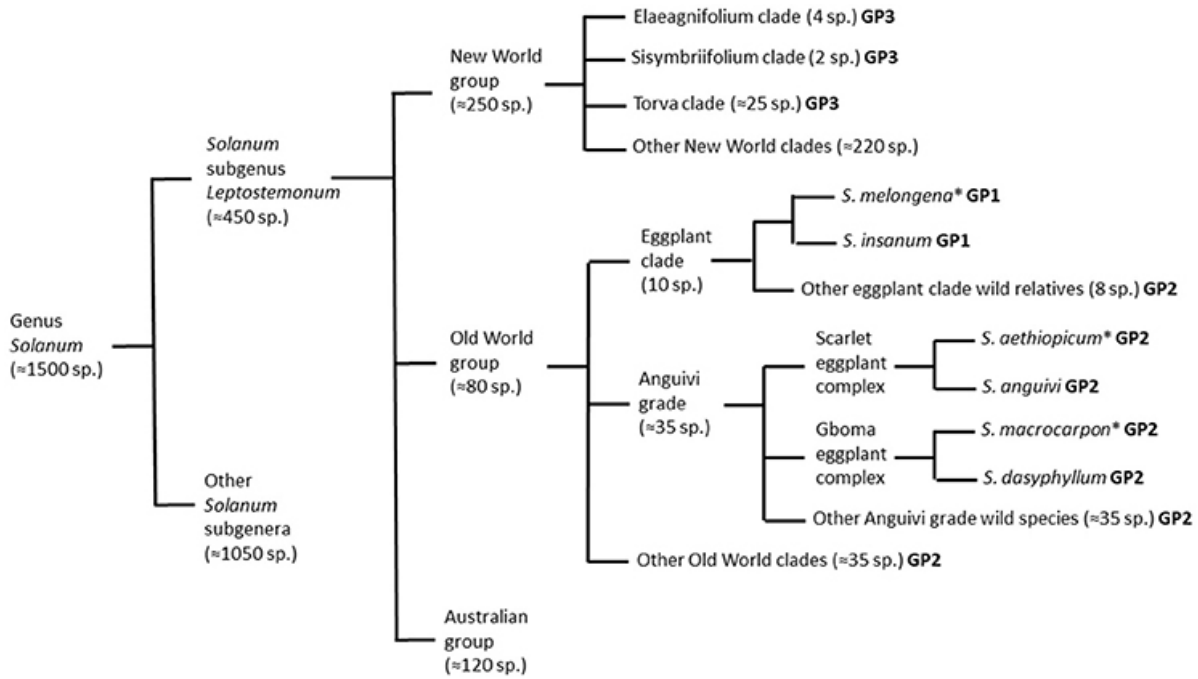

Fig.2. Schematic representation of taxonomic relationships between cultivated brinjal and other cultivated (scarlet eggplant, *S. aethiopicum*; and gboma eggplant, *S. macrocarpon*) and wild relatives from the genus *Solanum* based on Dalia *et al.* (2017), Nee (1999), Levin *et al.* (2006), Weese and Bohs (2010), Stern *et al.* (2011), Knapp *et al.* (2013), Syfert *et al.* (2016), and Vorontsova and Knapp (2016)

family. The distribution pattern of wild relatives of vegetable crops in different regions in India is presented in Table 1.

Table 1: Wild relatives of vegetable crops in different region of India

Region	Wild relatives of vegetables
Western Himalayas	*Cucumis sativus* var. *hardwickii, L. graveolens, Solanum incanum, S. indicum, Trichosanthes himalensi*
Eastern Himalayas	*Abelmoschus manihot, Cucumis hystrix, C. muriculatus*
North-eastern hills	*Abelmoschus, Alocasia macrorhiza, Amorphophallus bulbifer, Colocasia esculenta, Cucumix hystrix,, M. cochinchinensis, M. subangulata, Trichosanthes cucumerina, T. dioica, T. khasiana, T. ovata,*
Gangetic plains	*Abelmoschus tuberculatus, Luffa echinata, Momordica cymbalaria, M. dioica, Solanum incanum, S. indicum*
Indus plains	*Momordica balsamina, Citrullus colocynthis, Cucumis prophetarum*
Western peninsular tracts	*Abelmoschus angulosus, A. enbeepeegearense, A. moschatus, A. manihot, A. ficulneus, Cucumis setosus, C. trigonus, Momordica dioica, M. sahyadric Luffa graveolens, Solanum indicum, Trichosanthes anamalaiensis, T. bracteata, T. cuspidate, T. nerifolia, T. villosa*
Eastern peninsular tracts	*Amorphophallus campanulatus, Abelmoschus moschatus, A. crinitus, Colacasia antiquorum, Luffa acutangula* var. *amara, L. graveolens, L. umbellate, Momordica cymbalaria, M. dioica, M. subangulata, Trichosanthes bracteata, T. cordata,T. lepiniana, T. himalensis, T. multiloba*

The distribution pattern of wild relatives of vegetable crops in different phytographical regions and the areas of their occurrence and diversity is useful for germplasm collection and *in-situ* conservation.

The Base Collections are being maintained by NBPGR in the National Genegank (NGB) in form of seeds in Seed Genebank (where seeds dehydrated to ~5% moisture content and sealed in tri-layered laminated aluminum foil packets and conserved at -18^{0}C), in form of tissue culture in the *In vitro* Genebank and in Cryobank (-196^{0}C), and in form of live plants in Field Genebanks. The details of important vegetables crops maintained at National Genebank are presented in Table 2.

Utilization of wild species

In India, brinjal and some cucurbits are of Indian origin, whereas for tomato, okra and chilli, India considered as secondary centre of origin. *Solanum melongena* complex has three species, namely, the *S. melongena, S. incanum* and *S. melongena* var. *insanum.* Wild relatives of *Solanum viz. Solanum torvum, S. indicum, S. insanum, S. surattense, S. pubescens, S. gilo,* and *S. khasianum* are widely distributed in South India, Shivalik hills and North-eastern region. There are about 100 species of cucurbitacae family are reported to occur in India including 34 endemic species viz. *Cucumis hardwickii, C. trigonus, C. prophetarum, C. setosus, C. hystrix, Luffa graveolens, L. acutangula* var. *amara,*

Table.2: Status of cultivated and wild germplasm of major vegetable crops conserved in National Gene bank, India

Crop	Botanical name	No. of accession in NGB
Tomato and wild species	*Solanum lycopersicon, S. peruvianum, S. pimpinellifolium, S. lycopersicon var. cerasiforme, S. hirsutum, S. chilense*	2931
Brinjal and wild species	*Solanum melongena, S. aethiopicum, S. americanum, S. gilo, S. macrocarpum, S. melongena var. incanum, S. verbascifolium, S. viarum, S. melongena var. incanum, S. hispidum, S. incanum, S. melongena var. insanum, S. torvum, S. vagum, S. violaceum, S. albicans, S. anguivi, S. laciniatum, S. trilobatum,. S. pimpinellifolium, S. pubescens, S. seaforthianum, S. setosissimum, S. virginianum, S. xanthocarpum, S. aculeatissimum, S. aviculare, S. giganteum, S indicum, S. khasianum, S. nigrum, S. sisymbrifolium, S. surattense, S. lasiocarpum.*	4846
Chilli and wild species	*Capsicum annuum, C. baccatum, C. chinense, C. frutescense, C. annuum var. annuum, C. annuum var. grossum*	5402
Okra and wild species	*Abelmoschus esculentus, A. betulifolius, A. crinitus, A. ficulneus, A. manihot* spp. *manihot, A. manihot var. pungens, A. manihot var. tetraphyllus, A. moschatus var. tuberosus, A. pungens, A. tetraphyllus, A. tuberculatus, A. manihot, A. moschatus.*	4275
Ashgourd	*Benincasa hispida*	294
Bitter gourd	*Momordica charantia, M. charantia var. muricata, M.sahyadrica, M. tuberosa, M. cochinchinensis, M. dioica, Momordica subangulata* ssp. *renigera, M. balsamina.*	672
Bottle gourd	*Lagenaria siceraria, Lagenaria* sp.	800
Luffa spp. (Sponge gourd, Ridge gourd)	*Luffa echinata, Luffa pentandra, Luffa sp. Luffa tuberosa, Luffa acutangula, Luffa acutangula var. amara, Luffa hermaphrodita, Luffa aegyptiaca, Luffa cylindrica, Luffa graveolens*	988
Trichosanthes species (Snake Gourd)	*Trichosanthes tricuspidata, Trichosanthes dioica, Trichosanthes anguina, Trichosanthes cucumerina, Trichosanthes cucumeroides var. dicoelosperma, Trichosanthes palmata, Trichosanthes wallichiana, Trichosanthes bracteata, Trichosanthes cuspidata, Trichosanthes nervifolia, Trichosanthes lepiniana, Trichosanthes lobate, Trichosanthes spp.*	383
Cucumis spp.	*Cucumis melo var. flexuosus, Cucumis hardwickii, Cucumis sagittatus, Cucumis sativus, Cucumis melo var. inodorus, Cucumis metuliferus, Cucumis melo var. utilissimus, Cucumis melo var. agrestis, Cucumis setosus, Cucumis melo, Cucumis melo var. conomon, Cucumis melo var. reticulatus, Cucumis trigonus, Cucumis hystrix, Cucumis melo subsp. melo, Cucumis vulgaris, Cucumis prophetarum, Cucumis rati, Cucumis callosus,, Cucumis javanicus, Cucumis maderaspatanus, Cucumis silentvalleyi, Cucumis muriculatus, Cucumis leiospermus, Cucumis spp.*	2373
Cucurbita species	*Cucurbita moschatus, C. argyrosperma, C.maxima, C. pepo, Cucurbita* sp.	282
Citrullus species	*Citrullus colocyhtis, Citrullus lanatus, Citrullus Sp, Citrullus Vulgaris Var Citrode .*	466
Onion and wild species	*Allium cepa, A. altaicum, A. auriculatum, A. clarkei, A. stracheyi. A. fistulosum, A. griffithianum, A. humile, A. oschaninii, A. albidum, A. pskemense, A. ramosum, A. tuberosum, A. ampeloprasum, A. orepprasum, A. porrum, A. sativum, A. senescens.*	1151
Cabbage	*B. oleracea var. capitata*	283
Cauliflower	*B. oleracea var. botrytis*	219
Broccoli	*B. oleracea var. italica*	24
Brassica species	*Brassica perkensis, Brassica oleracea var. compestris, Brassica rapa subsp. Chinensis, Brassica campestris var. rapa, Brassica oleracea var. caulorapa, Brassica campestris var. rapifera, Brassica juncea var. rugosa, Brassica oleracea var. gemmifera*	494
Carrot	*Daucus carota, Daucus carota var. sativa*	152

Crop	Botanical name	No. of accession in NGB
Radish	*Raphanus caudatus, R. sativus*	334
Beet root	*Beta vulgaris, Beta vulgaris var. bengalensis*	92
Spinach	*Spinacia oleracea, Spinacia sp*	163
Amaranthus species	*Amaranthus blitum, Amaranthus dubius, Amaranthus graecizans, Amaranthus leucocorpus, Amaranthus spinosu, Amaranthus tristis, Amaranthus gangeticus, Amaranthus tricolo, Amaranthus viridis*	765
Fenugreek	*Trigonella corniculata, T. foenum-graecum, T. caerulea*	1432
Leguminous vegetable	*Vicia faba, lablab var typicus, Vigna unguiculata subsp. Sesquipedalis, Pisum sativum subsp. hortense, Pisum sativum var. arvense,* Adzuki Bean	1016
	Total	29837

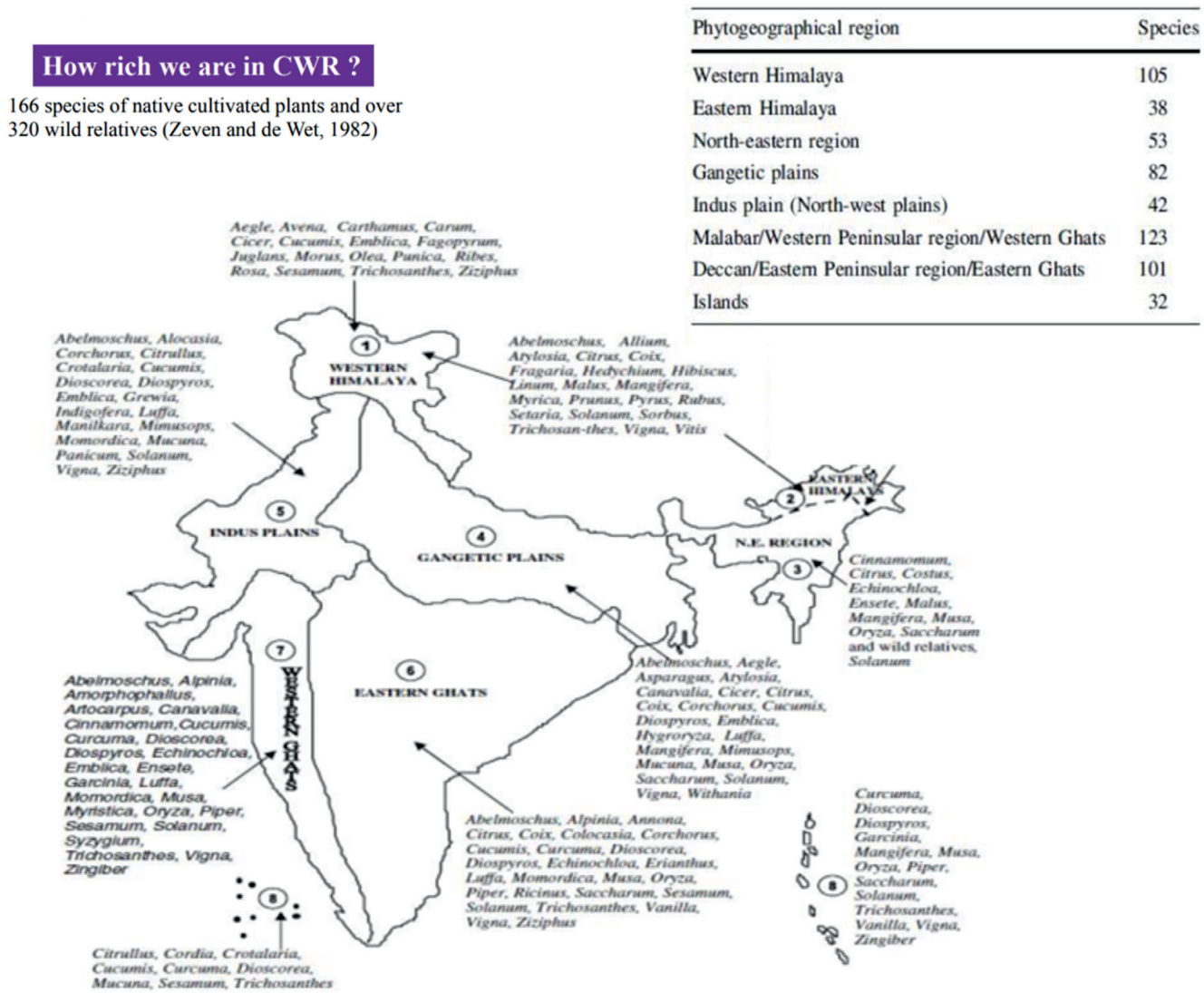

Fig. 3. Distribution pattern of wild relatives of vegetable crops in different region in India

L. cylindrica, L. tuberosa, L. echinata, L. umbellata, Trichosanthes anguina, T. dioica, T. dicaeleosperma, T. khasiana, T. ovata, T. truncata, T. multiloba, T. anamalaeiensis, T. bracteata, T. cuspidata, T. nervifolia, T. perotteliana, T. himalensis, Momordica cochinchinensis, M. macrophylla, M. subangulata, M. cymbalaria, M. dioica, M. cymbalaria, M. denticulata, M. balasamina, Neoluffa sikkimensis and *Citrullus colocynthis.* In *Abelmoschus,* 11 species and two varieties, namely, *A. angulosus, A. tuberculatus, A. manihot, A. moschatus, A. ficulneus, A. esculentus, A. tetraphyllus* var. *tetraphyllus, A. tetraphyllus* var. *pungens, A. crinitus, A. caillei, A. enbeepeegearense* and *A. palianus* are occurring in India. Of these, only *A. esculentus* is cultivated and others are wild taxa.

Rich genetic diversity in root and tuber crops, namely, *Amorphophallus paeoniifolius, Manihot esculenta, Ipomoea batatas, Dioscorea alata, Dioscorea rotundata, Psophocarpus Tetragonolobus, Dioscorea esculenta, Dioscorea bulbifera var. sativa, Colocasia esculenta, Alocasia macrorrhiza, Xanthosoma sagittifolium* in terms of species and landraces is occurring in India. Besides these crops, there are several tubers of minor importance, namely, *Maranta arundinacea, Solenostemon rotundifolius, Moghania vestita, Canna edulis, Psophocarpus tetragonolobus* and *Pachyrrhizus erosus* are also found and used as food in some parts of western peninsular region. Genus *Allium* represents a major group and about 30 species are found in Indian region. The cultivated Alliums are - *Allium cepa* var. *cepa, A. cepa* var. *aggregatum, A. cepa* var. *viviparum, A. fistulosum, A. tuberosum, A. sativum, A. ampeloprasum* var. *porrum, A. schoenoprasum*, whereas *A. carolinianum, A. chinensis, A. consanguineum, A. humile, A. przewalskianum, A. stolczkii, A. stracheyi, A. victorialis* and *A. wallichii* are important wild species occurring in Himalayan region.

Besides being identifying donors form cultivated form, their wild allies called CWR does have valuable genes with immense value for crop improvement and adaptation to changing environmental conditions. Utilization of CWR has enjoyed a great success only in a few crops. For example, in potato, (*Solanum demissum*) provided resistance to late blight while in tomato >40 resistant genes have been derived from *S. peruviannum, Solanum pennellii* Correll var. *pennellii, Lycopersicon cheesmanii, L. pimpinellifolium* for traits such as increased soluble solid content, fruit color, and adaptation to harvesting (Rick and Chetelat 1995). Broccoli varieties producing high levels of anti-cancer compounds have been developed using genes obtained from wild Italian *Brassica oleracea.* The species of *Solanum* complex such as *S. incanum, S. viarum, S. melongena* var. *insanum, S. khasianum* have provided gene for resistance to *Fusarium* wilt, bacterial wilt, frost tolerance and fruit and shoot borer.

The wild species of okra *Abelmoschus tuberculatus* to YVMV and wild cucumbers *Cucumis hardwickii* and *C. callosus* have resistance to downy mildew and fruit fly, *Cucumis melo* var. *chito* for *Fusarium* wilt resistance. Many genes are still lies untapped in these genetic resources, presumably due to the lack of useful genetic information and genetic bottlenecks as well. A good piece of work has been done by ICAR-NBPGR on biosystematics, screening and genomics of *Abelmoschus, Cucumis, Vigna, Alliums, Trichosanthes, Chenopodium* and *Amaranthus.* New records such as *Moringa concanensis* (Lakshadweep) and rare and endangered species *Cucumis silentvalleyi* (Anaimalai Hills in TN), and *Piper ribesioides* from Middle Andaman have been recorded. Similarly, new species have been described in *Momordica sahyadrica (Western Ghats), Curcuma amada var. glabra (Kerala), Curcuma longa var. vanaharidra, A. enbeepeegearense* and *A. palianus* in okra.

Table 3: Traits specific donors of wild species of major vegetable crops

Crop/trait	Wild species as donors
Tomato	
High TSS	*S. chmielewskii* (10%), S. *cheesmanii* (15%),
High temperature	*S. chilense, S. cheesmanii, S. pimpinellifolium*
Low temperature	*S. hirsutum, S habrochaites, S chilense, S lycopersicoides*
Drought	*S. Lycopersicum* var. *Cerasiformae, S pennellii, S pimpinellifolium*
Salt tolerant	*S. cheesmani, S. pennelli, S pimpinellifolium, S peruvianum*
Fusarium wilt / rot	*S. pimpinellifolium,*
Late blight	*S. hirsutum*, S. *pimpinellifolium*, S. *Lycopersicum* var. *cerasiforme*
Early blight	*S. peruvianum* var. d*entatum,* S. *peruvianum, SL. hirsutum* f. *glabratum*
TLCV	*S. hirsutum* f. *typicum*, S. *pimpinellifolium* 'A 1921', S. *hirsutum* f. *glabratum*
TYLCV, CMV	*S. chilense*
Grey mold	*S.neorickii*
Fruit fly	S. galapagense
Leaf miner	S. *hirsutum, S. hirsutum* f. *glabratum,*
Fruit borer	*S. hirsutum* f. *glabratum*
White fly	*S. hirsutum* f. *glabratum*
Nematode	*S. peruvianum*
Flooding	*S Lycopersicum var. cerasiforme, S. juglandifolium, S. ochranthum*

Crop/trait	Wild species as donors
Brinjal	
Fusarium wilt	*S. incanum, S. indicum, S. khasianum, S. sysimbrifolium, S aethiopicum*
Bacterial wilt	*S. torvum, S. melongena var. insanum, S. nigrum, S. sisymbriifolium,S. integrifolium*
Phomopsis blight	*S. gilo, S. integrifolium, S. sisymbrifloium*
Little leaf	*S. gilo, S. integrifolium, S. sysimbrifolium, . torvum, S. khasianum*
Verticillium wilt	*S. torvum, S. sysimbrifolium*
Shoot and fruit borer	*S. khasianum, S. incanum, S. gilo, S. indicum S. sisymbriifolium, S. hispidum, S. aethiopicum, S. macrocarpon*
Heat and drought tolerance	*S. macrocarpon, S. incanum, S. gilo*
Nematode	*S. sisymbrifolium*
Male sterility	*S. virginianum, S. angulvi*
Mites	*S. macrocarpon, S. integrifolium, S. mammosum*
Chilli	
Anthracnose	*C. baccatum*
Phytophthora blight	*C chinense*
Cucumber mosaic virus	*C chinense, C. frutescens*
Leaf curl virus	*C chinense, C. frutescens*
Bacterial leaf spot	*C. chacoense*
Curly top virus	*C. annuum, C. frutescens, C chinense, C. chacoense*
Pepper mosaic virus	*C. baccatum, C chinense*
Okra	
YVMV	*A. crinitus, A. angulosus*
Powdery mildew	*A. tetraphyllus, A. angulosus, A. crinitus*
Cercospora blight	*A. crinitus, A. moschatus, A. angulosus, A. ficulneus*
Enation leaf curl virus	*A. crinitus, A. ficulneus, A. manihot*
Fruit borer	*A. tuberculatus, A. moschatus*
Mites	*A. angulosus*
Jassids	*A. moschatus, A. crinitus*
Late blight	*Sollanum demissum*
Potato Virus Y	*Sollanum chacoense*
Colorado potato beetle	*Solanum chacoense*
Aphid	*S. polyadenium, S. berthaultii*
Nematode	*S. vernii*
Cucumber	
Downey mildew, powdery mildew, Anthracnose	*C. sativus* var. *hardwickii*
Muskmelon	
Water melon mosaic virus	*Cucumis metuliferus*
***Brassica* spp.**	
Black rot	*Brassica carinata, B. juncea, B. nigra,*
Cytoplasmic male sterility	*Brassica napus* 'nap and pol', *B. oleracea 'Ms-cd1', Diplotaxis berthautii, Trachystoma ballii 'trachystoma'*
Drought tolerance	*Brassica carinata, Brassica juncea, Brassica tournefortii*
Downy mildew	*Brassica oleracea*
Diamond-back moth	*Brassica juncea, Brassica oleracea*
Resistance to pod shattering	*Brassica juncea, Brassica macrocarpa, Brassica tournefortii*
Cabbage aphid	*Brassica fruticulosa, B. spinescens,,B. cretica, B. incana, B. macrocarpa, B. villosa*
Onion	
Cytoplasmic Male sterility	*A. galanthum*
Stemphilium blight	*A. tuberosum*
Downy mildew	*A. royeli*
Lettuce	
Leaf spot	*Lactuca saligna*
Downy mildew	*L. saligna, L. serriola*

For the past few decades, there is a significant success in introducing different traits from wild species into cultivated crops for overcoming biotic/abiotic stresses. For example, introduction of late blight resistance from the wild potato *Solanum demissum* Lindl is the main landmark. The primary approach for crop improvement today remains recurrent selection among elite modern varieties. Plant breeders are continuously looking into wild species as sources of novel genes to widen the genetic base of crops (Cooper *et al.*, 2001; Hodgkin and Hajjar, 2007; Moore, 2015)

Wild relatives of cultivated crops are the raw material for plant breeder. Recently the importance of CWR has been realized globally to breed climate resilient crop varieties to meet out the future food security. CWR's has many fold applications in crop improvement which include different traits such as biotic stresses (pest /

disease resistance, yield, quality, and male sterility) and abiotic stresses (heat, flood, cold and drought tolerance). To develop trait- specific genotypes, the CWRs have been utilized with varying degrees for significant traits. At present, most of the varieties (65%) released for commercial cultivation are either direct selection from germplasm or developed (20%) using trait specific germplasm as one of the parents in hybridization program. This highlights the worth of germplasm collection and conservation to enable their use in crop improvement programs.

Some of the important wild relatives of horticultural crops have successfully been utilized for the introgression of genes are *Solanum incanum, S. viarum, S. melongena* var. *insanum* for fusarium wilt, bacterial wilt resistance, and frost tolerance; *S. torvum S. sisymbrifolium* for verticillium wilt and *Meloidogyne incognita*; *S. gilo, S. integrifolium* for *M. incognita* race 1 and 2 and *S. khasianum* for shoot and fruit borer resistance in brinjal; *Allium ampeloprasum* for downy mildew in onion, *Pisum sativum* var. *arvense* for podwery mildew in pea. In brinjal, K61, K62 used for *Fusarium* wilt resistance; SM81, SM56, SM71, SM72, SM74, H8, Kopek for bacterial wilt resistance; MM392, MM450 for nematodes (*M. incognita* and *M. aremeriai*) and H165, H407, H408 for Shoot and fruit borer resistance. The species of *Solanum* complex such as *S. incanum, S. viarum, S. melongena* var. *insanum, S. khasianum* have provided genes for resistance to fusarium wilt, bacterial wilt, frost tolerance and fruit and shoot borer in brinjal.

Interspecific hybridization is an important tool which can be used to improve traits through chromosome manipulation in wild species that aid in their adaptability to different agricultural environments and compete with the cultivated forms. Inter-specific hybrids have been produced in several genera of Cucurbitaceae like *Cucumis* (Deakin *et al*. 1971; Chen *et al*. 1997), *Citrullus* (Valvilov 1925), *Luffa* (Singh 1991) and *Cucurbita* (Weeden & Robinson 1986).

The *Abelmoschus* is one of the major vegetable genera under family Malvaceae. *Abelmoschus* with 14 species reported so far (Misra *et al*., 2023), has two major species under cultivation viz., *A. esculentus* (L.) Moench (okra) and *A. caillei* (A.Chev.) J.M.C.Stevels (Guinean okra). In South Pacific Islands, Papua New Guinea, and eastern Indonesia, *A. manihot* (L.) Medik. is also popular as leafy vegetable (Prabawardani *et al*., 2016; Rubiang-Yalambing *et al*., 2016). Apart from the cultivated genepool, the wild *Abelmoschus* spp. has many desirable traits like perennation tendency, extended bearing, biotic and abiotic stress tolerance (Suma *et al*., 2023). Cultivated Okra is facing challenges of YVMV and ELCV, diseases are the two major ones causing significant yield losses, which require search for resistance in the wild related taxa and their incorporation into cultivated genome.

Though Pusa Sawani (a derivative of a cross between IC1542 and Pusa Makhmali) was the first ever YVMV resistant variety of okra to be released at national level in India, Parbhani Kranti, Arka Anamika and Arka Abhay were the ones released as a result of interspecific hybridization between *A. esculentus* and *A. manihot* for the former (Jambhale and Nerkar, 1986), and *A. manihot* subsp. *tetraphyllus* (Roxb. Ex Hornem.) Borss. Waalk. for the latter two (Dutta, 1991). Further, *A. manihot* was used for developing a variety Anjitha, by exploiting interspecific hybridization followed by mutation breeding by Kerala Agricultural University (KAU) for transferring YVMV resistance and tolerance to shoot and fruit borer. Susthira was another variety belonging to *A. caillei* reported as resistant to YVMV, released by KAU. Gangopadhyay *et al.* (2016) reported resistance to YVMV disease in accessions belonging to three wild species viz. *A. caillei, A. manihot* and *A. moschatus* Medik., while resistance to shoot and fruit borer and leaf hopper was found in all the three above besides *A. tuberculatus* Pal and Singh.

It was also been noted that *A. manihot* subsp. *tetraphyllus* is one of the most widely used species worldwide for transferring genes responsible for resistance or tolerance to YVMV, jassids, and fruit borer (Badiger and Yadav, 2019; Patel *et al*., 2021). Promising accessions of *A. moschatus* (IC141055), *A. tetraphyllus* (IC90476-1), and *A. caillei* (Sikkim) were also reported by Santhiya *et al.* (2022) under natural epiphytotic screening, where the above accessions demonstrated a very low prevalence of YVMV and no incidence of ELCV diseases. Singh *et al.* (2023a) revealed that *A. angulosus* accessions IC203833 and IC470751 were extremely resistant to YVMV disease under artificial screening conditions employing mass inoculation mediated by viruliferous whiteflies.

With the implementation of National Agriculture Innovation Project (NAIP) during 2009-13 by the Indian council of Agricultural Research (ICAR), the biosystematics and crossability studies among various *Abelmoschus* species caught momentum, which were further progressed under the ICAR-Extramural Project of the ICAR, Horticultural Sciences Division (2015-17) and later under the ICAR-Emeritus Scientist Programme (2018–2021) for transferring genes tolerant/ resistant to YVMV and ELCV diseases. The tolerant species (*A. pungens* var. *mizoramensis*, *A. enbeepeegeearensis, A. tetraphyllus*, and *A. angulosus* var. *grandiflorus, A. crinitus, A. ficulneus*) were also identified through the field screening of wild *Abelmoschus* species germplasm

(John *et al*., 2013a). These species were then employed in a wide hybridization program to produce interspecific hybrids with the cultivated okra at ICAR-National Bureau of Plant Genetic Resources, Regional Station, Thrissur to find out crossability relationships among various species of Abelmoschus.

A total of 113 amphidiploids generated were extensively characterized for the important morphological characters by Suma *et al.* (2023). The promising amphidiploids identified are currently being advanced through back crossing and selfing. Among them, 13 selfed derivatives (involving crosses between *A. esculentus* and *A. pungens* var. *mizoramensis*, and a multi-cross combinations of *A. esculentus, A. angulosus* var. *grandiflorus*, *A. tetraphyllus* and *A. pungens* var. *mizoramensis*), one back cross derivative (involving *A. esculentus* and a multi-cross combination of *A. esculentus, A. angulosus* var. *grandiflorus*, and *A. pungens* var. *mizoramensis*) and nine open pollinated bulked amphidiploid derivatives (involving *A. esculentus* with *A. angulosus* var. *grandiflorus*, and *A. pungens* var. *mizoramensis*) exhibited field resistance in three locations namely Varanasi, Ludhiana and New Delhi (not published).

In addition, *A. manihot* and newly described species *A. odishae* are also being currently utilized in wide hybridization programmes. Venkataravanappa *et al.* (2022) also identified cultivated, wild as well as advanced lines resistant to both YVMV and ELCV diseases. Embryo rescue was employed for successful production of F_1 hybrid for crosses involving *A. esculentus* and *A. moschatus* subsp. *tuberosus* (Zaman and Parihar, 2023) and *A. esculentus* and *A. tetraphyllus* (Rattan and Kumar, 2020).

Besides employing the wild species for transferring genes tolerant to biotic stresses, crosses were attempted to exploit the ornamental potential of hybrids of the cross between *A. moschatus* and *A. sagittifolius* as reported by John *et al.* (2013a and 2013b). All the plants derived from both direct and reciprocal crosses were yielding plants with bright red flowers. The F_2 plants showed segregation for the flower colour with various shades ranging from pink, yellow, light red, dark red and with combinations of these colors, including contrasting dark veins on petals with lighter shades (Suma *et al.,* 2024).

In tomato, several wild species have been used as donors, for example, genus *Lycopercicon hirsutum* and *L. pimpinellifoium* for fungus resistance, *Lycopercicon chilense* and *Lycopercicon peruvianum* for virus resistance, *Lycopercicon chmielewskii* for fruit quality and *Lycopercicon cheesmanii* for tolerance to adverse environments. And, further, use of quality genes such as 'Rin' in tomato resulted into better table and nutritional quality of the crop. Genes from *L. chilense* and *L.pennellii* species have been used to increase drought and salinity tolerance (Rick and Chetelat 1995). The TMS line of cassava, derived from an initial cross with a wild relative, gives a 40% more yield (Nweke 2004), which may be because of wild genes conferring disease resistance in the cross.

