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Modelling growth, yield, and future climate suitability for underutilized tropical tuber crops-'aroids': a review

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ABSTRACT

Elephant-foot yam and taro are important tropical tuber crops that are often overlooked and underutilized in the context of climate change and food security. This study aims to explore existing modelling studies focused on growth, yield, and future climate suitability of these crops. Several crop models have been tested internationally to simulate the growth and yield of aroids, including SUBSTOR-Aroids, AquaCrop, and WOFOST. In India, the QUEFTS model has been used to estimate crop yield for aroids based on site-specific nutrient management. Additionally, the EcoCrop model has been employed to predict the future climate suitability of aroids. However, it is important to note that there are limited studies available for aroids compared to other tropical tuber crops. This highlights the need to prioritize research on these underutilized aroids, considering their superior per-hectare production compared to major food grain crops. The review emphasizes the necessity for further modelling studies on aroids to identify or develop better model structures that can be applied across various agro-climatic conditions.

Key words: Elephant-foot yam, Taro, Aroids, Climate change, Food security, Crop models, Climate suitability

Aroids consists of tropical root and tuber crops, which are elephantfoot yam (*Amorphophallus paeoniifolius*(Dennst.) Nicolson) and taro (*Colocasia esculenta* var. antiquorum(L.) Schott) (Sunitha et al., 2023; Sunitha et al., 2021; Sunitha *et al*., 2013). Aroids encompass tropical root and tuber crops, including elephant-foot yam (*Amorphophallus paeoniifolius*) and taro (*Colocasia esculenta* var. *antiquorum*). Despite being staple foods in African countries, aroids have received relatively little attention in research (Bora and Handique, 2023; Raju and Byju, 2019; Ravi *et al*., 2011). However, they exhibit superior dry matter production per hectare compared to major food grain crops and are rich in carbohydrates and essential minerals, making them valuable as supplementary food to combat malnutrition in developing nations (Pushpalatha and Byju, 2020; Bradbury and Holloway, 1988; Nedunchezhiyan *et al*., 2022).

Elephant-foot yam is primarily grown in the Philippines, India, Malaysia, Indonesia, China, and Sri Lanka (Kamalkumaran*et al*., 2020; Sunitha *et al*., 2020), while taro is extensively cultivated in Nigeria, Cameroon, China (mainland), Ghana, and Papua New Guinea (FAO STAT, 2021). These crops are adaptable to a wide range of soil and climatic conditions, with an ideal pH of 5.5 - 6.5 and well-distributed rainfall ranging from 1000 - 3000 mm for elephant-foot yam and 1500 - 2000 mm for taro (Sunitha *et al*., 2020; https://www.cabi.org).

To comprehend crop growth stages and final yield under various environmental conditions and predict crop growth and yield changes due to climate change, modelling studies are essential. While crop models are available for major tropical root and tuber crops such as cassava, sweet potato, and yam (Raymundo *et al*., 2014; Moreno-Cadena *et al*., 2021), there are limited modelling studies for taro, and no specific crop growth modelling studies have been reported for elephant-foot yam, despite its significance as one of the major aroids.

The literature analysis reveals a knowledge gap in modelling studies for aroids, particularly elephant-foot yam and taro, compared to other tropical root and tuber crops (Pushpalatha *et al*., 2021a; Pushpalatha *et al*., 2021b; Pushpalatha *et al*., 2021c). As underutilized crops, elephant-foot yam and taro require more research attention worldwide. Interestingly, there is only one published article focusing on yield management through site-specific nutrient management for elephant-foot yam, and

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four published articles on taro, including studies on nutrient management.

Given the importance of aroids in terms of food security, it is crucial for researchers to focus on these crops. This study aims to analyze existing modelling studies and models for elephant-foot yam and taro, specifically in relation to their growth and yield. Additionally, it will discuss the prediction of future climate suitability for these crops. By addressing the knowledge gap and emphasizing the significance of aroids, this study aims to provide insights to researchers to address malnutrition and the food-demand gap in developing countries.

MODELS TESTED FOR CROP GROWTH, YIELD AND CLIMATE SUITABILITY

SUBSTOR-Aroids model

The SUBSTOR-Aroids model, developed by Singh *et al.* (1998), is specifically designed to simulate the growth and development of taro under various conditions, including unlimited, water-limited, and water and nitrogen-limited conditions. It also incorporates sub-models for upland and low-land conditions. The model considers temperature as a major factor influencing crop phenological development, expressed in terms of daily thermal time or growing degree-days (GDD), as estimated by Santhosh Mithra *et al.* (2012).

In SUBSTOR-Aroids, crop phenological development is directly proportional to temperature when the minimum temperature (Tmin) is greater than the base temperature (Tbase), and the daily maximum temperature (Tmax) is less than 33 °C. However, when Tmin is less than Tbase or Tmax exceeds 33 °C, the model estimates the daily thermal time using weighted 3-hourly temperature data. Crop maturity is influenced by both crop variety and temperature. Root formation and growth are also dependent on soil moisture conditions.

Photoperiod plays a significant role in determining the number of cormels in SUBSTOR-Aroids, as reported by Singh *et al.* (1992). Leaf area is considered crucial for biomass production through photosynthesis. The model estimates leaf appearance as a function of GDD and genotype, using the Gompertz function to simulate leaf area expansion. The number of leaves is determined based on daily thermal time. The specific leaf weight ratio for taro ranges from 38 to 42 g m-2. Potential biomass accumulation is a non-linear function of intercepted photosynthetically active radiation, which is an exponential function of the leaf area index. The optimum temperature for biomass accumulation in taro is found to be 28 °C. The model incorporates a water-stress reduction factor based on Ritchie (1985) and determines nitrogen deficiency using the concept described by Godwin and Jones (1991).

According to Singh *et al.* (1998), the phyllochron interval or the GDD required for a single leaf tip to appear in the crop varies depending on the variety, typically ranging from 122 to 180 °C. Assimilate allocation to roots, leaves, petiole, and corm is determined by the model. During the early growth stage, around 90-100% of assimilates are allocated to roots, leaves, and petiole, while this value drops to 20% during the late season due to accumulation as corm. Leaf growth is reduced under stress conditions, and water limitation leads to increased assimilate allocation to the roots. The model considers assimilate partitioning to be dependent on crop variety, growth stage, and water and nitrogen conditions of the soil. Senescence is influenced by crop growth stage, shading, soil conditions, and environmental factors.

The SUBSTOR-Aroids model demonstrated good performance with an agreement value of 0.95 based on a dataset from 1988 to 1992 in the USA (Singh *et al.*, 1998). However, there is limited available data on this model, and further testing is required. Subsequently, the SUBSTOR model was incorporated as an Aroid module in the Cropping System Model (CSM) of the revised Decision Support System for Agrotechnology Transfer (DSSAT-CSM) community (Jones *et al.*, 2003). The model's complexity and input requirements have limited its applications in developing countries.

FAO-AquaCrop model

The AquaCrop model, developed by FAO (Steduto *et al.*, 2009), is a water-driven model that is widely used to estimate crop yield, gross irrigation requirements, and water productivity. In AquaCrop, yield estimation is based on biomass accumulation and harvest index (HI), which is the ratio of harvested yield to total biomass (Steduto *et al.*, 2009; Hsiao *et al.*, 2009). The model assumes a linear relationship between biomass growth rate and transpiration. The daily soil-water balance in AquaCrop is determined by considering various factors such as infiltration, runoff, deep percolation, crop uptake, evaporation, transpiration, and capillary rise.

Evaporation is estimated based on the percentage of canopy cover (Raes *et al.*, 2009). The model requires input parameters related to the crop, soil, and monthly meteorological data. AquaCrop is known for its ability to work with minimum input data, which makes it suitable for underutilized crops like taro compared to other models in the DSSAT community. AquaCrop was first applied to taro by Mabhaudhi *et al.* (2014) in South Africa. They used field data from 2010-2011 and 2011-2012 to calibrate and validate the model. The results showed a good fit with R2 values of 0.92 and 0.844 for calibration and validation, respectively, and low root mean square error (RMSE) values of 2.38% and 1.85%.

However, further studies using AquaCrop on a wider scale and in different major growing regions of taro are needed to derive more general conclusions about its applicability for this crop. In summary, AquaCrop is a water-driven model that estimates crop yield, gross irrigation requirements, and water productivity. It has been used successfully for taro in South Africa, but more research is needed to validate its wider applicability in different taro-growing regions.

WOFOST model

The World Food Studies (WOFOST) model, developed by Boogaard *et al.* (1998), is a crop simulation model that calculates the potential crop yield, water-limited yield, and nutrient-limited yield on a daily basis from emergence to maturity, taking into account crop variety and environmental conditions.

In WOFOST, daily biomass accumulation is determined based on gross photosynthesis, growth, and maintenance respiration. The daily gross assimilation is the integration of the assimilation rate over the leaf layers throughout the day. A portion of the assimilate is allocated to maintenance respiration and growth respiration, while the remaining assimilate is partitioned among different plant organs.

Leaf area is calculated as a function of temperature and is derived from specific leaf area and the crop's development stage. Canopy growth stages are represented using a Gaussian interpretation. Temperature, solar radiation, and atmospheric CO2 are the major factors influencing crop growth and phenological development in WOFOST.

The soil-water balance in WOFOST is simulated using the tipping bucket approach (Boogaard *et al.*, 1998), and potential transpiration is estimated based on the approaches by Penman (1948, 1956) and Choisnel *et al.* (1992). Evaporation is estimated using the methods developed by Jarvis (1981) and Feddes *et al.* (1978).

Important crop parameters required for model calibration in WOFOST include variety-specific values of thermal times for different growth stages (such as emergence, tuber initiation, and maturity), assimilate conversion coefficients, maximum rooting depth, daily root development rate, and partitioning fractions. Thermal time, expressed as growing degree-days (GDD), for different growth stages is calculated using the daily mean temperature and base

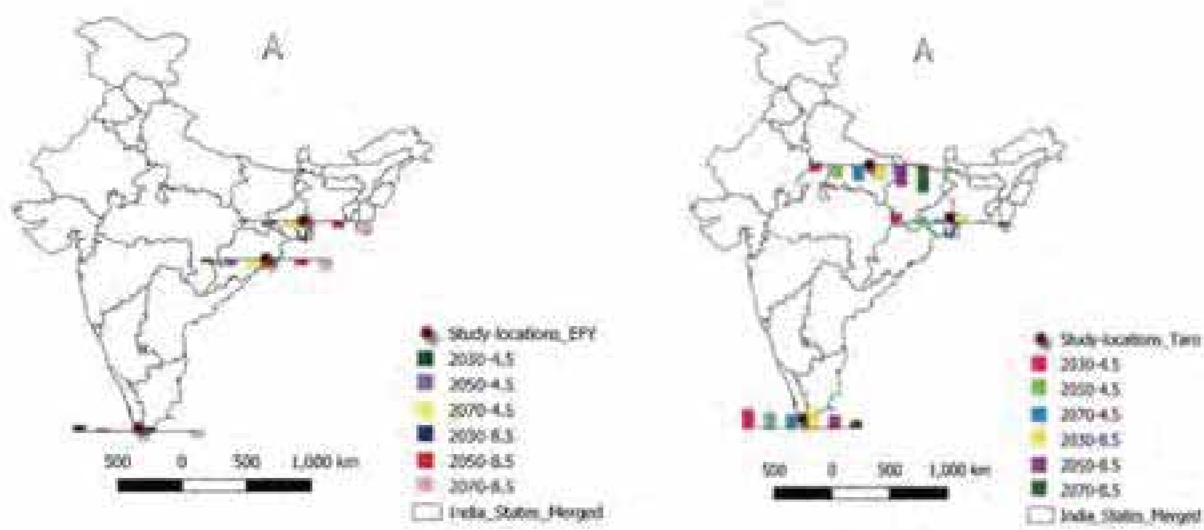

Fig. 1. Yield changes (%) in elephant-foot yam (EFY) and taro for 2030, 2050, and 2070 (*Source*: Pushpalatha *et al.*, 2022)

temperatures specific to each crop variety (Santhosh Mithra *et al.*, 2012).

In summary, the WOFOST model is a comprehensive crop simulation model that estimates crop yield, water-limited yield, and nutrient-limited yield based on crop variety and environmental conditions. It incorporates factors such as temperature, solar radiation, atmospheric CO2, and soil-water balance to simulate crop growth and development from emergence to maturity. Calibration of the model requires variety-specific parameters and thermal times for different growth stages.

This model is used in India to simulate the yield of elephantfoot yam and taro with a model error of -0.51 and -0.86%, respectively. The future yield predictions for these crops using WOFOST indicated a percentage change of -10 to 6, -12 to 4, and -16 to 19, -28 to 18 for the future scenarios (Figure 1) for the two representative concentration pathways 4.5 & 8.5 (Pushpalatha *et al.*, 2022). These results highlights the importance of these two crops in the future in ensuring food security, especially in rural tribal areas.

QUEFTS model- crop yield based on nutrient management

The QUEFTS (Quantitative Evaluation of the Fertility of Tropical Soils) model, developed by Janssen *et al.* (1990), is a tool for site-specific nutrient management of nitrogen (N), phosphorus (P), and potassium (K) in tropical soils. The model estimates crop yield based on the availability of these nutrients, assuming no other constraints such as water stress or other agronomic practices.

QUEFTS establishes the relationship between chemical soil tests, potential NPK supply from soils and fertilizers, actual NPK uptake by crops, and crop yield. It provides a practical approach for optimizing nutrient management to achieve higher yields in a site-specific manner. This model is particularly useful for understanding nutrient requirements and optimizing fertilizer application in tropical crops.

For elephantfoot yam, Byju *et al.* (2016) calibrated the QUEFTS model and reported a linear increase in corm yield with N, P, and K uptakes of 3.97, 0.71, and 7.05 kg N, P, and K per 1000 kg of corm. Similarly, Raju and Byju (2019) calibrated the QUEFTS model for taro and found a linear relationship between cormel yield and nutrient uptake at rates of 12.97, 2.97, and 17.47 kg N, P, and K per ton of cormel. These studies provide valuable insights into the nutrient requirements and their impact on yield for elephantfoot yam and taro.

However, it is important to note that these calibrations and relationships need to be validated across different major elephantfoot yam and taro growing regions worldwide. Validation studies will help to ensure the accuracy and applicability of the QUEFTS model in different agro-climatic conditions and soil types, enabling effective site-specific nutrient management for these crops.

EcoCrop tested to quantify climate suitability

The EcoCrop model, developed by Hijmans *et al.* (2001), is based on the FAO-EcoCrop database ((FAO, 2000) and focuses on the ecological requirements of crops. It considers optimal ranges of minimum and maximum temperatures, precipitation, and climatic limits where crop production is not possible. The model defines two ecological ranges for each crop, consisting of minimum and maximum absolute temperatures and rainfall. It also includes an optimum range of minimum and maximum temperatures and rainfall. The EcoCrop model calculates separate indices for precipitation and temperatures and then combines them to determine the suitability index for a specific crop. The suitability index ranges from 0 to 1, where a value of 1 indicates excellent suitability for crop growth. The model provides an indication of climate suitability for a crop based on these indices. In the case of elephantfoot yam, Byju *et al.* (2016) used the EcoCrop model to predict climate suitability in India. They assessed the future climate suitability and provided state-wise suitability values for major growing regions in India. The study reported a suitability change ranging from 0.8% to 9.6% across different regions. However, it is worth noting that researchers consider the EcoCrop model to be less sophisticated and less reliable compared to empirical niche models (Taba-Morales *et al.*, 2020). Empirical niche models, which are based on observed crop occurrences and environmental variables, tend to provide more accurate and reliable predictions of climate suitability compared to purely ecological models like EcoCrop. As of now, there are no available studies using the EcoCrop model for taro.

CONCLUSION

This study focuses on the existing modelling studies for the growth, yield, and future climate suitability of two tropical tuber crops, elephantfoot yam and taro. It highlights the limited information available on crop models for these aroids and the need for further research in this area. The reviewed crop models include SUBSTOR-Aroids, AquaCrop, WOFOST, and QUEFTS, which have been tested for growth and yield estimation. The EcoCrop model has been used to assess the climate suitability of elephantfoot yam. However, it is observed that there is a lack of studies specifically focused on aroids compared to other tropical tuber crops.

The review emphasizes the importance of studying aroids in the context of food security and climate change. Despite the limited available data, the existing studies suggest that aroids, including elephantfoot yam and taro, have the potential to be recommended as future crops due to their superior dry matter production per hectare compared to major foodgrain crops.

Furthermore, the review recommends conducting more modelling studies on aroids to develop better model structures that can be applied across different agro-climatic conditions. This would help in enhancing our understanding of aroids and their potential as underutilized crops, contributing to food security and sustainability.

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Insect pests of underutilized vegetables and their management: an appraisal

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ABSTRACT

The study focuses on underutilized vegetable crops that are not widely traded or economically developed on a large scale. Some of these vegetables include curry leaf, drumstick, amaranthus, cherry tomato, Chinese cabbage, winged bean, and aquatic vegitables. Despite their less common status, these vegetables are susceptible to various insect and mite attacks during their growth, which can result in significant yield reduction. The study provides information on the insect and acarine pests affecting these vegetables, including their bioecology, host range, damage symptoms, and integrated management techniques. The management strategies are discussed in the context of changing climatic conditions.

Key Words: Underutilized vegetables, Insect and acarine pests, Damage, Integrated management

Despite the diverse agroclimatic conditions in India that allow for the cultivation of over 60 commonly grown vegetable crops and around 30 lesser-known ones, underutilized vegetables have not received much attention. This lack of focus may be due to factors such as limited availability of planting material, insufficient awareness of their nutritional and medicinal importance, and a lack of information on their production techniques. Underutilized vegetable crops refer to those that are not grown commercially on a large scale or traded widely (Madhvi *et al*., 2020). Some examples of these crops include curry leaf, drumstick, amaranthus, cherry tomato, Chinese cabbage, winged bean, and aquatic vegetables.

These vegetables have significant potential to contribute to nutritional security as they are rich in vitamins, micronutrients, proteins, and other health-promoting factors, including high antioxidant activity. They are also known to be well-adapted to various environmental conditions and generally resistant to pests and diseases. However, the pests that affect underutilized vegetables worldwide have received limited research attention and understanding. As these vegetables gain prominence and are cultivated on a larger scale, it is likely that biotic stresses, such as pests and pathogens, will pose a serious threat to their sustainable production across the country. Additionally, the impacts of global warming may further influence biotic stresses by altering pest dynamics and increasing their reproduction rates. This article discusses the major insect and acarine pests of these lesser-used vegetables and provides suitable management strategies for their control.

Underutilized leafy vegetables

They are grown throughout sub-Saharan Africa and in South and Southeast Asia. Some of the examples of important leafy vegetables under Indian conditions are amaranth, Chinese cabbage, Chinese kale (*Brassica* spp.), curry leaf etc.

Amaranthus (*Amaranthus* spp.)

Amaranthus is an underutilized leafy vegetable widely cultivated in various regions of India, including the Himalayan region, southern India, and parts of Gujarat, Maharashtra, Odisha, Uttar Pradesh, Andhra Pradesh, Telangana, Tamil Nadu, West Bengal, and Tripura. The green or purple leaves of amaranth are consumed as a vegetable and also used as fodder for animals. In addition, its protein-rich grains are used as a high-quality human diet.

Among the insect pests that attack amaranth, the leaf-eating caterpillar and leaf webber are important foliage feeders (Bhag 1994) that can cause significant damage if left unattended (Halder *et al*., 2015(a)). Stem weevils can also occasionally damage the growing shoots and stems, particularly when winter amaranth is grown in summer.

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Leaf-eating caterpillar, *Spoladea recurvalis* (Fab.) (=*Hymenia recurvalis*) (Crambidae: Lepidoptera)

The leaf-eating caterpillar, also known as the beet webworm moth or Hawaiian beet webworm (*Spoladea recurvalis*), has a worldwide distribution but is primarily observed in tropical regions. The larvae feed on amaranth as well as spinach, beet, cotton, maize, and soybean. They are greenish in color with white dorsal lines and black crescents on the thorax, and they scrape portions of the leaf, leading to leaf drying. The larvae resemble the ribs of the leaf. The pupa is formed within a cocoon in a folded piece of leaf and is pale brown in color. The pupal period lasts about 12 days. The adult moths are brown with slender bodies and dark brown wings with patchy white wavy markings. They are nectarivores and capable of long-distance flights.

Management

Management of the leaf-eating caterpillar includes the collection and destruction of affected plant parts with caterpillars and the setting up of light traps to attract and kill the adults. Spraying *Bacillus thuringiensis* var. Kurstaki at a concentration of 2 ml/L water or Neem Seed Kernel Extract (NSKE) at 4% can also be effective.

Leaf webber, *Herpetogramma basalis* (Walker) (=*Psarabasalis*)) (Crambidae: Lepidoptera)

Another serious pest of amaranth is the leaf webber (*Herpetogramma basalis*). The larvae of this pest are green, and the adult moth is medium-sized with a yellowish-white thorax and abdomen, brownish-red forewings, and dark brown hindwings. The larvae are found within webbing on the leaves, and both the leaf feeders, the caterpillars and webbers, can be present on the same leaf, causing damage symptoms from both pests on a single leaf. The larvae make numerous small holes on the leaves.

Management

Management of the leaf webber involves collecting and destroying affected plant parts with caterpillars, setting up light traps to attract and kill the adults, and spraying *Bacillus thuringiensis* var. Kurstaki at a concentration of 2 g or 2 ml/L water.

Stemweevil, *Hypolixus truncatulus* (Fab.) (Curculionidae: Coleoptera)

The stem weevil (*Hypolixus truncatulus*) can become a serious pest of amaranth in some parts of the country. The grubs of this weevil cause irregular zig-zag tunnels in the pith region of the stem, which are filled with excreta. This leads to small gall-like thickenings and subsequent longitudinal splitting of the stem. The affected plants exhibit retarded growth. The adults of the stem weevil are ash grey with brown elytra and have a typical long snout. Female weevils lay eggs singly in the stem. The eggs are smooth, oval, and pale yellow, while the grubs are white in color with a fleshy curved body.

Management

Management of the stem weevil involves collecting and destroying wild amaranth hosts in the vicinity of the cultivated crop, along with the affected plant parts containing grubs and adults. Spraying Azadirachtin 300 ppm at a concentration of 5 ml/L water can also be effective.

Curry leaf (*Murraya koenigii* Spreng)

Curry leaf (*Murraya koenigii*) is a perennial herbal spice crop belonging to the Rutaceae family. It is widely used as a leafy spice in Indian cuisine and is grown for its aromatic leaves, which can be dried and powdered (Reddy *et al*., 2020). Curry leaf also has a wide range of medicinal properties. Although the crop is attacked by several insect pests, some of the important ones are described below.

Citrus butterfly, *Papilio demoleus* (Linn.) and *P. Polytes* (Linn.) (Papilionidae: Lepidoptera)

The citrus butterfly (*Papilio demoleus* and *P. polytes*) is a major pest of curry leaf. The caterpillars of these butterflies feed voraciously on tender leaves and can defoliate the entire plant, leaving behind only midribs. The female butterflies lay yellowish-white, round eggs singly on tender leaves, buds, and shoots. The eggs hatch in about 3-8 days. The neonate larvae are dark brown and soon develop irregular white markings on their body resembling bird droppings. The adult *P. demoleus* is a large butterfly with yellow and black markings on all four wings, while the hind wings are brick red with oval patches. Male *P. polytes* are black, and females vary in form.

Management

Management of the citrus butterfly involves collecting and destroying the larvae from the plant canopy. It is also important to conserve natural enemies such as egg parasitoids (*Telenomus* spp.), larval parasitoids (*Brachymeria* spp., Cotesia, and *Distatrix papilionis*), and pupal parasitoids (*Pteromalus* spp.). Installing bird perches at a rate of 10 per acre can facilitate field visits of predatory birds. Field releases of egg parasitoids *Trichogramma chilonis* and *Telenomus* spp. can be beneficial. The application of NSKE 5% and/or *Bacillus thuringiensis* at a rate of 1 kg/ha can be effective. It is important to harvest matured/ marketable leaves before spraying any pesticides or biopesticides.

Citrus psylla/psyllid, *Diaphorina citri* (Kuwayama) (Liviidae: Hemiptera)

Citrus Psylla/Psyllid, *Diaphorina citri* (Kuwayama) (Liviidae: Hemiptera): The citrus psylla is a serious sucking pest of curry leaf plants, primarily congregating on the terminal shoots, buds, and tender leaves. The nymphs of this insect are yellow, orange, or brown with oval flattened bodies. In addition to sap-sucking, both the nymphs and adults secrete honeydew, which promotes the growth of black sooty mold and hinders the plant's photosynthetic activity. Infested plant parts dry up and die. The mature psylla is a tiny insect with a shiny black body and a grayish dusting, and its wings extend past the tip of its abdomen.

Management

Close monitoring and pruning of the infested plant parts, conservation of natural predators such as predatory wasps, lacewings, ladybirds (*Chilocoris nigritus*), predatory ants, predatory mites, and the need-based application of NSKE (neem seed kernel extract) at 5%.

Tortoise Beetle, *Silana farinosa* (Boheman) (Chrysomelidae: Coleoptera)

The tortoise beetle has a globular and tortoise-like shape. After hatching from eggs, the body color of the larvae gradually changes from light yellow to dark brown. The larvae accumulate exuviae and feces at the urogomphi because they do not shed their entire cuticle during molting. The larvae are less mobile but exhibit a defensive action of flicking the ball-like material up and down when disturbed (Olmstead 1994). Eventually, the beetle turns metallic reddish-brown due to being completely covered in a waxy deposit, with a forked posterior and a flattened body. Both the adult and the grub of the tortoise beetle scrape on leaves, creating boreholes and causing defoliation. The larvae scrape the leaf epidermis, leaving a thin upper membrane, while the adults cause more severe damage by consuming all of the leaves. In heavily infested areas, the leaves turn yellow, and defoliation occurs.

Management

Natural predators of the larvae and pupa, such as garden lizards, yellow-vented bulbuls, Oriental magpie robins, and predatory pentatomid bugs, can help control the tortoise beetle population. Hand picking and destruction of larvae and adults, conservation of parasitoids such as *Distatrix papilionis* (larval), *Brachymeria* sp. (larval), *Pteromalus* sp. (pupal), and the application of NSKE at 5% or neem oil at 1-2% with a sticker, are effective management practices.

Mealy bugs, *Planococcus citri* Risso(Pseudococcidae: Hemiptera)

Mealybugs (*Planococcus citri*) are soft-bodied, wingless insects with a pinkish-white appearance and a waxy coating (Rao *et al*., 2006). They tend to gather in large numbers and can cause leaves to shrivel. Severe infestations of mealybugs can lead to premature leaf and fruit drop, as well as twig dieback. They also secrete honeydew, which attracts black sooty mold and reduces the photosynthesis of plants.

Management

Management of mealybugs involves collecting and destroying damaged leaves, twigs, and stems. Soil treatment with chlorpyrifos near the tree trunk can be effective. Field release of the Australian ladybird beetle *Cryptolaemus montrouzieri* at a rate of 10 per tree can help control mealybugs. Spraying NSKE 5% or neem oil at a concentration of 1-2% can also be used for management.

Underutilized cruciferous vegetables

The different underutilized cruciferous vegetables include Chinese cabbage (*Brassica rapa* subsp. *pekinensis*), pak-choi (*Brassica rapa* subsp. *chinensis*), choy sum (*Brassica chinensis* var. *parachinensis*) and Chinese kale (*Brassica oleracea* var. *alboglabra*). Various insect pests have been observed feeding on underutilized cruciferous vegetables. The striped flea beetle (*Phyllotreta striolata*) is a major insect pest of these leafy brassicas in Southeast Asia. Its occurrence during the seedling stage can result in plant death. Aphids (*Brevicoryne brassicae*, *Myzus persicae*, and *Lipaphis erysimi*) are the predominant sucking pests. Apart from causing direct feeding damage, aphids also transmit severe virus diseases to Ethiopian mustard.

Chinese cabbage (*Brassica rapa* subsp. *pekinensis*)

Chinese cabbage is an important vegetable, both fresh and processed, especially in Asian countries. Due to its good taste and high nutritional value, the demand for Chinese cabbage is constantly rising. The major insect pests encountered in Indian conditions include diamondback moth, cabbage caterpillar and aphids.

Diamondback moth, *Plutella xylostella* (Linn.) (Plutellidae: Lepidoptera)

The diamondback moth (*Plutella xylostella*) is a major pest of cruciferous vegetables. The moths are brown or gray in color with distinct white spots on the forewings. A female moth can lay between 40 and 300 eggs. The eggs hatch in 3-9 days, and the full-grown larvae are pale yellow-green with black hairs covering their bodies. The larval period lasts for 9-17 days, after which pupation occurs inside a barrel-shaped, loose silken cocoon attached to plant parts.

The life cycle of the diamondback moth is completed in 2-3 weeks, depending on the prevailing weather conditions, with 8 to 12 generations occurring in a year. The newly hatched larvae start by scraping leaf tissues, and as they grow older, they create holes in the leaves (Kodandaram *et al*., 2017). Severe infestations can lead to the formation of undersized heads in cruciferous crops. If the infestation occurs during the primordial stage of the crop, head formation may not take place.

Management

In endemic areas, avoiding early or late cropping, intercropping cole crops with tomato or carrot, and growing paired Indian mustard rows as trap crops every after 16 cabbage rows. The first row should be sown 15 days prior to cabbage planting, and the second row should be sown 25 days after planting. Only the trap crop should be sprayed with recommended insecticides to control the pest. To control the pest, NSKE 5% or *Bacillus thuringiensis* var Kurstaki @ 2 g or 2 ml/L of water should be applied alternatively on the main crop for effective control.

