STANDARDIZATION OF PRODUCTION TECHNOLOGY FOR AFRICAN MARIGOLD (*Tagetes erecta* L.)

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(2017-22-002)

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by

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THESIS

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KERALA, INDIA

2020

DECLARATION

I Jeevan U. (2017-22-002), hereby declare that this thesis entitled **"Standardization of production technology for African marigold (*Tagetes erecta* L.)"** is a bonafide record of research work done by me during the course of research and the thesis has not previously formed the basis for the award to me of any degree, diploma, associateship, fellowship or other similar title, of any other University or Society.

Vellanikkara

Date: 25/8/2020

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CERTIFICATE

Certified that this thesis entitled "**Standardization of production technology for African marigold (*Tagetes erecta* L.)**" is a record of research work done independently by **Mr. Jeevan U. (2017-22-002)** under my guidance and supervision and that it has not been previously formed the basis for the award of any degree, diploma, fellowship or associateship to him.

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We, the undersigned members of the advisory committee of **Mr. Jeevan U.**, a candidate for the degree of **Doctor of Philosophy in Horticulture**, with major field in **Floriculture and Landscaping**, agree that this thesis entitled **"Standardization of production technology for African marigold (*Tagetes erecta* L.)"** may be submitted by **Mr. Jeevan U.** (2017-22-002) in partial fulfillment of the requirement for the degree.

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LIST OF ABBREVIATIONS

cfu	: Colony forming unit
kg/ha	: Kilogram per hectare
DAT	: Days after transplanting
TTZ	: 2, 3, 5- Triphenyl Tetrazolium Chloride
NaOCl	: Sodium hypochlorite
rpm	: Rotation per minute
nBLAST	: Nucleotide basic local alignment searching tool
Epan	: Evaporation from the pan
RDF	: Recommended dose of fertilizers
WSF	: Water soluble fertilizers
SF	: Straight fertilizers
13:0:45	: Potassium nitrate
N	: Nitrogen
P	: Phosphorus
K	: Potassium
CCC	: Cholorocholine chloride
PBZ	: Paclobutrazol
ETHREL	: Ethepon
GA_3	: Gibberellic acid
NAA	: 1-Naphthaleneacetic acid
BA	: Benzyl adenine
mg/L	: Milligram per liter
SEM	: Scanning electron microscope
CPG	: Casamino acid–peptone–glucose
A_{300}	: Absorbance at 300 nanometer
PLW	: Physiological loss in weight
PDI	: Per cent diseases incidence
PSG	: Percent survival of grafts
WUE	: Water use efficiency

Introduction

1. INTRODUCTION

Marigold (*Tagetes* spp. L.) is a versatile crop belonging to the family Asteraceae. The genus *Tagetes* consists of nearly 55 species (Turner and Nesom, 1993). The generic name of marigold is derived from the word "*tages* – the god of wisdom". Marigold, indigenous to Mexico, was introduced to India by the Portuguese during the 16^{th} century.

Marigold occupies two-third of total loose flower growing area in India and ranks first in production. This flower crop has multiple uses as loose flower, as garden plant and also in industries like pharmaceutical, cosmetics, textile and production of poultry feed. The diuretic, antispasmodic, anti-inflammatory, anti-haemorrhagic, diaphoretic, anthelmintic and carminative properties (Abad *et al*., 1999) of marigold are being utilised in pharmaceutical industries. The rich lutein content add to its pharmaceutical value (Hojnik *et al*., 2008). *Tagetes* spp. due to the presence of alpha-tertheinyl compound in the roots are known for repellent activity against root knot nematodes (Somasundaram, 2017).

Major and traditional marigold growing tracts are in West Bengal, Karnataka, Andhra Pradesh, Maharashtra, and Tamil Nadu. Recently, cultivation of this crop is gaining popularity for festival seasons in Kerala. Farmers doing cultivation of marigold are preferring F_1 hybrids as these are having high yield with good quality flowers. However, bacterial wilt, which is very difficult to manage has become a major threat for successful marigold cultivation in Kerala. The farmers are looking for a high yielding genotype with good quality flowers for pursuing the cultivation of this crop. Screening hybrids/varieties having high yield with bacterial wilt resistance is an important researchable aspect that needs urgent attention. Hence studies were initiated by Kerala Agricultural University and in a previous study (Umesh, 2017) conducted with eight genotypes of African marigold suggested further studies to evaluate more genotypes for high yield and bacterial wilt resistance.

Grafting on wilt resistant rootstocks has emerged as the best technology to control mainly soil-borne pathogens like bacteria. In solanaceous crops, complete control of bacterial wilt through grafting has been reported (Narayankutty *et al*., 2015).

Cleft grafting four week old scion onto six week old rootstock (M-1) has been standardized as the best method in African marigold by Baburaj *et al.* (2019). The study was conducted using the already proven wilt resistant rootstock (M-1) in marigold. Evaluation of better rootstocks for grafting African marigold and studies on genotypical responses to grafting are needed to popularise marigold grafts in wilt prone regions.

African marigold can be cultivated in Kerala throughout the year due to its free flowering nature and short duration. However, the conventional system of farming is very labour consuming to maintain the crop in a healthy condition. Moreover, when grown during winter and summer, the crop requires additional resources like irrigation water and consequent manpower for irrigation. Water and nutrient management are the two essential factors directly influencing the crop yield. Nitrogen, phosphorus and potassium are basic macronutrients, which are essential to complete the normal lifecycle of the plant system. Nitrogen is part of amino acid that is needed for protein synthesis in plants, whereas phosphorous has a predominant role in energy transfer for structural integrity of plants. Potassium is required essentially for more than 40 enzymes as a cofactor active in plant metabolism (Ali *et al*., 2016).

Precision farming is the best choice for commercial cultivation of any crop, wherever irrigation water is a limiting factor. Since over the decades, water is becoming one of the scarce natural resources, production technology through drip irrigation with fertigation is to be resorted. Precision farming also reduce the labour cost, for cultivation and maintenance which is very high in Kerala. Drip irrigation and fertigation not only save water but also improve growth and yield of crops. Studies conducted at Tamil Nadu Agricultural University by Jawaharlal *et al*. (2013) have revealed significantly improved vegetative growth, flower yield as well as xanthophyll content in African marigold flowers by the application of 75 per cent recommended dose of fertilizers along with humic acid 0.2 per cent through drip fertigation. However, precision farming technology needs location wise as well as season wise standardization. Being an annual crop, growth and flowering in marigold is influenced by growing season. Previous studies on impact of seasons in two marigold varieties *viz.*, Pusa Narangi Gainda and Pusa Basanti Gainda have reported increased growth parameters like plant height, number of primary branches, leaf area and total biomass

during rainy season (Prakash, 2015). However, the study was conducted in conventional cultivation system utilising two varieties. Studies on the seasonal response of F_1 hybrids and local collections of marigold is to be conducted to elucidate the influence of these genotypes during different seasons.

Increased plant height for many marigold genotypes is a problem for growers as these are prone to lodging especially during the rainy season in Kerala. However, during winter and summer seasons, plant growth is very much restricted also. In this context, suitable plant growth regulators need to be administered for regulating the plant growth during different seasons. Previous study (Sunayana, 2017) on use of growth retardant has reported that spraying CCC @1000 ppm controlled plant growth during two seasons *viz.*, pre-monsoon and monsoon. However, there has not been an attempt to enhance the growth during winter season. Hence, a study on the effect of different growth regulators will be useful not only for regulating plant growth but also to understand its effect on flower production.

Keeping this in view, the present research program has been designed with the following objectives

- ✓ Performance evaluation of African marigold genotypes, to evaluate African marigold and other *Tagetes* spp. against bacterial wilt for use as rootstocks for African marigold
- ✓ To standardize precision farming techniques for African marigold
- ✓ To assess the performance of African marigold genotypes under precision farming during different seasons
- ✓ To study effect of growth regulators in African marigold

Review of Literature

2. REVIEW OF LITERATURE

Marigold is one of the easiest grown annual flowers and has wide adaptability to different soil and agro-climatic conditions. The plants with their attractive flower colour, bloom for a considerably long period and the flowers remain fresh for quite a long time after plucking from the plant. All these factors have made marigold as one of the most popular annual flowers in India, for garden display as well as for commercial cultivation.

The present research entitled "Standardization of production technology for African marigold (*Tagetes erecta* L.)" was conducted in the Department of Floriculture and Landscaping, College of Horticulture, Vellanikkara, Thrissur during the year 2018 to 2020. The research programme was conducted under five experiments *viz*.,

2.1. Field evaluation of African marigold genotypes and other *Tagetes* spp. against bacterial wilt

2.2. Artificial screening against bacterial wilt resistance

2.3. Evaluation of rootstocks for *Tagetes erecta* L.

2.4. Precision farming techniques and seasonal response

2.5. Effect of growth regulators on plant growth and yield in *Tagetes erecta* L.

With respect to above mentioned experiments relevant reviews have been collected and given briefly in this chapter.

