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Research Review

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Parthenocarpic brinjal *(Solanum melongena)*: a review

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ABSTRACT

Brinjal (*Solanum melongena* L.) is very popular vegetable in India and grown as a warm season vegetable crop. It is rich source of antioxidants, minerals and vitamins. The presence of seeds in brinjal fruit is undesirable to consumers and seedless fruits are therefore in demand due to improved flesh quality and suitability for processing. Phytohormones play important role in fruit development through genetic manipulation, leading to seedlessness. With the development of parthenocarpic brinjal, it can now be possible to grow under the protected conditions which ensure safer production of brinjal without using harmful chemicals. This trait is very useful to develop fruits in a particular environment (greenhouse cultivation) which are unfavourable for successful pollination and fertilization. The parthenocarpic trait has been transferred to desirable varieties through crossing that had high yield with favourable fruit quality. A few lines have been developed through interspecific crossing.The exploitation of molecular markers and transgenic technology have been utilized in developing parthenocarpic brinjal with enhanced fruit quality. Therefore, present review is focused on development and potentiality of parthenocarpic brinjal.

Key Words: Brinjal, Parthenocary, Seedless, Variety, Hybrid, Antioxidants, Pollination, Interspecific crossing

Brinjal *(Solanum melongena* L.*)* is most popular vegetable grown widely in India and other parts of the world. It is also known as eggplant or poor man's crop. Brinjal is particularly favoured in Asia where it has been cultivated for millennia, and in India it is considered Ring of Vegetables (Daunay and Janick, 2007). It is perennial but grown commercially as an annual crop which is rich source of anthocyanin, phenolics, calcium, phosphorus, iron and also contain vitamins, particularly of B group (Saha *et al.,* 2016). Since commercial ripeness of brinjal fruits precedes its physiological maturity, the presence of seeds considerably depreciates the value of fruits for fresh and processed purpose.

The negative effects associated with the presence of seeds in brinjal are browning of flesh upon cutting, increase in saponin and solasodin compounds which cause bitter taste (Aubert *et al.*, 1989) and harder flesh. Though developing seeds are source of phytohormones and stimulate fruit growth and development, however, in presence of seeds in fruit are undesirable due to hard or leathery texture, bitter taste and presence of toxic compounds (Ozga *et al.,* 2002; Dalal *et al.,* 2006). Seedless fruits are therefore desirable for improving the quality of fresh as well as of processed fruits in eggplant (Denna, 1973; Varoquaux *et al.,* 2000; Yin *et al.,* 2006). Therefore, replacing the seeds and seed cavities with edible fruit tissue is an attractive offer to consumers and challenge to researchers.

In brinjal cultivation, high temperature promotes growth of plants not suitable for formation and growth of flower buds and results in pollen sterility (Sanwal *et al.,* 1997). To overcome such difficulties, plant hormones have often been used under unfavorable conditions (Nothmann and Koller, 1975; Olympios, 1976). Under greenhouse conditions, fruit set and growth are often improved by using pollinator insects to support pollination and fertilization or bypassed by treating flowers with phytohormones to trigger the development fruits. However during winter cultivation, in unheated greenhouses, negative effect of suboptimal environmental conditions on fruit production is usually counteracted by treating flower buds with plant growth regulators. Phytohormonal treatments make the production process more expensive due to the cost of both chemicals and labour.

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To mitigate the defects of fruit setting under unfavorable conditions, breeding of parthenocarpic cultivars may be a cost-effective alternative.Intense breeding activities are currently in progress to obtain part-henocarpic hybrids. Parthenocarpy can be triggered by exogenous factors, such as plant growth regulators, or it can be achieved by genetic factors. Nitsch (1970) reported that a plant become parthenocarpic, if concentration of growth regulators exceeds a threshold level during a critical periodat anthesis. In brinjal, the first increase takes place during the first five days after anthesis, while a major peak of IAA appears 20 days after anthesis in both pollinated and auxin treated flowers (Lee *et al.,* 1997).

Application of growth regulators

Phytohormones, *viz*. auxins, gibberellins and cytokinins are involved in signaling processes that follow pollination and fertilization which act as major role for further growth and development of seeds and fruits (Fos *et al.,* 2001). Sharma and Barman (1997) used NOXA and the percentage of seedlessness increased with rise in concentration up to 15 ppm of NOXA. Parthenocarpic fruits were smaller in size and this resulted in reduction in weight. But fruits became richer in carbohydrate and vitamin contents. The total yield was higher due to large number of fruit setting.

Genetics of parthenocarpy

Genetic analysis of parthenocarpy in eggplant began in 1994 at the NARO Institute of Vegetable and Tea Science (NIVTS; Mie, Japan) with the crossing of a European parthenocarpic cultivar, Talina, and a Japanese non-parthenocarpic cultivar, EPL1 (Yoshida *et al.* 1998). Segregation tests in F_2 and BC_1F_1 populations suggested that parthenocarpy was controlled by a single major gene (Yoshida *et al.,* 1998). The progeny testing in a cross combination of a European parthenocarpic cultivar (Mileda) and a Japanese non-parthenocarpic line (ASL-1) confirmed the existence of a dominant single major gene (Kuno and Yabe, 2005).

Parthenocarpic variety development

A parthenocarpic eggplant F_1 cultivar, Talina is cultivated widely in Europe. However, despite its parthenocarpy, its fruit setting is not higher than that of typical eggplant cultivars grown under low or high temperatures in open-pollinated conditions, and hormonal treatment is still required to improve its productivity (Donzella *et al.,* 2000; Acciarri *et al.,* 2002). The parthenocarpic trait of Talina was introduced into the Japanese cultivars Nakate-Shinkuro and Nasu Chuukanbohon Nou 1 and breeding lines had high yield with favourable fruit quality (Saito *et al.,* 2005).

Molecular marker - assisted breeding

To identify the loci controlling parthenocarpy, Miyatake *et al.* (2012) constructed a linkage maps by using co-dominant simple sequence repeat and single nucleotide polymorphism markers in F_2 populations derived from intraspecific crosses between two non-parthenocarpiclines (LS1934 and Nakate-Shinkuro) and a parthenocarpicline (AE-P03). Total map distances were1,414.6cM (ALF2: LS1934 9 AE-P03) and 1,153.8 cM (NAF2: Nakate-Shinkuro 9 AE-P03), respectively. Quantitativ trait loci (QTL) analysis revealed two QTLs onchromosomes 3 and 8, which were controlling parthenocarpy and designated as Cop 3.1 and Cop 8.1, respectively. This is the first report concerning QTL analysis of parthenocarpy in eggplant using molecular markers. It will be useful in marker-assisted selection and in revealing the genomic mechanism underlying parthenocarpy in brinjal.

Transgenic parthenocarpic lines

Genes causing parthenocarpic fruit development have been identified in brinjal. The chimeric gene *DefH9-iaaM*, which is expressed especifically in placenta and ovules has been shown to cause parthenocarpic development in transgenic eggplant (Restaino *et al.,* 1992). It codes for an indol acetamide monoxigenase which converts tryptophan to indol acetamide, a precursor of auxin IAA (Yamada *et al.,* 1985). This led to significant increase in fruit production concomitant with a reduction in cultivation costs. The genetically modified parthenocarpic brinjal with *DefH9-iaaM* gene were more productive under environmental conditions which was unfavourable for pollination (Ficcadenti *et al.,* 1999; Acciarri *et al.,* 2002). The parthenocarpic fruits were equal or bigger size as compared with seeded fruits (Acciarri *et al.,* 2002; Pandolfini *et al.,* 2002).

Triploid seedless brinjal

In many countries, genetically modified crops are not well accepted. Therefore a triploid brinjal has been developed by Dirks *et al.* (2009) by crossing tetraploid brinjal (NCIMB41516) with diploid. The variety is almost seedless and still contains remnants of seeds.

Interspecific hybrids

Prohens *et al.* (2012) developed interspecific hybrid (*S. melongena* PI263727 × *S. aethiopicum* PI413783; *S. melongena* PI263727 × *S. aethiopicum* PI413784; *S. melongena* PI470273 × *S. aethiopicum* PI413784; *S. melongena* PI470273 × *S. aethiopicum* PI413783) which are seedless.

Recently, Devi *et al.* (2015) developed part-henocarpic interspecific F_1 hybrids by crossing *Solanum*

Fig. 1. Parthenocarpic fruit development in interspecific F_1 hybrid of *Solanum melongena* cv. DBSR-52 × *S. indicum*

melongena cv. DBSR-52 × *S. indicum* (Fig. 1), *Solanum melongena* cv. Pusa Ankur × *S. aethiopicum*, *S. melongena* cv. G-190 × *S. aethiopicum*, *S. melongena* cv. 91-2 × *S. aethiopicum* and *S. melongena* cv. 190-10-12 × *S. aethiopicum*. The fruits were seedless.

However, use of parthenocarpic varieties has been limited by several problems. The most relevant are the reduction in fruit set percentage and fruit size. Often the parthenocarpic trait is polygenic and, therefore, rather cumbersome to manage in a breeding programme. In addition, phenotypic expression of genetic parthenocarpy is, sometimes, associated with a loss of fruit quality. Thus, flanking DNA markers suitable for selecting parthenocarpic genes may be useful as a new tool for developing a wide variety of parthenocarpic eggplant cultivars. As breeding parthenocarpic cultivars inbrinjal takes a lot of time and labour, marker assisted breeding may be useful for parthenocarpic cultivars development in future.

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Evaluation of exogenous application of EE-GRSP on soil aggregation and root hormone levels in trifoliate orange *(Poncirus trifoliata)* under drought stress

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ABSTRACT

The experiment was conducted to evaluate the effect of exogenous EE-GRSP on soil aggregate distribution and root hormone levels under drought stress using controlled potted conditions, at College of Horticulture and Gardening, Yangtze University, Jingzhou, thubei, China. The easily extracted glomalin-related soil protein (EE-GRSP) was collected from rhizosphere soil of Satsuma mandarin orchard established on trifoliate orange (*Poncirus trifoliata* Rafin), at Jingzhou, China. The EE-GRSP solution was exogenously applied weekly into rhizosphere of trifoliate orange exposed to well-watered (WW) and drought stress (DS) under potted conditions. After 41 days, exogenous EE-GRSP significantly increased leaf relative water content under WW and DS, compared with non-EE-GRSP treatment. Application of EE-GRSP significantly increased root gibberellins, methyl-jasmonate (MeJA), zeatin riboside (ZR), and brassinosteroids (BRs) concentrations under WW and DS conditions over non-EE-GRSP treatment. Rhizosphere soil of EE-GRSP-treated seedlings showed a much higher distribution of water-stable aggregates in different sizes of 2.00-4.00, 1.00-2.00, 0.50-1.00, and 0.25-0.50 mm and soil greater mean weight diameter, compared to non-EE-GRSP-treated control, regardless of soil water status. These results suggested that exogenous EE-GRSP enhanced the drought tolerance of trifoliate orange seedlings by promoting soil aggregation and hormonal level of roots.

KEY WORDS: Citrus, Glomalin-related soil protein, Hormones, Soil aggregates Trifoliate orange, Drought stress, Rhizosphere

Drought stress (DS) is one of the important abiotic stresses, affecting the yield and quality of fruit crops (Panigrahi and Srivastava, 2016; Santamaria *et al.*, 2018). Citrus is an important economic crop in the world, but highly drought-sensitive in nature (Srivastava *et al.*, 2008; Zhang *et al.*, 2018). It is well known that one of the most predominant soil microbial communities that proliferates within the plant rhizosphere, is dominated by arbuscular mycorrhizal fungi (AMF), known enhancing drought tolerance ability of inoculated plants (Wu *et al.*, 2013; Park *et al.*, 2016; Zhang *et al.*, 2017a, 2018b).

In soil, AMF can improve soil properties through extensive mycelial network and production of extracellular compounds, in which spores and mycelia of AMF release a special N-linked glycoprotein complex (Qrtas, 2017; Qrtas et al. 2015), called as glomalin (Rillig and Mummey, 2006). In soils, glomalin is named as glomalin-related soil protein (GRSP) according to protocol of Bradford method (Rillig, 2004). The GRSP functions have been widely studied, and these roles include: i, expanding the storage capacity of soil for organic carbon (Kumar *et al.*, 2018); ii, improv-ing soil aggregation and stability (Zhang *et al.*, 2017b); iii, enhancing the resistance of plants (Zou *et al.*, 2016) and iv, moderating the metal toxicity through chelation (Rillig, 2004, Wu *et al.*, 2014). Wu *et al.* (2015) firstly reported that exogenous application of easily extractable glomalin-related soil protein (EE-GRSP) could be considered as an effective regulatory via medium affecting the soil fertility of citrus rhizosphere. Other studies by Wang *et al.* (2015b) reported a positive effect of exogenous EE-GRSP on plant growth and soil properties of trifoliate orange seedlings (Shao *et al.* 2018; Yi-Can Hand *et al.* 2017). Nevertheless, it is not

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clear whether exogenous application of GRSP can improve the adaptability of plants to drought stress (Du *et al.*, 2015). Thus, study was undertaken to evaluate the effects of exogenous EE-GRSP on soil aggregate distribution and root hormone levels under drought stress using controlled potted conditions on trifoliate orange (*Poncirus trifoliata* Rafin).

MATERIALS AND METHODS

The experiment was disigned in a 2^2 factorial completely randomized blocked design (4 treatments replicated four times) with two each EE-GRSP treatments (EE-GRSP and non-EE-GRSP) and water regimes (WW as well-watered at 75% of maximum water-holding capacity of soils and DS as drought stress at 55% of maximum water-holding capacity of soils). Three 4-leaf-old seedlings grown in autoclaved non-mycorrhized sands were transplanted into a plastic pot (19 cm × 15 cm × 18 cm, upper diameter × bottom diameter × height), each filled with 1.6 kg of autoclaved (121°C, 0.11 MPa, 2 h) soil sieved with 2 mm sieve. The soil was collected from a citrus orchard of Yangtze University campus, which had predominantly loam texture pH 6.2, organic carbon 9.9 mg/kg, and Bray-P 15.1 mg/kg.

After 16 days of transplanting of seedlings, half of plants were selected to apply 50 mL EE-GRSP /pot at weekly interval, and other half were watered with 50 mL 20 mM citrate buffer (pH 7.0) per pot as non-EE-GRSP treatment. The EE-GRPS solution was prepared as follows: 1 g soil samples from the above citrus orchard were mixed with 8 mL 20 m mol/L citrate buffer (pH 7.0), autoclaved (121°C, 0.11 MPa) for 30 min, and centrifuged at 10,000 × g for 5 min (Koide and Peoples, 2013; Wu *et al.*, 2015). The supernatant was collected as the EE-GRSP solution, which had 0.014 mg protein/mL according to Bradford assay (1976). Based on the findings of Wang *et al.* (2015b), the EE-GRSP extracted solution was diluted with the corresponding citrate buffers (20 m mol/L, pH 7.0) to 0.007 mg protein/mL.

After two months of seedlings acclimatization under soil WW conditions, DS was begun. Half of the plants were kept under DS status daily by weighing the pots. The soil water lost was replenished to corresponding pots to keep the designed soil water levels. A 50 mL EE-GRSP solution or citrate buffer was weekly used to replace the same amount of water. The experiment was completed after 41 days of DS treatment. All the seedlings were grown in a glasshouse, having photosynthetic photon flux density was 721-967 µmol/m2/s, day/night temperature was 25/19°C, and relative humidity of 85%.

The relative water content (RWC) of leaves was determined as per procedure suggested by Bajji *et al.* (2001). Soil water-stable aggregate (WSA) in the size of 2.00-4.00, 1.00-2.00, 0.50-1.00, and 0.25-0.50 mm were followed according to the wet-sieving method (Kemper and Rosenau, 1986). Mean weight diameter (MWD) was used to evaluate the stability of soil WSA, worked out using the following formula (Kemper and Rosenau, 1986): $\mathrm{MWD} = \sum_{i=1}^{n} W_i X_i$, where X_i is mean diameter of i sieve opening (mm), W_i is proportion of the i size fraction in the total sample mass, and n is number of size fractions.

Root endogenous hormones, including gibberellins (GAs), abscisic acid (ABA), indole-acetic acid (IAA), methyl-jasmonate (MeJA), zeatin riboside (ZR), and brassinosteroids (BRs) were extracted as per the protocol suggested by Wu *et al.* (2016) and measured using ELISAs (the Engineering Research Center of Plant Growth Regulator, China Agricultural University) as per user manual.

The data were subjected to variance (ANOVA) with the SAS software (8.1v, SAS Institute Inc., Cary, NC, USA), and the significant differences in means between treatments were compared with the Duncan's multiple range test at $P < 0.05$.

RESULTS AND DISCUSSION

The RWC is one of the effective indices of studying water stress conditions. In this study, DS significantly reduced RWC of trifoliate orange seedling, as compared with WW, regardless of exogenous EE-GRSP treatment (Fig. 1). Compared with non-EE-GRSP groups, the EE-GRSP application increased the leaf RWC by 19% and

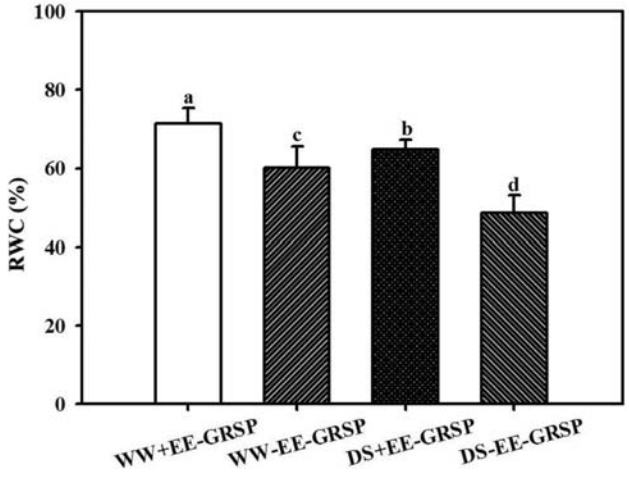

Fig. 1. Effect of exogenous EE-GRSP on leaf relative water content (RWC) in trifoliate orange trifoliate orange seedlings grown under well-watered (WW) and drought stress (DS) conditions. Data (means ± SD, $n = 4$) are significantly different *($P < 0.05$)* followed by different letters above the bars.

20% under WW and DS, respectively. Usually, RWC is used to study the ability of osmotic regulation and drought resistance in plants (Hu and Wang, 2017). Such higher RWC in EE-GRSP-treated seedlings suggested an elevated water relations in plants (Wang *et al.,* 2013), thereby, imparting better preparedness to plants to cope up with any water stress conditions.

Soil aggregates is basic unit of soil structure, besides an important component of multiple soil function (Wu *et al.,* 2016b), which relies heavily on soil microbes to provide adhesive effects on soil particles to bind together (Singh 2012). The > 0.25 mm WSA is called as the soil agglomerate structure body in the soil (Yu *et al.,* 2012). In this work, under WW treatment, the EE-GRSP applications significantly increased the percentage of WSAs in 2.00-4.00, 1.00-2.00, 0.50-1.00 and 0.25-0.50 mm size by 79%, 13%, 20% and 52%, respectively, compared with non-EE-GRSP treatment (Table 1). Compared with non-EE-GRSP treatment under DS conditions, the percentages of WSAs in 2.00-4.00, 1.00-2.00, 0.50-1.00 and 0.25-0.50 mm size were increased by 36%, 43%, 18% and 24%, respectively, with the application of EE-GRSP. Similar observations were earlier made by Wang *et al.* (2015a).

The MWD is an important index to measure the stability of soil aggregates (Kemper and Rosenau 1986). In this study, exogenous EE-GRSP increased MWD respectively by 44% and 34% than non-EE-GRSP under WW and DS conditions. We reported similar observations in our earlier studies (Wu *et al.,* 2015). GRSP can glue up soil WSA formation and stability through some unknown characteristics (Rillig 2004, Wu *et al.,* 2014). Greater soil WSAs distribution and stability means better soil environment for plants exposed to DS, a prerequisite for better crop performance in field.

Root growth is primarily a function of root hormones. In this work, both DS and EE-GRSP did not affect root ABA and IAA concentration of trifoliate orange seedlings (Fig. 2). While contrary to other these hormones, compared with non-EE-GRSP treatment, EE-GRSP increased the levels of GAs, BRs, MeJA and ZR in roots of trifoliate orange seedlings by 23%, 18%, 21% and 12% under WW, respectively (Fig. 2). Interestingly, DS+EE-GRSP treatment increased the concentrations of GAs, BRs, MeJA and ZR in roots as much by 20%, 10%, 17%, and 16%, respectively, as compared with DS-EE-GRSP. BRs play a role in enhancing plant resistance by means of improving osmosis regulation, enhancing antioxidant defense systems, stabilizing the structural function of the membrane system, maintaining high energy metabolism, and promoting physiological and biochemical metabolism (Krishna, 2003; Feng *et al.,* 2015; Duan *et al.,* 2017). Exogenous MeJA application has the ability to increase the tolerance level of many plants to DS by the common signal transduction pathway and the induction of plant "self-adaptation" (Cheong and Choi, 2003). As a result, such

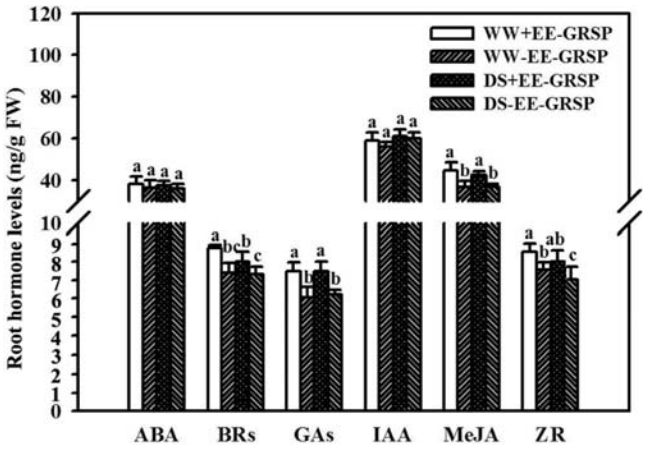

Fig. 2. Effects of exogenous EE-GRSP on root abscisic acid (ABA), brassinosteroids (BRs), gibberellins (GAs), indole-acetic acid (IAA), methyl jasmonate (MeJA), and zeatin riboside (ZR) levels in trifoliate orange seedlings grown under well-watered (WW) and drought stress (DS) conditions. Data (means ± SD, $n = 4$) are significantly different ($P < 0.05$) followed by different letters above the bars.