Cabbage caterpillar or cabbage butterfly, *Pieris brassicae* Linn. (Pieridae: Lepidoptera)

The cabbage caterpillar is a sporadic pest on crucifers, including Chinese cabbage, causing serious damage in northern and eastern parts of India. Newly hatched larvae are pale yellow, feed gregariously, scrape the leaf surface, and later turn greenish yellow (Dhingra *et al*., 2008). Adults are medium-sized, pale white with black markings. The butterfly lays 100-150 yellowish eggs on the upper or under leaf surface. The eggs hatch in 11-17 days in winter and 3-7 days in summer months. The older larvae eat up the leaves from the margins, leaving only the main vein.

Management

Management strategies include collection and destruction of caterpillars during the early stage of attack and spraying *Bacillus thuringiensis* var Kurstaki @ 1 kg/ha along with a sticker.

Aphids, *Myzus persicae*, *Lipaphis erysimi*, *Brevicoryne brassicae* (Aphididae: Hemiptera)

Aphids, including *Myzus persicae, Lipaphis erysimi*, and *Brevicoryne brassicae* (Aphididae: Hemiptera), appear in November and remain active till April. Cloudy and moist weather favors rapid pest multiplication. Direct feeding during the early crop growth period may lead to stunted growth. Additionally, aphids transmit viral diseases (Halder *et al*., 2021). Symptoms of viruses transmitted by *B. brassicae* include mosaic, chlorotic, and necrotic lesions on leaves.

Management

With the appearance of infestation, it is important to remove infested shoots. Conservation of insect predators such as *Chrysoperla carnea*, *Coccinella septempunctata*, *Episyrphus balteatus* is recommended. Spraying entomopathogens like *Beauveria bassiana* @ 5g/L or *Lecanicillium* (=*Verticillium*) *lecanii* @ 5g/L water, or NSKE 5% (Halder and Rai, 2016), can also be effective.

Underutilized solanaceous vegetables

Tree tomato (*Solanum betaceum* Cav.) and cherry tomato (*Solanum lycopersicum* var. *cerasiforme*) are two main underutilized solanaceous vegetables on the list. The tree tomato is a small, delicate tree that grows to a height of 2 to 3 meters. It bears copious clusters of egg-shaped berries with pointed ends near the new shoots. The cherry tomato is a variety of small, round tomato that is thought to have undergone some genetic admixture between domesticated garden tomatoes and wild tomatoes.

Solenopsis Mealybug *Phenacoccus solenopsis* (Tinsley) (Pseudococcidae: Hemiptera)

Solenopsis mealybug is an invasive bug that has recently been observed in serious proportions on a number of vegetables, including malvaceous (ladies finger), solanaceous (tomato, brinjal, potato, chilli, Capsicum), cucurbitaceous (pointed gourd, cucumber, pumpkins, and gourds), and leguminous (cow pea, field bean) vegetables, as well as many weeds, including *Parthenium* (Halder *et al*., 2015(b)). They suck the cell sap and also secrete honeydew, which leads to the development of black sooty mold and reduces the photosynthetic activity of the plants. The problems are more severe in protected conditions.

Management

It is recommended to remove alternate hosts such as *Parthenium hysterophorus*. Selective destruction of ant colonies and uprooting and burning of affected plants can be effective. Spraying of fish oil resin soap (FORS) @ 20g/L water or the application of entomopathogenic fungi *Lecanicillium lecanii* alone @ 5g/L water, or *Lecanicillium lecanii* @ 2.5g/L water + Neem oil (0.5%) at a 1:1 ratio (Halder *et al*., 2018(a)), along with the need-based application of Azadirachtin 300 ppm @ 5 ml/L water or NSKE @ 4%, is recommended.

Tomato pinworm, *Tuta absoluta* (Meyrick) (Gelechiidae: Lepidoptera)

Tomato pinworm is a key oligophagous invasive pest of tomato originating from South America and recently introduced to India. It causes reductions in yield and fruit quality, resulting in losses of 50-100% in either greenhouses or fields. In India, its infestation was first recorded in Pune, Maharashtra, and subsequently spread to other tomato-growing states. Apart from tomato, it also attacks potato, chilli, brinjal, and black nightshade (*Solanum nigrum*). The larvae feed on the mesophyll tissues of the leaves, leaving only the epidermis intact. They often cause irregular leaf blotches that later turn necrotic. On fruits, small minute pin-sized holes with frassy galleries are often visible (Halder *et al*., 2019(a)). Damaged fruits with open holes act as entry points for secondary pathogens, leading to fruit rot as a common damage symptom.

Management

Application of *Bacillus thuringiensis* var. Kurstaki @ 2 g/L or 2 ml/L and the release of *Trichogramma achaeae* are recommended.

Two-spotted spider mite, *Tetranychus* sp. (Tetranychidae: Trombidiformes)

Two-spotted spider mite causes damage to plants both in the nymph and adult stages. They prefer older leaves and suck the sap from the undersurface of the leaves. Infested leaves turn yellowish, lose chlorophyll, develop brownish patches, and ultimately wither and dry. The affected leaves dry up and wither away, giving an unhealthy appearance. The mites are more active during warmer months. The life cycle of the mite is completed within 9-19 days during the active period, and the red spider mite can complete 32 generations in a year.

Management

Frequent irrigation can deter mite activity. The use of sprinkler irrigation can help reduce the mite population (Halder *et al*., 2023). Conservation and release of native predatory mites such as Amblyseius sp. can be beneficial (Rai *et al*., 1995). The use of botanicals/biopesticides like Kochea and Calotropis leaf extract, NSKE 5%, Azadirachtin 300 ppm @ 5 ml/L water, or *Lecanicillium (=Verticillium) lecanii* @ 5 g/L water are recommended for management.

Underutilized legume vegetables

Underutilized legumes belonging to the family Fabaceae are considered rich in high-quality proteins and have significant impacts on nutrition, diet, and health worldwide (Popoola *et al*., 2019). In the list, leafy cowpea (*Vigna unguiculata*), yard-long bean (*V. unguiculata* subsp. *sesquipedalis*), lablab bean (*Lablab purpureus*), vegetable soybean (*Glycine max*), winged bean (*Psophocarpus tetragonolobus*), etc., are important. The major insect pests of these lesser-used leguminous vegetables are as follows:

- Black bean aphids (*Aphis craccivora*) and Bean thrips (*Megalurothrips* spp.): They are major pests that feed on the flowers of cowpea, yard-long bean, and vegetable soybean, especially during cold and cloudy periods, significantly reducing the harvestable grain yield.
- Pod borers (*Maruca vitrata*, *Etiella zinckenella*, and *Helicoverpa armigera*): They damage the reproductive organs of legume vegetables such as cowpea, yard-long bean, lablab bean, winged bean, soybean, *Sesbania grandiflora*, and *Canavalia* spp.
- Pod bugs (*Clavigralla* spp. and *Nezara viridula*): They also damage the reproductive organs of legume vegetables.
- Yellow mites (*Polyphagotarsonemus latus*): They are pests found on legume vegetables such as cowpea, yard-long bean, lablab bean, winged bean, soybean, *Sesbania grandiflora*, and *Canavalia* spp. (Halder and Srinivasan, 2012; Rai *et al*., 2017).
- In the South Pacific, *Aphis craccivora*, *Maruca vitrata*, and *Nezara viridula* are pests found on yard-long bean. For example, in the Solomon

Islands, *Riptortus pedestris* is also a pest on yard-long bean, and the achiote tree (*Bixa orellana*) is used as a trap crop for this pest by subsistence farmers on Malaita, one of the Solomon Islands.

Spotted pod borer, *Maruca vitrata* (Fab.) (Crambidae:Lepidoptera)

Spotted pod borer was previously considered a minor pest of red gram but has become a serious problem in many leguminous vegetables, including underutilized legumes. It causes pod damage of up to 42% in cowpea (Halder and Srinivasan, 2012). This pest also feeds on flowers, buds, and sometimes stems. Its activity is mainly observed in the southern, northern, and central parts of the country during the Rabi and pre-Kharif seasons. The overlapping generations, short life cycle, wide host range, and the pest's ability to form protective webs are the main reasons for its cosmopolitan distribution.

Management

Clean cultivation and removal of the webs are recommended. Conservation of bioagents like Apanteles sp. can be beneficial. Spraying azadirachtin at 0.005% or NSKE 4% or *Bacillus thuringiensis* var. Kurstaki at 1 kg/ha is effective for control.

Pod borer, *Helicoverpa armigera* (Hübner) (Noctuidae: Lepidoptera)

Pod borer is a polyphagous and polymorphous pest recognized worldwide. The larvae of this pest cause defoliation in early crop stages, and in later stages, they bore into the pods and devour the developing seeds. Affected pods with round holes can be observed. Gravid females lay spherical, creamy white eggs. The color of the larvae can range from green to brown, with green larvae having lateral white lines and dark and light bands on their body. Pupae are brown in color, and the adults are stout moths that are light pale brownish yellow. The forewings have a grey to pale brown V-shaped speck, and the outer margin of the hind wings is broad and blackish in color.

Management

Deep summer ploughing is recommended to expose the larvae and pupae of *H. armigera* to sunlight and predatory birds. Mechanical collection and destruction of mature larvae can also help. Installation of sex-pheromone traps for monitoring *H. armigera* at a density of 5 traps per hectare is useful. Planting marigold as a trap crop can attract and divert the pests. The application of HaNPV (*Helicoverpa armigera* nucleo polyhedron virus) at 250 LE/ha with jaggery, soap powder, and tinopal during evening hours is effective. Additionally, spraying azadirachtin at 0.005% or NSKE 4% or *Bacillus thuringiensis* var. Kurstaki at 1 kg/ha as needed is recommended for management.

Pod bugs, *Riptortus pedestris* (Fab.) (Alydidae: Hemiptera

Pod bugs are major agricultural pests in Asian countries such as Korea, Japan, China, Taiwan, Sri Lanka, Myanmar, and India (Rahman *et al*., 2022). They primarily feed on leguminous crops. Both adults and nymphs of *R. pedestris* cause significant damage to pods and seeds by piercing and sucking, resulting in a considerable reduction in yield of legume crops. They can also transmit yeast-spot disease to soybeans (Kimura *et al*., 2008). The feeding behavior of *R. pedestris* leads to shedding of green pods, infested pods with visible black spots, and poorly filled, shriveled, and mostly non-viable grains inside. Adults are brownish-black and hemispherical in shape, while nymphs resemble dark brown ants and are smaller in size.

Management

It is recommended to collect and destroy nymphs and adults of pod bugs. Clean cultivation practices and removal of associated weeds can help reduce their population. Additionally, need-based application of NSKE (Neem seed kernel extract) at 5% concentration with a sticker during the evening hours can be effective for management.

Winged bean, *Psophocarpus tetragonolobus* (L.) DC.

Winged bean is a self-fertilizing tropical grain legume known for its versatile uses. The leaves, pods, seeds, and tubers of winged bean are edible and rich in protein. Under Varanasi conditions, winged bean faces several major insect pests; including the Spotted pod borer, *Maruca vitrata*; tobacco caterpillar, *Spodoptera litura*; and bean thrips, *Megalurothrips distalis*. The Spotted pod borer is a polyphagous pest that attacks the crop during reproductive stages, feeds on flowers, and bores into the pods. The Tobacco caterpillar infests the foliage and can attack from the vegetative stage onwards. The bean thrips (both nymphs and adults) suck the sap from the flowers, causing withering, drying, and subsequent dropping of flowers in severe infestations. Other occasional and minor pests of winged bean include the gram pod borer, *Helicoverpa armigera*; pea blue butterfly, *Lampides boeticus*; whitefly, *Bemisia tabaci*; black bean aphid, *Aphis craccivora*; green stink bug, *Nezara viridula*; cowbug, *Tricentrus bicolor*; as well as two acarine pests, the yellow mite, *Polyphagotarsonemus latus*, and the red spider mite, *Tetranychus* spp. (Halder *et al*., 2018(b)).

Underutilized cucurbitaceous vegetables

Sponge gourd (*Luffa aegyptiaca* Mill.), spine gourd (*Momordica dioca* Roxb.), pointed gourd (*Trichosanthes dioica* Roxb.), *snake gourd* (*Trichosanthes cucumerina* L.); *ivy gourd* (*Coccinia grandis* (L.) Voigt), sweet gourd (*Momordica cochinchinensis* Roxb), etc. are a few examples of this type of vegetable. In India's Northern, Eastern, and Southern regions, the majority of them are significant minor vegetables (Thakur *et al*., 2021). These non-traditional cucurbitaceous vegetables are also attacked by a large number of insect pests throughout their growth period. Aphids (*Aphis gossypii*), Red Pumpkin beetles (*Aulacophora foveicollis*), and hadda beetles (*Epilachna spp.*) sometimes become serious defoliators. Cucumber moth (*Diaphania indica*) is a major pest feeding on the leaves, flowers, and young fruits of various gourds, whereas melon fruit fly (*Zeugodacus cucurbitae*) and melon thrips (*Thrips palmi*) are cosmopolitan pests on various cucurbit species.

Cucumber moth, *Diaphania indica* (Saunders) (Crambidae: Lepidoptera)

Cucumber moth is a pest that has been reported as a major pest of cucurbitaceous crops worldwide. In India, it was previously considered a minor pest of cucurbits, but its seriousness as a fruit borer on bitter gourd and cucumber has been noted in many parts of the country. It also infests tender leaves, flowers, and apical buds of the crop. The larva of the cucumber moth is light green with two prominent longitudinal dorsal whitish lines. It feeds on the chlorophyll portion of the leaves by webbing them together and makes holes in the fruits to feed within. Damage levels of up to 78% in fruits and 36% in shoots have been observed in cucumbers. In South India, damage to the leaves of pointed gourd ranged from 25-30%. The pest is highly active during August and September in the Varanasi region (Halder *et al*., 2017).

Management

Effective management of the cucumber moth includes the collection and destruction of larvae, spraying of NSKE (Neem seed kernel extract) at 4% concentration or *B. thuringiensis* var. Kurstaki at 2 g/L water. The use of biocontrol agents such as the egg parasitoid *Trichogramma chilonis* and the entomopathogen *Nomuraea rileyi* can also be employed. Additionally, a need-based spray of Chlorantraniliprole 18.5% SC at 0.2 ml/L water can be effective. It is important to harvest the mature or marketable fruits before spraying any pesticides or biopesticides.

Cucurbit fruit fly, *Zeugodacus (=Bactrocera) cucurbitae* (Coquillett) (Tephritidae: Diptera)

Cucurbit fruit fly is a polyphagous and cosmopolitan pest that is widely distributed in tropical, sub-tropical, and temperate countries. It is a serious pest of cucurbitaceous vegetables and has been recorded to damage 81 host plants ((Dhillon *et al*., 2005). Crop losses due to this pest can range from 20% to 100%, depending on the cucurbit species and prevailing weather conditions (Halder *et al*., 2022). In India, *Z. dorsalis*, *B. cucurbitae*, and *B. zonata* have been recorded on different vegetable crops. Besides being a significant pest, it is also important from an export point of view. Gravid females lay eggs singly or in small clusters on fruits, and the maggots are apodous and pale white in color. Pupation takes place in the soil. Fruits with maggot infestations drop off prematurely and become unfit for consumption due to the feeding of maggots on the fruit pulp, causing distortion and malformation.

Management

Effective management of the cucurbit fruit fly includes plowing the infested field after crop harvest, collection and destruction of infested fruits, earthing up the soil around the vines to expose pupae for desiccation and predation, bait spray on randomly selected plants (125 plants/acre) containing a mixture of 20 ml Malathion 50 EC, 10 g protein hydrolysate, and 500 g of molasses/jaggery in 20 liters of water. Male annihilation technique (MAT) can be used by setting up plastic bottle traps with ethanol to attract and kill adult flies. Insecticides such as spinosad and Cuelure (6:1:2) soaked in a wooden block for 24 hours and fan-dried can also be effective. It is recommended to install 25-30 traps per hectare for effective control.

Moringa or drumstick (*Moringa oleifera* Lam.)

Moringa is a significant tree with various uses. India is the main producer of Moringa, with a high annual production of 2.20 to 2.40 million tonnes of tender fruits from an area of 38,000ha leading to the productivity of around 63 tonnes per ha (Sekhar *et al*., 2017). However, its production is hindered by several insect pests throughout its growth period. While some pests are specific to drumstick, others are more general.

Moringa fruit/pod fly, *Gitona distigma* (Meigen) (Drosophilidae: Diptera)

Moringa fruit/pod fly is a major pest in Europe and Asian countries. It was first reported in India in 1968 and has become a serious pest in southern states, causing losses of up to 75%. Infestation starts from pod initiation and continues until harvest, resulting in severe damage, especially under poor management conditions. The maggots bore into developing fruits and feed on the pulp and seeds, leading to the oozing of gummy exudate. Infested pods can contain about 20-28 maggots. Eventually, the infestation results in drying and splitting of fruits from the tip to the base of the fruit stalk. Cigar-shaped eggs are laid in small groups on grooves of tender pods. The maggot is creamy white, and pupation takes place in the soil. The adult fly is yellowish with red eyes, and the forewing is transparent with two black spots.

Management

The economic injury level is set at 15% affected fruits. Effective management strategies include the collection and destruction of fallen and damaged fruits, raking up the soil under trees to expose and destroy puparia, using attractants such as citronella oil, eucalyptus oil, vinegar (acetic acid), dextrose, or lactic acid for adult trapping, setting up fish meal traps to attract and kill the flies, and spraying of NSKE (Neem seed kernel extract) at 5% concentration or Nimbecidine at 3 ml/L water at 50% fruit set and again 35 days later.

Budworm (*Noorda moringae* Tams) (Crambidae: Lepidoptera)

Budworm is a common pest found in almost all Moringa-growing states of India. The larvae bore into flower buds, and infested buds contain only one larva, resulting in limited flowering and potential bud shedding, causing up to 78% loss. Infestation is highest during summer months. The eggs are creamy oval and laid singly or in small groups on flower buds. The larva is dirty brown with a prominent mid-dorsal stripe, and the head is black with a prothoracic shield. Pupation takes place in an earthen cocoon in the soil, and the fore and hind wings are light yellowish-brown.

Management

Effective management strategies for budworm include plowing around trees to expose and kill pupae, collection and destruction of damaged buds along with larvae, setting up light traps at a rate of 1-2 traps per hectare to attract and kill adults, and the need-based spray of Azadirachtin at 300 ppm concentration at 5 ml/L water.

Implementing these management practices can help reduce the impact of these insect pests on Moringa crops and improve overall productivity.

Leaf caterpillar, *Noorda blitealis* Walker (Crambidae: Lepidoptera)

Leaf caterpillar is widely distributed in Africa and Asia, including Ethiopia, India, Sudan, Sri Lanka, UAE, and Australia. In the early stages, the larvae feed gregariously on leaflets, scraping chlorophyll and giving them a papery white appearance. In later stages, they become voracious feeders, creating irregular holes in leaves and eventually skeletonizing them, leaving only veins and petioles. Severe infestations can lead to 100% defoliation. The oval creamy white eggs are laid in clusters on leaves, and pupation occurs in the soil. The adult moth is similar to the budworm but larger in size. Apart from feeding on leaves, they also feed on the fruits and seeds of Moringa (Halder and Rai 2014; Seni and Halder 2020).

Management

Effective management strategies for leaf caterpillar include plowing around trees to expose pupae to avian predators, providing sitting arrangements for birds in the Moringa orchard, collecting and destroying fallen and damaged leaves, setting up light traps at a rate of 1-2 traps per hectare to attract and kill adult moths, and the need-based spray of Azadirachtin at 300 ppm concentration at 5 ml/L water.

Hairy caterpillar, *Euptroctis mollifera* Walker (Eupterotidae: Lepidoptera)

Hairy caterpillar causes significant damage during the main rainy season, reducing leaf biomass production by 31-70% in mixed cropping and over 75% in monocropping. They congregate on the stem during hot hours of the day and defoliate the tree quickly, becoming active at night. The red-colored eggs are laid in clusters on tender leaves and shoots. The larvae are brownish-black and covered with whitish dense hairs, which are poisonous and irritating (Seni and Halder, 2020). They generally pupate in an earthen cocoon in the soil, and sometimes inside cracked mature pods. The adult moth is large-sized with a uniform light yellowish-brown color.

Management

A Effective management strategies for hairy caterpillars include collecting and destroying egg masses and caterpillars, setting up light traps at a rate of 1 trap per hectare to attract and kill adult moths immediately after rain, using a burning torch or flame thrower to kill congregating larvae on the trunk, spraying Fish Oil Rosin Soap (FORS) at 25 g/L water or Chlorpyriphos 20EC at 2.5 ml/L water on trunks and foliage immediately after rain and again 15 days later (David and Ramamurthy, 2016). It is important to harvest matured/marketable fruits before spraying.

Bark Eating Caterpillar, *Indarbela tetraonis* Moore (Cossidae: Lepidoptera)

Bark Eating Caterpillar is a widely distributed pest found in India, Burma, Bangladesh, and Sri Lanka. The larvae feed on the bark, usually at night under a shelter of webs, making zig-zag galleries and silken webbed masses consisting of chewed material and excreta. They later bore inside the bark and stem (Seni and Halder, 2020). The larvae are long, stout, and pale brown in color, while the adult is light brown. The forewings have brown spots and streaks, whereas the hind wings are white.

Management

To manage bark eating caterpillars, it is recommended to clean all webbed material, plug the holes with cotton wool soaked in fumigants like chloroform, formalin, or petrol, or inject chemicals like chlorpyriphos emulsion into the bored holes and seal them with wet mud.

Long Horn Beetle, *Batocera rubus* Linn. (Cerambycidae: Coleoptera)

Long Horn Beetle is a pest found in Asia and Europe (CABI, 2016), including the Indian subcontinent. It has one generation per year. The yellowish-brown eggs are laid singly in cracks or crevices in the tree's bark. Upon hatching, the grubs create zig-zag burrows beneath the bark and feed on the internal tissues, eventually reaching the sapwood and causing the death of the affected branch or stem. The grubs are stout and whitish-yellow in color with prominent body segmentation. Adults feed on the bark of tender twigs. The egg, grub, and pupal periods last about 1-2 weeks, 24-28 weeks, and 12-24 weeks, respectively.

Management

To manage Long Horn Beetles, it is recommended to clean the affected portion of the tree by removing webbed materials, excreta, and other debris. Injecting chloroform, petrol, kerosene, or naphthalene balls into the bored holes and then sealing the treated holes with wet mud can help control the infestation.

Other insect pests

Other insect pests that affect drumstick (Moringa) include the longicorn beetle (*Monohammus sp*.), which is a common pest in South India. The female excavates small cavities in the stems and deposits one or two eggs in each cavity. Upon hatching, the grubs bore into the stems, sealing the entrance with their excreta, which results in wilting of the growing points of stems and shading of leaves.

Five species of ash weevils (*Myllocerus* sp.) are also known to cause damage to the leaves from July to December in South India. The adult weevils cause notching of leaves, while the grubs feed on roots, leading to wilting of plants. The white grub, *Holotricha insularis,* found in Rajasthan and South India, feeds voraciously on leaves as adults and grubs feed on roots, eventually pupating in the soil.

Numerous sap feeders such as whiteflies, aphids, scale insects, midges, mealybugs, and spider mites are known to infest drumstick in India. Additionally, red mites (*Tetranychus urticae*), defoliators, leaf-footed bugs (*Leptoglossus phyllopus*), and whiteflies (*Bemisia sp*.) have been observed in the field during trials with a large number of Moringa accessions in the Philippines (Patricio and Palada, 2017).

Underutilized Aquatic Vegetables

India has a vast diversity of aquatic vegetables, including water lily (*Nymphaea rubra* Roxb. ex Salisb.), water chestnut (*Trapa natans* Linn.), water spinach (*Ipomoea aquatica* Forssk.), lotus (*Nelumbo nucifera* Gaertn.), and others. However, like other underutilized vegetables, these aquatic plants are prone to infestation by a number of major and minor insect pests throughout their growth period. Here, we will discuss a few of the major insect pests associated with these vegetables.

Water lily aphid, *Rhopalosiphum nymphaeae* (Linnaeus) (Hemiptera: Aphididae)

Water lily aphid, a polyphagous, heteroecious, holocyclic aphid has been reported to feed on a wide variety of host plants, including many aquatic species. Interestingly, this aphid is capable of surviving underwater conditions (Holman, 2009). Large colonies of water lily aphids have been observed infesting several aquatic vegetables, such as water chestnut, water spinach, lotus, and water lily, in and around the Varanasi region of Uttar Pradesh, India. These aphids primarily feed on leaf petioles, leaf lamina, and fruit stalks, resulting in leaf curling, stunted plant growth, and reduced fruit production. Moreover, apart from extracting cell sap, they also secrete copious amounts of sugar-rich honeydew, which accumulates on the plant surfaces, promoting the development of black sooty mold. This mold further inhibits the normal photosynthesis of the plants (Halder *et al*., 2020).

Management

It is recommended to collect and destroy plant parts infested with aphids.

Singhara beetle, *Galerucella birmanica* Jacoby (Chrysomelidae: Coleoptera)

Singhara beetle is considered a serious pest of water chestnut in India and was recorded in other states such as Madhya Pradesh, Assam, Punjab, and Kashmir (Srivastava, 1956; Halder *et al*., 2019(b)). The entire life cycle of this pest, including the immature stages, is spent on the leaves of water chestnut plants. Both the adults and several grub stages feed on the leaves, petioles, and occasionally the fruit integument. Continuous feeding on the upper side of the leaves leads to the formation of small holes. Severe infestations often result in leaves being covered in numerous tiny holes. The grubs cause more damage compared to the adults (Srivastava *et al*., 1956).

Management

It is recommended to collect and destroy plant parts infested with Singhara beetles.

Tortoise beetle, *Cassida circumdata* Herbst (Chrysomelidae: Coleoptera)

The tortoise beetle, at times, poses a serious problem for crops like water chestnut. GresSitt (1952) reported that *C. circumdata* feeds on various plants from the Convolvulaceae family, including *Ipomoea palmata, I. batatas, I. aquatica, I. cairica*, and *I. digitata.* Close observation has revealed that its early instar grubs scrape the chlorophyll from the leaves, resulting in the leaves appearing skeletonized. Later instars create small, irregular shot holes and notches on the leaves, often occurring in large numbers on a single leaf. The upper surface of the leaves may show black excreta (Halder and Rai, 2021). Affected leaves have reduced photosynthetic activity and fetch lower market values.

Management

It is advisable to collect and destroy the grubs, adults, and severely infested plant parts.

Integrated Pest Management

In order to protect these underutilized vegetables from the ravages of various insect pests, it is essential to adopt suitable, need-based, and quick result-oriented control measures. These measures should take into account the resurgence of pests due to the development of resistance to insecticides, residual problems, minimum environmental pollution, and the preservation of natural enemies such as parasitoids, predators, and pollinators. To achieve this, an integrated approach should be adopted to suppress the pest population below the economic threshold level (ETL) through the proper and judicious use of suitable control measures at the right time. Prior to implementing integrated pest management (IPM), it is important to have a thorough understanding of the crop plant and its growth throughout the season, as well as knowledge of the threshold for economic damage. The stage of crop growth is a crucial factor because the relationship between insect injury and crop damage depends on the stage at which maximum injury occurs. Research has shown that injury during the vegetative stages is usually less detrimental to the plant compared to the reproductive stages (Dey and Halder, 2011). Periodic surveys and monitoring of insect pests are important tasks in obtaining information on population dynamics of pests and natural enemies, as well as estimating the damage to plants. Integrated pest management involves various methods of control, including mechanical and cultural practices, as well as the use of both bio-pesticides and chemicals.

Mechanical control

Deep summer ploughing of fields exposes the soil-inhabiting stage of insects, particularly pupae of fruit flies and mealy bugs, which hide in cracks and crevices in the soil. This practice helps expose them to natural enemies. Collection and destruction of developing stages (such as eggs, nymphs, caterpillars, or adults) of serious pests and infested plant parts from the fields can help reduce pest incidence. Installing yellow sticky traps attracts aphids, thrips, and other pests. By using such traps in the fields, the first appearance and density of pests can be monitored, allowing timely measures to be taken for pest control (Dey and Halder, 2011). Erecting bird perches at a rate of 20 per acre encourages predatory birds such as King crows and common Mynahs. It is also recommended to burn groups of hairy caterpillar larvae found on tree trunks with torches.

Cultural control

Practices such as clean cultivation, crop rotation, and judicious use of nitrogenous fertilizers are important for managing insect pests of underutilized vegetables. Periodically removing weeds is necessary. Ants can act as transporters for mealy bugs, so destroying ant colonies in and around the fields helps restrict their migration. Uprooting and burning severely infested twigs (infested with mealy bugs or mites) minimize future pest infestations. Nitrogen plays a significant role in pest intensity, so the judicious use of nitrogenous fertilizers during crop growth stages is recommended. Incorporating neem cake at a rate of 100 kg/ha can help protect the crop from pest attacks. Additionally, growing forage crops as mixed crops is advisable as it helps maintain ecological balance.