In a recent study, pyramiding of three independent yield-promoting genomic regions introduced from *Solanum pennellii*, a green-fruited wild relative of tomato has led to the development of hybrids with 50% more yield over a commercial variety (Gur and Zamir 2004). Wild relative of crop plants, as a source of cytoplasmic male sterile genes, can also play an important role in developing F_1 hybrids in vegetable crops. Attempts were made at Indian Agricultural Research Institute, New Delhi, IIHR, Bangaluru, IIVR, Varanasi, PAU, Ludhiana and some other palces to utilize wild relatives of tomato e.g. *Solanum habrochaites* for developing varieties/hybrids resistant to tomato leaf curl virus, Heat tolerance, and all these traits together as Tomato leaf curl virus + Heat tolerance+ superior fruit quality traits, *Solanum chilense* for Tomato leaf curl virus and varieties /hybrids like Pusa Tomato hybrid-6, Arka Abhed, Kashi Aman, PVB-4,Pusa Cocktail Tomato, Pusa Prasanskrit, Pusa Cherry Tomato Hybrid-1 were developed, *Solanum peruvianum* is also being utilized to address the problem of Root-knot nematode.

In potatoes, resistance to late blight incorporated from wild species *Solanum demissum* and *S. stoloniferum* Schltdl. and Bche ´is still effective in some areas. Presently, 40% of the total area covered by the most popular cultivars of potato in the United States has *S. demissum* in their ancestry (National Potato Council, 2003).

The anthracnose resistance genes from *C. baccatum* were introgressed in *C. annuum* gene pool through embryo rescue and resulted in anthracnose resistant *C. annuum* introgressed lines (Yoon *et al*., 2006). Interspecific hybridization with *C. baccatum* var. *pendulum* has been used for the introgression of resistance gene(s) into cultivated chilli peppers (Kim *et al*., 2010). Male sterile lines are developed through interspecific hybridzation between *C. chacoense* and *C. annuum* (Kumar et al., 2007). In onion, powdery mildew resistant cultivar was developed by introgressing resistance genes from wild onion species *A. roylei*.

This species is used as bridge species to introduce genes from *A. fistulosum* (welsch onion) into *A. cepa* genomes (Khrustaleva and Kik, 2000). Wild relatives of crop plants grow in natural habitat, hence require specific set of environmental conditions for characterization, evaluation and their multiplication. Due to genotype x

environment interaction, characterization and evaluation of different crop species becomes difficult especially in perennial species. In view of this, *in situ* characterization during exploration and collection visit is a feasible option. There are National Active Germplasm Sites (NAGs) which preserve the germplasm of perennial, recalcitrant and vegetatively propagated crop species. The trait specific evaluation and multiplication of germplasm of vegetables and wild species could be done at national active germplasm site.

Interspecific crosses are widely used in cucurbits to transfer desirable characteristics from wild progenitors or related species to cultivated genotypes. Interspecific hybrids have been produced in *Cucurbita, Cucumis, Citrullus, and Luffa*. However, only interspecific hybridization of *Cucurbita* has been successfully utilized for crop improvement (Robinson and Decker-Walters, 1997). In order to transfer certain desirable characters of one cultivated species to another *Cucurbita lundelliana* Bailey has been used as a bridge species (Rhode, 1959). *Cucurbita moschata* was also used as a bridge to transfer disease resistance (powdery mildew and cucumber mosaic virus), good fruit quality and insect resistance from *C. martinezii* to *C. pepo* (Whitaker and Robinson, 1986).

For enhanced fruit quality, cultivar 'Tetsukabuto' was developed which is an interspecific hybrid between C. maxima cv. 'Delicious' and C. moschata cv. 'Kurokawa no. 2' (Robinson and Decker-Walters, 1997). *Citrullus mucosospermus*, a close relative of *C. lanatus*, is native to west Africa and has a modified fleshy mucilaginous seed coat that becomes paper-thin when dried. The thin seed coat makes it easier to de-hull the seed. In China, specific varieties of watermelon have been bred for edible seeds (Levi *et al.,* 2017). The edible-seed watermelons can grow on marginal land and are drought tolerant, with small thin leaves, thin vines, and a large number of branches. Wild species such as *C. amarus* and *C. mucosospermus*, are valuable sources of resistance to many diseases and are crossable with *C. lanatus*, with variable fertility (Dhillon *et al.,* 2017; Levi *et al.,* 2017).

There are some multi-resistant accessions that have been deeply studied, such as the *C. mucosospermus* PI 595203 (readily crossable to watermelon) that display recessive resistance to the three potyviruses, ZYMV, WMV, and PRSV, which are most damaging to this crop, and the *C. amarus* PI 244019 (MartínHernández and Picó, 2021). In *Cucumis*, an amphidiploid was reported from the cross of *C. anguria L. and C. dipsaceus* E. ex S. (Yadava *et al.,* 1986). The cross made between cucumber and *C. hystrix* Chakr. (2n = 24) was the first repeatable cross between a cultivated *Cucumis* species and a wild relative (Chen *et al.,* 1997), and represented a breakthrough in interspecific hybridization in *Cucumis*.

The crosses of melon and cucumber genotypes with *C. prophetarum* (2n=24), *C. hystrix* (2n=24), *C. muriculatus* (2n=24), *C. setosus* (2n=24), *C. indicus* (2n=20) and *C. silentvalleyii* (2n=24) were produced with varying degrees of success but fertile F_1 hybrid could not be recovered. However intra-specific crosses with wild/weedy forms both as maternal and paternal parents were highly successful and F_1, F_2 generations were advanced through selfing at Thrissur. Backcross progenies of respective cultivated melon with *C. melo* var. *agrestis* and *C. melo* var. *callosus* and cucumber with *C. sativus* var. *hardwickii* were also produced. Under field epiphytotic conditions lines resisting aphid infestation, fruit rot, anthracnose and downy mildew were selected. *C. melo* var. *callosus* has high drought tolerance, high shelf life and bacterial fruit rot resistance but all F_1 and F_2 plants produced bitter fruits.

The wild melon *C. melo* var. *agrestis* (IC 539841) identified for prolificacy, non-bitterness and high rainfall tolerance has contributed to prolificacy, reduced fruit size and non-cracking skin in snap melon, musk melon and oriental pickling melon genotypes. The non-bitter fruity scented *C. melo* var. *agrestis* (Kachiri, JJK/03-1) was also used in crosses with cultivated melon groups for broadening the genetic base. The cross derivatives are conserved in the MTS for further field screening and utilization by breeders.

Extensive efforts made at Central Horticultural Experiment Station (ICAR-IIHR), Bhubaneswar and ICAR-NBPGR Regional Station, Thrissur have led to the development of fertile hybrids among *Momordica dioica, M. cochinchinensis*, and *M. subangulata* subsp. *renigera* through backcross and ploidy manipulation. The inter-specific hybrid (*M. suboica*) developed between *M. dioica* and *M. subangulata* subsp. *renigera* through ploidy manipulation and hybridization represents an important step in inter-specific hybridization in this genus. Fertile backcross progenies were also produced from inter-specific hybrids (*M. subangulata* subsp. *renigera* × M. *dioica*; *M. dioica* × *M. cochinchinensis*) by backcrossing the F_1 with the female parent. Movement of genes responsible for adventitious root character from *M. subangulata* subsp. *renigera* to *M. dioica* (for improved propagation efficiency), extended cropping period from *M. cochinchinensis* to *M. dioica* (for off season availability) through hybridization have been made possible.

Recently a new synthetic species (*M. suboica*; 2n=56) has been developed by crossing natural tetraploid *M. subangulata* subsp. *renigera* (2n=56) with induced tetraploid *Momordica dioica* (2n=4x=56). *M. suboica*, an

autoallo polyploid can be propagated easily through root cutting, set fruits naturally (>60% fruit set), has extended harvesting period and gives higher yield. Bharathi *et al.* (2010, 2011) obtained successful hybrids between *M. cochinchinensis* and *M. subangulata* subsp. *renigera* while Mondal *et al.* (2006) reported complete incompatibility between these two species.

Wild relatives of *Phaseolus* are currently being screened for resistances to web blight, rust, white mold, bean golden yellow mosaic, bruchids, and seed storage insects (Singh 2001; Gallepo 1988). Very few examples of wild relatives conferring genetic resistance to abiotic stresses in crops have reached to the stage of cultivar release although many wild relatives with potential have been described (Shannon 1997). In general, the crop wild relatives do not have high yield potential compare to improved crop varieties, so they are rarely used in crop improvement programs for increasing yield in modern cultivars.

The CMS system has been used in commercial F_1 hybrid seed production in *Brassica. oleracea* using an improved 'Ogura' cytoplasm (Pelletier *et al,* 1989). Alteration in the contents of quality traits have been observed in cauliflower cybrids introgression with ogura cytoplasm (Dey *et al.,* 2017). Other improved 'Ogura' cytoplasms'Ogura' cytoplasms are available in *B. oleracea* as well as in vegetable B. *rapa*.

The wild species of cucumbers *Cucumis hardwickii* and *C. callosus* have resistance to downy mildew and fruit fly, *Cucumis melo* var. *chito* for fusarium wilt. The lack of useful genetic information and fertility barriers, lots of genes present in wild species are still unused. Scientists, from all over the world have argued that breeders were not fully exploiting the full potential of CWR. New records of endangered species *Cucumis silentvalleyi* (Anaimalai Hills in TN), and *Piper ribesioides* from Middle Andaman have been recorded (Ahlawat and Pardeep, 2018). Similarly, new wild relatives have been described from westerm ghats *Momordica sahyadrica such as Curcuma amada* var. *glabra* (Kerala), *Curcuma longa* var. *vanaharidra, A. enbeepeegearense* and *A. palianus (Jharkhand)* in Okra. Therefore, there is an urgent need to develop a set of core collection in important vegetable crops having a large number of accessions so that the entire genetic diversity is captured and managed effectively.

FUTURE PROSPECTS

The global challenge of food security due to climate change highlights the importance of vegetable crop wild relatives (VCWRs) as a source of valuable traits which are lost during domestication. To conserve and utilize VCWRs effectively, national strategies for both *in situ* and *ex situ* conservation must be developed, including identifying priority taxa and establishing genetic reserves. GIS tools and gap analysis can aid in targeted germplasm collection, while studies on habitat ecology, breeding behavior, and seed storage will strengthen conservation efforts.

Engaging specialized scientists and forming dedicated research groups can enhance pre-breeding programs. Integrating modern technologies with conventional approaches will improve the identification and use of novel genes, contributing to climate-smart crop development and ensuring food and nutritional security.

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Research Article

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Genetic variability analysis for yield traits in sponge gourd (*Luffa cylindrica*) in arid environment

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Abstract

The genetic variability, heritability, and genetic advance for 12 yield and yield contributing traits were analyzed in 26 sponge gourd (*Luffa cylindrica* L.) genotypes at ICAR-CIAH, Bikaner during 2023. There were significant differences in all traits. A broad range of variation was observed in total marketable fruit yield, fruit weight, and days to first fruit harvesting. The phenotypic coefficient of variation (PCV) was higher than genotypic coefficient of variation (GCV), indicating the substantial influence of environmental factors on trait expression. High heritability and genetic advance were observed for fruit diameter and marketable fruit yield, suggesting the predominance of additive gene action. These findings indicate that fruit yield can be enhanced through selection, while traits with lower genetic advance may benefit from hybridization and other breeding approaches.

Key words: Genetic variability, Heritability, Genetic advance, Yield

Sponge gourd (*Luffa cylindrica* L.), of cucurbitaceae family, has diploid chromosome number of 2n = 26. It exhibits significant variability, with numerous landraces identified in North India and arid regions, showcasing a broad range of traits such as leaf shape, fruit size, shape, colour, and seed colour (Choudhary *et al.*, 2016). To achieve effective breeding, it is important to analyze variability and partition the total variation into heritable and non-heritable components. This can be done using genotypic coefficient of variation (GCV), phenotypic coefficient of variation (PCV), heritability percentage, and genetic advance percentage (Barma *et al.*, 1990; Singh *et al.*, 2023). Therefore, a present study was conducted to assess the genetic variability, heritability, and genetic advance in sponge gourd.

MATERIALS AND METHODS

The experiment comprised 26 diverse sponge gourd genotypes (Table 1). The study was carried out during *kharif* season of 2023 at of ICAR-Central Institute for Arid Horticulture Bikaner, Rajasthan, situated at 28°N latitude and 73°18'E longitude, with an altitude of 234.84 m above sea level. This location falls under the agroclimatic zone of Hyper Arid Partial Irrigated Zone I C. The experiment was laid out in a Randomized Block Design (RBD) with three replications maintaining 2.0 m x 0.80 m row-to-row and plant-to-plant spacing on drip system of irrigation.

Table 1: List of sponge gourd genotypes

Genotype	Source
AHSG-18, AHSG-19, AHSG-21, AHSG-23, AHSG-25, AHSG-28, AHSG-30, Thar Tapish	ICAR-CIAH, Bikaner
VRSG-3-13, VRSG-4-17, VRSG-5-17, VRSG-6, VRSG-8, VRSG-8-17, VRSG-11, VRSG-13, VRSG-18, VRSG-21-17, VRSG-40, VRSG-50, VRSG-66, VRSG-70, VRSG-73, VRSG-140 and VRSG-154	ICAR-IIVR, Varanasi
Pusa Sneha	ICAR-IARI, New Delhi

All the recommended cultural practices were adopted. Data were recorded on five randomly selected plants on days to 50% female flowering, node at which first female flower appeared, ovary length (cm), days to first fruit harvest after sowing, internodal length (cm), vine length at last harvesting (m), fruit length (cm), fruit diameter (cm), fruit weight (g), number of fruits/ vine, marketable fruit yield/ vine (kg) and total marketable fruit yield (q/ ha). The data were subjected to analysis of variance as per Panse and Sukhatme (1985). The phenotypic (PCV) and genotypic coefficient of variance (GCV) were calculated using the of Lush (1949). Heritability (h^2) in the broad sense and genetic advance (GA) as were estimated by formula given by Warner (1952). As per Johnson *et al.* (1955), heritability was categorized as low (0-30%), moderate (30-60%) and high (60% and above). The variance of genetic advance as per cent of mean was classified as advocated by Johnson

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et al. (1955), *viz.* low (<10%), moderate (10-20%) and high (>20%).

RESULTS AND DISCUSSION

The analysis of variance (Table 2) revealed significant differences among all traits. The analysis of variance indicated that the mean sum of squares for genotypes was highly significant. The significant mean sum of squares for fruit yield and related traits demonstrated substantial variability in genotypes, suggesting good potential for improvement. The mean values, range, coefficient of variation, heritability, and genetic advance for 12 traits examined are presented in Table 3. The results clearly show a substantial amount of variation among genotypes for each trait. The PCV was higher GCV, indicating that environmental factors influenced the expression of traits studied.

The mean sum of squares revealed significant differences for all the traits, indicating substantial variability among the genotypes. A wide range of variation was observed for total marketable fruit yield (104.17-213.75 q/ha), fruit weight (88.77-124.05 g), days to first fruit harvesting after sowing (52.4-69.27 days), and days to 50% female flowering (41-55 days). The data on mean performance of 26 genotypes revealed significant variation for all 12 traits studied. Days to 50% female flowering was found to be earliest in Pusa Sneha (41 days), whereas, AHSG-30 was found late (55 days). Node at which first female flower appeared was observed on lowest node number in genotype VRSG-50 (9.63), while VRSG-5-17 produced first female flower on node number 12.80. Ovary length was found to be maximum in genotype VRSG-50 (6.64 cm) followed by AHSG-18 (6.58 cm), while minimum length was observed in VRSG-6 (3.8 cm).

Table 2: Analysis of variance for fruit yield and its component traits

Character	Mean sums of square		
	Replication (df=2)	Genotypes (df=25)	Error (df=50)
Days to 50% female flowering	25.78	32.50**	9.86
Node at which first female flower appeared	0.71	1.84**	0.36
Ovary length (cm)	0.03	1.96**	0.08
Internodal length (cm)	2.05	1.70**	0.66
Days to first fruit harvesting after sowing	20.66	60.25**	10.21
Fruit length (cm)	3.89	23.49**	1.90
Fruit diameter (cm)	0.02	0.75**	0.03
Fruit weight (g)	13.25	153.99**	29.56
Number of marketable fruits/ vine	4.16	19.80**	1.40
Vine length at last harvest (m)	0.09	0.27**	0.03
Marketable fruit yield/ vine (kg)	0.04	0.62**	0.05
Total marketable fruit yield (q/ha)	147.97	2403.87**	183.51

**Significant at 1% probability level

The internodal length was maximum in Pusa Sneha (12.53 cm), followed by VRSG-5-17 (11.73 cm), while it was minimum in VRSG-6 (9.36 cm). The variety Pusa Sneha took 49.80 days to first fruit harvesting whereas VRSG-4-17 was found to be late (69.26 days) for first fruit harvesting after sowing. Fruit length was maximum in AHSG-23 (31.40 cm), followed by AHSG-28 (26.88 cm) and Thar Tapish (25.92 cm) which are at par to each other. The shortest fruit length was observed in VRSG-6 (17.80 cm). Fruit diameter was maximum in VRSG-3-13 (4.67 cm), followed by AHSG-25 (4.32). Whereas, minimum diameter was observed in VRSG-70 (2.55 cm). Fruit weight was maximum in AHSG-23 (124.05 g), followed by AHSG-28 (114 g), Pusa Sneha (108.0 g), while minimum fruit weight was observed in VRSG-6 (88.77 g). Number of marketable fruits/ vine was maximum in AHSG-23 (28.73), followed by Pusa Sneha (26.00), AHSG-28 (24.60), while it was minimum in VRSG-6 (17.73).

Vine length at last harvesting was maximum in Pusa Sneha (3.83 m), whereas shortest vine length was observed in VRSG-70 (2.60 m). Marketable fruit yield/ vine was highest in AHSG-23 (3.42 kg), followed by Pusa Sneha (3.41 kg), while lowest or minimum marketable fruit yield was observed in VRSG-6 (1.67 kg). Among genotypes, AHSG-23, Pusa Sneha and Thar Tapish were found to be better yield performer in arid environment. These findings align with the those of Abhijeet *et al.* (2018), Singh *et al.* (2019), Vijaykumar *et al.* (2020), Yadav *et al.* (2023) and Okusanya *et al.* (1981).

The PCV was moderate for total marketable fruit yield (19.62%), followed by ovary length (16.52%), fruit diameter (16.21%), fruit length (13.66%), and number of marketable fruits/ vine (13.08%). Similar findings were reported by Singh *et al.* (2019), Thulasiram *et al.* (2023) and Yadav *et al.* (2023). In contrast, lowest PCV was recorded for internodal length (9.38%), followed by days to first fruit harvest after sowing (8.69%), days to 50% female flowering (8.67%), fruit weight (8.44%), and node at which first female flower appeared (8.41%). Singh *et al.* (2009) and Vijaykumar *et al.* (2020) also reported such findings.

The GCV among genotypes showed a moderate range, with highest values (17.57%) observed for total marketable fruit yield followed by marketable fruit yield/

Table 3: Genetic parameter of variability for fruit yield and its component traits

Character	Mean	Range	PCV (%)	GCV (%)	h² in broad sense (%)	GA	GA as % of mean
Days to 50% female flowering	48.10	41-55	8.67	5.71	43.35	3.73	7.75
Node at which first female flower appeared	10.97	9.63-12.8	8.41	6.39	57.85	1.10	10.03
Ovary length (cm)	5.08	3.8-6.64	16.52	15.59	89.01	1.54	30.29
Internodal length (cm)	10.68	9.37-12.53	9.38	5.51	34.45	0.71	6.66
Days to first fruit harvesting after sowing	59.64	52.4-69.27	8.69	6.85	62.02	6.63	11.10
Fruit length (cm)	22.07	17.80-26.88	13.66	12.14	79.01	4.91	22.24
Fruit diameter (cm)	3.19	2.55-4.67	16.21	15.31	89.10	0.95	29.76
Fruit weight (g)	99.85	88.77-124.05	8.44	6.44	58.39	10.14	10.15
Number of marketable fruits/ vine	20.97	17.73-28.73	13.08	11.81	81.45	4.60	21.95
Vine length (m)	3.14	2.6-3.83	10.44	8.93	72.81	0.49	15.74
Marketable fruit yield/ vine (kg)	2.47	1.67-3.42	19.62	17.56	80.09	0.80	32.37
Total marketable fruit yield (q/ha)	154.87	104.17-213.75	19.62	17.57	80.13	50.17	32.39

vine (17.56%), ovary length (15.59%), fruit diameter (15.31%), and fruit length (12.14%). These findings are in consistent with those of Abhijeet *et al.* (2018), Kumar *et al.* (2019) and Vijaykumar *et al.* (2020). In contrast, lowest GCV values were recorded for vine length (8.93%), followed by days to first fruit harvesting after sowing (6.85%), fruit weight (6.44%), node at which first female flower appeared (6.39%), and days to 50% female flowering (5.71%). Similar estimates were reported by Kumar *et al.* (2013), Jethava *et al.* (2016), Abhijeet *et al.* (2018), Kumar *et al.* (2019) and Vijaykumar *et al.* (2020).

The highest heritability values were recorded for fruit diameter (89.10%), followed by ovary length (89.01%), number of marketable fruits/ vine (81.45%), total marketable fruit yield (80.13%), marketable fruit yield/ vine (80.09%), and fruit length (79.01%). High heritability was observed for various characters are according to the findings of Vijaykumar *et al.* (2020), Thulasiram *et al.* (2023) and Yadav *et al.* (2023). Moderate heritability was observed for fruit weight (58.39%), node at which first female flower appeared (57.85%), days to 50% female flowering (43.35%), and internodal length (34.45%). Similar findings were also reported by Choudhary *et al.* (2014), Abhijeet *et al.* (2018), Kumar *et al.* (2019), and Vijaykumar *et al.* (2020).

The highest genetic advance was observed for total marketable fruit yield (50.17). Moderate genetic advance was recorded for fruit weight (10.14), while the lowest values were noted for days to first fruit harvesting after sowing (6.63), followed by fruit length (4.91), number of marketable fruits/ vine (4.60), and days to 50% female flowering (3.73). The highest genetic advance as a percentage of the mean was recorded for total marketable fruit yield (32.39%), followed closely by marketable fruit yield/ vine (32.37%), ovary length (30.29%), fruit diameter (29.78%), fruit length (22.24%), and number of marketable fruits/ vine (21.95%). Moderate genetic advance as a percentage of the mean was observed for vine length (15.74%), followed by days to first fruit harvesting after sowing (11.10%), fruit weight (10.15%), and node at which first female flower appeared (10.03%). The lowest genetic advance as a percentage of the mean was recorded for internodal length (6.66%), followed by days to 50% female flowering (7.75%).

The high genetic advance observed for these traits suggests that they are controlled by additive genes, making selection effective for their further improvement. Moderate genetic advance indicates the involvement of both additive and non-additive variance in these traits, while traits with low genetic advance highlight the significance of non-additive gene effects. Heritability estimates, when considered alongside genetic advance, provide more valuable information than heritability values alone, as they offer a better basis for selecting the best individuals. High heritability and high genetic advance were observed for traits like total marketable fruit yield and fruit length, indicating the dominance of additive gene action, which can be effectively improved through selection. On the other hand, moderate heritability combined with low genetic advance suggested the influence of non-additive gene action for traits such as internodal length and days to first fruit harvest, which may be improved through hybridization and combination breeding methods. Similar estimates were reported by Abhijeet *et al.* (2018), Kumar *et al.* (2019), Vijaykumar *et al.* (2020), Myla *et al.* (2022) and Kousthubha *et al.* (2023), Singh *et al.* (2023).

CONCLUSION

Thus, it is concluded that total marketable fruit yield, fruit weight, and days to first fruit harvesting showed considerable potential for improvement. The AHSG-23, Pusa Sneha and Thar Tapish gave more yield.

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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 the genotypes guava (*Psidium guajava* L.) for air layering under sub humid southern plains of Rajasthan conditions was done from 5 to 15 July 2015-16. The genotypes, 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 were used. Among the genotypes, early root initiation, percentage of rooted air layers, survival percentage and vigour index were maximum in Lalit, while and the number of secondary roots were highest in L- 49 and root: shoot ratio in Shweta. Poor response to rooting was observed in One-Kg.

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 in uniform fruits (Bose *et al.,* 1986). Vegetative propagation in guava is done by layering, grafting and budding in different parts of the India (Chadha, 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 2015-16 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 1500 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 x 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), vigour index {vigour index= averaged root length (cm) + averaged shoot length (cm) X 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 are 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 taken for root initiation was in One-

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Kg (50 days). 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) supported these findings.

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 the findings reported by 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	Genotype	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.

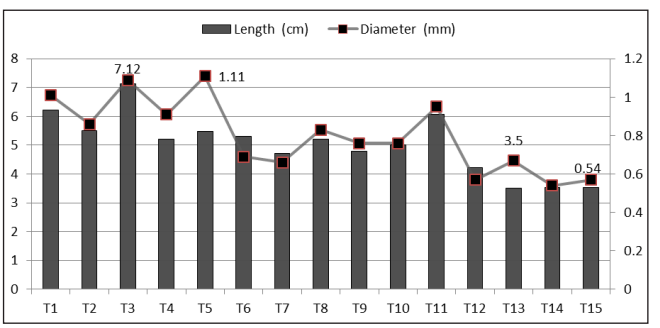

Fig.1. Air layer's secondary root length and diameter of different guava genotypes

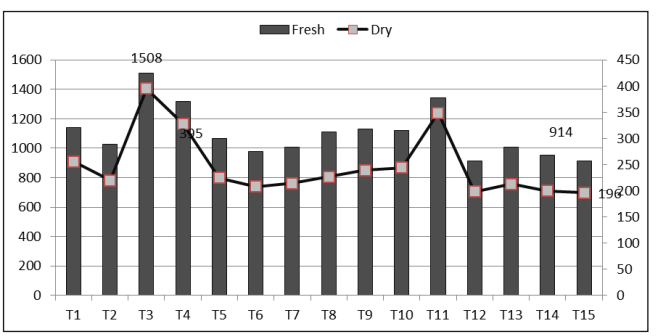

Fig.2. Air layer's root weight (mg) of different guava genotypes

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.

Genotype 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 of guava genotypes

Treatment	Genotyp	Survival of rooted air layers (%)	Vigour index	Success of layers in poly bag (at 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.

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Effect of rootstock girth and varieties of aonla (*Emblica officinalis*) on propagation

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Abstract

Five aonla (*Emblica officinalis* L.), varieties and three rootstock thickness were evaluated for various aspects of propagation under hot semi arid ecosystem of western India during 2010-2013. The rootstock girth and aonla varieties significantly affected all propagation aspects, except survival per cent of budding. The increasing thickness of stock increase plant height, maximum plant height was recorded in Chakaiya (15.06 m), followed by Anand 2 (15.02 m), Francis (14.26 m), Goma Aishwarya (13.02 m) and minimum in N.A. -7 (12.55) at >1.5 cm girth of stock. The maximum plant spread in East-West was recorded in Goma Aishwarya (12.05 m) followed by Franics (11.50 m), Anand 2 (11.02 m), Chakaiya (10.08 m) and minimum in N.A. 7 (10.96m). In case of North-South maximum was noted in Anand 2 (13.50m) followed by Goma Aishwarya (13.05m), Chakaiya (12.06 m), Franics (11.86 m) and minimum in N.A. 7 (11.16m) . The maximum stock and scion thickness were recorded in Anand 2 (66.08 and 63.05cm), followed by Frances (62.22 and 57.33cm), in Chakaiya (52.13 and 49.08 cm) in Goma Aishwarya (50.04 and 47.11 cm) and the minimum in N.A. 7 (44.25 and 44.25 cm). The rootstock and scion growth were equal in NA-7, this variety has more budding compatibility than other.

Key words: *In-situ*, Budding, Rootstock, varieties, scion thickness

Aonla (*Emblica officinalis* L.), is an important minor fruit crop of commercial significance. In *in-situ* budding, existing seedlings or rootstocks were budded after one year. This method is more useful in rainfed areas experiencing hot weather with low precipitation and non availability of genuine planting material. The plants are true-to-type, have shorter juvenile period, can be changed in improved variety after establishment of plants, low mortality, less price and disease and damaged plants can be improved (Singh and Singh, 2007). A lot of work was conducted to see the effect of rootstock age, environment, scion bud maturity, thickness of stocks, skill of budder etc in various crops, (Singh *et al.*, 2009, Chovatia and Singh, 2000, Singh and Singh, 2007, Singh *et al.*, 2003, Silvi *et al.*, 2008, Srivastava *et al.*, 2002, Roshan *et al.*, 2008, Awasthi and Shukla, 2003, Ravindran *et al.*, 2007, Singh *et al.*, 2020). Therefore, an experiment was conducted to find out the effect of rootstock girth on propagation in aonla.

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MATERIALS AND METHODS

The location of experiment is 113 m above msl on latitude 22° 41' 38" N and longitude 73° 33' 22" E and is characterised by hot semi-arid climate. The annual rainfall is mainly confined to three months (July-September) and actual mean precipitation is about 750 mm and total number of rainy days average to about 32. The mean summer temperature is 32.9° C while mean winter temperature is 21.3° C indicating that the area falls under hyperthermic soil regime. The mean annual maximum and minimum temperatures vary from 42 - 44° C (May) and 6 - 9° C (January), respectively. The soil depth of field was 0.65 - 1.0 m derived from mixed alluvial basalt, quartzite, granite and layers of limestone. The three months old rootstocks of aonla were planted at 5m x5 m distance, using the same package and practices were followed in all plants for one year.

After one year of rootstocks plantation during June 2011, the seedlings were tagged as per girth (<1, 1-1.5 and >1.5 cm) of distal end of stock. All the rootstocks were *in-situ* patch budded during June 2011 just before onset of monsoon rain. The genuine and true-to-type bud material of aonla were collected from well managed mother plants. The randomized block design (RBD) with three replications considering ten plants as unit of each treatment (variety and girth) was used. The uniform management practices were adopted for all cultivars. The collected data on per cent survival, rootstock, scion girth, plant height, plant spread (East-West and North-South), number of primary and secondary branches. The statistical analyses of data were carried out using standard method (Snedecer and Cochran, 1989).

RESULTS AND DISCUSSION

All the treatments have irregular effect by rootstocks girth and varieties. Among the varieties, 100 per cent survival was recorded in stock girth >1.5 cm, whereas in N A-7 and Francis rootstock girth significantly affected survival per cent. In case of Goma Aishwarya 100 % survival at 1-1.5 and >1.5 cm stock girth and 93.00 at <1cm was recorded (Fig. 1). In Anand 2, 100 % survival was recorded at <1 and 1-1.5 cm and 93.33 % at >1.5 cm girth. This may be due to survival per cent of budding are depends on season, girth of stock, maturity of bud and skill of budder. All the five varieties are genetically differed and survival per cent may differ. The similar findings are also reported by Singh (2018) and Mulla *et al.* (2011). The maximum plant height in all varieties was recorded at >1.5 cm (Fig. 2). Among varieties, at <1.0 cm stock diameter, maximum plant height was recorded in Anand 2 (13.66 m), followed by Francis (12.88 m), Goma Aishwarya (12.66 m), Chakaiya (10.50 m) and minimum in N.A. -7 (10.13 m), whereas at 1.0-1.5cm the same trend of plant height was recorded (Fig. 2). The maximum plant height at >1.5 cm was noted in Chakaiya (15.06m), followed by Anand 2 (15.02m), Francis (14.26m), Goma Aishwarya (13.02m) and minimum in N.A. -7 (12.55). The NA -7 was found dwarfest and Anand 2 tallest. The results of the study are in close conformity of Singh (2018) and Mulla *et al.* (2011). According to Kumar *et al.* (2016) Anand 2 was tall variety. However, variation in plant height in different cultivars may be attributed to genetic features of individual variety and their adoptability to agro-climatic conditions (Dhandar and Shukla, 2004).

The plant spread and number of branches were significantly affected by varieties and stock girth (Table-1 and Fig 3). Among all stock girth and varieties, plant spread was more in North – South compared to East-West. This may due to plant growth was significantly affected by direction of plantation because of North-South direction the plant got more sunlight as compression to East-West. The plant receive a plenty of sunlight more photosynthesis takes places and resulting the more spread of plants in North-South direction. The similar findings are also reported by Kumar *et al.* (2014). Among the rootstock girths, plant spread (E-W and N-S) was recorded at >1.5 cm girth of stock, followed by 1.0-1.5 and minimum at <1.0 cm in all varieties.