2.1. Evaluation of African marigold genotypes and other *Tagetes* spp. against bacterial wilt

2.1.1. Bacterial wilt in horticulture crops

Bacterial wilt is a devastating disease which is very difficult to manage in humid tropics. Cultivation of F_1 hybrids encounters heavy crop losses due to bacterial wilt incidence in Kerala. Considering the importance of this disease, the present investigation was undertaken with the objective to evaluate marigold genotypes for high yield with resistance to bacterial wilt.

In African marigold genotypes the percentage of bacterial wilt disease incidence have been ranged from 2.76 - 62.23 per cent (Mondal *et al.*, 2011).

Twenty four strains of *Ralstonia solanacearum* belonging to races 1, 2 and 3 of biovars I, II and III, isolated from various hosts were investigated for their ability to cause disease on *Strelitzia* seedlings through artificial inoculation. Findings of the study revealed that, only the strains isolated from *Musa* or *Heliconia* (classified as race 2) caused wilt symptoms on *Strelitzia*, indicating their pathogenic potential to those plant species (Rodrigues *et al.*, 2011).

Mondal *et al*. (2014) observed an increased wilt incidence in marigold in West Bengal immediately after rainy period *i.e.* during pre-winter month of October. Nimisha (2016) opined that incidence of bacterial wilt is a major threat for successful cultivation of African marigold under Kerala conditions.

A study by Umesh *et al.* (2018) using five marigold F_1 hybrids, two varieties and one local collection for yield and bacterial wilt resistance under tropical humid conditions of Kerala, revealed the local collection 'M-1' as completely resistant to bacterial wilt but reported with low yield (0.234 kg/plant) and poor quality flowers, whereas F_1 hybrid 'Sakura 031' was found highly susceptible with 100 per cent wilt incidence.

Sakthivel *et al*. (2016) reported bacterial wilt as a major disease affecting marigold cultivation in Andaman Islands. Upon testing the cross infectivity of the pathogen isolated from marigold in three Solanaceous vegetables and marigold, it was observed that the highest wilt incidence occurred in marigold and tomato (100%) followed by brinjal (55.6%) and chilli (22.3%).

Brinjal crop was evaluated including sixteen cultivars as well as hybrids for bacterial wilt under Baster Plateau of Chhattisgarh. Among the genotypes evaluated, hybrids such as Haragold (18%) and Mukta Keshi (20%) recorded moderate resistance with low mortality (Bhanwar *et al*., 2019).

Enterobacter cloacae is a ubiquitous gram negative, facultative anaerobic, rod shaped bacterium belonging to the *Enterobacteriaceae* family. More recently, *E. cloacae* has been developing importance as a plant pathogen.

Occurrence of *E. cloacae* has been reported as an internal yellowing diseases of papaya (Nishijima *et al.*, 1987) as well as internal decay of onion (Bishop and Davis, 1990; Schroeder *et al*., 2009) and *Odontioda* orchids in Japan (Takahashi *et al.*, 1997). Moreover, *E. cloacae* and other species complex of same genus are reported as pathogenic in macadamia nut (Nishijima *et al.,* 2007), dragon fruit (Masyahit *et al*., 2009), mulberry (Wang *et al.,* 2010), seeds of lucerne (Zhang and Nan, 2013), cassava (Santana *et al.,* 2012),tomato (Sarkar and Chaudhuri, 2015), ginger (Cosmas *et al.,* 2016) and chilli pepper seedlings (Garcia- Gonzalez *et al.,* 2018) at Hawaii, Malaysia, China, Venezuela, Mexico, Malaysia and West Bengal respectively.

2.1.2 Infection and symptomology of bacterial wilt

The typical symptoms of diseases exhibited in tomato plants *viz.*, leaf wilt, browning of vascular tissues and collapsing of the entire plant system was reported by Sarkar and Chaudhuri (2015) in West Bengal. In ginger, the bacterial wilted plants showed the symptom of yellowing and wilting (Cosmas *et al.* 2016). Mulberry plants showed the infection of bacteria starting from the bottom of the plants and move upwards (Sarkar and Chaudhuri, 2016). The initial symptom appeared on the leaves first as lesions with irregular small spots, further this showed as brown necrosis at margin tips. At advanced stages the spots became necrotic with chlorotic hallow leads to defoliation and finally turned into wilting symptoms was observed by Garcia-Gonzalez *et al.* (2018) in chilli pepper seedlings.

2.1.3. Vegetative characters

The important vegetative parameters studied in marigold are plant height, plant spread, number of branches, stem girth and leaf area. Studies on evaluation of genotypes for their vegetative growth and its relation with yield parameters are reviewed here.

The significant variation among the African marigold genotypes for growth traits under Marathwada condition was documented by Narsude *et al.* (2010). The maximum plant height (114.64 cm) and stem girth (5.37 cm) were recorded in the genotype 'Pakharsangavi L'. The genotype Tuljapur L-2 and Tuljapur L-1 were recorded for maximum plant spread (64.48 cm) and number of branches per plant (21.46), respectively.

Evaluation of forty four genotypes of marigold including twenty nine genotypes of *Tagetes erecta* (TEG-1 to TEG-29), thirteen types of *Tagetes patula* (TPG-1 to TPG-13) and two species of *Tagetes minuta* (TMG-1 and TMG-2) by Singh and Singh (2010) revealed that the maximum plant height (226.87 cm) was recorded in genotype 'TMG-2'. The genotype TMG-1 was recorded with maximum stem diameter (1.93 cm) and the highest number of branches per plant (53.67) whereas, genotype TEG-21 (79.10 cm) followed by TEG-22 (70.30 cm) recounted for maximum plant spread. .

The height plant height (121.85 cm) was recorded in the genotype 'AMC-10' and the minimum plant height (58.75 cm) in 'Namdhari Cracker Jack Mix'. The genotype AMC-7 had recorded maximum stem girth (18.02 mm) and plant spread (5560.80 cm^2). Significant variation among twenty eight genotypes of African marigold was investigated by Ingle *et al.* (2011).

Significant variations among French marigold genotypes for vegetative parameters was observed by Raghuvanshi and Sharma (2011) under Mid–Hill Zone of Himachal Pradesh. Maximum plant height (35.80 cm) was recorded in cultivar 'Safari Queen' which was on par with cv. 'Harmony Boy' (34.90 cm). The highest plant spread (30.37 cm) was recorded in cv. 'Harmony Boy'. The Maximum number of branches (8.33) was noticed in cv. 'Nana Jumbo Bicolor'. Cultivar 'Bonanza Bolero' had maximum leaf area (34.58 cm^2).

Bharathi *et al.* (2014) evaluated twenty eight genotypes of African marigold for growth parameters. Significant and positive correlation was recorded for flower yield with plant height (0.64) and stem girth (0.60).

Investigations were carried out in twenty eight genotypes of African marigold genotypes and two species of French marigold for pursuance of growing under semi-

arid climatic conditions of Haryana (Choudhary *et al.* 2014). The genotype Hisar Jafri-2 exhibited best performance in terms of plant spread (77.72 cm) and number of secondary branches per plant (150.97). The maximum stem diameter (2.14 cm) and dry weight of the plant (130.72 g) observed in the genotype MGH-148-3-3.

In a study by Gowda *et al.* (2016) evaluated nine African marigold genotypes for growth and yield. The best performing genotypes recorded maximum plant height (77.26 cm), number of branches (14.08) and number of leaves per plant (285.49) in 'Local African Tall'.

Manik and Sharma (2016) studied fifteen genotypes of African marigold for growth, yield and quality parameters. Genotypes differed significantly for growth characters. At 30 and 60 DAT, the maximum plant height was recorded in cultivar CGSG-1 whereas at 90 DAT for cv. CGJS-1. The maximum plant spared and primary branches per plant were in genotype CGSG-1. The number of secondary branches at 60 and 90 DAT were maximum in genotype CGRJ-1.

Deepa *et al.* (2016) assessed twelve marigold hybrids for growth and yield under Northern dry conditions of Dharwad, Karnataka. Hybrid 'Sarpan-33' exhibited the maximum plant height (84.90 cm), number of leaves per plant (416.80), secondary branches (45.40) and plant spread (47.50 cm) at 90 DAT.

Nimisha (2016) evaluated eight African marigold genotypes under different growing conditions in two seasons *viz*., from July to November and January to April. During the season from July to November, vegetative parameters like plant height, internodal length and number of secondary branches were the greatest in Orange Giant while during January to April, the highest plant spread, stem girth, number of primary branches and leaf length were recorded in Local Yellow. It was also observed that the vegetative growth in terms of plant height, plant spread, number of primary branches were better in rain shelter compared to open cultivation during both the seasons.

Basheer (2017) collected and evaluated of thirty marigold genotypes for humid tropics in two seasons *viz.*, May and October months. Among the genotypes there were significant difference noticed for vegetative parameters. During May month planting,

T. erecta species recorded maximum plant height in genotype, TEG-5(158.16 cm) and which was on par with TEG-6 (153.50 cm). Maximum plant spread was recorded in October month planting in the genotype TEG-5 (81.33 cm), whereas plant spread in *T. patula* of TPG- 21(100.83 cm) was superior in May month planting. Maximum number of branches per plant was in TEG-6 (26.66) in October month.