Use of resistant varieties

Certain lines or varieties of crops possess genetic characteristics that make them resistant to specific pests. Cultivating these resistant varieties requires minimal changes to normal cultivation practices and can be incorporated into insect pest management strategies. Resistant varieties are continuously being developed by various organizations, such as ICAR Institutes, State Agricultural Universities, and State Agriculture Departments. Recent information shows the existence of tolerance to aphids (*Rhopalosiphum pseudobrassicae* and *Myzus persicae*) in non-heading Chinese cabbage accessions (VI010611, VI010634, VI010635, and VI010637) (Keatinge *et al*., 2015). Moringa species, including *Moringa peregrina* and M. *borziana*, were found to be free from spider mite infestations, while *M. concanensis, M. oleifera,* and *M. rivae* were susceptible.

Biological Control

Biological control refers to the use of parasites, predators, or pathogens to maintain the population density of another organism at a lower level than would occur in their absence (DeBach, 1964). Biological control techniques involve using live populations of natural enemies to permanently or temporarily lower pest population densities, with human involvement. Biological control of pests, including insects, mites, weeds, and plant diseases, relies on predation, parasitism, herbivory, or other natural mechanisms. Biological control of insect pests is gaining importance due to its target specificity, self-perpetuity, and environmental safety (Halder *et al*., 2018(c)). Several parasitoids and predators have been reported to control major insect pests of many underutilized vegetables (see Table 1).

Botanicals as a tool for IPM

Botanicals, or pesticides derived from plants, have the potential to be an important tool in integrated pest management (IPM). These botanical insecticides are renewable, non-persistent in the environment, and relatively safe for natural enemies, non-target organisms, and humans. Therefore, they can contribute to sustainable agricultural production and pest management. However, there has been limited research evaluating different botanicals for the management of insect pests in underutilized vegetables.

Chemical control

Chemical control become necessary during outbreaks or resurgences of certain insect pests when mechanical, cultural, and biological control methods may not be sufficient to quickly suppress the pest population. In such cases, farmers may opt for chemical control measures for immediate results. For example, the management of fruit fly may involve monitoring and mass trapping using methyl eugenol traps or using bait sprays with insecticides and molasses. It is important to use only insecticides that are approved by the Central Insecticide Board & Registration Committee (CIB&RC) and follow the label instructions.

Future Strategies

In future strategies for pest management in underutilized vegetables, certain aspects need to be addressed. There is a need for more research focusing on cultural and biological control methods, as well as collaborative approaches in host plant resistance. Interspecific resistance should be a focal point. The role of agro ecosystem analysis, ecological engineering, and biological control, particularly with entomo pathogens and plant-derived toxins, should be explored.

Table 1. Different predators of major insect pests of underutilized vegetables

Name of the bioagents	Taxonomic position (Family : Order)	Target insect pests	Preferred stage(s)
Predators			
Cryptolaemus montrouzieri (Mulsant)*	Coccinellidae: Coleoptera	Soft-bodied isnect like scales, mealy bugs, aphids, whiteflies, jassids, neonate larvaeetc.	Nymphs and adults
Chrysoperla zastrowi sillemi Henry	Chrysopidae: Neuroptera		Nymphs and adults
Cheilomenes sexmaculata (Fabricius)	Coccinellidae: Coleoptera		Nymphs and adults
Scymnus coccivora Ayyar	Coccinellidae: Coleoptera		Nymphs and adults
Brumoides Suturalis Fab.	Coccinellidae: Coleoptera		Nymphs and adults
Nephus regularis (Sicard)	Coccinellidae: Coleoptera	Black bean aphid, *A. craccivora;*Solenopsismealy bug, *Phenacoccussolenopsis*	Nymphs and adults
Mallada boninensis (Okamoto)	Chrysopidae: Neuroptera	Soft-bodied insects	Eggs, nymphs and adults

Some important considerations for future strategies include:

- Conducting regular surveillance and pest monitoring at weekly intervals.
- Emphasizing the use of pheromone traps, sticky traps, and light traps for monitoring and mass trapping of pest populations.
- Searching for potential biocontrol agents, new plant-derived insecticides, and novel biorational molecules with green chemistry to reduce pesticide contamination.
- Developing genetically improved strains of bioagents with longer shelf-life and higher field persistence.
- Ensuring quality control of bioagents available in the market by state governments.
- Developing low-cost mass production technologies for potential bioagents and standardizing field release methods.
- Providing training programs to pesticide dealers to increase their understanding of IPM and the hazards associated with chemical pesticides.
- Promoting IPM among farmers through method demonstrations, farmers' field schools, and various media channels (radio, television, print media).
- Periodically validating and refining IPM modules for the management of pests in underutilized vegetables.

By addressing these future strategies, it is possible to enhance pest management practices and promote sustainable and effective approaches for the protection of underutilized vegetable crops.

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Research Article

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Effect of mycorrhiza applications on nutrient uptake in Prunus rootstock under water stress conditions

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ABSTRACT

The experiment was conducted in a glass greenhouse using pots to compare grafted and ungrafted plants. Four different rootstocks, namely Rootpac 40, Rootpac R, GF 677, and Garnem, were utilized. The control plants (K100) were irrigated to maintain a water level equivalent to 100% of the field capacity. For the K55 application, water was provided at 55% of K100 irrigation level, while K40 application received water at 40% of K100 application. During 2020 trial, water availability was limited, resulting in restricted water application to plants. Half of the seedlings were grafted with Carolina nectarine variety. During 2021 trial, limited water application was implemented by inoculating both the grafted and non-grafted nectarine plants with *Glomus mosseae* mycorrhiza species. Under drought stress, mycorrhizae-inoculated seedlings exhibited positive effects on concentrations of nitrogen (N), phosphorus (P), potassium (K), calcium (Ca), and magnesium (Mg) in their leaves.

Key Words: Stone fruits rootstocks, Drought resistance/tolerance, Mycorrhiza, Plant nutrients, Macro elements

Sert çekirdekli meyve üretimi bakımından dünyada sayılı ülkeler arasında bulunan ülkemizde 2021 yılında yaklaşık 3 milyon ton sert çekirdekli meyve üretimi gerçekleşmiştir (TUİK, 2023).

Kullanılan anaç üzerine aşılanan çeşidin gelişimini, verimini, meyvenin kalitesini, kurağa, dona, kirece, tuzluluğa, taban suyuna toleransını, bitki besin maddelerinin topraktan alımını ve hastalık ve zararlılara dayanımını etkilemektedir.

Bitkiler optimal bir şekilde büyüme ve gelişme gösterebilmeleri için besin maddelerine gereksinim duyarlar. Bitkilerde bulunan besin maddeleri miktarları üzerinde bitkinin türü, yaşı, kök büyümesi, toprağın fiziksel, kimyasal ve biyolojik özellikleri, toprakta yarayışlı şekilde bulunan elementlerin cins ve miktarları, uygulanan tarımsal yöntemler, hava koşulları gibi çok sayıda faktör etkilidir.

In Turkey, stone fruit industry is significant, with approximately 3 million tonnes of stone fruit produced in 2022 (TUIK, 2023). The main stone fruit types cultivated in include apricot (*Prunus armeniaca* L.), peach (*Prunus persica* L.), cherry (*Prunus avium* L.), and plum (*Prunus domestica* L.).

To ensure optimal vegetative growth during the spring season, prevent fruit drop, maintain normal fruit size, and promote the formation of an adequate number of flower buds for the following year, it is crucial to maintain sufficient soil moisture throughout the entire vegetation period. The soil moisture should never fall below the wilting point to meet the water requirements of the stone fruit trees (Kuden, 2019).

Abbaspour *et al*. (2017) conducted a study to investigate the impact of *Glomus etunicatum* species of mycorrhiza application on drought stress in 3-month-old pistachio seedlings (*Pistacia vera* L.) grown in pot culture. Gür and San (2017) examined three different restricted water treatments applied to wild pear seedlings, using BA 29, Farold 40, OHxF 333, and Fox 11 rootstocks commonly used in pear cultivation under greenhouse conditions. Hamedani *et al*. (2022) focused on studying the yield, irrigation water efficiency, and nutrient uptake of mycorrhiza-inoculated sesame (*Sesamum indicum* L.) under drought stress conditions. Yılmaz *et al*. (2020) investigated the effects of *Glomus mosseae* and *Glomus fasciculatum* on plant growth during the acclimatization of micropropagated sweet cherry (*Prunus avium* L.) rootstocks. Zou *et al*. (2020) conducted research

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on arbuscular mycorrhizal fungi (AMF) in the rhizosphere of citrus (*Citrus* spp.) crops, emphasizing their role in forming mutualistic symbiosis with roots and enhancing plant growth, nutrient acquisition, stress tolerance, fruit quality, and soil stability. Saroj and Choudhary in 2020 highlighted water stress as one of the most important environmental variables affecting plant growth and development. Water stress can result from either insufficient water due to drought conditions or excessive water activity. Climate forecasts indicate that global warming will continue in the coming decades, regardless of the actions taken today. Therefore, an experiment was conducted in pots to assess the effects of restricted water and mycorrhiza treatments on nutrient uptake in various *Prunus* rootstocks.

MATERIALS AND METHODS

For the plant selection in the study, one-year-old clonal rootstocks propagated through tissue culture were utilized. These selected plants were specifically chosen based on the criteria that they were unaffected by diseases and pests, exhibited similar physical characteristics, and had completed the rooting process. By using clonal rootstocks with these attributes, the researchers aimed to minimize any potential confounding factors related to disease susceptibility, pest damage, or physical variations among the plants.

Fig. 1. Rootstocks used (Rootpac 40, Rootpac R, GF 677 and Garnem)

Carolina nectarine, when grafted on rootstocks, exhibits early blooming characteristics. The harvest of Carolina nectarine typically takes place between the 1st and 10th of June. The texture of the fruit is influenced by the nutrient levels present in the growing medium used for cultivation.

For irrigation purposes, the water source utilized was a borehole located in the Alata Horticultural Research Institute. The conductivity of the irrigation water from this borehole ranges between 250 and 750 µs/cm, indicating a medium salinity level (salinity class C2). This water is suitable for irrigation of plants with moderate salt tolerance according to Table 1.

Table 1. Characteristics of irrigation water

pH	7.4
B	0.1
Ca	0.93
Mg	1.91
K	0.43
Na	6.35
Ca+Mg	2.81
HCO_3	3.5
Cl	2.5
SO_4	3.59
SAR	5.38

The experiment was carried out in pots within the glass greenhouse conditions of the Alata Horticultural Research Institute between 2020 and 2021. The study involved the use of different rootstocks and irrigation doses, with half of the rootstocks being grafted with the Carolina nectarine variety. Additionally, mycorrhiza application was performed on half of the rootstocks to assess the nutrient content in the leaves.

In total, four different rootstocks, one cultivar (Carolina nectarine), three irrigation doses, and 14-liter plastic pots were utilized in the experiment. The pots were divided into mycorrhizal (M+) and non-mycorrhizal (M-) treatments, as well as grafted and non-grafted applications. This experimental setup allowed for the evaluation of various factors on the nutrient levels in the leaves of the plants.

During the 2020 trial, the experiment was conducted in a greenhouse with shading and ventilation. Limited irrigations were implemented programmatically, starting on July 16, 2020, and ending on August 20, 2020, when the plants had become dried out due to stress. Restricted water applications were carried out for duration of 36 days, with a total of 12 applications during this period.

In the 2021 trial, *Glomus mosseae* mycorrhiza was inoculated into the plants. Restricted water applications were conducted over a period of 30 days, starting from July 12, 2021, and ending on August 10, 2021. These applications were made 10 times during the specified timeframe.

The pots used in the experiment were filled with a growing medium consisting of a mixture of 1 part sandy soil, 2 parts garden soil, and 1 part peat. The pots had a known weight, litter, and holes in the bottom. The growing medium used in the experiments was sterilized by autoclaving at 121°C for 90 minutes to eliminate any potential microorganisms.

To establish the mycorrhiza inoculum, Glomus mosseae species were reproduced using a soil Urgüp tuff and animal manure medium in a ratio of 3:6:1 (V/V/V). The reproduction was carried out under the presence of sorghum host plants. The resulting inoculum was stored in a cold environment at a temperature of +4°C until it was used in the experiment.

Glomus mosseae exhibits a range of colors from light yellow to dark orange-brown. Its morphology is generally spherical or hemispherical, although irregular shapes can also be observed. The size of *Glomus mosseae* spores ranges from 100 to 260 µm, with an average size of 195 µm (Invam, 2022).

To determine the field capacity of the growing medium in the pots, the method described by Unlukara *et al*. (2010) was followed. Initially, five pots without plants were filled with the mortar mixture and weighed. The mortar mixture was then saturated with water until leakage occurred, and aluminum foil was used to cover the pots and prevent evaporation. The process of adding water and allowing leakage to occur was repeated several times. After the infiltration process was completed, the pots were covered with aluminum foil and weighed after 48 hours. The average weight of these pots represented the field capacity.

For leaf samples, the middle leaf pair of the shoots was collected at the end of the experiment, specifically after the stress treatments were completed. The collected samples were cleaned with 0.1% theopol water, rinsed several times with distilled water, and then subjected to drying and grinding processes. The analysis of total nitrogen (N) was conducted using the modified Kjeldahl method (Kacar, 1972). Phosphorus content was determined using the vanadomolybdophosphoric acid method, which involves wet burning of the plant extract, followed by colorimetric measurement according to the yellow color method (Kaçar, 1972). Potassium, calcium, and magnesium analyses were performed using inductively coupled plasma (ICP) in the plant extract (Chapman and Pratt, 1961).

RESULTS AND DISCUSSION

In the 2020 experiment, it was observed that water stress generally led to a decrease in nutrient uptake in plants. Specifically, there was a decrease in nitrogen uptake with increasing water stress. The highest nitrogen uptake was observed in plants grafted with R 40 rootstock and GF 677 in the K 40 application.

For phosphorus uptake, the highest concentration (0.19%) was observed in plants grafted on R 40 rootstock in the K100 application, while the lowest concentration was found in GF 677 rootstock in the K40 application (0.05%).

With increasing water stress, there was a decrease in potassium uptake. The highest potassium concentration (1.40%) was observed in plants grafted on R 677 rootstock in the K100 application, while the lowest concentration (0.85%) was found in plants grafted on GF 677 rootstock in the K40 application.

Regarding calcium concentration, the highest value (1.29%) was observed in plants grafted on GF 677 rootstock in the K100 application, while the lowest concentration (1.09%) was found in plants grafted on GF 677 rootstock in the K 40 application.

For magnesium concentration, the highest values (0.30%) were observed in plants grafted on R 40 rootstock and RR in the K100 application. The lowest concentration (0.12%) was determined in plants grafted on GF 677 rootstock in the K40 application.

With an increase in water stress in plants, there was a decrease in nitrogen concentration. The highest nitrogen concentration (2.58%) was obtained in the R R rootstock in the K100 application.

Water stress also caused a decrease in phosphorus concentration, and the highest phosphorus concentration (0.18%) was obtained from the R R rootstock in the K100 application.

Similarly, the amount of potassium decreased with increasing water stress. The highest potassium concentration (1.32%) was obtained from the R 40 rootstock in the K100 application. The lowest potassium concentration (0.88%) in the K40 application was found in the GF 677 rootstock.

With an increase in water stress, the amount of calcium also decreased. The highest calcium concentration (1.29%) was obtained from the R 40 rootstock in the K100 application. The lowest calcium concentration (1.08%) in the K40 application was found in the GF 677 rootstock.

Table 2. Effect of restricted water applications on plant nutrients in grafted plants

Water application	N (Nitrogen) (%)				
	Rootstocks				Average
	R 40	R R	GF 677	Garnem	
K_{100}	2.50 a	2.40 a	2.50 a	2.35 ab	2.44 A
K_{55}	1.95 bc	1.65 cd	1.85 cd	1.65 cd	1.78 B
K_{40}	1.70 cd	1.55 d	1.70 cd	1.50 d	1.61 C
Average	2.05 A	1.87 BC	2.02 AB	1.83 B	

$LSD_{(0.05)}$: rootstock: 0.17 $LSD_{(0.05):irrigation:}$0.13 $LSD_{(0.05)}$ rootstockxirrrigation: 0.38

Water application	P (Phosphorus) (%)				
	Rootstocks				Average
	R 40	R R	GF 677	Garnem	
K_{100}	0.19 a	0.18 a	0.16 ab	0.15 abc	0.17 A
K_{55}	0.10 cd	0.11 bcd	0.10 cd	0.09 de	0.10 B
K_{40}	0.10 cd	0.08 def	0.05 f	0.06 ef	0.07 C
Average	0.13 A	0.12	0.10 B	0.10 B	

$LSD_{(0.05)rootstock:}$ 0.019 $LSD_{(0.05):irrigation\ :}$ 0.016 $LSD_{(0.05)rootstockxirrigation:}$ 0.046

Water application	K (Potassium) (%)				
	Rootstocks				Average
	R 40	R R	GF 677	Garnem	
K_{100}	1.12 cd	1.40 a	1.35 ab	1.15 bcd	1.26 A
K_{55}	1.20 abc	1.30 abc	1.29 abc	1.19 abc	1.25 A
K_{40}	0.99 de	0.98 de	0.85 e	0.90 e	0.93 B
Average	1.10 B	1.23 A	1.16 AB	1.08 B	

$LSD_{(0.05):rootstock:}$ 0.094 $LSD_{(0.05):irrigation:}$ 0.073 $LSD_{(0.05):rootstockxirrigation:}$ 0.212

Water application	Ca (Calcium) (%)				
	Rootstocks				Average
	R 40	R R	GF 677	Garnem	
K_{100}	1.28 ab	1.25 ab	1.29 a	1.21 bcd	1.26 A
K_{55}	1.23 abc	1.26 ab	1.21 bcd	1.17 cde	1.22 B
K_{40}	1.22 abc	1.10 ef	1.09 f	1.14 def	1.14 C
Average	1.24 A	1.20 B	1.20B	1.17 B	

$LSD_{(0.05)rootstock:}$ 0.094 $LSD_{(0.05)irrigation:}$ 0.026 $LSD_{(0.05)rootstockxirrigation:}$0.076

Water application	Mg (Magnesium) (%)				
	Rootstocks				Average
	R 40	R R	GF 677	Garnem	
K_{100}	0.30 a	0.30 a	0.28 ab	0.27 ab	0.29 A
K_{55}	0.26 abc	0.26 abc	0.22 cd	0.21 d	0.24 B
K_{40}	0.24 bcd	0.24 bcd	0.12 e	0.20 d	0.20 C
Average	0.27 A	0.27 A	0.21 C	0.23 B	

$LSD_{(0.05)rootstock:}$ 0.094 $LSD_{(0.05)irrigation:}$ 0.026 $LSD_{(0.05)rootstockxirrigation:}$ 0.076

Table 3. Effect of restricted water applications on plant nutrients in non-grafted plants

Water application	N (Nitrogen)(%)				
	Rootstocks				Average
	R 40	R R	GF 677	Garnem	
K_{100}	2.50 a	2.58 a	2.41 a	2.45 a	2.49 A
K_{55}	1.82 cd	2.40 a	1.91 c	2.15 b	2.07 B
K_{40}	1.65 d	2.10 b	1.70 d	1.65 d	1.78 C
Average	1.99 C	2.37 A	2.00 BC	2.08 B	
$LSD_{(0.05)rootstock:}$ 0.09 $LSD_{(0.05)irrigation:}$ 0.07 $LSD_{(0.05)rootstockxirrigation:}$ 0.020					

Water application	P (Phosphorus) (%)				
	Rootstocks				Average
	R 40	R R	GF 677	Garnem	
K_{100}	0.16 ab	0.18 a	0.15 abc	0.15 abc	0.16 A
K_{55}	0.14 abcd	0.11 cde	0.11 cde	0.11 cde	0.12 B
K_{40}	0.09 de	0.08 ef	0.05 f	0.08 ef	0.08 C
Average	0.13 A	0.12A	0.10 B	0.11 AB	
$LSD_{(0.05)\ rootstock:}$ 0.018 $LSD_{(0.05)irrigation:}$ 0.020 $LSD_{(0.05):rootstockxirrigation:}$ 0.035					

Water application	K (Potassium) (%)				
	Rootstocks				Average
	R 40	R R	GF 677	Garnem	
K_{100}	1.32	1.21	1.13	1.25	1.23 A
K_{55}	1.04	1.25	1.19	1.18	1.17 AB
K_{40}	1.28	1.06	0.88	0.92	1.03 B
Average	1.21	1.17	1.12	1.12	
$LSD_{(0.05)rootstock:}$ Ö.D. $LSD_{(0.05)irrigation:}$ 0.015 $LSD_{(0.05)rootstockxirrigation:}$ Ö.D.					

Water application	Ca (Calcium) (%)				
	Rootstock				Average
	R 40	R R	GF 677	Garnem	
K_{100}	1.29	1.26	1.21	1.26	1.26 A
K_{55}	1.14	1.23	1.14	1.24	1.19 AB
K_{40}	1.19	1.18	1.08	1.20	1.16 B
Average	1.21	1.22	1.14	1.23	
$LSD_{(0.05)rootstock:}$ Ö.D. $LSD_{(0.05)irrigation:}$ 0.08 $LSD_{(0.05)rootstockxirrigation:}$ Ö.D.					

Water application	Mg (Magnesium) (%)				
	Rootstocks				Average
	R 40	R R	GF 677	Garnem	
K_{100}	0.25 abc	0.30 a	0.29 a	0.28 ab	0.28 A
K_{55}	0.21 cd	0.23 bcd	0.25 abc	0.26 abc	0.24 B
K_{40}	0.21 cd	0.19 d	0.21 cd	0.23 bcd	0.21 C
Average	0.23 B	0.24 AB	0.25 AB	0.26 A	
$LSD_{(0.05)rootstock:}$ 0.026 $LSD_{(0.05)\ irrigation:}$ 0.020 $LSD_{(0.05:rootstockxirrigation:}$ 0.056					

Regarding magnesium concentration, the highest value (0.30%) was obtained from the R R rootstock in the K100 application, while the lowest value (0.19%) was obtained from the R R rootstock in the K40 application.

According to Mahieu *et al*. (2009), water stress has a significant impact on nitrogen accumulation in peas, leading to inhibited plant growth and chlorosis. Gur and San (2017) observed that the amounts of N, Cu, B, Zn, P, Ca, and K decreased in wild pear seedlings and different rootstocks under stress conditions, while Fe, Mg, and Mn values increased. Çerçi (2013) reported a decrease in N and P concentrations under water stress conditions.

Ipek (2015) found that in Myrobolan 29C rootstock, the concentrations of calcium, potassium, phosphorus, and magnesium decreased in all drought applications, while sodium and sulfur levels were higher in the -1.0 MPa drought application compared to others. The levels of boron, copper, iron, manganese, and zinc were lower in drought applications compared to the control. Similarly, in Garnem rootstock, reductions were observed in calcium, potassium, sodium, phosphorus, and magnesium under drought conditions, while sulfur content was higher than the control in all drought applications.

It was determined that the nitrogen (N), phosphorus (P), potassium (K), calcium (Ca), and magnesium (Mg) contents of both grafted and ungrafted plants decreased with stress applications. However, the effects of restricted water applications on nitrogen content were found to be statistically insignificant.

In the K40 application, the highest nitrogen concentration was found in plants grafted with GF 677 rootstock (2.55%), while the lowest concentration was determined in plants grafted with R R rootstock (1.87%).

Similarly, with an increase in water stress, there was a decrease in phosphorus concentration. In the K40 application, the highest phosphorus concentration was found in plants grafted with R 40 rootstock (0.15%), while the lowest concentration was observed in plants grafted with Garnem rootstock (0.11%). These findings suggest that different rootstocks may have varying responses to water stress in terms of nutrient uptake and accumulation.

With an increase in water stress, there was a decrease in potassium concentration. In the K40 application, the highest potassium concentration was found in plants grafted with RR rootstock (1.30%), while the lowest concentration was observed in plants grafted with GF 677 rootstock (1.25%).

Similarly, in the K40 application, the highest calcium concentration was found in plants grafted with R 40 rootstock (1.22%), while the lowest concentration was obtained from plants grafted with GF 677 and Garnem rootstocks (1.15%).

With an increase in water stress, the amount of magnesium decreased. In the K40 application, the highest magnesium concentration was observed in plants grafted with R R rootstock (0.29%), while the lowest concentration was obtained from plants grafted with GF 677 and Garnem rootstocks (0.21%).

The difference between rootstocks in terms of nitrogen values was non significant. The lowest nitrogen concentration in the K40 application was determined in plants grafted with R R rootstock (1.45%). In the K40 application, the highest phosphorus concentration was found in plants grafted with GF 677 rootstock (0.15%), while the lowest phosphorus concentration was found in plants grafted with R R rootstock (0.07%). There was also a decrease in potassium concentration in the leaves. In the K40 application, the highest potassium concentration was detected in plants grafted with R R rootstock (0.97%), while the lowest potassium concentration was obtained in plants grafted with GF 677 rootstock (0.12%).

Similarly, there was a decrease in calcium concentration. In the K40 application, the highest calcium concentration was obtained in plants grafted with R 40 rootstock (1.28%), while the lowest calcium concentration was observed in plants grafted with R R rootstock (1.08%).

In the K40 application, the highest magnesium concentration was observed in plants grafted with R 40 rootstock (0.25%), while the lowest magnesium concentration was obtained in plants grafted with R R rootstock (0.19%). These findings indicate that water stress and rootstock selection can influence the nutrient contents in plants, specifically in terms of potassium, calcium, and magnesium concentrations.

The effects of restricted water and mycorrhiza treatments on leaf nutrient concentrations in ungrafted and mycorrhizal plants on different rootstocks were examined, and the difference between rootstocks was generally found to be statistically insignificant (Table 6).

There was no significant difference between rootstocks in terms of nitrogen values. In the K40

Table 4. Effect of restricted water and mycorrhiza treatments on nutrients in grafted and mycorrhizal plants

Water application	N (Nitrogen)(%)				
	Rootstocks				Average
	R 40	R R	GF 677	Garnem	
K_{100}	2.10 cde	2.17 bcd	2.17 bcd	2.27 bc	2.18
K_{55}	2.33 abc	1.97 de	2.37 ab	2.32 abc	2.25
K_{40}	2.25 bc	1.87 e	2.55 a	2.18 bcd	2.21
Average	2.23 B	2.00 C	2.36 A	2.26 AB	
$LSD_{(0.05)\ rootstock:}$ 0.11	$LSD_{(0.05)\ irrigation:}$ 0.086	$LSD_{(0.05)\ rootstockxirrigation:}$ 0.025			
Water application	P(Phosphorus)(%)				
	Rootstocks				Average
	R 40	R R	GF 677	Garnem	
K_{100}	0.15 bcd	0.19 a	0.19 a	0.18 ab	0.18 A
K_{55}	0.16 abc	0.11 ef	0.12 de	0.13 cde	0.13 B
K_{40}	0.15 bcd	0.13 cde	0.12 de	0.11 ef	0.13 B
Average	0.15	0.14	0.14	0.14	
$LSD_{(0.05)\ rootstock:}$ 0.019	$LSD_{(0.05)irrigation:}$ 0.017	$LSD_{(0.05)rootstockxirrigation:}$ 0.048			
Water application	K(Potassium)(%)				
	Rootstocks				Average
	R 40	R R	GF 677	Garnem	
K_{100}	1.28 cd	1.60 a	1.30 c	1.25 d	1.36 A
K_{55}	1.29 cd	1.40 b	1.39 b	1.29 cd	1.34 A
K_{40}	1.29 cd	1.30 c	1.25 d	1.29 cd	1.28 B
Average	1.29 C	1.43 A	1.31 B	1.28 C	
$LSD_{(0.05):\ rootstock:}$ 0.022	$LSD_{(0.05):\ irrigation:}$ 0.017	$LSD_{(0.05):\ rootstockxirrigation:}$ 0.045			
Water application	Ca (Calcium) (%)				
	Rootstocks				Average
	R 40	R R	GF 677	Garnem	
K_{100}	1.26 ab	1.27 ab	1.29 a	1.25 abc	1.27 A
K_{55}	1.24 abc	1.26 ab	1.19 cd	1.19 cd	1.22 B
K_{40}	1.22 bc	1.19 cd	1.15 de	1.15 de	1.18 C
Average	1.24 A	1.21 B	1.20 B	1.20 B	
$LSD_{(0.05)rootstock:}$ 0.020	$LSD_{(0.05)irrigation:}$ 0.016	$LSD_{(0.05)\ rootstockxirrigation:}$ 0.046			
Water application	Mg (Magnesium) (%)				
	Rootstocks				Average
	R 40	R R	GF 677	Garnem	
K_{100}	0.35 a	0.34 a	0.28 abc	0.20 e	0.29 A
K_{55}	0.34 a	0.28 abc	0.22 bcde	0.27 abcd	0.28 A
K_{40}	0.27 abcd	0.29 ab	0.21 cde	0.21 cde	0.25 B
Average	0.32 A	0.31 A	0.24 B	0.22 B	
$LSD_{(0.05)rootstock:}$ 0.032	$LSD_{(0.05):\ irrigation:}$ 0.025	$LSD_{(0.05):\ rootstockxirrigation:}$ 0.072			

Table 5. Effect of restricted water and mycorrhiza applications on nutrients in grafted and untreated plants

Water application	N (Azot)(%)				
	Rootstocks				Average
	R 40	R R	GF 677	Garnem	
K_{100}	2.50 a	2.60 a	2.40 a	2.55 a	2.51 A
K_{55}	1.75 b	1.85 b	1.85 b	1.85 b	1.83 B
K_{40}	1.70 b	1.45 c	1.70 b	1.70 b	1.64 C
Ortalama	1.98	1.97	1.98	2.03	
$LSD_{(0.05)\ rootstock:}$ 0.013 $LSD_{(0.05):\ irrigation:}$ 0.088 $LSD_{(0.05)\ rootstockxirrigation:}$ 0.256					

Water application	P(Fosfor)(%)				
	Rootstocks				Average
	R 40	R R	GF 677	Garnem	
K_{100}	0.18 a	0.18 a	0.18 a	0.17 ab	0.18 A
K_{55}	0.11 abcd	0.11 abcd	0.17 ab	0.09 cd	0.12 B
K_{40}	0.10 bcd	0.07 d	0.15 abc	0.08 d	0.10 C
Ortalama	0.13 B	0.12 B	0.17 A	0.11 B	
$LSD_{(0.05)\ rootstock:}$0.030 $LSD_{(0.05)irrigation:}$ 0.023 $LSD_{(0.05)rootstockxirrigation:}$0.068					

Water application	K (Potassium) (%)				
	Rootstocks				Average
	R 40	R R	GF 677	Garnem	
K_{100}	1.32 ab	1.40 a	1.38 a	1.25 bc	1.34 A
K_{55}	1.30 ab	1.30 ab	1.19 cd	1.09 d	1.22 B
K_{40}	0.12 f	0.97 e	0.88 e	0.90 e	0.72 C
Ortalama	0.91 D	1.22 A	1.15 B	1.08 C	
$LSD_{(0.05)}$:$_{rootstock:}$ 0.043 $LSD_{(0.05)}$: $_{irrigation:}$0.034 $LSD_{(0.05)}$: $_{rootstockxirrigation:}$0.098					

Water application	Ca (Calcium) (%)				
	Rootstocks				Average
	R 40	R R	GF 677	Garnem	
K_{100}	1.32 ab	1.35 a	1.29 b	1.21 c	1.29 A
K_{55}	1.29 b	1.16 d	1.21 c	1.17 cd	1.21 B
K_{40}	1.28 b	1.08 e	1.09 e	1.14 d	1.15 C
Ortalama	1.30 A	1.20 B	1.20 B	1.17 C	
$LSD_{(0.05)rootstock:}$ 0.028 $LSD_{(0.05)irrigation}$ 0.023 $LSD_{(0.05)rootstockxirrigation:}$0.068					

Water application	Mg (Magnesium)(%)				
	Rootstocks				Average
	R 40	R R	GF 677	Garnem	
K_{100}	0.27 a	0.26 ab	0.29 a	0.26 ab	0.27 A
K_{55}	0.24 ab	0.26 ab	0.22 ab	0.25 ab	0.24 AB
K_{40}	0.25 ab	0.19 b	0.23 ab	0.21 ab	0.22 B
Ortalama	0.25	0.24	0.25	0.24	
$LSD_{(0.05)rootstock:}$0.035 $LSD_{(0.05)}$ irrigation: 0.027 $LSD_{(0.05)rootstockxirrigation:}$0.080					

application, the lowest phosphorus concentration was found in plants grafted with GF 677 rootstock (0.11%). In the K100 application, the lowest potassium concentration was observed in plants grafted with GF 677 rootstock (0.28%).