The maximum plant spread in East-West direction (12.05 m) was recorded in Goma Aishwarya, followed by in Francis (11.50 m), Chakaiya (11.08 m), Anand 2 (11.02m) and minimum in N.A. 7 (10.96m). The maximum plant spread in North-South direction (13.50 m) was recorded in Anand 2 followed by Goma Aishwarya (13.05 m), Chakaiya (12.06 m), in Francis (11.86m) and minimum in NA-7 (11.16 m). The more or less similar

Table 1: Effect of rootstock girth and varieties on plant spread (E-W and N-S) of in- situ budding in aonla

Rootstock girth (cm)	Varieties																			
	N.A. -7				Goma Aishwarya				Anand-2				Francis				Chakaiya			
	Plant spread (m)		No. of branches		Plant spread (m)		No. of branches		Plant spread (m)		No. of branches		Plant spread (m)		No. of branches		Plant spread (m)		No. of branches	
	E-W	N-S	P*	S**	E-W	N-S	P*	S**	E-W	N-S	P*	S**	E-W	N-S	P*	S**	E-W	N-S	P*	S**
<1	9.88	10.32	4.36	13.85	9.66	9.93	4.95	14.35	11.03	11.33	4.85	14.65	10.11	10.38	4.55	14.10	6.22	6.82	4.75	14.40
1-1.5	10.13	10.56	4.94	14.55	10.75	10.95	5.15	14.95	11.10	11.66	5.25	15.25	10.33	10.52	5.10	14.85	9.89	10.42	5.20	14.75
>1.5	10.96	11.16	5.23	15.05	12.05	13.05	5.45	16.10	11.02	13.50	5.85	16.35	11.50	11.86	5.45	15.15	11.08	12.06	5.65	16.05
SEm+	0.25	0.25	0.19	0.46	0.23	0.25	0.27	0.44	0.22	0.24	0.28	0.46	0.22	0.26	0.25	0.44	0.24	0.25	0.26	0.45
CV	5.34	5.14	8.78	6.67	5.16	5.21	11.65	5.86	5.19	5.21	11.15	6.71	5.18	5.23	10.16	6.42	5.14	5.27	9.53	6.39
CD-(5%)	0.81	0.82	0.81	1.49	0.83	0.84	0.91	1.23	0.86	0.87	0.87	1.28	0.82	0.84	0.86	0.123	0.86	0.85	0.88	1.26

*No. of primary branches,** No. of secondary branches

Table-2 Effect of rootstock girth and varieties on rootstock girth and scion diameter *in- situ* budding in aonla

Rootstock girth (cm)	Varieties (%)									
	N.A. -7		Goma Aishwarya		Anand-2		Francis		Chakaiya	
	Rootstock girth (cm)	Scion diameter (cm)	Rootstock girth (cm)	Scion diameter (cm)	Rootstock girth (cm)	Scion diameter (cm)	Rootstock girth (cm)	Scion diameter (cm)	Rootstock girth (cm)	Scion diameter (cm)
<1	41.86	41.86	42.33	39.08	56.33	44.04	38.91	37.07	37.12	34.07
1-1.5	45.24	45.24	46.26	43.66	48.61	54.33	42.88	41.28	45.81	39.20
>1.5	44.25	44.25	50.04	47.11	66.08	63.05	62.22	57.33	52.13	49.08
SEm+	0.92	0.65	1.24	0.98	1.09	0.47	0.88	1.30	0.92	0.80
CV	4.71	3.32	6.03	5.06	4.27	1.96	4.14	6.42	4.55	4.38
CD-(5%)	3.0	2.12	4.03	3.19	3.55	1.53	2.89	4.24	2.99	2.60

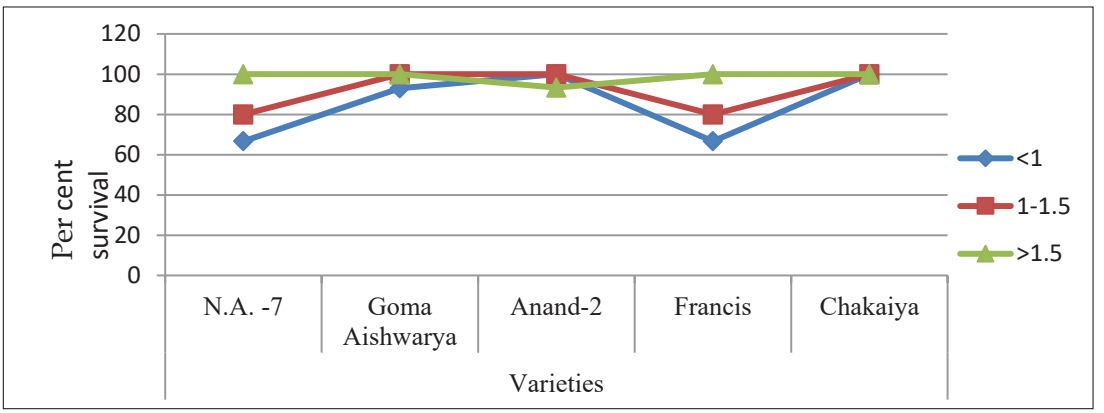

Fig.1 Effect of rootstock girth and varieties on survival per cent of *in- situ* budding in aonla

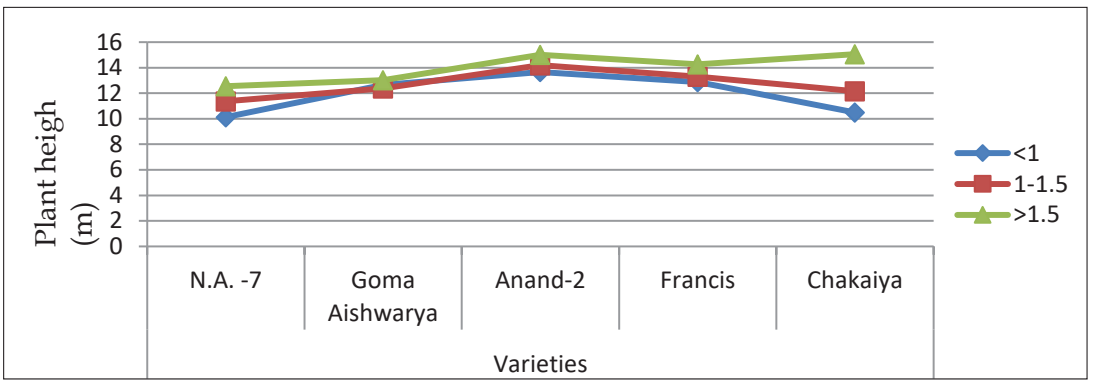

Fig.2 Effect of rootstock girth and varieties on plant height of *in- situ* budding in aonla

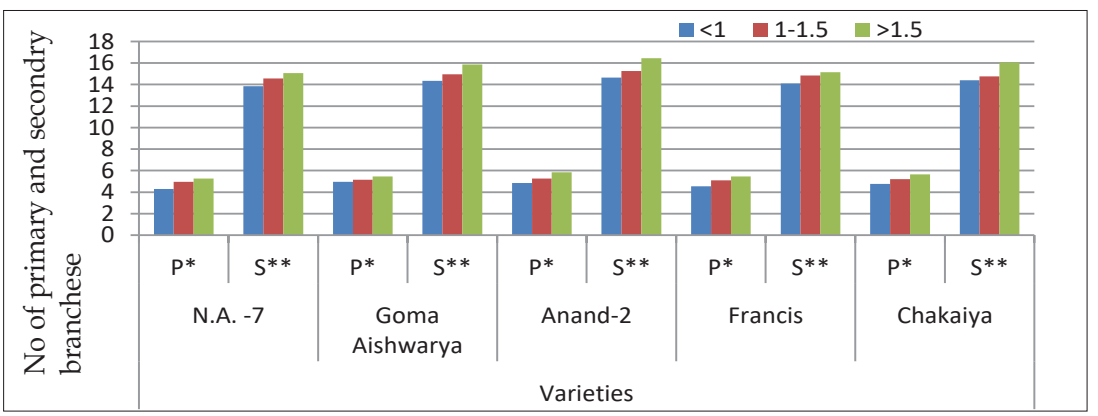

Fig.3 Effect of rootstock girth and varieties on number of primary and secondary branches in- situ budding in aonla

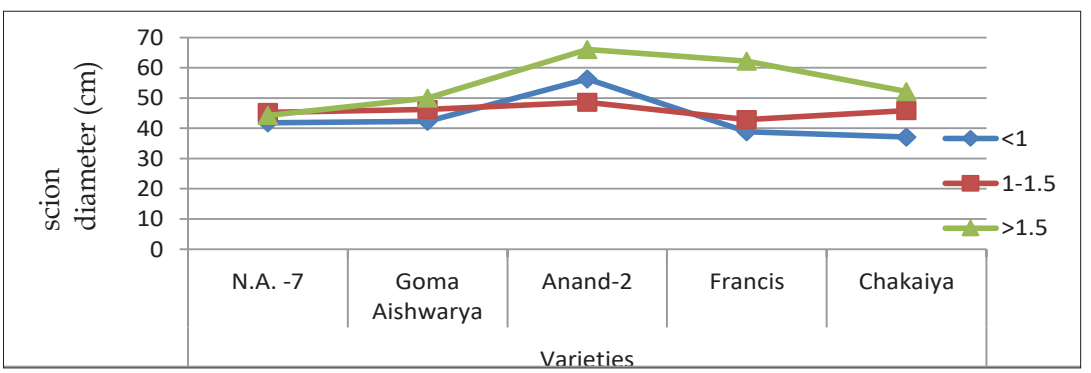

Fig.4 Effect of rootstock girth and varieties on girth of scion *in- situ* budding in aonla

findings are also reported by Dhandar and Shukla, (2004). All the treatments showed significant effect on number of primary and secondary branches. The increase stock girth significantly increased the primary and secondary branches in all varieties.

This may be due to initial strong plant may develop faster and produce more number of branches. The maximum primary (5.85) and secondary (16.35) branches were recorded in Anand 2, followed by Chakaiya (5.65 and 16.05), Goma Aishwarya (5.45 and 16.10), Francis (5. 45 and 15.15) and the same was minimum (5.23 and 15.05) in N.A. -7. However, variation in plant in different cultivars may be attributed to genetic features of individual variety and their adoptability to agroclimatic conditions (Dhandar and Shukla, 2004) and Kumar *et al.* (2014).

Varieties and girth of rootstock significantly affected girth of stock. The increasing stock diameter significantly increased girth of rootstock, maximum was recorded at >1.5 cm, followed by 1.0-1.5 cm and minimum at <1.0 cm in all varieties (table-3). Among the varieties, the maximum stock girth (66.08 cm) was recorded in Anand 2 followed by Francis (62.22 cm), Chakaiya (52.13 cm), Goma Aishwarya (50.04 cm) and minimum in NA -7 (44.25 cm). This may be due to the higher initial stock girth significantly having more root biomass per unit and uptake more nutrients and moisture from larger area and increase plant growth.

The results of the present study are in accorded to Srivastava *et al.* (2002). Aonla varieties and rootstock girths significantly affected the scion diameter. Among stock diameter, maximum scion diameter was recorded >1.5 cm stock diameter (Table-2 and Fig. 4). Among the varieties the maximum scion diameter was noted in Anand 2 (63.05cm) followed by in Francis (57.33 cm), in Chakaiya (49.08cm), in Goma Aishwarya (47.11 cm) and minimum in N. A. -7 (44.25 cm). This may be due to the higher initial stock girth significantly having more root biomass per unit and uptake more nutrients and moisture from larger area and increase plant growth. It is also revealed from the study among the varieties the rootstock and scion growth was equal in NA-7, it means, this variety is more budding compability than other tested varieties. The results of the present study are in accorded to Kumar *et al.* (2016) in aonla. The similar findings are also reported by Roshan *et al.* (2008) in aonla and Singh *et al.* (2003) in lasoda.

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Influence of time of planting and spacing on yield and quality of turmeric (*Curcuma longa* L.) in *terai* region of West Bengal

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Abstract

The turmeric productivity in West Bengal is very low (2.5 t/ha) as compared to national productivity (4.7 t/ha) and this is mainly because of poor knowledge of the farmers about suitable production technology. The present field study was conducted to evaluate the performance of turmeric (Megha Turmeric-1) under different planting time and spacing combinations in *Terai* region of West Bengal. The experiment was laid out in split plot design with three replications. The observations were recorded for different parameters like plant height, number of leaves per plant, total rhizome weight, primary rhizome weight, primary rhizome length, primary rhizome girth, primary rhizome width, fresh rhizome yield per hectare and curcumin content. The highest total rhizome weight (229.4 g), primary rhizome weight (94.8 g), primary rhizome length (8.1 cm), primary rhizome girth (5.8 cm) and primary rhizome diameter (1.0 cm), fresh rhizome yield (18.6 t/ha) was recorded when planting was done on first fortnight of April. There was increasing trend of primary rhizome weight when spacing was increased. The highest primary rhizome weight (74.1 g) was observed when the rhizome was planted at a distance of 50×30 cm whereas in 30×30 cm spacing it was 55.0 g. However, highest fresh rhizome yield (19.2 t/ha) was observed in 30×30 cm spacing. All the morphological and yield parameters significantly varied with combined effect of time of planting and spacing. The highest yield (24.3 t/ha) was obtained in first fortnight of April planting with 30×30 cm spacing. Therefore, for obtaining higher yield and high cucumin, the first fortnight of April planting at 30×30 cm spacing can be recommended as suitable production technology for turmeric (Megha Turmeric-1) in *Terai* region of West Bengal.

Keywords: Turmeric, Planting time, Spacing, yield, Curcumin

Turmeric (*Curcuma longa* L.) is a crop of Indian sub-continent and South East Asia. It belongs to Zingiberaceae family. Curcumin has antioxidant, antibacterial, antifungal, antiparasitic and anti-inflammatory and anti-cancerous properties (Jang *et al.*, 2008; Pisano *et al.*, 2010; Liang *et al.*, 2009; Bahl *et al.*, 2014). Tremendous increase of consumption of turmeric was observed from the COVID-19 pandemic period as an immunity booster (Vardhini *et al.*, 2023).

India is the largest producer, consumer and exporter with an area of 3.24 lakh ha and annual production of 11.6 lakh tones. The varied agro-climatic condition of West Bengal especially the *Terai* region is very much suitable to grow turmeric. In fact some promising varieties of Meghalaya like Megha Turmeric-1 and Lakadong have good potential. The crop is grown in 0.18 lakh hectares with a production of 0.4 lakh tones in West Bengal. Unfortunately, the productivity in west Bengal is very low (2.5 t/ha) as compared to national productivity (4.7 t/ha) and this is mainly because of poor knowledge of the farmers about suitable production technology. Region specific standard time of planting, spacing guidelines is not available in West Bengal for turmeric cultivation. Turmeric is generally planted in 22-35 cm apart by the farmers of West Bengal at variable planting times which affect its yield and quality. So, the time of planting and spacing are the major factors influencing growth and yield of turmeric although not much work on standardization of these factors has so far been done for this region (Ghosh *et al.*, 2011). Therefore, the present investigation was carried out with the objectives to determine optimum time of planting and spacing of turmeric (Megha Turmeric-1) in *Terai* region of West Bengal.

MATERIALS AND METHODS

The experiment was carried out at the research farm of ICAR-National Institute for Research on Commercial Agriculture, Research Station, Dinhata, West Bengal during 2022-23 and 2023-24. The experiment was laid out in split plot design with four planting time *i.e.,* D_1 (Second fortnight of March), D_2 (First fortnight of April), D_3 (Second fortnight of April), D_4 (First fortnight of May) as main plot and four spacing *i.e.,* S_1 (30×30 cm), S_2 (40×30

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cm), S_3 (50×30 cm), S_4 (60×30 cm) as subplot treatments, with three replications. The growth parameters like plant height, number of leaves per plant, were observed at 180 days after planting from three randomly selected plants in each plot. The rhizomes were dug out at maturity during neck-fall stage (270 days), physically cured by keeping under well ventilated-shade for a week and finally weighed to determine total rhizome weight (g), primary rhizome weight (g), primary rhizome length (cm), primary rhizome girth (cm), primary rhizome width (cm) and fresh rhizome yield (t/ha). The total curcumin content was measured as per standard procedure by using UV-VIS spectro-photometer (Motras, India) following the protocol given by Jansirani *et al.* (2014) after powdering the oven dried rhizome harvested from second season. The replicated mean data were subjected to statistical analysis of variance (ANOVA) using software available at https://www.kaugrapes.com/analysis-of-experiments/split-plot-analysis.

RESULTS AND DISCUSSION

Growth of plant and rhizome parameters as influenced by date of planting

The individual effect of time of planting on various growth and rhizome parameters are presented in Table 1. The plant height varied from 89.3 cm to 137.6 cm. The maximum plant height (137.6 cm) was observed when rhizomes are planted on first fortnight of April (D_2). Similar findings were recorded by Ponnuswamy and Muthuswami (1981). Significant variation was observed for number of leaves per plant as influenced by time of planting. The highest number of leaves per plant (12.9) was observed when planted on first fortnight of April (D_2). The highest total rhizome weight (229.4 cm), primary rhizome weight (94.8 cm), primary rhizome length (8.1 cm), primary rhizome girth (5.8 cm) and primary rhizome diameter (1.0 cm) was recorded when planting was done on first fortnight of April (D_2). It clearly depicts that planting date has great role in regulating rhizome parameters. As like plant height, the total rhizome weight and primary rhizome weight were also found to be significantly higher in first fortnight of April (D_2) planting time. On the contrary, the study of Singh *et al.* (2013) showed high fresh rhizome weight and total yield in last week of April in the same variety as used in the present study *i.e.*, Mega Turmeric-1. The difference in yield in both studies is due to the varied agro-climatic condition. The data of total fresh rhizome yield (t/ha) is presented in Fig. 1. During second fortnight of March (D_1), the total fresh rhizome yield was less (14.2 t/ha) then it was increased. The highest total fresh rhizome yield (18.6 t/ha) was observed at first fortnight of April planting (D_2). After that the yield had shown a reducing trend in delayed planting. Ishimine *et al.* (2004) had also presented a significant effect of planting dates on rhizome yield. Our study also corroborate the findings of Manhas *et al.* (2011) who reported the higher yield and yield attributes with April planting than May planting. As quality trait, curcumin content is presented as box plot in Fig. 2. The curcumin content (%) was maximum (5.1%) in rhizomes collected from first fortnight of April (D_2). The content drastically reduced in the later (D_3 and D_4) due to delay in planting. Singh *et al.* (2013) found maximum curcumin in Megha Turmeric-1 (7.0 %) during last week of April planting. Although Singh *et al.* (2013) reported about highest curcumin content in the second fortnight of April planting but, in current experiment, highest curcumin expression in the first fortnight of the April represents about effect of different climatic condition.

Growth of plant and rhizome parameters as influenced by different spacing

The individual effect of spacing on various growths, rhizome parameters are presented in Table 1. Decreasing trend in plant height was observed when the spacing is increased. The highest plant height (157.8 cm) was observed in the closest spacing (30×30 cm) while the minimum plant height (98.5 cm) was recorded when plants are raised at 50×30 cm spacing. But the plant height again increased at widest spacing of 60×30 cm. Similar findings was reported by Ponnuswamy and Muthuswami (1981) and Ghosh *et al.* (2011). This may be discussed as in case of close spacing, the competition for light may be the reason for more height due to intra-row mutual shading takes (Ghosh *et al.*, 2011). Our result is also confirmed by previous study of Singh *et al.* (2000); Tirkey *et al.* (2022); Vidanapathirana *et al.* (2022). The spacing did not show any significant effect on number of leaves per plant and total rhizome weight. But spacing had significant role in other rhizome parameters like primary rhizome weight, primary rhizome length, primary rhizome girth and primary rhizome diameter. There was increasing trend of primary rhizome weight when spacing was increased. The highest primary rhizome weight (74.1 g) was found when the rhizome was planted at a distance of 50×30 cm (D_3). The effect of spacing on total fresh rhizome yield (t/ha) is presented in Fig. 1. The highest total fresh rhizome yield (19.2 t/ha) was observed in 30×30 cm although the primary rhizome weight was less in this spacing. Wider spacing showed significant reduction in total fresh rhizome yield per hectare which was due to less number plant accommodated per unit of area. Closer spacing might have impacted the growth

Table 1: Individual effect of time of planting and spacing on plant growth and rhizome traits of turmeric variety Megha Turmeric-1

Treatment	Plant height (cm)	Number of leaves per Plant	Total rhizome weight (g)	Primary rhizome weight (g)	Primary rhizome length (cm)	Primary rhizome girth (cm)	Primary rhizome diameter (cm)
D_1	89.3	11.2	178.6	57.6	7.3	5.7	0.9
D_2	137.6	12.9	229.4	94.8	8.1	5.8	1.0
D_3	135.1	11.5	197.3	58.3	7.5	5.5	0.8
D_4	131.3	9.1	159.9	52.3	6.8	5.2	0.8
SEm±	2.3	0.2	8.8	3.0	0.06	0.10	0.02
CD (P=0.05)	8.01	0.8	30.5	10.5	0.2	0.3	0.09
S_1	157.8	10.8	173.4	55.0	7.1	5.4	1.0
S_2	126.2	11.2	199.6	66.0	7.8	5.9	1.0
S_3	98.5	11.5	196.5	74.1	7.5	5.4	0.8
S_4	110.9	11.2	195.7	67.9	7.2	5.5	0.7
SEm±	2.03	0.2	7.5	2.9	0.1	0.08	0.02
CD at 0.05 (P=0.05)	5.9	NS	NS	8.54	0.3	0.2	0.08

(D_1: Second fortnight of March, D_2: First fortnight of April, D_3: Second fortnight of April, D_4: First fortnight of May, S_1: 30×30 cm, S_2: 40×30 cm, S_3: 50×30 cm, S_4: 60×30 cm)

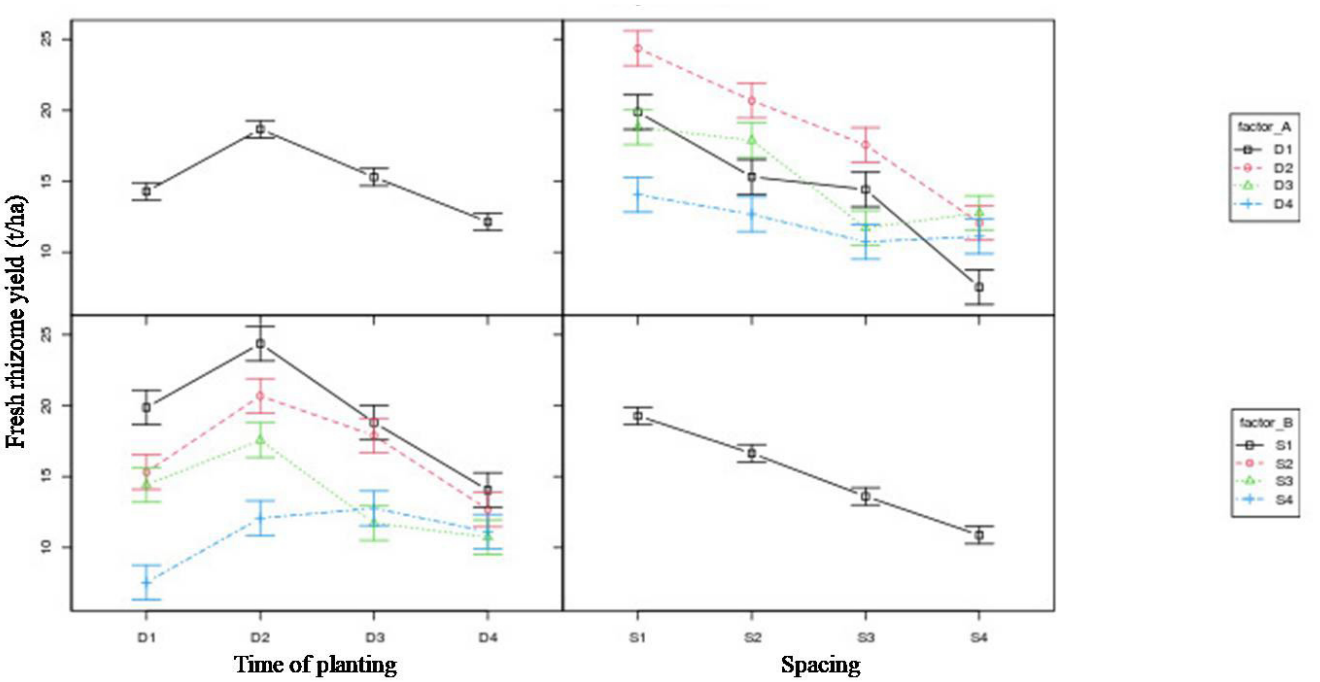

Fig. 1. Effect of time of planting, spacing and their interaction on yield of turmeric variety Megha Turmeric-1 (Factor A: Time of planting; Factor B: Spacing; D_1: Second fortnight of March, D_2: First fortnight of April, D_3: Second fortnight of April, D_4: First fortnight of May, S_1: 30×30 cm, S_2: 40×30 cm, S_3: 50×30 cm, S_4: 60×30 cm)

and development of primary rhizome due to competition among the plants for nutrition and light available per unit area. It is pertinent to discuss here that in wider spacing, there will be less population, less utilization of the land and thereby the yield might have been reduced (Rajput *et al.* (1982); Philip (1985); Singh and Kar (1991).

The individual effect of spacing on curcumin content is presented in Fig. 3. There was no significant difference between the spacing which can affect the curcumin content. But, highest curcumin (3.9%) was obtained in closest spacing (30×30 cm).

Growth of plant and rhizome parameters as

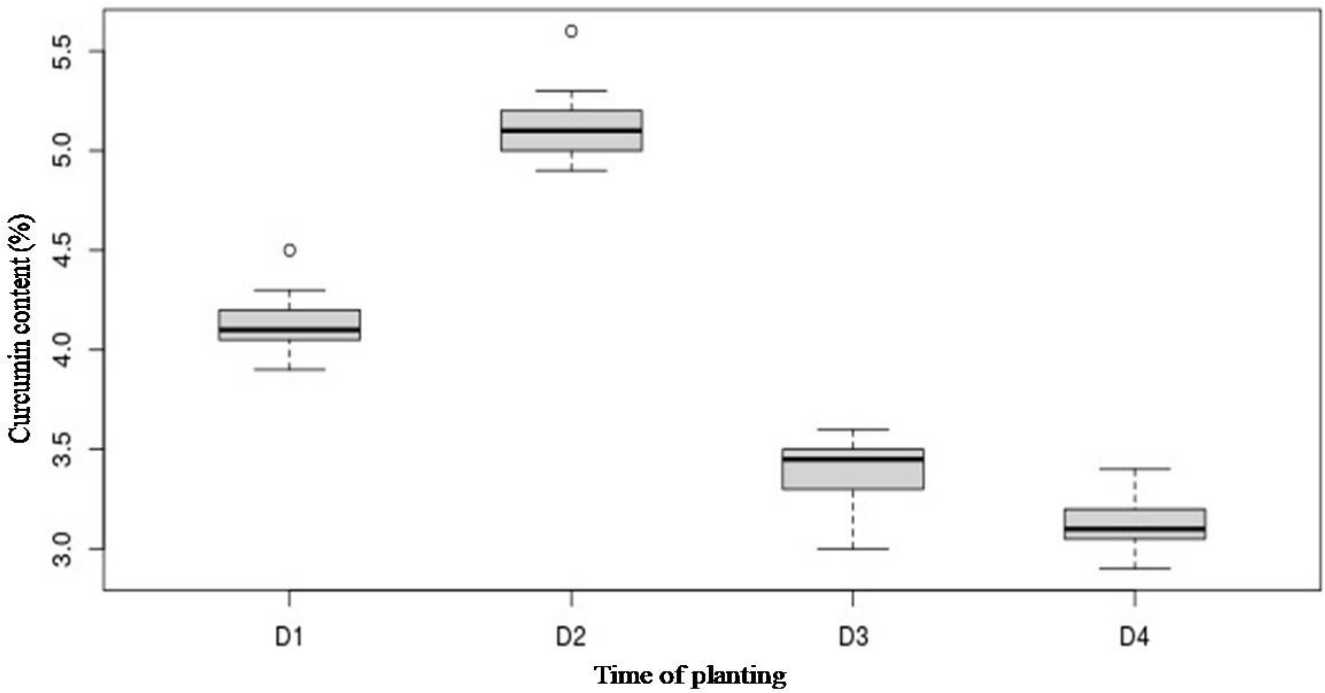

Fig. 2. Box plot depicting the effect of time of planting on curcumin content (%) of turmeric variety Megha Turmeric-1 (D_1: Second fortnight of March, D_2: First fortnight of April, D_3: Second fortnight of April, D_4: First fortnight of May)

influenced by interaction effect of different time of planting and spacing

The interaction effects are presented in Table 2. The highest plant height (184.6 cm) was observed in D_2S_1 (First fortnight of planting with 30×30 cm spacing). The highest total rhizome weight (248.1 g), highest primary rhizome length (8.9 cm), primary rhizome girth (6.4 cm) were observed when the planting was done during the first fortnight of April with a spacing of 40×30 cm (D_2S_2). The total yield per hectare (Fig. 1) and curcumin content (Fig. 4) were higher in case of interaction than the individual effect of time of planting and spacing. The highest total fresh rhizome yield (24.3 t/ha) was obtained in D_2S_1 (First fortnight of planting with 30×30 cm spacing). The lowest total fresh rhizome yield (7.5 t/ha) was measured in D_1S_4 (Second fortnight of March with 60×30 cm). Similar observations were also reported by Bandopadhyay *et al.* (2005) and Kandiannam and Chandaragir (2006). Interestingly the curcumin content was also highest (5.3%) in these treatment combinations might be due to lower yield.

CONCLUSION

Standardization of production technology for time of planting and spacing is very much important aspects to follow in turmeric cultivation for getting higher yield and quality of the crop. Based on the findings from the present experiment, it is concluded that for achieving higher yield and high curcumin content, first fortnight of April planting with 30×30 cm spacing can be recommended as suitable production technology for growing turmeric variety Megha Turmeric-1 in *Terai* region of West Bengal.