Umesh (2017) evaluated eight African marigold genotypes under Kerala conditions and there were significant differences recorded for vegetative parameters. The maximum plant height (129.27 cm) was observed in cv. 'Royal Orange'. The plant spread (107.48 cm) and stem girth (8.52 cm) was superior in hybrid 'P-4'. The highest number of primary branches (15.54) was noticed in hybrid 'Rupa' whereas, maximum leaf area was observed in genotype M-1 (68.75 cm^2).

Performance of African marigold varieties for growth under Vidarbha condition of Maharashtra was evaluated by Patokar *et al.* (2018). The plant height (135.39 cm), number of branches per plant (19.73), leaf area (28.67 cm^2), plant spread E-W (44.63 cm) and plant spread N-S (45.69 cm) was recorded significantly greater in NAM-2 variety.

Evaluation of eight African marigold genotypes for vegetative traits under Southern Telangana condition was reported by Mahanthesh *et al.* (2018). Performance of the genotypes significantly varied for growth and other attributes. The maximum plant height (81.79 cm) was in 'Double Orange'. Plant spread (N-S) of 48.83 cm, plant spread (E-W) of 52.80 cm and number of secondary branches of 24.13 were recorded maximum in genotype 'Arka Agni'. The cultivar 'Erecta Naana Moon Light' had the highest stem girth (5.17 cm).

Suvija *et al.* (2019) assessed three African marigold hybrids in summer rice fallows of Wayanad condition of Kerala and they recorded the highest plant height (111.36 cm), plant spread (49.49 cm) and number of branches per plant (15.54) at 90 DAT in hybrid 'Garland Orange'.

Twenty genotypes of marigold was investigated by Giri *et al*. (2019). Among the genotypes, the maximum plant height (69.17 cm) was in 'African Selection 14'.

The highest plant spread (62.90 cm) was in ‘Farmer Selection-6’. Maximum stem diameter (1.86 cm) was recorded in ‘African Selection 11’. The number of primary branches (15.50) was high in ‘African Selection 4’ whereas, number of secondary branches (40.67) was maximum in ‘African Selection 10’.

2.1.4. Reproductive characters

Marigold is an annual plant exhibiting prolific vegetative growth during initial stages. It takes about 30-45 days to complete vegetative phase and at this stage of growth, flower bud emerges and the plant enters into reproductive stage. Vegetative growth of marigold plant before flowering is very important for better quality and productivity. An optimum vegetative growth leads to production of high quality flowers. Reproductive parameters consists of days to bud initiation, days to initiation of flower opening, days to complete flower opening , flower diameter, stalk length, flower weight, petal weight, number of flowers per plant, flower yield per plant and number of harvests.

In a study conducted by Raghuvanshi and Sharma (2011) on varietal evaluation of French marigold (*Tagetes patula* L.), it was observed a highly significant variation among varieties for the traits studied. Cultivar ‘Safari Queen’ recorded maximum flower yield per square meter (8.27 kg) while maximum flower diameter (5.26 cm) was observed in cv. ‘Bonanza Bolero’. Longest duration of flowering was recorded in cv. ‘Safari Tangerine’ (39.67 days).

Beniwal and Dahiya (2012) evaluated thirty eight genotypes of marigold and among them five genotypes of African marigold (MGH 133-1, 133-1-1, 160-8-2, 160-8 and 160-9-1) were promising for characters *viz*., number of flowers per plant (10- 64) flower size (5.0- 12.27 cm), fresh weight of flower (5.2-22.0 g), days to first flower (72- 138) and duration of flowering (18- 42 days). In case of French marigold, four genotypes (Hissar Beauty, Hissar Jaffri-2, MGH 17-1 and MGH 8-2) were superior for number of flowers per plant (20- 224), flower size (3.2- 6.1 cm), fresh weight of flower (2.0- 5.6 g), days to first flower (89- 121) and flowering duration (39-55 days).

Evaluation of twenty eight genotypes of African marigold (*Tagetes erecta* L.) for flower traits by Bharathi and Jawaharlal (2014) revealed the highest plant height in

Dharmapuri local (113.27 cm) and the highest number of primary and secondary branches per plant in Bidhan-1 (22.40 and 41.47 respectively). The earliest bud emergence was in 'Bangalore Local Tall' (29.47 days), but the earliest flower bud opening was observed in 'Double Orange' (46.00 days). Maximum flower yield per plant was recorded in 'Coimbatore Local Orange' (1.48 kg) followed by 'Coimbatore Local Yellow' (1.12 kg).

Choudhary *et al.* (2014) studied twenty eight genotypes of African marigold genotypes and two species of French marigold for pursuance of growing under Semi-arid climatic conditions of Haryana. The number of flower buds per plant (217.10), duration flowering (76.53 days) and flower yield per plot (20.99 kg) were recorded the maximum in genotype 'Hisar Jafri -2'. The greatest flower diameter (8.21 cm) was observed in MGH-09-276 while it was minimum in 'Hisar Jafri-2' (4.01 cm).

A study conducted by Gowda *et al.* (2016) using nine African marigold genotypes for growth and yield parameters, revealed that the genotype 'Local African Tall' had maximum flowering duration (98.50 days), flower yield per hectare (15.05 t), petal meal yield per hectare (15.15 q). The genotypes 'Indam Yellow' and 'Inca Orange' had registered the least number of days (17.46 days) for emergence of first flower bud and the least number of days taken for 50 per cent flowering was in genotype 'Indam Yellow' (57 days).

Deepa *et al.* (2016) evaluated twelve marigold (*Tagetes* spp.) hybrids under Dharwad condition. They observed that the hybrid 'Garland Orange' had the significantly maximum flower diameter (8.50 cm), fresh weight of flower (16.89 g) and flower yield per hectare (23.70 t).

Nimisha (2016) studied the performance of eight African marigold (*T. erecta* L.) cultivars with regards to various floral characters under open field and rain shelter condition. The parameters *viz*., days to 50 per cent flowering, number of flowers per plant, marketable flower yield and shelf life of flowers in all the cultivars were significantly influenced by different growing conditions whereas, flower length, pedicel length and seed yield per flower of the cultivars were not significantly

influenced by growing conditions. The greatest number of flowers per plant (76.83) was recorded in cultivar 'Local Orange' and marketable yield (665.02 g/plant) for 'Orange Giant' both under rain shelter condition.

Basheer (2017) collected and evaluated marigold genotypes for humid tropics in two seasons *viz.* May and October months. During May month planting, *Tagetes erecta* genotype, TEG 11 recorded the lowest number of days to flower initiation (49.00) and flower opening (68.33). The maximum number of flowers per plant and flower yield per plant were observed in TEG 16 in October planting. In May planting, TPG 18 followed by TEG 16 recorded the maximum number of flowers. The genotype TEG 16 also recorded the highest flower yield per plant in May planting. During both seasons, fresh weight of flower was higher for TEG 11.

Evaluation of eight African marigold genotypes by Umesh (2017) reported wide variation for floral characters as well as in yield. The genotypes P-4 and Rupa recorded largest flowers (9.08 cm and 9.06 cm, respectively). Fresh flower weight and petal yield per flower were very high for Rupa (23.36 g and 18.16 g) and P-4 (22.66 g and 16.56 g). The genotype P-4 recorded the maximum number of flowers (116.91) and yield per plant (1.034 kg).

Performance evaluation of African marigold varieties for growth under Vidarbha conditions of Maharashtra (Patokar *et al.,* 2018) revealed that the genotype 'Cracker Jack Mix' recorded minimum days (32.60) to first flower bud initiation. Days to opening of flower from bud emergence (14.60 days), days to 50 per cent flowering (50.67 days) were recorded minimum in 'African Double Orange'. The maximum blooming period (69.00 days) was recorded in 'African Giant Double' while flower yield per plant (642.15g) was the greatest in hybrid NAM-2.

Mahantesh *et al.* (2018) revealed reproductive characters in African marigold genotypes under Southern Telangana condition. The genotype 'Erecta Naana Moon Light' recorded the lowest number of days to first flower bud emergence (46.63 days) and maximum flower diameter (6.13 cm). Arka Bangara-2 was noticed for the earliest in first flower opening (48.40 days). However, the genotype Arka Agni recorded significant higher flower yield per plant (0.44 kg) in comparison with other genotypes.

Twenty genotypes of marigold were evaluated by Giri *et al*. (2019) and they recorded the maximum duration of flowering (78.33 days) in genotype 'Pusa Narangi Gainda' which had also the maximum number of fresh flowers per plant (67.85) and diameter of the flower (6.63 cm). The maximum fresh flower weight per flower (8.14 g) was recorded in 'Pusa Basanti Gainda'. Fresh flower yield per plant was the maximum in Pusa Narangi Gainda (488.40 g) which was followed by Pusa Basanti Gainda (481.47 g).