With an increase in water stress in plants, there was a decrease in calcium concentration. In the K40 application, the highest calcium concentration was observed in plants grafted with Garnem rootstock (1.28%), while the lowest concentration was obtained in plants grafted with GF 677 rootstock (1.19%). Similarly, in the K40 application, the highest magnesium concentration was observed in plants grafted with R rootstock (0.34%), while the lowest concentration was found in plants grafted with GF 677 rootstock (0.18%) (Table 6).

These results indicate that the effect of restricted water and mycorrhiza treatments on leaf nutrient concentrations is not significantly influenced by the different rootstocks used in the study.

In the K40 application, the lowest nitrogen concentration (1.65%) was determined in plants grafted with Garnem rootstock. With an increase in water stress in plants, phosphorus and potassium concentrations decreased. The highest phosphorus concentration (0.10%) and potassium concentration (1.25%) were obtained in the K40 application with R 40 rootstock. The lowest potassium concentration (0.18%) was determined in plants grafted with GF 677 rootstock (Table 7).

In terms of phosphorus and calcium values in the K40 application, there was no significant difference between rootstocks. The amount of calcium decreased with an increase in water stress in plants. In the K40 application, the highest calcium concentration was observed in Garnem rootstock (1.20%), while the lowest calcium concentration was determined in GF 677 rootstock (1.09%).

With an increase in water stress in plants, the magnesium concentration decreased. The highest magnesium concentration in the K40 application was obtained in plants grafted with GF 677 rootstock (0.21%).

The studies mentioned by Calıskan *et al*. (2017), Akpınar and Ortas (2020), and Guissou *et al*.

Table 6. Effect of restricted water applications on nutrients in ungrafted and mycorrhizal plants

	N (Nitrogen)(%)				
	Rootstocks				
Water application	R 40	R R	GF 677	Garnem	Average
K_{100}	1.90 d	2.20 bc	2.10 cd	2.15 bc	2.09 B
K_{55}	2.35 ab	2.30 abc	2.20 bc	2.33 ab	2.30 A
K_{40}	2.48 a	2.33 ab	2.25 abc	2.20 bc	2.32 A
Avarage	2.24	2.28	2.18	2.23	
$LSD_{(0.05)rootstock:}$0.035 $LSD_{(0.05)}$ irrigation: 0.027 $LSD_{(0.05)rootstockxirrigation:}$ 0.080					

	P (Phosphorus)(%)				
	Rootstocks				
Water application	R 40	R R	GF 677	Garnem	Average
K_{100}	0.16 cd	0.18 ab	0.16 cd	0.19 a	0.173 A
K_{55}	0.17 bc	0.19 a	0.18 ab	0.19 a	0.183 A
K_{40}	0.19 a	0.19 a	0.11 e	0.14 d	0.158 B
Avarage	0.17 B	0.19 A	0.15 C	0.17 B	
$LSD_{(0.05)rootstock:}$0.035 $LSD_{(0.05)}$ irrigation:0.027 $LSD_{(0.05)\ rootstockxirrigation:}$ 0.080					

	K (Potassium) (%)				
	Rootstocks				
Water application	R 40	R R	GF 677	Garnem	Average
K_{100}	1.29 a	1.31 a	1.27 a	1.25 a	1.28 A
K_{55}	1.31 a	1.35 a	1.29 a	1.27 a	1.31 A
K_{40}	1.34 a	1.34 a	0.28 b	1.35 a	1.08 B
Avarage	1.31 A	1.33 A	0.95 B	1.29 A	
$LSD_{(0.05)\ rootstock:}$ 0.035 $LSD_{(0.05)\ irrigation:}$ 0.027 $LSD_{(0.05)\ rootstockxirrigation:}$0.080					

Water application	Ca (Calcium)(%) Rootstocks R 40	R R	GF 677	Garnem	Average
K_{100}	1.26 abc	1.28 ab	1.24 abcd	1.30 a	1.27 A
K_{55}	1.24 abcd	1.25 abcd	1.22 bcd	1.25 abcd	1.24 B
K_{40}	1.20 cd	1.27 ab	1.19 d	1.28 ab	1.24 B
Avarage	1.23 B	1.27 A	1.22 B	1.28 A	

$LSD_{(0.05): rootstock:}$ 0.035 $LSD_{(0.05)}$: $_{irrigation:}$0.027 $LSD_{(0.05):rootstockxirrigation:}$0.080

Water application	Mg (Magnesium) (%) Rootstocks R 40	R R	GF 677	Garnem	Average
K_{100}	0.25 de	0.32 ab	0.29 bc	0.27 cd	0.28 A
K_{55}	0.20 g	0.29 bc	0.25 de	0.25 de	0.25 B
K_{40}	0.23 ef	0.34 a	0.18 g	0.20g	0.24 B
Avarage	0.23 B	0.32 A	0.24 B	0.24 B	

$LSD_{(0.05): rootstock:}$0.035 $LSD_{(0.05): rootstock:}$ 0.027 $LSD_{(0.05)rootstockxirrrigation:}$0.080

Table 7. The effect of restricted water applications on nutrients in ungrafted and non-mycorrhizal plants

Water application	N (Nitrogen)(%) Rootstocks R 40	R R	GF 677	Garnem	Average
K_{100}	2.30 bc	2.40 b	2.70 a	2.85 a	2.56 A
K_{55}	1.95 def	2.30 bc	1.90 efg	2.15 cd	2.08 B
K_{40}	1.85 fgh	2.10 cde	1.70 gh	1.65 h	1.83 C
Average	2.03 B	2.27 A	2.10 B	2.22 A	

$LSD_{(0.05)\ rootstock:}$ 0.035 $LSD_{(0.05)}$ sulama 0.027 $LSD_{(0.05)}$ anaçxsulama: 0.080

Water application	P(Phosphorus)(%) Rootstocks R 40	R R	GF 677	Garnem	Average
K_{100}	0.19 a	0.18 a	0.16 ab	0.15 abc	0.17 A
K_{55}	0.10 cd	0.11 bcd	0.10 cd	0.09 de	0.10 B
K_{40}	0.10 cd	0.08 def	0.05 f	0.06 ef	0.07 C
Average	0.13 A	0.12	0.11 B	0.10 B	

$LSD_{(0.05)}$ anaç: 0.035 $LSD_{(0.05)}$ sulama: 0.027 $LSD_{(0.05)}$ anaçxsulama: 0.080

Water application	K(Potassium) (%) Rootstocks R 40	R R	GF 677	Garnem	Average
K_{100}	1.38 a	1.28 abc	1.32 ab	1.25 bc	1.31 A
K_{55}	1.28 abc	1.25 bc	1.30 ab	1.18 cd	1.25 B
K_{40}	1.25 bc	1.09 d	0.18 f	0.92 e	0.86 C
Average	1.30 A	1.20 B	0.93 D	1.12 C	

$LSD_{(0.05)}$ anaç: 0.035 $LSD_{(0.05)}$ sulama: 0.027 $LSD_{(0.05)}$ anaçxsulama: 0.080

Water application	Ca (Calcium) (%) Rootstocks R 40	R R	GF 677	Garnem	Average
K_{100}	1.22 abcde	1.26 abc	1.30 a	1.27 ab	1.26 A
K_{55}	1.18 cde	1.23 abcd	1.17 de	1.14 ef	1.18 B
K_{40}	1.16 def	1.15 def	1.09 f	1.20 bcde	1.15 C
Average	1.19	1.21	1.19	1.20	
$LSD_{(0.05)}$ anaç: 0.035	$LSD_{(0.05)}$ sulama: 0.027	$LSD_{(0.05)}$ anaçxsulama: 0.080			

Water application	Mg (Magnesium) (%) Rootstocks R 40	R R	GF 677	Garnem	Average
K_{100}	0.23 bcde	0.30 a	0.21 cde	0.28 ab	0.26 A
K_{55}	0.21 cde	0.23 bcde	0.25 abcd	0.26 abc	0.24 A
K_{40}	0.20 de	0.18 e	0.21 cde	0.18 e	0.19 B
Ortalama	0.21 B	0.24 A	0.22 AB	0.24 A	
$LSD_{(0.05)}$ anaç: 0.035	$LSD_{(0.05)}$ sulama: 0.027	$LSD_{(0.05)}$ anaçxsulama: 0.080			

(2016) highlight the positive effects of mycorrhiza applications on plant nutrient uptake and growth. These studies show that mycorrhiza inoculation can enhance the bioavailability and transport of essential nutrients such as nitrogen, phosphorus, and potassium by plants. This increased nutrient uptake can lead to improved plant growth and development.

In particular, mycorrhiza applications were found to significantly increase phosphorus and zinc uptake in banana plants (Akpınar and Ortas, 2020). Similarly, tamarind and jujube plants exhibited greater shoot length and dry weight when treated with mycorrhiza, along with increased contents of nitrogen, phosphorus, and potassium (Guissou et al., 2016). These findings align with the observations in the current study, where mycorrhiza applications appear to positively affect the uptake of macronutrients like nitrogen and phosphorus.

Moreover, the mentioned studies also emphasize the importance of mycorrhiza in improving nutrient utilization by plants. They suggest that mycorrhiza can help mitigate the global problem of low phosphorus availability for plants, which often limits crop productivity. Additionally, the studies caution against over-fertilization, which can lead to the accumulation of unused phosphorus in the soil.

Overall, the findings from these previous studies support and corroborate the positive effects of mycorrhiza applications on nutrient uptake and plant growth observed in the current study.

CONCLUSION

The concentration of N, P, K, Ca and Mg in plant tissues decreased with water stress. The results indicate that mycorrhizal inoculation can enhance nutrient absorption in plants, particularly under water-restricted conditions, potentially contributing to improved plant resilience and performance in challenging environments.

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

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

Guava (*Psidium guajava* L.) can be propagated by seeds and vegetative means. Seed-propagated plants start bearing fruits in 6-8 years with variation in fruit yield and quality, whereas vegetatively propagated ones are precocious in bearing (3-4 years after planting) and produce uniform fruits (Bose *et al.*, 1986). Vegetative propagation in guava is done by layering, grafting, and budding in different parts of India (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 the variety, types of plant material, and time of operation (Sharma *et al.,* 1975; Dod *et al.,* 1998; Tomar, 2016). Since multiplication of desired genotype through air layering under sub-humid conditions in the southern plains of Rajasthan is not carried out to meet the demand, an experiment was conducted.

MATERIALS AND METHODS

The experiment was conducted at Rajasthan College of Agriculture, Udaipur, Rajasthan, from June to December. Fifteen genotypes, namely 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 utilized.

In July, a total of 100 air-layerings were performed on each mother plant of 5-6 years old, resulting in a total of 1500 layers. Healthy shoots, approximately one year old, were selected for the process. A ring of bark, about 1.5-2 cm wide between two nodes, was carefully removed from each selected shoot using two circular cuts with a sharp knife. The exposed portion was then covered with a handful of moistened sphagnum moss, previously soaked in water for 2-3 hours. A piece of polyethylene sheet (150 gauges) was used to wrap around the operated portion, holding the moss in place. Plastic strips were firmly tied at both ends to secure the wrapping.

The layers were separated from the plant when roots became visible through the polythene sheet. After detachment, the polythene sheet was unwrapped, and the layers were treated with copper oxychloride (COC) at a rate of 3 g per liter. Following shoot pruning, the layers were planted in polythene bags (10 cm x 15 cm).

Observations were recorded on the following parameters:

1. Days taken for root initiation
2. Percentage of air layers rooted
3. Root characteristics (number of secondary roots, length of the longest root, diameter of the longest root, fresh weight, and dry weight of roots)

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4. Root/shoot ratio (calculated as averaged root length (cm) divided by averaged shoot length (cm))
5. Vigour index (calculated as averaged root length (cm) + averaged shoot length (cm) multiplied by survival percentage)
6. Survival percentage after shifting to poly bags at 15 days and one month after shifting
7. Survival percentage recorded again at 15 days after shifting in poly bags.

RESULTS AND DISCUSSION

The genotypes had a significant effect on days taken to rooting, percent 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 vigor index.

Minimum days taken for root initiation were observed in Lalit (39 days), followed by Red Fleshed (40.60 days), while the maximum days taken for root initiation were in One-Kg (50 days). The probable reason might be due to the genetic makeup of varieties (vigorous, dwarf, and intermediate) and interaction with environmental factors. These findings are supported by Manna *et al.* (2001).

The 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 better to air layering due to genetic and physiological behavior. Better rooting occurs in layers when the shoot is physiologically mature and in the active sap flow stage, which varies with genotypes (Table 1). These results are analogous to the findings reported by Sarkar and Ghosh (2006).

Maximum number of secondary roots was recorded in L-49 (11.20), length of the longest root in Lalit (7.12 cm), diameter of the longest root in Pant Prabhat (1.11 mm), fresh weight (1508 mg) and dry weight (395 mg) in Lalit, and the minimum number of secondary roots (4.20), fresh weight (914 mg), and dry weight (196 mg) in One-Kg. Sarbati exhibited the longest root length (3.50 cm), and RCGH-1 had the smallest root diameter (0.54 mm) (Table 2, Fig. 1). The better root characteristics observed could be attributed to the genetic makeup of the genotypes, either alone or in combination with environmental factors, which may have contributed to a higher carbohydrate supply to the roots, resulting in better vegetative growth as evidenced by our study. Similar results were also reported by Ramteke *et al.* (1998) and Tripathi *et al.* (2018).

The root-to-shoot ratio showed significant differences among the varieties. The highest root-to-shoot ratio was observed in Shweta (1.24), followed by Lalit (1.19), and One-Kg (0.97). The greater root-to-shoot ratio in Shweta could be attributed to its

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

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

higher root growth, indirectly improving the root-to-shoot ratio. This finding is consistent with the study conducted by Vaghela and Sharma (2015).

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

The survival percentage of rooted air layers was highest in Lalit (81.40%), followed by Shweta (78.40%) and One-Kg (47.80%). Lalit air layers exhibited higher survivability, which could be attributed to the production of healthy, stout, and a greater number of secondary feeder roots. These roots not only support

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

Treatment	Genotypes	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 (5%)		2.547	26.998	2.695

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

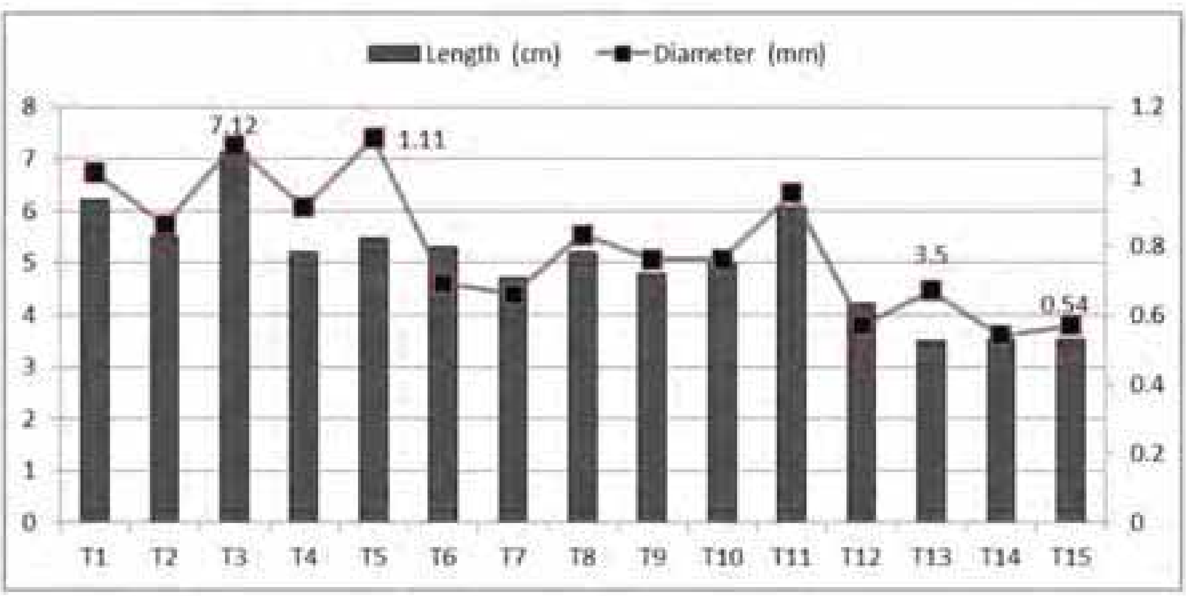

Fig. 1. Air layer's secondary root length and diameter of different guava genotypes

the uptake of water and nutrients from the media but also contribute to a higher survival percentage (Table 2). These findings are supported by Rehman *et al.* (2013) and Chand *et al*. (2018).

Lalit genotype recorded a higher vigor index (838.42), closely followed by Red Fleshed (697.37). This difference in vigor index might be due to variations in the nature of the varieties regarding growth, development, survivability, root-to-shoot ratio, and moisture uptake, which play a key role in enhancing the vigor index of polybag-shifted layers. This finding aligns with the studies conducted by Tripathi *et al*. (2018).

The maximum success rate was observed in Lalit (91.00%), followed by Shweta (88.00%) and One-Kg (58.00%). While there is no direct reference available to support these specific results, it is likely that Lalit's early root initiation, higher percentage of rooted air layers, higher root-to-shoot ratio, and vigor index contribute to the higher survival percentage of rooted air layers after shifting. These findings are in line with the studies by Chand *et al.* (2018) and Rehman *et al.* (2013).

CONCLUSION

The evaluation of guava genotypes for air layering demonstrated that Lalit genotype exhibited highest values for early root initiation, percentage of rooted air layers, survival percentage, and vigor index. The L-49 genotype had greatest number of secondary roots, while Shweta showed maximum root-to-shoot ratio. On the other hand, One-Kg genotype displayed a poor response to air layering. The response of guava genotypes to air-layering followed an overall trend as follows: Lalit (better) > Red Fleshed > Shweta > L-49 > Allahabad Safeda > Pant Prabhat > MPUAT S-1 > Arka Mridula > Sarbati > RCGH-1 > Burfkhan > Arka Amulya > MPUAT S-2 > Safed Jam > One-Kg (poor).

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Studies of different growth stages of wood apple (*Feronia limonia*) through extended BBCH-scale under rainfed semi-arid conditions of western India

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ABSTRACT

Twenty-eight genotypes of wood apple (*Feronia limonia* L.) were studies at CHES, ICAR (CIAH), Godhra, during 2017-2019. Eight principal growth stages of wood apple were found, starting from vegetative bud dormancy (stage 0) to maturity of fruit (stage 8). Three principal growth stages like stage 0, 1 and 3 are denoting to vegetative growth. Remaining stages (5, 6, 7 and 8) were reported to reproductive growth and development. The principle growth stages were divided in sub categorized called as secondary stages, which denoting the shorter developmental intervals. The first digit of code in BBCH scale denotes the principle growth stage (0-8) and second digit defined by the meso stages (1 to n). The third digit is numerical value between 0-9 that refer to percentage development of buds, leaves, shoots, flowering, fruit development, fruit maturity and senescence.

Key Words: Semi-arid, Development stages, Extended BBCH-scale.

Wood apple grow well in rainfed semi-arid conditions (Singh *et al.,* 2020), (Hiwale, 2015). It can propagated by soft wood grafting and patch budding both in field as well as nursery conditions**.** The knowledge of timing of phenological events can help to get more stable yield with quality traits through improved management practices. Since there are no such specific information reported on its growth and development phases by which farmers can know what stage of plant is appropriate for proper cultural practice, the study was undertaken by using of BBCH-scale.

MATERIALS AND METHODS

A wood apple germplasm block was selected at Central Horticultural Experiment Station, ICAR-CIAH, Vejalpur, India, during 2017-19. The germplasm block was planted at 10m×10m spacing 13 years ago. The soil was clay loam. Average rainfall for three year study was about 620 mm and relative humidity 62%. The average annual temperature was 28.04^{0}C. The phenological stages were observed as per Gil-Albert (1989). The trees and branches were marked for study. One healthy trees of each germplasm was randomly selected, and three branches from each tree were studied. Three replicates of the experimental block were made.

For the collection of data and observation, frequency of visits ranged from 1 to 4 days in vegetative (bud break to shoot development) and fruiting stage (flowering to fruit set time) of trees and 7 days later stage of trees (fruit development to fruit ripening time), on the basis how quickly the wood apple trees showed their phenology. Fruit diameter (mm) was measured weekly with digital Varnier caliper. The duration of every phonological stage was observed in days starting at the beginning of bud development.

Three principal growth stages, 0, 1 and 3, denote to vegetative growth. Remaining stages (5, 6, 7 and 8) show reproductive growth and development. Rosette leaves (2), vegetative harvestable parts (4) and senescence (9) stages are not found in wood apple. The principle growth stages were sub categorized as secondary stages which denote the shorter developmental intervals. The first digit of code in BBCH scale denotes the principle growth stage (0-9) and second digit defined by the meso stage (1 to n).The third digit is numerical value between 0-9 that refer to percentage development of buds, leaves, shoots, flowering, fruit development, fruit maturity and senescence.

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Fig. 1: Flower morphology in wood apple

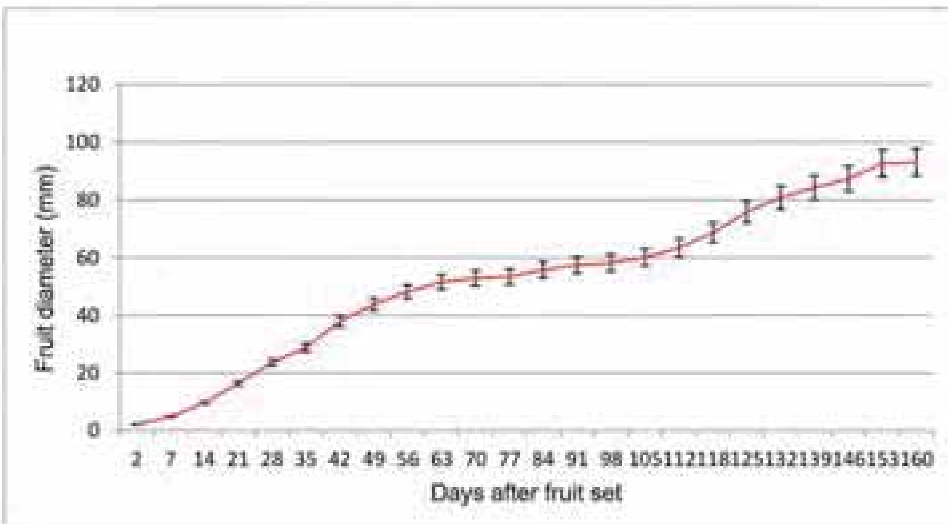

Fig. 2: Fruit growth in wood apple

RESULTS AND DISCUSSION

There were seven principle growth stages and 33 secondary growth stages. Fruit development start just after end of flowering and ovary also start to swelling (Fig. 1). The fruits showed the double sigmoid growth (Fig. 2), which starts from fruit set (711 stage) and end with full maturity (819 stage). The fruit growth is completed in 20-22 weeks with three distinct stages. The first stage was completed in 1-63 days with 51.56 mm fruit diameter. Fruit size increases in this stage mainly due to fruit cell division (Hopping, 1990). the maximum fruit growth was obtained in third stage (106-160days). It may be due accumulation of water and solutes within vacuoles and completion of this stage fruit attain maximum size (93.13mm).

The vegetative growth have three periodical events which start from growing of bud (010-019 stages), leaf (110-119 stages), and end with shoot (311-319 stages) development. During February-March, when temperature reach up to 25°c, auxiliary bud starts to growing (011stage) and after 7-9 weeks full shoot development is completed. The peak period of vegetative phase generally was occurred between Februarys and May. The vegetative stage normally completes in 18-22 weeks. Auxiliary bud break starts during spring month on first few nods of both new and old shoots. Different phonological events have been reported in bael (Singh *et al.*, 2015), wood apple (Singh *et al.*, 2016) and jamun (Singh *et al.*, 2022).

The flowers are mainly produced on terminal of new shoots and laterals of old shoot (Vijayvargiya and Vijayvergia, 2014). The inflorescence bud growth (510-519) start in March. The flowering (610-619 stages) continues up to June, but peak flowering occurs during March-April and lasts about 2-5 weeks. The greenish-reddish flowers born in small loose panicle and anthesis of all flower in panicle completed in 1-2 weeks. For high quality fruit yield, fertilizers should be applied in identified phonological stage like bud swelling (011) and fruit development (712-715 stages).

CONCLUSION

Thus, phonological stages would be helpful to increase yield with quality fruit at farmers' fields under rainfed semi-arid ecosystem. Application of farm input with considering BBCH scale also minimise the cost of cultivation, improving net income..

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Phenological development and production potential of different cultivars of holy basil (*Ocimum sanctum*) in lower hills of Uttarakhand

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ABSTRACT

The experiment was conducted to compare the phenological development and production potential of seven varieties of holy basil (*Ocimum sanctum* L.) at CSIR-Central Institute of Medicinal and Aromatic Plants Research Centre in Purara, Bageshwar, Uttarakhand, during 2018-19 and 2019-20. The varieties tested were CIM-Jyoti, CIM-Surabhi, CIM-Snigdha, CIM-Saumya, CIM-Ayu, CIM-Sharada, and CIM-Angna. The experiment followed a randomized block design with three replications. Among seven varieties tested, CIM-Ayu performed the best in terms of growth and yield parameters, except for plant height. CIM-Surabhi had highest seed yield, while CIM-Ayu had highest dry herb yield and oil production. By choosing CIM-Ayu, farmers can enhance their yield and improve overall crop production.

Key Words: Essential oil, Morphology, Growth, Plant height, Herb yield, Dry herb

Holy basil (*Ocimum sanctum* L.) has been utilized for its medicinal and economic value for centuries in the African and Asian subcontinents (Mathur *et al*., 2021). The Lamiaceae family contains around 150 species of holy basil known for their ability to treat various ailments (Singh *et al*., 2022). The tropical and subtropical climate of India is well-suited for growth and development of holy basil. Consequently, holy basil emerges as a viable option for farmers seeking to earn a steady income while minimizing their efforts and resources (Gupta *et al*., 2022). The present study aims to examine the varietal performance of holy basil in lower Himalayan range of Uttarakhand. Therefore, an experiment was conducted to evaluate the production potential of different varieties of holy basil.

MATERIALS AND METHODS

A field experiment was conducted at the CSIR-Central Institute of Medicinal and Aromatic Plant Research Centre in Purara, Bageshwar, Uttarakhand, during 2018-19 and 2019-20. The experiment aimed to compare the phenological development and production potential of seven varieties of holy basil: CIM-Ayu, CIM-Saumya, CIM-Surabhi, CIM-Sharada, CIM-Jyoti, CIM-Snigdha, and CIM-Angna. The experiment followed a randomized block design (RBD) with three replications in each year. On 15th May of each year, the seeds of all seven varieties were sown in a raised nursery bed, and seedlings were transplanted to the main field after 30 days. The crop was harvested 110 days after transplanting, and various growth and yield observations were recorded annually.