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Table 2: Effect of interaction of time of planting and spacing on plant growth and rhizome traits of turmeric variety Megha Turmeric-1

Treatment	Plant height (cm)	Number of leaves per Plant	Total rhizome weight (g)	Primary rhizome weight (g)	Primary rhizome length (cm)	Primary rhizome girth (cm)	Primary rhizome diameter (g)
D_1S_1	98.7	10.0	178.8	52.4	6.3	5.4	1.1
D_1S_2	80.8	11.6	183.7	51.3	7.8	6.3	1.0
D_1S_3	86.9	11.3	216.2	86.1	7.6	5.3	0.8
D_1S_4	90.9	11.9	135.7	40.8	7.4	5.8	0.7
D_2S_1	184.6	12.3	219.2	75.9	7.9	5.9	1.2
D_2S_2	142.7	12.8	248.1	99.4	8.9	6.4	1.1
D_2S_3	96.8	12.9	232.9	113.2	7.8	5.5	1.0
D_2S_4	126.3	13.5	217.3	90.6	7.8	5.5	0.8
D_3S_1	178.4	11.3	169.2	44.5	7.8	5.4	1.1
D_3S_2	142.4	11.4	214.5	67.4	7.5	5.9	0.8
D_3S_3	105.4	12.8	175.7	42.6	7.7	5.4	0.7
D_3S_4	114.1	10.6	229.8	78.7	7.1	5.4	0.5
D_4S_1	169.6	9.8	126.4	47.3	6.4	4.9	0.8
D_4S_2	138.7	9.1	152.1	45.8	7.1	5.2	1.0
D_4S_3	104.8	9.1	161.0	54.4	7.0	5.5	0.8
D_4S_4	112.2	8.6	200.1	61.7	6.5	5.3	0.8
SEm±	4.0	0.4	15.0	5.8	0.2	0.1	0.0
CD (P=0.05)	13.0	1.3	43.9	17.0	0.7	0.5	0.1

(D_1: Second fortnight of March, D_2: First fortnight of April, D_3: Second fortnight of April, D_4: First fortnight of May, S_1: 30×30 cm, S_2: 40×30 cm, S_3: 50×30 cm, S_4: 60×30 cm)

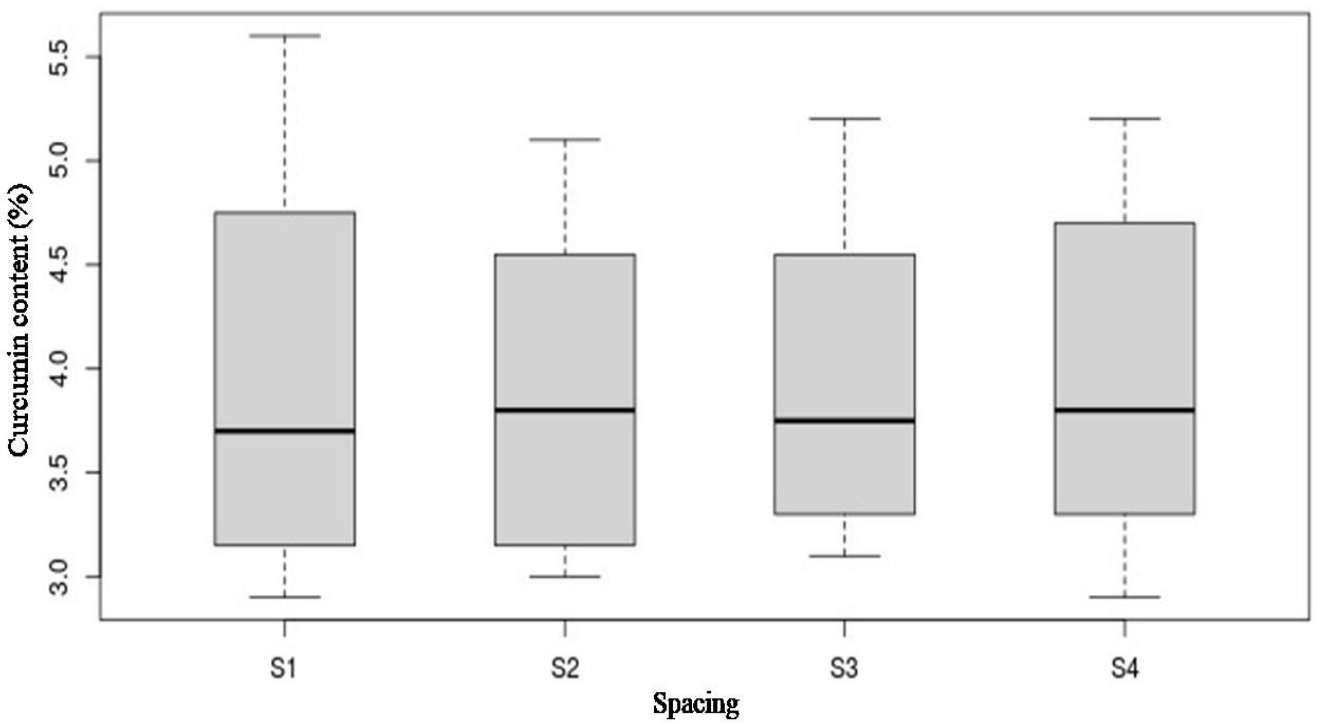

Fig. 3. Box plot depicting the effect of spacing on curcumin content (%) of turmeric variety Megha Turmric-1 (S_1: 30×30 cm, S_2: 40×30 cm, S_3: 50×30 cm, S_4: 60×30 cm)

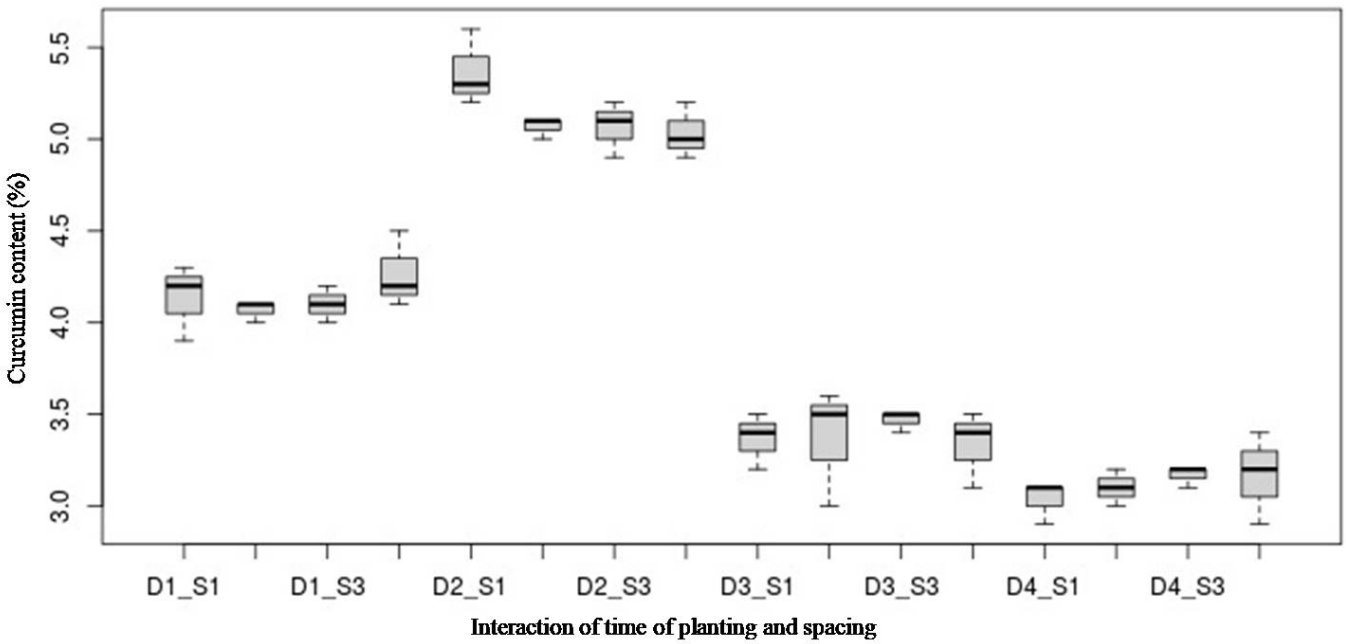

Fig. 4. Box plot depicting the interaction effect of date of planting and spacing on curcumin content (%) of turmeric variety Megha Turmeric-1 (D_1: Second fortnight of March, D_2: First fortnight of April, D_3: Second fortnight of April, D_4: First fortnight of May, S_1: 30×30 cm, S_2: 40×30 cm, S_3: 50×30 cm, S_4: 60×30 cm)

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Studies on leaf traits of different stionic combinations in pear (*Pyrus communis*)

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Abstract

The biochemical and physiological evaluation of pear (*Pyrus communis*) cultivars, Carmen, Concorde, Red Bartlett and Packham's Triumph was done on Quince A, BA 29, Quince C and Kainth rootstocks at Dr Yashwant Singh Parmar University of Horticulture and Forestry, Nauni, Solan, Himachal Pradesh, India during 2018-19. The highest leaf carbohydrate and starch content were reported in plants grafted on Quince C rootstock, whereas lowest on Quince A rootstock. Maximum total sugars and phenols were found in plants of Red Bartlett grafted on Quince C rootstock and minimum on Carmen grafted on Quince A. However, Carmen grafted on Quince A rootstock had highest total leaf chlorophyll content and uptake of nitrogen, phosphorus and potassium, whereas minimum on Red Bartlett grafted on Quince C rootstock. The correlation studies revealed a negative correlation among plant height, total sugars and phenols.

Key words: Stionic combinations, Traits plant height, leaf starch

Traditionally pear (*Pyrus* spp.) is grafted on *Pyrus pashia* (Kainth) rootstock that produces vigorous trees with long juvenile phase and problem of alternate bearing (Francescatto *et al.*, 2010). Presently, Quince (*Cydonia* spp.) is being adopted as a size-controlling rootstock for pear; however, it shows graft incompatibility with various pear cultivars and the mechanism by which it regulates scion vigor is not clear. The growth regulating effect might be attributed to anatomical feature like presence of small vessels which affects the hydraulic conductivity, decreased sap solute content and production of growth hormones (Dubey *et al.*, 2021). These factors result in series of physiochemical changes in carbohydrate metabolism and nutrient uptake, thereby affecting growth of stionic combinations. Auxin (IAA) plays a crucial role growth of the plants and naturally occurring substances like phenols alter the activity of IAA oxidase and transportation of IAA (Francescatto *et al.*, 2010). Therefore, evaluation of pear cultivars on *Cydonia* spp (Quince A, BA 29, Quince C) and Kainth rootstocks was done.

MATERIALS AND METHODS

The experiment was conducted at the Experimental Nursery Block at Dr Yashwant Singh Parmar University of Horticulture and Forestry, Nauni, Solan, Himachal Pradesh, India (30°51'N; 77°88'E; 1300 m amsl) during 2018-19. The region has sub-temperate climate with moderate summers and distinct winters. Raised nursery beds (3 m × 1 m) were prepared after leveling the surface and one-year-old Quince A, BA 29, Quince C and Kainth rootstocks were planted in three individual rows per bed during the last week of December 2018. Each row contained ten plants spaced at 25 cm × 20 cm. During first week of February 2019, these rootstocks were grafted with one-year-old scions of Carmen, Concorde, Packham's Triumph and Red Bartlett pears, at a height of approximately 15 cm above the ground using tongue grafting method. The plants were subjected to standardized cultural practices. The experiment was done in a completely randomized block design. Estimation of leaf carbohydrates, sugars, starch and nutrient content were done on dry leaf samples, while chlorophyll and phenolic contents were measured from fresh leaves plucked during last week of June as per the procedure described by Sharma *et al.*, (2020). The data were analyzed using OPSTAT software.

RESULTS AND DISCUSSION

Quince C exerted the most pronounced dwarfing effect, resulting in a 22.19 and 14.94% reduction in plant height compared to Quince A and Kainth rootstocks, respectively (Table 1). Among cultivars, Carmen registered maximum plant height, followed by Packham's Triumph, while Red Bartlett attained minimum height with a reduction of 24.56% compared to Carmen. Regarding different stionic combinations, Carmen grafted on Quince A rootstock obtained maximum plant height (95.15±0.87 cm), followed by Packham's Triumph on Quince A rootstock. However, lowest plant height (49.34 cm) was observed in plants of Red Bartlett on Quince C rootstock. Comparisons within stionic combinations revealed that plant height of Red Bartlett on Quince C was statistically similar to Red Bartlett on Quince A. The variations in plant

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Table 1: Effect of stionic combinations on plant height, total carbohydrates and total sugars in the leaves of pear nursery plant

	Plant height (cm)				Total carbohydrate content (%)				Total sugar content (%)			
Rootstock/ scion	**Carmen**	**Concorde**	**Red Bartlett**	**Packham's Triumph**	**Carmen**	**Concorde**	**Red Bartlett**	**Packham's Triumph**	**Carmen**	**Concorde**	**Red Bartlett**	**Packham's Triumph**
Quince A	95.15	69.51	52.81	89.53	12.43	12.23	11.70	11.80	1.18	2.30	2.51	1.18
BA 29	75.52	65.03	69.15	77.58	12.87	13.17	13.03	12.57	2.44	1.65	2.57	1.60
Quince C	68.41	56.03	49.34	65.10	13.95	14.54	14.46	13.43	2.22	2.95	2.85	2.76
Kainth	76.82	65.93	67.02	71.05	13.08	13.45	13.99	12.13	1.54	1.75	2.14	1.62
$CD_{(0.05)}$ Rootstock: 1.77 Scion: 1.77 Rootstock × Scion:3.54					$CD_{(0.05)}$ Rootstock: 0.73 Scion: NS Rootstock × Scion: NS				$CD_{(0.05)}$ Rootstock: 0.09 Scion: 0.09 Rootstock × Scion: 0.17			

height could be attributed to vigor potential of different rootstocks, scions and varying levels and proportions of auxin and cytokinin in apical meristem of pear varieties (Rahman *et al.*, 2017).

Rootstocks exhibited a significant effect on total carbohydrate content in leaves. Maximum leaf carbohydrate content (14.10%) was recorded in plants grafted on Quince C rootstock, followed by Kainth (13.16%), which was statistically lower than plants on Quince A rootstock but at par with plants on BA 29. While, minimum carbohydrates were found in plants grafted on Quince A (12.04%). Individually, the scion cultivar and interaction between rootstock and scion did not have significant effect on total leaf carbohydrate content (Table 1). Correlation estimation revealed a positive correlation between plant height and carbohydrate content (Table 4). Leaf carbohydrate status is significantly affected by grafting due to modifications in sugar transport. The results are in conformity with the those of *Li et al.* (2015). However, contradictory to those of Whiting and Lang (2004) who observed negative effect of smaller canopies on storage carbohydrates.

The sugar levels in leaf tissue of grafted nursery plants were significantly influenced by different rootstocks, scions and interaction between them (Table 1). Mean effect of rootstocks revealed the presence of high sugars in leaves of plants grafted on dwarf rootstock Quince C (2.70%) and minimum on Kainth (1.76%), followed by Quince A (1.79%). Among cultivars, Red Bartlett accumulated maximum sugars (2.52%), while Packham's Triumph (1.79%) had minimum value for total sugars. Rootstock/scion combinations significantly affected leaf sugar contents, Concorde grafted on Quince C had 58.60% higher leaf sugar content in comparison to Carmen and Packham's Triumph grafted on Quince A. Plant height was negatively correlated with total leaf sugar content (Table 4). Gonclaves *et al.* (2006) also reported that total soluble sugars were highest in cherry plants grafted on dwarfing rootstocks.

Maximum starch content was reported on Quince C rootstock to the tune of 52.11 mg/100g DW which was statistically at par with BA 29 and Kainth while, Quince C had the minimum starch content (Table 2). The results are in accordance with the findings of Foster *et al.* (2017). However, Gonclave *et al.* (2006) observed highest starch content in plants grafted on invigorating rootstocks. Leaf phenolic content was significantly affected rootstock, scion and their interactions (Table 2). Considering rootstocks, Quince C had highest leaf phenolic content (25.82 mg/g FW), while among scion cultivars Red Bartlett obtained maximum value (24.79 mg/g FW). Interaction among various stionic combinations revealed that most dwarf combination (Red Bartlett grafted on Quince C) had 29.80% higher accumulation of phenolics in leaves in comparison to the most vigorous combination (Carmen grafted on Quince A) that had lowest values for leaf phenolic content.

Phenols regulates plant growth and its content which may vary depending upon rootstock, cultivar, organ, developmental stage and cultural practices (Garcia *et al.* 2004). In present study higher content of phenolics have been reported in dwarf combinations (Table 4) as previously reported by Andreotti *et al.* (2006). Polyphenols determine the function of IAA oxidase, affects the IAA synthesis and thereby plays important role in growth reduction (Yildirim *et al.*, 2016). In contrast, Gonclaves *et al.* (2006) observed higher phenolic concentrations in plants grafted on vigrous rootstocks.

Individually, Quince A rootstock and Carmen cultivar and interaction between this stionic combination registered maximum value for total chlorophyll content (2.58 mg/g FW, 2.51 mg/g FW, 3.072.51 mg/g FW, respectively) (Table 2). Fallahi *et al.*, (2019) reported higher chlorophyll content was on invigorating rootstocks due to higher nitrogen. All the factors *i.e.*, rootstock, scion and their interaction influenced the leaf nitrogen, phosphorus and potassium levels (Table 3). These nutrients were found highest in Quince A rootstock (2.04% N, 0.225% P, 1.20% K), while lowest value was recorded in plants grafted on Quince C (1.79% N, 0.132% P, 1.08% K). In scion cultivars, Carmen accumulated maximum (2.09% N, 0.188% P and

Table 2: Effect of stionic combinations on leaf starch, phenolic and total chlorophyll in pear nursery plants

	Leaf starch content (mg/g DW)				Total phenolic content (mg/g DW)				Total chlorophyll (mg/g FW)			
Rootstock/ scion	**Carmen**	**Concorde**	**Red Bartlett**	**Packham's Triumph**	**Carmen**	**Concorde**	**Red Bartlett**	**Packham's Triumph**	**Carmen**	**Concorde**	**Red Bartlett**	**Packham's Triumph**
Quince A	45.91	47.75	46.47	50.32	19.52	23.92	21.97	20.71	3.07	1.84	2.51	2.88
BA 29	50.58	49.35	50.76	50.86	22.66	20.96	26.81	22.82	2.58	2.28	1.97	2.58
Quince C	51.66	52.36	51.10	53.33	26.20	24.17	27.81	25.10	2.36	1.89	1.69	2.23
Kainth	51.34	49.75	50.34	49.85	21.89	23.07	22.56	22.39	2.58	2.48	2.00	2.99
$CD_{(0.05)}$ Rootstock: 1.48 Scion: NS Rootstock × Scion: NS					$CD_{(0.05)}$ Rootstock: 1.6 Scion: 1.6 Rootstock × Scion: 3.2				$CD_{(0.05)}$ Rootstock: 0.19 Scion: 0.19 Rootstock × Scion: 0.37			

Table 3: Effect of stionic combinations on leaf nitrogen, phosphorus and leaf potassium content in pear nursery plants

	Nitrogen content (%)				Phosphorus content (%)				Potassium content (%)			
Rootstock/ scion	**Carmen**	**Concorde**	**Red Bartlett**	**Packham's Triumph**	**Carmen**	**Concorde**	**Red Bartlett**	**Packham's Triumph**	**Carmen**	**Concorde**	**Red Bartlett**	**Packham's Triumph**
Quince A	2.25	1.98	1.73	2.18	0.253	0.209	0.199	0.236	1.25	1.20	1.10	1.24
BA 29	2.05	1.68	1.67	2.09	0.160	0.160	0.119	0.169	1.22	1.12	0.98	1.24
Quince C	1.96	1.70	1.62	1.87	0.150	0.130	0.120	0.129	1.17	1.10	0.92	1.14
Kainth	2.09	1.88	1.93	2.02	0.189	0.180	0.160	0.189	1.23	1.15	1.17	1.21
$CD_{(0.05)}$ Rootstock: 0.05 Scion: 0.05 Rootstock × Scion: 0.09					$CD_{(0.05)}$ Rootstock: 0.004 Scion: 0.004 Rootstock × Scion: 0.009				$CD_{(0.05)}$ Rootstock: 0.02 Scion: 0.02 Rootstock × Scion: 0.04			

Table 4: Correlation analysis of different leaf physiological and biochemical parameters

Parameter	**Plant height**	**Total CHO**	**Starch**	**Total Sugars**	**Total Phenols**	**Total Chl content**	**N**	**P**	**K**
Plant height	1								
Total CHO	.202	1							
Starch	-.177	-.323*	1						
Total Sugars	-.775**	-.232	.299*	1					
Total Phenols	-.492**	-.450**	.338*	.597**	1				
Total Chl	.630**	.043	-.299*	-.708**	-.479**	1			
N	.855**	.138	-.162	-.709**	-.462**	.634**	1		
P	.674**	.499**	-.568**	-.749**	-.654**	.631**	.713**	1	
K	.722**	.237	-.155	-.676**	-.592**	.647**	.833**	.676**	1

*Correlation is significant at the 0.05 level (2-tailed), **Correlation is significant at the 0.01 level (2-tailed)

1.22% K) and minimum in Red Bartlett (1.74% N, 0.150% P and 1.04% K). Carmen grafted on Quince A had highest levels of these leaf nutrients. North and Cook (2008) found that leaf mineral status is influenced by rootstock/scion interaction rather than the rootstock or scion alone.

The genetic constitution of rootstock and variety affects the nutrient uptake and accumulation (Kucukyumuk and Erdal, 2011). Each rootstock exhibits a range of size-controlling potential and may have a different potential of transport rate of raw sap (amount of minerals) from root to leaf (Tombesi *et al.*, 2011; Tworkoski and Fazio, 2016). Correlation studies reveal a positive correlation between plant height, leaf chlorophyll content and N, P, K (Table 4). Higher nutrient contents in plants grafted on vigorous rootstocks (Quince A and Kainth) might be due to well developed and efficient root system.

CONCLUSION

The Quince C rootstock and Red Bartlett pear cultivar exhibited significant dwarfing effects, indicating their suitability for high-density plantation. Observed biochemical and mineral variations shows interactions among different rootstocks and scions.

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Impact of plant growth regulators and nutrients on guava (*Psidium guajava*) yield in south- eastern Rajasthan

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Abstract

The experiment was conducted at Horticulture Research Farm, Career Point University, Kota, during 2023-24 to examine the influence of plant growth regulators and nutrients on fruit setting and physiochemical attributes of guava (*Psidium guajava* L.) cv. L-49. The plants received first dose of PGRs and nutrients at fruit setting and second at fruit development stage. Foliar application of potassium sulphate (1.0 %) significantly reduced fruit drop (39.77%), while improved fruit setting (71.05%) and fruit retention (60.23%). The foliar application of potassium sulphate (1.0%) increased fruit weight (142.43g), fruit length (8.71cm), fruit width (7.89cm), fruit volume (132.77cc), TSS (11.70%), TSS: acid ratio (30.00), vitamin C (174.10), pectin (1.83 %), reducing sugar (3.80%), non-reducing sugar (3.45%) and total sugars (7.25%) and minimum acidity (0.39%). The foliar application of potassium sulphate (1.0%) also improved the fruiting and physiochemical characteristics of guava cv. L-49 as compared to the control.

Key words: Fruit drop, Fruit retention, Fruit setting, PGRs, Sugars, Vitamin C

Guava (*Psidium guajava* L.) is extensively cultivated in tropical and subtropical regions of India. In India, it is cultivated in 2.70 million ha with an annual production of 26.29 tonnes/ ha (FAOSTAT, 2022). The application of exogenous plant growth regulators can help enhance fruit setting. The total soluble solid and vitamin C levels are raised and its acidity is decreased by applying NAA (Lenka *et al.* 2019). Flowering and fruiting of guava fruit was significantly enhanced by foliar application NAA (Sharma and Tiwari, 2015). GA_3 may have contributed to the fruit's higher TSS content by stimulating the activity of several enzymes involved in physiological processes in guava (Lal and Das, 2017). In a variety of physiological and biochemical processes essential to plant growth, yield, and quality as well as under stressful circumstances, potassium plays a significant role (Kumar *et al.* 2017). Because potassium makes it easier for photosynthates to transport from leaves to immature fruits, (Kumar *et al.* 2017). Keeping in view, an experiment was conducted to investigate the impact of plant growth regulators (PGRs) and nutrients on fruiting characteristics and physiochemical attributes of guava.

MATERIALS AND METHODS

The experiment was conducted in 14-year-old guava orchards during 2023-24 at the Horticultural Research Farm, Career Point University, Kota, Rajasthan. The experimental site covers a tropical climate region with temperatures ranging from 3°-48° C and an annual rainfall of 660 mm. The soil texture was black soil, which is well-drained and well-aerated with a pH of 7.2-8.5 and plant-available KMnO4- 166.09 mg/kg, Olsen-P-10.50 mg/kg, and NH4OAc-K- 177.9 mg/kg. Fourteen-year-old uniform guava (cv. L-49) plants spaced 6 x 6 m apart were chosen for the study. The experiment had nine treatments consisting of NAA (50 ppm), NAA (100 ppm), GA_3 (25 ppm), GA_3 (50 ppm), Potassium sulphate (1%), Potassium sulphate (2.0%), Calcium nitrate (1.0%), Calcium nitrate (2.0%), and control plants sprayed with normal water, along with four replications and was set up in a Randomized Block Design. The crop received its initial foliar spray of nutrients and plant growth regulators in the first week of August, coinciding with the fruit set stage. The same treatment was applied again in the second week of September, during the fruit development stage.

Fruit set, fruit retention, and fruit drop were evaluated as per the standard formula described by (Darshan *et al.* 2023).

$$Fruit\ drop\ (\%) = \frac{Total\ number\ of\ fruits\ set\ -\ total\ number\ of\ fruits\ retained}{Total\ number\ of\ fruits\ set} \times 100$$

$$Fruit\ set\ (\%) = \frac{Number\ of\ fruit\ set}{Number\ of\ flower\ appeared} \times 100$$

$$Fruit\ retention\ (\%) = \frac{Total\ number\ of\ fruits\ retained}{Total\ number\ of\ fruits\ set} \times 100$$

The weight of five fruits from each replication was measured with help of digital weighing balance and results were expressed as gram. The length and width of five fruits from each replication was measured with help of a

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Vernier Callipers, and the results were expressed as cm and mm, respectively. Water displacement method was followed to obtain the fruit volume and the results were expressed as cubic centimetres (Darshan *et al.* 2023). The total soluble solids (TSS) content was measured using an Erma hand-held refractometer from Japan, and expressed as a percentage of soluble solids after correcting for temperature at 20°C (Gill *et al.* 2016). Ascorbic acid and titratable acidity were determined following the method outlined by the AOAC, (2005). Pectin was quantified using the gravimetric method described by Gill *et al.* (2016), where pectin was precipitated as calcium pectate from an acidic solution through the addition of calcium chloride. The precipitate was washed with water until free of chlorine, then dried and weighed, with results reported as a percentage of calcium pectate. Reducing, non-reducing, and total sugars contents were measured according to the method by Priyadarshi *et al.* (2018), with results expressed as percentages.

The experiment was laid out as per Randomized Block Design, and data were analysed using statistical software SAS 9.4 (V 9.4, SAS Institute Inc., USA) package. The interaction means were subjected to analysis of variance and pairwise comparison using Tukey HSD ($p \leq 0.05$) where found significant.

RESULTS AND DISCUSSION

Pre-harvest application of plant growth regulators (PGRs) and nutrients significantly reduced fruit drop of guava cv. L-49 (Fig. 1A). The application of lower concentration of PGRs (NAA and GA_3) and potassium sulphate, while the higher concentration calcium nitrate is more effective for reducing fruit drop percentage of guava. Foliar application of potassium sulphate 1.0% recorded minimum fruit drop percentage (39.77 %), which was statistically at par with NAA 50 ppm (41.67%) and GA_3 25 ppm (42.05%). However, significantly the maximum fruit drop percentage was recorded in plants sprayed with water (61.24%). Many fruiting plants face a severe economic risk from fruit drop, with about 50% of the blossoms and immature fruits falling off during growth due to a variety of pressures (Iqbal *et al.* 2009). The foliar application of K_2SO_4 leads to enhanced lignin and cellulose formation because the synthesis of both polymers is necessary to start the process of endogenous hormone synthesis. It also improves plant structure because the synthesis of carbohydrates prevents the formation of the abscission layer, which reduces drop at an early stage (Reetika *et al.* 2018). Similar outcomes were also observed in date palm by Khan *et al.* (2022).

Fruit set and fruit retention percentage in guava fruits was significantly altered by foliar application of plant growth regulators (PGRs) and nutrients (Fig. 1B and C). The plants received lower concentration of PGRs (NAA and GA_3) and potassium sulphate, whereas the higher concentration of calcium nitrate noted significantly maximum percentage of fruit set and fruit retention. The plants sprayed with potassium sulphate 1.0% recorded significantly maximum fruit set (71.05%) and fruit retention percentage (60.23%), which was followed by NAA 50 ppm (68.67 % and 58.33%). The control plant (sprayed with normal water) recorded significantly minimum fruit set (46.32%) and fruit retention (38.76%) percentage. The role that potassium plays in preserving cell water content, in the production of carbohydrates, and in the subsequent translocation and mobilization of carbohydrates in plant tissues may account for the improved fruit set and fruit retention observed with potassium administration. Consequently carbohydrates played important role in fruit set (Shareef, 2016). Similar results were reported by Singh *et al.* (2022) who reported highest fruit set and with application of 0.50 % potassium sulphate in ber cv. Umran.

Fruit weight and fruit volume of guava cv. L-49 was significantly influenced by the foliar application of plant growth regulators (PGRs) and nutrients (Fig. 1D and G). The plants sprayed with potassium sulphate 1.0 % produced maximum fruit weight (142.43g) and fruit volume (132.77cc) which was followed by NAA 50 ppm (130.11g and 123.56cc, respectively) and calcium nitrate 1.0 % (127.66g and 125.76cc, respectively) and potassium sulphate 2.0% (126.88g and 12177cc, respectively). On the other hands, plants sprayed with water (control) produced minimum fruit weight (111.34g) and fruit volume (112.33cc). The increase in fruit weight and fruit volume could be due to the reinforcement of the middle lamella and subsequent cell wall strengthening, which may have facilitated the enhanced movement of solutes into the fruits. This increase in volume and growth may be explained by better metabolite production, better water absorption, and better mobilization of carbohydrates and minerals inside the mesocarp enlarged cells and intercellular space. Application of potassium sulphate showed an enhancement in fruit weight in date palm (Omar *et al.* 2017) and fruit volume in Washington Navel Orange (Ali *et al.* 2015).

The data highlighted in Fig. 1E and F showed that foliar application of plant growth regulators (PGRs) and nutrients significantly improved the fruit length and fruit width of guava cv. L-49. Foliar application of nutrients (potassium sulphate 1.0%) produced significantly maximum fruit length (8.71cm) and fruit width (7.89mm) which was followed by NAA 50 ppm (8.54cm and 7.44mm). However, the plants sprayed with normal water (control)

produced significantly minimum fruit length (7.13cm) and fruit width (6.15mm). The increased in length and width in fruits could be the result of potassium, a mineral that appears to play an indirect role in accelerating the process of cell division and elongation. As a result, the fruit's size may have improved (Mishra *et al.* 2017). Similar increase in fruit length and fruit breadth with potassium applications was reported by in pear (Gill *et al.* 2012).

An increase in total soluble solids in guava cv. L-49 was recorded after foliar application of plant growth regulators (PGRs) and nutrients (Table 1). The improvement in total soluble solids content was recorded in response to plants received lower concentration of potassium sulphate 1.0% and NAA 50 ppm than the other treatments. Plants sprayed with potassium sulphate 1.0% exhibited maximum total soluble solids (11.70%) content, which was followed by foliar application of NAA 50ppm (11.43%). The reduction in acidity content was recorded in all the treated guava fruits, whereas untreated guava fruits recorded maximum acidity content. Foliar application of potassium sulphate 1.0% noted significantly minimum acidity (0.39%) content which was closely followed by foliar application of NAA 50 ppm and GA_3 50 ppm (0.41% and 0.42%, respectively). However, the plants sprayed with normal water (control) resulted maximum acidity (0.54%). The increased total soluble solids (TSS) content of guava fruits may be the result of potassium's significant role in the translocation of sugars, other soluble solids, and photo-assimilates, which raises TSS levels. The present results regarding to total soluble solids are in accordance with the earlier findings of Mandal *et al.* (2012) and Jitendra *et al.* (2015) in guava. The guava fruit pulp exhibited lower acidity with potassium treatments compared to other treatments. This might be due to a higher accumulation of sugars, improved translocation of sugars into fruit tissues, and the conversion of organic acids into sugars. Additionally, the neutralization of organic acids due to elevated potassium levels in the tissue could have contributed to the reduction in acidity (Kumar *et al.* 2017).

A significant variation was recorded in all the TSS: acid ratio and vitamin C content in guava fruits in response to foliar application of PGRs) and nutrients (Table 1). Foliar application of potassium sulphate 1.0% recorded maximum TSS: acid ratio (30.00) and vitamin C content (174.10 mg/100g), which was followed by NAA 50ppm (27.88 and 171.04 mg/100g). On the other hands, plants received only normal water (control) noted minimum TSS acid ration (18.09) and vitamin C (144.12 mg/100g) content. Potassium sulphates effect on this ratio can be explained through its influence on both the synthesis of soluble solids and the reduction of organic acids. Potassium contributes to the synthesis of organic compounds while also affecting the acid metabolism in plants. The reduction in acidity, alongside the increase in TSS, leads to an improved TSS: acid ratio, enhancing the sweetness and palatability of the fruits or produce. The present findings align with Zaied *et al.* (2006), who observed a significant increase in the T.S.S/acid ratio in juice with potassium application on Washington navel orange trees in both seasons. The increase in ascorbic acid content in guava fruit pulp with foliar potassium sprays may be attributed to the enhanced synthesis of certain metabolites and intermediate substances that promote the formation of ascorbic acid precursors. These results are consistent with the earlier findings of (Agarwal, 2012) and Manivannan *et al.* (2015) in guava fruits.

The data highlighted in (Table 1) showed that foliar application of plant growth regulators (PGRs) and nutrients increased the pectin content of guava fruits. The lower concentration of potassium sulphate and NAA 50 ppm is more effective for increasing the pectin content in guava fruits as compared to other treatments than control. The maximum pectin (1.83 %) was recorded in plants sprayed with potassium sulphate 1.0%, which was followed by NAA 50 (1.72%). However, the minimum

Table 1: Effect of plant growth regulators and nutrients on biochemical characteristics of guava cv. L-49.