Table 1. Effect of exogenous EE-GRSP on percentage of water-stable aggregates (WSA) in different sizes and mean weight diameter (MWD) in trifoliate orange seedlings grown under well-watered (WW) and drought stress (DS) conditions

Treatment	Distribution of WSA (%) MWD				
	2-4 mm	1-2 mm	0.5-1 mm	0.25-0.5 mm	MWD (mm)
WW+EE-GRSP	38.01 ± 2.49a	20.03 ± 1.04a	19.98 ± 1.66a	14.31 ± 1.37c	1.64 ± 0.09a
WW-EE-GRSP	21.28 ± 1.20c	17.77 ± 1.07b	16.59 ± 1.09b	9.44 ± 0.91d	1.06 ± 0.04c
DS+EE-GRSP	26.44 ± 1.43b	20.67 ± 1.40a	19.01 ± 1.63a	20.42 ± 1.75a	1.32 ± 0.04b
DS-EE-GRSP	19.40 ± 1.19c	14.43 ± 1.07c	16.13 ± 1.27b	16.53 ± 1.29b	0.98 ± 0.03d

Note: Data (means ± SD, n = 4) followed by different letters in same column are significantly different at P < 0.05

higher BRs and MeJA levels in roots indicated a greater decrease of drought tolerance in trifoliate orange treated with EE-GRSP under DS. These observations also supplemented that EE-GRSP application could avert the negative impact of DS on trifoliate orange seedlings.

There were diverse effects on various plants exposed to DS with regard to root GAs. Zhong et al. (2014) observed that drought resistance of tobacco plants was increased by reduced GAs concentration. Liu *et al.* (2015) reported that the DS did not alter root GAs levels of trifoliate orange. However, GAs were essential for the processes of plants development, including stem elongation, leaf expansion, trichome development, pollen maturation and regulation of flowering (Achard and Genschik, 2009). In this study, better root GAs levels following exogenous EE-GRSP treatment under WW and DS control (Fig. 2) implied that EE-GRSP stimulated the accumulation of root GAs to facilitate better plant growth.

CONCLUSION

Exogenous application of EE-GRSP has straight implications on leaf RWC, aiding in accumulation of root GAs, BRs, MeJA and ZR, and thereby, increasing WSA distribution and stability within rhizosphere soil of trifoliate orange seedlings under DS. These observations established the role of GRSP as soil conditioners having multiple functions. Future works needs unravel underlying mechanisms involved in plant response to exogenous EE-GRSP under different soil moisture regimes.

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Evaluation of genetic variability in wild *Musa* spp. suitable for ornamental value

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ABSTRACT

The studies were carried out to evaluate five wild banana (*Musa* spp.) and three hybrids for morphological characters and their suitability of ornamental value based on 12 quantitative and 6 qualitative traits at NRC for Banana, Tiruchirappalli, during 2016-17. The results showed that all the eight species varied significantly for all the traits. The wild were dwarf (<1.0 m height) and slender (<20 cm stem girth) and recorded an average of 7-9 leaves/plant. The hybrids were larger (>1.0 m height) and little sturdy (>30.0 cm stem girth). The wild bananas recorded an average of 4 hands/bunch and 4 fruits/hand while hybrids recorded more than 4 hands/bunch and 10 fruits/hand. The inflorescence was erect and bract colour ranged from lilac, brick-red, red, yellow and pink. Based on the study, the wild bananas were highly suitable for potted plants, cut flowers, male inflorescence, and landscape plants while hybrids were suitable only for landscape purposes.

Key Words: *Musa* spp., Genetic diversity, Ornamentals, Potted plants, Cut flower, Variability

Banana belongs to the family Musaceae which has two genera: Musa and Ensete. Based on morphological characters, and chromosome numbers, genus Musa has been classified into five sections: Eumusa (2n=22), Rhodochlamys (2n=22), Australimusa (2n=20), Callimusa (2n=20) and Ingentimusa (2n=14) (Stover and Simmonds, 1987). India is rich in genetic diversity of Musaceae and this rich gene pool is spread across Northeast India, Western Ghats, Eastern Ghats and Andaman and Nicobar Islands. This vast genetic diversity of Indian *Musa* species which mainly consists of section Eumusa and Rhodochlamys includes, seedless bananas, seeded bananas and cultivated landraces and varieties of different ploidy levels. Most of the wild bananas are native to tropical evergreen forests and moist rainforests of South and Southeast Asia. Hilly terrains, dense jungles, wild animals, poisonous creatures, and inaccessible roads prevent the researchers across the world to explore most of these areas. Explorations conducted by several authors reported the presence of numerous species like *Musa laterita, M. velunita, M. sanguine, M. arunachelnsis, M. aurantiaca, M. sikkimensis, M. nagnesium, M. acuminata, M. balbisiana, M. flaviflora, Ensete glaucum, E. superbum, etc.* (Simmonds, 1962; Singh and Chadha, 1993; Singh and Uma, 2000).

Rhodochlamys members are short and slender plants which grow at a height of 1 - 2 m. They have erect inflorescence with attractive coloured bracts (Cheesman, 1947; Simmonds, 1962; Shepperd, 1999; Uma *et al.*, 2006; Hakkinen, 2007) which makes them ornamentals. Explorations conducted by Chakravorti, 1948; Sundararaj and Balasubramanyam, 1952, Jacob, 1952, Uma *et al.*, 2002, evidenced that members of Rhodochlamys spread across Northeast India, the Western Ghats, and Arakku valley of Eastern Ghats. Though the ornamental nature of Rhodochlamys has been reported by several authours and the potential of these species into ornamental industries could not be exploited fully. Few species like *Musa laterita, M. siamensis* and *M. velutina* are being marketed at very limited scale in Nagercoil district of Tamil Nadu and Trivandrum district of Kerala, still, it lacks commercial exploitation. They can be better exploited and could be potentially used for development of new hybrids.

To exploit Rhodochlamys members in commercial ornamental horticulture, characterization of these species is essential. The characterization and evaluation of ornamental bananas will give the knowledge on genetic variability and database which could be used for identification of suitability of these species as

ornamental plants and development of new ornamental hybrids. Therefore, present studies aimed at morphological characterization of ornamental wild bananas and estimating the genetic variability so that they can be exploited for ornamental purposes.

MATERIALS AND METHODS

The studies were carried out at ICAR-National Research Centre for Banana, Tiruchirapalli, Tamil Nadu, during 2016-17. The experimental field was situated at 10°78'33" N latitude and 78°58'37" E longitude, 90 m above MSL. The climate is warm and humid and the average minimum and maximum temperature are 25°C and 35°C respectively. The centre receives an average of 800 mm rainfall annually. Five wild *Musa* species and three hybrids with ornamental value were evaluated for 12 quantitative, *viz*. plant height (cm), stem girth (cm), number. of leaves at flowering, leaf length (cm), leaf width (cm), number of suckers / plant, number of hands / bunch, number of fingers / hand, finger length (cm), finger girth (cm), pedicel length (cm), and pedicel girth (cm) and 6 qualitative characters, *viz*. immature fruit colour, mature fruit colour, peduncle colour, bunch position, rachis position, and bract colour (Table 1).

The *Musa* species were characterized based on Santos-Serejo *et al.* (2007) to identify the suitability of these species for different categories of ornamental plants, *viz*. 1. potted plants (plant height 145 cm height, stalk length < 25 cm), 2. cut flowers (stalk > 30 cm), 3. mini fruits (Size, shape, number of fruits, distance between two hands and colour of fruits), 4. male inflorescence (size and shape of heart, presence of imbrications, persistence and opening of floral bracts), and 5. landscape plants (wide category includes potted, cut, mini fruits, and small male flowers and mainly suckering habit).

The experiment was conducted in a randomized block design with three replications. The IPGRI guidelines were used for recording quantitative and qualitative characters (IPGRI, 1996). The data were collected from four plants in each replication. Ten fruits were used for taking observations of fruits related characters. The data were statistically analyzed using HAU statistical software package developed by Sheoran *et al.* (1998).

RESULTS AND DISCUSSION

The analysis of data revealed vast genetic diversity was observed among *Musa* species. All the *Musa* species significantly varied for all the characters. The maximum plant height was recorded by *Musa rubra* × Calcutta 4 (185.9 cm) and minimum plant height was recorded by *Musa rubra* (76 cm). *Musa laterita* × Chendawat recorded maximum stem girth of 36.3 cm and *Musa velutina* recorded minimum stem girth of 11.8 cm (Table 2). Among wild species, *Musa ornata* recorded maximum height (91.0 cm). Similar results were earlier reported by Everton *et al.* (2012). These wild species have grown up to 1.0 m height at tropical conditions of south India, whereas they can reach up to 1.5 - 2.0 m height at tropical evergreen forests and rain forests (Hakkinen, 2007).

These species are highly drought tolerant and could tolerate hot climatic conditions (Uma *et al.*, 2006). Musa laterita recorded the maximum number of leaves (9.3) and *Musa rubra* × Calcutta 4 and *Musa ornata* recorded minimum number of leaves / plant (6.7). The maximum leaf length (183.7 cm) and leaf width (52.3 cm) were recorded by *Musa laterita* × Chendawat and *Musa*

Table 1. Details of *Musa* species used and characterized

Musa species	Section	Collection site	Distribution
Musa ornata	Rhodochalyms	Arunachal Pradesh	Northeast India, Western Ghats, Eastern Ghats, Myanmar, Thailand, Bangladesh
Musa laterita	Rhodochalyms	Arunachal Pradesh	Northeast India, Western Ghats, Eastern Ghats, Myanmar, Thailand
Musa velutina	Rhodochalyms	Arunachal Pradesh	Northeast India, Myanmar
Musa rubra	Rhodochalyms	Indian Institute of Horticulture Research, Bengaluru	Reported only from Mizoram, but recent surveys could not find its distribution
Musa siamensis	Rhodochalyms	Private nursery, Trivandrum	Thailand, Cambodia
Calcutta 4 × *Musa rubra*	Hybrid	Developed by IIHR	Conserved in IIHR and NRCB field gene bank
Musa laterita × Pisang Jajee	Hybrid	Developed by NRCB	Conserved in NRCB field gene bank
Musa laterita × Chendawat	Hybrid	Developed by NRCB	Conserved in NRCB field gene bank

Table 2. Evaluation of *Musa* species for plant morphological and fruit traits

Musa species	Plant height (cm)	Stem girth (cm)	No. of leaves / plant	Leaf length (cm)	Leaf girth (cm)	No. of suckers / plant	No. of hands / bunch	No. of fingers / hand	Finger length (cm)	Finger girth (cm)	Pedicel length (cm)	Pedicel girth (cm)
Musa ornata	91.0	18.7	6.7	97.3	37.2	5.2	4.2	4.0	10.3	4.4	0.6	3.5
Musa laterita	86.8	18.4	9.3	90.3	34.2	10.4	4.0	5.9	5.6	3.4	0.4	3.3
Musa rubra	76.0	14.1	8.3	84.9	27.8	6.2	4.0	4.5	4.3	2.2	0.3	2.9
Musa siamensis	82.0	16.2	7.4	88.9	31.1	3.6	3.8	3.7	5.1	2.4	0.5	3.1
Musa velutina	89.0	11.8	7.1	84.7	31.4	2.9	5.2	4.8	9.3	11.9	0.8	3.7
Musa laterita × Pisang Jajee	128.7	30.6	8.4	125.0	49.9	11.1	4.6	11.7	4.1	1.2	0.2	2.9
Musa laterita × Chendawat	170.1	36.3	7.4	183.7	52.3	15.0	5.9	14.9	4.7	1.0	0.4	3.3
Calcutta 4 × *Musa rubra*	185.9	28.5	6.7	147.7	44.0	13.5	4.7	12.1	4.9	1.2	0.3	3.0
CD (0.05)	5.01	0.95	0.43	1.82	1.41	0.76	0.48	0.56	0.29	0.25	0.11	0.18

Table 3. Qualitative characters of *Musa* species and their suitability in ornamental horticulture

Musa species	Immature fruit colour	Mature fruit colour	Peduncle colour	Bunch position	Rachis position	Bract colour	Potted plant	Cut flower	Mini fruits	Male inflore-scence	Land-scape plants
Musa ornata	Watery green	Bright yellow	Green	Erect	Erect	Lilac	"	"	×	"	"
Musa laterita	Green	Yellow	Dark green	Erect	Erect	Brick red	"	"	×	"	"
Musa rubra	Green	Yellow	Dark green	Erect	Erect	Red	"	"	×	"	"
Musa siamensis	Green	Bright yellow	Green	Erect	Erect	Yellow	"	"	×	"	"
Musa velutina	Pink	Pink	Pink	Erect	Erect	Pink	"	"	×	"	"
Musa laterita × Pisang Jajee	Green	Yellow	Green	Erect	Erect, slightly becomes bent at later stages	Brick red	"	×	×	×	"
Musa laterita × Chendawat	Green	Yellow	Green	Erect	Erect, slightly becomes bent at later stages	Brick red	×	×	×	×	"
Calcutta 4 × *Musa rubra*	Green	Yellow	Green	Erect	Erect, slightly becomes bent at later stages	Red	×	×	×	×	"

velutina recorded minimum leaf length (84.7 cm) and *Musa rubra* recorded minimum leaf width (27.8 cm). These variations were due to inherent genetic nature of plants. The maximum number of suckers / plant was recorded by *Musa laterita* × Chendawat (15), followed by *Musa laterita* (10.4) and minimum number of suckers / plant was recorded by *Musa velutina* (2.9). The free suckering habit of Rhodochlamys section, especially *Musa laterita* was earlier reported by (Cheesman, 1949).

The data revealed that different species varied significantly for the all the characters. The maximum number of hands / bunch (5.9) and number of fingers / hand (14.9) were recorded in *Musa laterita* × Chendawat. The minimum number of hands (3.8) and minimum number of fingers / hand (3.7) were recorded in *M. siamensis*. *Musa ornata* recorded the maximum finger length (10.3 cm) and *Musa laterita* × Chendawat recorded minimum finger length (4.1). The maximum finger girth (11.9), pedicel length (0.8 cm) and pedicel girth (3.7 cm) was recorded by *M. velutina*. The minimum finger girth was recorded by *M. rubra* (2.2 cm) and the minimum pedicel length (0.2 cm) and pedicel girth (2.9 cm) was recorded by *M. laterita* × Pisang Jajee. The variation in fruit related traits among the genotypes was due to inherent genetic nature of plants. Similar kind of results of wild ornamental bananas were recorded by Hakkinen (2007) and Everton *et al.*, (2012).

Six qualitative, all bunch related traits have varied with species (Table 3). This was due to inherent genetic nature of different species. The immature fruit colour was green to dark green in all the species expect *Musa velutina* which was pink. When the fruit matured, the colour of the fruit turned to yellow in *M. laterita, Musa rubra* and hybrids; bright yellow in *M. laterita* and Musa *siamensis* and it remained pink in *M. velutina*. The peduncle colour is an important character for ornamental purpose.

The colour ranged from green (*M. siamensis, M. ornata* and hybrids), dark green (*M. laterita* and *M. rubra*) and pink *(M. velutina)*. Unlike other Musaceae sections, the bunch and rachis were erect in ornamental *Musa* species. In hybrids, bunch position was erect. However, rachis was slightly angled. The bract colour is very much important which ultimately decides the ornamental value of these species and hybrids. Most of the species had attractive bright coloured bracts. The bract colour was lilac in *M. ornata*, brick red in *M. laterita*, yellow in *M. siamensis*, pink in *M. velutina*, red in *M. rubra*. Because of these attractive bracts, they are considered as ornamental bananas (Uma *et al.*, 2006; Hakkinen, 2007; Santos-Serejo *et al.*, 2007 Joe and Sabu, 2016).

Five wild species, *viz. M. ornata, M. laterita, M. rubra, M. siamensis*, and *M. velutina* were small, grown less than 1.0 m, and stem diameter was less than 20 cm (Table 2) and they were highly suitable for potted plants (Table 3). They had minimum number of fruits / finger, hands / bunch and colour was not attractive (Table 2). So they were not suitable for mini fruits. Though the stalk length was less than 35 cm, they could be used for cut flower and inflorescence due to their attractive coloured bracts. All the five species were highly suitable for landscape plants (Table 3). The potential use of *M. velutina, M. ornata* and *M. laterita* as potted plants, cut flower, inflorescence and landscape plants was earlier described by Everton *et al.* (2012).

In case of hybrids, they have grown more than 1.5 m except for *M. laterita* × Pisang Jajee and had maximum number of fingers / hand which were not attractive (Table 2). These hybrids inherited the growth habit from the respective male parents and inherited the bunch characters and bract colour from the respective female parents. Due to these undesirable characters, they were not suitable for potted plants, cut flower, mini fruits and inflorescence. They can be utilized for landscape purposes.

Thus, it was concluded that wild species are short, slender and grow up to 1.0 m height in tropical conditions of south India. The bracts are highly colourful and attractive. Hence, these species could be commercially exploited for ornamental purposes as potted plants, cut flowers, male inflorescence, and landscape plants. Though hybrids have attractive coloured bracts, they could only be used as landscape plants.

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Effect of tree rhizosphere properties on growth of citrus (*Citrus* spp.) rootstocks

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ABSTRACT

The experiment was conducted to find out the effect of rhizosphre of different tree species on germination and growth of rough lemon and Rangpur lime rootstocks at Dr Panjabrao Krishi Vidyalaya, Nagpur, during 2014-15. The rhizosphere properties of different trees showed maximum organic carbon in rhizosphere soil of banyan tree (*Ficus benghalensis* L.) soil (0.90%), while $CaCO_3$ was maximum in mango (*Mangifera indica* L.) tree rhizosphere soil. The KM_nO_4-N (254.0 kg/ha), NH_4OAc (369.6 kg/ha) and $CaCl_2$-S (9.6 kg/ha) were found maximum in Nagpur mandarin tree rhizosphere soil. The available phosphorus Olsen-P was found maximum in banyan tree rhizosphere soil (15.3 kg/ha), in addition to NH_4OAc -Ca and NH_4OAc -Mg. The maximum bacterial colonies (42.4×10^3 cfu/g) were observed in Nagpur mandarin (*Citrus reticulate* Blanco) tree rhizosphere soil. Fungal colonies on other hand, were found maximum in banyan tree rhizosphere soil (26.6×10^3 cfu/g). The germination of rough lemon and Rangpur lime seeds was maximum in Nagpur mandarin rhizosphere soil than in bulk field soil. The growth parameters like plant height (3.90 cm) and number of leaves/seedling (2.00) were maximum in Nagpur mandarin tree rhizosphere soil due to presence of native homologous microorganisms in Nagpur mandarin tree rhizosphere soil.

Key Words: Nutrient status, Soil properties, Rootstock growth, Rhizosphere soil, Phosphorus Olsen-P, Bacterial colonies

Rhizosphere processes are one of the most important but least understood ways in which plants affect nutrient cycling (Srivastava *et al.*, 2007, 2015; Srivastava, 2010a; 2010b; Srivastava and Singh 2015; Du *et al.*, 2014; Shao *et al.*, 2018; Zhang *et al.* 2017). Plant roots influence rhizosphere nutrient cycling by nutrient uptake, rhizodeposition and interaction with microorganisms, which is crucial in maintaining forest growth and ecosystem stability (Gobran *et al.*, 1998; Wang and Zabowaski, 1998). Since, rhizosphere processes have been well described for agricultural crops and grasses grown under controlled conditions, information on rhizosphere processes of tree species under natural conditions is limited and opposite (Kuzyakov, 2002; Srivastava and Ngullie, 2009, Srivastava, 2014). Therefore, an experiment was conducted to study the effect of rhizosphere of different tree species on germination and growth of rough lemon and Rampur lime rootstocks.

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MATERIALS AND METHODS

Rhizosphere soils from different trees like banyan (*Ficus benghalensis* L.), peepal (*Ficus religiosa* L.), mango (*Magnifera indica* L.), acid lime (*Citrus aurantifolia* Swingle), Nagpur mandarin (*Citrus reticulata* Blanco) and field soil were collected for growing the rootstock seeds to find out the effect of these rhizosphere soils at Dr Punjabrao Krishi Vidyalaya, Nagpur, during 2014-15. The soil sample were air dried. As many 12 treatments were tested in a randomized complete block design.

The details of different treatments are as follows: T_1 (BCSJR, soil from banyan tree canopy with rough lemon seeds), T_2 (PCSJR, soil under peepal tree canopy with rough lemon seeds), T_3 (MCSJR, soil under mango

tree canopy with rough lemon seeds), T_4 (LCSJR, soil under acid lime tree canopy with rough lemon seeds), T_5 (OCSJR, soil under Nagpur mandarin tree canopy with rough lemon seeds), T_6 (FSJR, field soil with rough lemon seeds), T_7 (BCSRLR, soil under banyan tree canopy with Rangpur lime seeds), T_8 (PCSRLR, soil under peepal tree canopy with Rangpur lime seeds), T_9 (MCSRLR, soil under mango tree canopy with Rangpur lime seeds), T_{10} (LCSRLR, soil under acid lime tree canopy with Rangpur lime seeds), T_{11} (OCSRLR, soil under Nagpur mandarin tree canopy with Rangpur lime seeds) and T_{12} (FSRLR, field soil with Rangpur lime seeds).

Five seeds were sown in each pot. After 45 days of germination, observations were recorded on germination percentage, height of seedlings, number of leaves / seedling, thickness of stem and leaf area. To study physico-chemical and biological properties of different rhizosphere soils, 5 soil samples were collected from 5 different trees, *i.e.* banyan, peepal, mango, acid lime, Nagpur mandarin and one field soil were collected. The samples were air dried under shed and ground in wooden mortar and pestle, and passed through a 2-mm sieve. The processed soil samples (< 2 mm) were used for further analysis.