A study on the performance of three African marigold hybrids in summer rice fallows of Wayanad in Kerala by Suvija *et al*. (2019) revealed that among the three hybrids, 'Garland Orange' performed better under the humid tropical region of Wayanad followed by the yellow flowered hybrid, 'Inca Yellow'. Observations on flowering stage exhibited that the minimum number of days taken for 50 per cent of flowering (95.22 days) was observed in 'Maxima Yellow' which was on par with 'Garland Orange' (95.67 days). The yield parameter, such as number of flowers per plant was the highest in 'Maxima Yellow' (75.09) followed by 'Inca Yellow' (67.93). The highest individual flower weight of 6.20 g was reported in 'Garland Orange'. With respect to yield per plant, Garland Orange recorded the maximum yield of 298.7 g which was followed by 'Inca Yellow' (251.5 g).

2.1.5. Post harvest characters

Singh and Mishra (2008) assessed nine parents and 36 F_1 hybrids of marigold for shelf life and they reported that the cross between 'Sutton Yellow' x 'Cracker Jack' showed the maximum shelf life of 8.33 days under room temperature.

Narsude *et al.* (2010) evaluated ten African marigold genotypes during rainy season for vase life and observed the maximum vase life (8.87 days) in the genotype 'African Marigold Double Giant' which was significantly superior over rest of the genotypes. Shelf life was minimum in genotype 'Marigold Orange Bunch' (6.20 days). Under room temperature the genotype 'African Marigold Double Giant' exhibited the minimum physiological weight loss (29.80%) which maintained the freshness for two days and maximum physiological weight loss was in 'Akolner Local' (47.06%).

Raghuvanshi and Sharma (2011) reported that shelf life of 'Cupid Varie Orange' under ambient condition of Mid Hills Zone of Himachal Pradesh was 4.00 days whereas, under cold storage condition a shelf life 8.67 days was recorded.

Nimisha (2016) studied the shelf life of eight cultivars of African marigold (*Tagetes erecta* L.) in ambient room temperature grown under rain shelter and open condition in two seasons from July to November and January to April. During June to November, a shelf life of 4.57 days was observed in Sonata Orange while during the season from January to April, maximum shelf life of 3.17 days was observed in orange Giant. Under ambient conditions, rain shelter raised marigold cultivars 'Sonata Orange' and 'Sonata Yellow' recorded the maximum shelf life of 4.79 days compared to the same cultivars raised in open condition. .

Umesh (2017) studied the post-harvest life in eight African marigold genotypes and recorded significant difference among the genotypes. Minimum physiological loss in weight (PLW) was recorded in genotype Arka Bangara -2 (12.34%), while maximum PLW in Maria 91 (43.14%) which was followed by M-1 (33.73%) on fourth day at room temperature.

Maximum shelf life (4.07 days) was recorded in 'African Giant Double' which was significantly superior over all other cultivars except the genotype 'African Double Orange' (3.87 days) to which it was statistically at par as reported by Patokar *et al*. (2018).

2.1.6. Biochemical parameters

Marigold plants are rich in various biochemical compounds which facilitates a wider utility of flowers in industries like cosmetics, pharmaceuticals, dye and perfumery. Some bio active compounds also impart to resistance against various biotic and abiotic stress. The major parameters like carotenoids, flavonoids and essential oil in marigold genotypes are reviewed here.

Rao *et al.* (2005) recorded the highest carotenoid per gram fresh weight of flower petals in the var. Pusa Narangi Gainda (2.69 mg/g) followed by Orange Double (2.66 mg/g) while evaluating ten African marigold genotypes.

Raghuvanshi and Sharma (2011) carried out varietal evaluation in French marigold (*Tagetes patula* L.) and estimated maximum carotene content (3747.50 µg/g FW) in the cv. 'Honey comb' which was on par with cv. 'Hero Harmony' (3745.83 µg/g).

Manik and Sharma (2016) estimated fifteen African marigold (*T. erecta* L.) genotypes for xanthophyll content and reported the maximum xanthophyll content per kg petal meal in the genotype 'CGSG-1'.

Sunayana *et al*. (2018) evaluated two African marigold genotypes *viz*., Pusa Narangi Gainda and Maxima Yellow for their carotenoid content during different planting time. Between the genotypes, the carotenoid content in Maxima Yellow was the greatest (32.57 mg/1000g) when planted in the month of May, whereas in January planting, Pusa Narangi Gainda registered maximum carotenoids content (74.28 mg/1000g).

The cv. 'Pusa Narangi Gainda' recorded significantly higher carotenoids (100.53 mg/100g) and flavonoids (34.43 mg RE/g) under West Bengal condition (Lohar *et al.*, 2018). The minimum carotenoid content (56.07 mg/100g) and flavonoids content (24.67 mg RE/g) were noticed in cv. 'Cracker Jack'.

2.2. Artificial screening against bacterial wilt resistance

Main field evaluation in a bacterial wilt sick plot would not give a clear indication about the response of a genotype because either the inoculum in the field may not be sufficient enough to infest the plant or the genotype may get escaped. Artificial inoculation with the pathogen is needed for confirmation about disease resistance of genotypes.

Disease incidence through artificial inoculation methods depends on the concentration of the inoculum, age of the plants, congenial environment and where the plants are kept, and also the reaction of the host plant.

Root dip is a fast and frequently used method for artificial inoculation. Winstead and Kelman (1952) differentiated bacterial wilt resistant and susceptible varieties of

potato tubers by pouring the inoculum around the base of plant and cutting the roots by piercing a knife.

Rahman *et al*. (2011) studied the artificially inoculated pathogen for eight cultivars of brinjal *viz.*, Nayantara, Singhnath, Dhundul, Kazla, Marich Begun, Luffa-S, Kata Begun and Uttara for bacterial wilt incidence. Among the cultivars screened, Luffa-s exhibited the highest (80%) and Kata Begun exhibited the lowest (30%) bacterial wilt incidence at 55 DAT.

Artal *et al.* (2013) screened Solanaceous vegetables such as tomato, brinjal and chilli plants for bacterial wilt resistance using three artificial inoculation methods *viz*., soil drenching, leaf clipping and axial puncturing. Artificial inoculation through soil drenching recorded significantly higher bacterial wilt incidence in tomato, brinjal and chilli (98.0, 95.0, 90.0%, respectively) followed by inoculation through axil puncturing which recorded 78.0, 88.0 and 78.0 per cent wilt incidence, respectively. However, the lowest wilt incidence of 74.0, 48.0 and 40.0 per cent was recorded in tomato, brinjal and chilli, respectively in leaf clipping method.

Thomas *et al.* (2015) conducted a study to screen the susceptible and resistant genotypes of tomato against *Ralstonia solanacearum*. A pure bacterial inoculum of 0.1 OD; 10^8 cfu ml^{-1} was used for inoculation. Five different inoculation methods such as seed-soaking in inoculum, seed-sowing followed by inoculum drenching, or at two week stage through petiole-excision inoculation, soaking of planting medium with inoculum either directly or after imparting seedling root-injury were used. The results revealed that seed-based inoculations or medium inoculum drenching at 2 weeks did not induce any symptoms in seedlings but petiole inoculation induced 90 to 100 per cent mortality in susceptible checks and 50 to 60 per cent mortality in normally resistant genotypes within 7 to 10 days after inoculation. Root-injury inoculation in two weeks old seedlings appeared to be the best for early and clear distinction of resistant lines.

A wild brinjal (*Solanum torvum*) was completely resistant to *R. solanacearum* in soil drench and petiole inoculation methods. *S. torvum* is used as a potential rootstock in grafting to combat bacterial wilt disease. However, this species was incompatible with cultivated brinjal for breeding programme (Ramesh *et al*., 2016).

Kim *et al.* (2016) evaluated 285 tomato accessions at seedlings stage for bacterial wilt incidence caused by *R. solanacearum* under greenhouse. Disease severity of tomato accessions was investigated from 7 to 14 days at an interval of 7 days after inoculation of *R. solanacearum.* They reported that 279 accessions were susceptible (70 to 90% wilt), two accessions were moderately resistant and only four accessions were highly resistant to bacterial wilt. Microscopic view of bacterial wilt resistant tomato stems infected with *R. solanacearum* revealed limited bacterial spread due to thickening of pith membrane and gum production.

Umesh (2017) compared different methods like media drenching, root dip and stem injection for artificial screening for bacterial wilt disease in African marigold genotypes. Significant difference was observed with respect to per cent incidence among the genotypes, but not with respect to the different inoculation methods. The genotype Sakura -031 recorded 100 per cent bacterial wilt incidence followed by 'Arka Agni' (93.33%), 'P-4' (88.88%), 'Arka Bangara-2' (82.22%) and 'Maria 91' (71.11%) which were considered as highly susceptible genotypes. The genotype 'Royal Orange' showed a disease incidence of 44.44 per cent which was considered as susceptible while hybrid 'Rupa' was considered as moderately susceptible with the lowest PDI (22.22 %). The genotype 'M-1' did not show any wilt incidence and was considered as resistant to bacterial wilt.