Treatment	TSS (%)	Acidity (%)	TSS: acid ratio	Vitamin C (mg/100)	Pectin (per cent pectate)	Reducing sugar (%)	Non-reducing sugar (%)	Total sugars (%)
NAA 50 ppm	11.43 ± 0.09^{b}	0.41 ± 0.00^{h}	27.88 ± 0.23^{b}	171.04 ± 1.64^{ab}	1.72 ± 0.01^{b}	3.71 ± 0.03^{b}	3.33 ± 0.02^{b}	7.04 ± 0.05^{b}
NAA 100 ppm	11.32 ± 0.09^{b}	0.43 ± 0.00^{f}	26.33 ± 0.22^{c}	153.88 ± 1.48^{f}	1.44 ± 0.01^{f}	3.40 ± 0.02^{d}	2.88 ± 0.02^{f}	6.28 ± 0.04^{e}
GA_3 25 ppm	10.47 ± 0.08^{d}	0.45 ± 0.00^{d}	23.27 ± 0.19^{e}	156.34 ± 1.50^{ef}	1.51 ± 0.01^{de}	3.33 ± 0.02^{de}	3.09 ± 0.02^{d}	6.42 ± 0.05^{cd}
GA_3 50 ppm	10.75 ± 0.08^{c}	0.42 ± 0.00^{g}	25.60 ± 0.21^{d}	162.88 ± 1.56^{d}	1.54 ± 0.01^{d}	3.52 ± 0.02^{c}	2.86 ± 0.02^{f}	6.38 ± 0.04^{de}
Potassium sulphate 1.0%	11.70 ± 0.10^{a}	0.39 ± 0.00^{i}	30.00 ± 0.25^{a}	174.10 ± 1.67^{a}	1.83 ± 0.01^{a}	3.80 ± 0.03^{a}	3.45 ± 0.02^{a}	7.25 ± 0.05^{a}
Potassium sulphate 2.0%	11.35 ± 0.09^{b}	0.44 ± 0.00^{e}	25.80 ± 0.21^{cd}	168.81 ± 1.62^{bc}	1.60 ± 0.01^{c}	3.49 ± 0.02^{c}	2.98 ± 0.02^{e}	6.47 ± 0.05^{cd}
Calcium nitrate 1.0%	10.60 ± 0.08^{cd}	0.49 ± 0.00^{b}	21.63 ± 0.18^{g}	160.77 ± 1.54^{de}	1.48 ± 0.01^{e}	3.39 ± 0.02^{d}	3.14 ± 0.02 ^{cd}	6.53 ± 0.05^{c}
Calcium nitrate 2.0%	10.71 ± 0.08^{cd}	0.48 ± 0.00^{c}	22.31 ± 0.19^{f}	164.81 ± 1.58^{cd}	1.63 ± 0.01^{c}	3.27 ± 0.02^{e}	3.18 ± 0.02^{c}	6.45 ± 0.05^{cd}
Water spray (Control)	9.77 ± 0.08^{e}	0.54 ± 0.00^{a}	18.09 ± 0.15^{h}	144.12 ±1.38^{g}	1.22 ± 0.009^{g}	3.10 ± 0.02^{f}	2.67 ± 0.01^{g}	5.77 ± 0.04^{f}
Tukey HSD (P ≤ 0.05)	**0.27**	**0.009**	**0.61**	**4.62**	**0.04**	**0.08**	**0.07**	**0.14**

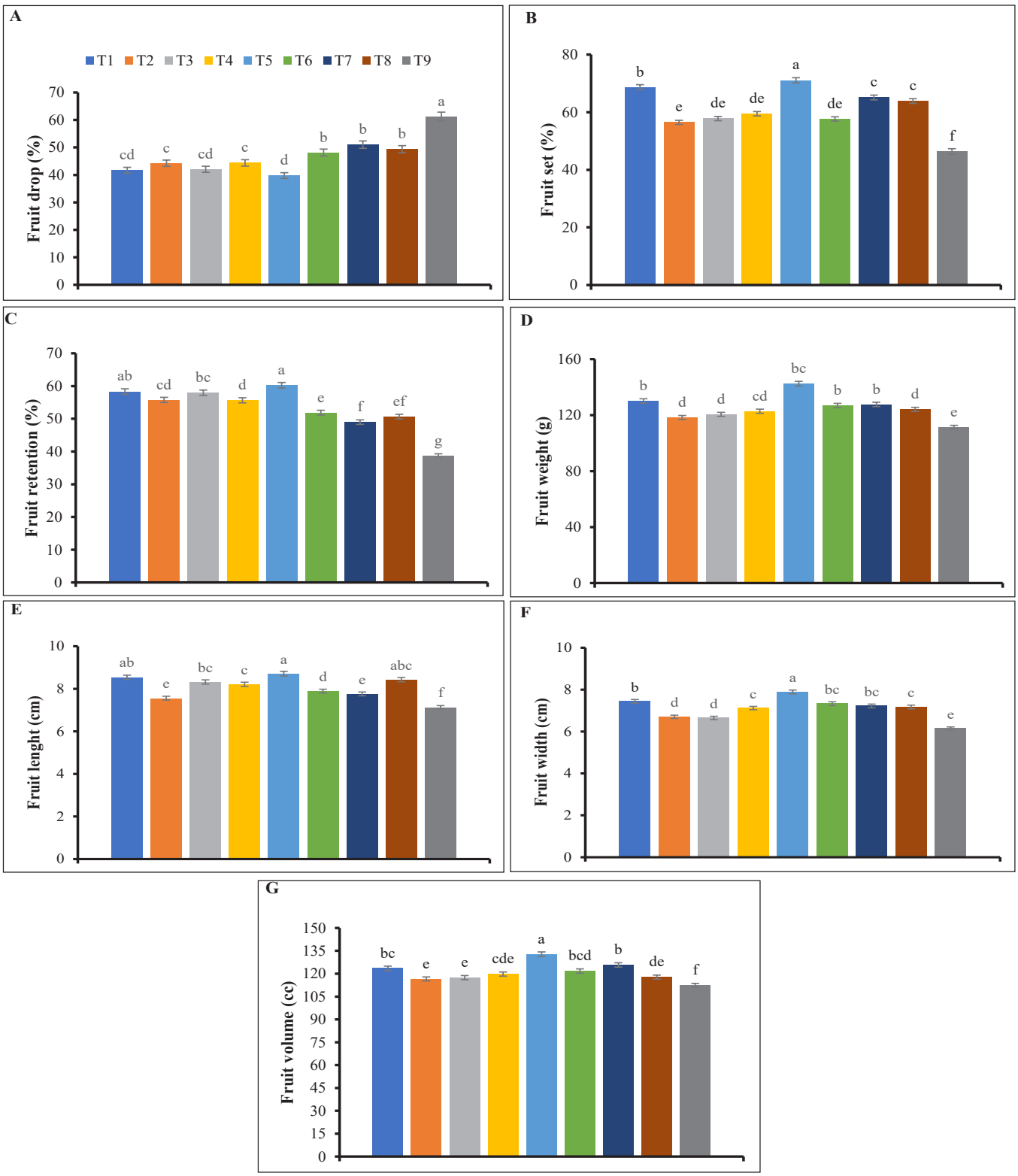

Fig 1: Effect of plant growth regulators and nutrients on biochemical characteristics on the (A) fruit drop; (B) fruit set; (C) fruit retention; (D) fruit weight; (E) fruit length; (F) fruit width; and (G) fruit volume of guava. Vertical bars represent the standard error of means for three replicates. Means with same letters are not statistically different from each other by Tukey HSD ($P \leq 0.05$). T_1 = NAA 50ppm, T_2 = NAA 100ppm, T_3 = GA_3 25ppm, T_4 = GA_3 50ppm, T_5 = Potassium sulphate 1.0 %, T_6 = Potassium sulphate 2.0 %, T_7 = Calcium nitrate 1.0%, T_8 = Calcium nitrate 2.0% and T_9 = Control

pectin (1.22 %) content was recorded in plants sprayed with normal water (control). Potassium enhances the pectin content in fruits by promoting the translocation of photosynthates from leaves to young fruits, which are partially utilized in the synthesis of pectic substances (Kumar *et al.* 2017).

A significant improvement was recorded in guava fruits after foliar application of plant growth regulators (PGRs) and nutrients (Table 1). The plants sprayed with lower concentration of nutrients (potassium sulphate 1.0%) significantly recorded maximum reducing (3.80%), non-reducing (3.45%) and total sugars content (7.25%), followed by foliar application of NAA 50ppm (3.71%, 3.33% and 7.04 %, respectively). However, the plants received only normal water (control) noted least amount of reducing (3.10%), non-reducing (2.67%) and total sugars (5.77%) content. The increase in reducing sugars in guava pulp following nutrient application through foliar sprays may be attributed to the enhancement of photophosphorylation and the dark reaction of photosynthesis by potassium.

This process results in the accumulation of more carbohydrates in the fruits and improves nutrient accessibility to developing fruits. Similar findings have been reported by Singh *et al.* (2002) in peach, Prasad *et al.* (2015) in pear, and Manivannan *et al.* (2015) in guava. The improvement in non-reducing sugars in guava pulp with nutrient application might be due to the activation of enzymes that hydrolyze polysaccharides into simpler forms such as mono and disaccharides. This process, along with better transportation of assimilates and nutrients from leaves to fruits, increases nutrient availability and enhances fruit quality. These results are consistent with the earlier findings of Kumar *et al.,* (1990) in grape cv. Delight and (Kaur and Dhillon, 2006) in guava. The increase in total sugars in guava pulp from pre-harvest potassium sprays might be due to the conversion of starch and acid into sugars, coupled with the continuous mobilization of sugars from leaves to fruits. These findings align with the results reported by Manivannan *et al.* (2015) and Jitendra *et al.* (2015) in guava.

CONCLUSION

Thus, foliar application of plant growth regulators and nutrients is most effective treatments as compared to the control. The lower concentrations of potassium sulphate 1.0 % and NAA 50 ppm is more effective than rest of treatments. Foliar application of potassium sulphate 1.0% significantly reduced fruit drop percentage, improved fruit set, fruit retention.

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Study on structural break analysis in Indian coconut (*Cocos nucifera*) production

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Abstract

Coconut (*Cocos Nucifera.L*) is distributed across the tropical belt in Asia, East Africa, and America. The CGR and structural break analysis were employed to examine the growth rates and multiple break period respectively. The results show the structural break year of area, production and productivity for major states in India was found after 1996, 2005 and 2011 which showed the impact of WTO, NHM and establishment. Based on structural break, growth rate of area, production and yield of coconut was estimated using compound growth rate. Coconut production and productivity increased at a rapid rate in Karnataka, Tamil Nadu, and Andhra Pradesh. It suggests that these states, which are India's top producers of coconuts, have a bright future in the industry. Kerala's negative growth rate shows that other crops in the state are only little expanding their production areas relative to coconuts. Though the Coconut Development Board established a Technology Mission on Coconut, yield of coconut has not significantly increased. Therefore, it is suggested that improved coconut cultivation technology should be used.

Key words: Coconut, Growth rate, Structural break and TMoC

Coconut (Cocos Nucifera.L) is distributed across the tropical belt in Asia, East Africa, and America. The top coconut producers, accounted to 79% of the global production. Indonesia, India, and the Philippines being main producers. Indonesia, the Philippines, India, Brazil, Sri Lanka, Thailand, Vietnam, Malaysia, Papua New Guinea, and Tanzania are other countries producing coconut (Elias, 2015). Among these nations, Indian coconut production has shown an upward trend over time, as seen by an increase in coconut area from 1.82 to 2.15 million ha, production of 12.67 to 22.96 billion nuts, with average productivity of 6,951 to 10,668 nuts/ha between 2000-01 and 2020-21. (CDB, 2022).

In India, Kerala, Tamil Nadu, Karnataka, and Andhra Pradesh, account for around 89% of the total coconut area and 90% of total production, (Jayasekhar and Jacob, 2021). The Indian government recognised the value of coconuts and established the Coconut Development Board (CDB) (Narmadha *et al.*, 2022). Since 2001, CDB has been carrying out a technology mission on coconuts to enhance value- addition through processing (Lathika and Kumar, 2005). Hence, critical analysis of structural break and trend in Indian coconut production is needed.

MATERIALS AND METHODS

The study is based on annual time series data covering the period of 30 years, viz 1990-91 to 2020-21. The secondary data on area, production and productivity of coconut for four major coconut-growing states Kerala, Karnataka, Tamil Nadu, and Andhra Pradesh, and India, were collected from CDB and Directorate of Economics and Statistic, Ministry of Agriculture, Government of India. The Compound growth rates (CGR) is computed by applying the formula: $Yt = ab^t$

In the log form, it is written as: $\text{Log } Y_t = \text{Log } a + t \log b$

where, Y_t = area/production/productivity in year 't', t = time element which takes the value 1, 2, 3, ... N, a = intercept and b = regression coefficient.

The value of b is computed by using OLS method. Further, value of CGR was worked out as follows: CGR (r) = (antilog b - 1) x 100

Udhayakumar *et al.* (2021) used Student't test to check the significance of the CGR.

The instability index is a simple analytical tool for determining the variation or instability in any time series data (Narmadha and Kandeepan, 2017). It was estimated using Coppock's instability index (Coppock, 1962). The estimable form is given below:

$$V \log = \sum[\log (X_{t+1} / X_t) - m]^2 / n$$

The instability index = Antilog ($\sqrt{}$ V log – 1) x 100)

where,

Xt = area/production/productivity in the year 't',

t = number of years.

M= mean of difference between Logs of Xt+1, Xt.

Log V = logarithmic variance of the series.

An unanticipated shift in time series data causes a structural break. During the shift, the values of linear regression model's parameters do not remain constant and this could be due to external influences, major

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policy changes, or a variety of other factors. If breaks are not identified, a continuous analysis taking entire period may lead to forecast errors and may make the proposed model questionable. In this regard, break in the Clemente– Montañes–Reyes test (1998) was employed which estimates two endogenous structural breaks in the data series by using stata software. Based on identified structural break, CGR was computed (Anbukkani *et al*., 2017) and Narmadha and Karunakaran, 2022).

RESULTS AND DISCUSSION

The major coconut-producing states in India are shown by their triennium ends in the Table 1. During TE 2020, 89 % of the area under coconut farming were Kerala (35%), Karnataka (29%), Tamil Nadu (20%), and Andhra Pradesh (5%). The Triennium Ending was calculated for four periods: TE1990-91, TE2000-01, TE2010-11, and TE2020-21 and the results demonstrate that, with the exception of Kerala, all other states exhibit an increase in area under coconut, which doubles at TE2020-21 compared to TE1990-91.

The four states with the highest coconut production during TE2020–21 was Kerala (35%), Tamil Nadu (26%), Karnataka (24%), and Andhra Pradesh (6 %). Together, they produced almost 92 % of country's coconut total production. The Triennium Ending results show that during four Triennium Endings, the production of coconuts doubled in major states. Production and productivity of coconuts have significantly increased since the establishment of CBD, which increased productivity, area expansion, replanting and rejuvenation, processing, and value- addition, and implemented the Technology Mission on Coconut (TMoC) in 2001–2002. (Gandhimathy, 2021).

The results show a rising yield that doubles by TE 2020–21 compared to TE 1990–91. Andhra Pradesh produced the most nuts (13,003), followed by Tamil Nadu (12,510), Kerala (9,833), and Karnataka (8,776) (Table 1). As a result, India's average output of 9,888 nuts grew by a significant margin. The widespread use of high-yielding varieties as crop and farm management activities, policy support to improve irrigation facilities, market infrastructure, and thus the supply of agricultural credit, farm input subsidies, and farmers' enthusiasm for adopting high-yielding varieties were the main drivers of impressive growth in coconut in India (Abeysekara and Waidyarathne, 2020).

The change in area, production and productivity trend of coconut were analyzed using Clemente–Montañes–Reyes test method of structural break analysis for major coconut- producing states in India (Table 2). The area under major coconut growing states has found a first break year between 1996 and 1999 due to the impact of WTO implementation on 1995 and second break year found after 2001 which showed that Technology Mission on Coconut was enacted during the corresponding period. The first estimated break year of coconut production has been found to be 1999 for Kerala and India and late 2005's for Tamil Nadu, Karnataka and Andhra Pradesh which

Table 1: Triennium Ending (TE) of area, production and yield of major coconut producing states in India

	States	Kerala	Karnataka	Tamil Nadu	Andhra Pradesh	India
Area ('000 ha)	TE 1990-91	840 (57.10)	226 (15.37)	207 (14.05)	57 (3.90)	1471 (100)
	TE 2000-01	968 (54.29)	314 (17.63)	307 (17.22)	101 (5.66)	1782 (100)
	TE 2010-11	784 (41.38)	435 (22.95)	397 (20.94)	104 (5.49)	1895 (100)
	TE 2020-21	759 (34.99)	622 (28.68)	423 (19.51)	117 (5.39)	2170 (100)
Production (million nuts)	TE 1990-91	4268 (46.39)	1167 (12.68)	2240 (24.34)	694 (7.54)	9200 (100)
	TE 2000-01	5758 (46.26)	1640 (13.18)	3180 (25.54)	1356 (10.89)	12448 (100)
	TE 2010-11	6091 (36.85)	3064 (18.54)	5974 (36.14)	1156 (6.99)	16530 (100)
	TE 2020-21	7504 (34.97)	5206 (24.26)	5623 (26.21)	1386 (6.46)	21458 (100)
Yield (Nuts/ha)	TE 1990-91	5086	5161	11022	11964	6252
	TE 2000-01	5941	5218	10465	13522	6985
	TE 2010-11	7795	6222	14678	10580	8722
	TE 2020-21	9883	8776	12510	13003	9888

Parentheses indicates the percentage share to India
Source: Calculations are based on data from CDB, 2022

showed impact of TMoC, increased coconut production. The second break year of coconut production was found on late 2010's for all the selected sample states which shows the export promotion council was launched in 2009, hence production changed during the equivalent period. The first estimated break year of coconut yield has been found to be 1993 for Tamil Nadu and Andhra Pradesh and late 2005's for Kerala, Karnataka and India. As same as production, second break year of coconut productivity also found on late 2010's except Tamil Nadu. Because Tamil Nadu appreciated productivity improved programmes through National Horticulture Mission (NHM) on 2005. These results clearly indicate that the effects of technological and institutional change on coconut production in India are determined as the structural breaks.

Table 2: Structural break of major coconut producing states in India – 1990 to 2020

States	Area		Production		Yield	
	Break 1	Break 2	Break 1	Break 2	Break 1	Break 2
Kerala	1999	2004	1999	2012	2005	2012
Karnataka	1996	2007	2007	2011	2012	2015
Tamil Nadu	1997	2009	2006	2011	1993	2006
Andhra Pradesh	1999	2008	2010	2013	1993	2010
India	1996	2013	1999	2010	2007	2013

Source: Author calculation based on data from CDB, 2022

There was two break years in each category. So, three growth rates were analysed based on break years. In that, coconut area and production growth rate of India was 3.87 and 3.28% before first break year and decreased between two break years growth rate was 2.55 and 3.10% and increased after the second break year as 2.85 and 3.88% respectively. But growth rate of coconut yield increased over the period of 2.95% and slightly decreased after the second break year as 2.29% (Figure 1).

The growth rate of area, production and yield of coconut in Kerala was estimated based on break years (Figure 2). Before the first break year, there was a drastic growth in area (3.03 %), production (3.90 %) and productivity (2.79 %). But between the first and second break year, growth rate became negatively on area (2.05 %) which affected the production and yield growth rate. This was realized during 2005, ie. after implementation of NHM which depicts that area expansion in coconut cultivation is merely nominal for other crops. After the second break year 2012, again there was slight increase on growth rate of coconut production due to the export of coconut products which gain more profit.

In Karnataka, Tamil Nadu and Andhra Pradesh, growth rate showing increasing trend in coconut area, production and yield of coconut compared with first break year to second break year (Fig. 3, 4 and 5). This may due to State Mission on Horticulture give special attention to productivity programmes on coconut production and area expansion on coconut.

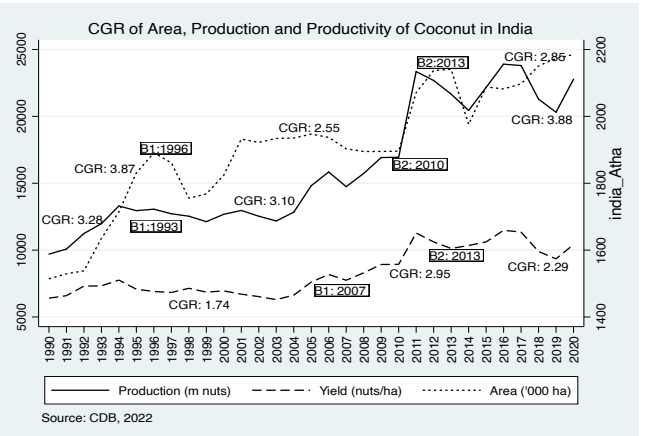

Fig 1: CGR based on structural break for Indian coconut production

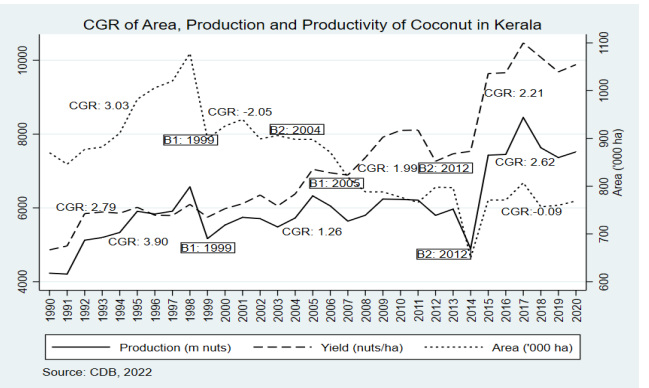

Fig 2: CGR based on structural break for coconut production in Kerala

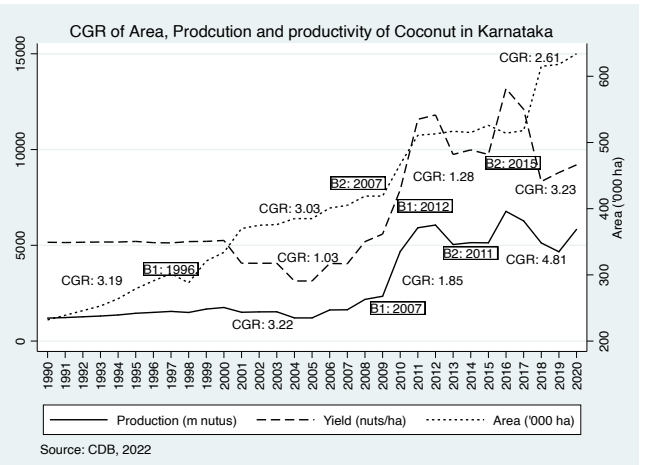

Fig. 3: CGR based on structural break for coconut production in Karnataka

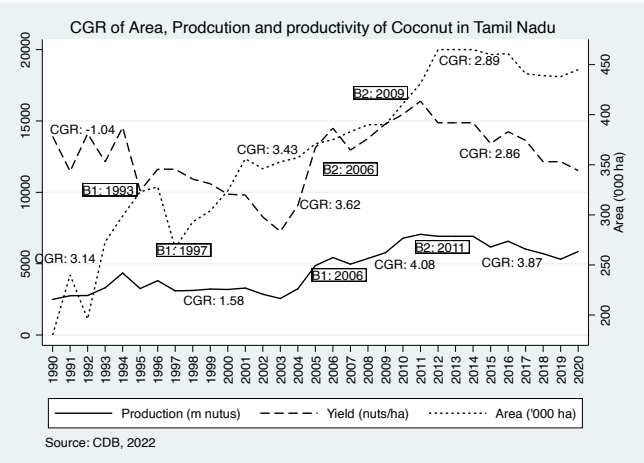

Fig 4: CGR based on structural break for coconut production in Tamil Nadu

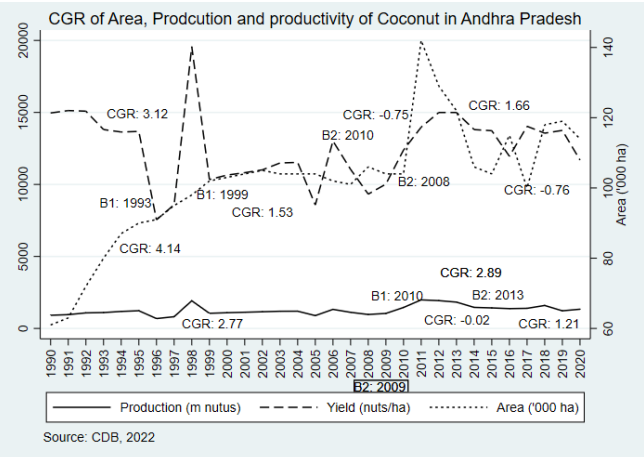

Fig 5: CGR based on structural break for coconut production in Andhra Pradesh

CONCLUSION

Thus, it was concluded that there was structural break year in area, production and productivity for major coconut-growing states in India after 1996, 2005 and 2011 which showed the impact of WTO and NHM.

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Impact of zinc and iron, their applicability techniques, and PGRs on yield of fennel (*Foeniculum vulgare*)

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Abstract

The experiment was conducted to find out the impact of zinc and iron, their applicability techniques, and PGRs on yield of fennel (*Foeniculum vulgare* Mill.) at Rajasthan Agricultural Research Institute, Durgapura, Jaipur. during 2020-21 and 2021-22. The experiment consisted of 25 treatment combinations with five levels of fertilization (control, soil application of $ZnSO_4$ @ 25 kg/ha, Soil application of $FeSO_4$ @ 50 kg/ha, foliar application of $ZnSO_4$ @ 0.5 % and foliar application of $FeSO_4$ @ 0.5 %) and five levels of plant growth regulators (control, GA_3 @ 50 ppm, GA_3 @ 100 ppm, NAA @ 25 ppm and NAA @ 50 ppm in a factorial randomized block design with three replications. The results revealed that integration of fertilization and plant growth regulators was more effective in increasing growth and yield of fennel. The application of application of $ZnSO_4$ @ 25 kg/ha significantly increased plant height (145.32 cm), number of primary branches per plant (7.08), number of secondary branches/plant (15.83), chlorophyll content (mg/g) at 75 DAS (1.82), seed yield (kg /ha) (1666) and stover yield (kg /ha) (2881) as compared to control. Similarly, plant growth regulators GA_3 @ 50 ppm also significantly increased the plant height (144.20 cm), Number of primary branches/plant (7.02), number of secondary branches/plant (15.72), chlorophyll content (mg/g) at 75 DAS (1.83), seed yield (kg /ha) (1648) and stover yield (kg /ha) (2867) as compared to the control.

Key words: $ZnSO_4$, Growth, Yield, PGRs, Seed yield, Chlorophyll content, Branches

Fennel (*Foeniculum vulgare* Mill.), belonging to the family Apiaceae, it is mainly cultivated in Gujarat, Rajasthan, and Uttar Pradesh. Rajasthan, it is mainly cultivated in Tonk, Jodhpur, Sirohi, Pali, Nagaur, and, to a limited extent, in Bharatpur, Kota, and Ajmer districts. It contributed 34,276 tonnes of production of fennel from a 31,622-ha area with a productivity of 1084 kg/ ha to the national pool (DASD, 2023). Zinc is the main nutrient in building blocks of some enzymes like alcohol dehydrogenase, carbonic anhydrase, superoxide dismutase, etc. and is needed for the formation of plant enzymes and many enzymatic reactions that become active with zinc (Pedler *et al.*, 2000). Similarly, iron is taken up by plants in the form of ferrous ions. Its concentration in the range of 100–500 mg/kg in mature leaf tissues is sufficient for optimum crop production. The (PGRs) are play an important role in mitigating stress and increasing flower seting. Exogenous application of PGR's has been reported to improves growth and yield of various crops (Bharud *et al.*, 1988). Hence an experiment was conducted to find out the effect of zinc, iron and PGR on fennel yield.

MATERIALS AND METHODS

The experiment was conducted at RARI, Durgapura, (Jaipur) during rabi season 2020-21 and 2021-22. This region falls under agroclimatic zone-IIIA (semi-arid eastern plains) in Rajasthan in India. It consisted of 25 treatment combinations with five levels of fertilization (control, soil application of $ZnSO_4$ @ 25 kg/ha, soil application of $FeSO_4$ @ 50 kg/ha, foliar application of $ZnSO_4$ @ 0.5 % and foliar application of $FeSO_4$ @ 0.5 %) and five levels of plant growth regulators (control, GA_3 @ 50 ppm, GA_3 @ 100 ppm, NAA @ 25 ppm and NAA @ 50 ppm in a factorial randomized block design with three replications.

The treatments were applied during October 2020-21 and 2021-22 after recording initial (base) yields attributing parameters of plants and observations were noted. Ferrous sulphate at 50 kg/ha and zinc sulphate at 25 kg/ha were applied as per treatment as basal. The required micronutrients for foliar spray were weighted and dissolved in water @ 500 l/ha. The $ZnSO_4$ @ 0.5% and $FeSO_4$ @ 0.5% were sprayed as per treatments. Sprays of NAA (25 and 50 ppm) and GA_3 (50 and 100 ppm) were administered as foliar sprays as per treatments. Before application, lime @ 2 g/litter of water was used to neutralize the solution of $ZnSO_4$ and $FeSO_4$. The plant height of plants was measured at harvesting from the base of plant to the top of the main shoot on a meter scale, and their mean was expressed as average plant height during both years.

Number of primary branches/plant, number of primary branches or plants was counted on five already selected and tagged plants in each plot at harvesting to compute the mean number of primary branches or plants during. Number of secondary branches/plant was counted on five already selected and tagged plants in each plot

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at harvest, and then mean was recorded. The fresh leaf samples were taken to determine the chlorophyll content of leaves at the flowering stage. These were washed with distilled water and dried with blotting paper. The total biomass harvested from each net plot was threshed and cleaned. The seeds so obtained were weighed in kg/plot and then converted into kg/ha and stover yield kg per plot was obtained by subtracting the seed yield/plot from the biological yield and then converting it into kg/ha.

The data were statistically analyzed as per 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 the different treatments.

RESULTS AND DISCUSSION

Application of zinc had a significant effect on plant height at harvest during both years. The number of primary branches/plant increased significantly due to application of zinc and iron over the control. Soil application of $ZnSO_4$ @ 25 kg/ha produced higher number of primary branches per plant (7.08). The application of zinc and iron considerably enhanced the number of secondary branches/plant. The $ZnSO_4$ (25 kg/ha) resulted in significantly higher number of secondary branches (15.83). The chlorophyll content in leaves (7 DAS) and seed yield increased significantly due to application of iron and zinc treatments as compared to the control in both the years and in pooled analysis. The soil application of $ZnSO_4$ @ 25 kg/ha, closely followed by foliar application of $ZnSO_4$ @ 0.5% recorded maximum stover yield (2881 kg/ha) during both the years.

Application of GA_3 at 50 ppm (144.20 cm), being at par with GA_3 at 100 ppm produced higher plant height at harvesting (142.56 cm) as compared to the control. Higher number of primary branches to (7.02), was recorded with application of GA_3 at 50 ppm, was superior to rest of the treatments. The use of plant growth regulators resulted in significant difference in number of secondary branches. Application of GA_3 at 50 ppm (15.72) resulted the maximum increase in number of secondary branches and was significantly higher as compared to all other treatments. The chlorophyll content in leaves at 75 DAS. significantly enhanced due to plant growth regulators as compared to the control. Significantly maximum chlorophyll content (1.83 mg/g) was observed with application of GA_3 @ 50 ppm which was significantly higher as compared to all other remaining treatments except application of GA_3 @ 100 ppm (1.82 mg/g) which remained at par to it.

The seed yield was significantly influenced by different treatments of plant growth regulators as compared to the control. The maximum seed yield was recorded with the application of GA_3 @ 50 ppm (1648 kg/ha) which was remained at par with application of GA_3 @ 100 ppm (1628 kg/ha) and found superior over the control (1405 kg/ha). The application of plant growth regulators had a substantial impact on stover production of fennel when compared to the control. Higher stover yield of fennel was recorded with application of GA_3 @ 50 ppm (2867 kg/ha) which was significantly higher as compared to the control (2433 kg/ha).

The soil application of $ZnSO_4$ @ 25 kg/ha, being remained at par with foliar application of $ZnSO_4$ @ 0.5% and recorded significantly highest plant height, number of primary branches and number of secondary branches as compared to the control, soil application of $FeSO_4$ @ 50 kg/ha and foliar application of $FeSO_4$ @ 0.5%. Further, the soil application of $FeSO_4$ @ 50 kg/ha and foliar application of $FeSO_4$ @ 0.5% also gave higher values for above parameters over the control.

According to Gour *et al.* (2011), the maximum plant height was achieved with combined application of zinc sulphate and ferrous sulphate (as soil application at 5 kg/ha and 10 kg/ha + foliar application at 0.5% and 0.25%, respectively). When zinc was sprayed to fennel at a rate of 6 kg/ha, a notable rise in plant height was noted (Gupta, 2012). Kumawat et al. (2015) also observed maximum plant height with application of $ZnSO_4$ @ 30 kg/ha.

Singh *et al.* (2009) reported that application of zinc sulphate @ 20 kg/ha produced maximum number of primary and secondary branches. Mounika *et al.* (2018a) also reported that foliar application of zinc sulphate @ 0.5% recorded highest number of primary and secondary branches over the control. Our findings clearly stated that seed yield, stover yield and biological yield was significantly enhanced due to different treatments of zinc and iron over the control during both the years. The maximum values were obtained with soil application of $ZnSO_4$ @ 25 kg/ha which was significantly higher over control, soil application of $FeSO_4$ @ 50 kg/ha and foliar application of $FeSO_4$ @ 0.5%. Further, analysis of data stated that soil application of $FeSO_4$ @ 50 kg/ha and foliar application of $FeSO_4$ @ 0.5% remained at par to each other and recorded significantly higher seed, stover and biological yield of fennel as compared to the control. The increase in seed yield due to zinc and iron application may be attributed due to fact that initial status of available zinc and iron in soil was low (Table 3.2). Under such a situation an increase in the yield is quite natural. Further, increased seed yield is the manifestation of increase in yield attributes, *i.e.*, umbel/plant and number of seeds/umbellate.

The significantly maximum values were recorded with the application of GA_3 @ 50 ppm which was

Table 1: Effect of zinc and iron, their methods of application and plant growth regulators on chlorophyll content and days taken to maturity of fennel.

Treatments	Chlorophyll content (mg/g) at 75 DAS		
	2020-21	2021-22	Pooled
Control	1.65	1.72	1.68
Soil application of $ZnSO_4$ @ 25 kg/ha	1.70	1.79	1.74
Soil application of $FeSO_4$ @ 50 kg/ha	1.76	1.87	1.81
Foliar application of $ZnSO_4$ @ 0.5 %	1.75	1.86	1.80
Foliar application of $FeSO_4$ @ 0.5 %	1.77	1.88	1.82
SEm±	**0.02**	**0.02**	**0.01**
CD (P=0.05)	**0.04**	**0.05**	**0.03**
Control	1.64	1.75	1.70
GA_3 @ 50 ppm	1.78	1.88	1.83
GA_3 @ 100 ppm	1.77	1.87	1.82
NAA @ 25 ppm	1.71	1.80	1.76
NAA @ 50 ppm	1.72	1.81	1.76
SEm±	**0.02**	**0.02**	**0.01**
CD (P=0.05)	**0.04**	**0.05**	**0.03**

Table 2: Effect of zinc and iron, their methods of application and plant growth regulators on seed yield and stover yield of fennel

Treatments	Seed yield (kg /ha)			Stover yield (kg /ha)		
	2020-21	2021-22	Pooled	2020-21	2021-22	Pooled
Fertilization						
Control	1339	1431	1385	2408	2423	2415
Soil application of $ZnSO_4$ @ 25 kg/ha	1603	1730	1666	2917	2844	2881
Soil application of $FeSO_4$ @ 50 kg/ha	1477	1586	1532	2659	2648	2654
Foliar application of $ZnSO_4$ @ 0.5 %	1583	1692	1637	2868	2816	2842
Foliar application of $FeSO_4$ @ 0.5 %	1452	1544	1498	2625	2610	2618
SEm±	**23**	**26**	**17**	**54**	**52**	**37**
CD (P=0.05)	**66**	**73**	**49**	**154**	**148**	**105**
Plant Growth Regulators						
Control	1362	1447	1405	2440	2427	2433
GA_3 @ 50 ppm	1586	1709	1648	2883	2852	2867
GA_3 @ 100 ppm	1568	1688	1628	2861	2812	2837
NAA @ 25 ppm	1462	1557	1509	2632	2610	2621
NAA @ 50 ppm	1475	1582	1529	2661	2642	2652
SEm±	**23**	**26**	**17**	**54**	**52**	**37**
CD (P=0.05)	**66**	**73**	**49**	**154**	**148**	**105**
Interaction (F x P)			**Sig**			

remained at par with application of GA_3 @ 100 ppm and found superior over control, application of NAA @ 25 ppm and application of NAA @ 50 ppm. Maximum seed yield was produced may be due to GA_3 application. The increase in seed yield could be also attributed to increasing in number of umbels/plant, number of umbellets/umbel, number of seeds/umbel and test weight of fennel. Prajapat *et al.* (2015) recorded that seed yield of fennel significantly increased with the application of 100 ppm gibberellic acid over the control. Rathod *et al.* (2023) also recorded that the foliar application of GA_3 at 50 ppm resulted in significantly for seed yield. Higher stover yield is due to different plant growth regulators which initiate the physiological process to modify the morphological, biochemical and physiological changes in plants.