The collected rhizosphere soil samples were processed and analysed for pH, EC and organic carbon following standards methods (Jackson, 1967). Free calcium carbonate was determined (Jackson, 1967). Soil samples were analysed for available $KMnO_4$ N (Subbiah and Asija, 1956), Olsen-P, NH_4OAc -K (Jackson, 1967) and $CaCl_2$-S (Chesnin and Yien, 1951) as per standard procedures. The available Ca and Mg were analysed by versanate titration method in NH_4OAc extract (Richard, 1954). The available Zn, Fe, Mn and Cu were extracted with DTPA extractant (Lindsay and Norvell, 1978). The biological properties were studied by serial dilution plate method proposed by Dhingra and Sinclair (1993).

RESULTS AND DISCUSSION

The soils varied widely in their properties and content of available nutrients. The all rhizosphere soils was neutral in reaction with moderate to high in organic carbon (0.55%-0.90%) and rarely to moderately calcareous in nature (0.95-4.50%), low to medium in $KMnO_4$-N (219.5-254.0 kg / ha) and Olsen-P (7.1-15.3 kg / ha) and high to very high in NH_4OAC-K (257.6-369.6 kg / ha). The $CaCl_2$-S was 6.8-9.6 kg / ha, NH_4OAC-Ca 10.2-15.4 cmol (p+) / kg and NH_4OAc-Mg 3.5-7.1 cmol (p+) / kg were also maximum in banyan tree rhizosphere (Table 1). The micronutrients, *viz*. DTPA-Zn, DTPA-Cu, DTPA- Fe and DTPA-Mn varied from 0.40-.56 mg / kg, 1.27-2.3556 mg / kg, 2.75-5.1056 mg / kg and 3.24-6.1556 mg / kg, respectively. The bacteria and fungal counts were found in rhizosphere soil as 30.0-42.4×10^3 and 20.0-26.6×10^3, respectively.

There was significant variation in seed germination percentage in all the treatments (Table 2). The maximum germination was observed in banyan tree rhizosphere soil with Jambheri rootstock (T_1), mango tree rhizosphere soil with Jambheri rootstock (T_3), banyan tree rhizosphere soil with Rangpur lime rootstock (T_7), orange tree rhizosphere soil with Jambheri rootstock (T_5), peepal tree rhizosphere soil with Rangpur lime rootstock (T_8) and orange tree rhizosphere soil with Rangpur lime rootstock (T_{11}).

The maximum seedling height (3.9 cm) was observed in orange tree rhizosphere soil with Rangpur lime rootstock (T_{11}) and minimum seedling height (2.00 cm) was observed in field soil with Jambheri rootstock (T_6). Plant growth promoting rhizobacteria presented in rhizosphere soil may produce several different metabolites which stimulated plant growth directly or indirectly. These similar results were obtained by Kloepper *et al.* (1991). The maximum number of leaves (2.0) was recorded in orange tree rhizosphere soil with Rangpur lime rootstock (T_{11}), while minimum number of leaves (1.00) was observed in field soil with Rangpur lime rootstock (T_{12}).There was non-significant difference in thickness of stem in all treatments.

There was non-significant difference between pH of soil. The pH is most important factor which regulates solubility and availability of micronutrient cations in soil. There was non-significant variation between EC of soil. The soil was moderate to high in organic carbon content (0.51-0.90%). There was maximum percentage of organic carbon (0.90%) in banyan tree rhizosphere soil with Rangpur lime rootstock (T_7). Organic carbon content in rhizosphere soil was high as compared to field soil. Similar findings were reported by Casal *et al.* (2013) and Yang *et al.* (2013). The magnitude of free lime content in soil ranged from 0.85 to 3.93%, indicating that these soils are slightly to moderately calcareous in nature. Mango tree rhizosphere soil with Jambheri rootstock (T_3) has significantly higher $CaCO_3$ content than other treatments, minimum $CaCO_3$ (0.85%) content being in lemon tree rhizosphere soil with Rangpur lime rootstock (T_{10}).

The $KMnO_4$-N content in soil after removal of seedlings decreased significantly compared to initial soil sample (Table 3). It ranges from lowest value of N (210.10 kg / ha) in field soil with Jambheri rootstock (T_6) and highest value of $KMnO_4$-N (243.55 kg / ha) was observed in orange tree rhizosphere soil with Rangpur lime rootstock (T_{11}). Nagpur mandarin rhizosphere soil with Rangpur lime rootstock (T_{11}) was significantly superior over all others. Similar trends were observed by Dijkastra *et al.* (2009) and Rengel (2008).

Table 1. Rhizosphere properties of different tree species vis-à-vis citrus species

Tree species	pH	EC (dS/m)	Organic carbon (%)	$CaCO_3$ (%)
Banyan	7.27	0.24	0.90	3.82
Peepal	7.16	0.25	0.70	1.55
Mango	7.27	0.24	0.60	4.50
Acid Lime	7.16	0.24	0.62	0.95
Mandarin	7.21	0.23	0.81	1.62
Bulk soil	7.13	0.23	0.55	2.42
CD (P=0.05)	NS	NS	0.12	1.10

Tree species	$KMnO_4$-N (kg/ha)	Olsen-P (kg/ha)	NH_4OAc-K (kg/ha)	$CaCl_2$-S (kg/ha)	NH_4OAC-Ca (cmol(p+kg)	NH_4OAc -Mg (cmol(p+kg)
Banyan	247.7	15.3	347.2	7.2	10.8	4.7
Peepal	222.7	14.8	257.6	6.8	13.6	5.2
Mango	238.3	10.5	268.8	8.5	11.4	4.0
Acid Lime	228.9	13.9	302.4	7.5	12.5	5.5
Mandarin	254.0	10.7	369.6	9.6	15.4	7.1
Bulk soil	219.5	7.1	336.0	7.5	10.2	3.5
CD (P=0.05)	4.3	1.1	11.4	1.2	1.8	2.1

Tree species	DTPA-Zn (mg/kg)	DTPA-Cu (mg/kg)	DTPA-Mn (mg/kg)	DTPA-Fe (mg/kg)
Banyan	0.42	1.27	5.31	4.80
Peepal	0.40	1.48	3.24	2.86
Mango	0.45	2.35	3.52	2.75
Acid Lime	0.48	1.41	6.15	5.10
Mandarin	0.56	1.49	4.40	3.32
Bulk soil	0.40	2.30	4.25	4.45
CD (P=0.05)	0.06	0.11	0.52	0.58

Tree species	Bacterial count ($\times 10^3$ cfu/g)	Fungi count ($\times 10^3$ cfu/g)	Actinomycetes count ($\times 10^3$ cfu/g)
Banyan	36.3	26.6	3.5
Peepal	32.2	22.4	3.1
Mango	40.2	25.3	2.5
Acid Lime	33.1	22.0	5.0
Mandarin	42.4	20.0	3.0
Bulk soil	30.0	21.0	2.0
CD (P=0.05)	3.1	2.2	0.80

Olsen-P after removal of seedlings were recorded maximum (14.5 kg/ha) in banyan tree rhizosphere soil with Jambheri rootstock (T_1) which was significantly higher than rest of the treatments and minimum phosphorus (6.30 kg/ha) was found in field soil sample with Jambheri rootstock (T_6). The available phosphorus present in rhizosphere soil was higher compared to field soil. These may be due to the rate of organic P hydrolysis exceeds the P uptake by plant roots and rhizosphere microorganisms.

The presence of trees increased the available P. Similar results were supported with findings of Casal *et al.* (2013) and Zhao *et al.* (2010). The NH_4OAc-K after removal of seedlings was recorded highest (362.13 kg/ha) in orange tree rhizosphere soil with Jambheri rootstock (T_5), which was significantly superior over rest of treatments and minimum value of available potassium (253.86 kg/ha) was observed in mango tree rhizosphere soil with Jambheri rootstock (T_3). The K uptake by plant depends on degree of development of root system.

The maximum value of $Cacl_2$-S (9.61 kg/ha) was observed in orange tree rhizosphere soil with Jambheri rootstock (T_5) and the minimum S (6.33 kg/ha) was found in peepal tree rhizosphere soil with Rangpur lime rootstock (T_8). The maximum NH_4OAc-Ca (14.37

Table 2. Tree rhizosphere properties and biometric response of acid lime seeds (period : 45 days)

Treatment	Biometric response				
	Germination percentage (%)	Height of seedling (cm)	No. of leaves / seedling	Stem thickness (mm)	Leaf area (cm^2)
T_1 (BCSJR)	80.00	3.80	1.33	0.09	12.43
T_2 (PCSJR)	66.67	2.24	1.33	0.09	11.40
T_3 (MCSJR)	80.00	3.29	1.73	0.12	11.90
T_4 (LCSJR)	73.33	2.53	1.46	0.11	11.60
T_5 (OCSJR)	80.00	3.69	1.73	0.12	12.53
T_6 (FSJR)	66.67	2.00	1.03	0.07	10.70
T_7 (BCSRLR)	80.00	3.67	1.13	0.12	12.43
T_8 (PCSRLR)	80.00	3.40	1.46	0.11	12.57
T_9 (MCSRLR)	73.33	3.26	1.20	0.09	11.33
T_{10} (LCSRLR)	66.67	2.80	1.60	0.12	11.77
T_{11} (OCSRLR)	80.00	3.90	2.00	0.10	12.90
T_{12} (FSRLR)	66.67	2.50	1.00	0.08	9.83
CD (P=0.05)	11.22	0.66	0.37	NS	1.37

Table 3. Effect of rhizosphere soil changes in soil fertility and soil microbial population

Treatment	Soil fertility							Soil micronutrient count ($x10^3$ cfu / g)	
	Macronutrient (mg / kg)			Micronutrient (mg / kg)					
	N	P	K	Fe	Mn	Cu	Zn	Bacterial count	Fungal count
T_1 (BCSJR)	241.5	14.5	339.7	4.8	5.3	1.2	0.4	40.3	30.6
T_2 (PCSJR)	216.4	14.3	291.2	2.8	3.1	1.4	0.5	37.0	24.0
T_3 (MCSJR)	229.9	9.8	253.9	2.8	3.5	2.3	0.4	43.3	27.6
T_4 (LCSJR)	223.8	12.9	257.2	4.6	6.1	1.4	0.4	34.6	24.0
T_5 (OCSJR)	243.4	10.2	362.1	3.3	4.4	0.7	0.5	48.0	24.3
T_6 (FSJR)	210.1	6.3	309.9	4.4	4.1	2.2	0.4	32.8	23.3
T_7 (BCSRLR)	237.9	13.9	336.0	4.8	5.3	1.3	0.4	46.0	29.0
T_8 (PCSRLR)	226.8	13.0	253.9	2.6	3.2	1.5	0.5	46.3	30.3
T_9 (MCSRLR)	226.8	8.0	287.5	2.7	3.5	2.3	0.4	44.3	26.6
T_{10} (LCSRLR)	218.5	9.8	257.6	4.9	6.1	1.3	0.5	44.6	29.0
T_{11} (OCSRLR)	243.5	9.6	354.7	3.3	4.3	0.6	0.5	49.0	21.3
T_{12} (FSRLR)	212.2	7.1	321.0	4.3	4.2	2.3	0.4	33.5	21.0
CD (P=0.05)	7.3	0.7	23.5	0.2	0.1	0.04	0.03	3.4	2.1

cmol (p+) / kg) was observed in orange tree rhizosphere soil with Jambheri rootstock (T_5) which was significantly superior to rest of the treatments and minimum Ca (9.70 cmol (p+) / kg) was found in field soil with Rangpur lime rootstock (T_{12}). The NH_4OAc-Mg was observed significantly higher (6.83 cmol (p+) / kg) in orange tree rhizosphere soil with Jambheri rootstock (T_5) than rest of the treatments and minimum value of magnesium (3.23 cmol (p+) / kg) was observed in field soil with rough lemon (T_6).

The available Zn extracted by DTPA varied from 0.37 to 0.53 ppm in the sample. The orange tree rhizosphere soil with Rangpur lime rootstock (T_{11}) was significantly superior over rest of the treatments. The available copper extracted by DTPA various from 0.61 to 2.33 ppm. The highest value of Cu (2.33 ppm) was observed in mango tree rhizosphere soil with Jambheri rootstock (T_3) which was found superior than rest of the treatments and lowest value (0.61 ppm) was observed in orange tree rhizosphere soil with Rangpur

lime rootstock (T_{11}). The DTPA -extractable manganese in soil was significantly highest (6.13 ppm) in lemon tree rhizosphere soil with Rangpur lime rootstock (T_{10}) and lowest value (3.12 ppm) of available Mn was observed in peepal tree rhizosphere soil with Jambheri rootstock (T_2). The maximum content of iron (4.86 ppm) was recorded in lemon tree rhizosphere soil with Rangpur lime rootstock (T_{10}) and minimum value of Fe (2.62 ppm) was observed in peepal tree rhizosphere soil with Rangpur lime rootstock (T_8).

The maximum number of bacterial colonies (49×10^3 cfu / g) were noticed in orange tree rhizosphere soil with Rangpur lime rootstock (T_{11}) and lowest bacterial colonies (32.8×10^3 cfu / g) were noticed in field soil with Jambheri rootstock (T_6). The higher microbial activity was observed in rhizosphere soil compared to field soil because organic substances are released from the plant to rhizosphere soil. Similar trends were reported by earlier studies (Rengel, 2008; Nannipieri *et al.,* 2007; Srivastava *et al.,* 2012). The highest fungal colonies (30.6×10^3 cfu / g) has recorded in banyan tree rhizosphere soil with Jambheri rootstock (T_1) which was significantly superior over rest of treatment and minimum fungal count (21×10^3 cfu / g) was observed in field soil with Rangpur lime rootstock (T_{12}). It was observed that rhizosphere soils were rich in fungi compared to field soil (Table 3). Thus, rhizosphere properties defined, either in terms of nutrient pool or microbial pool, have a strong effect on plant growth responses, depending upon diversity and evenness of rhizosphere of different tree species.

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Bacterial degradation of Imidacloprid and Carbosulfan under *in-vitro* conditions in mango (*Mangifera indica*) — a preliminary study

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ABSTRACT

The experiment was conducted to isolate and identify soil microflora from mango (*Mangifera indica* L.)orchard soil which can degrade Imidacloprid and Carbosulfan, at Central Institute for Subtropical Horticulture, Lucknow. Two bacteria, CISH I-1 and CISH C-1, were isolated from soil, both having the ability to degrade Imidacloprid and Carbosulfan. These bacteria were characterized as gram negative, rod-shaped and catalase positive bacteria, and they used these insecticides as carbon source for their growth and survival. Increase in bacterial growth was recorded up to 8 and 12 days in Imidacloprid and Carbosulfan containing media, respectively. The HPLC analysis revealed that 97 and 91 per cent of Imidacloprid and Carbosulfan were degraded in soil containing CISH I-1 and CISH C-1, respectively. Further study is required for their final identification and large-scale use in mango orchard soil.

Key Words: Imidacloprid, Carbosulfan, Bacterial degradation, Soil, Carbon source, Gram negative, Rod-shaped, Insecticides

Mango (*Mangifera indica* L.) is a commercially important fruit crop heavily infested by many insect pests throughout its growth period, necessitating application of several insecticides for better production. Hopper, mealy bug and leaf webber are major insects of mango. The Insecticides, Imidacloprid and Carbosulfan, are widely used to control these pests (Bhattacherjee, 2013). Imidacloprid, a neonicotinoid insecticide, has the potential to persist in soil for 48-190 days (Baskaran, 1997), while Carbosulfan is a systemic insecticide from carbamate group and can persist in soil for 60-75 days (Rajeswaran *et al.,* 2005). During the last decade, many researchers in India and abroad have tested various microorganisms for degradation of Imidacloprid (Anhalt *et al.*, 2007; Pandey *et al.,* 2009; Sharma *et al.,* 2014a, 2014b) and Carbosulfan (Sahoo *et al.,* 1990; Sahoo *et al.,* 1998; Sharif and Mollick, 2013) in soil under different crop environment. Though, both insecticides are very common for mango ecosystem, information on degradation by microorganisms in mango orchard soil is very scanty. Therefore, an experiment was conducted to isolate pesticide degrading microorganisms from the soil pool and to test its pesticide degrading efficiency under *in-vitro* condition.

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MATERIALS AND METHODS

The experiment was conducted at Central Institute for Subtropical Horticulture, Lucknow. The media used consisted of samples collected from mango orchards located at Rehmankhera farm. Aseptic technique was applied to prevent contamination during collection of samples. The microorganisms were isolated from mango orchard soil samples. In 200 ml nutrient broth, 400 ppm Carbosulfan / Imidacloprid was added and inoculated with 1 ml orchard soil suspension. After 6 days of growth, one ml was serially diluted and poured on nutrient agar (NA) plates poisoned with 400 ppm Carbosulfan / Imidacloprid. These plates were incubated at 35°C for 48 h. The colonies were isolated and maintained on NA slants.

The well isolated colonies on NA were identified as per Bergey's manual of systematic bacteriology (Garrity *et al.,* 2005). Growth curve studies of identified microbes were conducted in nutrient broth containing 2% pesticide (Carbosulfan and Imidacloprid). Bacterial

growth was observed in terms of absorbance at 420 nm. Growth curve was obtained by plotting cell growth (absorbance) versus the incubation time.

The organisms were inoculated in 15 ml nutrient broth in 30 ml test tube containing 2% pesticide. Two controls (nutrient broth with and without pesticide) were also run simultaneously to find out the actual change brought by bacteria to pesticide. All the inoculated tubes were incubated at 35°C. Samples were taken at 0, 4, 6, 8, 10, 12, 14 and 16 days interval from the medium and absorbance was recorded at 600 nm.

Pesticide working solutions were prepared by dissolving analytical standards in methanol and storing in amber coloured bottles at 4°C. These solutions were diluted in water and added to each soil microorganism in order to obtain the desired water potential and a final concentration of 0.5 and 1.0 mg depending on the treatment. These pesticide solutions were added to the soil with a pipette (dripping the solution very carefully), then homogenised by grinding with a mortar and pestle and were left to equilibrate overnight at 4ºC.

To 50 g of carbosulfan treated soil, 100 ml acetone was added and shook overnight using incubator shaker at 150 rpm at 25°C. The contents were filtered through filter paper. The soil washing was repeated, filtered and total volume of 200 ml was collected. It was then evaporated in water bath (60°C) till volume was reduced to 50 ml. Equal amount of water and 100 ml mixture of hexane + dichloromethane (1:1) were added and shook vigorously in separating funnel for 4-6 min. Upper layer was discarded and lower layer was passed through anhydrous sodium sulphate and collected in 50 ml conical flask. The collected sample was fully evaporated and remaining residue was dissolved in 10 ml HPLC grade acetonitrile and filtered by 0.45 m syringe filter before injecting to HPLC.

To inoculated 50 g Imidacloprid treated soil, 100 ml acetonitrile was added and shook overnight at 150 rpm at 25°C. The contents were filtered through Whatman no. 44 filter paper. The washing was repeated twice and total 200 ml volume was collected. It was then evaporated in water bath at 60°C till volume is reduced to 50 ml. An equal amount of water and 40 ml NaCl solution along with 1 ml HCl was added to it. The mixture was extracted with hexane 2 times and lower layer was collected. About 100 ml mixture of hexane + ethyl acetate (98:2) were added to it and shook vigorously in a separating funnel. Lower layer was collected by passing through anhydrous sodium sulphate in 50 ml conical flask. The pooled samples were evaporated at 45°C and residue obtained was dissolved in 5 ml HPLC grade acetonitrile and filtered by 0.45 m syringe filter before analysis by HPLC.

A Shimadzu make HPLC (model LC 10 ATVP) coupled with a photodiode array detector and rheodyne injector was used for analysis of Carbosulfan and Imidacloprid as per the method of Bhattacherjee (2013). Stationary phase was reverse phase C-18 column for both insecticides. Mobile phase was acetonitrile:water (50:50 for Carbosulfan and 35:65 for Imidacloprid). The detector wavelength, injection volume and retention time of Carbosulfan and Imidacloprid were 272 and 270 nm, 20 µL, and 4.459 and 6.379 min, respectively.

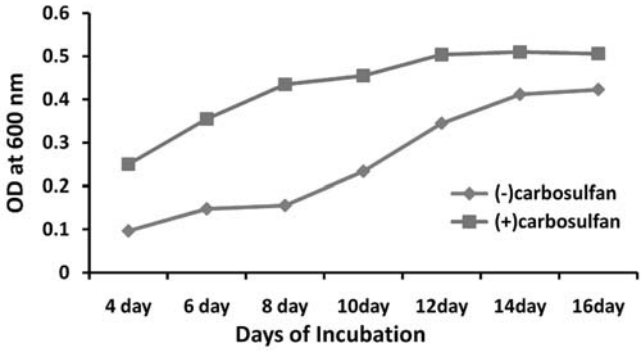
RESULTS AND DISCUSSION

The sources of microorganisms with the ability to degrade pesticides are: pesticide industry's effluent, sewage sludge, activated sludge, wastewater, natural water, sediments, *etc.* The general procedure for isolating pesticide degrading microorganism is isolating microbes from soil of areas surrounding the manufacturing of pesticides, and soil of areas where constant application of pesticides is done, increasing the concentration of pesticides to ensure the adaptation of microorganisms to conditions of culture in the laboratory as well as the growth of those that used the pesticide as their only source of carbon. Similar protocol was followed in the present study.

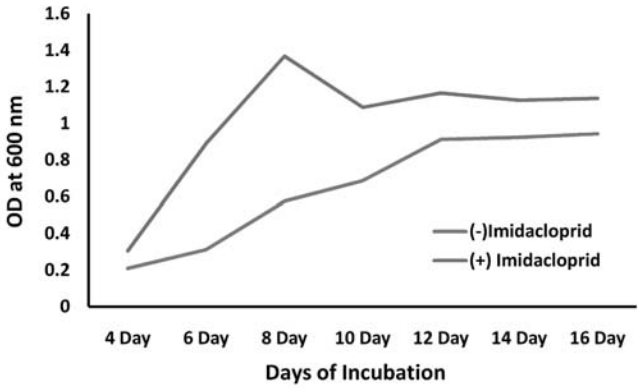
Two Carbosulfan and Imidacloprid degrading bacterial strains were isolated from soils applied with respective pesticide. Based on morphological and biochemical tests these were identified as two different strains of *Pseudomonas* sp. and were designated as CISH C-1 CISH and I-1. The strains, C-1 and I-1 which are isolated from soil are rod-shaped, gram-negative and catalase positive bacteria. Sharif and Mollick (2013) isolated a *Pseudomonas* strain from brinjal cultivated soil capable of degrading Carbosulfan. Sharma *et al.* (2016) reported that *Bacillus aerophilus*, isolated from sugarcane-growing soil, has maximum potential to degrade Imidacloprid, followed by Bacillus alkalinitrilicus. Pandey *et al.* (2009) isolated *Pseudomonas* sp 1G from soil for degradation of Imidacloprid and thiamethoxam. Another soil isolated bacteria *Leifsonia* sp. strain PC-21 also has the ability to degrade Imidacloprid (Anhalt *et al.*, 2007).