Sadarunnisa *et al.* (2018) screened fifty varieties of eggplant in a polyhouse for resistance to bacterial wilt caused by *Ralstonia solanacearum* by artificial inoculation of bacterial suspension using both soil drenching and leaf axil puncturing methods. Among the fifty eggplant varieties, four varieties *viz*., Arka Keshav, Surya, Arka Neelkanth and Arka Nidhi showed resistance, while 17 accessions were susceptible and 29 accessions showed high susceptibility to bacterial wilt. Arka Shirish was used as susceptible check which exhibited 90.67 per cent wilt incidence.

Bhanwar *et al*. (2019) identified the resistance sources against bacterial wilt of few brinjal varieties and hybrids which were screened in artificially inoculated soil under pot culture. The variety 'Hara Gold Improved' (18.00%) and 'Mukta Keshi' (20.00%) recorded resistance with low mortality. Eight cultivars *viz.*, VNR-60, Sakya, Pusa Kranti, Green Round, Super White Long, Pusa Purle Cluster and Grafted brinjal

found moderately resistant (21-40%). Rest of the five varieties VNR-212, Navina, Mathy-112, White Gucchedar and Green Long (Pahuja) were recorded moderately susceptible (41-60%).

Kumbar (2019) observed per cent disease incidence in brinjal genotypes using the different inoculation methods, in which both, the genotypes and inoculation methods had showed significant difference for the bacterial wilt incidence. The genotype of *Solanum sisymbrifolium* recorded 73.33 per cent disease incidence and was classified as highly susceptible to bacterial wilt. The susceptible check Pusa Ruby exhibited 86.6 per cent disease incidence. Except the *Solanum sisymbrifolium* and Pusa Ruby, all other genotypes *viz*., Surya, Haritha, SM1, SM2, SM3, SM116, SM398, *Solanum torvum* KAU-1, *Solanum torvum*, TNAU-1 did not show any wilt incidence and hence these were considered as highly resistant to bacterial wilt in artificial inoculation.

2.3. Grafting on resistant rootstocks to combat bacterial wilt

Grafting desirable scion genotypes on wilt resistant rootstocks has facilitated successful cultivation of F_1 hybrids and varieties in various solanaceous and cucurbitaceous vegetables. Similar practices are also being attempted in marigold to combat bacterial wilt.

Complete control of bacterial wilt through grafting in solanaceous crops *viz.*, tomato, brinjal and chilli was reported by Narayanankutty *et al*. (2015).

Akhila and George (2018) studied on grafting in bitter gourd on various cucurbitaceous rootstocks. The bitter gourd scion var. Preethi was grafted on six rootstocks of ash gourd, bottle gourd, smooth gourd, pumpkin, oriental pickling melon and its own rootstocks by using two methods of wedge grafting (WG) and tongue approach grafting (TAG). There was significant difference in graft success among the rootstocks in WG. Best rootstock in terms of graft success was smooth gourd (80%) followed by pumpkin, bottle gourd, ash gourd, OP melon and own rootstocks of bitter gourd. WG (67%) was superior to TAG (15.17%) in terms of final graft success. Graft success had significant positive correlation with relative humidity and significant negative correlation with maximum and minimum temperature.

Umesh (2017) had identified a wilt resistant genotype (M-1) in African marigold and reported that grafting of susceptible genotypes on this resistant rootstock was found to be an effective tool for controlling bacterial wilt. Highly significant differences were observed among genotypes with respect to per cent survival of grafts in the field. Maximum survival of grafts was observed in 'P-4' (94.44 %) followed by 'Arka Agni' and 'Arka Bangara-2' (each with 88.88%), 'Maria-91' (83.33%). Minimum field survival of grafts was observed in 'Sakura-031' (61.11%) followed by 'Rupa' (66.66%) and 'Royal Orange' (72.22%).

Tamilselvi and Pugalendhi (2017) studied the graft compatibility in bitter gourd with cucurbitaceous rootstocks and grafting success was maximum at 45 DAG in Palee (F_1 scion) with pumpkin (*Cucurbita moschata*) of 71.70 per cent. Graft incompatibility with other rootstocks was mainly due to presence of necrotic layer at the graft interface.

Baburaj (2018) standardized the grafting method in African marigold using the local type of marigold genotype 'M-1' as rootstock which was resistant to bacterial wilt. The F_1 hybrid 'Maria-91' was used as a scion which was susceptible to bacterial wilt. Cleft grafting of four week old scion onto six week old rootstock showed maximum survival per cent (61.00%) which was on par with five week old scion onto six week old root stock (56.00%).

2.4. Precision farming techniques and seasonal response

Current commercial flower production mainly depends on utilization of F_1 hybrids, and marigold is no exception. Commercial cultivation will be successful only if flowers could be supplied throughout the year to the markets. Cultivation during winter and summer seasons require judicious use of all inputs including water. Precision farming is the best choice for commercial cultivation of any crop where all inputs could be applied judiciously.

2.4.1. Effect of fertigation and irrigation on growth and yield in African marigold

Jawaharlal *et al.* (2013) investigated the precision farming of African marigold with conventional farming system and revealed that application of 75 per cent RDF along with humic acid 0.2 per cent achieved the superior plant height (19.71 cm) and

dry matter production (62.42 g) at 60 DAT. The same dosage of fertigation also increased the number of flowers (60.26) with individual flower weight (17.36g) and more flower yield per plant (1.02 kg). The fertigation also enhanced the xanthophyll content (1.81 g/kg) in the fresh marigold flowers.

Siddapur *et al*. (2014) studied the response of marigold to different irrigation levels for plant height, number of flowers per plant, number of branches, flower weight and diameter of flower and these parameters showed significantly superiority to the treatment of irrigation at 80 per cent ET followed by 100 per cent ET level under Raichur condition of Karnataka. The highest yield of marigold flowers (19.63 t/ha) and benefit cost ratio (2.52) was recorded in 80 per cent ET level which was followed by 100 per cent ET level (17.03 t/ha).

In an experiment conducted to study the effect of fertigation on growth and flowering in cv. Pusa Narangi Gainda, Divya *et al*. (2017) found significant difference for plant height (81.57 cm) and number of primary branches (6.18), but there was no significant difference for characters *viz*., plant spread and stem girth. With respect to flowering characters, the minimum days to bud initiation (29.12 days), more number of flowers per plant (23.50) and greater flower yield (23.37 kg/plot) were recorded by applying 75 per cent RDF in form of WSF through fertigation. At this dosage of fertigation they also obtained maximum benefit cost ratio of 2.10.

Babu *et al.* (2018) studied the effect of irrigation at 1.0 ER and recorded significantly greater plant height (47.98 cm), primary branches (7.73), plant spread (81.17 cm), dry matter production (58.87 g), duration of flowering (77.74 days), flower diameter (5.57 cm), shelf life (3.56 days), individual flower weight (10.47 g), flower yield per plant (748.54 g). But lower irrigation of 0.8 ER recorded more number of flowers per plant (84.83). Influence of fertigation at 100 per cent RDF in combination with polyethylene mulching recorded the greatest plant height (51.10 cm), primary branches (8.05), plant spread (89.54 cm), stem girth (10.07 cm), dry matter production (66.21 g), earlier flower bud initiation (35.05 days), duration of flowering (77.73 days), flower diameter (5.75 cm), shelf life (4.08 days), single flower weight (11.04 g) and flower yield per plant (771.25 g).

Sumangala *et al.* (2018) investigated to see the influence of fertigation, irrigation and mulching in rainy season and revealed maximum uptake of nitrogen (279.19 kg/ha), phosphorous (79.30 kg/ha), potassium (396.48 kg/ha), iron (3.83 kg/ha), manganese (0.74 kg/ha), zinc (0.62 kg/ha), and copper (0.31 kg/ha) in irrigation at 1.0 ER along with 100 per cent RDF through fertigation in combination with polyethylene mulching.

Divya *et al*. (2018) studied the soil biochemical status before and after the crop in marigold cv. Pusa Narangi Gainda at different levels of fertigation. During first flower bud stage the N, P.K content in the leaf sample varied significantly with levels of fertigation. The highest N (3.82%), P (0.26%), and K (1.37%) content in leaf was recorded in 75 per cent RDF using WSF. They also achieved maximum flower yield per hectare (14.42 t) at this level of fertigation.

Srinivas *et al*. (2018) investigated in the hybrid Inca-II marigold at different levels of fertigation and irrigation levels in Andhra Pradesh and they recorded maximum flower size (7.36 cm), flower yield (222.76 kg/plot), more number of flowers (44.13/plant) under 100 per cent RDF whereas, with respect to nutrient use efficiency, the highest nitrogen (143.16%), phosphorous (214.73%) and potassium (156.32%) use efficiency was obtained in 100 per cent RDF through fertigation with WSF.