CONCLUSION

In our study application of $ZnSO_4$ @ 25 kg/ha in the soil, closely succeeded by a 0.5% foliar application, resulted in more yield, nutrient uptake, and net returns of fennel compared to the control. Applying 50 ppm of GA_3, which is equivalent to applying 100 ppm, resulted in more yield and nutrient uptake, as well as better net returns compared to other treatments.

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Performance evaluation of novel vibrant multi-petalous germplasm in Adenium (*Adenium obesum*)

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Abstract

Research aiming on crop improvement has been conducted in Adenium, a popular flowering pot plant with the basic objective of novel flower morphological traits at the Advance Technology Centre of Soilless System, Department of Floriculture and Landscape Architecture, NAU, Navsari, during 2016-2021. Hybridization was done in Adenium involving six parents where in three varieties were taken as male parents, *viz.,* Double Sweet Heart (DSH), Vithoons White (VW), Pineapple Rose (PR) and three as female parents, *viz.,* Arrogant(A), Mor Lok Dok (MD) and Black Dragon (BD) and their crosses were studied. Among the different crosses, NAMDDSH (MD × DSH) and NAADSH (A × DSH) appeared to have novel traits with multipetalous flower form in white and deep red flower colour respectively. These crosses were further multiplied by grafting and evaluated along with their parent varieties for stability during 2019 to 2021. NAMDDSH bearing white flowers and NAADSH with red flowers were found novel and significantly superior in terms of the flower form with 10 petals, number of flowers per cluster (8-9), flowers opened at a time on a cluster (3.6-4.4) and flower longevity (11-12.5 days). Besides NAADSH exhibited enhanced flower size (8-8.16 cm) among all the germplasms. These germplasms can be further exploited for commercial application as well as for breeding.

Key words: Adenium, Flowering pot plant, Novel traits, Multipetalous

The *Adenium obesum* (Forssk.) Roem. & Schult, has recently been gaining high popularity as a pot plant in the floriculture industry at the global level (Paul *et al.,* 2015, McBride *et al.*, 2014, Wannakrairoj *et al.*, 2008, Sindhuja *et al.*, 2020 and Singh *et al.,* 2018).

Belonging to the family Apocynaceae, it is an attractive flowering plant with sculptural caudex, good branching habits and tolerance to drought stress. A native of Africa, it is also found in Oman, Saudi Arabia and Yemen as a wild plant. It is popularly in cultivation now in many tropical countries including Thailand and India (Chavan *et al.*, 2016, Colombo *et al.*, 2018, Hossain 2018 and Singh *et al.,* 2023). There is high perspective of expansion of protected cultivation technology in India, contributing towards creation of self- employment and national economy (Singh, 2023). Adenium is a potential remunerative ornamental crop under protected cultivation (Singh *et al.*, 2018). Highly heterozygous in nature, adeniums are cross-pollinated plants. Work on genetic improvement in Adenium has been inadequate in our country (Chavan *et al.*, 2017, Chavan *et al.*, 2018, Singh *et al.*, 2019, Singh *et al.*, 2020). With the basic objective of introducing novelty in flower colour, doubleness and flowering habit, research integrating hybridization and selection in *Adenium* was conducted at the Department of Floriculture and Landscape Architecture, NAU, Navsari. New crosses in Adenium, *viz.,* NAMDDSH (MD X DSH) and NAADSH (A X DSH) were selected for novel morphological traits with regard to flower form flower colour, flower size, doubleness, flower longevity and clustering habit.

MATERIALS AND METHODS

Adenium germplasm

The hybridization in adenium was conducted at the Department of Floriculture and Landscape Architecture, ASPEE College of Horticulture, Navsari Agricultural University, Navsari, Gujarat, during 2016-2021. Completely randomized block design with four repetitions, consisting of five germplasms of adenium, comprising two crosses, *viz*., NAMDDSH (MD X DSH) and NAADSH (A X DSH) and three varieties as their parents, viz., Mor Lok Dok (MD), Arrogant (A) and Double Sweet Heart (DSH) was used. Initially, hybridization was carried out involving 6 parents, three male parent, *viz.,*Double Sweet Heart, Vithoons White and Pineapple Rose and three female parent, *viz.,* Arrogant, Mor Lok Dok and Black Dragon. Two crosses NAMDDSH (MD X DSH) and NAADSH (A X DSH) appeared to be superior with novel morphological traits with regard to flower form, flower colour, flower size, doubleness and flower clustering habit over their parents. These two crosses along with their parents were further multiplied by grafting as per the standardized method (Singh *et al.*, 2023) and evaluated for

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morphological characters and stability during 2019-2021. Observation on different flower traits was recorded from five randomly selected plants from each genotype in each replication. The data were recorded during 2019, 2020 and 2021. Observations were taken on flower form with number of petals/flower, colour variation in context to petal colour, petal margin colour and corolla tube colour. The observation on number of flowers/cluster, flowers opened at a time on a cluster, flower size and flower longevity by counting number of days from flower bud opening till the day of flower senescence were taken. The data were analysed statistically in CRD using OP Stat software.

RESULTS AND DISCUSSION

The NAMDDSH bearing white flowers and NAADSH bearing red flowers as well as one parent Double Sweet Heart (DSH) bearing pink flowers exhibited multipetalous flower form with ten petals in each flower while other two parent varieties Mor Lok Dok (MD) bearing white and Arrogant (A) bearing red flowers had five petals (Table 1 and Fig. 1). The NAMDDSH exhibited white color flower including petal and margin with pale greenish yellow tinge in centre of corolla tube while, NAADSH exhibited red-colored petals with deep red color petal margin with bright yellow colour in centre of corolla tube. Among parents, Mor Lok Dok (MD) showed white petals with pale greenish yellow tinge in the centre of corolla tube, flowers of Arrogant (A) showed red petals with bright yellow in the centre of corolla tube while Double Sweet Heart DSH beared pink flowers with deep pink petals margin along with with pale pink colour in the centre of corolla tube. These traits were stable for three years.

Genetic factor expresses morphological differences when different germplasm collections are grown under identical conditions and management practices. Doubleness, in crosses NAMDDSH and NAADSH were obtained from DSH as a Male parent which showed the bearing of multipetalous flowers having ten petals in each flower, this character was thus transmitted in the crosses. The heritability of multi-petalous flowering character from a parent has been previously observed in adenium (Singh *et al.*, 2019 and 2020). Similar observations have also been earlier recorded in adenium (Singh *et al.,* 2020). Observations depicting variation in a number of petals in different germplasm have also been earlier recorded in adenium (Sindhuja *et al.,* 2020 Singh *et al.,* 2019, Singh *et al.,* 2020).

The number of flowers/ cluster were more in NAMDDSH (8.0-8.58), NAADSH (8.17-8.92) and one parent MD (8.2-8.5). Number of flowers opened at a time on a cluster were more in NAMDDSH (4.25-4.42), NAADSH (3.67-4.67) and one parent MD (3.5-4.2) (Table 2). The flower size was maximum in NAADSH (8.02-8.16 cm) and minimum in MD (6.50-6.75 cm). The flower longevity was maximum in NAMDDSH (11.9-12.5

Table 1: Number of petals and flower colour as influenced by selected crosses and parent genotypes in adenium

Genotype	No of Petals	Flower Colour		
		Petal margin colour	Petal colour	Corolla tube colour
Mor Lok Dok X Double Sweet Heart (NAMDDSH)	10	White	White	Pale greenish yellow
Arrogant X Double Sweet Heart (NAADSH)	10	Deep red	Red	Bright yellow
Mor Lok Dok (MD)	5	White	White	Pale greenish yellow
Arrogant (A)	5	Deep red	Red	Bright yellow
Double Sweet Heart (DSH)	10	Deep pink	Pink	Pale pink

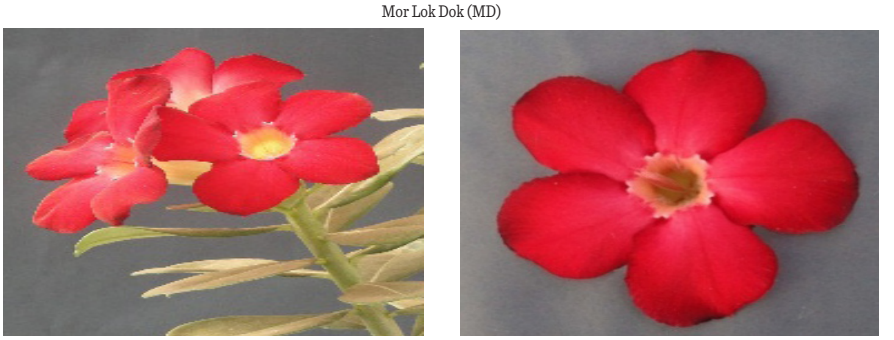
Table 2: Number of flowers/cluster, number of flowers opened at a time per cluster, flower size (cm) and flower longevity (days) as influenced by selected crosses and parent genotypes in adenium

Genotype	Number of flowers/ cluster			Number of flowers opened at a time on a cluster			Flower size (cm)			Flower longevity (days)		
	2019	2020	2021	2019	2020	2021	2019	2020	2021	2019	2020	2021
Mor Lok Dok X Double Sweet Heart (NAMDDSH)	8.00	9.58	8.25	4.42	4.33	4.25	7.40	7.19	7.16	11.92	12.00	12.50
Arrogant X Double Sweet Heart (NAADSH)	8.75	9.92	8.17	3.67	4.25	4.67	8.02	8.14	8.16	11.25	11.00	11.42
Mor Lok Dok (MD)	8.50	8.60	8.20	3.60	3.50	4.20	6.50	6.75	6.75	8.50	7.75	8.50
Arrogant (A)	3.44	3.77	3.67	2.56	2.33	2.33	7.53	7.45	7.43	6.89	7.11	7.22
Double Sweet Heart (DSH)	5.11	5.33	4.89	3.22	3.33	2.89	7.44	7.59	7.43	10.44	9.89	9.33
S.Em ±	0.35	0.26	0.04	0.18	0.17	0.17	0.07	0.05	0.03	0.40	0.24	0.22
CD @ 5 %	1.06	0.79	0.11	0.56	0.52	0.51	0.21	0.15	0.10	1.21	0.73	0.66
CV %	10.01	6.77	2.94	11.38	11.03	11.43	1.89	1.35	0.87	6.67	4.29	3.96

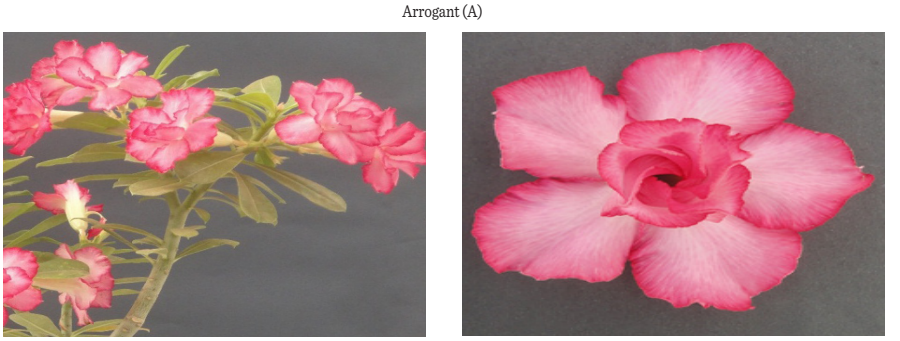
NAMDDSH (Mor Lok Dok X Double Sweet Heart)

NAADSH (Arrogant X Double Sweet Heart)

Mor Lok Dok (MD)



Arrogant (A)



Double Sweet Heart (DSH)

Fig 1. Flowers of selected crosses and parent genotypes of Adenium

days), followed by NAADSH (11.3-11.4 days), (Table 2). Thus, variation observed in flowering parameters among different germplasms, i.e. crosses and parent varieties can be attributed to differences in their genetic make-up. Thus, variation in different floral characters indicates genetic divergence in genotypes also suggested by Varella *et al.* (2015), Sindhuja *et al.* (2022), Singh *et al.* (2017) and Singh *et al.* (2024).

CONCLUSION

The hybrids, NAMDDSH bearing white flowers and NAADSH bearing red flowers, assumes significance owing to their superiority and novelty in respect of flower colour and flower morphology with multipetalous flower form having ten petals in each flower along with more number of flowers/ cluster and *in-situ* flower longevity. These germplasms can be further registered and used for breeding.

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Effects of post-harvest treatments and packaging materials on physico-chemical properties and shelf-life of guava (*Psidium guajava*)

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Abstract

The study was undertaken to find out efficacy of different post-harvest treatments and packaging materials on improving the quality and shelf-life of guava fruits variety Allahabad Safeda at post-harvest laboratory, Department of Horticulture, SKN College of Agriculture, Jobner, during 2022-23 and 2023-24. The fruits were subject to dipping in tap water for 3 minutes, oxalic acid (OA) 10 mM 3 min., salicylic acid (SA) 2.0 mM 3min., calcium chloride at 1.5% 3min., with different packaging material, polythene bag (LDPE 25 Micron), corrugated boxes, gunny bag and untreated fruits without packing. The fruits were stored at ambient storage conditions for 12th days. Fruits were analyzed for various physico-chemical characteristics, viz., PLW, decay percentage, shelf life, TSS, acidity, ascorbic acid, reducing, non-reducing and total sugars at an interval of 0, 4, 8 and 12 days. The results revealed that perforated calcium chloride 1.5% with polythene bag was the most effective in reducing weight loss and decay as compared to other treatments. Total soluble solids, reducing sugars, total sugars and ascorbic acid content were higher in fruits stored in perforated calcium chloride with polythene bag and it was also effective in extending the shelf -life of guava fruits to 13 days. Thus, it can be concluded that perforated calcium chloride 1.5 % with polythene bag can be recommended for extending storage period of guava fruits.

Key words: Oxalic acid, physiological loss in weight (PLW), shelf-life, storage, polythene bag (LDPE 25 Micron)

Guava (*Psidium guajava* L.), belonging to Myrtaceae family. It is mostly grown in Uttar Pradesh, Madhya Pradesh, Andhra Pradesh, Bihar, Chhattisgarh, West Bangal, Maharashtra, and Gujarat, covering an area of 352.49 thousand ha. yielding 5428.73 tonnes of production**.** In Rajasthan, it is grown in 12.45 thousand ha. with total production of 150.50 tonnes and a productivity of 12.09 tonnes/ ha in Sawai Madhopur, Tonk, Dholpur, Bharatpur and Kota districts of Rajasthan (MAFW, 2022).

There are many post-harvest treatments which maintain quality and enhance shelf-life of its fruits. Oxalic acid reduces production of polygalacturonase (PG) and pectin methyl esterase (PME), which is responsible for cell wall degradation, so that treated fruits maintain the firmness (Wu *et al*., 2011). Salicylic acid is an endogenous plant hormone which plays an important role in enhancing fruit quality and positively effects on reducing respiration and ethylene biosynthesis rates, weight loss, decay and softening of fruits (Shafiee *et al.,* 2010).

MATERIALS AND METHODS

The study was carried out at Department of Horticulture, SKN College of Agriculture, Jobner, during 2022-23 and 2023-24. Physiologically mature fruits of guava cv. Allahabad Safeda were harvested from progressive farmer's field, in tonk district. Healthy fruits of uniform size were selected. The fruits were subject to dipping in oxalic acid (OA) 10 mM for 3 minutes (T_1) salicylic acid (SA) 2.0 mM for 3 minutes (T_2), calcium chloride at 1.5% for 3 minutes (T_3), tap water for 3 minutes (T_4), with different polythene bags, (LDPE 25 micron) (P_1), corrugated boxes (P_2), gunny bags (P_3) and untreated fruits without packing (P_4). They were stored at ambient storage conditions for 12 days. The data on physiological loss in weight (PLW), decay percentage, shelf-life, TSS, acidity, ascorbic acid, reducing, non-reducing and total sugars were recorded at an interval of 0, 4, 8 and 12 days.

The PLW was calculated by subtracting the weight of fruit on the day of observation from the initial fresh weight and expressed as percentage loss in reference to initial fruit weight. Fruit decay was worked out by counting the number of spoiled fruits against total number of fruits on the day of observation and was expressed in percentage. The TSS was measured at room temperature with Huwaki hand refractometer having 0-32 % range. Sugars, titratable acidity and ascorbic acid were estimated by the methods described by Ranganna (1986). Shelf-life of fruits was determined by counting the number of days till the fruits retained optimum marketing and eating qualities. The experimental data was analysed with two factorial Completely Randomised Design (CRD) given by Snedecor and Cochran (1987) at 5 % level of significance.

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RESULTS AND DISCUSSION

The post-harvest life of fruits is significantly affected by the rate of water loss from the fruits. The number of storage days affected the physiological loss in weight (PLW) significantly, which increased gradually as the storage period progressed, irrespective of the treatment applied (Table 1). Fruits packed in perforated white calcium chloride 1.5 % with polythene bag (T_3P_1) recorded lowest PLW (19.81%). The highest PLW (28.58 %) was registered in the control fruits. Interactions between treatments and storage period was also found to be significant with maximum PLW (43.60%) in fruits under the control on 12th day of storage. These observations were similar to those of Ismail *et al.* (2010). The main reason of loss the weight in fruits may be due to loss of water caused by transpiration and respiration processes (Zhu *et al.* 2008). Packaging in polythene bags might have increased the CO_2 concentration and decreased the O_2 which eventually lowered the respiration rate of fruits (Thompson, 2010).

Decay percen0tage of fruits directly contributes to post-harvest losses. The maximum decay (23.14%) was observed in the control (T_4), while it was minimum (10.73%) in fruits treated with calcium chloride (1.5%) with polythene bag (T_3P_1). There was no fruit decay on initial day of storage. All the treatments exerted significant positive influence in reducing the decay percentage. The symptoms of decay started from 4th day onward in various treatments. However, fruits stored in perforated calcium chloride 1.5% with polythene bag (T_3P_1), started decaying from 8th day onward. Highest decay (23.08 %) was recorded on 12th day of storage, while it was lowest (0.49 %) on 4th day of storage. The decay in guava was maximum in the control and it increased during storage period (Ismail *et al.*, 2010). As storage period advanced, there was gradual softening of fruits in all the treatments. In fruits where no treatment was applied (control), maximum softening of fruits was observed facilitating entrance for decay causing microbes. In the fruits kept in calcium chloride 1.5% with polythene bag (T_3P_1), rate of softening was slow and also the product was not in direct contact with the external environment which might have resulted in lower decay percentage.

The longest shelf-life (13.12 days) and shortest (9.87 days) were observed in fruits packed in perforated calcium chloride 1.5% with polythene bag (T_3P_1) and the control fruits, respectively. The increase in shelf-life of fruits in calcium chloride (1.5%) with polythene bag (T_3P_1) may be due to lesser permeability of moisture along with reduced level of O_2 and increased level of CO_2 gas as compared to other treatments which might have modified the microclimate and preserved fruit quality. Better isolation of fruits in calcium chloride (1.5%) with polythene bag might have extended shelf-life of fruits due to lesser exposure to pathogens and contaminants (Beaudry, 2000).

Total soluble solids (TSS) content of fruits increased initially up to 8th days and thereafter declined as the storage period progressed (Table 2). Highest TSS (11.78 °B) was

Table 1: Effect of post-harvest treatments on physiological loss in weight of guava under ambient storage condition

	Physiological loss in weight (%) (DAS)											
	2022-23				2023-24				Pooled			
	0 day	4th	8th	12th	0 day	4th	8th	12th	0 day	4th	8th	12th
Factor A: Chemical treatments												
T_1	0.00	7.05	11.72	21.91	0.00	6.71	11.43	21.65	0.00	6.88	11.57	21.78
T_2	0.00	6.69	11.02	21.12	0.00	6.36	10.67	20.81	0.00	6.52	10.84	20.97
T_3	0.00	6.43	10.23	19.97	0.00	6.09	9.87	19.65	0.00	6.26	10.05	19.81
T_4	0.00	8.77	15.38	28.82	0.00	8.45	15.12	28.34	0.00	8.61	15.25	28.58
SEm±	-	0.11	0.18	0.36	-	0.10	0.18	0.35	-	0.11	0.18	0.35
CD (5%)	-	0.32	0.53	1.02	-	0.30	0.51	1.01	-	0.31	0.52	1.01
Factor B: Packaging material												
P_1	0.00	6.44	10.36	20.15	0.00	6.12	10.01	19.84	0.00	6.28	10.18	19.99
P_2	0.00	6.69	10.86	20.88	0.00	6.35	10.55	20.58	0.00	6.52	10.70	20.73
P_3	0.00	7.21	12.03	22.42	0.00	6.87	11.69	22.13	0.00	7.04	11.86	22.27
P_4	0.00	8.60	15.09	28.38	0.00	8.27	14.83	27.90	0.00	8.43	14.96	28.14
SEm±	-	0.11	0.18	0.36	-	0.10	0.18	0.35	-	0.11	0.18	0.35
CD (5%)	-	0.32	0.53	1.02	-	0.30	0.51	1.01	-	0.31	0.52	1.01
Interaction A×B												
SEm±	-	0.22	0.37	0.71	-	0.21	0.36	0.70	-	0.21	0.36	0.70
CD (5%)	-	0.63	1.05	2.05	-	0.60	1.02	2.01	-	0.62	1.04	2.03

Table 2: Effect of post-harvest treatments on decay loss of guava under ambient storage condition

	Decay loss (%) (DAS)											
	2022-23				2023-24				Pooled			
	0 day	4th	8th	12th	0 day	4th	8th	12th	0 day	4th	8th	12th
Factor A: Chemical treatments												
T_1	0.00	0.14	8.29	12.17	0.00	0.12	7.61	11.51	0.00	0.13	7.95	11.84
T_2	0.00	0.10	7.19	11.47	0.00	0.08	6.53	10.80	0.00	0.09	6.86	11.14
T_3	0.00	0.04	6.15	11.08	0.00	0.03	5.49	10.39	0.00	0.03	5.82	10.73
T_4	0.00	0.54	13.51	23.61	0.00	0.49	12.56	22.67	0.00	0.52	13.04	23.14
SEm±	-	0.00	0.13	0.25	-	0.00	0.12	0.24	-	0.00	0.13	0.24
CD (5%)	-	0.01	0.38	0.71	-	0.01	0.34	0.68	-	0.01	0.36	0.70
Factor B: Packaging material												
P_1	0.00	0.04	6.20	10.91	0.00	0.04	5.54	10.25	0.00	0.04	5.87	10.58
P_2	0.00	0.08	7.08	11.42	0.00	0.07	6.42	10.74	0.00	0.08	6.75	11.08
P_3	0.00	0.17	8.62	12.44	0.00	0.16	7.95	11.78	0.00	0.16	8.28	12.11
P_4	0.00	0.52	13.25	23.56	0.00	0.46	12.30	22.61	0.00	0.49	12.77	23.08
SEm±	-	0.00	0.13	0.25	-	0.00	0.12	0.24	-	0.00	0.13	0.24
CD (5%)	-	0.01	0.38	0.71	-	0.01	0.34	0.68	-	0.01	0.36	0.70
Interaction A×B												
SEm±	-	0.01	0.26	0.50	-	0.01	0.24	0.47	-	0.01	0.25	0.48
CD (5%)	-	0.02	0.75	1.43	-	0.02	0.69	1.36	-	0.02	0.72	1.40

reported in fruits stored in perforated calcium chloride 1.5% with polythene bag (T_3P_1) whereas minimum TSS (11.46 °B) was recorded in control fruits. In case of (T_3P_1), TSS increased gradually till 8th day of storage (13.86 °B) while in the control fruits, TSS was highest on 8th day, after which there was a sharp decline and lowest TSS was observed on 12th day of storage (11.78 °B). Initial increase in TSS content and then gradual decrease later during storage was similar to there of Singh *et al.* (2018). Gradual increase in the TSS content with increasing storage period for all the treatments might be due to hydrolysis. of starch into sugar. The decrease in total soluble solids at advanced stage might be the result of increased rate of respiration in later stages of storage which led to its faster utilization in oxidation process through Kreb's cycle.

Fruits treated with calcium chloride (1.5%) with polythene bag (T_3P_1) recorded minimum titratable acidity (0.55%), while it was maximum (0.62%) in the control (Table 2). There was gradual decrease in acidity of fruits with advancing storage period. It was highest on 4th day of storage (0.71%) and decreased to 0.62% on 12th day of storage. The decline in titratable acidity in all treatments and the control during storage period might be due to oxidation of ascorbic acid. The decrease in titratable acidity may also be attributed to increased rate of metabolic activities and conversion of different organic compounds into sugars during storage period (Echeverria and Valich, 1989).

Highest ascorbic acid (122.28 mg/100g pulp) was found in fruits stored in perforated calcium chloride (1.5%) with polythene bag (T_3P_1). The minimum ascorbic acid content (110.48 mg/100 g pulp) was observed in the control (T_4P_4). This might be due to lower rate of oxidation of ascorbic acid inside perforated calcium chloride (1.5%) with polythene bag as compared to fruits kept in open (control). Storage days exerted significant influence on ascorbic acid of fruits, which decreased gradually with increase in storage period.

Maximum reducing sugars (8.24%) were reported in calcium chloride 1.5% with polythene bag (T_3P_1). Minimum reducing sugars (8.09%) were recorded in the control fruits (T_4P_4). An increase in reducing sugars in all treatments was observed with the advancement of storage period, but this increase was registered only up to 8th day of storage (8.24%) and thereafter it declined as storage period advanced and minimum was registered on 12th day of storage (6.78%). Non-reducing sugars increased initially up to 8th day and later decreased gradually as the storage period progressed. total sugars content increased during storage period. The initial rise may be due to water loss from fruits through evapo-transpiration and inhibition of activities of enzymes responsible for degradation of sugars, while the subsequent decline may be due to utilization of sugars in respiration (Alsawmahi *et al.*, 2018).

CONCLUSION

The physico-chemical changes during storage were slow in case of calcium chloride 1.5% with polythene bag (T_3P_1) as compared to other treatments and it can be used

to extend the storage period, marketability and maintain the quality of fruits during storage in guava cv. Allahabad Safeda.

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Comparative efficacy of soil and foliar application of zinc on garlic (*Allium sativum*) production in sandy loam soils of Rajasthan

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Abstract

An experiment was conducted to assess the impact of various levels and modes of zinc (Zn) application on garlic (*Allium sativum* L.) at College of Agriculture, Jodhpur during rabi 2021-22. There were seven treatments, three soil applications of $ZnSO_4$ (5, 10, and 15 kg/ha), three foliar applications of $ZnSO_4$ (0.3%, 0.5%, and 0.7%), and control in a randomized block design with three replications. The results indicated that $ZnSO_4$ applications significantly improved growth parameters, yield attributes and bulb yield of garlic. The highest plant height (69.5.cm) and number of leaves (8.64 at 120 days after planting) were observed with soil application of $ZnSO_4$ 15 kg/ha and foliar application of $ZnSO_4$ 0.7%. Foliar application of $ZnSO_4$ 0.7% also recorded significantly highest values of bulb weight (26.1 g), neck thickness (0.78 cm), and weight of 50 cloves (65.2 g). Both soil application of $ZnSO_4$ 15 kg/ha and foliar application $ZnSO_4$ 0.7% treatments achieved the maximum bulb yield (15.4 t/ha), compared to the control (11.5 t/ha), indicating a 33.9% increase in bulb yield. Zinc use efficiency was highest with soil application of $ZnSO_4$ 15 kg/ha (0.29 t/ha/kg $ZnSO_4$). The highest net returns (₹ 465,154/ha) were recorded with foliar application of $ZnSO_4$ 0.7% and the highest B:C ratio (3.08) in soil application of $ZnSO_4$ 15 kg/ha. These results highlights the higher efficacy of $ZnSO_4$ applications, particularly with foliar, enhancing growth, yield, quality, and economic returns of garlic in arid regions.

Key words: Arid regions, Foliar fertilization, micronutrient application, Zinc application

Garlic (*Allium sativum* L.) is a widely cultivated bulb crop known for its culinary, nutritional, and medicinal properties. India ranks second globally in garlic production, with Rajasthan being a major garlic-producing state. However, the productivity and quality of garlic in arid regions are often constrained by deficiencies of essential micronutrients, particularly zinc (Zn) (Anonymous, 2021). The deficiency of Zn can adversely impact plant growth, bulb development, and overall yield, necessitating external supplementation. Among all micronutrients, Zn meticulously regulates various metabolic processes in plants which helps to enhance growth, and storage organs (Rani *et al.*, 2017; Vyas *et al.*, 2024).

As an alternative, foliar application of Zn has gained attention as a more effective approach, allowing plants to absorb Zn directly through leaf surfaces, bypassing soil-related constraints (Alam *et al.*, 2019). Foliar fertilization has been reported to improve plant growth, yield, and nutrient-use efficiency while enhancing the effectiveness of macronutrient uptake (Tripathi *et al.*, 2022). Therefore, study was undertaken to evaluate the effect of different levels and modes of Zn application (soil and foliar) on garlic production.

MATERIALS AND METHODS

A field experiment was conducted during *rabi* 2021-22 at College of Agriculture, Jodhpur, located at an altitude of 231 m above sealevel (26°15' to 26°45' N latitude and 73°00' to 73°29' E longitude). The sandy loam soil of the experimental field is slightly alkaline (pH 8.3), low in organic carbon (0.13%), deficient in available zinc (0.48 ppm), low in available nitrogen (174 kg/ha), medium in phosphorus (22.2 kg/ha), and high in potassium (325 kg/ha).

The experiment was laid out in a randomized block design with three replications comprising seven treatment *viz*, soil applications of $ZnSO_4$ (5, 10, and 15 kg/ha), foliar applications of $ZnSO_4$ (0.3%, 0.5%, and 0.7%), and the control. Farmyard manure (25 t/ha) was incorporated into the soil during final field preparation. A uniform dose of 50 kg P_2O_5/ha (DAP), 100 kg K_2O/ha (MoP), and 50 kg N/ha (urea) was applied at planting, with an additional 50 kg N/ha was broadcast in two splits 30 and 45 days after transplanting (DAT). $ZnSO_4$ was applied either through broadcasting at sowing (soil application) or as a foliar spray at 60 and 90 DAT. The garlic cultivar 'G-282' was planted on 29 October, 2021, and harvested on 28 March, 2022. Garlic cloves were planted in rows (15 cm x 7.5 cm) at a seed rate of 500 kg/ha.

A uniform soil moisture was maintained throughout the growing period, with shallow hoeing for weed control and need based pest control. Observations on plant height at 120 DAT, number of leaves/plant at 30, 60, 90, and 120 DAT, bulb weight, number of cloves/bulb, and weight of 50 cloves were recorded. Bulb yield (t/ha) was calculated

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from the harvest of net plot. The TSS content in bulbs was measured using a digital refractometer. Zinc content in bulbs and foliage was analyzed using standard laboratory procedure.

Economic calculations are based on average bulb yields, market rates, and input costs, using the following formulas:

Gross returns (₹/ha) = bulb yield (kg) × bulb market rate (₹/kg)

Net returns (₹/ha) = gross returns (₹/ha) – cost of cultivation (₹/ha)

Benefit: Cost ratio = net returns (₹/ha)/cost of cultivation (₹/ha)

Relative Yield Increase (%) = ($yield_{treatment}$ – $yield_{control}$ / $yield_{control}$) × 100

Zinc Use Efficiency (ZUE) = ($yield_{treatment}$ – $yield_{control}$) /amount of znso4 applied

Cost per Unit Yield = total cost / $yield_{treatment}$

Return on Investment (ROI %) = (net returns / total cost) × 100

Yield per unit cost = $yield_{treatment}$ / total cost

Data were analyzed using ANOVA as per Fisher (1950), with treatment differences tested by the 'F' test at a 5% significance level. Additionally, t-test was used to compare the effectiveness of soil *versus* foliar application methods.