Growth study of microbe with reference to use of Carbosulfan and Imidacloprid as carbon source indicated that presence of pesticide is promoting growth of tested organisms. The growth increased up to 12^{th} and 8th day in media containing Carbosulfan and Imidacloprid (Fig. 1) and decreased thereafter. This showed that pesticides were being used for carbon metabolism by organisms. The data indicated that up to 14 days there was approximately 50 per cent reduction in Carbosulfan residues in soil, which increased up to 90 per cent after 28 days (Table 1).

Sahoo *et al.* (1998) concluded that though both



Growth curve of microbial isolate C-1 in presence of Carbosulfan



Growth curve of microbial isolate I-1 in presence of Imidacloprid

Fig. 1. Growth curves of microbial isolates C-1 and I-1 in absence and presence of Carbosulfan and Imidacloprid

Table 1. Degradation of Carbosulfan and Imidacloprid in inoculated soil samples

Treatment	Residues (mg/kg)				
	0 d	7 d	14 d	21 d	28 d
Sterilized soil treated with Carbosulfan degrading microbe	8.0	-*	3.951	0.823	0.736
Sterilized soil treated with Imidacloprid degrading microbe	8.0	4.246	2.06	1.02	0.25

-* Observation not recorded

Carbosulfan and Carbofuran could readily be degraded by both Carbosulfan and Carbofuran-retreated soil, still Carbosulfan appeared to be more resistant to degradation by enrichment culture than Carbofuran, possibly due to the presence of N-S-N linkage in functional unit of Carbosulfan. In Imidacloprid, degradation rate was faster and there were almost 50 and 97 per cent reduction of residues in soil after 7 and 28 days, respectively. These results are also in coherence with Pandey *et al.* (2009) who reported that 70 per cent of 50 ppm Imidacloprid was degraded within 14 days under microaerophilic conditions. It was observed that two soil-free stable enrichment cultures of bacteria can degrade 43 and 16 per cent of Imidacloprid in three weeks (Anhalt *et al.*, 2007). The biodegradation capability of strains isolated in this study can be valuable for further study towards bioremediation of pesticide contaminated soils.

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Standerdizing time and methods of propagation in mango *(Mangifera indica)* for vindhya region of Madhya Pradesh

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ABSTRACT

An experiment was conducted to find out suitable time of grafting and method of grafting in mango (*Mangifera indica* L.) at J N Krishi Vishwa Vidyalaya, Rewa, during 2010. Various dates of grafting and methods of grafting differed significantly, whereas interaction between date of grafting and method of grafting was significant for all characters. The maximum bud sprouting (83.33%), grafts or bud survival percentage (83.27%), grafts or bud success percentage (73.33%) and saleable plants percentage (73.33%) were recorded in 15 July among all dates of grafting. Whereas minimum bud sprouting (51.65%), grafts or bud survival percentage (52.21%), grafts or bud success percentage (48.88%) and saleable plants percentage (48.88%) were found in 30 December. Thus, it was concluded that date of grafting (15 July) was most suitable for propagation of mango, followed by 30 July and 15 August. Among methods of propagation, patch budding was found superior grafting method. Vindhya region in Madhya Pradesh showed maximum success with production quality of planting material. Mango was prepared by patch budding with maximum survival (86.67%) compared with of other methods.

Key Words: Propagation methods, Vindhya region, Grafting, Bud sprouting, Grafts, Propagation

Mango (*Mangifera indica* L.) is most important tropical and subtropical fruit grown in more than 110 countries in the world. In ancient days, it was mainly propagated by seeds. But with the technological advancement, it is propagated by vegetative methods, layering, budding or grafting. The extensive use of vegetative propagation method would be greatest which could be taken for improvement in mango orcharding. Several vegetative techniques are used for multiplication of mango. In grafting, usually a seed of a mono embryonic mango is planted to serve as a rootstock, when it reaches up to half inch in diameter, it is ready for grafting. A piece of original tree is transferred to rootstock plant. It is this piece (the scion), bearing the gene bank of desirable fruit tree. Several methods of vegetative propagation have been tried with varying degrees of success. Therefore, an experiment was conducted to study different propogation methods and suitable time of grafting in mango in Vindhya region.

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MATERIALS AND METHODS

The experiment was conducted to find out most appropriate method of grafting and to determine suitable date of grafting for propagation of mango grafts during 15 July - 30 December 2010 at Fruit Research Station, Kuthulia, College of Agriculture, Rewa, Jawaharlal Nehru Krishi Vishwa Vidyalaya, Jabalpur, Madhya Pradesh. The experiment was laid out in a randomized block design (factorial) in three replications. The 48 treatment combinations consisting of 12 dates of grafting T_1 (15 July), T_2 (30 July), T_3 (15 August), T_4 (30 August), T_5 (15 September), T_6 (30 September), T_7 (25 October), T_8 (30 October), T_9 (15 November), T_{10} (30 November), T_{11} (15 December) and T_{12} (30 December) and four methods of grafting M_1 (veneer grafting), M_2 (side grafting), M_3 (wedge grafting) and M_4 (patch budding).

The data were recorded on percentage of bud sprouting 30 days after operation, percentage of graft survival after 45 days and graft take success percentage 180 days after along with different data like time taken for bud sprouting taken 30 days after and different

shoot characters, *viz.* shoot length at 15 days interval (cm), number of leaves / shoot at 15 days interval and shoot at 15 days interval and shoot diameter (mm) at 15 and 30 days interval. Leaf chlorophyll content, leaf area index and saleable plants percentage were recorded after 180 days of operation. The data on bud sprouting percentage (%), graft or bud survival (%), graft / bud takes success (%) , time taken for bud sprouting (days), shoot length at 15 days interval (cm), number of leaves / shoot at 15 days interval, shoot length (cm), shoot diameter (mm) were measured with the help of vernier calipers, leaf chlorophyll content with the help of chlorophyll content meter "CCM- 200", leaf area index was divided by ground area (b) and multiplied with constant K, saleable plants (%). The final data of each characters recorded during investigation were analysed statistically by the method of Analysis of variance (Fisher, 1958).

RESULTS AND DISCUSSION

Various dates of grafting and methods of grafting differed significantly (Table 1). The maximum bud sprouting was recorded on 15 July (83.33%), followed by 30 August (80.63%), 15 September (79.99%), 30 September (79.93%), 15 August (79.35%) and 30 July (78.88%), where as minimum bud sprouting was noted on 30 December (51.65%). The patch budding gave significantly maximum bud sprouting (74.62%) percentage among other methods. Side grafting (73.16%) and veneer grafting (70.29%) were significantly superior than wedge grafting (69.88%). The interaction between date of grafting and method of grafting was significant. These results were in conformity with those of Ram and Bist (1982). Similarly, Kulwal and Tayde (1989) also obtained higher bud sprouting (70-90%) in August grafted plants. Singh and Srivastava (1980) also reported 84% graft sprout with patch budding.

The data on bud or grafts survival percentage showed that various dates of grafting and methods of grafting were significant (Table 1). The maximum grafts or bud survival percentage was found on 15 July (83.27%) among all dates of grafting, 30 July (82.21%) and 15 August (78.33%). The minimum grafts survival percentage was recorded on 30 December (52.21%). Maximum grafts or bud survival percentage was found in patch budding (73.37%). Side grafting (71.38%) and veneer grafting (70.02%) gave results at par and were significantly superior than wedge grafting (65.80%). The interaction between dates of grafting and methods of grafting was significant. Kulwal and Tayde (1989) and Brahamchari *et al.* (1997) also confirmed the findings and reported higher survival percentage in mango in August. Jacob *et al.* (2001) also reported higher survival in patch budding in mango.

Table 1. Bud sprouting percentage and grafts or bud survival percentage as influenced by date of grafting and methods of grafting

Date of grafting	Bud sprouting percentage					Grafts or bud survival percentage				
	Methods of grafting					Methods of grafting				
	Veneer grafting	Side grafting	Wedge grafting	Patch budding	Mean	Veneer grafting	Side grafting	Wedge grafting	Patch budding	Mean
15 July	73.33	86.66	86.66	86.66	83.33	79.77	82.21	84.44	86.67	83.27
30 July	73.33	82.22	77.77	82.22	78.88	88.88	82.22	77.77	79.99	82.21
15 August	74.33	77.77	76.44	88.88	79.35	77.77	71.11	77.77	86.66	78.33
30 August	73.66	82.22	82.22	84.44	80.63	73.33	77.77	71.11	77.77	74.99
15 September	82.22	82.22	75.55	79.99	79.99	71.66	73.88	71.11	73.88	72.63
30 September	75.55	77.55	79.99	86.66	79.93	66.66	73.33	68.66	75.55	71.05
15 October	77.77	73.88	73.33	79.99	76.24	71.11	73.33	66.66	86.66	74.44
30 October	75.55	75.55	59.99	68.88	69.99	68.88	73.88	66.66	73.33	70.69
15 November	66.66	68.55	62.22	66.66	66.02	62.22	68.88	43.33	66.66	60.27
30 November	64.44	62.44	64.44	62.22	63.38	64.44	64.44	55.55	68.88	63.32
15 December	55.55	57.77	51.10	53.33	54.43	62.22	64.44	51.10	55.55	58.33
30 December	51.10	51.10	48.88	55.55	51.65	53.33	51.10	55.55	48.88	52.21
Mean	70.29	73.16	69.88	74.62		70.02	71.38	65.80	73.37	
	D	M		D X M		D	M		D X M	
SEM ±	1.744	1.006		3.488		1.829	1.056		3.658	
CD (5%)	4.883	3.819		9.767		5.121	2.956		10.243	

D, dates of grafting; M, methods of grafting and D × M, interaction.

Table 2. Grafts or bud take success percentage and time taken for bud sprouting as influenced by dates of grafting and methods of grafting

Date of grafting	Grafts or bud take success percentage					Time taken for bud sprouting (in days)				
	Methods of grafting					Methods of grafting				
	Veneer grafting	Side grafting	Wedge grafting	Patch budding	Mean	Veneer grafting	Side grafting	Wedge grafting	Patch budding	Mean
15 July	73.33	68.88	75.55	75.55	73.33	8.8	7.2	6.53	17.43	9.99
30 July	68.68	66.66	66.66	75.50	69.44	8.43	7.86	7.2	18.06	10.38
15 August	71.11	66.66	66.66	66.66	67.77	8.36	8.53	8.96	17.2	10.76
30 August	66.66	62.22	64.44	68.88	65.55	8.73	8.93	7.9	17.13	10.67
15 September	62.22	62.22	62.22	66.66	64.44	8.93	7.4	9.1	17.9	10.83
30 September	66.66	62.22	62.22	71.11	65.55	8.5	8.66	17.7	19.6	11.11
15 October	62.22	59.99	62.22	71.11	65.55	9.13	7.8	9.76	22.6	12.07
30 October	66.66	53.33	43.33	66.66	57.49	10.76	8.86	8.13	18.6	11.58
15 November	59.99	53.33	43.33	59.99	54.16	11.46	7.73	9.1	19.63	11.98
30 November	53.00	43.33	53.33	59.99	52.41	12.3	9.8	15.03	20.13	14.31
15 December	53.00	53.33	51.10	43.33	50.19	13.33	16.7	16.03	23.93	17.5
30 December	51.10	46.66	48.88	48.88	48.88	15.83	16.2	16.83	31.4	20.06
Mean	62.90	58.23	58.32	63.97		10.38	9.63	10.10	20.30	
	D	M		D X M		D	M		D X M	
SEM ±	2.618	1.511		5.237		0.226	0.130		0.452	
CD (5%)	7.332	4.233		14.665		0.633	0.365		1.267	

D, dates of grafting, M, methods of grafting and D × M, interaction

Various dates of grafting and methods of grafting both were significant. The maximum grafts or bud success percentage was noted on 15 July (73.33%) among all dates of grafting, followed by 30 July (69.44%) and 15 August (67.77%) (Table 2). The minimum graft or bud success percentage was found on 30 December (48.88%). In patch budding, grafting **shl** water found maximum percentage (63.97%) among other methods of grafting. Veneer grafting (62.90%) and wedge grafting (58.32%) gave results at par and significantly superior than side grafting (58.23%). The interaction between dates of grafting and methods of grafting was significant. Singh and Suryanarayan (1996) also obtained 87% success in mango through soft wood grafting in August.

Time taken for bud sprouting in different treatments was recorded at various dates and time was counted from August to December 2010 (Table 2).

The grafting on 30 December took maximum time (20.16 days) for bud sprouting in grafted plants compared with 15 July (9.99), 30 July (10.39), 15 August (10.78), 30 August (10.67), 15 September (10.82), 30 September (11.16), 15 October (11.25), 30 October (11.58), 15 November (11.98), 30 November (14.36) and 15 December (17.5). The patch budding took maximum time for bud sprouting (20.02) compared with veneer grafting (10.38), side grafting (9.65) and wedge grafting (10.10). Although date of grafting on 15 July took minimum time for bud sprouting (9.99) compared with other dates of grafting. Among methods of grafting, side grafting took minimum time for bud sprouting (9.65) compared with veneer grafting, wedge grafting and patch budding. The interaction of date of grafting on 30 December (T_{12}) and Patch budding (M_4) interaction (T_{12} M_4) took maximum time for bud sprouting (31.4) among all the treatment combinations, which was significant.

The data on shoot length (cm) were recorded after 15 days till 240 days after operation at a regular interval of 15 days under different treatments of dates of grafting and methods of grafting. It is clear that date of grafting (15 July) produced significantly higher shoot length (5.62 cm), followed by 15 August, 15 September, 30 July, 30 August and 30 September (Table 3). Minimum shoot length (4.02 cm) was found 30 December. The side grafting gave significantly higher percentage (4.93 cm), followed by veneer grafting (4.92 cm) and wedge grafting (4.81 cm). The interaction between dates of grafting and methods of grafting was significant. The final data of shoot length (cm) obtained under various treatments of dates of grafting and methods of grafting 240 days after operation were statistically analyzed.

The date of grafting on 15 July gave significantly maximum shoot length (5.62 cm), followed by 15 August (5.09 cm), 15 September (5.09 cm), 30 July (4.95 cm), 30

Table 3. Shoot length (cm) and number of leaves / shoot as influenced by dates of grafting and methods of grafting

Date of grafting	Shoot length (cm)					Number of leaves / shoot				
	Methods of grafting					Methods of grafting				
	Veneer grafting	Side grafting	Wedge grafting	Patch budding	Mean	Veneer grafting	Side grafting	Wedge grafting	Patch budding	Mean
15 July	6.08	5.40	5.41	5.59	5.62	14.36	14.73	14.1	14.33	14.38
30 July	5.14	5.03	5.08	4.55	4.95	14.53	12.83	14	15.1	14.11
15 August	4.92	4.9	5.27	5.28	5.09	15.00	14.06	13.36	14.2	14.15
30 August	5.03	4.99	4.81	5.00	4.95	14.36	14.76	13.7	14.33	14.28
15 September	5.02	5.1	5.11	5.15	5.09	14.13	14.7	14.6	14.06	14.37
30 September	4.7	5.24	5.07	4.66	4.91	14.26	13.06	12.96	14.5	13.69
15 October	4.65	4.87	5.07	4.95	4.88	13.56	12.53	13.1	13.88	13.26
30 October	4.8	4.7	4.53	4.32	4.58	12.9	12.86	14.16	13.15	13.27
15 November	4.61	4.48	4.90	4.23	4.55	13.1	13.26	13.43	12.46	13.06
30 November	4.84	4.98	4.45	3.94	4.55	13.03	8.33	11.1	11.5	10.99
15 December	5.00	4.93	4.44	3.57	4.48	10.16	6.7	8.63	8.13	8.40
30 December	4.3	4.65	3.65	3.49	4.02	8.6	12.5	6.96	5.53	8.4
Mean	4.92	4.93	4.81	4.56		13.16	12.52	12.50	12.59	
	D	M		D X M		D	M		D X M	
SEM ±	0.226	0.130		0.452		0.226	0.130		0.452	
CD (5%)	0.633	0.365		1.267		0.633	0.365		1.267	

D, dates of grafting, M, methods of grafting and D × M, interaction

August (4.95 cm) and 30 September (4.91 cm) (Table 3). The side grafting produced maximum shoot length (4.93 cm) among other methods. Veneer grafting (4.92 cm) and wedge grafting (4.81 cm) gave significantly superior results than patch budding (4.56 cm). These results were in conformity with those of Dod *et al.*, (1997). Singh *et al.* (1984) confirmed the same finding and reported that veneer grafting gave maximum shoot length.

The date of grafting on 15 July produced significantly maximum number of leaves / shoot (14.38), followed by 15 September (14.37), 30 August (14.28), 15 August (14.15) and 30 July (14.11) (Table 3). The veneer grafting produced maximum number of leaves (13.16) among patch budding (12.59) and side grafting. The interaction between dates of grafting and methods of grafting was significant. Dod *et al.* (1997) also reported maximum number of leaves / shoot (29.75). The number of leaves / shoot were recorded after 15 days till 240 days after operation at a regular interval of 15 days under different treatments of dates of grafting and methods of grafting. The date of grafting on 15 July produced maximum number of leaves, followed by 15 September, 30 August, 25 August and 30 July. Minimum number (8.4) of leaves was found on 30 December. The veneer grafting produced maximum number of leaves (13.16), followed by patch budding, side grafting and wedge grafting.

Among all dates and methods of grafting, 15 July and wedge grafting encouraged diameter of sprouted shoots (mm) at all the successive stages of growth of grafted plants over 30 July, 15 August, 30 August, 15 September, 30 September, 15 October, 30 October, 15 November, 30 November, 15 December and 30 December, followed by wedge grafting, side grafting and veneer grafting (Table 4). Whereas, date of grafting on 15 December and patch budding gave minimum girth of sprouted shoot than other dates of grafting and methods of grafting during all successive growth stages of shoot.

The final data of diameter of sprouted shoots (mm) obtained under various treatments of dates of grafting and methods of grafting 180 days after operation were statistically analyzed (Table 4). The dates of grafting and methods of grafting significant increased the diameter of sprouted shoots (mm) 180 days after operation. Dates of grafting (15 July) gave significantly maximum diameter of sprouted shoots (20.44 mm), followed by 15 September (19.15 mm). Among methods of grafting, wedge grafting recorded significantly maximum diameter of sprouted shoots (19.08 mm) among other methods of grafting, *i.e.* side grafting (18.34 mm) and veneer grafting (17.73 mm). The interaction of date of grafting on 15 July and wedge grafting (T_1, M_3)

Table 4. Diameter of sprouted shoot (mm) and saleable plants percentage as influenced by dates of grafting and methods of grafting

Date of grafting	Diameter of sprouted shoot (mm)					Saleable plants percentage				
	Methods of grafting					Methods of grafting				
	Veneer grafting	Side grafting	Wedge grafting	Patch budding	Mean	Veneer grafting	Side grafting	Wedge grafting	Patch budding	Mean
15 July	20.6	21.06	22.6	17.5	20.44	73.33	68.88	75.55	75.55	73.33
30 July	21.6	16.53	18.3	20.33	19.19	68.68	66.66	66.66	75.5	69.44
15 August	19.3	16.8	20.9	16.53	18.31	71.11	66.66	66.66	66.66	67.77
30 August	19.56	21.23	20.0	14.5	18.82	66.66	62.22	64.44	68.88	65.55
15 September	18.23	18.46	18.66	15.63	17.75	62.22	62.22	62.22	66.66	64.44
30 September	16.4	21.5	20.8	16.8	18.87	66.66	62.22	62.22	71.11	65.55
15 October	18.06	14.8	21.4	17.5	17.94	62.22	59.99	62.22	71.11	65.55
30 October	15.00	14.76	18.44	16.43	16.15	66.66	53.33	43.33	66.66	57.49
15 November	16.56	16.6	16.6	17.66	16.85	59.99	53.33	43.33	59.99	54.16
30 November	15.6	19.6	18.46	16.16	17.45	53.00	43.33	53.33	59.99	52.41
15 December	15.6	18.13	16.26	15.93	16.48	53.00	53.33	51.10	43.33	50.19
30 December	16.6	20.7	16.6	13.6	16.87	51.10	46.66	48.88	48.88	48.88
Mean	17.73	18.34	19.08	16.54		62.90	58.23	58.32	63.97	
	D	M		D X M		D	M		D X M	
SEM ±	0.353	0.203		0.706		2.618	1.511		5.237	
CD (5%)	0.998	0.570		1.977		7.332	4.233		14.665	

D, dates of grafting, M, methods of grafting and D × M, interaction

Table 5. Leaf chlorophyll contents and leaf area index as influenced by dates of grafting and methods of grafting

Date of grafting	Leaf chlorophyll contents					Leaf area index				
	Methods of grafting					Methods of grafting				
	Veneer grafting	Side grafting	Wedge grafting	Patch budding	Mean	Veneer grafting	Side grafting	Wedge grafting	Patch budding	Mean
15 July	31.13	20.16	30.2	31.63	28.28	8.3	10.2	9.56	11.03	9.77
30 July	20.26	20.5	27.63	32.26	25.16	8.1	9.8	9.2	10.86	9.49
15 August	19.96	21.53	26.6	33.13	25.30	8.5	9.26	8.5	11.06	9.33
30 August	18.5	21.03	30.16	35.00	26.17	7.96	10.1	8.2	10.4	9.26
15 September	19.66	19.6	29.00	32.00	25.07	7.93	10.00	8.53	11.1	9.39
30 September	18.26	18.00	31.4	30.96	24.65	8.46	9.5	8.7	11.53	9.55
15 October	19.2	20.66	30.96	36.63	26.86	8.13	9.36	8.6	11.5	9.4
30 October	19.8	17.9	29.00	35.33	25.50	8.2	10.36	9.33	10.5	9.6
15 November	19.00	17.83	29.43	34.00	25.06	8.6	10.5	9.16	10.23	9.62
30 November	17.4	16.63	28.00	31.00	23.25	8.00	10.3	9.36	9.23	9.22
15 December	16.36	17.4	26.7	30.86	22.83	7.43	9.6	9.53	8.63	8.8
30 December	16.8	17.1	26.1	31.33	22.83	7.56	8.00	8.56	8.00	8.03
Mean	19.69	19.03	28.76	32.84		8.1	9.75	8.93	10.37	
	D	M		D X M		D	M		D X M	
SEM ±	0.261	0.151		0.523		0.111	0.064		0.223	
CD (5%)	0.732	0.422		1.465		0.313	0.189		0.626	