Sinha *et al.* (2018) studied the suitability of mulching and effect of drip irrigation in African marigold in *rabi* season. The highest yield (15.12 t/ha) was recorded by application of 90 per cent ET_C met through drip under 27 µ BPM. They also noticed the maximum water use efficiency (6.67 q/ha/cm) and benefit cost ratio (2.19) for the mentioned treatment.

Narayan (2018) carried out an experiment in African marigold to know the effect of liquid feeding of NPK in marigold cv. 'Double Afrcian Yellow'. The results revealed that at two per cent liquid feeding of NPK significantly effective to get floriferous crop. Also, the same treatment enhanced plant height (55.25 cm), stem diameter (1.81 cm), plant spread (41.23 cm), primary branches (12.98), length of primary branches (40.14 cm), fresh canopy weight (432.02 g), full bloom duration

(115.25 days), flower size (13.81cm), number of flowers per plant (19.23) and flower yield per plant (57.20 g).

Snehitha *et al*. (2019) conducted the experiment in cv. Inca-II marigold in Andhra Pradesh to know the effect of WSF through drip irrigation. They observed the maximum flower size (7.4 cm), highest number of branches and flower yield in 100 per cent RDF through fertigation in African marigold.

Vashista *et al.* (2020) evaluated the drip irrigation and fertigation techniques consequently for two summer seasons of 2017 and 2018 in African marigold cv. Punjab Gainda No.1. Yield parameters such as number of flowers per plant (115.22 and 127.00 respectively for 2017 and 2018) and flower yield per plant (515.23 g and 557.79 g respectively for 2017 and 2018) were maximum in treatment combination I_3N_3 (1.0 ET_C with drip irrigation + fertigation with nitrogen at 100% RDF). Highest water use efficiency (10.04 q/ha-cm and 14.70 q/ha-cm) were recorded in 0.6 % ET_C + 100 per cent RDF for 2017 and 2018 years, respectively.

2.4.2. Effect of fertigation and irrigation on growth and yield in other flower crops

Talukdar *et al*. (2010) evaluated the fertigation doses in production of standard and spray chrysanthemum under polyhouse condition. Standard chrysanthemum had significantly higher plant height (53.33 cm), early flowering (81.66 days), maximum blooming period (39.66 days), maximum vase life (25.30 days), highest yield per 100 m^2 (198.36 g) at 75 per cent RDF. Maximum fertigation efficiency (52.95) was also recorded in the same treatment. Similarly, in case of spray chrysanthemum, the highest plant height (60.30 cm), maximum number of leaves (108.66), maximum diameter of flower (7.00 cm), maximum vase life (26.33 days), highest fresh weight (20.02 g), dry weight (0.34 g) and highest yield per 100 m^2 (87.86 kg) was recorded in 75 per cent fertigation which was significantly different over conventional method of cultivation.

Jainag *et al*. (2011) conducted different fertigation levels on growth and yield of bird of paradise (*Strelitzia reginae* Ait.). The study revealed that at higher fertigation level of 120 per cent RDF + 12 liters of water per day per plant was found significantly

superior for plant height (113.26 cm), leaf length (85.70 cm), number of leaves per plant (12.75), early emergence of inflorescence (24.66 days), early flower initiation (20 days), maximum number of inflorescence per plant per month (2.72) and maximum number of florets per inflorescence (4.33).

Deshmukh (2012) investigated various irrigation methods on growth, flowering and yield in tuberose var. 'Suvasini'. Among the irrigation methods, drip irrigation system proved to be the best and gave flower yield of 6.77 lakh spikes per ha with superior quality of flowers and recorded benefit cost ratio of 2.68.

Effect of different fertigation levels on growth and yield attributes in commercial cultivars of gerbera under polyhouse condition was studied by Salma *et al.* (2014). Among the cultivars, cv. Amelia was found significantly superior in terms of growth, yield and quality parameters. The maximum plant height (50.43cm), number of leaves per plant (24.12), leaf area (5334.72 cm^2), early bud emerging (9.67 days), longer stalk (60.33 cm), ray floret length (4.45 cm), flower diameter (10.48 cm) and flower yield (26.15 /m^2/month) were obtained in fertigation with 100% WSF and it was on par with 100% SF. The highest number of vase life (10.61 days) recorded in 100% WSF and it was on par with 80% and 100% SF.

Jeevan *et al*. (2016) reported highest plant height (48.11 cm), number of leaves per plant (38.26), SPAD value (64.50), spike length (44.10 cm), floret length (6.01cm), flower yield (7215 kg per ha) and weed control efficiency (97.58%) in mulched plots with black polythene in 'Hyderabad Single' variety of tuberose.

Tejaswini *et al.* (2018) studied the effect of fertigation levels on commercial varieties of Anthurium under shade net conditions. The greatest stalk length (68.20 cm), stalk diameter (7.60 mm), spathe length (18.33 cm), spathe width (12.61 cm), spadix angle (34.95^o), number of flowers per plant (8.75), per m^2 (61.25) and per hectare (4.90 lakh), first grade flowers (71.81%), cumulative water uptake (73.17 g), minimum cumulative transpiration loss (44.46 g), fresh weight (47.75 g) and vase life (27.0 days) were recorded in 125 per cent RDF through fertigation. Among the varieties, maximum stalk length (64.46 cm), stalk diameter (7.52 cm), spathe length (18.24 cm), grade I flowers (68.75%), cumulative water uptake (62.85 g), less cumulative transpiration loss

(60.18 g), fresh weight (49.08 g) and vase life (25.83 days) were recorded in cv. Xavia., whereas spathe width (12.12 cm), spadix angle (40.33o), number of flowers per plant (7.63), per m^2 (53.43) and per hectare (4.27 lakh) were observed in cv. Tropical.

2.4.3. Seasonal response of African marigold

Jawaharlal *et al.* (2013) compared the precision farming of African marigold with conventional farming system in two seasons of March-May and June-September under Coimbatore conditions, Tamil Nadu. The application of 75 per cent RDF and along with humic acid 0.2 per cent in first and second season increased the plant height (19.71 and 19.75 cm) and dry matter production (62.42 and 61.42 g) at 60 DAT. At the same fertigation dose, the maximum number of flowers (60.26 and 62.29) with individual flower weight (17.36 g and 16.47 g) and more flower yield per plant (1.02 kg and 1.05 kg) were also recorded. The estimated xanthophyll content (1.81 g/kg and 1.76 g/kg) was maximum with the precision farming of marigold.

Meena *et al*. (2015) conducted the experiment in different growing months for seed yield traits in cv. Pusa Narangi Gainda *viz.*, September, October and November months. Significant effect of treatments had noticed in September month by showing the maximum plant height (57.75 cm) and seed yield per plant (17.82 g), whereas, more number of branches (18.79) and high seed yield per plant (19.01 g) were recorded in the month of October.

Mohanty *et al*. (2015) conducted the field experiment by planting African marigold cv. 'Sirakole' in different months *viz.,* November, December, January and February under Bhubaneswar condition. November planting resulted in more plant spread, number of leaves, primary and secondary branches per plant. November planting was also found to be beneficial in improving floral characters like flower diameter (5.00 cm), number (843.55) and weight of flowers (5422.66 g) per plot.

Prakash (2015) studied the seasonal impact and effect of pinching on growth and flowering in two African marigold (*Tagetes erecta* L.). varieties *viz.,* 'Pusa Narangi Gainda' and 'Pusa Basanti Gainda.' The experiment was conducted in three seasons *viz.*, pre monsoon, monsoon and post monsoon with two levels of pinching (P_0 – no pinching and P_1- pinching at 30 DAT). The results revealed that the September

sown crop was showing early flowering. There was no influence of season and pinching on flower diameter, length of flower stalk and flower weight. However, the maximum number of flowers and flower yield was observed in January sown crop in both the varieties with pinching. The results concluded that among the two varieties, 'Pusa Basanti Gainda' was suitable for cultivation in pre-monsoon season and 'Pusa Narangi Gainda' found suitable for monsoon cultivation.

Sunayana *et al*. (2017) planted two African marigold genotypes *viz*., Pusa Narangi Gainda and Maxima Yellow in two growing seasons like May and January months. May planting recorded maximum number of flowers (32.26 and 46.50), flower yield per pant (177.87 g and 603.74 g) in both the genotypes. However, maximum carotenoids content in genotype Maxima Yellow (32.57 mg/1000g) was noticed for May planting while in Pusa Narangi Gainda, maximum carotenoids content (74.28 mg/1000g) was noticed for January planting.

Anitha *et al.* (2018) investigated on nutrient uptake in African marigold cv. Sirakole in three different season's *viz., kharif, rabi* and summer. Nitrogen, phosphorous and potassium uptake was the highest in the plants supplied with 25 per cent organic and 75 per cent inorganic fertilizer along with bio-fertilizers in *rabi* season. The study revealed that the integrated nutrient management exhibited the highest nutrient uptake in *rabi* season under Orissa condition.