RESULTS AND DISCUSSION

The application of $ZnSO_4$, both as soil application and foliar application, significantly influenced the growth parameters of garlic plants. Soil application of $ZnSO_4$ 15 kg/ha resulted in highest plant height (69.5 cm) at 120 DAP, followed by soil application of $ZnSO_4$ 10 kg/ha (65.5 cm) and foliar application of $ZnSO_4$ 0.7% (64.8 cm), which were significantly higher than control (47.2 cm) (Fig. 1). It may be possible due to the fact that Zn induces the synthesis of tryptophan, an amino acid, which is the processor of IAA which stimulates plant growth and act as plant hormone. These results are consistant with Nehra and Malik (2024). Similarly, number of leaves/plant increased significantly with $ZnSO_4$ treatments at all growth stages (30, 60, 90, and 120 DAP), with soil application of $ZnSO_4$ 15 kg/ha consistently outperforming other treatments (Fig. 2). This can be attributed to essential role of Zn in various biochemical processes, including enzyme activation, protein synthesis, and hormone production (Alam *et al.*, 2019). These findings align those of Gar *et al.* (2021) and Vyas *et al.* (2024).

Application of $ZnSO_4$ significantly enhanced yield attributes such as the weight of bulb, neck thickness, number of cloves/bulb, and weight of 50 cloves (Table 1). Foliar application of $ZnSO_4$ (0.7%) recorded highest weight

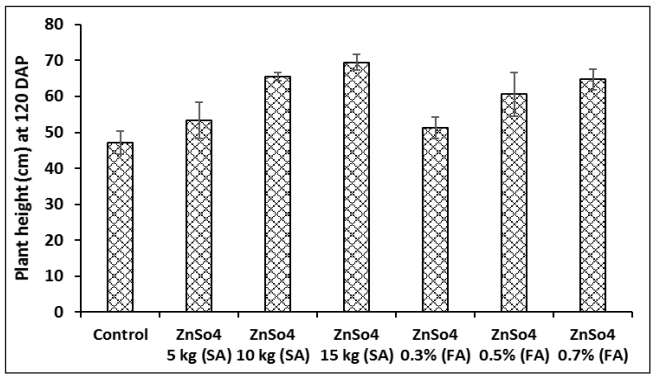

Fig. 1. Effect of soil appliction and foliar application of $ZnSo_4$ on plant height of garlic at 120 DAP.

of bulb (26.1 g) and bulb yield (15.4 t/ha), significantly higher than the control (19.7 g and 11.5 t/ha, respectively). Similarly, number of cloves/bulb and the weight of 50 cloves were highest with soil application of $ZnSO_4$ (15 kg/ha) and foliar application of $ZnSO_4$ (0.7%). The significant increase in yield attributes can be attributed to enhanced Zn uptake and utilization, which play a critical role in chlorophyll synthesis, photosynthesis, and nutrient translocation within plant (Maurya *et al.*, 2018). These results are consistent with those of Pramanik and Tripathy (2017) and Jat *et al.* (2023).

The relative increase in yield compared to the control was highest in soil application of $ZnSO_4$ (15 kg/ha) and

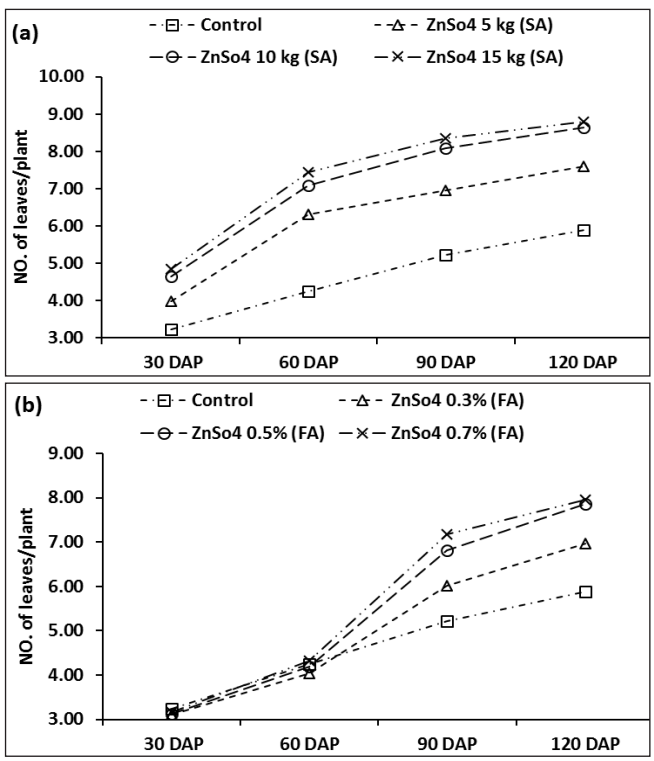

Fig. 2. Effect of a) soil appliction and b) foliar application of $ZnSo_4$ on number of leaves/plant at different growth stages in garlic.

foliar application of $ZnSO_4$ 0.7%, both achieving a 33.91% increase (Table 1). Soil application at 15 kg $ZnSO_4$/ha and foliar application at 0.7% were significantly more effective than other treatments, indicating their more efficacy in enhancing bulb yield. Zinc use efficiency (ZUE) was highest for soil application of $ZnSO_4$ (15 kg/ha) at 0.29 t/ha/kg $ZnSO_4$. The highest foliar application 0.7% achieved a ZUE of 0.14 t/ha/kg $ZnSO_4$. Soil applications of Zn showed higher efficiency, suggesting that direct soil incorporation of $ZnSO_4$ is more effective in improving yield per unit of zinc applied. Further, comparing soil and foliar application of $ZnSO_4$ showed that foliar application significantly improved weight of 50 cloves, TSS content, and zinc content in both foliage and bulbs ($p < 0.05$).

The foliar application $ZnSO_4$ (0.7%) attained the highest TSS content (44.3), significantly higher than the control (37.8). Similarly, Zn content in bulbs was highest with foliar application of 0.7% $ZnSO_4$ (30.0 mg/kg), indicating enhanced Zn accumulation with foliar applications (Table 1). The increase in TSS content can be linked to role of Zn in carbohydrate metabolism and synthesis of soluble solids, which contribute to sweetness and quality of bulbs (Tripathi *et al.*, 2022). The higher Zn content in foliage and bulbs with $ZnSO_4$ treatments is likely due to improved absorption and translocation of Zn within plant, facilitated by both soil and foliar applications. These findings are in agreement with those of Alam *et al.* (2019).

The highest net returns (₹ 465,154/ha) was obtained from foliar application of 0.7% $ZnSO_4$, followed by soil application of 15 kg/ha $ZnSO_4$ (₹ 464,979/ha). However, highest B:C ratio (3.08) was recorded with soil application of $ZnSO_4$ 15 kg/ha, indicating economic feasibility of this treatment (Table 2). The higher net return and B:C ratio with $ZnSO_4$ treatments can be attributed to substantial increase in bulb yield, which outweighs the additional costs of $ZnSO_4$ application. These results highlight the economic benefits of using $ZnSO_4$ in garlic cultivation, as also reported by Yadav *et al.* (2018). The economic analysis revealed that the cost per unit yield was lowest for soil application of $ZnSO_4$ (15 kg/ha) at ₹ 9782/t, indicating superior economic efficiency of soil application. Among foliar applications, $ZnSO_4$ (0.7%) had a cost per unit yield of ₹ 9873/t. Soil application of $ZnSO_4$ (15 kg/ha) also

Table 1: Effects of soil and foliar application of $ZnSO_4$ on bulb attributes, bulb yield and Zn content in garlic bulb

Treatment	Weight of bulb (g)	Neck thickness (cm)	No. cloves/ bulb	Weight of 50 cloves (g)	Bulb yield (t/ ha)	Relative Increase in Yield (%)	Zinc Use Efficiency (t/ha per kg $ZnSO_4$)	TSS content of bulb	Zinc content in foliage (mg/kg)	Zinc content in bulb (mg/kg)
Control	19.7	1.1	18.3	47.2	11.5	0.00	0.00	37.8	15.2	19.4
$ZnSo_4$ 5 kg/ha (SA)	21.3	0.9	18.5	56.9	12.5	8.70	0.16	38.8	17.6	22.2
$ZnSo_4$ 10 kg/ha (SA)	24.3	0.8	20.5	62.8	14.6	26.96	0.28	41.7	19.3	24.8
$ZnSo_4$ 15 kg/ha (SA)	25.0	0.8	21.3	64.3	15.4	33.91	0.29	41.9	20.0	25.5
$ZnSo_4$ 0.3% (FA)	21.3	0.9	18.7	54.1	12.3	6.96	0.12	39.7	19.1	24.7
$ZnSo_4$ 0.5% (FA)	25.3	0.8	19.0	63.7	15.1	31.30	0.14	42.9	21.3	28.3
$ZnSo_4$ 0.7% (FA)	26.1	0.8	20.3	65.2	15.4	33.91	0.14	44.3	22.3	30.0
SEm±	0.41	0.03	0.71	1.83	0.89			1.26	0.44	0.33
CD (P=0.05)	1.28	0.08	NS	5.63	2.74			3.88	1.35	1.00
Soil appliction versus foliar application (t-test)										
P values (0.05)	0.052	0.374	0.097	0.039	0.05			0.023	0.013	0.017
Significance	NS	NS	NS	*	NS			*	*	*

SA- Soil application; FA- Foliar application *Significant at p=0.05; NS- non-significant

Table 2: Effect of soil and foliar application of different levels of $ZnSO_4$ on economics of garlic cultivation.

Treatment	Treatment cost (₹/ha)	*Total Cost (₹/ha)	**Gross Return (₹/ ha)	Net returns (₹/ha)	B:C ratio	Cost/ Unit Yield (₹/t)	Return on Investment (%)	Yield / Unit Cost (kg/₹)
Control	-	149864	460000	310136	2.06	13031	206	0.077
$ZnSo_4$ 5 kg/ha (SA)	630	150494	500133	349639	2.32	12039	232	0.083
$ZnSo_4$ 10 kg/ha (SA)	760	150624	584000	433376	2.88	10317	287	0.097
$ZnSo_4$ 15 kg/ha (SA)	890	150754	615733	464979	3.08	9782	308	0.102
$ZnSo_4$ 0.3% (FA)	2078	151942	490400	338458	2.23	12352	222	0.081
$ZnSo_4$ 0.5% (FA)	2130	151994	604000	452006	2.97	10066	297	0.099
$ZnSo_4$ 0.7% (FA)	2182	152046	617200	465154	3.06	9873	305	0.101

SA- Soil application; FA- Foliar application

* Common cost of cultivation (₹ 149864/ha) ** Soil applicationle price of garlic- ₹ 40/kg

achieved the highest return on investment at 308.3%, slightly outperforming foliar application of $ZnSO_4$ (0.7%) at 305.8%. Yield/unit cost was highest for soil application of $ZnSO_4$ 15 kg 0.102 kg/₹, indicating marginally better efficiency compared to foliar application of $ZnSO_4$ (0.7%), thus emphasizing the economic advantage of soil application.

CONCLUSION

Both soil and foliar applications of $ZnSO_4$ significantly enhance garlic growth, yield, and quality. The economic viability of $ZnSO_4$ applications is crucial for foliar application, as it ensures that additional investment in micronutrients translates to higher profitability.

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Response of foliar feeding of nutrients on quality attribute of guava (*Psidium guajava*)

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Abstract

The experiment was conducted at Department of Fruit Science. K.N.K. College of Horticulture, Mandsaur,during 2017-18,factorial randomized block design replicated three times. The treatment consisted of two factor (A) variety V_1- Chittidar, V_2- Allahabad Safeda and factor (B) nine levels of nutrients- N_0- control, N_1-zinc sulphate @ 0.3%, N_2- zinc sulphate @ 0.4%,N_3- calcium nitrate @ 1%,N_4- calcium nitrate @ 2%,N_5 -potassium sulphate @ 1%,N_6- potassium sulphate @ 2%,N_7- boron @ 0.2%,N_8- boron @ 0.4%. Among, varieties, maximum TSS (11.59^{0}Brix) and non-reducing sugar (4.39%) were found in Chittidar (V_1) and maximum, TSS/Acid ratio (36.79) , reducing sugar (5.62%) and ascorbic acid (156.84 mg/100 pulp)was recorded in Allahabad Safeda (V_2) and the minimum acidity (0.32%) in Allahabad Safeda (V_2). The maximum, TSS (12.60^{0}Brix), non-reducing sugar (4.56%) and TSS/ acid ratio (43.77)were observed in N_6potassium sulphate @ 2%, maximum reducing sugar (5.74%), ascorbic acid,(170.28mg/100 pulp) and total sugar (9.68%) in N_8 (boron@0.4%) and minimum, acidity (0.28%) was recorded in N_2 (zinc sulphate @0.4%).

Keywords: Guava, Nutrients, Variety, Quality, Foliar feeding, Reducing sugar and Non-reducing sugar.

Guava (*Psidium guajava* L.) is the fourth most important fruit crop in area and production (Anjanawe *et al.,* 2024). Foliar feeding of nutrients is advantageous in terms of low application rate, uniform distribution of fertilizer material and quick response to applied nutrients as stated by Dongre *et al.* (2022). Nutrients like nitrogen, phosphorus and potash play a vital role in promoting the plant vigour and productivity, whereas micronutrients like zinc and iron perform a specific role in growth and development of plant, quality produce and uptake of major nutrients as stated by Zagade *et al.* (2020). Hence an experiment was conducted.

MATERIALS AND METHODS

The experiment was conducted on eleven year old well-established guava orchard planted at 6.0 m × 6.0 m spacing during 2017-18 Guava Chittidar and Allahabad Safeda were used. This experiment was laid out in factorial randomized block design with three replications comprising eighteen treatments including two variety V_1- Chittidar, V_2- Allahabad Safeda and nine levels of nutrients- N_0- control, N_1-zinc sulphate @ 0.3%, N_2- zinc sulphate @ 0.4%,N_3- calcium nitrate @ 1%,N_4- calcium nitrate @ 2%,N_5 -potassium sulphate @ 1%,N_6- potassium sulphate @ 2%,N_7- boron @ 0.2%,N_8- boron @ 0.4%. The nutrients were applied through foliar spray on 25 September 2017 in guava plant. The observations on quality attributes were recorded as per standard procedures. Hand refractometer was used for determination of TSS in ^{0}Brix. The percent titrable acidity was estimated by simple acid / alkaline titration method as described in AOCC (1984) .The ascorbic acid was estimated as per Assay method given by (Ranganna, 1986) . The reducing sugar, total sugar per cent in fruit juice was estimated by the method as suggested by (Nelson, 1944) and non-reducing sugar is estimated by subtracting of reducing sugar in total sugar.

RESULTS AND DISCUSSION

The minimum acidity (0.32%) was observed in Allahabad Safeda (V_2) and maximum (0.33%) in Chittidar (V_1). The minimum, acidity (0.28%) was recorded in N_2 (zinc sulphate @0.4%) and maximum (0.38%) in N_0 (control)(Table-1 and Figure-1). Among, treatment combinations, minimum, acidity (0.25%) was recorded in V_2N_2 (Allahabad Safeda with zinc sulphate@0.4%) and maximum (0.40%) in V_2N_0 (Allahabad Safeda with control). It might be due to lower acidity in fruits due to higher accumulation of sugar, better translocation of sugar into fruit tissues conversion of organic acids into sugars. Similar finding have also been reported by Jat and Kacha (2014), Kumar *et al.* (2015) and Kumar *et al.* (2017).

Among, varieties maximum TSS (11.59^{0}Brix) was found in Chittidar (V_1) and minimum,TSS (11.35^{0}Brix) in Allahabad Safeda (V_2). The maximum, TSS (12.60^{0}Brix) in N_6 (potassium sulphate @ 2%) and the minimum (9.83^{0}Brix) in N_0 (control). Among, treatment combinations, significantly highest TSS (12.67^{0}Brix) was recorded in treatment V_1N_6 (Chittidar with potassium sulphate@2%),followed by V_2N_6 (Allahabad Safeda

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with potassium sulphate@2%) with respect to TSS (12.57^{0}Brix). The minimum (9.74^{0}Brix) was found in V_1N_0 (Chittidar with control).It might be due to highest TSS in those due to, potassium has predominant role in translocation of photo-assimilates; sugar and soluble solids, which are responsible for increased TSS (Table-1 and Figure-1). The present results regarding TSS are in accordance with the findings of Kumar *et al.* (2015), Choudhary *et al.* (2017) and Kumar *et al.* (2017).

The total soluble solids/acid ratio was significantly found during investigation. With respect to variety maximum, TSS/acid ratio (36.79) was recorded in Allahabad Safeda (V_2) and minimum (35.09) in Chittidar (V_1).Among, foliar application of nutrients highest TSS/ acid ratio (43.77) was observed in N_6 (potassium sulphate @ 2%) and minimum (25.25) in N_0 (control) (Table-1 and Figure-1). Among the treatment combination of variety and nutrients, significantly highest, TSS/Acid ratio (47.62) was recorded in V_2N_6 (Allahabad Safeda with potassium sulphate@2%) followed by V_2N_2 (Allahabad Safeda with zinc sulphate@0.4%) with respect to TSS/Acid ratio (45.34). The minimum (25.66) was found in V_1N_0 (Chittidar with control). It might be due to increase TSS/acid ratio is due to consistent decrease in acid content and increase in TSS resulted into an increase in TSS/acid ratio. It may be due to that the increased sugar and reduced leaf starch content, which was due to more transformation of starch into sugar and its translocation into the fruits. These results are conformity with the finding of Kumar *et al.* (2009) in litchi and Kumar *et al.* (2017).

The maximum reducing sugar (5.62%) was found in Allahabad Safeda (V_2) and minimum (5.02) was found in V_1 (Chittidar) (Table-2 and Figure-2). With respect to nutrients maximum reducing sugar (5.74%) was recorded in N_8 (boron@0.4%) and minimum (4.85) in N_6 (potassium sulphate @ 2%). The interactions study of varieties and nutrients, maximum reducing sugar(5.78%) was obtained in the treatments V_2N_8 (Allahabad Safeda with boron@0.4%), followed by V_1N_8 (Chittidar with boron@0.4%) with respect to reducing sugar (5.71%). The minimum (4.16) in V_1N_6 (Chittidar with potassium sulphate@2%). The results are in agreement with the earlier findings of Kaur and Dhillon (2006), Dutta and Banik (2007) and Bhatt *et al.* (2025).

The maximum non-reducing sugar (4.39%) was recorded in the variety of Chittidar (V_1) and minimum (3.75%) in Allahabad Safeda (V_2). With respect to nutrients maximum non-reducing sugar (4.56%) was recorded in N_6Potassium sulphate @ 2% and minimum (3.57%) in N_0 control (Table-2 and Figure-2). The interactions of varieties and nutrients, the results found that significantly higher non- reducing sugar (5.18%) was recorded in V_1N_6 (Chittidar with potassium sulphate @2%), followed by V_1N_4 (Chittidar with Calcium nitrate @ 2%) (5.17%). The minimum in V_2N_0 (Allahabad Safeda with control). The results are in agreement with the earlier findings of Dutta and Banik (2007), Kumar *et al.* (2015) and Nehra and Malik (2024).

The maximum total sugar (9.41%) was recorded in Chittidar (V_1) and minimum (9.37) was found in Allahabad Safeda (V_2). With respect to nutrients, maximum total sugar (9.68%) was observed in N_8 (boron@0.4%) and minimum (9.03%) in N_0 (control). The treatment combinations of variety and nutrients was found non-significant the highest total sugar (9.73%) in V_1N_8 (Chittidar with boron@0.4%), followed by V_2N_8(Allahabad Safeda) 9.64%(Table-2 and Figure-2).The higher percentage of total sugar, reducing and non-reducing sugar might have been due to efficient translocation of photosynthesis to the fruits by regulation of boric acid. The positive effects of boron on reducing sugar are in agreement with the findings of Dutta and Banik (2007), Bhatt *et al.* (2012), Kumar *et al.* (2015) and Parmar *et al.* (2020).

The maximum ascorbic acid (156.84mg/100 pulp) was found in the variety of Allahabad Safeda (V_2) and minimum (154.43mg/100 pulp) in Chittidar (V_1) (Table-2 and Figure-2). The maximum (170.28mg/100 pulp) was observed in N_8 (boron@0.4%) and minimum (136.09mg/100 pulp) in N_0 (control). The interactions of varieties and nutrients, the results was found non-significant the higher ascorbic acid (173.15mg/100 pulp) was recorded in V_2N_8 (Allahabad Safeda with Boron @ 0.4%.), followed by V_2N_7 (Allahabad Safeda with Boron @ 0.2%) 169.20mg/100 pulp. The minimum (133.66mg/100 pulp) in V_1N_0 (Chittidar with control).It might be due to augmentation of ascorbic acid percentage of guava fruit might have been due to higher synthesis of nucleic acid, on account of maximum availability of plant metabolism. The result of present study are closely conformity with the findings of Awasthi and Lal (2009), Yadav *et al.* (2011), Bhatt *et al.* (2012) , Baranwal *et al.* (2017).

CONCLUSION

Thus, concluded the variety and nutrients and their combinations significantly influenced the quality attributes and treatment combinations, the maximum TSS (12.67^{0}Brix) and non reducing sugar (5.18%) were found in V_1N_6 (Chittidar with potassium

sulphate@2%) and minimum in V_2N_0 (Allahabad Safeda with control).

Table 1: Effect of foliar application on quality attribute of guava.

Treatment	Acidity (%)	TSS (°Brix)	TSS/Acid ratio
Varieties			
V_1	0.33	11.59	35.09
V_2	0.32	11.35	36.79
S.Em±	0.005	0.03	0.27
CD at 5%	0.014	0.11	0.78
Nutrients			
N_0	0.38	9.83	25.25
N_1	0.29	11.83	40.43
N_2	0.28	11.69	42.00
N_3	0.34	11.08	32.59
N_4	0.31	11.20	35.68
N_5	0.30	12.13	39.79
N_6	0.29	12.60	43.77
N_7	0.37	10.81	29.01
N_8	0.34	12.02	34.89
S.Em±	0.01	0.08	0.58
CD at 5%	0.03	0.24	1.67
Interactions			
V_1N_0	0.38	9.74	25.66
V_1N_1	0.31	11.97	37.81
V_1N_2	0.30	11.90	38.68
V_1N_3	0.33	11.17	33.52
V_1N_4	0.32	11.37	34.83
V_1N_5	0.32	12.13	38.00
V_1N_6	0.31	12.67	39.94
V_1N_7	0.36	10.90	30.00
V_1N_8	0.33	12.57	37.35
V_2N_0	0.40	9.93	24.85
V_2N_1	0.27	11.70	43.05
V_2N_2	0.25	11.48	45.34
V_2N_3	0.34	11.00	31.66
V_2N_4	0.30	11.03	36.54
V_2N_5	0.29	12.13	41.59
V_2N_6	0.26	12.64	47.62
V_2N_7	0.38	10.74	28.04
V_2N_8	0.35	11.48	32.43
S.Em±	0.015	0.11	0.82
CD at 5%	0.043	0.34	2.36

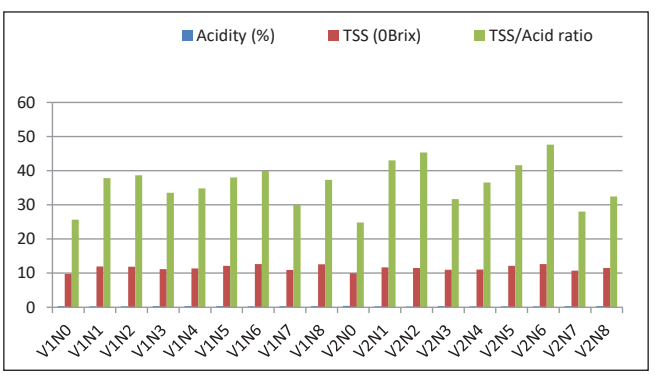

Fig. 1 Effect of foliar application on quality attribute of guava

Table 2: Effect of foliar application on quality attribute of guava

Treatments	Reducing sugars (%)	Non-reducing sugars (%)	Total sugars (%)	Ascorbic acid (mg/100 pulp)
Varieties				
V_1	5.02	4.39	9.41	154.43
V_2	5.62	3.75	9.37	156.84
S.Em±	0.08	0.009	0.05	0.78
CD at 5%	0.25	0.026	NS	2.26
Nutrients				
N_0	5.46	3.57	9.03	136.09
N_1	5.63	3.65	9.28	161.49
N_2	5.69	3.86	9.55	164.10
N_3	4.89	4.43	9.33	147.20
N_4	5.06	4.51	9.57	150.14
N_5	4.86	4.41	9.27	150.33
N_6	4.85	4.56	9.41	155.35
N_7	5.66	3.68	9.35	165.86
N_8	5.74	3.94	9.68	170.28
S.Em±	0.19	0.019	0.11	1.66
CD at 5%	0.54	0.055	0.32	4.79
Interactions				
V_1N_0	5.44	3.63	9.07	133.66
V_1N_1	5.62	3.77	9.39	161.54
V_1N_2	5.69	3.90	9.59	162.89
V_1N_3	4.23	5.04	9.27	147.10
V_1N_4	4.50	5.17	9.67	150.44
V_1N_5	4.21	4.93	9.14	149.07
V_1N_6	4.16	5.18	9.33	155.18
V_1N_7	5.65	3.82	9.47	162.53
V_1N_8	5.71	4.02	9.73	167.42
V_2N_0	5.49	3.51	9.00	138.53
V_2N_1	5.64	3.54	9.18	161.44
V_2N_2	5.70	3.81	9.51	165.32
V_2N_3	5.56	3.83	9.39	146.95
V_2N_4	5.62	3.86	9.48	149.84
V_2N_5	5.51	3.90	9.41	151.60
V_2N_6	5.55	3.95	9.50	155.53
V_2N_7	5.69	3.54	9.23	169.20
V_2N_8	5.78	3.86	9.64	173.15
S.Em±	0.26	0.027	0.16	2.36
CD at 5%	0.77	0.078	NS	NS

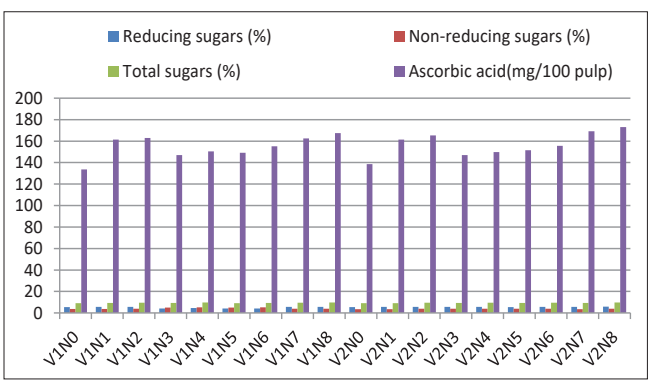

Fig.2 Effect of foliar application on quality attribute of guava

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Short Communication

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Effects of night break light sources on morphology and pigment content in standard chrysanthemum (*Chrysanthemum morifolium*)

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Abstract

This study investigated the effects of incandescent bulbs, compact fluorescent lamps (CFL), and light-emitting diodes (LED) on morphological and pigment traits of ten *Chrysanthemum morifolium* Ramat. Varieties, in a factorial completely randomized design with three replications. The plant height, leaf area index (LAI), flowering time, duration, and pigment content were measured. The LED lighting produced tallest plants (103.35 cm), highest LAI (6.28), and largest flowers (19.58 cm), yielding highest anthocyanin (1.84 mg/g) and carotenoid (96.12 mg/g). Incandescent lighting induced earliest flowering (158.87 days), while LED extended flowering duration to 36.34 days. There was significant influence of night break light sources on growth, flowering, and pigment synthesis, LEDs showing the greatest overall benefit.

Key words: Genotypes, Light sources, LED, Morphological traits, Pigments

Chrysanthemum morifolium Ramat., a member of the Asteraceae family, is widely cultivated for ornamental purposes. In India, it is extensively cultivated for various purposes (Koley and Sarkar, 2013). Light perception in chrysanthemums plays a crucial role in regulating flowering and physiological processes, mediated by the circadian clock (Jackson, 2009). Various light sources are used in horticulture for photoperiodic control, with LEDs emerging as promising alternatives due to their spectral specificity and energy efficiency (Bergstrand and Schussler, 2012). Schamp *et al.* (2012) suggested that LEDs could potentially replace high-pressure sodium lamps in flower production systems. Thakur and Grewal (2018) demonstrated that supplementary light treatments can modulate flowering timing of *C. morifolium.*

Recent studies have highlighted the benefits of LED lighting compared to traditional sources. Wang *et al.* (2023) reported significant height variations among chrysanthemum cultivars under different light treatments, while Li *et al.* (2022) found that specific LED spectra enhanced plant growth. Zhang *et al.* (2021), observed improved plant characteristics under optimized lighting conditions. This study builds upon existing research by evaluating the effects of incandescent bulbs, CFLs, and LEDs on multiple morphological and pigment-related traits of *C. morifolium*. By manipulating photoperiods with various light sources, we aim to address challenges in commercialization within sub-tropical regions and contribute to the optimization of chrysanthemum cultivation practices.

Three light sources (incandescent bulbs, CFL, LED) were tested using a factorial CRD design with three replications and three pots per replication. Plant propagation was achieved through terminal stem cuttings (2-3 cm long) treated with NAA (500 mg/l) for 30 seconds. Cuttings were planted in propagation trays using burnt rice husk as a rooting medium and maintained under high humidity conditions. After two weeks, rooted cuttings were transplanted into 20 cm diameter pots containing a 2:1 mixture of garden soil and well-rotten farmyard manure, supplemented with diammonium phosphate (1 kg/ft^3). Long-day conditions were simulated using night breaks from August 15 to October 31 (consecutive years 2018-19), with the three light sources applied for two hours nightly (22:00-00:00). Plants were subsequently shifted to natural day length on November 1. Standard cultural practices, including pinching and disbudding, were implemented throughout the growth period until flowering.

The leaf area index (LAI) was calculated as total leaf area per plant multiplied by number of plants/m^2, divided by surface area of land (Gardener *et al.*, 2003). Anthocyanin content (mg/g)- Five ml of sample were diluted to 100 ml with ethanolic HCl (85% ethanol, 15% 1.5 N HCl) and kept overnight at 4°C. Filtered through Whatman No.1 and fine Millipore, a 10 ml aliquot was diluted to 20 ml with ethanolic HCl. Absorbance at 535 nm was measured, and anthocyanin content was calculated (Harborne 1967). Carotenoids content (mg/g) were extracted from 100 mg of ray florets with 10 ml acetone. Absorbance at 440 nm was measured, and carotenoid concentration was calculated using Wettstein's formula (Wettstein 1957). Number of stomata per unit area were counted on three 1 mm^2 leaf areas using 100× magnification on an Olympus trinocular microscope, on both abaxial and adaxial surfaces.

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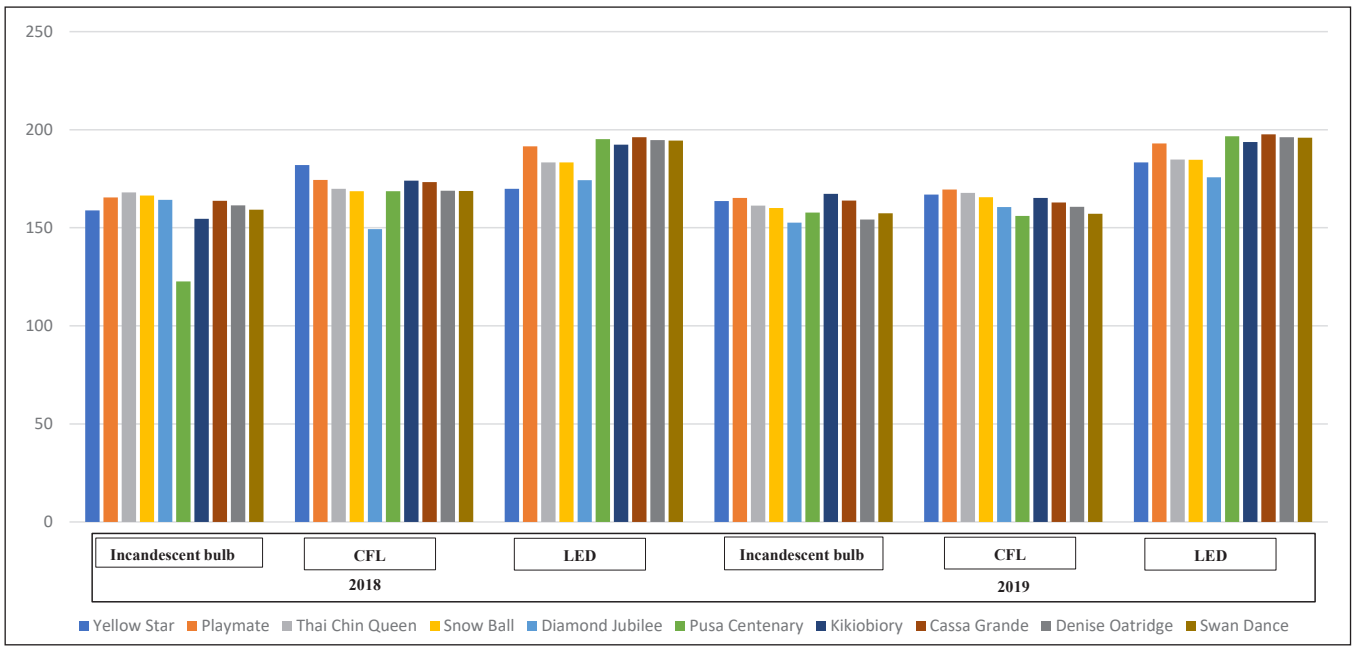

Fig. 1 Effect of different sources of light as night break on days taken for flowering in standard chrysanthemum

Table 1: Effect of different sources of light as night break on flower size in standard chrysanthemum

Genotype	Flower size (cm)							
	2018			Mean	2019			Mean
	Incandescent bulb	CFL	LED		Incandescent bulb	CFL	LED	
Yellow Star	12.32	13.64	15.34	13.77^{h}	13.85	15.07	16.78	15.23^{g}
Playmate	15.90	16.34	17.82	16.69^{d}	17.43	17.77	19.25	18.15^{cd}
Thai Chen Queen	13.50	14.25	16.38	14.71^{g}	15.03	15.68	17.82	16.18^{f}
Snow Ball	17.33	17.27	19.83	18.14^{a}	18.77	18.70	21.26	19.58^{a}
Diamond Jubilee	16.23	16.02	16.27	16.17^{e}	17.67	17.45	17.71	17.61^{d}
Pusa Centenary	15.23	16.34	17.61	16.39^{e}	16.67	17.77	19.04	17.83^{d}
Kikiobiory	17.20	18.03	18.05	17.76^{b}	18.63	19.47	19.49	19.20^{ab}
Cassa Grande	17.24	16.99	17.48	17.24^{c}	18.67	18.43	18.91	18.67^{bc}
Denise Oatridge	12.40	13.35	15.37	13.71^{h}	13.83	14.78	16.81	15.14^{g}
Swan Dance	14.35	15.30	16.39	15.35^{f}	15.78	16.73	17.83	16.78^{e}
Mean	15.17^{c}	15.75^{b}	17.06^{a}		16.63^{c}	17.19^{b}	18.49^{a}	

Mean values in each column with the same letter are not significantly different at $p < 0.05$ according to DMRT. *Significant at $p < 0.05$

Plant height varied among genotypes and light treatments. It was highest in 'Playmate' (101.88-103.35 cm), and shortest (70.23-76.23 cm) in 'Kikiobiory'. LED lighting consistently produced tallest plants (average 95.12 cm), followed by CFL and incandescent bulbs. These results align with Wang *et al.* (2023). The superiority of LED lighting supports Li *et al.* (2022) work showing enhanced growth under specific LED spectra and also concurs with findings by Seif *et al.* (2021) on red light promoting shoot growth in chrysanthemums.