The gas-liquid chromatography (GLC) technique was employed to analyze the phytochemicals present in oil extracted from different varieties. Economic analyses, including the cost of cultivation, gross return, and net return, were conducted for both years. The statistical analysis of the data during both years was performed using the OPSTAT software (Sheoran, 2010).

RESULTS AND DISCUSSION

The average plant height (cm) recorded during both years was highest in CIM-Saumya variety

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(90.64 cm), followed by CIM-Jyoti (88.29 cm). The lowest average plant height was recorded in CIM-Snigdha (70.69 cm). In terms of average number of branches per plant, CIM-Ayu had the highest value (24.67), followed by CIM-Angna (15.00), while lowest value was recorded in CIM-Jyoti (10.00). CIM-Ayu also exhibited superior performance in terms of maximum average plant diameter (98.57 cm), whereas CIM-Jyoti had a mean value of 95.83 cm, and CIM-Surabhi had the lowest mean value of 38.84 cm. Additionally, CIM-Ayu had highest number of leaves/plant (1739.30), followed by CIM-Saumya (1504.40), and CIM-Angna (551.18). Therefore, CIM-Ayu outperformed other varieties in all growth and yield parameters except for plant height. (Table 1).

Pandu *et al*. (2013) reported a maximum height of CIM-Ayu as 73 cm, which is slightly lower than height recorded in the current study. Gupta *et al*. (2014) recommended that proper spacing could result in improved growth and yield.

Regarding seed yield, CIM-Surabhi had highest yield (873.33 kg/ha), followed by CIM-Ayu (620 kg/ha), while lowest seed yield was recorded in CIM-Jyoti (166.67 kg/ha). Moreover, CIM-Ayu exhibited highest dry herb yield (97.60 q/ha), followed by CIM-Saumya (75.40 q/ha), while lowest dry herb weight was observed in CIM-Jyoti (31.23 q/ha). Among varieties, CIM-Saumya, CIM-Surabhi, and CIM-Ayu yielded the highest oil (216.83, 155.34, and 133.71 kg/ha, respectively), compared to others. The lowest oil yield was recorded in CIM-Jyoti (31.07 q/ha) (Table 2). The herb and oil yield were strongly influenced by growth parameters such as plant height, number of branches/plant, plant diameter, and number of leaves/plant. The results indicate that cultivation of CIM-Ayu for dry herb production was the most profitable. These observations are consistent with Pandu *et al*. (2013) and Lal *et al*. (2018), who recorded the highest leaf yield in CIM-Angna. The plant diameter, number of branches/plant, and number of leaves/plant have a direct effect on both fresh and dry herb yield. The dry herb yield of other varieties was comparatively lower than CIM-Ayu, as they exhibited inferior growth and development.

Kumar *et al*. (2018) evaluated the highest yield and essential oil content in Krishna Tulsi (0.8%), while cultivar Rama Tulsi had highest fresh leaf yield (7.8 t/ha). Similarly, Singh *et al*. (2019) reported highest leaf yield and essential oil content in Vishnu Tulsi (0.8%), while Rama Tulsi had highest fresh leaf yield (8.9 t/ha). The cultivar Kapoor Tulsi exhibited a good balance between essential oil content and fresh leaf yield. These observations align with Lal *et al*. (2018) and Kuniyal *et al*. (2014), Kumar *et al.* (2016) recorded variations in vegetative and fruit characteristics in five varieties of *Emblica officinalis*, while Ram *et al.* (2023) evaluated the variation in nut quality in *Cocos nucifera*.

The average net return recorded during both years was highest in CIM-Ayu (₹179,000.00), followed by CIM-Saumya (₹123,500.00). The remaining varieties also yielded positive net returns. However, CIM-Angna had the lowest performance, with a net return of only ₹33,333.34. Therefore, it is not recommended for cultivation in the lower Himalayan region.

The hydro-distilled essential oil of holy basil revealed various constituents in different varieties. The highest percentage of linalool (77.6%) was recorded in CIM-Snigdha. Methylchavicol was dominantly present in CIM-Surabhi (74.1%), CIM-Saumya (75.2%), and CIM-Angna (78%). Variety CIM-Ayu had highest percentage of neral (32.2%) and geranial (41.7%). CIM-Sharada contained (Z)-Methyl cinnamate (11.1%) and (E)-Methyl cinnamate (70.8%), which were not present in other varieties. CIM-Jyoti had highest content of eugenol (22.7%), β-Elemene (9.7%), and β-Caryophyllene (10%). A similar study on chemical homogeneity was documented by Kumari *et al*. (2017) in CIM-Saumya, where they found that two major classes of secondary metabolites were present, namely phenylpropanoids (73–91%) and terpenoids (Sesquiterpene (4.3–17.9%) and monoterpene (1.21–3.3%)]. Methylchavicol (73–91%) was found to be one of the major constituents of phenylpropanoid. The oxygenated monoterpene linalool (2–3%) was present in all analyzed samples. Kaur *et al*. (2020) reported significant variations in chemical composition of oils from different varieties, which correlated with differences in aroma and flavour. This indicates that the varietal evolution of holy basil in Uttarakhand has led to the development of varieties with unique sensory properties that are highly valued in local and international markets.

Table 1. Plant growth, yield, and oil composition in different varieties of holy basil during 2018-19 and 2019-20.

Plant growth, yield and economics of cultivation

Treatment	Plant height (cm)	Number of branches/ plant	Plant diameter (cm)	Number of leaves /plant	Seed yield/ha (kg)	Dry herb yield/ha(q)	Oil yield/ ha(K/g)	*Net return/ ha (INR)	B:C ratio
T_1 (CIM-Jyoti)	88.29	10.00	95.83	586.37	166.67	48.27	31.07	55666.67	1.85
T_2 (CIM-Surabhi)	82.84	12.33	38.84	1323.83	873.33	71.33	155.34	113333.3	2.74
T_3 (CIM-Snigdha)	70.69	13.17	75.99	1205.55	373.33	42.13	72.84	40333.34	1.62
T_4 (CIM-Saumya)	90.64	10.50	60.77	1504.40	546.67	75.40	216.83	123500.00	2.9
T_5 (CIM-Ayu)	75.93	24.33	98.57	1739.30	620.00	97.60	133.71	179000.00	4.015
T_6 (CIM-Sharada)	83.39	11.67	77.95	907.66	493.33	57.13	49.20	77833.34	2.19
T_7 (CIM-Angna)	74.38	15.00	66.30	551.18	346.67	39.33	77.79	33333.34	1.512
SEM±	0.443	0.504	0.524	1.267	0.1633	0.1953	5.105	488.289	0.008
CD (0.05%)	1.365	1.554	1.615	3.905	0.5031	0.6018	15.730	1,521.23	0.023

*Based on dry herb production of basil; Selling Price of dried herb = Rs. 2500/Q, cost of cultivation- 65000.00 INR

Table 2. Composition of essential oils of different varieties

Treatment	Content (%)								
	Linalool	Neral	Geranial	(*Z*)-Methyl cinnamate	(*E*)-Methyl cinnamate	Eugenol	β-Elemene	β-Caryophyllene	Methyl Chavicol
T_1 (CIM-Jyoti)	0.9	1.2	0	0	0	22.7	9.7	10.0	0
T_2 (CIM-Surabhi)	18.4	0.7	0.9	0	0	0	T	0.3	74.1
T_3 (CIM-Snigdha)	77.6	T	0.2	0	0	0	0.2	0.2	0
T_4 (CIM-Saumya)	16.4	1.1	1.5	0	0	T	T	0.4	75.2
T_5 (CIM-Ayu)	0.7	32.2	41.7	0	0	0	0.1	1.1	0
T_6 (CIM-Sharada)	0.3	0	T	11.1	70.8	0	0.3	0.1	0
T_7 (CIM-Angna)	4.6	T	0	0	0	0	0.5	0.4	78.0
Total identified	118.9	35.2	44.3	11.1	70.8	22.7	10.8	12.5	227.3
T- Trace amount									

CONCLUSION

The CIM-Ayu variety is considered the most suitable. It exhibits superior performance in terms of dry biomass production. CIM-Saumya, is best choice for oil production due to its high oil yield. If seed production is the primary objective, CIM-Surabhi is recommended. Thus, basil oil production is most beneficial in areas located above 1,200 meters mean sea-level. Therefore, farmers in these regions should cultivate holy basil for oil and dry herb production, while seed production can also be pursued but with a lower priority.

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Effect of varieties and planting dates on yield-attributing characters in onion (*Allium cepa*)

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ABSTRACT

The experiment was conducted at farmers' fields during 2020-21 season to evaluate the effects of varieties and planting dates on onion (*Allium cepa* L.) yield parameters. The highest bulb yield was recorded in T_3, followed by T_4, T_2, and T_1. Similarly, D_2 exhibited the highest yield, followed by D_3 and D_1. T4 also resulted in the maximum plant height, average bulb weight, and bulb diameter. The planting date significantly influenced bulb weight and plant height. Consequently, T_3 (PRO-6) demonstrated the highest benefit-to-cost ratio and yield, followed by T_4 (PRO-7), T_2 (Punjab Naroya), and T_1 (farmers' practices). Among planting dates, D_2 yielded the highest, with a benefit: cost ratio of 4.58, followed by D_1 (4.42) and D_3 (4.35). The combined effects indicate that PRO-6, along with a planting date of January 1st, resulted in maximum yield and profit.

Key Words: Planting date, Bulb yield, Economics, Farmers' fields, Plant height, Profit

Onion (*Allium cepa* L.) is a cross-pollinated crop with a diploid chromosome number of 2n = 16. It is widely cultivated in the S.A.S. Nagar (Mohali) district of Punjab during the *rabi* season. The successful production of onions relies on selecting varieties that are well-suited to different climatic conditions (Choudhary *et al*., 2022). Inappropriate selection of varieties and planting dates can result in lower onion production. The planting date affects the impact of soil and environmental factors on growth, yield, and bulb quality, which vary significantly from region to region (Kandil *et al*., 2013). Due to its high sensitivity to photoperiod and temperature, onion has limited adaptability to different parts of the world. Therefore, performance and stability of onion varieties in specific environmental conditions need to be analyzed (Sharma, 2009). Hence, an experiment was conducted to determine the best variety and planting date in S.A.S. Nagar (Mohali) district of Punjab.

MATERIALS AND METHODS

The experiment was conducted at five different locations at farmers' fields during *rabi* 2020-21 season. Each experiment covered an area of one acre. The soil at the experimental sites was loose, deep, and sandy loam. A factorial randomized block design (RBD) was employed, with four varieties: T_1 (farmers' practice/local variety), T_2 (Punjab Naroya), T_3 (PRO-6), and T_4 (PRO-7) as factor one, and three planting dates: D_1 (December 15th), D_2 (January 1st), and D_3 (January 15th) as factor two. Observations were made on growth, yield, and economic parameters. The crop was cultivated following recommended practices, with a seeding rate of 5 kg/acre and a spacing of 15 cm between ridges and 7.5 cm between plants.

Data collection involved randomly selecting five plants from each replication within each experimental plot to record observations such as days to harvesting, bulb diameter, number of leaves/plant, bulb weight, plant height, and bulb yield. The days to harvesting were calculated as the number of days from planting to first harvesting.

The cost of cultivation and gross returns were calculated using prevailing market prices. The benefit: cost ratio (BCR) was calculated using the formula: BCR = gross return (Rs/ha) / total cost of cultivation (Rs/ha). Statistical analysis was performed as per Panse and Sukhatme (1985).

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RESULTS AND DISCUSSION

The varieties had a significant effect on number of days taken to harvesting, with variety T_4 being the earliest (118 days), followed by T_3 (121 days), T_2 (128 days), and T_1 (144 days). The planting dates did not have a significant effect on days taken to harvesting. Specifically, variety PRO-7 exhibited the shortest time to harvesting compared to other varieties. These findings align closely with the studies conducted by Tesfaye *et al*. (2018) and Fufa *et al*. (2021), suggesting that genetic factors and inherited traits contribute to early acclimatization and improved growth and development.

Regarding bulb diameter, the varieties had a significant effect, while the planting date did not. Variety T_4 had the largest bulb diameter (5.05 cm), followed by T_3 (5.03 cm), T_2 (4.31 cm), and T_1 (4.19 cm). These variations among varieties can be attributed to their genetic backgrounds, which strongly influence growth potential of plants. The morphological and biochemical characteristics specific to each onion variety may also play a role in determining bulb size (Fufa *et al*., 2021). Similar findings have been reported by Bosekeng and Coetzer (2015) and Misu *et al*. (2018).

Variety significantly influenced the number of leaves/plant, while planting date did not. Variety T_4 recorded the highest number of leaves/plant (11.53), followed by T_3 (11.30), T_2 (9.77), and T_1 (8.86). The variety with highest number of leaves/plant also exhibited greater plant height, larger bulb diameter, and earlier harvesting. Similar results were reported by Ashagrie *et al*. (2021).

Both varieties and planting dates had a significant effect on weight of bulbs. Among varieties, T_3 exhibited highest weight of bulbs (72.40 g), followed by T_4 (71.56 g), T_1 (70.12 g), and T_2 (64.39 g). Regarding planting dates, highest weight of bulbs was recorded in D_1 (70.37 g), followed by D_3 (69.64 g), and D_2 (68.84 g). The performance potential of different onion varieties depends on interaction between their genetic make-up and the environment. These findings align with those of Misu *et al*. (2018).

Varieties and planting dates also had a significant effect on plant height. Variety T_4 exhibited the tallest plant height (45.11 cm), followed by T_3 (41.73 cm), T_2 (39.27 cm), and T_1 (34.11 cm). Among the planting dates, D_1 recorded the maximum plant height (40.73 cm), followed by D_3 (40.52 cm), and D_2 (38.93 cm). Similar results were reported by Kandil *et al*. (2013), Ashagrie *et al*. (2021), and Fufa *et al*. (2021). The decrease in plant height can be attributed to rigorous cell division and expansion, which are influenced by protein synthesis. Therefore, variations in cell metabolism can affect plant height (Sharma *et al*., 2016).

There was a significant effect on yield as well. T_3 exhibited the highest yield (388.32 q/ha), followed by T_4 (365.82 q/ha), T_2 (353.90 q/ha), and T_1 (303.05 q/ha). Among the planting dates, maximum yield was recorded in D_2 (362.92 q/ha), followed by D_3 (351.25 q/ha), and D_1 (346.67 q/ha). Similar results were reported by Kandil *et al*. (2013), Rugi *et al*. (2018), Choudhary *et al*. (2022), and Singh *et al*. (2022). The higher yield of PRO-6 was primarily attributed to the increased weight of bulbs and plant height.

Table 1: Effect of varieties and planting dates on yield-contributing characters

Treatment	Days taken to harvesting	Bulb diameter (cm)	No. of leaves/ plant	Weight of bulb (g)	Plant height (cm)	Yield (q/ha)
T_1	144.56	4.19	8.86	70.12	34.11	303.05
T_2	128.44	4.31	9.77	64.39	39.27	353.9
T_3	121.00	5.03	11.30	72.40	41.73	388.32
T_4	118.44	5.05	11.53	71.56	45.11	365.82
S E(m)	1.09	0.09	0.17	0.44	0.57	0.85
CD@0.05	3.25	0.28	0.50	1.28	1.69	2.50
D_1	128.50	4.6	10.48	70.37	40.73	346.67
D_2	127.00	4.56	10.22	68.84	38.93	362.92
D_3	128.83	4.77	10.39	69.64	40.52	351.25
S E(m)	0.95	0.08	0.15	0.38	0.50	0.73
CD@0.05	NA	NA	NA	1.11	1.47	2.06

Bulb yield is the result of the interaction between the variety and specific agroclimatic conditions and crop management factors. Additionally, planting date played a role in determining the yield as it influenced the suitable environmental conditions required for the proper growth and development of plants.

Among varieties, treatment T_3 yielded a net return of ₹6,14,150/ha with a B:C ratio of 4.78:1. Treatment T_4 yielded a net return of ₹5,70,400/ha with a B:C ratio of 4.54:1, T_2 yielded ₹5,50,300/ha with a B:C ratio of 4.49:1, and T_1 yielded ₹4,49,850/ha with a B:C ratio of 3.88:1. The total cost of production was highest for treatment T_3 (₹1,62,500/-), followed by T_4 (₹1,61,250/-), T_2 (₹1,57,500/-), and the farmers' practice (₹1,56,250/-). Gross returns were highest for T_3 (₹7,76,650/-), followed by T_4 (₹7,31,650/-), T_2 (₹7,07,800), and the farmers' practice (₹6,06,100/-).

Regarding planting dates, D_2 recorded the maximum net returns (₹5,67,350/-) with a B:C ratio of 4.58, followed by D_3 (₹5,41,100/-) with a B:C ratio of 4.35, and D_1 (₹5,36,475/-) with a B:C ratio of 4.42. These results are consistent with the findings of Rugi *et al*. (2018) and Poovamma *et al*. (2021).

CONCLUSION

PRO-6 variety demonstrated highest B:C ratio and yield, followed by PRO-7, Punjab Naroya, and farmers' practice. Among planting dates, D_2 resulted in highest yield and B:C ratio (4.58), followed by D_1 (4.42) and D_3 (4.35). The combined effects indicate that PRO-6 variety, along with planting on 1st of January, resulted in maximum yield and profitability.

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Effect of glycerine on drying of cut foliage of silver oak (*Grevillea robusta*)

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ABSTRACT

The study was undertaken to evaluate the impact of glycerine on drying process of cut foliage of silver oak (*Grevillea robusta* L.). Two methods of glycerinisation, namely uptake and full dip, were used, and different concentrations of glycerine (10%, 20%, and 40%) were tested. The overall acceptability of dried foliage was assessed, with a higher score indicating better quality. The results showed that full dip method achieved the highest score for overall acceptability (3.36) compared to uptake method. Among concentrations of glycerine, 40% was identified as the optimum for drying process. The maximum score obtained for overall acceptability of dried foliage was 4.98, indicating a relatively high level of satisfaction with quality. Using the full dip method and a glycerine concentration of 40% can result in dried foliage with good overall acceptability. These findings can be useful for improving the drying process of silver oak foliage and enhancing its quality for various applications.

Key Words: Glycerinisation, Dry flowers, Brittleness, Full dip method, Acceptability

Dried or dehydrated plant parts are cost-effective and offer an everlasting charm (Mir and Jana, 2015). Glycerinisation results in flexible and pliable foliage, even though the stems and leaves may turn brown during the process (White *et al*., 2007). Compared to other drying techniques, glycerinisation is considered superior method for drying various types of foliage (Jhanji *et al*., 2018; Mondal *et al*., 2018). It yields fresh-looking results and maintains the flexibility and pliability of plant materials. Therefore, an experiment was conducted on silver oak (*Grevillea robusta* L.) to explore their potential use in creating dry flower products.

MATERIALS AND METHODS

The experiment was conducted at the Department of Floriculture and Landscape Architecture, Dr Y S Parmar University of Horticulture and Forestry, Nauni, Solan, during 2016-17. The experimental design used was a completely randomized design with a factorial arrangement of treatments.

Leaves of *Grevillea robusta* were harvested from mature plants, and leaf samples measuring 15 cm in length were taken for preservation. Two methods of glycerinisation were employed: the uptake method and full dip method. Different concentrations of glycerine (10%, 20%, and 40%) were used. To prevent fungal and bacterial infections on treated leaves, Carbendazim, mancozeb, and Streptocycline were added to glycerine solutions.

The observations and assessments were conducted during the experiment. These included measuring the percentage change in leaf weight (Ranganna, 1977), the percentage change in leaf area, membrane integrity (Leopold *et al*., 1981), chlorophyll content, and quality parameters such as texture, brittleness (Peryam, 1957), and shape retention, and overall acceptance (Vishnupriya, 2011). Sensory evaluation was performed by scoring the observations on a five-point scale ranging from excellent to very poor. The data were analyzed as per (Panse and Sukhatme, 1985).

RESULTS AND DISCUSSION

The application of glycerine did not have significant effect on change in leaf weight and leaf area. However, foliage treated with 40% glycerine (T_4) showed the best results in terms of weight gain, with a decrease of 10.62%. On the other hand, foliage kept in distilled water (T_1) exhibited highest weight loss of 44.16%. The higher concentration of glycerine in T_4 may have resulted in greater weight gain due to increased uptake and moisture content. Glycerine replaces moisture through capillary action

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when leaves are subjected to the uptake method and through the leaf surface in the full dip method (White *et al*., 2007). (Table 1).

Regarding leaf area, foliage treated with 40% glycerine (T_4) showed the least change in leaf area (1.42%), while maximum change in leaf area (6.07%) was observed when leaves were kept in distilled water (T_1). In the uptake method (M_1), leaves treated with 40% glycerine (T_4) exhibited the minimum change in leaf area (1.72%), while foliage kept in distilled water (T_1) showed maximum change in leaf area (5.56%). In full dip method (M_2), minimum change in leaf area (1.12%) was recorded when treated with a 40% glycerine solution (T_4), and maximum change in leaf area (6.58%) was observed in the control group (T_1), where leaves were kept in distilled water. As leaves lose water, the cellular turgor pressure decreases, leading to separation of cell membrane from cell wall. Eventually, collapse of cell wall results in deformations, folds, and subsequent shrinkage of the leaf (Vicre *et al*., 2004). After a critical point is reached cell wall collapses resulting in deformations, folds, and subsequent shrinkage of leaf (Kramer and Boyer, 1995). Maximum change in leaf area in leaves kept in distilled water may be attributed to high dehydration and shrinkage of leaf tissue. Simultaneous replacement of water loss with glycerine uptake in leaves treated with glycerine resulted in less change in leaf area.

In terms of membrane integrity, foliage treated with 40% glycerine (T_4) using uptake method (M_1) showed better membrane integrity compared to full dip method (M_2), with a leachate percentage of 90.21% and 92.04% respectively. The foliage treated with 40% glycerine (T_4) produced the best results in terms of membrane integrity, with a leachate percentage of 87.63%. In contrast, foliage kept in distilled water (T_1) exhibited a higher leachate percentage (92.84%), which was similar to T_3 (91.63%). The higher percentage of leachate in leaves with greater moisture loss is due to increased cell injury. The damage to cell membranes under conditions of water loss leads to increased permeability and leakage of ions (Bajji *et al*., 2001; Surendar *et al*., 2013).

The leaves treated with the uptake method (M_1) exhibited higher chlorophyll 'a' (1.86 mg/g and 0.85 mg/g), chlorophyll 'b' (2.685 mg/g and 1.350 mg/g), and total chlorophyll (2.376 mg/g and 1.190 mg/g) content compared to leaves treated with full dip method (M_2). When the leaves were kept in distilled water (T_1), they showed higher chlorophyll 'a' content (1.98 mg/g), which was similar to T_2 (1.29 mg/g). When leaves were treated with 10% glycerine (T_2), they exhibited higher chlorophyll 'b' (2.175 mg/g) and total chlorophyll (1.915 mg/g) content. However, when leaves were treated with a 40% glycerine solution, they showed lower chlorophyll 'a' content (1.06 mg/g), while leaves treated with distilled water showed lower chlorophyll 'b' content (1.715 mg/g) and total chlorophyll content (1.512 mg/g).

The chlorophyll content of leaves may vary depending on their age. The addition of glycerol increases the rate of chlorophyll degradation (Lajolo and Marquez, 1982). The minimum change in chlorophyll concentration may be due to minimal water loss, as chlorophyll is an oily pigment. The lower chlorophyll content in leaves treated with glycerine may be attributed to higher dehydration. High dehydration can lead to the decomposition of chloroplasts and the disappearance of thylakoid membranes, resulting in discoloration due to the leaching of pigments. Additionally, the pigments may still be present in the leaves but may have diffused due to senescence (Surendar *et al*., 2013).

The uptake method (M_1) was found to be superior compared to the full dip method (M_2) in terms of brittleness (4.11 and 3.69) and overall acceptance (3.50 and 3.36). However, there was no significant difference observed in texture and shape retention of dried leaves among different glycerine application methods. (Figs 1 and 2).

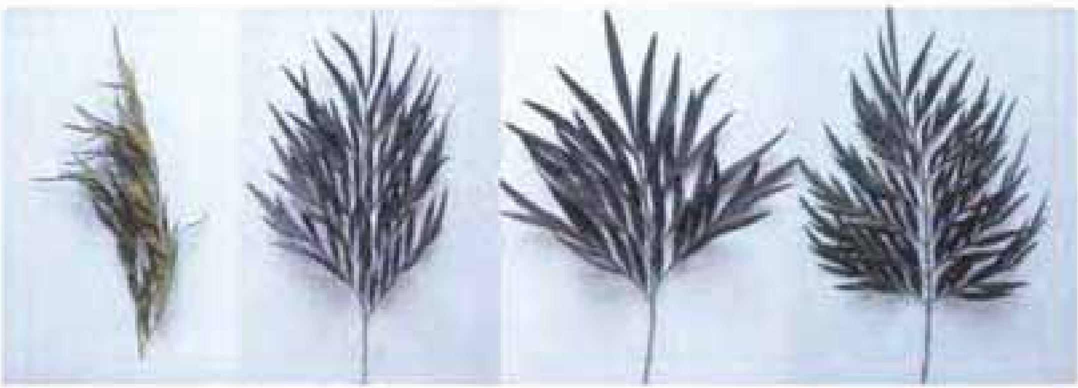
Among different treatments in uptake method (M_1), the foliage treated with 40% glycerine (T_4) obtained the highest scores for texture (4.89), shape retention (5.00), brittleness (5.00), and overall acceptance (4.97). On the other hand, leaves kept in distilled water (T_1) received the lowest scores for texture (1.00), shape retention (1.00), brittleness (3.00), and overall acceptance (1.67). Similar results were observed in full dip method (M_2), where foliage treated with a 40% glycerine solution (T_4) obtained the highest scores (5.00) for texture, shape retention, brittleness, and overall acceptance.

The cut foliage treated with a high concentration of glycerine appeared smooth and glossy, which is consistent with the findings of Day (2000). The treated leaves retained their shape to a great extent, and they were soft, pliable, and long-lasting. Other studies have also highlighted the softness, natural

Table 1: Sensory score (texture, shape retention, brittleness and overall acceptance) for foliage under different methods

Glycerine concentration (C)	Texture (5)			Shape retention (5)			Brittleness (5)			Overall acceptance (5)		
	Method of glycerine treatment (M)											
	M_1	M_2	Mean	M_1	M_2	Mean	M_1	M_2	Mean	M_1	M_2	Mean
T_1 : Control (distilled water)	1.00	1.00	1.00	1.00	1.00	1.00	3.00	2.00	2.50	1.67	1.33	1.50
T_2 : 10% glycerine	3.00	3.11	3.05	1.67	1.78	1.72	3.78	3.00	3.39	2.81	2.63	2.72
T_3 : 20% glycerine	4.78	4.33	4.55	4.22	4.33	4.27	4.66	4.78	4.72	4.56	4.48	4.51
T_4 : 40% glycerine	4.89	5.00	4.94	5.00	5.00	5.00	5.00	5.00	5.00	4.97	5.00	4.98
Mean	3.41	3.36		2.97	3.02		4.11	3.69		3.50	3.36	
$CD_{0.05}$	M		: NS	M		:NS	M		:0.13	M		: 0.05
	C		:0.14	C		:0.12	C		: 0.19	C		: 0.07
	C x M		:0.20	C x M		: NS	C x M		:0.26	C x M		: 0.11

M_1, Uptake method; M_2, full dip method



Control (distilled water) 10% glycerine 20% glycerine 40% glycerine

Fig.1. Leaves treated by uptake method

Control (distilled water) 10% glycerine 20% glycerine 40% glycerine

Fig.2. Leaves treated by full dip method

appearance, minimal moisture loss, and maximum color and shape retention of leaves treated with glycerine (Visalakshi and Jawaharlal, 2014).

Treating foliage with glycerine yields unique results, as it allows the leaves to remain flexible, pliable, and retain their natural shapes indefinitely. Glycerine-dried foliage can be utilized in various applications such as dry flower arrangements, bouquets, and the preparation of greeting cards.

CONCLUSION

The study suggests that the full dip method of glycerine application was better compared to the uptake method. Additionally, the optimal concentration of glycerine for drying the cut foliage was found to be 40%. This concentration resulted in favorable outcomes in terms of texture, shape retention, brittleness, and overall acceptance of the dried foliage.

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Response surface modeling of low-cost pneumatic nursery protray seeder parameters for tomato (*Solanum lycopersicum*) seedlings

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ABSTRACT

The performance of pneumatic nursery protray seeder was evaluated in terms of miss seeding, single seeding, multiple seeding, seeding efficiency, and seeder output for different levels of mouthpiece diameter and suction pressure for tomato (*Solanum lycopersicum* L.). With a mouthpiece diameter of 0.84 mm and suction pressure of 6.2 kPa, it was found that 59.25% of single seeding, 97.69% seeding efficiency, and a seeder output of 67 cells/min were suitable for tomato seedlings. The pneumatic protray seeder resulted in a saving of ₹15.04 per 1000 cells sown compared to manual seeding. The payback period was 104.7 hours (3.58% of the expected life of pneumatic protray seeder).