Jyothi *et al.* (2018) evaluated four different planting times *viz*., second fortnight of September, first fortnight of October, second fortnight of October and first fortnight of November in the var. 'Arka Agni' under Telangana condition. Among the different planting times, second fortnight of October was the best time of planting that recorded the maximum number of flowers (55.1/plant) and flower yield (440.88 g/plant).

2.5. Effect of growth regulators on plant growth and yield in *Tagetes erecta* L.

In humid tropics with high rainfall, increased plant height of many genotypes especially commercial hybrids is a major problem for growers as these are prone to lodging during heavy rainfall. But during winter and summer seasons, plant growth is very much restricted also. Hence, a study on the effect of different growth regulators will be useful as it will not only regulate plant growth but also improve flower

production. Studies on impact of suitable growth regulators for their vegetative growth and its relation with yield parameters are reviewed here.

Swaroop *et al*. (2007) studied the influence of different growth regulators on vegetative growth and flower characters of African marigold cv. 'Pusa Narangi Gainda' during early winter. The results revealed that application of GA_3 at 300 ppm had recorded maximum plant height (89.50 cm), number of branches per plant (8.75), number of flowers per plant (23.75), fresh weight of flower (6.92 g) and yield per plant (433.00 g). Similar results with respect to GA_3 at 300 ppm in cv. Pusa Narangi Gainda have been reported by Gopichand *et al*., 2014 and in cv. Lemon yellow (Arti *et al.,* 2019)

Effect of GA_3 and NAA on growth and flowering in French marigold was studied by Pandey and Hemchandra (2008). Among the different treatments, GA_3 450 ppm significantly increased plant height, number of branches, diameter of main stem, and number of flowers and total yield of flowers as compared to other treatments.

Ramadevaputra *et al*. (2009) reported that spraying GA_3 at 300 ppm in cv. Pusa Narangi Gainda showed maximum plant height at first flower initiation and full bloom stage (57.37 and 63.83 cm, respectively), plant spread at flower initiation and full bloom stage (49.66 and 53.95 cm^2, respectively), fresh weight of plant (375.85 g), maximum flower diameter (6.39 cm) and vase life (7.46 days) while maximum number of branches per plant (13.62) and flowering span (64.17 days) was observed in treatment with 200 ppm GA_3 in African marigold. Similar results were reported by Mithileshkumar *et al*. (2015) and Mishra (2017).

Dani *et al.* (2010) studied the treatment effect of plant growth retardants *viz*. CCC 750 ppm and PBZ 50 ppm on 30 days old African marigold (*Tagetes erecta* L.) cv. 'Double Orange' seedlings. The number of branches per plant and plant spread were recorded maximum under plants sprayed with CCC at 750 ppm. Naidu *et al.* (2014) reported significantly enhanced flower yield (26.23 t/ha) in var. 'Pusa Narangi Gainda by spraying CCC @750 ppm.

Amitkumar *et al*. (2012) reported maximum plant height (43.78 cm and 66.96 cm in 45 and 90 DAT, respectively), number of flowers per plant (28.15) and fresh

weight of flowers (12.45 g) by spraying GA_3 at 350 ppm in African marigold (*Tagetes erecta* L.) cv. Pusa Narangi Gainda. They also found that Cycocel at 2000 ppm was beneficial for increased flower yield and reduced vegetative growth without affecting initiation of flower bud and commencement of flowers.

Early flower bud initiation (48.00 days), opening of first flower and maximum duration of flowering (50.47 days), flower stalk length (8.95 cm), number of flowers per plant (60.33), and weight of flower (13.13 g) in African marigold var. Pusa Narangi Gainda was reported with the application of GA_3 300 ppm (Mishra, 2017).

CCC (1000 ppm) was found to be the best growth retardant in marigold as it influenced growth and flower parameters *viz*., plant height (46.87 cm), no. of branches per plant (5.78), plant spread (39.33), leaves per plant (679.13), days taken for first flower bud initiation (50.38), days taken for first flowering after transplanting (61.23), diameter of flower (5.94 cm) and flower stalk length (8.84 cm). The same treatment also showed maximum yield parameters *viz*., no. of flowers per plant (24.12), flower yield per plant (210.09 g), flower yield per ha (13.13 t/ha), fresh flower weight (12.67 g) as well as flower quality in *Tagetes erecta* L. cv. Pusa Basanti Gainda (Majeed *et al.,* 2017).

Sunayana (2017) conducted studies on effect of growth retardants *viz*., CCC at 1000, 1500 and 2000 ppm and Alar at 500, 1000 and 1500 ppm on two African marigold genotypes Pusa Narangi Gainda and Maxima Yellow sown during two seasons *viz.*, May and January. Number of flowers for May sown crop was the highest for Maxima Yellow treated with CCC 1000 ppm which was on par with Alar 1000 and 1500 ppm in the same genotype. The same treatments were showing significantly higher flower yield in Maxima Yellow sown during May. However for January sown crop, both number of flowers as well as yield did not show any variation among the treatments. For May sown crop, CCC 1000 and 1500 ppm recorded the highest but on par carotenoids content (53.13 and 49.36 mg/1000g respectively) in Pusa Narangi Gainda. For January sown crop also, the carotenoid content was the highest recorded for Pusa Narangi Gainda treated with CCC 2000 ppm which was on par with CCC 1500 ppm and Alar 1500 ppm.

Swathi and Reddy (2017) recorded the maximum plant height (50.71 cm and 74.57 cm), number of branches (15.59 and 19.45) at 60 and 90 DAT respectively, whereas, minimum number of days to first floret appearance (44.25 days), 50 per cent flowering (58.37 days), number of flowers per plant (72.81), flower weight (10.7 g) and flower yield per plant (524.6 g) were significantly greater by spraying GA_3 @ 150 ppm in African marigold cv. 'Siracole'.

Materials and Methods

3. MATERIALS AND METHODS

The present research entitled "Standardization of production technology for African Marigold (*Tagetes erecta* L.)" was conducted at the Department of Floriculture and landscaping, College of Horticulture, Vellanikkara, Thrissur during the year 2018 to 2020. The entire research programme was consisted of five major experiments *viz.*,

3.1. Field evaluation of African marigold genotypes and other *Tagetes* species against bacterial wilt

3.2. Artificial screening against bacterial wilt resistance

3.3. Evaluation of rootstocks for *Tagetes erecta* L.

3.4. Precision farming techniques and seasonal response

3.5. Effect of growth regulators on plant growth and yield in *Tagetes erecta* L.

3.1 Field evaluation of African marigold genotypes and other *Tagetes* species against bacterial wilt

3.1.1 Experiment site

The experiment site was situated at 76^{o} 10' E longitude and 10^{o} 32' N latitude at an altitude of 22.5 m above MSL. The bacterial wilt sick plots selected for field evaluation were installed with drip irrigation and fertigation facilities (Plate 1).

3.1.2 Treatments (Genotypes)

Thirty two marigold genotypes were collected for evaluation. Among the thirty two genotypes, there were eight F_1 hybrids, eight varieties, seven local collections of *T. erecta,* eight genotypes of *T. patula* (including three varieties and five local collections) and one genotype of *T. tenuifolia.* The details of the genotypes used for the study as well as the source of seeds/planting materials are given in Table 1 and Plate 2 (a,b and c).

Table 1. Marigold genotypes selected for field evaluation

Sl. No.	Species	Genotypes	Source
1	*Tagetes erecta*	Double Orange	Namdhari Seeds, Bengaluru
2		Double Yellow	Namdhari Seeds, Bengaluru
3		Pusa Narangi Gainda	ICAR-IARI, New Delhi
4		Pusa Basanti Gainda	ICAR-IARI, New Delhi
5		Suvarna Orange	Suvarna Hybrid seeds, Bengaluru
6		Suvarna Yellow	Suvarna Hybrid Seeds, Bengaluru
7		Arka Agni	ICAR-IIHR, Bengaluru
8		Arka Bangara 2	ICAR-IIHR, Bengaluru
9		Bhuvana	Keonics Seeds, Bengaluru
10		Hawaii Orange	Plantsman's Seeds, Punjab
11		Rupa	Sakura Seeds, Bengaluru
12		P-4	JYK-Seeds, China
13		Bhagwati	Kalash Seeds, Maharashtra
14		Royal Orange	Sagar Hybrid Seeds, Gujarat
15		Sakura 031	Sakura Seeds, Bengaluru
16		Maria 91	Sakura Seeds, Bengaluru
17		M-1	Local collection from Kerala
18		M-2	Local collection from Kerala
19		Dharmapuri Local	TNAU, Coimbatore
20		Coimbatore Local	TNAU, Coimbatore
21		Madikeri Local	Local collection from Karnataka
22		Nilakottai Local	TNAU, Coimbatore
23		TNAU marigold	TNAU Coimbatore
24	*Tagetes patula*	Hisar Jafri 2	CCHAU, Hissar
25		Pusa Arpita	ICAR-IARI, New Delhi
26		Red brocade	Suttons Seeds
27		TNAU Dwarf Marigold	TNAU, Coimbatore
28		KDA-2	Local collection from Karnataka
29		KDA-3	Local collection from Karnataka
30		KDA-4	Local collection from Karnataka
31		Chintamani Red	Local collection from Karnataka
32	*Tagetes tenuifolia*	Mexican Paprika	Red Gem Seeds