D, dates of grafting, M, methods of grafting and D × M, interaction

Table 6. Shoot length (cm) as influenced by dates of grafting and methods of grafting at various stages

Treatment	Days after operation															
Days of grafting	15	30	45	60	75	90	105	120	135	150	165	180	195	210	225	240
15 July	3.39	3.67	3.64	3.73	3.81	3.83	3.86	4.08	4.38	4.60	4.81	4.92	5.07	5.21	5.36	5.62
30 July	2.96	3.09	3.25	3.37	3.40	3.47	3.56	4.09	4.18	4.1	4.25	4.37	4.47	4.59	4.72	4.95
15 August	3.23	3.32	3.46	3.59	3.65	3.93	3.89	3.92	4.14	4.38	4.57	4.55	4.64	4.79	4.88	5.09
30 August	3.12	3.29	3.31	3.29	3.38	3.48	3.59	3.68	3.89	4.03	4.29	4.39	4.49	4.63	4.79	4.95
15 September	2.84	3.11	3.25	3.32	3.45	3.51	3.59	3.74	3.91	4.14	4.43	4.51	4.60	4.72	4.86	5.09
30 September	2.99	3.08	3.22	3.36	3.44	3.45	3.54	3.67	3.86	4.01	4.19	4.30	4.45	4.63	4.79	4.91
15 October	2.87	2.90	3.00	3.21	3.30	3.36	3.48	3.63	3.83	3.98	4.11	4.24	4.37	4.50	4.67	4.88
30 October	2.53	2.56	2.69	2.82	2.89	2.94	3.02	3.13	3.43	3.63	3.80	3.87	4.0	4.11	4.29	4.58
15 November	2.74	2.87	2.95	3.04	3.12	3.20	3.31	3.48	3.66	3.80	3.87	3.96	4.13	4.32	4.4	4.55
30 November	2.56	2.72	2.85	3.02	3.07	3.13	3.24	3.39	3.60	3.77	3.93	3.99	4.12	4.22	4.36	4.55
15 December	2.64	2.75	2.88	2.96	3.04	3.11	3.19	3.33	3.57	3.70	3.80	3.92	4.01	4.11	4.24	4.48
30 December	2.30	2.42	2.50	2.61	2.66	271	2.76	2.89	3.04	3.22	3.32	3.43	3.53	3.72	3.81	4.02
Methods of grafting																
Veneer grafting	2.98	3.16	3.25	3.31	3.38	3.45	3.51	3.60	3.92	4.05	4.25	4.37	4.51	4.60	4.73	4.92
Side grafting	2.95	3.08	3.21	3.30	3.39	3.48	3.56	3.63	3.87	4.10	4.28	4.40	4.50	4.61	4.70	4.93
Wedge grafting	2.85	2.96	3.05	3.18	3.27	3.31	3.42	3.53	3.74	3.94	4.08	4.14	4.26	4.39	4.57	4.81
Patch budding	2.62	2.72	2.82	2.97	3.05	3.12	3.26	3.41	3.55	3.70	3.84	3.90	4.04	4.25	4.39	4.56

Table 7. Number of leaves/shoot as influenced by dates of grafting and methods of grafting at various stages

Treatment	Days after operation															
Days of grafting	15	30	45	60	75	90	105	120	135	150	165	180	195	210	225	240
15 July	3.41	3.37	3.87	5.06	6.65	10.63	11.26	11.9	12.25	12.79	13.12	13.43	13.76	14.09	14.34	14.38
30 July	3.13	3.5	3.69	5.11	6.62	9.96	11.51	11.99	12.35	12.62	12.92	13.24	13.50	13.79	14.06	14.11
15 August	2.95	3.30	3.76	5.17	6.86	10.03	11.32	11.88	12.29	12.59	12.91	13.25	13.51	13.81	14.11	14.15
30 August	3.57	3.70	3.94	5.41	7.63	10.27	11.70	12.26	12.67	13.0	13.23	13.47	13.68	14.0	14.25	14.28
15 September	3.59	3.98	4.1	5.63	7.56	10.71	11.26	11.86	12.30	12.60	13.08	13.65	13.62	14.08	14.35	14.37
30 September	3.33	3.66	3.82	3.53	7.16	9.06	10.86	11.47	11.99	12.29	12.55	12.84	13.08	13.32	13.64	13.69
15 October	3.32	3.65	4.04	5.4	7.6	9.2	10.46	11.06	11.37	11.72	12.0	12.45	12.6	12.85	1.20	13.26
30 October	2.92	3.32	3.56	5.28	7.10	9.52	10.46	11.05	11.35	11.68	11.91	12.45	12.63	12.95	13.06	13.27
15 November	3.26	3.52	3.66	5.14	7.05	9.74	10.91	10.43	11.66	11.94	12.16	12.44	12.65	12.82	13.24	13.06
30 November	3.12	3.43	3.58	4.75	6.20	8.82	9.76	10.30	9.58	9.8	9.99	10.26	10.48	10.67	10.89	10.99
15 December	2.69	3.09	3.57	5.02	6.35	7.19	7.8	9.07	7.82	7.91	8.01	8.12	8.3	8.34	8.37	8.40
30 December	3.00	3.21	3.56	4.67	5.39	6.25	6.29	6.40	7.91	8.00	8.09	8.15	8.25	8.30	8.39	8.4
Methods of grafting																
Veneer grafting	3.01	3.38	3.74	4.94	7.13	8.86	10.70	11.37	11.73	11.90	12.09	12.38	12.62	12.85	13.12	13.16
Side grafting	3.31	3.57	3.91	5.35	6.26	9.18	10.27	10.91	11.16	11.41	11.60	11.89	12.02	12.23	12.49	12.52
Wedge grafting	3.3	3.54	3.76	5.1	6.94	9.63	10.26	10.63	10.91	11.23	11.50	11.83	12.05	12.26	12.46	12.50
Patch budding	3.15	3.55	3.63	5.33	7.05	11.94	9.96	10.37	10.71	11.10	11.46	11.81	12.06	12.33	12.56	12.59

Table 8. Diameter of sprouted shoot (mm) as influenced by dates of grafting and methods of grafting at various stages

Treatment	Days after operation					
Date of grafting	30	60	90	120	150	180
15 July	18.56	19	19.39	19.72	20.19	20.44
30 July	15.75	16.28	16.73	17.10	17.69	17.94
15 August	14.17	14.63	15.03	15.37	15.89	16.15
30 August	14.87	15.34	15.74	16.05	16.58	16.85
15 September	17.26	17.74	18.12	18.45	18.99	19.19
30 September	16.37	16.86	17.18	17.6	18.04	18.31
15 October	16.79	17.19	17.65	18.07	18.64	18.85
30 October	15.64	16.14	16.53	16.94	17.44	17.75
15 November	16.93	17.37	17.79	18.18	17.49	18.82
30 November	15.47	15.94	16.33	16.78	17.17	17.45
15 December	14.99	15.10	15.49	15.88	16.2	16.48
30 December	15.26	15.65	15.97	16.26	16.6	16.87
			Methods of grafting			
Veneer grafting	15.88	16.39	16.78	17.19	17.55	17.73
Side grafting	16.33	16.83	17.24	17.61	18.07	18.34
Wedge grafting	17.26	17.64	18.00	18.33	18.82	19.08
Patch budding	14.48	14.890	15.28	15.73	16.15	16.54

gave maximum diameter of sprouted shoots (22.6 mm) compared to all other treatment combinations.

The data on leaf chlorophyll content showed that various dates of grafting and methods of grafting were significant (Table 5). The leaf chlorophyll content was maximum on 15 July (28.28) among all dates of grafting, followed by 30 July (25.16), 15 August (25.30), 30 August (26.17), 15 September (25.06), 30 September (24.65), 15 October (26.86), 30 October (25.50), 15 November (25.06), 30 November (23.25), 15 December (22.83) and 30 December (22.83). The maximum leaf chlorophyll content was recorded in patch budding (32.84) compared to wedge grafting (28.76) and veneer grafting (19.69. The interaction between dates of grafting and methods of grafting was significant.

The data on leaf area index showed that various dates of grafting and methods of grafting both were significant (Tables 5-8). The leaf area index in 15 July was significantly higher (9.77) than other dates of grafting, 30 July (9.49), 15 August (9.33), 30 August (9.26), 15 September (9.39), 30 September (9.55), 15 October (9.4), 30 October (9.6), 15 November (9.62), 30 November (9.22), 15 December (8.8) and 30 December (8.03). The methods of grafting in patch budding showed maximum leaf area index (10.37) compared to side grafting (9.75) and wedge grafting (8.93) and were at par and significantly superior than veneer grafting (8.1). Interaction between dates of grafting and methods of grafting was significant.

The data on saleable plants percentage showed that various dates of grafting and methods of grafting both were significant. The maximum saleable plants percentage was found on 15 July (73.33%) among all dates of grafting, followed by 30 July (69.44%) and 15 August (67.77%). The minimum saleable plants percentage was found on 30 December (48.88%). As regards to methods of grafting, patch budding recorded maximum saleable plants percentage (63.97%) among other methods of grafting. Veneer grafting (62.90%) and wedge grafting (58.32%) gave at par results and significantly superior than side grafting (58.23%).

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Effect of post-shooting foliar spray of fertilizes on yield and economics of banana *(Musa paradisiaca)* cv. Grand Nain

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ABSTRACT

The experiment was conducted to find out the effect of post-shooting foliar spray of fertilizers on yield and economics of banana (*Musa paradisiaca* L.) cv. Grand Nain during 2012-13 at Regional Horticultural Research Station, ASPEE College of Horticulture and Forestry, Navsari Agricultural University, Navsari (Gujarat). The experiment was laid out with 11 treatments in a randomized block design with three replications. The treatments included SOP (1.0%, 1.5% and 2.0%), urea (1.0%, 1.5% and 2.0%), KNO_3 (0.5%, 1.0% and 1.5%) and pouch feeding (300g fresh cowdung + 20g ammonium sulphate + 10g SOP) along with the control. The first spray was done immediately after complete emergence of bunch while the second was done 15 days after first spray. All bunches were covered with 18 µ blue polythene. Quantity parameters were recorded and analyzed statistically. The minimum days taken from flowering to harvesting and maximum length of bunch, girth of bunch, weight of third hand, length of finger, girth of finger, weight of bunch and yield were significant in SOP (1.5%). The bunches sprayed twice with SOP (1.5%) and sleeve with 18µ blue polythene were most remunerative since they gave highest gross income and net return with maximum benefit cost ratio.

Key Words: Post-shooting, Foliar spraying, Yield, Sleeving, Pouch feeding, SOP, Urea, KNO_3

India is the largest banana (*Musa paradisiaca* L.) cv. Grand Nain consumer and producing country in the world, followed by Brazil, contributing 15 per cent of the total world production. Among fruits, banana holds first position in production and productivity in India. It ranks second in area after mango. Nowadays, application of chemicals on banana bunch for improving the growth, maturity, yield and quality of fruits is gaining popularity. Since urea is well-known for its growth-promoting activity, it can prolong the growth period of developing fruits by keeping them in an active stage of growth (Gandhi, 1984). Bunch feeding in banana, the technology of enhancing size of fingers of banana, was successfully developed at the Navsari Agricultural University, Navsari. De-navelling saves mobilization of nutrients into unwanted rink of banana plant and earns additional income when excised male bud is used as a vegetable. Sulphate of potash spray get higher bunch size with good quality. It helps in photosynthesis, thus reflecting in fruit size and yield. The higher chlorophyll content in leaves and developing fruits reflects the efficiency of photosynthesis. Hence an experiment was conducted to find out the effect of post-shooting foliar spray of fertilizers on yield of banana.

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MATERIALS AND METHODS

An experiment was conducted at Regional Horticultural Research Station, Navsari Agricultural University, Navsari, to find out the effect of post-shooting foliar spraying of fertilizers on yield and economics of banana cv. Grand Nain during 2012-13. The experiment was laid out with 11 treatments in a randomized block design and replicated three times. The treatments included SOP (1.0%, 1.5% and 2.0%), urea (1.0%, 1.5% and 2.0%), KNO_3 (0.5%, 1.0% and 1.5%) and pouch feeding (300g fresh cow dung + 20g ammonium sulphate + 10g SOP) along with the control.

The first spray was done immediately after complete emergence of bunch, while second was done 15 days after first spray. All bunches were covered with 18µ blue polythene. The pits of 30 cm × 30 cm × 30 cm were

dug out and planting was done in August at a spacing of 2.4 m × 1.2 m. All the packages of practices were followed as per the recommendation of the university.

RESULTS AND DISCUSSION

The days taken from flowering to harvesting, length of bunch (cm), girth of bunch (cm), weight of third hand (kg), length of finger (cm), girth of finger (cm), weight of bunch (kg) and yield (tonnes/ha) were affected due to various treatments. All these parameters showed significant differences through various foliar sprays of fertilizers (Table 1).

The minimum days taken from flowering to harvesting was recorded when bunches were sprayed with SOP 1.5% twice, first immediately after bunch emergence and second 15 days after first spray. In post-shooting nutrient spray, the reduction in days taken from flowering to harvesting was due to faster growth rate of fingers and higher leaf chlorophyll contents owing to additional nutrient supply and faster rate of translocation of assimilates from source to sink, aided by additional potassium because it is a general metabolic activator increasing the respiration and photosynthetic rate. Thus, additional K application as foliar spray induced earlier days from flowering to harvesting (Evans, 1971; Martin and Prevel, 1972).

The foliar spraying of urea delayed the harvesting. This might be due to urea as a nitrogenous fertilizer and is well-known for its growth-promoting activity in plant tissues. Urea can be expected to prolong the growth period of developing fruits by keeping them in active stage of growth (Gandhi, 1984).

Length of bunch includes number of hands and finger length which were positively correlated to each other. The maximum length of bunch and finger were noted in SOP 1.5% treatment. Baruah and Mohan (1992) reported that banana bunch treated with 1.5% SOP resulted in longest length of bunch.

Girth of bunch includes number and girth of finger in each hand. The maximum girth of bunch and finger were noted with SOP 1.5% treatment. The additional K application as foliar spray induced faster growth of fingers length, girth of fingers so ultimately increase in girth of bunch.

Significantly maximum yield, weight of third hand and bunch were observed in SOP 1.5% treatment. The favourable influence of SOP on production of heavier bunches might be due to heavier dry-matter and starch accumulation and additionally promoted by sulphur present in SOP (Kumar and Kumar, 2008). Post-shooting spray of SOP (1.5%) significantly altered the chlorophyll content of leaves at the time of harvesting. The sprayed plants were more efficient in maintaining a better photosynthetic status which ultimately reflected on

Table 1. Effect of post-shooting treatments on yield and economics of banana cv. Grand Nain

Treatment	Days taken from flowering to harvesting	Length of bunch (cm)	Girth of bunch (cm)	Weight of 3rd hand (kg)	Length of finger (g)	Girth of finger (cm)	Weight of bunch (kg)	Yield (tonnes/ha)	Net-return (₹/ha)	Benefit: cost ratio
T_1, Control	88.84	66.08	78.25	1.83	20.52	11.82	16.59	57.60	400427	2:29
T_2, SOP 1.0%	88.18	79.42	96.38	3.01	23.44	13.49	21.53	74.75	570997	3:24
T_3, SOP 1.5%	88.11	85.58	104.30	3.44	24.55	14.08	23.78	82.56	648872	3:67
T_4, SOP 2.0%	88.93	76.50	95.92	2.37	22.69	12.87	20.58	71.45	537547	3:04
T_5, Urea 1.0%	88.93	76.20	92.67	2.22	22.31	12.72	19.12	66.38	487729	2:78
T_6, Urea 1.5%	89.51	79.00	96.50	2.93	23.08	13.22	20.92	72.61	550020	3:13
T_7, Urea 2.0%	92.36	80.67	97.42	3.14	23.73	13.72	21.98	76.29	586811	3:33
T_8, KNO_3 0.5%	90.49	75.25	87.17	2.08	21.83	12.38	18.66	64.76	471269	2:68
T_9, KNO_3 1.0%	91.27	78.42	96.17	2.61	22.75	12.91	20.73	71.95	542891	3:08
T_{10}, KNO_3 1.5%	88.80	81.25	99.42	3.28	24.06	14.01	22.11	76.74	590513	3:34
T_{11}, Pouch feeding	91.61	73.08	86.17	1.98	20.91	11.97	18.22	63.24	446758	2:41
S Em±	0.38	3.00	3.84	0.14	0.82	0.50	0.96	3.34		-
CD (5%)	1.11	8.86	11.34	0.40	2.41	1.47	2.84	9.85		-
CV (%)	9.00	6.72	7.10	9.03	6.22	6.62	8.12	8.12		-

various bunch characters and ultimately on yield.

Increase in bunch weight is associated with corresponding significant increase in number of hands, total number of fingers, finger weight, length and circumference (Kumar and Kumar, 2008). In banana, retention of higher chlorophyll pigment during post-shooting stage helps bunches to accumulate more photosynthates. Thus, reflecting in bunch size and yield (Kumar *et al.*, 2008). There was a beneficial role of S nutrition in enhancing bunch weight in bananas (Martin and Prevel, 1972). The influence of sulphur in enhancing fruit yield in bananas was stressed by Lahav and Turner (1983).

Economics of various treatments revealed that SOP 1.5% recorded maximum net realization per hectare with BCR. This is due to SOP 1.5% produce more yield compared to other treatments. Kumar and Kumar (2007) and Kumar *et al.* (2008) also reported similar results.

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Distribution of nutrient constraints in Khasi mandarin *(Citrus reticulata)* orchards of Manipur

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ABSTRACT

The studies were carried out covering as many as 40 orchards of Khasi mandarin (*Citrus reticulate* Blanco) in Thangal village of sub-division Nungba under Tamenglong district during 2010-2011. Nutrient constraints in the form of N, P, Ca, Mg, Cu, and Zn were identified using these diagnostics which must find a due place in a fertilizer programme of mandarin orchards in the region to obtain sustainable optimum fruit yield. The values of available nutrients, viz. N, P, and K across 40 orchards varied from 92.2 to 348.2 mg/kg, 5.0 to 9.4 mg/kg, 110.0 to 440.1 mg/kg, respectively, with corresponding coefficient of variation of 11.8, 9.2, and 16.4% respectively. Soil micronutrients showed a large variation of 11.2- 48.1 mg/kg Fe (CV 16.2%), 11.4-44.0 mg/kg Mn (CV 11.2%), 0.80-2.5 mg/kg Cu (CV 6.9%) and 0.50-2.8 mg/kg Zn (CV 7.4%). Leaf nutrient concentration like soil fertility showed a wide variation from 1.62-2.62 % N, 0.04-0.12% P, 0.72-1.89% K, 0.90-2.24% Ca and 0.28-0.61% Mg. Similarly, micronutrients, Fe, Mn, Cu, and Zn varied from 118.4-282.3, 32.3-92.4, 1.0-3.8 and 14.6-28.4 ppm. These observations give an insight about the order in which, different nutrients are preferred by specific citrus cultivar, and the ratio in which different nutrients are removed. Such nutrient removal patterns are to be meted out in order to maintain the sustained supply of nutrients through soil.

Key Words: Khasi mandarin, Macro-micro nutrients status, Orchard, Nutrient removal

Citrus is being cultivated in 3.35 million ha with a total production of 91 million tonnes. The current average productivity of citrus orchards in India is 8.9 tonnes / ha compared to 4.52 tonnes / ha (Srivastava and Singh 2002 a). Cultivation of Khasi mandarin (*Citrus reticulata* Blanco) in northeast India is mainly confined to midhills up to an elevation of 1,200 m above mean sea-level under humid tropical climate. The highest production is obtained in various soil orders, viz. Alfisol, Oxisol, Ultisol, Entisol, and Inceptisol (Srivastava and Singh, 2002b; Srivastava 2014; Punecar *et al.*, 2017; Du *et al.*, 2015; Shao *et al.*, 2018; Hang *et al.*, 2018). Resultantly, orchards continue to produce sub-optimally due to increasing gap between the amount of nutrients added to that of annual demand with orchard age. The establishment of citrus orchards on steep slopes without contour trench planting or terracing has accelerated the menace of problem by exposing the comparatively more acidic and infertile sub-surface having poor nutrient reserve to support the required nutrition of plants (Srivastava and Singh 2002 a). Of the different diagnostic tools, leaf-and soil- based nutrient standards have established their superiority over rest of the diagnostic methods. Therefore, studies were carried out to determine nutrient status anddeveloping the fertilizer requirement of Khasi mandarin (*Citrus reticulata* Blanco).