Key Words: Mouthpiece diameter, Nursery protray seeder, Optimization, Suction pressure, Suction unit, Seedlings

Protray seedling production under protected cultivation is a promising technology that fulfills this requirement, providing benefits to both growers and entrepreneurs (Singh, 2013; Saiful-Islam *et al*., 2002). It also enables growers to perform timely planting to maximize the benefits from healthy seedlings (Barik *et al*., 2020). However, manual seeding in protray is a labor-intensive and highly tiresome operation, taking around 8 man-hours for seeding in 100 protrays with a total of 9,800 cells (Nandede *et al*., 2017). The farm power availability in the country has increased from 0.25 kW.ha-1 to 4 kW.ha-1 between 1951 and 2022 (Chandra-Shekara, 2022). Mechanical advancements can enhance the speed and precision of protray seeding operations. However, commercially available seeders are generally designed for large-scale nursery management and are not affordable for small and marginal growers (Rathinakumari *et al*., 2020). Several seeders have been developed for protray seeding, utilizing various principles of operation, such as mechanical (Sriwongras and Dostál, 2014), magnetic (Jianping *et al*., 2003; Yan *et al*., 2013), and pneumatic (Gaikwad *et al*., 2007; Kim *et al*., 2011; Rathinakumari and Kumaran, 2020; Xia *et al*., 2021; Jadhav *et al*., 2023). Due to their desired output, pneumatic devices are preferred for protray seeding. Hence, this study was carried out to optimize a small and cost-effective pneumatic protray seeder.

MATERIALS AND METHODS

The seeder consists of seed picking mouthpieces, a cut-off device, a pressure regulating unit, and a suction unit. Hypodermic needles were used as seed picking mouthpieces, enabling seed picking through the effect of negative pressure controlled by a cut-off device. A flexible pipe was utilized to connect the seeding unit to the pressure regulating assembly, facilitating ease of movement for the seeder. The pressure regulating assembly includes a pressure dial gauge and a control valve connected to the suction unit. The optimization was conducted for DS-21 cultivar of tomato (*Solanum lycopersicum*) seeds in a protray containing 104 circular cells (13×8). The moisture content of the seeds was recorded as 9.71% on a wet basis.

The seeder pipe was constructed using a 12.7 mm diameter and 330 mm long hollow CPVC (Chlorinated Poly Vinyl Chloride) pipe. As the selected protray consisted of 8 cells in a row, the seeder was equipped with 8 seed picking units spaced at a uniform distance of 38 mm, similar to spacing between two consecutive

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cells in protray (Fig. 1). Seed picking mouthpieces were created by trimming nibs of hypodermic needles to a suitable and uniform height. When designing the parts of seeding and planting devices, engineering properties of seeds such as width, geometric mean diameter, thousand seed weight, bulk density, true density, and angle of repose are of utmost importance (Jadhav *et al.*, 2020; Jayan and Kumar, 2004; Singh *et al.*, 2018). The range of mouthpiece diameter selected was based on seed size (Yitao *et al.*, 2017). Needles with gauge sizes (diameters) of 20 (0.60 mm), 18 (0.84 mm), and 16 (1.19 mm) were chosen. The seeder assembly consists of a cut-off device to control the supply and stoppage of suction pressure. To facilitate the handling of seeder assembly without hindrance, it is connected to the pressure regulating assembly by a flexible hose pipe with a thickness of 2 mm, which sustains the suction pressure. The pressure regulating assembly includes a pressure dial gauge (make: Imperial Precision Engineering Pvt. Ltd) and a control valve (CPVC ball valve) connected to the suction unit to maintain the desired pressure in the line. A household vacuum cleaner (make: Eureka Forbes, model: Easy Clean Plus) was used as the suction source. The dimensions of the seed holder were determined based on the engineering properties of the seeds, such as weight and bulk density (Jadhav *et al.*, 2017). To facilitate the flow of seeds towards the bottom center of the seed holder, a half-circle cross-section shape was employed. The length of the seed holder (320 mm) exceeded the distance between the farthest picking units on the seeder pipe

1, Mouthpiece; 2, seeder pipe; 3, pressure cut-off device; 4, flexible hose pipe; 5, pressure dial gauge; 6, pressure control valve; 7, suction unit; 8, protray

Fig. 1. Components of pneumatic protray seeder

The seed holder containing seeds was placed above the tray filled with soil media. Adequate line pressure was maintained as the pneumatic tray seeder drew in the seeds through suction. When the cut-off unit was in the pressed position, suction pressure was supplied to the seeder pipe, enabling seeds to be drawn from the seed holder using the mouthpiece. The cut-off unit was then released as seeder pipe moved over the cells to be sown. Once the pressure supply ceased, the seeds held by the mouthpiece were deposited into the cells of the tray.

The parameters that significantly influence the performance of pneumatic seeding devices are the mouthpiece diameter and suction pressure (Ismail, 2008). Therefore, impact of varying mouthpiece diameters from 0.60 to 1.19 mm and suction pressures ranging from 4 to 6.2 kPa was investigated to assess their effect on seeder performance. To facilitate easy detection of yellow-colored seeds, white-colored paper pieces were affixed to the bottom of the tray cells. The following mathematical expressions (Abdulkadir *et al.*, 2019; Jadhav *et al.*, 2023) were utilized to calculate the dependent parameters, namely miss seeding (MS), single seeding (SS), multiple seeding (MUS), seeding efficiency (SE), and seeder output (SO), in the laboratory.

$$\text{Miss seeding, \%} = \frac{\text{Number of cells without any seed after sowing}}{\text{Total number of cells}} \times 100 \quad (1)$$

$$\text{Single seeding, \%} = \frac{\text{Number of cells with single seed after sowing}}{\text{Total number of cells}} \times 100 \quad (2)$$

$$\text{Multiple seeding, \%} = \frac{\text{Number of cells with more than one seeds after sowing}}{\text{Total number of cells}} \times 100 \quad (3)$$

$$\text{Seeding efficiency, \%} = \frac{\text{Number of cells with atleast one seed after sowing}}{\text{Total number of cells}} \times 100 \quad (4)$$

$$\text{Seeder output, cells.min}^{-1} = \frac{\text{Total number of cells sown}}{\text{Time required for sowing}} \quad (5)$$

Miss seeding refers to the absence of seeds and is considered an undesirable parameter, thus its value should be minimized. Conversely, single seeding is desirable as it signifies the proper utilization of inputs. Higher values of multiple seeding indicate greater seed wastage. Seeding efficiency is an important parameter as it reflects the actual population of cells in the tray that contain seeds. Seeder output is a necessary parameter for determining the operational cost of the seeder.

A full factorial experiment was conducted using a completely randomized design to examine the effects of the independent parameters. The experiment comprised 12 treatment combinations, including three mouthpiece diameters (0.60 mm, 0.84 mm, and 1.19 mm) and four suction pressures (4.1 kPa, 4.8 kPa, 5.5 kPa, and 6.2 kPa). Each treatment was replicated three times to enhance error estimation. The experiments were carried out for duration of ten minutes, and the dependent parameters were manually observed and recorded for calculation.

To optimize the parameters of the pneumatic protray seeder, Response Surface Methodology (RSM) was employed using the Stat-ease Design Expert-10 software. Second-order polynomial equations were fitted to analyze the behavior of the dependent parameters. Numerical optimization was performed to suggest the best treatment combination for tomato seeding in the portray.

RESULTS AND DISCUSSION

The ANOVA results demonstrate that the models for miss seeding (MS), single seeding (SS), multiple seeding (MUS), seeding efficiency (SE), and seeder output (SO) were highly significant at a significance level of 0.01% (Table 1). Additionally, the coefficient of determination values for all models exceeded 85%. Consequently, models were deemed capable of accurately representing the variability of the responses.

The linear and quadratic terms of regression equation shows the individual effects of independent parameters. The linear effect of MD was most significant at 0.01% significance level for all the five responses. The negative linear coefficient for *MS* and *SS* indicates that increase in MD decreased both the parameters. On the other hand MUS, SE and SO had positive linear component of *MD*. The quadratic term of MD affected the MS, MUS and SE significantly at 0.01% significance level and the *SS* at 1% level of significance but had no effect on SO. Positive sign of quadratic component of MD explained that the values of MS and SS were increased after central level of MD. Similar to the MD, the linear component of SP also showed a statistically significant ($p<0.0001$) effect on all the responses under study. The linear component of SP had inverse relation with MS and direct relation with remaining parameters, as denoted by the signs of their respective coefficients. Quadratic term of SP possessed no effect on any of the response, except MUS. The negative coefficient showed that after central level, MUS decreased with increasing SP^2.

The interaction between MD and SP was found highly significant at 0.01% level of significance for MS, SS and QS. Also, the term had most significant effect at 1% level of significance on MUS. However, there was no effect of interaction was recorded on *SO*. Fig. 2 (a) shows that at all levels of SP, the MS reduced with increase in MD for the selected experimental range. Similarly for any MD, increase in SP also decreased the MS. The reason may be that with the increased MD and *SP*, suction force was easily able to overcome seeds inertia. Fig. 2 (b) shows that initially increasing in MD at given *SP*, reduced SS. However, after certain value further increase in MD stabilized the *SS*. However, when *SP* was increased at any MD in experimental range, *SS* was improved. The behavior is obvious as in lower range *MS* was more and in higher range *MUS* was more Fig. 2(c). It can also be observed that increasing *SP* at any given level of MD did not increased MUS significantly. The behavior was also reflected by the F values of MD and SP in ANOVA. Fig. 2(d) showed that initially increasing MD and SP resulted in increased *SE* and saturated after certain value.

The quadratic regression equations for the dependent parameters *viz*. MS, SS, MUS, SE and SO

Table 1. ANOVA of response surface regression experiment for tomato protray seedings

	Miss seeding (%)		Single seeding (%)		Multiple seeding (%)		Seeding efficiency (%)		Seeder output ($cells.min^{-1}$)	
SOV	F value	Coeff.	F value	Coeff.	F value	Coeff.	F value	Coeff.	F value	Coeff.
Model	175.64^{***}	9.86	256.58^{***}	48.05	1531.07^{***}	42.09	175.64^{***}	90.14	40.49^{***}	62.63
MD	385.43^{***}	-8.57	1120.98^{***}	-18.27	7496.93^{***}	26.84	385.43^{***}	8.57	38.22^{***}	1.91
SP	420.57^{***}	-9.84	106.08^{***}	6.17	115.80^{***}	3.66	420.57^{***}	9.84	162.39^{***}	4.32
MD×SP	33.39^{***}	3.37	44.11^{***}	-4.83	12.60^{**}	1.47	33.39^{***}	-3.37	0.13^{NS}	-
MD^2	37.25^{***}	4.81	10.54^{**}	3.20	204.81^{***}	-8.01	37.25^{***}	-4.81	078^{NS}	-
SP^2	2.03^{NS}	-	23.76^{NS}	-	9.36^{***}	-1.74	2.03^{NS*}	-	$1.14E-003^{NS}$	-
Mean	14.29		51.69		34.02		85.71		62.16	
R^2	0.97		0.98		0.99		0.97		0.87	

MD, Mouthpiece diameter, mm; SP, Suction pressure, kPa; R^2, Coefficient of determination; Coeff., Coded coefficients of regression equations; ***significant at $p<0.0001$; **significant at $p<0.05$; *significant at $p<0.01$.

of developed pneumatic protray seeder with their R^2 are represented by equation 6 to 10, respectively.

$$MS = 205.97 - 183.98\,MD - 29.76\,SP + 10.87\,MD \times SP + 55.28\,MD^2 \ldots \left(R^2 = 0.97\right) \quad (6)$$

$$SS = 45.14 - 47.31\,MD + 14.23\,SP - 15.61\,MD \times SP + 36.73\,MD^2 \ldots \left(R^2 = 0.98\right) \quad (7)$$

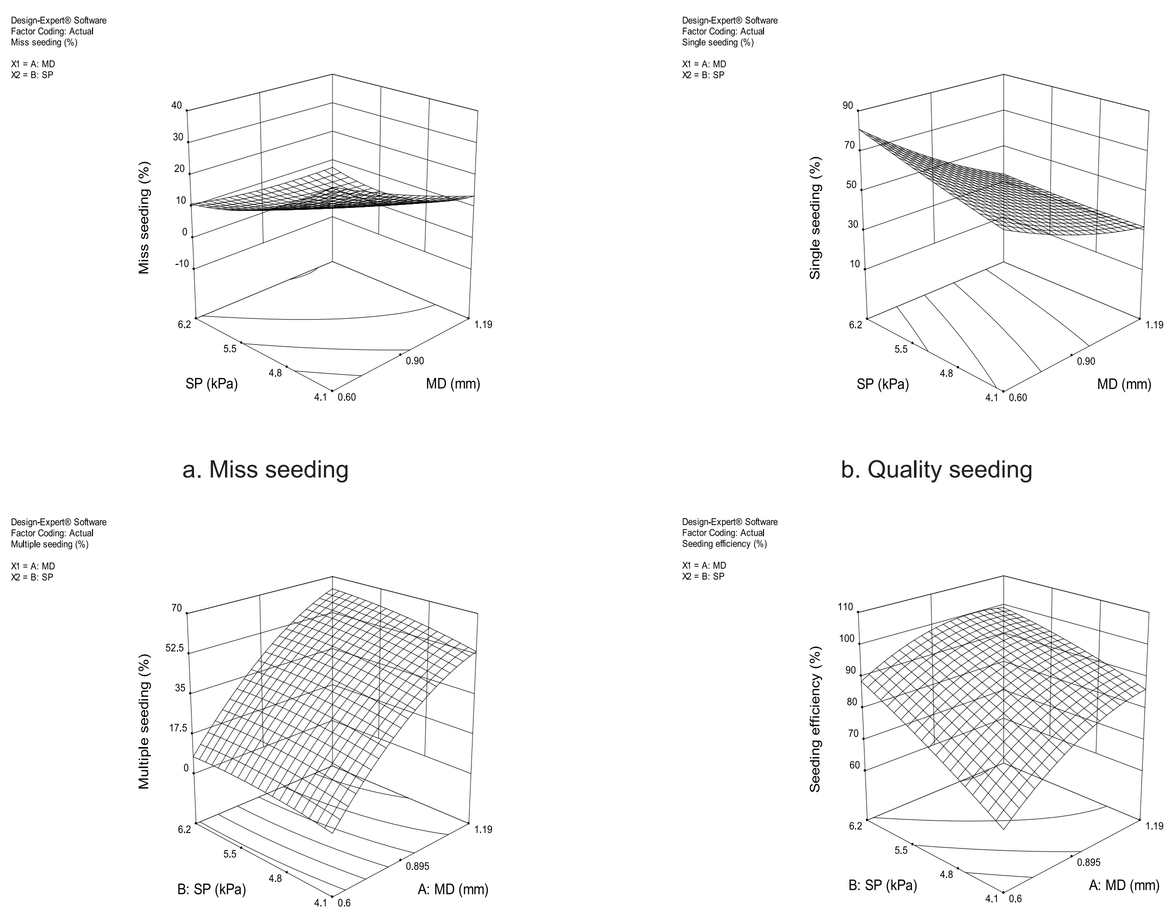
$$MUS = -151.11 + 231.29\,MD + 15.53\,SP + 4.74\,MD \times SP - 92.01\,MD^2 - 1.58\,SP^2 \ldots \left(R^2 = 0.99\right) \quad (8)$$

$$SE = -105.97 + 183.98\,MD + 29.76\,SP - 10.87\,MD \times SP - 55.28\,MD^2 \ldots \left(R^2 = 0.97\right) \quad (9)$$

$$SO = 28.43 + 19.08\,MD + 4.73\,SP \ldots \left(R^2 = 0.87\right) \quad (10)$$

To achieve an acceptable output from the developed seeder, optimization was carried out by applying criteria to SS, MUS, SE, and SO. The desired output aimed for the least MS and MUS while maximizing SS, SE, and SO. Numerical optimization was conducted with the following criteria: MD and SP were kept within the specified range, MS and MUS were set to minimize, and SS, SE, and SO were set to maximize. Table 2 presents some of the solutions suggested by the Design Expert software.

In the first solution, SS was deemed acceptable at 81.13%. However, the higher MS (11.18%) and lower SE (88.82%) could result in a higher likelihood of empty cells, thus making this solution unfavorable. The second solution had a good SE value of 90.04%, but the MUS was considerably high (60.22%), and the MS remained relatively high (6.97%). Due to the potential increase in seeding costs associated with these factors, the second solution was rejected.



a. Miss seeding b. Quality seeding

c. Multiple seeding d. Seeding efficiency

Fig. 2. Surface plot for interaction between mouthpiece diameter and suction pressure

Table 2. Solutions suggested by numerical optimization

Mouthpiece diameter, mm	Suction pressure, kPa	Miss seeding, %	Single seeding, %	Multiple seeding, %	Seeding efficiency, %	Seeder output, cells.min^{-1}	Desirability
0.60	6.2	11.18	81.13	7.69	88.82	65	0.79
1.19	5.0	6.97	32.82	60.22	93.04	63	0.29
0.84	6.2	2.30	59.25	38.45	97.69	67	0.71

The third solution exhibited SS and MUS values of 59.25% and 38.45%, respectively. Although the MUS value was higher, the MS value (2.30) was the lowest among all the solutions. The preference for multiples over misses lies in ensuring the presence of seeds in cells. Furthermore, the SE value (97.69%) was found to be the maximum in this solution. Considering these justifications, the third solution was selected as the optimized solution, using a 0.84 mm mouthpiece diameter and 6.2 kPa suction pressure.

The solution of numerical optimization is shown in the form of overlay plot (Fig. 3) by superimposing the significant responses in respect to interaction of MD and SP.

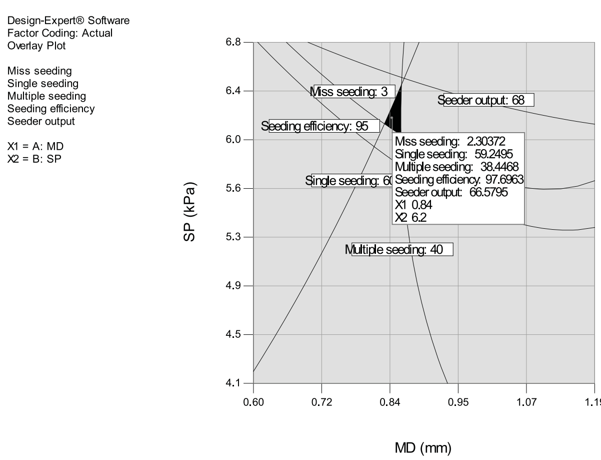


Fig. 3. Overlay plot

The cost of seeding using the developed pneumatic protray seeder was calculated and compared with manual operation. The development cost of the seeder was ₹5,600. The capacity of manual seeding was determined to be 1,225 cells per hour, while the developed seeder had a capacity of 3,350 cells per hour. The cost of seeding 1,000 cells manually was found to be ₹30.61, whereas the cost with the developed seeder was ₹15.04, resulting in a total saving of ₹15.57 using the pneumatic seeder.

The payback period, considering the hours of seeder operation and its total expected life, was determined to be 104.7 hours and 3.58%, respectively.

CONCLUSION

The operational cost of the protray seeder was determined to be ₹15.04 per 1000 cells. The payback period, calculated based on the hours of seeder operation and its total expected life, was found to be 104.7 hours, with a total expected life of 3.58%.

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Evaluation of yield characters of marigold (*Tagetes* species) genotypes under summer condition in alluvial Gangetic plains of North India

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ABSTRACT

A study was conducted at the Department of Horticulture, Bihar Agricultural University, Sabour, Bhagalpur, to evaluate 26 marigold (*Tagetes* species) genotypes, including 23 experimental lines and three controls during summer season of 2016. The experiment followed a randomized complete block design with three replications. There were highly significant differences ($p<0.05$) among genotypes for various growth, flowering, and yield-related traits. Among the genotypes, BRMG 113 exhibited the best performance in terms of number of flowers/plant (394.98), duration of flowering (76.80 days), flower yield (39.98 kg/plot), and overall yield (53.31 tonnes/ha). The genotype Super Red showed the minimum number of days for appearance of first flower (48.20 days) and 50% flowering (65.73 days). On the other hand, BRMG 113 had maximum flowering duration (76.80 days), number of flowers/plant (394.98), and flower yield (1599.21 g/plant). The genotype MDU 1 recorded significantly highest number of days for appearance of first flower (95.73 days), while Pusa Arpita had shortest flowering duration (29.07 days). The genotype BRMG 113 shows promising characteristics for summer season, particularly in terms of flower yield and duration of flowering. Super Red also exhibited early flowering, which may be desirable in certain contexts.

Key words: Morphological characters, High temperature, Summer season, Yield

Marigold (*Tagetes* species) is a highly significant commercial flower crop belonging to the family Asteraceae. It holds immense importance due to its diverse uses, (Shilpa *et al*., 2022). In India, marigold is cultivated on approximately 68.33 thousand hectares, with a production of 608.96 thousand metric tones. in (NHB, Gurgaon, 2019). However, there is a lack of suitable varieties for summer season. Therefore, there is a great opportunity to capture this market by introducing varieties specifically suited for summer cultivation. Therefore, an evaluation of marigold genotypes was conducted to assess their growth and flowering characteristics suitable for the summer season.

MATERIALS AND METHODS

A field trial was conducted at the Department of Horticulture, Bihar Agricultural University, Sabour, Bhagalpur during 2016. The experiment comprised 23 experimental lines and 3 control treatments, arranged in a randomized complete block design with three replications. Seedlings were initially grown in plug trays. At the 4-6 leaf stage, which typically occurs after four weeks, seedlings were transplanted into plots measuring 3m × 2.5m in February. The plants were planted 50 cm within rows and 60 cm apart between rows.

Observations were taken from five selected plants within each replication, after discarding the border plants at both ends of the plot. Data were recorded for plant height (cm), plant spread (cm), stalk length (cm), stem diameter (cm), number of primary branches, number of secondary branches, number of flowers/plant, days to first flower, days to 50% flowering, fresh weight/flower (g), flower diameter (cm), duration of flowering (days), flower yield/plot (kg), and yield/hectare (t/ha). The data were subjected to analysis of variance as per Panse and Sukhatme (1967).

Plant height was measured by determining the distance from the base to the top of plant at the time of flowering. The measurements were taken for multiple plants, and the average height was calculated. The number of days to first flowering was recorded by counting the number of days from the date of transplanting to appearance of first flower. To determine the days to 50% flowering, number of days from date of transplanting to when 50% of the plants in each plot had their initial flower

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open was calculated. For plant spread, maximum horizontal spread of plants within each replication was measured in both East-West and North-South directions. The duration of flowering was calculated by subtracting the number of days to first flower from the number of days to last flowering. To determine the number of flowers/plant, total number of flowers on five randomly selected plants within each replication was counted and recorded. Flower diameter was measured at the time of full opening of flower.

Individual flower weight was calculated for each flower. For flower yield, total number of flowers was counted, and the total yield was calculated based on this count.

RESULTS AND DISCUSSION

There was a wide variation among genotypes. Plant height showed significant variation, ranging from 26.33 cm to 87.58 cm. BRMG 414 HG had tallest plants at the first flowering stage, while Cross China had the shortest plants. The variation in vegetative attributes can be attributed to differences in growth rate and genetic make-up of the genotypes (Thakur *et al.,* 2013; Singh *et al*., 2014; Swaroop *et al*., 2019).

Plant spread also exhibited significant variation, ranging from 20.43 cm to 68.31 cm. BRMG 414 HG showed maximum spreading in plants, followed by BRMG 714 and China 2, while Pusa Basanti Gainda had minimum spread.

Vandana had maximum number of primary branches/plant (12.40), while Hooghly yellow and Pusa Basanti Gainda had least number of primary branches (5.07). The differences in branch production can be attributed to inherent genetic factors, as suggested by Bharathi and Jawaharlal (2014).

The number of secondary branches/plant also showed significant variation among marigold genotypes, ranging from 14.53 to 32.60. Shyam China had maximum number of secondary branches (32.60), while MDU 1 had minimum. The number of secondary branches/plant is likely primarily governed by genetic make-up of genotypes. It was observed that maximum number of secondary branches/plant significantly increased after pinching of the plant, which stimulated the auxiliary buds to flourish well. This finding is consistent with those of Munikrishnappa *et al.* (2013).

The stalk length varied among genotypes, with 'Hooghly 1 (O)' recording the maximum stalk length (9.00 cm), followed by Light (8.38 cm) and Shiv (8.35 cm), while 'Pusa Arpita' had the minimum stalk length (4.88 cm) (Namita *et al.,* 2009). The stem diameter also showed variation, ranging from 1.25 cm to 2.48 cm. BRMG 114 had maximum stem diameter (2.48 cm), followed by Shyam China, New China (2.35 cm), Tapur Basanti (2.37 cm), BRMG 113 (2.21 cm), and Pusa Narangi Gainda had minimum (1.25 cm). The variation in stem diameter could be attributed to both their genetic make-up and environmental conditions.

The BRMG 113 had maximum number of flowers/ plant (394.98), followed by BRMG 114 (271.87), New China (265.25), and China 2 (18.48). The variation in number of flowers can be attributed to both genetic and environmental factors. Genotypes with more branches/plant tend to have a higher number of flowers. The number of flowers/plant may increase with an increase in number of branches/plant (Laishram *et al*., 2013). Furthermore, variations in photosynthetic efficiency among genotypes can lead to increased food accumulation, resulting in enhanced plant growth and a higher number of flowers/plant (Sunitha *et al.,* 2007).

Super Red was the earliest to flower (48.20 days), followed by BRMG 113 (55.53 days) and Light (52.53 days). The maximum number of days taken for flowering was recorded in MDU1 (95.73 days), followed by Pusa Basanti Gainda (90.33 days) and Pusa Arpita (82 days). The variation in early and late blooming among genotypes is likely a genetically controlled trait. Similar observations have been reported by Negi *et al.* (2015). For 50% flowering, Super Red took 65.73 days, followed by Gones Yellow (69.07 days) and Light (63.40 days). The maximum number of days taken for 50% flowering was recorded in Pusa Basanti Gainda (106.80 days) and MDU 1 (102.53 days).

The variations in flowering time can be attributed to different time periods required by different genotypes based on their genetic make-up. This finding aligns with the study by Namita *et al*. (2011). BRMG 113 had a longer flowering period (76.80 days), similar to Gones Yellow (71.20 days) and Ball (72.13 days). The minimum flowering duration (29.07 days) was recorded in Pusa Arpita. The variation in duration of flowering can be attributed to differences in genetic make-up. Similar findings have been reported by Choudhary *et al.* (2014) and are in line with the studies by Raghuvanshi and Sharma (2011) and Panwar *et al.* (2013).

The flower diameter ranged from 2.20 cm to 5.67 cm. The largest flower size (5.67 cm) was observed in

BRMG 714, followed by BRMG 414 HG (5.65 cm) and Pusa Basanti Gainda (2.20 cm). The variation in flower size can be attributed to the inherent characteristics of the genotypes (Panwar *et al*., 2013).

The fresh weight per flower also showed significant variation, with the maximum weight observed in Local Jalbhara (6.74 g), followed by Tapur Basanti (6.23 g), Local Yellow (5.56 g), and Pusa Narangi Gainda (1.91 g). This variation may be due to differences in number of ray florets and the effect of the season. Similar results have been reported by Kumar *et al.* (2014).

Significant differences were found in flower yield per plot, ranging from 1.48 kg to 39.98 kg. The maximum flower yield per plot was recorded in BRMG 113 (39.98 kg), followed by Hooghly1 Orange (33.06 kg/plot), BRMG 114 (30.55 kg/plot), and Pusa Arpita (1.48 kg/plot). Similar findings have been reported by Bharathi and Jawaharlal (2014), and Raghuvanshi and Sharma (2011) observed significant variation in flower yield (1.69 kg to 8.27 kg/m2). The variation in flower yield can be attributed to the intrinsic capacity of the genotypes to produce flowers (Narsude *et al*., 2010a).

The BRMG 113 exhibited the maximum flower yield (53.31 tonnes/ha), followed by Hooghly1 Orange (44.07 tonnes/ha), BRMG 114 (40.73 tonnes/ha), and Pusa Arpita (1.97 tonnes/ha). The increase in flower yield may be attributed to higher number of flowers/plant and longer duration of flowering during summer season.

CONCLUSION

Thus, BRMG 113 showed maximum flower yield (53.31 tonnes/ha) under summer conditions. This genotype can be considered a good option for marigold farmers.

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Combining ability analysis for yield-attributing traits in cytoplasmic male sterility based hybrids of chilli (*Capsicum annum*)

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ABSTRACT

The combining ability analysis was done for yield-attributing traits in CMS based hybrids of chilli (*Capscum annuum* L.) at Vasantrao Naik Marathvada Krishi Vidyapeeth, Parbhani, Maharashtra, India, during 2017-18 and 2018-19. Sixteen parents and 60 F_1 s produced in line × tester mating design were used. The variance due to GCA and SCA were significant for all characters. The fruit diameter of SCA variance were non - significant. The parents, BSPRL-171, BSPRL-066, BSPRL-188, Phule Jyoti, Pusa Sadabahar, PBNC-1, and Parbhani Tejas, were good general combiner for fruit and yield. Hybrids, BSPRL-066 × Phule Jyoti, BSPRL-171 × Phule Jyoti, BSPRL-171 × Bydagi, BSPRL-171 × G-4, BSPRL-226 × Kokan Kirti and BSPRL-189 × Bydagi had good SCA effects for fruit and yield.

Key words: Combining ability, Line × tester analysis, Hybrids, Genotypes, Variance

Chilli (*Capsicum annuum* L.) 2n = 24 is an important spice-cum-vegetable crop of family Solanaceae. Studying the combining ability is important for selecting parents for hybridization. The GCA variance is due to additive variance while SCA variance is due to non-additive variance and both acts as an important diagnostic tool in selection of suitable parents. Usually local cultivars are grown due to regional preferences and hence developing region-specific high-yielding early hybrids is necessity.