Leaf Area Index (LAI) was highest in 'Yellow Star' (6.86-7.33), while 'Swan Dance' had lowest (4.77-5.19). LED lighting produced highest mean LAI (5.85-6.28), followed by CFL and incandescent bulbs. The superior LAI of 'Yellow Star' supports work by Liu *et al.* (2022) on cultivar-specific leaf traits. LED lighting's efficacy in promoting LAI corroborates Chen *et al.* (2023) findings on spectral effects on chrysanthemum leaf expansion, also aligns with observations recorded by Lim *et al.* (2023) during in vitro culture of Gerbera under varying LED spectra.

The LED lighting resulted in longest flowering times (up to 196.15 days), while incandescent bulbs produced shortest (minimum 122.59 days). The CFLs yielded intermediate results. These findings align with Wang *et al.* (2023) and Zhang *et al.* (2021), supporting the efficacy of LED lighting in extending the vegetative phase and enhancing plant attributes. 'Kikiobiory' had longest flowering period (35.75-36.34 days), while 'Yellow Star' and 'Swan Dance' had shortest. The LED lighting produced

longest flowering durations (average 32.5 days), followed by CFL and incandescent bulbs. These findings support recent research by Li *et al.* (2023) and Wang *et al.* (2022) on regulation of flowering time in chrysanthemums and benefits of specific LED spectra.

'Snow Ball' produced largest flowers (18.14-19.58 cm), while 'Yellow Star' and 'Denise Oatridge' had smallest (13.71-15.23 cm). LED lighting consistently produced largest flowers across genotypes (average 17.2 cm), followed by CFL and incandescent bulbs. These findings align with Zhang *et al.* (2023). Genotypic variations reflect genetic diversity in flower development mechanisms noted by Liu *et al.* (2022).

Only 'Thai Chen Queen', 'Playmate' and 'Denise Oatridge' showed detectable anthocyanin levels. 'Thai Chin Queen' exhibited highest content (1.67-1.84 mg/g). LED lighting consistently produced highest anthocyanin levels (average 1.2 mg/g), followed by CFL and incandescent bulbs. These findings align with Li *et al.* (2023). Zhang *et al.* (2022) demonstrated enhanced flavonoid biosynthesis under specific LED spectra. 'Pusa Centenary' exhibited highest carotenoid levels (94.68-96.12 mg/g), while 'Diamond Jubilee' showed lowest (22.57-24.00 mg/g). LED lighting generally produced highest carotenoid levels (average 65.3 mg/g), followed by CFL and incandescent bulbs. These findings align with Liu *et al.* (2023). Chen *et al.* (2023) reported light quality effects on secondary metabolite accumulation in chrysanthemums. LED lighting consistently produced highest stomatal density (mean 55.38-55.39 mm^2). 'Denise Oatridge' exhibited highest density under LED (55.65-55.70 mm^2), while 'Diamond Jubilee' had lowest under incandescent bulbs (51.67-51.87 mm^2). These findings align with Zhang *et al.* (2023), who reported enhanced stomatal development in *C. morifolium* under optimized LED spectra. Results support Wang *et al.*'s (2024) observations on impact of lighting quality on physiological traits.

Thus, LED lighting significantly enhanced various growth parameters and pigment contents in *Chrysanthemum morifolium* compared to CFL and incandescent bulbs. Specifically, LED lighting resulted in taller plants, more leaf area index, and larger flowers, as well as higher levels of anthocyanins and carotenoids (Table 1 and Fig. 1). These findings are consistent with recent studies highlighting the efficacy of LED lighting in improving plant quality and productivity.

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Validation of downy mildew resistance in cucumber germplasm through artificial screening

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Abstract

The present study was conducted to validate downy mildew resistance in three promising cucumber accessions, IC527431, IC527400, and IC572024, through artificial inoculation at the greenhouse facility of ICAR-IIHR, Bengaluru, during 2024–25. These lines were previously identified through a multi-location trial conducted at New Delhi, Varanasi, and Bengaluru, India, from 2022–24. Three check varieties, Pusa Uday, Pusa Barkha, and Arka Veera were included to compare the performance of the selected genotypes. Thirty-five days after inoculation, the check varieties Pusa Uday (77.78% PDI) and Pusa Barkha (51.85% PDI) exhibited highly susceptible reactions. In contrast, only mild symptoms were observed on the leaves of IC572024, IC527431, and IC527400, with average Per cent Disease Index (PDI) values of 12.96, 15.74, and 29.63, respectively indicating resistant to moderately resistant responses. These germplasm lines appear promising as sources of resistance to downy mildew in cucumber and hold potential for use in the development of resistant cultivars.

Key words: Cucumber, Downy mildew, Challenged inoculation, Artificial screening, Resistant source

Cucumber (*Cucumis sativus* L.) is an important salad vegetable valued for its flavour and nutritional benefits. Downy mildew, caused by *Pseudoperonospora cubensis* [(Berkeley & M.A. Curtis) Rostovzev], is the most prevalent foliar disease affecting cucumber and other cucurbit crops worldwide. Under favourable environmental conditions, the disease spreads rapidly and can devastate the crop, leading to yield losses of up to 100% (Núñez-Palenius *et al.*, 2022). It significantly reduces both the quality and productivity of the cucumber, resulting in significant economic losses for growers. Although downy mildew can be managed through fungicides, the extensive use of pesticides raises serious concerns regarding human health and environmental safety.

Therefore, the development and deployment of resistant cultivars remain the most effective and sustainable strategy for managing diseases and pests in cucumber. Globally, several downy mildew-resistant cucumber cultivars have been developed using Indian-origin genotypes PI 197086, PI 197087, and PI 197088 as sources of resistance. In India, over the past five decades, a total of 587 vegetable varieties across 28 crops have been recommended for cultivation in various agroclimatic zones of India, including 54 varieties resistant to different biotic and abiotic stresses (Pandey *et al.*, 2024). However, to date, no indigenous cucumber cultivar with resistance to downy mildew has been reported in India. To address this gap, the present study was undertaken to identify a new source of resistance to downy mildew in cucumber.

Three cucumber accessions (IC572024, IC527400 and IC527431) identified through multi-location evaluation were validated through challenged inoculation conducted under greenhouse at ICAR-IIHR Bengaluru during 2024-25. Three checks were used to compare the performance of selected genotypes. Diseased cucumber plants maintained in greenhouse conditions were used to extract the source of inoculum and 20 to 25 -old seedlings were inoculated with a sporangium suspension containing 10,000/ml sporangia using hand sprayer.

After inoculation, plants were kept in the dark at 100% relative humidity (RH) for 24 h, followed by 7 to 10 days at 80/100% RH by day/night at a temperature of 20 to 23°C. Disease scoring was carried out on the basis of per cent leaf area infected by the downy mildew lesions and 0-9 rating scale was adopted for disease ratings. Genotypes were screened on 0 to 9 scale (Jenkins and Wehner, 1983) based on the percentage of symptomatic leaf area (0=0%, 1 =1–5%, 2 = 6–10%, 3 = 11–20%, 4 = 21–30%, 5 = 31–50%, 6 = 51–65%, 7 = 66–80%, 8 = 81–99%, and 9 = 100%). The per cent disease index (PDI) was calculated by the following formula given by Wheeler (1969).

$$PDI = \frac{N_1 \times 1 + N_2 \times 2 + N_3 \times 3 + N_4 \times 4 + N_5 \times 5 + N_6 \times 6 + N_7 \times 7 + N_8 \times 8 + N_9 \times 9}{\text{Total number of observed leaves} \times \text{Maximum grade}} \times 100$$

Where N_1 to N_9 represents total number of leaves falling under 1–9 scales, respectively.

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Based on PDI the disease reaction of genotype was classified into four groups namely resistant (0–20%), moderately resistant (21–40%), susceptible (41–60%) and highly susceptible (> 60%) based on the average PDI (Reddy, 2002). The differences among genotypes for PDI value was analyzed through open source statistical software 'R'. Artificial inoculation of the pathogen on cucumber revealed that disease initiation occurred on the fourth day post-inoculation. Symptom scoring began on the tenth day and was conducted weekly thereafter. Disease symptoms appeared 3–6 days post-inoculation in the check varieties and progressed gradually over time (Fig. 1).

In contrast, the accessions IC572024, IC527431, and IC527400 showed no signs of infection until 14 days post-inoculation, and only mild symptoms were observed even after 35 days. At 35 days post-inoculation, Percent Disease Index (PDI) values ranged from 12.96 to 77.78 (Table 1), indicating varying levels of resistance among the tested genotypes. At 35 days post-inoculation, the check varieties Pusa Uday and Pusa Barkha exhibited highly susceptible and susceptible reactions, respectively. In contrast, only mild symptoms were observed on the leaves of IC572024, IC527431, and IC527400, with average PDI values of 12.96, 15.74, and 29.63, respectively. These results indicate that IC572024 and IC527431 are resistant, while IC527400 shows a moderately resistant reaction. Notably, all three germplasms performed better than the moderately resistant check Arka Veera, which recorded a PDI of 33.33.

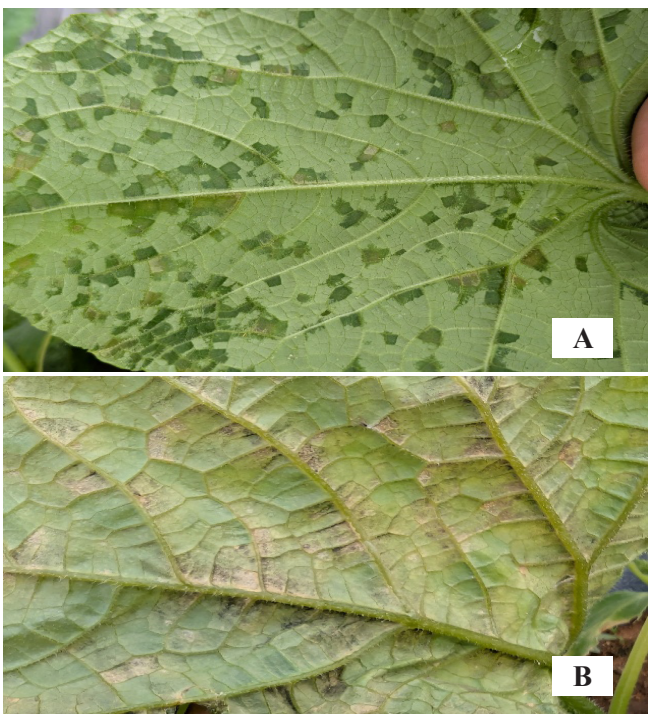

Fig 1. (a) Symptoms of Downy mildew after 20 days and 30 days after sowing on susceptible genotype Pusa Uday under artificial screening.

Table 1. Disease reaction of cucumber genotypes and checks against downy mildew incidence under artificial epiphytotic conditions

Genotype	Severity (Per cent disease Index – PDI*) Mean ± S.E.
IC527431	15.74±0.93 (23.35±0.74)
IC572024	12.96±0.93 (21.07±0.80)
IC527400	29.63±3.70 (32.87±2.38)
Pusa Uday	77.78±1.60 (61.88±1.11)
Pusa Bharka	51.85±1.85 (46.05±1.06)
Arka Veera	33.33±0.00 (35.25±0.00)
C.D.@1%	3.86
SE(m)	1.24
SE(d)	1.75
C.V.	5.84

*Values in parentheses are arc sine transformed values of PDI

Protocols for artificial screening in cucumber are well established and widely employed for evaluating downy mildew (DM) resistance across large germplasm collections (Criswell, 2008). Artificial screening of Indian cucumber lines for DM resistance was previously reported by Pitchaimuthu *et al.* (2024). Several genetic resources from the Indian gene centre including PI 197085, PI 197086, PI 197087, and PI 197088 have been documented to possess resistance to downy mildew (Call *et al.*, 2012; Barnes and Epps, 1954), and are globally utilized as sources of resistance. However, the emergence of new races and pathotypes due to changing climatic conditions necessitates the continuous identification of novel resistance sources. Indian researchers have reported various cucumber accessions exhibiting resistance to DM (Ranjan *et al.*, 2015; Bhutia *et al.*, 2015; Gautam *et al.*, 2020; Reddy *et al.*, 2022). Yet, many of these accessions have not undergone multi-location testing, limiting their applicability to specific agro-climatic zones. The lines identified in the present study IC572024, IC527431, and IC527400 demonstrated promising resistance and represent potential novel sources for breeding. These germplasms should be prioritized in cucumber improvement programs aimed at developing cultivars with durable resistance to downy mildew in India.

CONCLUSION

The validation of downy mildew resistance in cucumber accessions IC572024, IC527431, and IC527400 under greenhouse conditions confirms their potential as resistant genetic resources. The markedly lower PDI

values observed in these lines, compared to the susceptible check varieties, underscore their robustness against downy mildew infection. These results are consistent with previous multi-location trials, reinforcing the reliability of their resistance across environments.

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Evaluation of jackfruit (*Artocarpus heterophyllus*) seed powder-based pasta - a case study

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Abstract

Jackfruit seeds, comprising 10-15% of the fruit, are nutrient-rich with high protein, carbohydrate, and mineral content. Analysis of jackfruit seed flour (JSF) revealed substantial protein (13.49%) and essential minerals like potassium and magnesium. The JSF, with high water and oil absorption capacities, enhanced pasta's nutritional value and texture when added in proportions of 5-20%, with 10% substitution preferred for optimal consumer satisfaction. Jackfruit seeds offer significant potential as a valuable resource in addressing food security challenges, particularly in densely populated regions. Their conversion into flour provides a sustainable solution to mitigate waste during seasonal abundance. With rich nutritional content and favourable functional properties, jackfruit seed flour enhances the nutrient profile and quality of various food products, such as pasta, while maintaining consumer acceptability. Moreover, the unique twist of roasting jackfruit seeds in sand adds a distinctive flavour and texture to dishes, contributing to culinary innovation. Embracing such natural processes not only enhances taste but also preserves essential nutrients, underscoring the importance of sustainable food practices.

Key words: Nutrient content, Consumer acceptability, Seed flour, Pasta, Nutrient rich

Jackfruit (*Artocarpus heterophyllus* Lam.) seeds make-up around 10-15% of the total fruit weight and have high carbohydrate and protein contents, dietary fiber, vitamins, minerals and phytonutrients. To increase the shelf life, jackfruit seed flour is a better option, so that the analysis had done. Jackfruit seed flour (JSF) is a cheap source of protein (13.49%), ash (2.47%) and carbohydrate (70.73%). The calorific value was 357.665 kcal/100g. It was also rich in potassium (6466 ppm), magnesium (4582 ppm) and sodium (8906 ppm). High water absorption capacity (2.91 ml/g), oil absorption capacity (0.884 ml/g) and bulk density (0.873 g/ml) were recorded for JSF. It had a least gelation capacity of 17%. The addition of JSF at different proportions (5%, 10%, 15% and 20%) to the pasta increased the nutrient content and textural properties. 10% JSF substituted pasta has got the maximum consumer acceptability.

Jackfruit, a tropical fruit widely cultivated across various regions including India, Burma, Ceylon, and parts of Africa and South America, is not only renowned for its deliciously sweet bulbs but also for its often-overlooked seeds, rich in nutrients and health-promoting compounds. In recent years, there has been a growing recognition of the potential benefits of utilizing jackfruit seeds, particularly in the creation of value-added products such as flour for incorporation into convenience foods. (Morton, J. (1987). *Jackfruit (Artocarpus heterophyllus).* In: Fruits of Warm Climates. Julia F. Morton, Miami, FL. pp. 58–64.)

The Jackfruit seed, wheat flour, and water ingredients of pasta are purchased from market. Preparation of Jackfruit seed flour by sand roasting, peeling then milling. There are some steps guide on how to do it first of all we make Jackfruit seed powder recipe. (Haq, N. (2006). Jackfruit seed powder can be prepared by sand roasting the seeds. The preparation of jackfruit seed flour begins with cleaning the seeds to remove any dirt or foreign materials. After cleaning, the seeds are sorted to ensure uniform quality. The sorted seeds are then sand roasted to reduce moisture and improve flavor. Once roasted, the seeds are peeled to remove the outer seed coat. The peeled seeds are then ground into a fine powder to obtain jackfruit seed (JFS) flour.

Fresh Jackfruit seeds were collected and cleaned now dry the seeds in oven and also preheat the sand, roast the seeds and let them cool down after this separate them now grind them into powder form and store the powder. Refined wheat flour (Maida) was purchased from market. The reagents and chemicals used are of analytical grade (AR) unless and otherwise specified. (Haq, 2006).

By using Physio-chemical method we will analysis Jackfruit seed flour the proximate composition of Jackfruit seed flour (JSF) was determined using association of official analytical chemist (AOAC, 2000) methods. (AOAC (2000). The analysis included: moisture content using

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oven drying method, Ash content by burning in a muffle furnace, protein content by Kelda method, fat content by Soxhlet extraction using petroleum ether, crude fibre by acid and alkali digestion method, carbohydrate content calculated by deducting the sum of moisture, protein, fat, ash, and crude fibre from 100. Now we analysis the moisture of jackfruit seed flour by using oven drying method in this analysis we use the following equipment and materials: analytical balance, drying oven, sample containers, desiccators, heat-resistant gloves, spatula or scoop, stopwatch. After this we analysed Jackfruit ash by bumming it in a muffler fumie to determine its composition and elemental content.

Blends of wheat flour and jackfruit seed flour (JSF) were prepared in different ratios (100:0, 95:5, 90:10, 85:15, 80:20) and analysed for moisture, protein, and ash. Wheat Flour Gluten content in wheat flour was estimated by washing the dough to remove starch, sugars, water-soluble proteins, and other minor components. The pasting properties of wheat flour-JSF blends were measured using a rapid visco-amylographn to determine onset gelatinization temperature, peak viscosity, breakdown, and setback values. Pasting properties of wheat flour JSF blends were measured using a Rapid Visco Analyser (RVA Starchmaster2, Newport Scientific, Warri wood, Australia), following the AACC method 22-10A [1 4] to determine the onset gelatinization temperature, peak viscosity, breakdown and setback values.

The viscosity values were reported in terms of Brabender Units (BU). Pasta was prepared using wheat flour and different concentrations of JSF (10%, 15%, and 20%). The dough was mixed, hydrated, extruded, and dried. The cooking quality determination involved analysing cooked pasta for water absorption, cooking loss, and firmness using a universal texture measuring system. The parameters including moisture, crude protein, crude fat, crude fibre, and crude ash were determined for both wheat flour and jackfruit seed flour.

Firmness of cooked pasta was measured using a universal texture measuring system, with stickiness expressed in gram force and firmness in kg-s. The scanning electron microscopy was used to study the changes in pasta structure during cooking, particularly starch-protein interactions. These methods provide a comprehensive approach to analysing both jackfruit seed flour and pasta, ensuring thorough examination of their physio-chemical properties and quality characteristics.

The moisture content of jackfruit seed flour was found to be 7.758%. This relatively low moisture content indicates good shelf stability. The fat content was 2.317%, comparable to literature values but slightly higher and ash content was 2.472%, within the range reported for jackfruit seeds, suggesting consistency. Jackfruit seed flour showed a protein content of 13.49%, lower than some literature values but consistent with varietal differences and environmental factors. The crude fibre content was 3.25%, comparable to literature values with potential varietal and locational influences. Carbohydrates were the major component, constituting 70.713% of the flour, consistent with previous studies. The caloric value was 357.66 kcal/100g, in line with literature but slightly higher, providing substantial energy. The pH was 6.02, indicating a slightly acidic nature, while titratable acidity (as lactic acid) was 0.574%, contributing to the overall flavour profile and preservation. Jackfruit seed flour was rich in sodium, potassium, and magnesium, but low in copper and manganese, consistent with literature, albeit with some variations.

The results demonstrate the nutritional richness and potential health benefits of jackfruit seed flour. While some variations from literature values were observed, they could be attributed to varietal differences and environmental factors. Further research could explore the impact of these variations on nutritional value and functional properties. Overall, jackfruit seed flour presents an opportunity for value addition and utilization in various food applications, contributing to both nutrition and economic empowerment.

The process of making jackfruit seed pasta begins by mixing wheat flour and jackfruit seed (JFS) flour in a spar mixer at 60 rpm. After mixing, the dough is allowed to hydrate for 15 minutes. The hydrated dough is then transferred to a pasta extruder machine, where it is kneaded for 1 minute. Using a single-screw extruder, the dough is shaped into pasta and cut into the desired size. The pasta is then dried at 75°C for 3 hours. Once dried, the pasta is packed and stored properly for future use.

CONCLUSION

In countries with high population where the food requirements are not being fulfilled by seasonal vegetables, jackfruit seeds can be used as a good substitute.

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Effect of nitrogen on growth and yield of beet root (*Beta vulgaris*)

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Abstract

A field experiment was conducted to study the effect of nitrogen on growth and yield of beet root (*Beta vulgaris*) during *rabi* season 2020-21 at S.K.N. College of Agriculture, Jobner (Rajasthan). The experiment consisted of Twelve treatment combinations including four nitrogen levels (control, 30 kg N/ha, 60 kg N/ha and 90 kg N/ha) and three treatments of plant geometry (15 cm x 10 cm, 30 cm x 10 cm and 45 cm x 10 cm) were under taken in a factorial randomized block design with three replications. The application of 60 kg nitrogen was significantly. However, 60 kg nitrogen significantly increased plant height (42.47 cm), No. of leave plant (16.53 cm leaf area, (cm^2) (1.05), chlorophyll content (mg/100 g) (5.14g), yield per plot (26.16 kg), yield (261.60 q), net return (Rs/ha) 174 601.21/ ha and B: C ratio (2.01)

Key words: Geometry, Nitrogen, Growth , Yield, Plant height

Beet root (*Beta vulgaris* L.) is additionally referred to as garden beet or table beet. It is one of the major root vegetable crop within the chenopodiaceae family with chromosome number of 2n=18. Beet root originated in Mediterranean region and North Africa region wherever they were cultivated to feed humans and eutherian mammal. It is vital cool season annual root crop whereas biennial for seed production. Beet root is grown mostly in northern and southern parts of India. The beetroot growing was found to be profitable compared to the existing cropping systems within the post rainy season in Rajasthan, Punjab, Haryana, Maharashtra and North Karnataka (Kulkarni *et al.,* 2013). Beetroot contain between 16-18 percent sucrose and have a vital role within the sucrose industry (Harveson, 2011). It have the natural food that boosts the energy in athletes because it contains one of the highest nitrates and sugar contents.

In India, beet root is mostly grown in September to November in northern plains whereas in southern plains the sowing is done from July to November while March and July in hills. The seeds are planted at a depth of about 2.5 cm to confirm good germination with 45-60 cm x 8-10 cm distance. Nitrogen plays important role physiological and chemical characteristics of the crop. So nitrogen may cause fascinating impact on sugar beet growth and yield characters (Kadam *et al.,* 2018). Nitrogen has the best effects on root yield and quality of sugar beet (Sincik M. and Canigenis T., 2016).Nitrogen is the macronutrient needed for sugarbeet growth and the second most limiting nutrient in crop production (Hergert, 2012). Plant nitrogen demand largely with inorganic N equipped by the soil, biological fixation, or by the applying of commercial fertilizers (Galloway *et al.,* 2003). Therefore, an experiment was conducted.

The experiment comprised 12 treatment combinations, *viz,* four nitrogen levels, viz. control (N_1), 30 kg/ha (N_2), 60 kg/ha (N_3) and 90 kg/ha (N_4) and three levels of plant spacing *viz.,* 15 cm x 10 cm (S_1), 30 cm x 10 cm (S_2) and 45 cm x 10 cm (S_3). As per treatments nitrogen was applied through urea in three doses. The half dose of nitrogen was given of at the time of planting, while remaining was administered 20 days after sowing (DAS). The applications of nitrogen was done as control (N_1), 30 kg/ha (N_2), 60 kg/ha (N_3) and 90 kg/ha (N_4) through urea. The plant height was measured from soil surface up to tip of leaves with the help of measuring scale and average was worked out. Height of the five randomly selected and tagged plants were measured at 45 days after planting and at harvesting stage.

The number of leaves from five randomly selected plants of each plot was counted 45 days after sowing and at harvesting stage. The average was computed and expressed as number of leaves per plant. The five tagged plants were also used for leaf area measurement 45 days after sowing. The leaf area was measured with the help of leaf area meter. The average leaf area (cm^2) was recorded as mean value to calculate total leaf area (cm^2) per plant. The chlorophyll content of leaves was determined 45. The representative fresh leaf samples were taken. These were washed with distilled water and dried with blotting paper. Out of this, 100 mg fresh leaves were taken in mortar and ground well by pestle with 5 ml 80 per cent acetone and centrifuged at 2000 rpm for 10 minutes and filtered through Whatman filter paper No. 1. Volume of supernatant was made to 10 ml with 80 per cent acetone.

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The resultant intensity of colour was measured on Spectronbic-20 at Absorance (A) of 652 nm.

Total chlorophyll content was calculated with the help of following formula and expressed in mg g^{-1} fresh weight of leaves (Arnon, 1949).

$$\text{Total chlorophyll (mg/g leaf weight)} = \frac{\text{A(652) x 29 X Total volume (ml)}}{\alpha \text{ x 1000 x Weight of sample (g)}}$$

where,

α is the path length = 1 cm.

After cutting leaves, roots were weighed on digital balance and root yield per net plot was recorded in kilogram. Per (q/ha) after cutting the leaves, roots were weighed on digital balance and root yield per net plot was recorded in kilogram which was converted into quintal per hectare of the economics of the treatments is the most important consideration for making any recommendation to the farmer for its wide adoption. To calculate economics, the average treatment yield along with prevailing market rates of the produce and cost of inputs were used. The net return was calculated by subtracting cost of cultivation for each treatment from gross return gained from the economic yield. B:C ratio was computed by dividing net return by cost of cultivation for each treatment.

These finding were reported by previous worker also indicated that suitable of nitrogen at split doses increased vegetative growth of plant by activation in physiological and biochemical process. Nitrogen plays an important role to stimulate growth and development *i.e.* vegetative growth, impart deep green colour of the leaves etc. that's why expanded quicker growth and more number of leaves with high chlorophyll content (Hussein and Hanan, 2014).This might be due to required quantity of nitrogen was supplied for proper development and foliage colour of beetroot because nitrogen elements is important and super molecule for chlorophyll development.

The positive effect of nitrogen on growth by providing balanced environment features both is soil and in plant system (Kandil *et al,.* 2004 and Dadashpour A and Jonk M. 2012). Plant density of 30 × 10 cm exhibited maximum plant height (23.90 cm and 41.96 cm at 45 DAS and at harvest), number of leaves per plant (9.80 and 15.90 at 45 DAS and at harvest), leaf area (193.60 cm^2) and chlorophyll content (4.98 mg/100g) followed by 45 × 10 cm plant spacing (S_3) as reported similar with S_2 in beetroot. Plants which are widely spaced produced more number of leaves and wider canopies. This might be because the wider spacing reduced the competition for soil nutrients, moisture, carbon dioxide and light among the plants. This probably enhanced photosynthesis which resulted in the production of more leaves and wider canopies. When there is optimum spacing growth parameters also increase due to free availability of space, nutrient, air, water, sunlight and others. Canopy width is important to determine plant spacing for its contribution to total amount of light that plant intercepts for photosynthesis efficiency of crop. Plant density has been recognized as a significant consider decisive the degree of competition between plants (Sadre *et al.*, 2012).

Similarly the soil application of 60 kg nitrogen per ha significantly increased the yield and yield attributes like yield per plot and yield per hectare of beetroot followed by 90 kg nitrogen per ha as reported as at par with N_3 in beetroot.The significantly important in yield and yield attributes on account of application of important nitrogen fertilization might have attributed to the translocation of nutrient from soil, further, increased vegetative growth might have provide more sites of translocation of photosynthetes, which ultimately resulted increased in yield (Moniruzzaman *et al.* 2013). During this respect, increasing nitrogen application as soil chemical recorded considerably increase length, diameter and weight of roots. sowing of beetroot at 30 × 10 cm plant spacing significantly influenced the maximum yield attributes like), yield per plot (24.77 kg), yield per hectare (247.74 q) of beetroot followed by 45 × 10 cm of plant density (S_3) as reported as at par with S_2 in beetroot.

These results suggest that an ideal plant population is needed for proper distribution of photosynthetic rate, with consequent increase in root yield. The interaction effect between soil application of nitrogen and different levels of plant spacing on the maximum in yield and yield parameters on beetroot were reported effective under N_3S_2 treatment where 60 kg N per ha as soil application along with 30 x 10 cm plant spacing (Table 4.7 and 4.8). The maximum yield per plot (26.66 kg) and total yield per hectare (266.62 q) were recorded in N_3S_2. The interaction effect between soil application of nitrogen and different levels of plant spacing on the maximum in yield and yield parameters on beetroot were reported effective under N_3S_2 treatment where 60 kg N per ha as soil application along with 30 x 10 cm plant spacing (Table 4.7 and 4.8).

The maximum yield per plot (26.66 kg) and total yield per hectare (266.62 q) were recorded in N_3S_2.This treatment combination was reported best on production point of view. These results might be due to availability of adequate amount of essential nutrients as well as suitable sunlight, water, air and less of crop competition to the plants along with balanced form of nitrogen amount to the plant. Beetroots are produced good yield if they gain good nitrogen amount and spacing with in row (Fikru, 2017 and Gupta A K and Tripathi V K. 2012). These finding are close conformity with Desuki *et al.* (2005) in carrot, Khogli *et al.* (2012) in fodder beet and Tripathi *et al.* (2017) in radish.

Table 1: Effect of Nitrogen and plant geometry on yield attributes of beetroot.

Treatment	Yield per plot (kg)	Yield per ha (q)	Net return (Rs/ha)	B: C ratio
N1 (control)	20.56	205.60	120698.59	1.42
N2 (30 kg)	24.48	244.80	158232.32	1.83
N3 (60 kg)	26.16	261.60	174601.21	2.01
N4 (90 kg)	26.03	260.30	172567.22	1.97
SEm+	0.46	1.21	3807.87	0.04
CD (p=0.05)	1.31	3.47	10901.64	0.11
Plant spacing				
S1 (15 cm x 10 cm)	23.47	234.74	148171.50	1.71
S2 (30 cm x 10 cm)	24.77	247.74	161191.50	1.86
S3 (45 cm x 10 cm)	24.67	246.74	160211.50	1.85
SEm+	0.40	1.05	3297.71	0.03
CD (p=0.05)	1.13	3.00	9441.10	0.09

Table 2: Interactive effect of nitrogen and plant geometry on root yield (q/ha)

Treatment	N_1	N_2	N_3	N_4	Mean
S_1	198.53	236.39	252.61	251.35	234.72
S_2	209.55	249.50	266.62	265.30	247.74
S_3	208.72	248.57	265.57	264.25	246.77
Mean	205.60	244.82	261.60	260.30	
SEm+	4.57				
CD (p=0.05)	13.09				

CONCLUSION

Thus, it is concluded that application of nitrogen of 60 kg/ha with 30 cm x 10 cm plant spacing was best to obtain yield. A combination of treatment also showed maximum net return (Rs, 179, 624/ha) with highest B:C ratio (2.06) statistically.

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