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MATERIALS AND METHODS

Extensive surveys were carried out covering as many as 40 orchards of Khasi mandarin in Thangal village of sub-division Nungba under Tamenglong district during 2010-2011. The topography of tamenglong district's topography is made up of mostly of rugged hills, lofty mountains and rolling valleys with occasional human habitation in bucolic hamlets. The district encompasses an area of 4,391 km^2, stretching across the latitudinal parallel to 24° 59' north and longitudinal meridian of 93° 30' east. The mean summer and mean winter temperature of the region vary from 31°C and 4°C and annual rainfall of 3135 mm with

Table 1. Available supply of micronutrients in soil relation to fruit yield in Khasi mandarin orchards of Manipur

Orchard No. (I-X)	Macronutrients (mg/kg)					Fruit yield	
	N	P	K	Ca	Mg	Fruits/tree	kg/tree
I							
1a	348.2	9.4	440.1	313.4	64.2	310	46.8
1b	280.4	8.1	330.2	280.2	63.1	210	38.4
1c	240.2	8.0	280.4	210.3	52.0	180	32.0
1d	238.1	7.4	282.4	204.0	40.0	140	20.3
II							
2a	240.8	7.1	210.3	192.3	42.4	140	18.4
2b	260.1	8.2	300.4	204.6	52.4	240	28.2
2c	210.4	6.3	182.3	111.0	31.0	220	22.0
2d	218.6	6.2	186.0	128.6	31.3	200	24.6
III							
3a	262.0	8.8	310.4	210.4	52.3	195	40.4
3b	210.4	7.2	210.0	180.3	44.8	170	32.2
3c	228.3	8.2	282.3	210.4	33.2	220	36.2
3d	212.4	6.4	189.0	180.3	32.1	195	28.2
IV							
4a	162.1	6.4	160.0	150.0	28.2	110	20.6
4b	156.2	7.0	168.0	152.3	32.2	150	22.7
4c	128.3	5.2	122.3	100.0	19.4	100	18.4
4d	210.4	7.2	210.4	160.4	40.2	160	30.0
V							
5a	172.0	7.0	131.0	104.0	42.0	100	19.4
5b	210.1	8.4	180.4	140.3	38.2	200	36.4
5c	180.0	7.6	140.2	110.8	22.1	110	21.0
5d	192.2	8.0	170.6	130.2	61.1	190	32.3
VI							
6a	194.0	8.0	190.4	162.2	44.1	150	30.4
6b	183.1	7.2	192.0	160.3	50.2	135	28.3
6c	110.0	6.4	180.3	140.0	40.3	80	18.2
6d	204.3	8.2	280.4	240.3	58.2	190	42.3
VII							
7a	122.0	5.0	186.0	166.1	21.3	140	20.3
7b	120.2	6.2	182.0	102.0	22.0	100	19.4
7c	182.2	8.4	234.2	210.3	42.0	180	40.3
7d	162.0	5.2	180.2	180.2	30.8	140	32.2
VIII							
8a	100.0	5.2	140.3	110.2	22.0	100	18.2
8b	114.6	7.4	152.0	162.1	23.0	166	32.6
8c	110.3	7.2	182.0	160.4	32.8	158	30.4
8d	92.2	6.1	172.0	98.2	28.1	118	19.6
IX							
9a	86.4	6.2	110.6	172.0	24.2	145	21.3
9b	210.2	8.1	161.9	182.3	32.2	200	40.4
9c	110.2	5.8	110.0	90.3	27.1	90	12.4
9d	180.4	6.0	118.1	106.7	30.2	145	16.9
X							
10a	152.2	5.2	132.7	111.8	22.4	148	22.9
10b	142.2	6.1	158.6	122.0	24.3	158	26.4
10c	161.2	7.8	182.0	132.8	41.3	200	32.3
10d	110.0	5.8	112.0	80.3	22.0	84	11.6
Mean	180.5	7.0	196.1	156.8	36.5	159.2	27.1
CV (%)	11.8	9.2	16.4	8.9	7.2	16.4	13.8

Total number of units/observations = 40

Table 2. Available supply of micronutrients in soil in relation to fruit yield in Khasi mandarin orchards of Manipur

Orchard No. (I-X)	Micronutrients (mg/kg)				Fruit yield	
	Fe	Mn	Cu	Zn	Fruits/tree	kg/tree
I						
1a	32.2	42.0	2.5	2.8	310	46.8
1b	30.2	44.0	2.2	1.4	210	38.4
1c	34.2	38.2	1.7	1.4	180	32.0
1d	41.4	32.0	1.2	0.80	140	20.3
II						
2a	34.6	24.2	1.8	0.74	140	18.4
2b	38.2	23.2	2.1	0.82	240	28.2
2c	31.3	24.1	1.2	0.60	220	22.0
2d	41.4	22.0	1.0	0.62	200	24.6
III						
3a	44.2	18.4	1.8	0.90	195	40.4
3b	41.2	22.2	1.2	0.80	170	32.2
3c	38.2	21.2	1.4	0.82	220	36.2
3d	40.2	23.2	1.2	0.65	195	28.2
IV						
4a	19.4	14.6	1.0	0.64	110	20.6
4b	24.2	16.2	1.1	0.60	150	22.7
4c	24.2	18.1	1.2	0.56	100	18.4
4d	32.1	20.1	1.4	0.70	160	30.0
V						
5a	42.1	32.1	1.2	0.52	100	19.4
5b	48.1	28.2	1.4	0.86	200	36.4
5c	37.2	22.4	1.6	0.52	110	21.0
5d	24.3	22.0	1.0	0.76	190	32.3
VI						
6a	34.2	21.0	2.0	0.55	150	30.4
6b	32.1	18.9	1.8	0.50	135	28.3
6c	22.8	24.0	1.4	0.60	80	18.2
6d	24.2	22.0	2.2	1.20	190	42.3
VII						
7a	34.2	18.4	1.1	0.80	140	20.3
7b	28.1	20.0	1.0	1.0	100	19.4
7c	22.0	22.0	1.4	1.5	180	40.3
7d	21.0	20.0	1.1	1.2	140	32.2
VIII						
8a	21.0	18.1	0.80	0.82	100	18.2
8b	18.2	18.4	1.7	0.96	166	32.6
8c	11.2	17.1	1.8	0.90	158	30.4
8d	17.4	14.2	1.2	0.61	118	19.6
IX						
9a	18.2	18.2	1.0	0.80	145	21.3
9b	19.2	11.6	1.6	0.86	200	40.4
9c	20.1	11.3	0.80	0.60	90	12.4
9d	22.2	14.2	1.10	0.66	145	16.9
X						
10a	21.2	13.2	1.4	0.60	148	22.9
10b	19.6	12.2	1.7	0.66	158	26.4
10c	20.2	12.1	1.9	0.78	200	32.3
10d	22.3	11.4	0.90	0.54	84	11.6
Mean	28.7	21.2	1.4	0.8	159.2	27.1
CV (%)	16.2	11.2	6.9	7.4	16.4	13.8

Total number of units/observations = 40

Table 3. Micronutrient composition in leaves in relation to fruit yield in Khasi madarin orchards in Manipur

Orchard No. (I-X)	Macronutrients (%)					Fruit yield	
	N	P	K	Ca	Mg	Fruits/tree	kg/tree
I							
1a	2.62	0.12	1.89	2.10	0.56	310	46.8
1b	2.44	0.10	1.62	1.92	0.42	210	38.4
1c	1.70	0.07	1.40	1.61	0.30	180	32.0
1d	1.62	0.05	1.10	1.42	0.20	140	20.3
II							
2a	2.01	0.06	1.10	1.80	0.32	140	18.4
2b	2.32	0.09	1.30	1.90	0.46	240	28.2
2c	2.30	0.08	0.90	1.82	0.38	220	22.0
2d	2.20	0.07	0.94	1.89	0.40	200	24.6
III							
3a	2.42	0.12	1.94	2.04	0.61	195	40.4
3b	2.30	0.10	1.82	2.01	0.52	170	32.2
3c	2.34	0.11	1.92	2.12	0.56	220	36.2
3d	2.20	0.07	1.72	2.01	0.48	195	28.2
IV							
4a	1.72	0.07	1.32	1.60	0.29	110	20.6
4b	1.82	0.06	1.42	1.70	0.42	150	22.7
4c	1.62	0.06	1.12	1.82	0.32	100	18.4
4d	2.12	0.11	1.82	1.92	0.40	160	30.0
V							
5a	1.10	0.05	0.92	0.90	0.32	100	19.4
5b	2.20	0.10	1.94	1.72	0.56	200	36.4
5c	1.80	0.08	1.82	1.42	0.40	110	21.0
5d	1.70	0.06	1.74	0.98	0.40	190	32.3
VI							
6a	2.30	0.10	1.56	1.93	0.54	150	30.4
6b	2.10	0.09	1.42	1.91	0.48	135	28.3
6c	1.70	0.07	0.92	1.64	0.40	80	18.2
6d	2.42	0.12	1.62	2.12	0.61	190	42.3
VII							
7a	1.98	0.08	0.98	1.28	0.28	140	20.3
7b	2.12	0.07	1.12	1.72	0.32	100	19.4
7c	2.42	0.13	1.72	2.12	0.61	180	40.3
7d	2.32	0.11	1.78	2.10	0.52	140	32.2
VIII							
8a	1.70	0.06	1.01	1.84	0.30	100	18.2
8b	2.20	0.12	1.82	2.12	0.61	166	32.6
8c	2.30	0.13	1.58	2.24	0.52	158	30.4
8d	1.81	0.08	0.94	1.11	0.32	118	19.6
IX							
9a	1.89	0.06	1.04	1.89	0.30	145	21.3
9b	2.48	0.13	2.12	2.32	0.61	200	40.4
9c	1.72	0.05	1.11	1.11	0.42	90	12.4
9d	1.82	0.04	0.92	1.32	0.32	145	16.9
X							
10a	2.12	0.10	1.02	1.82	0.36	148	22.9
10b	2.22	0.09	1.12	2.11	0.42	158	26.4
10c	2.42	0.10	1.96	2.21	0.56	200	32.3
10d	2.02	0.06	0.72	1.01	0.32	84	11.6
Mean	2.1	0.09	1.4	1.76	0.62	159.2	27.1
CV (%)	15.45	29.02	28.47	21.14	36.35	16.4	15.8

Total number of units/observations = 40

Table 4. Micronutrient composition in leaves relation to fruit yield in Khasi mandarin orchards in Manipur

Orchard No. (I-X)	Micronutrients (ppm)				Fruit yield	
	Fe	Mn	Cu	Zn	Fruits/tree	kg/tree
I						
1a	226.3	61.9	3.4	28.2	310	46.8
1b	210.4	52.8	2.8	24.6	210	38.4
1c	218.4	44.6	1.4	22.2	180	32.0
1d	222.2	32.3	3.4	17.8	140	20.3
II						
2a	118.4	33.2	1.4	18.0	140	18.4
2b	179.8	42.4	1.2	20.4	240	28.2
2c	204.3	44.2	2.8	21.2	220	22.0
2d	210.6	43.1	3.1	20.4	200	24.6
III						
3a	214.0	53.8	3.8	27.9	195	40.4
3b	218.6	61.4	2.8	23.6	170	32.2
3c	210.4	64.4	1.7	28.2	220	36.2
3d	178.6	58.9	2.0	21.2	195	28.2
IV						
4a	204.3	54.6	2.2	17.2	110	20.6
4b	192.4	61.8	3.2	17.6	150	22.7
4c	178.1	79.6	1.8	18.1	100	18.4
4d	142.4	81.2	2.1	21.2	160	30.0
V						
5a	214.2	69.4	2.2	19.2	100	19.4
5b	119.4	92.4	2.3	22.3	200	36.4
5c	136.8	64.3	3.1	18.4	110	21.0
5d	172.8	71.2	1.9	26.3	190	32.3
VI						
6a	224.2	78.4	1.3	21.4	150	30.4
6b	178.4	72.2	1.4	18.2	135	28.3
6c	192.0	61.4	1.1	16.8	80	18.2
6d	198.6	74.6	2.8	31.2	190	42.3
VII						
7a	178.4	61.3	1.0	19.2	140	20.3
7b	218.3	58.2	1.2	17.8	100	19.4
7c	279.4	79.2	3.2	28.4	180	40.3
7d	270.3	61.4	2.1	24.3	140	32.2
VIII						
8a	261.4	42.8	1.2	20.4	100	18.2
8b	228.4	53.8	2.8	27.0	166	32.6
8c	182.9	52.4	1.8	28.1	158	30.4
8d	172.2	41.2	2.1	18.0	118	19.6
IX						
9a	194.6	82.0	1.7	20.4	145	21.3
9b	282.3	92.3	2.4	29.4	200	40.4
9c	211.4	61.0	3.2	17.2	90	12.4
9d	189.3	81.2	2.8	14.6	145	16.9
X						
10a	182.2	48.2	2.6	22.1	148	22.9
10b	192.2	52.3	2.2	24.3	158	26.4
10c	214.3	61.9	2.8	28.4	200	32.3
10d	228.4	92.2	3.1	18.1	84	11.6
Mean	201.3	61.9	2.3	22.0	159.2	27.1
CV (%)	18.21	25.52	33.16	19.72	16.4	15.8

Total number of units/observations = 40

relative humidity 76% (minimum), 92% (maximum). Soil samples were collected from skirt belt / perimeter of trees, zone having maximum concentration of feeder roots at soil depth of 0-20 cm. Likewise; leaf positions from non-fruiting terminals covering 2-10% trees at a height of 1.5-1.8 m from the ground were sampled.

The soil samples were air dried, ground, and passed through 2-mm sieve, and subjected to analysis of available nitrogen using Alkaline Permanganate Method (Subbiah and Asija, 1956), Bray-P using ammonium fluoride extraction by shaking 1g soil in 20 ml of 0.03 (N) NH_4F in 0.025 N HCl for 30 min., Ca, Mg, and K extractable in 1 N neutral NH_4OAc in 1:2 soil : extractant ratio after shaking for 30 min. (Lanyon and Heald, 1982) and micronutrients (Zn, Cu, Mn and Fe) in 0.05 M (pH 7.3) DTPA- $CaCl_2$ after shaking 20g soil and 50 ml extracatant together for 2 hours (Linsay and Norvell, 1978).

Leaf samples were thoroughly washed (Chapman 1964) and ground using a Wiley-Grinding machine to obtain homogenous samples. Tri-acid ($HClO_4$: HNO_3: H_2SO_4 in 2:5:1) extracts of leaf samples (Chapman and Pratt 1961) were subjected to analysis of P using Vanadomolybdophosphoric acid (ammonium molybdate + ammonium metavanadate) method, K flame photometrically, calcium and magnesium by versene titration (Lanyon and Heald 1982) using ammonium purpurate (murexide) and erichrome black-T as indicators for Ca and Ca+Mg, respectively, and micronutrients by Atomic Absorption Spectro-photometer. While, total N in leaves was determined using auto-nitrogen analyzer.

RESULTS AND DISCUSSION

The available nutrients, *viz*. N, P, and K across 40 orchards varied from 92.2 to 348.2 mg / kg, 5.0 to 9.4 mg / kg, 110.0 to 440.1 mg / kg, respectively, with corresponding coefficient of variation (%) of 11.8, 9.2, and 16.4 respectively. The mean values of N, P, K, Ca and Mg were observed as 180.5, 7.0, 196.1, 156.8 and 36.5 mg / kg respectively (Table 1). Similar observations were earlier made by Srivastava and Singh (2001a, 2001c).

The mean values of Fe, Mn, Cu, and Zn were observed as 28.7, 21.2, 1.4 and 0.8 mg / kg. Micronutrients likewise showed a large variation of 11.2- 48.1 mg / kg Fe (CV 16.2%), 11.4-44.0 mg / kg Mn (CV 11.2%), 0.80-2.5 mg / kg Cu (CV 6.9%) and 0.50-2.8 mg / kg Zn (CV 7.4%) (Table 2). These results are similar to those of Srivastava and Singh (2002a, 2002b)

Validity of leaf analysis as an instrument for controlling the mineral nutrition is related to significance. The total concentration in leaf gives a precise image of production output of crop and its dependence on supply of each nutrient. Leaf nutrient concentration like soil fertility showed a wide variation from 1.62-2.62 % N, 0.04-0.12% P, 0.72-1.89% K, 0.90-2.24% Ca and 0.28-0.61% Mg. The mean values of N, P, K, Ca, Mg were observed as 2.1%, 0.09%, 1.4%, 1.76% and 0.62% respectively with corresponding co-efficient of variation (%) of 15.45, 29.02, 28.47, 21.14 and 36.35 respectively (Table 3). Srivastava and Singh (2001c, 2003a) showed similar kind of delineation of nutrient levels having statistically significant difference in relation to fruit level. Under similar conditions, Ko and Kim (1987) recommended optimum leaf N, P, K, Ca, Mg as 2.5-2.8, 0.19-0.20, 1.5-1.7, 2.5-3.0, and 0.30-0.35 % respectively, for Satsuma mandarin grown in Jeju Island of Korea. Terblance and Du Plessis (1992) also observed optimum values of different nutrients as: 2.5-2.7% N, 0.10-0.15% P, 0.80-0.90% K, 4.0-5.0% Ca, and 0.25-0.30% Mg. the variation in optimum values are dominantly governed by specific diagnostic norms for precise identification of nutrient constraints comensurating with field conditions (Srivastava and Singh, 2003a).

Similarly, micronutrients, Fe, Mn, Cu, and Zn expressed in ppm, varied from 118.4-282.3, 32.3-92.4, 1.0-3.8 and 14.6-28.4. The concentration of different nutrients in leaf showed a significant difference when separated at various levels, except Mg, Fe and Mn. The mean values of Fe, Mn, Cu, and Zn were observed as 201.3, 61.9, 2.3 and 22.0 with corresponding coefficient variation (%) of 18.2, 25.52, 33.16 and 19.72 respectively (Table 4). These results are similar to those of Srivastava and Singh, (2004a, 2004b, 2004c 2005).

Thus, the results give an insight about the order in which, different nutrients are preferred by specific citrus cultivar, and ratio in which different nutrients are removed. Such nutrient removal patterns are to be meted out in order to maintain the sustained supply of nutrients through soil.

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Effect of GA_3 and SA on growth and yield of limonium var. Misty Blue

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ABSTRACT

The experiment was conducted to find out the effect of GA_3 and SA on growth and yield of Limonium var. Misty Blue at Greenhouse Complex, Navsari Agricultural University, Navsari, during September 2014 to May 2015. The results indicate that application of salicylic acid (SA) @ 150 mg/lite recorded significantly higher plant height (20.95 cm), minimum days to flowering (84.07) with maximum inflorescence length (172.90 cm), whereas application of gibberellic acid (GA_3) @ 200 mg/lite recorded significantly maximum number of shoots/plant (1.80), flowering duration (16.60 days), weight of inflorescence/plant (79.24 g), number of inflorescences/plant (5.93) and vase-life (6.13 days).

Key Words: Plant growth regulators, Salicylic acid, Gibberellic acid yield, Inflorescence, Shoots.

Limonium (statice) belonging to family Plumbaginaceae, originated from eastern mediterrranean region. Perennial statices have unique branches of very high value which are essential for bouquets, corsages and other flower arrangements.

The use of fertilizers and plant growth regulators (PGRs) in limonium enhances yield and improve quality by modifying and forcing the plant growth and development. Among PGRs, GA_3 stimulates both cell division, cell elongation and ultimately it is helpful in increasing growth of plants. Different concentrations of salicylic acid delays senescence, affecting rate of photosynthesis and physiology of stomata as well as it enhances vase-life when used in post-harvest treatment. The use of growth regulators in horticultural crops has brought about a sort of revolution in floriculture industry. But there is scanty information on limonium, therefore different plant growth regulators were tried to find out their effect on limonium under polyhouse in south Gujarat agroclimatic conditions.

MATERIALS AND METHODS

The experiment was conducted to find out the effect of plant growth regulators on growth and yield of limonium var. Misty Blue, during 2014-15 at Green House Complex, Department of Floriculture and Landscape Architecture, ASPEE College of Horticulture and Forestry, Navsari Agricultural University, Navsari. The experiment was laid out in a randomized block design with three replications under naturally ventilated polyhouse. Plants were planted on 60 cm wide raised bed in 2 lines with planting distance of 30 cm × 30 cm. Eleven treatments consisted of various levels of plant growth regulators, *viz.*, GA_3 @ 50, 100, 200, 300, 400, 500 and 600 mg/l, SA @ 50, 100 and 150 mg/lite and the control (water spray).

Different plant growth enhancers were sprayed 40 days after planting. The crop was irrigated through drip system by employing two laterals of 2 lph dripper per bed at a spacing of 30 cm running along the length of the bed. Misting was carried out by overhead 4 way foggers in summer months to bring the temperature and humidity at optimum level. The data were recorded on vegetative and flowering parameters. Five plants were selected randomly from each treatment for recording the data and statistically analyzed as per the method of Panse and Sukhatme (1967).

RESULTS AND DISCUSSION

Application of salicylic acid (SA) and gibberellic acid (GA_3) significantly enhanced vegetative growth of

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limonium (Table 1). Spraying of salicylic acid @ 150 mg/lite recorded highest plant height without panicle (20.95 cm), while application of GA_3 produced maximum number of shoots/plant (1.80). The effect of GA_3 and SA on plant spread and leaf area was non-significant.

It is possible due to application of SA which is responsible for regulation of cell enlargement and division in synergy with other substances such as auxin, The IAA and phenolic which cause stimulatory effect to increase plant height and plant spread. Misra *et al.* (1993) reported that pre-harvest treatment of SA in tuberose at the concentration of 100 mg/l significantly increased plant height and vegetative growth. These results are in also agreement with those of Swaroop *et al.* (2007) in African marigold, Sable *et al.* (2015), Aier *et al.* (2015), Rahmania *et al.* (2015) and Patel *et al.* (2013) in gladiolus and Dalal *et al.* (2009) in gerbera.

The increase in number of shoots/plant as a result of application of gibbrelic acid might be due to that GA_3 induced active cell division and cell elongation (Misra *et al.*, 1993). Growth might also be increased due to osmotic uptake of water and nutrients under the influence of GA_3, which maintains swelling force against softening of cell wall, thereby increasing plant height (Lockhart, 1960). These results are also in agreement to those of Umrao *et al.* (2008) in gladiolus, Dhaduk *et al.* (2007) in anthurium, and Tyagi and Singh (2006) in African marigold.

There was a significant increase in flowering parameters with application of both plant growth regulators (GA_3 and SA) compared to the control which affected all the floral and yield characters of limonium var. Misty Blue (Table 2).