MATERIAL AND METHODS

The study material consisted of six lines, viz, BSPRL-066, BSPRL-171, BSPRL-188, BSPRL-189, BSPRL-224, BSPRL-226 and ten Testers, viz, PBNC-1, Parbhani Tejas, Pusa Jwala, Phule Jyoti, Kokan Kirti, Pusa Sadabahar, Bydagi, Bydagi-341,Teja,G-4, and three hybrid controls, BSS-355, BSS-378, BSS-273. Hybridization was carried out during 2017-18 and evaluation in 2018-19 *kharif* season. The experiment was laid out in a randomized block design with two replications. The 16 parents and 60 hybrids were studied. Each entry was planted in three rows of 30 plants each with a spacing of 60 cm × 45 cm. The recommended package of practices were followed. The data on plant height, number of primary branches/ pant, day to first flowering, days to 50% flowering, number of fruits / plant, fruit yield / plant, fruit yield / plot, first fruit ripening, fruit length, fruit diameter, fruit weight / plant, dry fruit weight/ plant, dry fruit yield/ plot, number of picking/plant, pedicel length, dry fruit weight and number of seeds/ fruit were recorded from five randomly selected plants of each treatment. The combining ability analysis was computed as per Kempthorne (1957).

RESULTS AND DISCUSSION

Teja (13.83), BSPRL-224 (11.86) and Pusa Jwala (9.52) were the tallest. Similar GCA effect was recorded by Jethava *et al.* (2016), Singh and Chaudhary (2005) and Gangadhar *et al*. (2016). The number of primary branches/plant was highest in parents, Bydagi (0.98), BSPRL-171 (0.74) and Teja (0.57), supporting the findings of Singh *et al*. (2014), Gandhi *et al.* (2000) and Kumar *et al.* (2014). Days to first flowering, days to 50% flowering, and days to first fruit ripening were influenced by Bydagi (-341, -5.81), BSPRL-066 (-4.92), and Parbhani Tejas (-4.71) respectively, as reported by Ananda and Subbaraman (2004). Parent Pusa Sadabahar exhibited highest number of fruits/plant (63.78), followed by Bydagi (59.28), BSPRL-171 (58.01), and Phule Jyoti

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Table 1. Estimates of general combining ability (GCA) effects of parents in chilli

Source of variation	Plant height (cm)	Number of primary branches/ plant	Days to first flowering	Days to 50 % flowering	Days to first fruit ripening	Number of fruit/ plant	Fruit weight (g)	Fruit length (cm)	Fruit diameter (mm)
Line									
BSPRL-066	1.53***	-0.15	-5.23***	-4.92***	-7.71***	-4.33	0.82***	-0.11	0.11*
BSPRL-224	11.86***	0.23	1.99***	2.72***	1.65***	19.77***	0.61***	1.51***	0.021
BSPRL-226	-3.34***	-0.11	-1.49***	-2.38***	-0.92***	-25.35***	1.4***	1.48***	0.032
BSPRL-188	3.69***	-0.46***	3.21***	2.25***	2.16***	-81.02***	0.65***	-0.291	0.052
BSPRL-189	-12.37***	-0.25	-1.10***	-0.53***	1.29***	32.92***	-1.88***	-1.68***	-0.091
BSPRL-171	-1.37***	0.74***	2.62***	2.86***	3.52***	58.01***	-1.61***	-1.13***	-0.12*
SE	0.26	0.13	0.14	0.17	0.218	3.18	0.11	0.15	0.049
CD95%	0.51	0.26	0.28	0.3	0.43	6.30	0.23	0.30	0.097
CD99%	0.68	0.34	0.37	0.46	0.571	8.34	0.30	0.47	0.12
Gi-Gj	0.96	0.49	0.53	0.66	0.80	17.79	0.43	0.56	0.18
Tester									
Parbhani Tejas	-3.28***	-0.82***	-5.29***	-4.71***	0.77**	-65.03***	0.90***	2.05***	0.011
PBNC-1	-5.43***	-0.12**	0.74***	0.29	-1.28***	-11.25**	1.07***	1.03***	0.072
Kokan Kirti	4.87***	-0.10	-0.98***	-0.39	-3.22***	-31.61***	-0.88***	-0.93***	-0.107
Phule Jyoti	-17.58***	-0.031	-3.23***	-1.73***	-1.83***	38.30***	-1.25***	-2.28***	0.02
G-4	1.38***	0.032	4.40***	4.89***	-0.009	-14.77***	1.49***	-0.18	0.12*
Bydagi	-10.18***	0.098**	-1.29***	-0.85***	-5.04***	59.28***	-0.47**	-0.035	-0.08
Bydagi-341	8.37***	0.24	-4.54***	-5.81***	2.50***	-35.62***	-0.65***	-0.021	-0.14*
Teja	13.83***	0.57***	2.11***	-1.69***	1.27***	-5.99	0.15	0.55**	0.052
Pusa Jwala	9.52***	-0.11	2.79***	2.45***	0.32	2.93	-0.24	0.72***	0.049
Pusa sadabahar	-1.50***	0.24	5.29***	7.55***	6.51***	63.78***	-0.10	-0.89***	-0.003
SE	0.33	0.17	0.18	0.23	0.28	4.11	0.15	0.19	0.063
CD95%	0.66	0.33	0.36	0.45	0.557	8.14	0.29	0.39	0.12
CD99%	0.88	0.44	0.48	0.60	0.73	10.76	0.39	0.51	0.16
Gi-Gj	1.24	0.63	0.69	0.85	1.04	15.22	0.55	0.73	0.23

Source of variation	Plant height (cm)	Number of primary branches/ plant	Days to first flowering	Days to 50 % flowering	Days to first fruit ripening	Number of fruit/ plant	Fruit weight (g)	Fruit length (cm)	Fruit diameter (mm)
Line									
BSPRL-066	-0.15*	158.26***	33.42***	3.66***	0.106*	-2.91	0.15*	1.32***	
BSPRL-224	0.029	329.28***	75.36***	9.46***	0.008	5.91***	0.65***	2.31***	
BSPRL-226	0.46***	100.71***	11.76	3.80***	0.13**	-0.079**	-0.003	0.063**	
BSPRL-188	-0.36***	-54.76***	-7.68	-0.77***	0.28***	-0.22	-0.20*	-0.24**	
BSPRL-189	-0.059	-211.89***	-42.64***	-6.54***	-0.24***	-0.80**	-0.27***	-1.12***	
BSPRL-171	0.085	-321.61***	-70.19***	-9.60***	-0.28***	-1.87**	-0.32***	-2.34***	
SE	0.072	10.361	8.52	0.13	0.046	1.59	0.078	0.15	
CD95%	0.14	20.519	16.88	0.27	0.092	3.16	0.15	0.30	
CD99%	0.18	27.12	22.32	0.35	0.12	4.17	0.20	0.39	
Gi-Gj	0.26	38.36	31.57	0.50	0.17	5.91	0.29	0.56	
Tester									
Parbhani Tejas	-0.039	-60.45***	-1.57	-1.67***	0.18**	14.46***	-0.03	-0.60**	
PBNC-1	0.034	15.27	38.31***	0.90***	0.14*	6.73**	0.29***	0.66***	
Kokan Kirti	-0.075	-114.05***	-39.98***	-3.02***	0.011	-5.006*	-0.14**	-1.01***	
Phule Jyoti	-0.43***	-36.82***	-11.50	-0.97***	-0.14*	-9.31***	-0.16**	-1.05***	
G-4	0.28**	47.27***	19.17	1.373***	0.29***	-2.86**	0.27***	0.35	
Bydagi	0.27**	1.14	-9.33	0.144	-0.22***	-2.34*	0.55***	0.54**	
Bydagi-341	0.14	-77.75***	-57.75***	-1.93***	-0.01	-3.21**	-0.33**	-0.47**	
Teja	-0.17	20.66	-4.13	1.08***	-0.014	-1.74**	-0.24*	0.34	
Pusa Jwala	0.17	-21.89	10.24	0.08***	-0.20**	0.85	-0.21*	-0.31	
Pusa sadabahar	-0.19*	226.61***	56.53**	4.02**	-0.035	2.44**	0.012**	1.56***	
SE	0.093	13.37	11.0097	0.17	0.06	2.06	0.10	0.19	
CD95%	0.18	26.49	21.80	0.35	0.11	4.08	0.20	0.38	
CD99%	0.24	35.02	28.82	0.46	0.15	5.39	0.26	0.51	
Gi-Gj	0.34	49.53	40.76	0.65	0.22	7.63	0.37	0.72	

*, ** - Significant at 5% and 15% level, respectively

(38.30), showing highly significant positive GCA effects. These findings are supported by Jethava *et al*. (2016), Kumar *et al.* (2014) and Sitaramesmi *et al.* (2010). The Parent G-4 showed a fruit weight of (1.49) g, indicating a significant positive GCA effect, as reported by Gangadhar *et al*. (2016). Highly significant positive GCA effects were observed for parents Parbhani Tejas (2.05) and BSPRL-224 (1.51). For fruit length and pedicel length (2.05 and 0.46), Parbhani Tejas and BSPRL-226, and for dry fruit weight (0.106), BSPRL-066, and fruit diameter (0.12), Phule Jyoti, and parent BSPRL-066 (0.11), highly significant positive GCA effects were recorded. Similar results were reported by Kumar *et al.* (2014) and Jethava *et al.* (2016). Parent BSPRL-224 exhibited maximum positively significant fruit weight/plant, dry fruit weight/plant, dry fruit yield/plot, number of pickings/ plant, and fruit yield/plot compared to other parents. These results are supported by Singh and Pan (2009), Singh *et al.* (2014), Gawali *et al.* (2015), and Neelavathi *et al.* (2015). Parbhani Tejas yielded highest number of seeds/fruit (14.46), followed by PBNC-1 (6.73) compared to other parents. Prasath and Ponnuswami (2008), Kumar *et al*. (2014), Neelavathi *et al*. (2015), and Meena *et al.* (2018) also support these findings.

The estimates of specific combining ability (SCA) for plant height showed a positive effect in BSPRL-188 × Teja (29.12), as reported by Singh and Chaudhary (2005) and Gangadhar *et al.* (2016). The number of primary branches/plant was observed in BSPRL-226 × PBNC-1, while days to first flowering and days to 50% flowering showed highly significant negative SCA effects in hybrid BSPRL-188 × G-4 (-10.96) and BSPRL-189 × Pusa Sadabahar (-10.87), as reported by Ananda *et al.* (2004) and Karthik *et al.* (2009). For the number of fruits/plant, the hybrid BSPRL-171 × G-4 (145.03) exhibited the maximum positive SCA effects, followed by BSPRL-224 × Kokan Kirti (118.90), as reported by Kumar *et al.* (2014) and Sitamresmi *et al.* (2010). Hybrids BSPRL-171 × Bydagi (2.72) and BSPRL-171 × G-4 (2.33) showed highly significant positive SCA effects for fruit diameter and fruit length. Kumar *et al.* (2014) supported these findings. Hybrids BSPRL-224 × Parbhani Tejas (0.97) and BSPRL-188 × G-4 (0.87) exhibited highly significant positive SCA effects for pedicel length. The fruit weight, dry fruit weight, fruit weight/plant, dry fruit weight/plant, dry fruit yield/plot, and fruit yield/plot were recorded in hybrid BSPRL-171 × Phule Jyoti and BSPRL-066 × Phule Jyoti (338.49 and 154.13), showing highly significant positive SCA effects, as reported by Gawali *et al.* (2015). Hybrid BSPRL-226 × Kokan Kirti exhibited a highly positive significant SCA effect, followed by BSPRL-066 × Pusa Sadabahar, supported by Chadchan and Mohan Kumar (2008) and Grajales *et al.* (2009). The crosses BSPRL-189 × Bydagi (0.60) and BSPRL-189 × G-4 (0.47) showed highly significant positive SCA effects for various traits, as reported by Gawali *et al.* (2015) and Kumar *et al.* (2014). The hybrid BSPRL-226 × G-4 (27.51) exhibited a positive significant SCA effect for the number of pickings/ plant. The crosses BSPRL-226 × Bydagi (1.12) and BSPRL-189 × G-4 (0.72) showed highly significant positive SCA effects for dry fruit yield, while BSPRL-066 × Pusa Sadabahar (2.13) exhibited a highly positive significant SCA effect. Similar results were reported by Tembhurne *et al.* (2012), Kumar *et al.* (2014), and Meena *et al.* (2018).

CONCLUSION

The GCA and SCA variances were highly significant for all characters except fruit diameter. Among Parents, BSPRL-066, BSPRL-171, BSPRL-224, Phule Jyoti, PBNC-1, G-4, Teja, Bydagi, and Pusa Jwala, were good general combiners for fruit and yield-contributing characters. Hybrids BSPRL-066 x Teja, BSPRL-171 x Phule Jyoti, BSPRL-066 x Phule Jyoti, BSPRL-224 x Kokan Kirti,BSPRL-188 x Bydagi, BSPRL-189 x Bydagi, BSPRL-189 x Pusa Sadabahar, BSPRL-171 x Bydagi, BSPRL-171 x G-4, BSPRL-171 x PBNC-1, BSPRL-188 x Pusa Jwala, BSPRL-188 x Teja, BSPRL-066 x Konkan Kirti, BSPRL-066 x PBNC-1, BSPRL-188 x Phule Jyoti, and BSPRL-171 x Pusa Jwala, were best promising combinations for green fruit yield.

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Evaluation of ber (*Ziziphus mauritiana*) germplasm for fruit setting characters

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ABSTRACT

The study was carried out to evaluate variability between different ber (*Ziziphus mauritiana* Lamk.) germplasm on the basis of flowering and fruit setting. Bawal Ber 12 exhibited early initiation, while BS 3 showed delayed flower initiation. The shortest flowering duration was recorded in Bawal Ber 9 (37 days), whereas longest flowering duration was recorded in Bawal Ber 1, Bawal Ber 5 and BS 1 (42 days). Different germplasm displayed notable variation in mature fruit colour, including greenish-yellow, yellow and green. Oval shaped fruits were observed in Bawal Ber 1, Bawal Ber 9 and BS 3 while Bawal Ber 2, Bawal Ber 5, Bawal Ber 6, Bawal Ber 7, Bawal Ber 8, Bawal Ber 10 and BS 2 exhibited ovate shape. Bawal Ber 3, Bawal Ber 4 and BS 1 had oblong fruits and Bawal Ber 11 displayed an oblate shape whereas Bawal Ber 12 had round fruits. The stone shape of ber germplasm varied with some exhibiting a spindle, oblong, club or oval shape. Bawal Ber 1, Bawal Ber 2, Bawal Ber 3, Bawal Ber 4, Bawal Ber 5, Bawal Ber 7, Bawal Ber 9, Bawal Ber 10 and Bawal Ber 12 had a plain fruit surface, while Bawal Ber 6, Bawal Ber 8, Bawal Ber 11, BS 1, BS 2 and BS 3 showed a ridged and wart fruit surface.

Key words: Fruit setting, Colour, Flowering, Oval, Ovate, Ridged, Variability

Clonal selection for early maturing ber (*Ziziphus mauritiana* Lamk.) clones has been a major area of focus in ber breeding. The majority of common cultivars are the outcome of selection in various geographic areas. The diverse features of ber in India exhibit a wide range of variability, indicating significant potental for further development. However, there have been limited systematic efforts to characterise the existing variability in ber germplasm across the country. In India, for plant varieties to be protected under the Protection of Plant Varieties and Farmer's Right Act, 2001 (PPV&FR Act, 2016),they must undergo distinctness, uniformity, and stability (DUS) testing . The objective of this study was to evaluate 15 different germplasm samples based on their flowering and fruit maturity characteristics to determine the distinctness of each variety compared to others.

MATERIALS AND METHODS

A total of 15 ber germplasm, Bawal Ber 1, Bawal Ber 2, Bawal Ber 3, Bawal Ber 4, Bawal Ber 5, Bawal Ber 6, Bawal Ber 7, Bawal Ber 8, Bawal Ber 9, Bawal Ber 10, Bawal Ber 11, Bawal Ber 12, BS 1, BS 2 and BS 3, were evaluated in a randomized block design with three replications at the Regional Research Station, Bawal (Rewari) of CCS HAU, Hisar (Haryana) during 2019-2020. Each plant was sampled three times from different directions. The adopted spacing between plants was 8 m x 8 m.

The parameters were recorded at specific stages following the regular DUS testing procedures of PPV&FRA. Flowering characters were observed in September, while observations on fruit parameters were recorded from ripe fruits collected from tagged branches.

Twenty branches per tree (five branches from each quarter of the tree) were randomly selected and tagged to observe the date of flowering. The dates were recorded when five per cent of the flower buds on the tagged branches had opened (Mahajan *et al*., 2002). The nature of flowering branchlets was visually observed on the tagged branches. The presence of flowers on primary and secondary branches was noted with naked eyes. Additionally, the flower position on the tagged branches was observed at the flowering stage, categorizing them as axillary cyme, terminal or axillary clusters based on the grouping or clustering of flowers on a branch following the guidelines for

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DUS testing of PPV and FRA (PPV&FRA, 2016).The date of the end of flowering was also recorded on the branches tagged for the flowering date. When 85-90 per cent flower buds were opened, it was considered as the end of flowering (Mahajan *et al*., 2002) .The flowering duration was calculated by counting the number of days from from the start of flowering to the end of flowering on the tagged branches and the average duration was calculated.

The time taken from flowering to fruit setting (in days) was calculated by counting the number of days from the date of peak flowering to the date when 50 per cent fruits on tagged branches had set. The date of 50 percent fruits maturity was noted when approximately 50 percent fruits on the tagged branches had reached maturity and the average date was calculated. The time taken from fruit setting to fruit maturity (in days) was calculated by counting the number of days from the date of 50 percent fruit setting to the date when 50 percent fruits on the tagged fruit had reached maturity .

To examine the anthocyanin blush of immature fruits, twenty immature fruits per tree were selected from the tagged branches (five fruits from each quarter of the plant). The presence or absence of anthocyanin blush in mature fruits was visually observed and marked.The bearing habit of fruits was observed visually on tagged branches of tree following the guidelines for DUS testing of PPV and FRA (PPV&FRA, 2016). The shape of mature fruits at the apex end was determined using the same fruits used for determining fruit cracking. The shape was observed and categorized as round, flat, or pointed, according to the guidelines for DUS testing of PPV and FRA. The fruit surface was determined using the fruits used for determining fruit cracking. It was observed and categorized as plain or ridged and wart, following the guidelines for DUS testing of PPV and FRA (PPV&FRA, 2016).The visual interpretation of fruit skin colour was carried out by considering the outer surface colour of matured fruits picked from tagged branches. The color was marked as yellow, greenish-yellow, chocolate brown *etc.* based on standard colour chart. The stones used for determining the stone size/ stone weight were also used to examine the stone shape. The shape was visually observed and categorized as oval, oblong, spindle, club or falcate following the guidelines for DUS testing of PPV and FRA (PPV&FRA, 2016).

RESULTS AND DISCUSSION

The data regarding the nature of flowering branchlet and flower position on branchlet did not exhibit significant variation. In all germplasm samples, the flowering position was observed on secondary branches and flowering was observed on the leaf axis (Fig. 1). These similarities in inflorescence and flowering branchlets could be attributed to a close relationship within the *Ziziphus mauritiana* species (Saran, 2005).

Flowering initiation occurred between 5th and 25th September. Bawal Ber 12 exhibited early flowering (September 5th-10th), while BS 3 showed comparatively late flowering (September 20th - 25th). The flowering period ended in the first week of October when 85-90% of the flowers had opened. Different germplasm samples completed their flowering period between the third week of October and the first week of November. The variability in flowering duration aligns with the findings reported by Nehra *et al.* (1984). The variation in flowering time in ber can be attributed to factors such as temperature, humidity, rainfall, and genetic constitution (Saran, 2005).

The duration of flowering, time taken from flowering to fruit setting, and time taken from fruit setting to fruit maturity also exhibited significant variation. Bawal Ber 9 had the shortest flowering duration (37 days), while Bawal Ber 1, Bawal Ber 5, and BS 1 had the longest flowering duration (42 days). The minimum time taken from flowering to fruit setting was observed in Bawal Ber 5, Bawal Ber 7, and Bawal Ber 12 (16 days), while the maximum time taken was observed in Bawal Ber 1, Bawal Ber 2, and BS 2 (21 days). The minimum time taken from fruit setting to fruit maturity was recorded in Bawal Ber 12 (126 days), while the maximum was observed in Bawal Ber 9 (155 days). It was noted that the flowering season in ber is prolonged, and the duration of flowering varies among different genotypes. These findings regarding flowering duration and the time taken for fruit setting and fruit maturity in ber are consistent with the results reported by Krishna *et al*. (2016).

The variability in flowering duration, time taken from flowering to fruit setting, and time taken from fruit setting to fruit maturity in ber can be influenced by various factors, including the location of the experiment (Nath and Bhargava, 2000; Raja, 2004). Temperature, humidity, nutritional status, and genetic factors are also known to contribute to the variation observed in these traits (Saran, 2005;

Sharif *et al.,* 2013; Choudhary *et al*., 2017; Choudhary *et al.,* 2020).In terms of immature fruit characteristics, anthocyanin blush was observed in Bawal Ber 4, Bawal Ber 8, Bawal Ber 9, Bawal Ber 10, and Bawal Ber 11, while it was absent in the remaining germplasm (Table 1). This variation in anthocyanin blush in immature ber fruits has been previously reported by Raja (2004) and Saran (2005). Bunching of fruits was present in Bawal Ber 2, Bawal Ber 3, Bawal Ber 4, Bawal Ber 5, Bawal Ber 8, Bawal Ber 9, Bawal Ber 11, and BS 2, while it was absent in Bawal Ber 1, Bawal Ber 6, Bawal Ber 7, Bawal Ber 10, Bawal Ber 12, BS 1, and BS 3 (Table 1). The variation in the bearing habit of ber fruits has also been documented by Godi *et al.* (2016). These variations in immature fruit color and bearing habit among different germplasm may be inherent characteristics of the specific germplasm (Krishna *et al*., 2016). The fruits of Bawal Ber 2, Bawal Ber 6, Bawal Ber 7, Bawal Ber 9 and Bawal Ber 12 were yellow incolour. The fruits of BS 3 were green in colour and remaining germplasm had a greenish-yellow color. Bawal Ber 1 to 5, Bawal Ber 7, Bawal Ber 9, Bawal Ber 10 and Bawal Ber 12 showed plain fruit surface, while other germplasm had ridged and wart fruit surface (Table 1). Ezhilarasi and Tamilmani (2009) reported that the change in fruit colour during ripening can be attributed to factors such as loss of chlorophyll, the coalescence of carotenoids and presence of pigmental phenolic compounds such as anthocyanins, β carotenes *etc*. Selection of cultivar/germplasm by consumers depends on their appearance and other physical properties for an attractive look. Similar findings on mature fruit colour and fruit surface were also reported by Krishna *et al.*,2016; Singh and Deen, 2022.

Fruits of Bawal Ber 1, Bawal Ber 9 and BS 3 were oval in shape The fruits of Bawal Ber 3, Bawal Ber 4 and BS 1 were oblong and the fruits of Bawal Ber 11 were oblate. On the other hand, fruits of Bawal Ber 12 were roundwhile the rest of the germplasm were ovate. The fruit apex of Bawal Ber 2, Bawal Ber 8 and Bawal Ber 11 was flat in shape while the fruit apex of Bawal Ber 6, Bawal Ber 7, Bawal Ber 10 and BS 3 waspointed. The remaining germplasm had a round fruit apex (Table 2). The stones of Bawal Ber 1, Bawal Ber 2 and Bawal Ber 7 were spindle in shape; the stones of Bawal Ber 3 were oblong; stones of Bawal Ber 4, Bawal Ber 8, Bawal Ber 10 and BS 3 were a club in shape; however, the stones of Bawal Ber 5, Bawal Ber 6, Bawal Ber 9, Bawal Ber 11, Bawal Ber 12, BS 1 and BS 2 were oval (Table 2). The similar variations in the shape of fruits and stone were observed by Nehra *et al*. (1984), Kundi *et al*. (1989), Bal (1992), Raja (2004) and Torahi (2004). These variations in shape of fruits and stones may be attributed to the genetic makeup of the germplasm (Saran, 2005).

Table 1: Fruit phenotypic attributes of ber germplasm under semi-arid conditions of Haryana

Germplasm	Immature fruit: Anthocyanin blush	Bearing habit: Bunching	Mature fruit colour	Fruit surface	Mature fruit shape	Fruit shape: Apex	Stone shape
Bawal Ber 1	Absent	Absent	Greenish yellow	Plain	Oval	Round	Spindle
Bawal Ber 2	Absent	Present	Yellow	Plain	Ovate	Flat	Spindle
Bawal Ber 3	Absent	Present	Greenish yellow	Plain	Oblong	Round	Oblong
Bawal Ber 4	Present	Present	Greenish yellow	Plain	Oblong	Round	Club
Bawal Ber 5	Absent	Present	Greenish yellow	Plain	Ovate	Round	Oval
Bawal Ber 6	Absent	Absent	Yellow	Ridged and wart	Ovate	Pointed	Oval
Bawal Ber 7	Absent	Absent	Yellow	Plain	Ovate	Pointed	Spindle
Bawal Ber 8	Present	Present	Greenish yellow	Ridged and wart	Ovate	Flat	Club
Bawal Ber 9	Present	Present	Yellow	Plain	Oval	Round	Oval
Bawal Ber 10	Present	Absent	Greenish yellow	Plain	Ovate	Pointed	Club
Bawal Ber 11	Present	Present	Greenish yellow	Ridged and wart	Oblate	Flat	Oval
Bawal Ber 12	Absent	Absent	Yellow	Plain	Round	Round	Oval
BS 1	Absent	Absent	Greenish yellow	Ridged and wart	Oblong	Round	Oval
BS 2	Absent	Present	Greenish yellow	Ridged and wart	Ovate	Round	Oval
BS 3	Absent	Absent	Green	Ridged and wart	Oval	Pointed	Club

CONCLUSION

Bawal Ber 12 exhibited early initiation and completion of flowering, as well as early fruit setting and maturity. On the other hand, BS 3 showed late flowering and fruit setting, and BS 3, Bawal Ber 8, Bawal Ber 9, and Bawal Ber 11 exhibited late fruit maturity. The fruit color of the different germplasm varied significantly. This color change can be attributed to the conversion of chlorophyll to anthocyanin. The fruit surface of Bawal Ber 1, Bawal Ber 2, Bawal Ber 3, Bawal Ber 4, Bawal Ber 5, Bawal Ber 7, Bawal Ber 9, Bawal Ber 10, and Bawal Ber 12 was observed to be plain.The shape of fruits differed among the germplasm. Bawal Ber 1, Bawal Ber 9, and BS 3 had oval-shaped fruits, Bawal Ber 2, Bawal Ber 5, Bawal Ber 6, Bawal Ber 7, Bawal Ber 8, Bawal Ber 10, and BS 2 had ovate-shaped fruits, Bawal Ber 3, Bawal Ber 4, and BS 1 had oblong-shaped fruits, Bawal Ber 11 had oblate-shaped fruits, and Bawal Ber 12 had round-shaped fruits.

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Character association and path analysis for green pod yield in French bean (*Phaseolus vulgaris*)

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ABSTRACT

Sixty-six genotypes of French bean (*Phaseolus vulgaris* L.) were evaluated for correlation and path coefficient analysis at KRCCH, Arabhavi, University of Horticultural Sciences, Bagalkot. In most cases, genotypic correlations were higher than phenotypic correlations, indicating highly heritable nature of green pod yield/plant. It showed positive and significant correlation with plant height, number of branches/plant 60 days after sowing and 100-seed weight both at genotypic and phenotypic level, whereas number of branches/plant at 30 days after sowing, number of pods/plant and number of seeds/plant showed positive and significant correlation at genotypic level. Path coefficient revealed that number of branches/plant at 60 days after sowing and pod weight characters have direct positive effect on green pod yield/plant. Thus, these characters deserve greater weightage during selection for yield. The direct selection in these traits would be rewarding for improvement in pod yield/plant.

Key Words: Weight, Branches/plant, Genotypes, Seed Correlation

French bean (*Phaseolus vulgaris* L., 2n=22) family Leguminosae has evolved from wild growing vine distributed in high lands of Middle-America and Andes. A study of correlation between different quantitative characters provides an idea of association. It could be effectively exploited to formulate selection strategies for improving yield and quality. The path coefficient technique developed by Wright (1921) helps in estimating direct and indirect contribution of various components in building up the correlation towards yield. This study will help the breeder to know the degree of association among traits, which can be used for crop improvement through selection of component traits.

MATERIAL AND METHODS

The study was carried out to assess the variability and character association in 66 diverse genotypes of French bean at KRCCH, Arabhavi, University of Horticultural Sciences, Bagalkot. The experimental plot was ploughed repeatedly and land was brought to a fine tilth . About 25 tonnes of FYM per hectare and recommended basal dose of fertilizers (62.5: 100: 75 kg NPK/ha) were incorporated into the soil, just before sowing as per the packages of practices of UAS, Dharwad. Ridges and furrows were opened at a distance of 30 cm. Seeds of each genotype were dibbled at a distance of 10 cm in a row.

Observations were recorded on five plants chosen at random in each cross and in each replication and the mean of five plants were taken for analysis. The correlation co-efficient among all possible character combinations at phenotypic (rp) and genotypic (rg) level were estimated employing formula (Al-Jibouri *et al.*, 1958). Path co-efficient analysis (Wright, 1921) and Dewey and Lu (1959) were carried out to know the direct and indirect effect of morphological traits on plant yield.