Table 1. Effect of GA_3 and SA on vegetative characters of limonium var. Misty Blue

Treatment	Plant height (cm)	Plant spread (cm)	Number of shoots/plant	Leaf area (cm^2)
T_1 : SA 50 mg/l	17.65	27.43	1.07	68.87
T_2 : SA 100 mg/l	19.15	27.58	1.13	68.87
T_3 : SA 150 mg/l	20.95	28.19	1.67	68.63
T_4 : GA_3 50 mg/l	18.64	27.98	1.47	69.67
T_5 : GA_3 100 mg/l	19.48	27.86	1.73	69.40
T_6 : GA_3 200 mg/l	20.89	27.90	1.80	70.17
T_7 : GA_3 300 mg/l	18.54	27.67	1.73	69.40
T_8 : GA_3 400 mg/l	18.46	27.79	1.60	68.53
T_9 : GA_3 500 mg/l	18.11	27.61	1.53	67.83
T_{10} : GA_3 600 mg/l	17.53	26.64	1.47	66.63
T_{11} : Control	17.11	26.57	1.27	67.53
CD (5%)	2.42	NS	0.17	NS

Table 2. Effect of GA_3 and SA on flowering characters of limonium var. Misty Blue

Treatment	Days to flowering	Flowering duration (days)	Inflorescence length (cm)	Weight of inflorescence (g)	Inflorescence /plant	Vase-life (days)
T_1: SA 50 mg/l	89.07	15.47	167.27	49.21	4.53	5.33
T_2 : SA 100 mg/l	87.63	15.50	170.20	52.55	4.73	5.73
T_3 : SA 150 mg/l	84.07	16.27	172.90	76.07	5.73	5.93
T_4 : GA_3 50 mg/l	88.27	15.53	161.20	64.91	4.60	5.73
T_5 : GA_3 100 mg/l	86.67	15.77	163.53	71.39	5.87	5.93
T_6 : GA_3 200 mg/l	84.00	16.60	170.30	79.24	5.93	6.13
T_7 : GA_3 300 mg/l	85.67	16.10	166.67	74.44	5.53	6.07
T_8 : GA_3 400 mg/l	86.87	15.87	162.70	70.50	5.27	5.80
T_9 : GA_3 500 mg/l	88.27	15.80	162.00	64.90	5.20	5.80
T_{10} : GA_3 600 mg/l	89.20	15.37	161.70	63.17	4.80	5.80
T_{11} : Control	89.73	14.13	162.53	48.82	4.60	5.53
CD (5%)	3.81	0.88	6.21	7.92	0.67	0.28

The minimum days to flowering (84.07) with maximum inflorescence length (172.90 cm) were noted in plants treated with @ 150 mg/l, while significantly maximum flowering duration (16.60 days), weight of inflorescence/plant (79.24 g), number of inflorescence per plant (5.93) and vase-life (6.13 days) were recorded with application of GA_3 @ 200 mg/l in limonium var. Misty Blue.

The increase in floral and yield parameters by application of GA_3 may be due to that GA_3 was quite effective in reducing juvenile period of plants because of its higher capacity of cell division and cell elongation which cause early maturity in plants (Lockhart, 1960). These results are also in consonance with those of Patil (2001) in gerbera *cv*. Sangria and Dahiya and Rana (2001) in chrysanthemum *cv*. Vasantika. Moreover, length of inflorescences increased because of growth-promoting effects of SA which could be related to changes in hormonal status or by improvement in photosynthesis, transpiration and stomatal conductance. Similar results were obtained by Rahmania *et al.* (2015) in gladiolus.

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Effect of sowing date and sulphur levels on growth and yield of garlic *(Allium sativum)*

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ABSTRACT

A field experiment was conducted to find out the suitable sowing date and optimum dose of sulphur to obtain quality yield of garlic (*Allium sativum* L.) at the SKN College of Agriculture, Jobner, during *rabi* season of 2014-15. Sixteen treatment combinations with four dates of sowing, *viz.* 10 October (D_1), 25 October (D_2), 10 November (D_3) and 25 November (D_4) and four levels of sulphur (control, 30, 60 and 90 kg/ ha) were taken. Sowing of garlic crop on 25 October along with application of sulphur @ 90 kg/ha significantly increased polar diameter of bulb, average weight of bulb and yield. It may be concluded that most suitable time for sowing of garlic crop is 25 October and a dose of 90 kg/ha sulphur as good for more yield and net returns under semi-arid region of Rajasthan.

Key Words: Sowing dates, Sulphur content, Bulb yield, Cloves, Polar diameter, Semi-arid

Garlic (*Allium sativum* L), a member of the Alliaceae family, is one of the most aromatic herbaceous annual spices. Besides nutritive value of garlic, it is included in Indian system of medicines in treatments of disease like chronic infection of stomach and intestine, dysentery, typhoid, cholera and diseased lungs, garlic is successfully used (Chopra *et al.*, 1958). India ranks second in area and third in production of garlic in the world. Its productivity is quite low, *i.e.* 5 tonnes/ha which is far less than that of China and Egypt. The poor situation of crop may be due to its unscientific cultivation and lesser care of growers to its nutritional management, especially due to deficiency of sulphur. The date of sowing and appropriate dose of sulphur are crucial factors that can decide establishment, growth and performance of garlic crop through changing morphological system, physiological functioning and time available to complete its life-cycle (Rahim and Fordham, 1988). Keeping in view, on experiment was conducted to find out the date of sowing and sulphur nutrition.

MATERIALS AND METHODS

A field experiment on garlic *cv*. G-282 was conducted during *rabi* season of 2014-15 at Horticulture farm, SKN College of Agriculture, Jobner, Jaipur. The experimental soil was loamy sand (entisol) with a pH of 8.2, ECe 1.35 dS/m, organic carbon 0.15%, available nitrogen 135 kg/ha, available phosphorus 16.25 kg/ha, available potassium 148.6 kg/ha and sulphur 8.40 mg/kg. The experiment comprised 16 treatment combinations with four dates of sowing, *viz.* 10 October (D_1), 25 October (D_2), 10 November (D_3) and 25 November (D_4) and four levels of sulphur, *viz*. the control (S_0), sulphur 30 kg/ha (S_{30}), sulphur 60 kg/ha (S_{60}) and sulphur 90 kg/ha (S_{90}). It was laid out in randomized block design with three replications. Sulphur was applied as a basal dose in its elemental form. Besides, recommended dose of NPK for garlic (120:40:100 kg/ha) was also applied. Full dose of phosphorus and potassium and half dose of nitrogen were applied as basal dose just before sowing and rest half dose of nitrogen was applied as topdressing.

Sowing was done manually as per the dates of sowing at a spacing of 15 cm × 10 cm maintaining a seed rate of 500 kg cloves/ha. Five plants were selected randomly from each plot for recording plant height, number of leaves/plant, chlorophyll content of leaves, fresh weight of leaves, neck thickness, bulb diameter, weight of bulb and bulb yield. The chlorophyll content of leaves was determined 50 days after sowing as per the method advocated by Arnon (1949).

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RESULTS AND DISCUSSION

The results clearly indicate that plant height, number of leaves / plant, chlorophyll content of leaves and fresh weight of leaves increased significantly when crop was sown on 25 October over rest of sowing dates (Table 1). These findings clearly indicated that 25 October sowing date played a significant role on enhancing growth of garlic. Improvement in plant growth attributes due to 25 October sowing date might be due to that too early and delayed sowing of crop adversely affected the growth by variation in maximum and minimum temperature. Further, favourable agroclimatic conditions prevailed with sowing on 25 October have improved the germination and seedling emergence than 10 October, 10 November and 25 November sowing. Hornok (1986) also observed that too high and low temperature at the time of emergence caused slow germination of garlic as well as poor growth of seedlings. These findings are in close confirmative with those of Jat (1995).

Further, sowing of crop on various date significantly increased the neck thickness, bulb diameter (polar), weight of bulb and bulb yield (Tables 1-3). The improvement in yield attributes and yield were observed maximum when crop sown on 25 October which might be due to favourable environmental condition prevailed during germination and initial growth. Although, early and delay in sowing adversely affected plant yield due to that plants are exposed to high as well as low temperature during the period of growth and development of plant and bulb. These findings are in close confirmative with the results of Baswana *et al.* (1989) and Faruq (2000).

The plant height, number of leaves / plant, chlorophyll content of leaves and neck thickness increased significantly up to application of sulphur @ 60 kg / ha. This is supported by the fact that sulphur deficiency prevents utilization of nitrogen and brings about accumulation of soluble nitrogen in leaves (Table 1). Thus, increasing level of sulphur in turn improved plant growth by meeting higher nutritional demand for plant growth. These results are also in close conformity with those of Hariyappa (2003), Dabhi and Patel (2004) and Jaggi (2005).

The results indicate that yield-attributing characters namely bulb diameter and bulb yield increased significantly with increasing level of sulphur fertilization up to 60 kg / ha (Tables 1-3). Although, highest values for these parameters were recorded with the application of highest dose (90 kg / ha) of sulphur being statistically at par with each other. Sulphur being an integral constituent of certain amino acids of which nitrogen is also essential constituent, might have helped in increasing net assimilation rate of nitrogen along with other nutrients. Thus, it might have resulted in increased yield attributes and yield. These results are also in close conformity with the findings of Harendra *et al.* (2005) and Verma *et al.* (2012).

The results shows that sowing dates of garlic crop along with different levels of sulphur increased yield significantly (Table 2-3). Maximum diameter, weight of bulb and yield were obtained when crop sown on 25 October and fed with 90 kg S / ha (D_2S_{90}). However, this

Table 1. Effect of sowing date and sulphur levels on plant height, number of leaves, total chlorophyll content, fresh weight of leaves and neck thickness of garlic

Treatment	Plant height (cm)	No. of leaves / plant	Total chlorophyll content (mg / g)	Fresh weight of leaves (g)	Neck thickness (cm)
Sowing dates					
10 October (D_1)	36.90	7.78	1.20	20.50	0.699
25 October (D_2)	36.95	8.85	1.24	21.88	0.775
10 November (D_3)	34.25	7.68	1.10	19.91	0.710
25 November (D_4)	31.55	6.05	0.87	18.39	0.680
SEm±	0.84	0.19	0.03	0.47	0.014
CD (P=0.05)	2.43	0.54	0.08	1.36	0.042
Sulphur levels					
Control (S0)	31.28	5.85	0.87	17.21	0.635
Sulphur 30 kg / ha (S_{30})	34.24	7.42	1.09	19.90	0.700
Sulphur 60 kg / ha (S_{60})	36.82	8.39	1.21	21.54	0.754
Sulphur 90 kg / ha (S_{90})	37.31	8.71	1.24	22.04	0.775
SEm±	0.84	0.19	0.03	0.47	0.014
CD (P=0.05)	2.43	0.54	0.08	1.36	0.042

Table 2. Effect of sowing date and sulphur levels on diameter and weight of bulb (after curing) of garlic

Treatment	Polar diameter (cm)					Weight of bulb after curing (g)				
Sowing dates →	10th Oct	25th Oct	10th Nov	25th Nov	Mean	10th Oct	25th Oct	10th Nov	25th Nov	Mean
Sulphur ↓	(D_1)	(D_2)	v (D_3)	v (D_4)		(D_1)	(D_2)	v (D_3)	v (D_4)	
Control (S_0)	2.56	3.12	2.10	1.56	2.33	18.52	23.77	17.63	13.99	18.48
Sulphur 30 kg/ha (S_{30})	3.80	4.64	3.12	2.33	3.47	26.79	34.38	25.50	20.25	26.73
Sulphur 60 kg/ha (S_{60})	4.55	5.56	3.74	2.78	4.16	31.07	39.88	29.58	23.48	31.00
Sulphur 90 kg/ha (S_{90})	4.72	5.76	3.88	2.89	4.31	32.23	41.37	30.69	24.36	32.16
Mean	3.91	4.77	3.21	2.39		27.15	34.85	25.85	20.52	
	SEm +			CD (P=0.05)		SEm +			CD (P=0.05)	
D	0.08			0.24		0.44			1.26	
S	0.08			0.24		0.44			1.26	
D × S	0.17			0.49		0.87			2.52	

Table 3. Effect of sowing date and sulphur levels on bulb yield and net returns of garlic crop

Treatment	Bulb yield (q/ha)					Net returns (₹/ha)				
Sowing dates →	10th Oct	25th Oct	10th Nov	25th Nov	Mean	10th Oct	25th Oct	10th Nov	25th Nov	Mean
Sulphur ↓	(D_1)	(D_2)	v (D_3)	v (D_4)		(D_1)	(D_2)	v (D_3)	v (D_4)	
Control (S_0)	110.47	153.33	105.71	96.19	116.43	118945	196093	110377	93241	129664
Sulphur 30 kg/ha (S_{30})	142.85	199.04	124.76	111.42	144.52	176479	277621	143917	119905	179481
Sulphur 60 kg/ha (S_{60})	162.85	226.66	142.85	126.66	164.76	211729	326587	175729	146587	215158
Sulphur 90 kg/ha (S_{90})	167.61	232.37	146.66	134.28	170.23	219547	336115	181837	159553	224263
Mean	145.95	202.85	130.00	117.14		181675	284104	152965	129822	
	SEm +			CD (P=0.05)		SEm +			CD (P=0.05)	
D	2.26			6.53		2709			7823	
S	2.26			6.53		2709			7823	
D × S	4.52			13.06		5417			15646	

combination was found statistically at par with treatment D_2S_{60} where crop sown on 25 October and fed with 60 kg S/ha. The combined effect of sowing dates and sulphur levels significantly increased yield attributes and yield which might be due to that appropriate sowing date along with optimum dose of sulphur helped to absorb most of the essential nutrients in proper amount and increased microbial population in rhizosphere, required by plants for better growth and development. Such favourable environment conditions were provided under 25 October sown crop.

The results are in close confirmative with Faruq (2000) and Harendra *et al.* (2005). The data also shows that net returns increased when crop sown on 25 October along with increasing level of sulphur up to 60 kg/ha (Table 3). These results can be directly correlated with corresponding increase in yield of garlic due to different sowing dates and sulphur as a direct effect on net returns (Jat, 1995). Thus, it can be concluded that sowing of garlic on 25 October along with application of sulphur @ 60 kg/ha (D_2S_{60}) under semi-arid region of Rajasthan was found better to harvest a good crop with yield of 142.85 q/ha and net returns of ₹ 1,75,729/ha.

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Exploring morphovariations in bael *(Aegle marmelos)*

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ABSTRACT

Bael (*Aegle marmelos* Correa), an indigenous tree having wide genetic diversity, is found growing in different parts except at high altitude and in cold region of the country. Most of the woody plants produce flowers and fruits on new growth or on young leafy shoots, but a few plants bear fruits on main stems, primary and secondary woody branches. This phenomenon is known as cauliflory. Such flowering and fruiting are also observed in bael germplasm established at field gene bank at CHES, Godhra. It has been noticed that bael produce flowering and fruiting on main stems and primary, secondary, tertiary, fourth and fifth branches, and even on previous and current season's growth of shoots. Simultaneously, it has also been also observed that fruits may appear on first, second, third, fourth, fifth, sixth, seventh and eighth year growing woody stems of bael tree under semi-arid conditions in western India. Therefore, bael is a culiflorous and ramiflorus tree, such type of flowering and fruiting are found in bael, but it is common in bael variety, Goma Yashi and NB-16. Vivipary is of unusual occurrence in bael. Generally, such fruits are not good in taste. If cut exposed, germinated seeds inside the fruits are visible very clearly. High humidity and warm weathers appear to be associated with viviparous fruits in bael. The pollen-grains of bael are found to exert a direct effect on size, shape and styler end cavity of fruits, seeds and speed of development of fruits and on time of ripening of fruits of asexually propagated bael plant. Such effect on fruits may be due to metaxenia effect in bael. Variations in number of petals and sepals, number of leaflets and thorns are also observed.

Key Words: Morphovariations, Culiflory, Flowering, Metaxenia, Vivipary, Ramiflorus

Bael (*Aegle marmelos* Correa), an important indigenous fruit of India, is known since ancient times. It is found growing in Nepal, Sri Lanka, Malesia Pakistan, Bangladesh, Myanmar, Thailand and most of the South-East Asian countries. Because of its status as sacred tree, it is also grown in north Malaya, dry area of Java and to a limited extent in northern Luzol of Philippines and gardens of Egypt, Surinam and Thailand. It is distributed throughout the country, but concentrated area under bael is in eastern parts of Gangetic plains and nearby areas, particularly in Uttar Pradesh, Bihar, Madhya Pradesh, Chhatisgarh and Jharkhand, and it can also be seen growing in West Bengal, Punjab and Odisha. In Gujarat, bael trees are found growing naturally in the forest with great diversity.

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Most of the genotypes available in forest areas of Gujarat having small-sized fruits, but plants growing in temple promise or in courtyard of house having big size fruits were brought by travelers, saints, pilgrims from north India (Singh *et al.*, 2014). In India, bael is being grown throughout the country and is also known by other vernacular names (John and Stevenson, 1979). Om Prakash (1961) found bael in Yajur Veda and also observed that in early Buddhist and Jain literature (C 800 B.C. - C 325 B.C.). In the 'Ramayana' period, bael fruit was known and its trees were reported to be growing in 'Chitrakuta' hills and 'Panchvati'.

In the 'Upavana Vinod' a Sanskrit treatise on silviculture (Majumdar, 1935) and in 'Brihat Samhita' mention had been made of bael fruit, and as the legend goes, in the forest, the Lord Rama performed religious rites by offering various fruits including bael (Aiyer, 1956). Bael fruit has been portrayed in painting of Ajanta Caves along with other fruits (Om Prakash, 1961).

MORTHOVARIATIONS IN BAEL

Cauliflory

Most woody flowering plants produce inflorescences on new growth and or young leafy shoots. A few, however, flower and fruit directly on their trunks or main branches. This phenomenon is known as cauliflory (from the latin words 'stem' and 'flower'), and plants themselves are considered cauliflorous. Many fruits are most interesting examples of cauliflory in fig *(F. auriculata)*, jackfruit *(Artocarpus heterophyllus)*, papaya *(Carica papaya)*, cacao *(Theobroma cacao) and* loquat *(Eriobotrya japonica)* grown in India commercially, whereas brazilian grape trees *(Plinia cauliflora)*, cannonball tree *(Couroupita guianensis)* growing in tropical forest (Armstrong, 1998).

In contrast, no instance of this phenomenon has ever been described in bael. At CHES, Godhra, 190 germplasm have been established in field repository which were characterized for various horticultural traits. The flowers and fruits appeared on trunk, primary, secondary tertiary, fourth, fifth and sixth branches, and first, second, third, fourth, fifth, sixth, seventh and eighth year growth of growing shoots (Fig. 1). Bael is an ideal cauliflorous example of fruit tree. Similar results have been reported by Ullah and Haque (2008) in jackfruit. Generally, cauliflorous blossoms are sturdy and well attached and can withstand in aberrant conditions. The adaptive significance of cauliflory is mainly associated with cross pollination.

Metaxenia

Metaxenia is the effect of pollen-grains on fruit shape and other fruit characters. Metaxenia may able to be used to identify best pollinizer parents to decrease fruit development period and increase yield in mixed cultivar planting. This direct effect of pollen-grains on parts of fruit lying outside the embryo and endosperm is called metaxenia. The simplest and most probable theory to explain metaxenia is that embryo or endosperm or both of them secrete hormones, or soluble substances analogous to them. Probably, no instance of this phenomenon has ever been described in bael earlier. The source of pollen exert a direct effect on size, shape and styler end cavity of fruits, seeds and speed of development, and on time of ripening of fruits (Fig. 3)

Fig. 1. Differen views of cauliflorous woody branches in bael

Fig. 2a. Fruit shape affected by pollen-grains (metaxenia) and b: original fruit shape

Fig. 3. Effect of pollen on fruit shape and time of ripening

of and quality of fruit of asexual propagated plant (Fig. 2a and b).

This direct effect of male parent on development of fruit is precise and definite and varies with a particular male to fecundate female flowers which diffuse out into tissues of mother plant that constitute seed and fruit, exerting a specific effect on these tissues varying according to a particular male parent used to fecundate embryo and endosperm (metaxenia). The effect of pollen source on fruit development has been reported in several species of different families, including date palm (Swingle, 1928), raspberry (Colbert and de Oliveria, 1990), blueberries (Gupton and Spiers, 1994), pomegranate (Purohit, 1987) and cherimoya (Khan *et al.*, 1994). However, effect of pollen source on sugar accumulation should be carefully examined since pollen source might affect taste qualities of fruit. These results are similar to those reported for dates, cherimoya, grapes and mandarins, in which the source of pollen had an effect on maternal tissue characteristics (Denney, 1992; Wallace and Lee, 1999).

Bael is a cross-pollinated crop. At the time of flowering (May-June), large number of honey bees; beetles, house flies, ants and different kinds of butterflies less in number arrive and start visiting the flowers for foraging purpose (6 AM to 1.0 PM), and they directly enter on central portion of flowers whether it is completely opened or just started to open due to which large number of pollens stick to their abdomen and legs (Fig. 4). Effective pollination occurred through honeybees followed by butterflies. Honeybees have been recognized as ultimate and legitimate pollinators in bael (Singh *et al.*, 2014).

Vivipary

In vivipary, germination of seed takes place inside the fruits while still attached to the mother plant. Viviary is noticed naturally in some species of mangrove like *Rhizophora mangle, R. Mucronata, Bruguiera gymnorhiza,*

Fig. 4. Pollinating agents in bael

Kandelia reedi, K. candel, Ceriops decandra (all belong to Rhizophoraceae) in which it is considered as an aid to adaptation in wet ecosystem where germinated seeds after falling in mud establish itself and grow as a plant (NHB, 2012). It is very often noticed in *Avicennia* sp (Verbenaceae); *Aegialitis rotundifolia* (Plumbaginaceae); *Aegiceras majus* (Myrsinaceae); *Cocos nucifera* (Arecaceae); *Cucumis melo, Sechium edule* (both Cucurbitaceae plants); *Oryza sativa, Triticum aestivum, Zea mays* (Graminae) *etc*. For most plant species, vivipary is considered undesirable. This holds especially true in cultivated types which are grown mainly for their edible fruits.

Bael fruits as usually remain free from viviparous seeds. Till now, no instance of this phenomenon has ever been described in bael. In contrary, while cutting the fruits for study, an unusual occurrence of vivipary was observed in one of the bael germplasm. The fruit was having a weight of 650 g, its pulp was yellow in colour and was slightly insipid in taste. The cavity formed in fruit pulp were full of amber or honey coloured viscous very sticky or glutinous (mucilage), translucent pulp, which is slightly sweet and feebly aromatic. As appeared physically, it was tree ripen fruits harvested from field gene bank at CHES, Godhra, during 2015. The seeds manifest light yellow coloured radical embedded in mucilage of locule cavity (Fig. 5. a, b and c). Vivipary is considered genetic mutation but its manifestation can be modified by the environment (Stoutmeyer, 1960). Increased precious germination has been reported in susceptible species during wet season (Allard, 1999). The genetics of viviparous mutant has been studied in corn and it has been reported to be associated with nine genes (Libby and Router, 1984). Reduced production or insensitivity of fruit to abscisic acid has also been marked as a feature of vivipary (Hartmann *et al.* 2002). High humidity might play inciting role in expression of vivipary in papaya (Singh, 2013).

Morphological diversity

All varieties of bael showed considerable morphological variation with respect to shape, margin, base and apex of leaf (Singh *et al.*, 2015). Leaves alternate, compound, trifoliate with one pair of shortly stalked opposite showing pulvinus leaflet, ovate or ovate lanceolate, crenate, acuminate and membranous, and midrib prominent beneath which is common in bael. It has also been observed that in place of thee leaflets (trifoliate), in very few leaves, 4-8 leaflets are also found rarely in bael plant emerged directly from root sucker of bael germplasm (Fig. 6). Quantification of total leaflet number is different in different leaves arose from root sucker of single plant of bael. Nicotra *et al.* (2011) reported that different leaf shapes can be found in association with variation in other leaf traits due to different climatic factors.

Fig. 6. Variations in leaf morphology

Variation in thorn

Bael tree armed with straight, sharp, axillary thorns, 2-5 cm long. Considerable variation in thorn, its number, size, shape is found in different in different genotypes (Fig. 7). In some of the genotypes, thorn is small and stout, whereas in few genotypes, three thorns can be

Fig. 5. Transverse section showing viviparous seed, b: vivipery in extracted seed and c. vivipary in individual seed

Fig. 7. Variation in thorn pattern in genotypes under dryland conditions

seen at a node. It can also be observed that the leaf convert into spine in pair in very few genotypes. Generally, two thorns at a node are common. Goma Yashi is thornless under rainfed dryland conditions of western India (Singh *et al.*, 2012). In some of the genotypes, thorn may be seen in primary branches, but not at secondary or tertiary branches under dry land condition. However, it may vary in different agro-climatic conditions (Nicotra *et al.*, 2011).

Variation in flower organs

Bisexual flowers are born in clusters and they are greenish white, axillary or terminal cymes. The calyx is shallow with 4 or 5 short sepals (tetramerous and pentamerous), broad teeth, pubescent outside. Petals are oblong oval, 4 or 5 are common (Fig. 9) and 6 or 7 rarely observed in flower (Fig. 8) and pale greenish white in colour. Stamens are numerous, hypogynous with short filaments. Flower bud emergence, flowering duration, time of anthesis, dehiscence of anther, stigma receptivity and pollen viability vary according to variety and locality (Singhal *et al.*, 2011 and Singh *et. al.* 2014 a and b). Size and shape of floral organs in terms of bud size, flower size, petal size *etc*. of the varieties evaluated at CHES, Godhra under rainfed condition of semi-arid ecosystem according to Singh *et. al.* (2016).

Fig. 8. Flower biology in bael

Fig. 9. Four and five petals are common in Goma Yashi variety of bael

CONCLUSION

Thus, it is concluded that bael is cauliflorous and ramiflorous fruit tree, which can bear fruits on any age of shoots. Quantum of flowering, fruit setting and retention varied based on age of woody shoots. Variation in fruit shape and other qualitative characters in fruits of the same mother plant were also observed owing to metaxenia effect. The fruits during ripening may manifest vivipary occasionally. Although, trifoliate leaf is common but 4 - 8 leaflets may also be seen in very few germplasm rarely. Morhpovariation in flower organ, thorn and leaf were also observed.

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Effect of planting dates on growth, flowering and multiplication of gladiolus *(Gladiolus grandiflorus)* cv. 'Solan Mangla'

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ABSTRACT

The experiment was conducted to find out the effect of planting dates on growth, flowering and multiplication of gladiolus *(Gladiolus grandiflorus* Andrews*)* cv. Solan Mangla at experimental farm of Department of Floriculture and Landscape Architecture, Dr Y. S. Parmar University of Horticulture and Forestry, Nauni, Solan, during 2015-16. The experiment was laid out in a randomized block design, comprising twelve planting dates starting from 13 February to 28 July 2015 at 15 days intervals. Among all the planting dates, earliest sprouting, slipping, bud break and flowering were observed for 28 July planting. Whereas, 13 February gave 100% sprouting, maximum number of florets (15.06), size of corms (3.99 cm), number of cormels/plant (97.40), weight of corms/plant (24.64 g) weight of cormels/plant (24.78 g) and 28 February planting were found to be at par with 13 February planting for all these parameters as well. Other than that, 28 February planting also recorded highest number of spikes (2.50), vase-life (7 days) and duration of flowering (39.33 days). However, maximum size of floret (10.33 cm) and heaviest spikes (89.03 g) were recorded for 30 March planting. This planting was also in accordance with 13 February and 14 April plantings for maximum number of florets (14.13) and spike length (93.54 cm). Hence, 13 February, 28 February and 30 March plantings were found to be the best for flower spike production. Moreover, 13 February also recorded best results for corms and cormel production in equivalence with 28 February planting for most of the corm and cormel parameters. However for marketable spikes, it is advisable to conduct staggered planting from during February-April.

Key Words: Flowering, Corm, Planting dates, Growth, Multiplication, Slipping, Bud break.

Gladiolus (*Gladiolus grandiflorus* Andrews), popularly known as Sword lily, is known for majestic spikes having florets of massive form, brilliant colours, varying sizes and excellent keeping quality. The flower has been rightly classified as winter season bulbous annual but in hills where temperature during winter times goes beyond or up to freezing point, it is grown in summer season. To satisfy consumer demands, it is important that gladiolus flower is available round the year. However, there is a huge gap in its supply and demand. Planting schedule vary because of differences in photoperiod, temperature, humidity and light intensity. Environmental factors have a quantitative as well as qualitative effect on flowering. Different planting schedule can supply gladiolus steadily to market as well as it adds to beauty of landscape longer. Its growth and yield depend on proper planting time. Therefore, an experiment was conducted to find out suitable planting dates to get quality spikes, flower regulation for the market.

MATERIALS AND METHODS

The experiment was conducted at the experimental farm of the Department of Floriculture and Landscape Architecture, Dr Y S Parmar University of Horticulture and Forestry, Nauni, Solan, Himachal Pradesh, during 2015-2016, located in hilly areas of the Western Himalayas at an altitude of 1276 m above mean sea-level. The uniformly-sized corms were procured from multiplication block of the department and treated thereafter in a solution of Dithane M-45 (0.2%) and Bavistin (0.1%) for 30 minutes. These were again dried properly in shade and stored in a room under prevailing climatic conditions till January 2015.

The corms were taken out of the storage room before first planting in February, checked properly to

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remove any decaying and infected corms and again treated with Dithane M-45 (0.2%) and Bavistin (0.1%) in a similar fashion. After this, shade-dried corms were stored in a cool chamber at 4°C till planting which was done at a fortnightly interval starting from 13 February to 14 May 2015, to prevent sprouting of corms before planting. For subsequent planting after 14 May 2015, January harvested corms were procured from multiplication block.

These were again given the same treatments as mentioned above. In April, corms treated with above mentioned fungicides and shade-dried were then transferred to a cool chamber at 4°C for storage and used at the time of planting, accordingly. Raised beds of 15 cm in height, 1 m in width and 1 m in length were prepared. While field preparation was carried out, well-rotten FYM @ 5 kg / m^2 was mixed thoroughly in soil. This was followed by application of recommended dose of fertilizers comprising 30 g nitrogen / m^2, 20 g each of phosphorus and potassium / m^2 in the form of urea, single superphosphate (SSP) and muriate of potash (MOP). Full dose of phosphorus and potassium and half of nitrogen was mixed in soil before planting. Remaining half dose was applied at the time of 6-leaf stage.

The spacing of corms was 30 cm × 10 cm, accommodating 30 corms / m^2. Irrigation, weeding, hoeing, staking, and disease and pest management with spraying of fungicides and insecticides, respectively were carried out on a regular basis.

RESULTS AND DISCUSSION

There was significant effect of different planting dates on various vegetative parameters. The corms planted on 28 July recorded minimum days to sprouting (14.30 days). In contrast, maximum days taken to sprouting was observed for 29 April planting (26.44 days), followed by 28 and 13 February planting dates (26.05 and 24.46 days, respectively). A delay in days taken to sprouting was observed in earlier planted corms due to prevalence of low temperature and vice versa for later planting dates. Ahmad *et al.* (2011) observed earlier sprouting (20.1 days) for April planting, whereas late sprouting (24 days) for February planting date. Similar results were reported by Arora and Sandhu (1987) and Hong *et al.* (1989).

There was a decrease in per cent sprouting of corms with delayed planting (Table 1). The 13 February, 28 February and 15 March planting dates recorded 100% sprouting, followed closely by 30 March (97.77%), 29 April (95.55%) and 14 April (89.99%) planting dates. On the contrary, 13 July (58.88%) and 28 June (61.10%) recorded least sprouting percentage. Earlier planting came into contact with favourable climate, whereas later plantings had to withstand high temperatures and heavy monsoon rains. Similar result was also reported by Hong *et al.* (1989) and Ahmad *et al.* (2011) who observed that delay in planting decreased the per cent sprouting of cormels.

The earliest slipping stage was observed during 28 July planting (67.46 days), whereas 28 February (95.14 days) planting accorded for longest time taken for plants to reach slipping stage (Table 1). The possible reason could be due to prevalence of higher temperature during

Table 1. Effect of different planting dates on vegetative parameters of gladiolus cv. 'Solan Mangla'

Planting date	Parameters						
	Days taken to sprouting	Sprouting (%)	Days taken slipping	Plant height (cm)	Spike length (cm)	Weight of spike (g)	No. of spikes / plant
13 February 2015	24.46	100.00 (10.05)	91.78	111.20	93.20	75.49	2.30
28 February 2015	26.05	100.00 (10.05)	95.14	104.61	84.91	69.89	2.50
15 March 2015	22.56	100.00 (10.05)	89.59	107.62	79.49	71.60	2.23
30 March 2015	21.25	97.77 (9.93)	83.43	109.76	93.54	89.03	1.97
14 April 2015	24.17	89.99 (9.53)	84.27	112.08	95.99	73.50	1.91
29 April 2015	26.44	95.55 (9.82)	81.40	98.30	80.28	73.21	1.66
14 May 2015	22.39	85.55 (9.29)	74.59	101.99	82.08	65.04	1.17
29 May 2015	22.60	79.99 (8.99)	69.49	91.73	76.53	65.46	1.20
13 June 2015	21.57	64.44 (8.08)	72.00	75.06	63.06	46.40	1.13
28 June 2015	21.73	61.10 (7.87)	72.26	65.52	52.80	45.46	1.00
13 July 2015	21.16	58.88 (7.73)	70.13	64.00	53.60	41.46	1.00
28 July 2015	14.30	68.88 (8.33)	67.46	66.66	55.93	41.73	1.06
CD	2.13	8.60 (0.52)	3.51	7.01	5.29	8.53	0.17
SE(m)	0.72	2.91 (0.17)	1.19	2.37	1.79	2.89	006

later planting dates and lower temperature during early planting dates. Similar results were reported by Sheikh and Jhon (2005) that corms planted on 1 March took longest time to reach slipping stage than 15 May planted corms. McCalla *et al.* (2011) reported increase in number of days to inflorescence formation in gladiolus under lower temperatures.

The tallest plants were recorded for 14 April planting (112.08 cm), followed closely by 13 February (111.20 cm), 15 March (109.76 cm) and 30 March (107.62 cm) planting dates. The 13 July planting date (64.00 cm) gave shortest plants (Table 1). The same result was reported by Vasanthakumar *et al.* (2015). The increase in plant height of gladiolus at slightly higher temperature is also reported by Gursan *et al.* (1990) and Adil *et al.* (2013). Exposure to favourable temperature and relative humidity allowed plants to produce more photosynthates and encourage growth.

The spike length was maximum (95.99 cm) from corms planted on 14 April. Minimum spike length was obtained in plants planted on 28 June (52.80 cm). The plant height and spike length were found to be complementary with each other. Plant height increased with increase in growth temperature levels as with higher temperature root activity increases which eventually led to an increase in nutrient absorption and enhanced growth. Davies *et al.* (2002) observed increase in spike length with increased temperature. Similar results were noticed by Sheikh and Jhon (2005).

Heaviest spikes were obtained from corms planted on 30 March (89.03 g) planting date (Table 1). Vasanthakumar *et al.* (2015) reported the same results. The increase in plant height of gladiolus at slightly higher temperature is also reported by Gursan *et al.* (1990) and Adil *et al.* (2013). Exposure to favourable temperature and relative humidity allowed plants to produce more photosynthates and encouraged growth. On the contrary, minimum weight (41.46 g) was observed when corms were planted on 13 July. Optimum availability of moisture and production of photosynthates might also have led to production of heavy spikes. Adil *et al.* (2013) also reported a positive correlation between temperature and fresh weight of spikes. The results are in line with those of Grassotii *et al.* (2003) who reported heavier cut stems of lily hybrids for March planting.

There were maximum number of spikes / plant obtained in plants planted on 28 February planting date (2.50). With delay in planting, there was a decline in number of spikes / plant. Minimum number of spikes / plant was recorded to be 1.00 which was obtained in plants planted on 13 July and 28 June planting dates. This decline could be due to lack of favourable conditions for vegetative growth. The earlier planted corms were exposed to cooler temperature which helped in delay of flowering and helped to attain more vegetative growth. Arora and Sandhu (1987) reported that prevalence of low temperature during growing period and reduction in respiration improved various floral characters. The greatest number of inflorescence stalks / corm in Sparaxis tricolor plants were observed in earliest date planting (Marcinek and Hetman, 2006).

There was earliest bud break in 73.80 days during 28 July planting. On other hand, bud break was found to be delayed during 28 February planting (104.61 days). The early planted corms being exposed to lower temperatures showed delayed flower initiation in plants, however warmer temperature promoted it. Prasanna *et al.* (2016) also witnessed earlier appearance of flower buds for *kharif* season (July planting) compared to winter season (October planting) in Asiatic lily hybrids. Shoub *et al.* (1971) also reported that initiation was slow at 2°C and 30°C but relatively faster at 20°C mild temperature.

Like days taken to bud break, minimum time taken (75.20 days) from planting to flowering was noticed for 28 July. Whereas maximum days taken to flowering in 106.40 days was observed for the corms planted on 28 February. Since later planting date were exposed to higher temperature, it resulted in early flowering. These results are in close conformity with those of Dod *et al.* (1989). Sheikh and Jhon (2005) also reported minimum days taken to flowering for 15 May planting (86.15 days) and maximum for 1 March (121.13 days). Banker and Mukhopadhyay (1980) and Khanna and Gill (1983) who attributed earliness in flowering to higher temperature.

Maximum size (10.33 cm) of floret was observed during 30 March planting date. There was minimum size of floret (7.00 cm) during 13 July planting date. Sheikh and Jhon (2005) also reported that 31 March planting gave maximum floret size (9.79 cm) for flower spikes of gladiolus. Marcinek and Hetman (2006) reported maximum diameter for 20 April planting and smallest diameter of flowers for May planted corms. With further delay in planting, the quality of flowers also deteriorated.

The data reveals maximum florets (15.06), for 13 February planted corms followed by 28 February (14.93), 15 March (14.20) and 30 March (14.13). A decline in number of florets was observed with delay in planting time with 28 July (6.00) planting representing minimum number of florets. The number of florets / spike is said to be a genetical character but however, it is somewhat influenced by environmental factors also, particularly temperature and light.

The present results are similar to those of Sheikh and Jhon (2005). Kadam *et al.* (2013) found maximum number of florets / spike in gladiolus under mild

temperature treatment of 20/18°C (day/night temperature). As the floral parameters in terms of spike length and number of florets are related with plant height, more number of florets could be obtained from plants which were taller and having longer spikes (Thakur *et al.* 2015).

Maximum vase-life (7.00 days), was obtained for flower spikes of 28 February planted crop, followed closely by 13 February (6.66 days), 15 March (6.33 days) and 30 March (6.33 days). The minimum vase-life of 3 days was obtained in flower spikes obtained from 28 July planting. The flower spikes obtained from February and March were of good quality compared to later plantings. Since number of florets was more, vase-life was also longer. Similar results were found by Vasanthakumar *et al.* (2015).

There was maximum duration of flowering for 28 February planting date (39.33 days) (Table 2). With a delay in planting the flowering duration shortened. Minimum duration (10.66 days) of flowering was observed for 13 June planting date. It was 100 per cent sprouting along with maximum number of spikes planted on 28 February. The flower spikes appeared gradually which eventually led to production of spikes in a steady manner and prolonged the flowering duration. Kadam *et al.* (2013) reported significant reduction in duration of flowering with increase in temperature.

There was maximum number (4.20) of corms/plant was noticed for corms planted on 30 March. Nevertheless, it was found to be at par with number of corms/plant observed on 13 February, 28 February and 29 April planting (3.66 for all planting dates). With delay in planting time number of corms/plant decreased gradually with minimum number of corms (1.33) obtained from 13 July planting. Khan *et al.* (2008) also recorded more number of bulbs during early planting than later planting for tulip grown under polyhouse conditions.

The largest size of corms was obtained from corms planted on 13 February (3.99 cm), followed by 28 February (3.97 cm) and 15 March (3.70 cm) planting. The smallest corms were obtained from 13 July planted corms (2.57 cm). Asif *et al.* (2001) also found biggest bulbs of tuberose in February. Ahmad *et al.* (2011) also reported maximum diameter of corms for February planting. Small corms produced by June and July planting witnessed early sprouting, early flowering, leading to early production of corms. The plants did not produce enough biomass as well.

The maximum number of cormels/plant was obtained from corms planted on 13 February (97.40), followed by 28 February (81.80) and 15 March (78.60) planting. On contrary, minimum number of cormels/plant was obtained in 13 July planted crop (6.06) (Table 3). Prevalence of favourable environmental conditions for vegetative growth ultimately lead to optimum production and assimilation of photosynthates. The February planted crops were exposed to higher temperature during corm and cormel production stage hence an increase in number of cormels/plant was observed. The results are in line with those of Laskar and Jana (1994).

Table 2. Effect of planting dates on flowering parameters of gladiolus cv. 'Solan Mangla'

Planting date	Parameters					
	Days taken to bud break	Days taken to flowering	Size of floret (cm)	No. of florets	Vase-life (days)	Duration of flowering (days)
13 February 2015	101.41	103.17	9.80	15.06	6.66	30.66
28 February 2015	104.61	106.40	9.48	14.93	7.00	39.33
15 March 2015	99.95	100.69	9.62	14.20	6.33	34.00
30 March 2015	91.57	94.53	10.33	14.13	6.33	29.33
14 April 2015	93.85	95.82	8.69	13.53	5.66	25.33
29 April 2015	91.28	93.34	8.11	12.73	6.00	21.33
14 May 2015	84.06	86.21	8.22	12.26	5.66	18.33
29 May 2015	78.83	80.66	8.28	11.93	5.66	14.66
13 June 2015	79.13	80.86	7.51	7.60	4.00	10.66
28 June 2015	79.60	81.20	7.22	6.73	3.66	15.00
13 July 2015	77.33	78.33	7.00	6.40	3.33	11.33
28 July 2015	73.80	75.20	7.01	6.00	3.00	11.66
CD	3.49	3.35	0.26	1.09	0.80	5.00
SE(m)	1.18	1.13	0.08	0.29	0.27	1.69

Table 3. Effect of different planting dates on corm and cormel production of gladiolus cv. 'Solan Mangla'

Planting date	Parameters					
	No. of corms/ plant	Size of corms (cm)	Total no. of cormels/ plant	Weight of corm(s) /plant (g)	Weight of cormels/ plant (g)	Time taken from from flowering to harvesting
13 February 2015	3.66	3.99	97.40	83.66	24.78	118.58
28 February 2015	3.66	3.97	81.80	80.03	20.72	116.39
15 March 2015	2.93	3.70	78.60	67.46	9.25	106.04
30 March 2015	4.20	3.40	58.20	66.85	13.04	108.42
14 April 2015	3.33	3.49	44.40	54.99	8.49	114.15
29 April 2015	3.66	3.29	43.33	53.46	9.21	101.72
14 May 2015	3.33	3.25	30.86	54.01	8.46	103.93
29 May 2015	2.60	3.25	26.26	61.24	13.79	103.17
13 June 2015	1.53	2.82	7.00	15.59	5.14	101.86
28 June 2015	1.73	2.96	6.20	14.45	5.55	98.40
13 July 2015	1.33	2.57	6.06	12.27	4.97	106.66
28 July 2015	1.60	2.72	6.93	11.72	5.86	95.20
CD	0.63	0.35	25.56	12.17	6.71	3.49
SE(m)	0.21	0.12	8.66	4.12	2.27	1.18

Heaviest corms were obtained from 13 February planting (83.66 g), followed by 28 February (80. 03 g). However, minimum weight of corm(s)/plant was observed in corms planted on 28 July (11.72 g). This complements the corm size parameter where largest corms were also accounted for February planted corms. Less weight of corm(s) in late planting might be due to rise in temperature, leading to early maturation and early senescence and less production and accumulation of photosynthates and lighter corms. Ahmad *et al.* (2011) also reported heaviest corm(s) for February planting.

The maximum weight of cormels was observed in 13 February planted crop (24.78 g), followed by 28 February (20.72 g) and 15 March (19.23 g). Minimum weight of cormels was obtained from 13 July planting (4.97 g).

The minimum days were recorded when corms were planted on 28 July (95.20 days) (Table 3). While maximum days for harvesting of corms from flower harvesting were recorded for 13 February planting (118.58 days). The fluctuation of environmental conditions from February to July is reason for variation in duration of crop. The early planted corms sprouted late; hence they flowered late and came into full maturity late as well. Moreover, biomass production was more for February planted crop which led to gradual senescence.

Thus, it is concluded that out of 12 planting dates, 13 February, 28 February and 30 March were best for flower spike production. Moreover, 13 February was best for corm and cormel production in equivalence with 28 February planting for most of the corm and cormel parameters. Despite fact that quality of flower spikes was not uniform for all planting dates. Nevertheless, flower regulation was possible from May to October. However for marketable spikes, it is advisable to conduct staggered planting from February to April under Solan conditions.

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