RESULTS AND DISCUSSION

There was highly significant (P=0.01) difference among genotypes for all the characters. Similarly, highly significant variations for all characters were reported by Makhdoomi and Dar (2011) and Kamaluddin and Shahid (2011). In any crop improvement programme, it becomes necessary to have simultaneous progress of more than one character, especially in yield, which is influenced by many other traits (Tripathi*et al.*, 2018; Singh *et al.*, 2021).

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This is due to physiological and linkage relationship of genes governing various characters. The genotypic correlation was higher than phenotypic correlations for all the characters, indicating little influence of environment and presence of inherent association among characters (Tables 1 and 2).

In genotypic level, plant height at 30 DAS showed highly significant and positive correlation with plant height at 60 DAS(0.865), number of pods/plant (0.816), number of branches/plant at 30 DAS (0.776), number of branches/plant at 60 DAS (0.636), green pod yield/plant (0.449) and 100-seed weight (0.404). There was positive and significant association with number of seeds/plant (0.253). Plant height at 60 DAS exhibited highly significant and positive correlation with number of pods /plant (1.121), number of branches/plant at 60 DAS (0.929), green pod yield/plant (0.725), number of seeds/plant (0.554), number of branches/plant at 30 DAS (0.443) and 100-seed weight (0.344).

In phenotypic level, plant height at 30 DAS showed highly significant and positive correlation with plant height at 60 DAS (0.750), number of branches at 60 DAS (0.459) and green pod yield/plant (0.380). It also reflected positive and significant association with 100-seed weight (0.266), whereas plant height at 60 DAS showed highly significant and positive correlation with number of branches/plant at 60 DAS (0.656), green pod yield/plant (0.530) and number of seeds/ plant (0.334). It also showed positive and significant association with 100-seed weight (0.282) and number of pods/plant (0.279). Similar results were reported by Roy *et al.* (2006), Bhushan *et al.* (2007) and Mishra *et al.* (2006).

In genotypic level, number of branches/plant at 30 DAS showed highly significant and positive correlation with number of pods/plant (0.974), 100-seed weight (0.812), number of seeds/plant (0.664), number of branches/plant at 60 DAS (0.656), green pod yield/plant (0.570) and days to 50% flowering (0.365). Number of branches/plant at 60 DAS exhibited highly significant and positive correlation with number of pods/plant (1.032), green pod yield/plant (0.782), number of seeds/plant (0.597) and 100-seed weight (0.449).

At phenotypic level, number of branches/plant at 30 DAS manifested positive correlation with 100-seed weight (0.241) and green pod yield (0.095). Number of branches/plant at 60 DAS reflected highly significant and positive correlation with green pod yield/plant (0.812) and 100-seed weight (0.357). It also showed positive and significant association with number of seeds/plant (0.270) and number of pods/plant (0.252). Similar results were given by Karasu and Oz (2010). Pod weight showed significant and positive correlation with green pod yield/plant and pod length both at genotypic (0.314 and 0.271) and phenotypic levels (0.212 and 0.186). Pod length showed highly significant and positive correlation with green pod yield/plant both at genotypic (0.672) and phenotypic (0.596) levels. It also showed significant and negative correlation with days to 50% flowering at both genotypic (-0.285) and phenotypic (-0.161) levels.

It indicates that as the days to 50% flowering increases there is decrease in pod length. Anjani *et al.* (2009), Chaudhary *et al.* (2017) and Basavaraj *et al.* (2022) also supported these finding. At the genotypic level, number of per plant showed highly significant and positive correlation with number of seeds/ plant (0.950) and green pod yield/plant (0.746). Phenotypic level, number of pods/plant showed highly significant and positive correlation only with number of seeds/ plant (0.732). Similar results were reported by Raffi and Nath (2004), Mishra *et al.* (2009), Karasu and Oz (2010). In genotypic level, number of seeds/plant exhibited highly significant and positive correlation with days to 50% flowering (0.381). It is also showed significant and positive correlation with green pod yield/plant (0.303).

Number of seeds/plant showed only positive association with days to 50% flowering (0.053) and green pod yield (0.172) at phenotypic level. These results are in agreement with Verma *et al.* (2015). The 100-seed weight showed highly significant and positive correlation with green pod yield/plant in both genotypic (0.471) and phenotypic levels (0.379). Days to 50% flowering showed negative correlation with green pod yield at both genotypic (-0.122) and phenotypic (-0.046) levels. It indicates that as days to 50% flowering increases with decrease in green pod yield. Similar results were given by Mishra *et al.* (2009) and Kamaluddin and Shahid (2011). The green pod yield/plant had highly significant association with number of branches/plant at 60 DAS (0.782), number of pods/plant (0.746), plant height at 60 DAS (0.725), pod length (0.672), number of branches/plant at 30 DAS (0.570), 100-seed weight (0.471) and plant height at 30 DAS (0.449). Hence, selection of component characters is worth rewarding for improving the yield.

The number of branches/plant at 60 DAS and pod length, indicate their true positive significant association with green pod yield/plant. Similar results were obtained by Roy *et al.* (2006), Dursen (2007), Anjani *et al*. (2009) and Karasu and Oz (2010). The plant height at 60 DAS despite its negative direct effect (-0.022) had strong positive association with green pod yield/plant (rG=0.725). This is mainly because of its high indirect positive effect through number of branches/plant at 60 DAS (0.757) and pod length (0.047). The negative indirect effect of trait through plant height failed to alter its positive association was observed at both genotypic and phenotypic levels. Similar results have been reported by Karasu and Oz (2010).Number of branches/plant at 30 DAS showed negative and direct effect (-0.016) on green pod yield/plant (rG=0.570).

However, its strong positive association with green pod yield was mainly of its positive indirect effect through number of branches/plant at 60 DAS (0.535) and pod length (0.118). The negative indirect effect of trait *via* plant height was observed. Number of branches/plant at 60 DAS showed positive and direct effect (0.816) on green pod yield/plant (rG=0.782 and

Table 1. Genotypic correlation for growth and yield characters

character	1	2	3	4	5	6	7	8	9	10	11
1	1.000	0.865**	0.776**	0.636**	0.100	0.009	0.816**	0.253*	0.404**	0.081	0.449**
2		1.000	0.443**	0.929**	0.234	0.076	1.121**	0.554**	0.344**	0.084	0.725**
3			1.000	0.656**	0.061	0.192	0.974**	0.664**	0.812**	0.365**	0.570**
4				1.000	0.201	0.070	1.032**	0.597**	0.449**	0.115	0.782**
5					1.000	0.271*	-0.001	-0.091	-0.018	-0.240	0.314*
6						1.000	-0.007	-0.186	0.239	-0.285	0.672**
7							1.000	0.950**	0.100	-0.060	0.746**
8								1.000	0.095	0.381**	0.303*
9									1.000	0.025	0.471**
10										1.000	-0.122
11											1.000

Critical r- 1% = 0.325 5%= 0.250 *Significant at 5% ** Significant at 1%

Table 2: Genotypic path coefficient analysis for growth and yield characters

character	1	2	3	4	5	6	7	8	9	10	rG
1	**-0.0270**	-0.0190	-0.0130	0.5180	-0.0020	0.0050	-0.0030	-0.0070	-0.0030	-0.0020	0.449**
2	-0.0230	**-0.0220**	-0.0070	0.7570	-0.0040	0.0470	-0.0040	-0.0150	-0.0020	-0.0020	0.725**
3	-0.0210	-0.0100	**-0.0160**	0.5350	-0.0010	0.1180	-0.0030	-0.0180	-0.0050	-0.0090	0.570**
4	-0.0170	-0.0210	-0.0110	**0.8160**	-0.0030	0.0430	-0.0040	-0.0160	-0.0030	-0.0030	0.782**
5	-0.0030	-0.0050	-0.0010	0.1640	**-0.0160**	0.1660	0.0000	0.0020	0.0000	0.0060	0.314*
6	0.0000	-0.0020	-0.0030	0.0570	-0.0040	**0.6140**	0.0000	0.0050	-0.0020	0.0070	0.672**
7	-0.0220	-0.0250	-0.0160	0.8420	0.0000	-0.0040	**-0.0030**	-0.0260	-0.0010	0.0010	0.746**
8	-0.0070	-0.0120	-0.0110	0.4870	0.0010	-0.1140	-0.0030	**-0.0270**	-0.0010	-0.0090	0.303*
9	-0.0110	-0.0080	-0.0130	0.3660	0.0000	0.1470	0.0000	-0.0030	**-0.0060**	-0.0010	0.471**
10	-0.0020	-0.0020	-0.0060	0.0940	0.0040	-0.1750	0.0000	-0.0100	0.0000	**-0.0250**	-0.122

Residual= 0.0032 Diagonal indicates direct effect

* Significant at 5% ** Significant at 1% rG. Genotypic correlation with green pod yield per plant

1, Plant height at 30 DAS (cm)
2, Plant height at 60 DAS (cm)
3, No. of branches per plant at 30 DAS
4, No. of branches per plant at 60 DAS
5, Pod weight (g)
6, Pod length (cm)
7, No. of pods per plant
8, No. of seeds per plant
9, 100-seed weight (g)
10, Days to 50% flowering
11, Green pod yield plant (g)

rP=0.812), because of its indirect positive association through pod length (0.043 and 0.017) at both genotypic and phenotypic levels. Similar results were obtained by Raffi and Nath (2004) and Karasu and Oz (2010).

The pod weight despite its negative direct effect (-0.016) had strong positive association with green pod yield/plant (rG=0.314). This is mainly because of its high indirect positive effect through pod length (0.166) and number of branches/plant at 60 DAS (0.164) in genotypic level. These results are in accordance with findings of (Dursun, 2010). The pod length showed positive direct effect (0.614) and had strong positive association with green pod yield/plant. This might be its indirect positive effect through number of branches/plant at 60 DAS observed at genotypic and phenotypic levels. Negative indirect effect on green yield/plant *via* plant height at 60 DAS was observed only in phenotypic level. Similar results have been reported by Anjani *et al.* (2009), Verma *et al.* (2015) and Basavaraj *et al.* (2022).The number of pods/ plant showed negative direct effect (-0.0030) and strong positive association with green pod yield/plant (rG=0.746). This is mainly because of its strong indirect positive effect through number of branches/plant at 60 DAS (0.842) and strong indirect negative effect through number of seeds/plant (-0.026), plant height at 60 DAS(-0.025), plant height at 30 DAS (-0.022) and number of branches/plant at 30 DAS (0.016) was observed in genotypic level. Number of pods/plant had positive strong association (rP=0.176) with green pod yield. The trait had also high indirect positive effect on yield *via* number of branches/plant (0.209). Its indirect negative effect was due to number of seeds/plant (-0.023) and plant height at 60 DAS (-0.009) was observed in phenotypic level. Similar results were obtained by Raffi and Nath (2004), Mishra *et al.* (2009) and Karasu and Oz (2010).The number of seeds/plant showed negative direct effect (-0.027) and had strong positive association with green pod yield/plant (rG=0.303). This is mainly because of its high indirect positive effect through number of branches/plant at 60 DAS (0.487) and negative indirect effect through pod length (-0.114) at genotypic level and number of seeds/plant had positive association (rP=0.127) with green pod yield but negative direct effect (-0.031) on green pod yield.

The trait had also high indirect positive effect on yield *via* number of branches/plant (0.224). Its indirect negative effect was due to number pods/ plant at 60 DAS (-0.055) at phenotypic level. This is mainly because of its high indirect positive effect through number of branches/plant at 60 DAS and pod length. There is a negative indirect effect through number of branches/plant at 30 DAS, plant height at 30 DAS and plant height at 60 DAS at both genotypic and phenotypic levels. Similar results were obtained by Mishra *et al.* (2008) Singh *et al.* (2023) .and Sandeep *et al.* (2009). Days to 50% flowering showed negative direct effect and negative association with green pod yield/plant. This is because of its high indirect positive effect through number of branches/plant at 60 DAS and negative indirect effect through pod length. There is no association with number of pods/ plant and 100-seed weight was observed at both genotypic and phenotypic levels. Similar results have been reported by Roy *et al.* (2006), Mishra *et al.* (2009), Kamaluddin and Shahid (2020), Noopur *et al.* (2019) and Kalauni and Dhakal in French bean.

CONCLUSION

Thus, it can be concluded that number of branches/plant at 60 DAS, number of pods/plant, green pod yield/plant and, 100-seed weight and pod length are the most important factors influencing green pod yield through direct effect coupled with high positive correlation. These characters deserve greater weightage during selection for yield. The direct selection in these traits would be rewarding for improvement in pod yield/plant.

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Evaluation of acid lime (*Citrus aurantifolia*) clones for pickling

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ABSTRACT

An experiment was conducted to evaluate acid lime (*Citrus aurantifolia* Swingle) clones for pickle making at Citrus Research Station, Tirupati, during 2021 and 2022 with two replications in a completely randomized design with fifteen acid lime clones. The mean performance of pickle recovery was 49.26%, highest in TAL 94/14 (56.00%) and least in Phule Sharbati (42.00%). There was good texture (8.20), taste (8.50) and overall acceptability (8.40) in TAL94/14, whereas, best colour (8.20) and flavour (8.30) were observed in Local Kagzi lime and Balaji clones. The total bacterial population (CFU/g) was counted for four months period from the 0th day to 120th day at monthly interval. The least bacterial count was observed in clone TAL 94/14 on the 0th, 30th and 90th day. However, Balaji recorded least bacterial population on 60th and 120th day.

Key Words: Pickle, Total bacterial population, Sensory evaluation, Drying.

Acid lime (*Citrus aurantifolia* Swingle) can be used to make pickles and seasonal cuisine diced, quartered, halved, or whole, limes are pickled with salt and occasionally spices are included as well. In India, limes and lemon are used in Indian traditional medicines Siddha Medicine and Ayurveda (Mohanapriya *et al*., 2013). Pickling is a traditional method for preserving and restoring the inherent bioactive substances and antioxidant properties of fruits and vegetables (Sayin and Alkan, 2015).To identify the fermentation of lime pickle under ambient room temperature which would affect the physicochemical, microbiological, and organoleptic qualities of pickle during storage. This helps to preserve lime pickle for long term with its acidity and vitamin C. Therefore an, experiment was conducted.

MATERIALS AND METHODS

The experiment was conducted at Citrus Research Station, Dr YSR Horticultural University, Tirupati, during 2021-2022 with two replications in a completely randomized design. Fifteen acid lime clones were evaluated for pickle making. The pickle recovery (per cent dry weight) was calculated by known weight of pickle (100 g) after four months and strained to separate solids and liquids. The weight of solids separated was taken and made to its percent. The ingredients were lime 250 g, salt 25 g, red chilli powder 25 g, turmeric 1 g, cumin, fenugreek, dry chilli, asafoetida and mustard. The entire bacterial population per gram of sample was enumerated through repeated dilutions with distilled water, followed by pour plate method through nutrient agar media.

The colonies were counted after 24 hours. Total bacterial population (CFU/g) at serial dilutions of 10^{-6} starting from 0th day to 120 days for 4 months period at monthly intervals were carried out. The data were analyzed in CRD design. Nine-point hedonic scale method was followed for conducting the sensory evaluation of pickle. The overall acceptability was recorded based on colour, flavor, texture and taste of the pickle. Randomized Block Design (RBD) is used for sensory evaluation with ten evaluators.

RESULTS AND DISCUSSION

The maximum pickle recovery was observed in TAL 94/14 (56.00 %), followed by Pramalini and NRCC Nimboo-2 (54.00 %) and Balaji (53.00 %), which were identical to each other and significantly superior among other clones. However, least pickle recovery was noticed in Phule Sharbati (42.00%). Sensory evaluation at ambient conditions for colour, flavour, taste, texture and overall acceptability was

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observed through 0-9 point hedonic scale. A good quality colour was observed in Local Kagzi lime (8.20), followed by TAL 94/14, Balaji, Phule Sharbati and Akola lime (8.00). The quality of pickle colour was not attractive in Pramalini, Petlur Pulusunimma (7.00), followed by NRCC Nimboo 3 (7.20). The pickle made from Balaji has best flavour (8.30), followed by TAL 94/14 (8.00), Sai Sharbati (7.80) and Petlur Pulusnimma (7.70). The flavour quality in Vikram (6.70) scored least, followed by NRCC Nimboo-3 (7.10). The texture of TAL 94/14 (8.20) pickle was best, followed by TAL 94/13 (8.10), NRCC Nimboo-4 (8.00), and Balaji (7.90), which are similar to each other and significantly superior among other clones. NRCC Nimboo-3 (6.60) has lowest pickle texture quality.

The best taste was noticed in TAL 94/14 (8.50), followed by Sai Sharbati (8.00), Phule Sharbati and Balaji (7.90). The overall acceptability of pickle was good in TAL 94/14 (8.40), followed by Balaji (7.90), Local Kagzi lime (7.50), NRCC Nimboo-3 (6.60) and KL-12 (6.70). Vasugi *et al*. (2008) of unique mango accessions for whole-fruit pickle. Sivakumar *et al*. (2010) informed that appearance refers to physical appearance. Aneena *et al*. (2015) on Indian gooseberry, Zeenath *et al*. (2016) for accessions of pickling mangoes for tender mango pickling, Gahane *et al*. (2019) and Madhumati and Reddy (2020) on local mango genotypes. Thus, overall acceptability was observed high in TAL 94/14 (8.40), and minimum was found in NRCC Nimboo-3 (6.60), which was identical to those of Banana genotype Kadali (8.18), and Namarai (6.26) (Suhasini *et al*., 2021).

Table 1. Pickle making for sensory evaluation and total bacterial population (CFU/g) under ambient storage conditions from different acid lime clones

Clone	Pickle recovery (% dry weight)	Colour	Flavour	Texture	Taste	Overall acceptability	Storage period(days)				
							0	**30**	**60**	**90**	**120**
Balaji	53.00	8.00	8.30	7.90	7.90	7.90	3.50×10^6	10.00×10^6	43.50×10^6	74.00×10^6	291.00×10^6
Vikram	43.00	7.30	6.70	6.80	6.80	6.80	5.50×10^6	11.50×10^6	53.00×10^6	83.00×10^6	302.00×10^6
Pramalini	54.00	7.00	7.30	6.90	6.70	6.90	6.50×10^6	12.00×10^6	51.50×10^6	82.00×10^6	306.00×10^6
Jai Devi	48.50	7.90	7.40	7.70	7.60	7.40	5.00×10^6	10.50×10^6	47.00×10^6	75.00×10^6	293.50×10^6
Sai Sharbati	48.50	7.80	7.80	7.70	8.00	7.40	4.00×10^6	10.50×10^6	46.00×10^6	76.00×10^6	293.00×10^6
Phule Sharbati	42.00	8.00	7.50	7.60	7.90	7.00	4.50×10^6	9.50×10^6	45.50×10^6	75.50×10^6	293.00×10^6
Petlur Pulusunimma	46.50	7.00	7.70	7.70	7.10	7.30	4.00×10^6	10.50×10^6	44.00×10^6	77.00×10^6	291.00×10^6
TAL 94/14	56.00	8.10	8.00	8.20	8.50	8.40	3.00×10^6	9.00×10^6	45.00×10^6	73.50×10^6	292.00×10^6
TAL 94/13	47.50	7.70	7.60	8.10	7.50	7.20	5.00×10^6	10.50×10^6	46.50×10^6	76.50×10^6	297.00×10^6
NRCC Nimboo-2	54.00	7.50	7.40	6.90	6.60	6.90	4.00×10^6	10.00×10^6	47.50×10^6	77.50×10^6	298.00×10^6
NRCC Nimboo-3	44.00	7.20	7.10	6.60	7.10	6.60	6.00×10^6	12.50×10^6	52.00×10^6	82.00×10^6	306.50×10^6
NRCC Nimboo-4	50.00	7.70	7.30	8.00	7.60	7.40	4.00×10^6	10.00×10^6	44.50×10^6	74.50×10^6	291.50×10^6
Akola lime	49.50	8.00	7.40	6.90	7.30	6.90	5.50×10^6	10.50×10^6	48.00×10^6	78.00×10^6	298.50×10^6
KL-12	52.50	7.50	7.30	7.10	7.40	6.70	5.00×10^6	11.50×10^6	49.50×10^6	79.50×10^6	305.50×10^6
Local Kagzi lime	50.00	8.20	7.60	7.10	7.70	7.50	4.00×10^6	10.50×10^6	45.00×10^6	75.00×10^6	292.50×10^6
SEm±	2.35	0.24	0.25	0.22	0.22	0.20	0.54	0.42	1.64	1.68	3.11
CD @5%	7.17	0.68	0.71	0.62	0.61	0.56	1.66	1.30	5.01	5.12	9.48
CV (%)	6.77	10.02	10.67	9.51	9.29	8.70	16.59	5.69	4.93	3.08	1.48

At 0-day bacterial population, least bacterial plate count was ascertained in TAL 94/14 (3.00 x 10^6), followed by Balaji (3.50 x 10^6), and more in Pramalini (6.50 x 10^6). At 30th day the least bacterial plate count was in TAL 94/14 (9.00 x 10^6), followed by Phule Sharbati (9.50 x 10^6), Balaji, NRCC Nimboo- 2 and NRCC Nimboo-4 (10.00 x 10^6), which were on a par with each other and significantly superior, whereas, NRCC Nimboo-3 (12.50 x 10^6) clone recorded highest bacterial plate count, followed by Pramalini (12.00 x 10^6).

During 60th day, plate count of bacteria was least in Balaji (43.50 x 10^6), followed by Petlur Pulusunimma (44.00 x 10^6), NRCC Nimboo-4 (44.50 x 10^6), TAL 94/14 (45.00 X 10^6) and maximum count in Vikram (53.00 x 10^6), followed by NRCC Nimboo-3 (52.00 x 10^6). On 90th day, plate count was least in TAL 94/14 (73.50 x 10^6), followed by Balaji (74.00 x 10^6), NRCC Nimboo-4 (74.50 x 10^6), Jai Devi and Local Kagzi lime (75.00 x 10^6) and maximum in Vikram (83.00 x 10^6), followed by NRCC Nimboo-3 (82.00 x 10^6).During 120th day, least bacterial population was observed in Balaji, Petlur Pulusuninmma (291.00 x 10^6), followed by NRCC Nimboo-4 (291.50 x 10^6), TAL 94/14 (292.00 x 10^6), Local Kagzi Lime (292.50 x 10^6). However, NRCC Nimboo-3 recorded the highest plate count (306.50 x 10^6), followed by Pramalini (306.00 x 10^6).

Under ambient storage conditions from 0 day to 120th day, total plate count increased, whereas fungal growth also increased and the pickle got spoiled in a few clones and while in some pickles it became slimy due to excessive growth of lactic acid bacteria, These are also in line with Mani *et al*. (2017) reported effect of sodium substitution on lactic acid bacteria and total bacterial population.

CONCLUSION

The TAL 94/14 recorded best for pickle recovery (56.00 %), texture, taste and overall acceptability with the least bacterial count on 0th, 30th day, 90th day. However, Balaji recorded best for flavour, least bacterial population for 60th and 120th day. Thus Local Kagzi lime is best for pickle colour, whereas Pramalini, Phule Sharbati, Petlur Pulusunimma, and NRCC Nimboo -4 are promising clones for pickle making.

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Short Communication

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Vegetable production potential and income generation in Barmer district

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Barmer district offers very good opportunities for cultivation of arid vegetables like mateera (*Citrullus lanatus*), snapmelon (*Cucumis melo*), kachari, brinjal (*Solanum melongena*), bottle gourds (*Lagenaria siceraria*), round melon (*Praecitrullus fistulosus*), Indian aloe (*Aloe barbadensis*), and Khejri sangari (green pods of *Prosopis cineraria*). The data about the present situation, production potential, and problems are not available. To determine the production and yield potential, income generation, and profits, it is essential to know the vegetables grown during the kharif and rabi seasons to make suitable plans and strategies to encourage their production.

Out of the 15 tehsils in Barmer district, Gudamalani, Siwana, Pachpadra, Dhorimanna, and Barmer Tehsil were purposively selected for the study. Five villages were chosen from each tehsil, resulting in a total of 15 villages. From these villages, four farmers were randomly selected, making a total sample size of 60 farmers. The selected farmers were personally contacted, interviewed, and their responses were recorded using a semi-structured interview schedule. Statistical analysis, including measures such as percentage, area in hectares, price, and income, was used to draw conclusions and inferences from the data.

The results showed that farmers cultivate a variety of vegetables during the kharif and rabi seasons. I'm kharif season, 63.33% of the farmers grew combinations of mateera, snapmelon, kachari, round melon, tinda, pearl millet, sesame, moth bean, and cluster bean as rainfed crops. The vegetables grown in different cropping systems, under different seasons and combinations, ranged from mateera, snapmelon, kachari, brinjal, bottle gourd, ridge gourds, cluster bean, round melon, okra, tomato, chili, cauliflowers, cabbage, spinach, carrot, radish, pea, green onion, sangari (pods), and khejri. The major vegetable cropping systems practiced by the farmers included sole cropping, intercropping, mixed cropping systems, and perennial plantation.

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The findings are supported by Mishra *et al*. (2003), further emphasizing the suitability of these vegetable cropping systems in the region.

During kharif season, 36.66% of farmers district grew mateera, snapmelon, and kachari as sole crops on areas ranging from 0.2 to 1.5 hectares. In irrigated conditions, 56.66% of vegetable growers cultivated brinjal, bottle gourd, ridge gourd, round melon, tomato, okra, chilli, etc. as sole crops on areas ranging from 0.2 to 2.0 hectares.

In rainfed conditions during kharif season, farmers adopted a mixed cropping system. They grew mateera, snapmelon, kachari, round melons, etc., in combination with pearl millet, groundnut, sesame, moth bean, cluster bean, and other crops (Bairwa *et al*., 2020). This type of cropping system was practised by 63.33% of vegetable growers on areas ranging from 0.5 to 4.0 hectares. The mixed cropping system was found to be the most prominent method of vegetable cultivation in the arid environment of Barmer district, with the majority of farmers adopting this system and covering the largest area (0.5-4.0 hectares).

On 61.66% of vegetable-growing farmer fields, there were 15-25 perennial khejri plants per hectare. These khejri plants served as a major source of vegetables and fodder for farm animals. The plants were either grown naturally or cultivated by farmers and cared for and protected (Meena *et al*., 2007).

During rabi season, farmers grew watermelon, musk melon, cucumber, bitter gourd, kheera, brinjal, bottle gourd, ridge gourd, and other crops as sole crops. Approximately 56.66% of farmers cultivated these crops on areas ranging from 0.2 to 2.0 hectares. Sharma and Khurana (2000) had stated that majority of the farmer grew pulses (moong, mash and cowpea), vegetables ,and oilseeds as intercrops in mango orchards in Gurdaspur district of Punjab. Similarly, during the *zaid* season under irrigated conditions, 31.66% of farmers grew watermelon, musk melon, cucumber, bitter gourd, brinjal, bottle gourd, ridge gourd, and other crops as sole crops on areas ranging from 0.2 to 3.0 hectares.

During kharif season, farmers grow these crops on their fields and earn net income per hectare as follows: snapmelon (₹46,158), kachari (₹36,162), bottlegourd (₹49,566), ridge gourd (₹49,320), round melon (₹52,254), tomato (₹73,026), brinjal (₹51,117), chilli (₹78,504), and cluster bean (₹33,380).

Among other vegetable crops, cabbage, carrot, radish, and cauliflower have the highest yield potential at 218, 170, 200, and 198 quintals per hectare, respectively. However, net income is highest from pea and cauliflower, followed by cabbage, carrot, and spinach. Farmers earn ₹47,380, ₹43,288, ₹40,209, ₹38,336, and ₹33,302 per hectare from pea and cauliflower, cabbage, carrot, and spinach crops, respectively. However, area under pea and cabbage cultivation is limited due to unsuitable groundwater and other climatic conditions, causing farmers to avoid growing them.

The yield potential of longmelon, muskmelon, watermelon, and cucumber is approximately 90-100, 70-80, 120-135, and 60-80 quintals per hectare, respectively. However, the net income per hectare is highest for cucumber, followed by watermelon, longmelon, and muskmelon, with earnings of ₹15,000, ₹50,192, ₹46,675, and ₹35,163, respectively. Nevertheless, area under cucumber cultivation is limited due to unsuitable groundwater and other climatic conditions, causing farmers to avoid growing it.

It is important to note that these statistics reflect the specific conditions and results observed in the Barmer district and may vary in other regions or contexts.

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New vegetable varieties

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Ridge gourd (*Luffa acutangula*) Thar Karni

Thar Karni takes 51-55 days to reach the first picking stage from sowing. The fruits, measuring 20-25 cm in length and weighing 90-110 g, are cylindrical with 10 longitudinal shallow ridges. The plants bear short internodes and are profusely branched. The yield potential is 180-240 q/ha. It is tolerant to mosaic disease under field conditions and is suitable for cultivation in the spring-summer and Kharif seasons. Thar Karni exhibits fruit setting at high temperatures, making it suitable for cultivation in hot arid conditions during the summer season.

Longmelon (*Cucumis melo*) Thar Sheetal

The fruits of Thar Sheetal are 25-30 cm long, tender, and delicious. They are harvested 45-50 days after sowing. The fruits are free from bitterness. The inherent tolerance to high temperatures allows for its cultivation even during the summer season. Thar Sheetal can yield 150-200 q/ha, which amounts to ₹2.0-2.4 lakh/ha.

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