Plate 1. Field view of the experimental plot

Double Orange

Double Yellow

Pusa Narangi Gainda

Pusa Basanti Gainda

Suvarna Orange

Suvarna Yellow

Arka Agni

Arka Bangara-2

Bhuvana

Hawaii Orange

Plate 2a. Marigold (*T. erecta)* genotypes selected for evaluation

Rupa

P-4

Bhagwati

Royal Orange

Maria-91

Sakura-031

M-1

M-2

Dharampuri Local

Coimbatore Local

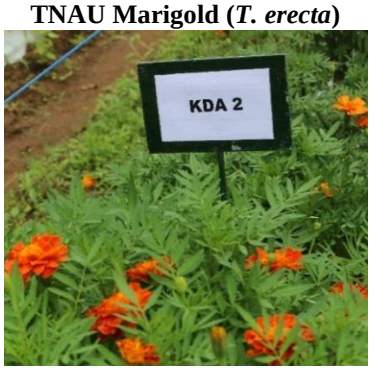
Madikeri Local

Nilakottai Local

Plate 2b. Marigold(*T. erecta)* genotypes selected for evaluation

TNAU Marigold (*T. erecta*)

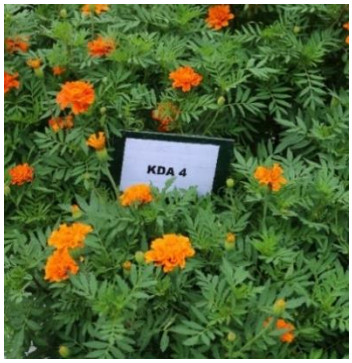
Tagetes tenuifoila



KDA-2

T. patula

KDA-3



KDA-4

Chintamani Red

TNAU Dwarf Marigold

Plate 2c. Marigold genotypes selected for evaluation

3.1.3 Field evaluation of marigold genotypes for bacterial wilt resistance

Evaluation for bacterial wilt resistance was carried out during two seasons *viz*. June-September (rainy) and October-January (winter) in 2018-19 while, morphological and yield observations were recorded only during June-September (rainy season). The experiment was laid out in randomized block design with 32 treatments with three replications. The plot size was 2m x 1m and spacing adopted was 0.5 m x 0.5 m.

3.1.4. Nursery practices

Seeds of the marigold genotypes (except Arka Agni and Arka Bangara-2) were sown in protrays filled with soilless media comprising of cocopeat, vermiculite, and perlite in the ratio of 3:1:1(v/v) and seedlings were given foliar nutrition weekly till these reached the transplanting stage. Rooted cuttings of Arka Agni and Arka Bangara-2 were procured from IIHR Bengaluru.

3.1.5. Preparation of the main field

The experiment plot was ploughed twice and beds of size 2.0 m x 1.0 m were prepared. The beds were mulched with 30µ silver black polythene film and holes were punched at a spacing of 0.5 m x 0.5 m and one-month-old seedlings were transplanted.

3.1.6. Application of manures and fertilizers

Fertilizer application was done as per the package of practice recommended for marigold (KAU PoP, 2016). FYM @ 20 t/ha was incorporated into the soil basally. Half a dose of N (112.5 kg/ha), the full dose of P_2O_5 (60 kg/ha) and half K_2O (30 kg/ha) was applied as a basal dose. The rest of the dose of N and K_2O was given through fertigation in 30 equal splits (twice in a week). Factomphos and Muriate of Potash (MOP) were used for supplying nutrients for the basal dose. Potassium nitrate (13:0:45) and urea were used for fertigation.

3.1.7. Intercultural operations

A single pinching was given at 20 DAT and plants were staked at 45 DAT. Weeding the interspaces of plots was done at regular intervals. Need-based plant protection measures were taken during the cropping period.

3.1.8. Harvesting

Fully opened flowers were harvested and observation were recorded.

3.1.9. Estimation of pathogen population before and during field evaluation

Bacterial load in the soil of the wilt sick plot was estimated using TTZ medium test at monthly intervals from June 2018 to November 2018 and the estimated bacterial load is given below.

Population of the pathogen in the experimental field during evaluation studies

Month	**cfu/ml**
Before field evaluation (June-2018)	:5.06 x 10^5
July -2018	:4.9 x 10^5
August -2018	:6.2 x 10^5
September -2018	:6.21 x 10^5
October -2018	:6.89 x 10^5
November -2018	:7.92 x 10^5

Daily inspection in the field was done to identify the wilt incidence and wilted plants were collected and confirmed by the ooze test. The bacteria were isolated on TTZ (2, 3, 5-Triphenyl Tetrazolium Chloride) medium and further ascertained by conducting Koch's postulates. The severity of the disease incidence in the genotypes was scored as per the scoring followed by Sinha *et al*. (1988), as furnished below.

Score chart for bacterial wilt incidence

Reaction	**Per cent disease incidence**
R (Resistant)	: < 10
MR (Moderately resistant)	: >10-20
MS (Moderately susceptible)	: >20- 30
S (Susceptible)	: >30 -70
HS (Highly susceptible)	:>70 -100

3.2. Screening against bacterial wilt through artificial inoculation

Twelve genotypes that were resistant and moderately resistant in field evaluation, were subjected to artificial screening studies by inoculating the pathogen by root dip method (Plate 3). The bacterial isolate collected from the infected marigold plants was used for inoculation. The bacterial suspension containing an inoculum load of 3.01 x 10^5 cfu/ ml was used for the study. The seedlings were raised in protrays in sterile soilless media (cocopeat + vermiculite + perlite in 3:1:1 ratio). One month old seedlings were transplanted to six-inch plastic pots filled with the same sterile soilless media as used for the nursery. Total number of treatments were 12 and experiment was laid out in CRD with three replications with five pots per genotype per replication. The pots were maintained in a mist chamber ensuring 70-80 per cent relative humidity. Percent disease incidence, as well as days to wilt, were observed.

3.2.1 Bacterial isolation, identification and molecular characterization

Marigold plant showing wilting symptoms in the field were collected from two different locations *viz*., Department of Floriculture and Landscaping and Centre for Excellence on Hi Tech Horticulture and Protected Cultivation, Vellanikkara. In the former location, the previous crop was marigold, whereas in the later location the previous crop was brinjal. The water streaming test was done for bacterial ooze to confirm the bacterial wilt (Plate 6). Surface sterilization of samples (stems) of collected plants was done by dipping in one per cent NaOCl for 8 minute, followed by several washings with sterilized distilled water. The stems were cut into small pieces and placed in petri plates containing TTZ agar and incubated for about 36 hour in the dark at 25-28°C. Colonies were then selected and assessed in fresh TTZ plates for purity. The appearance of colonies on the medium was recorded. This was followed by bacterial streaking of the isolated single colonies on casamino acid – peptone – glucose slants, since the growth of bacteria on selective media (TTZ), in order to reduce the pathogenicity.

The viscous mixture was then centrifuged at 10000 rpm for 10 minute at 3°C. To the clear supernatant, an equal volume of chloroform was added and shaken. After

centrifuging at 10000 rpm for 2 min, the upper layer was carefully collected into a fresh vial, and DNA was precipitated with 100 per cent ethanol. The pellet was washed twice with 70 per cent ethanol and air dried.

16S rDNA sequencing for molecular identification

The cultures of the two bacterial isolates collected from the two locations were taken for colony PCR analysis of 16S rDNA sequencing.

The ~1.5 kb PCR products of a subset of the bacterial isolates were sent to Rajiv Gandhi Centre for Biotechnology (RGCB), Thiruvananthapuram, Kerala, where they were sequenced using the Sanger sequencing method. Analyses of sequences for bacterial identification were performed using the basic sequence alignment nBLAST program run against the nucleotide database Gene Bank (http://www.ncbi.nlm.nih.gov/ blast). The sequences were submitted to the Gene Bank for obtaining accession numbers.

Phylogenetic analysis

Phylogenetic analysis of the 16S rDNA sequences of the two isolates of marigold sequences were performed. The sequences of the isolates were aligned with five each of *Ralstonia solanacearum* and *Enterobacter spp.* isolates retrieved from the NCBI database using Clustal W program available in the MEGA X software. The phylogenetic analysis of these aligned sequences was conducted using MEGA X software and the phylogenetic tree was constructed using Neighbor-joining method (Saitou and Nei, 1987).

Scanning electron microscopy

The bacterial cell morphology was observed using scanning electron microscope (Tescan Vega-3 LMU) at Central Instrumentation Laboratory, Kerala Veterinary and Animal Sciences University, Mannuthy. The protocol used was slightly modified from the protocol described by Anjali, 2019. Working distance of 5.05 mm giving magnifications of 11.2 kx respectively, yielded high resolution images of the bacterial cells and SEM micrographs were taken.

Plate 3. Field view of artificial inoculation studies

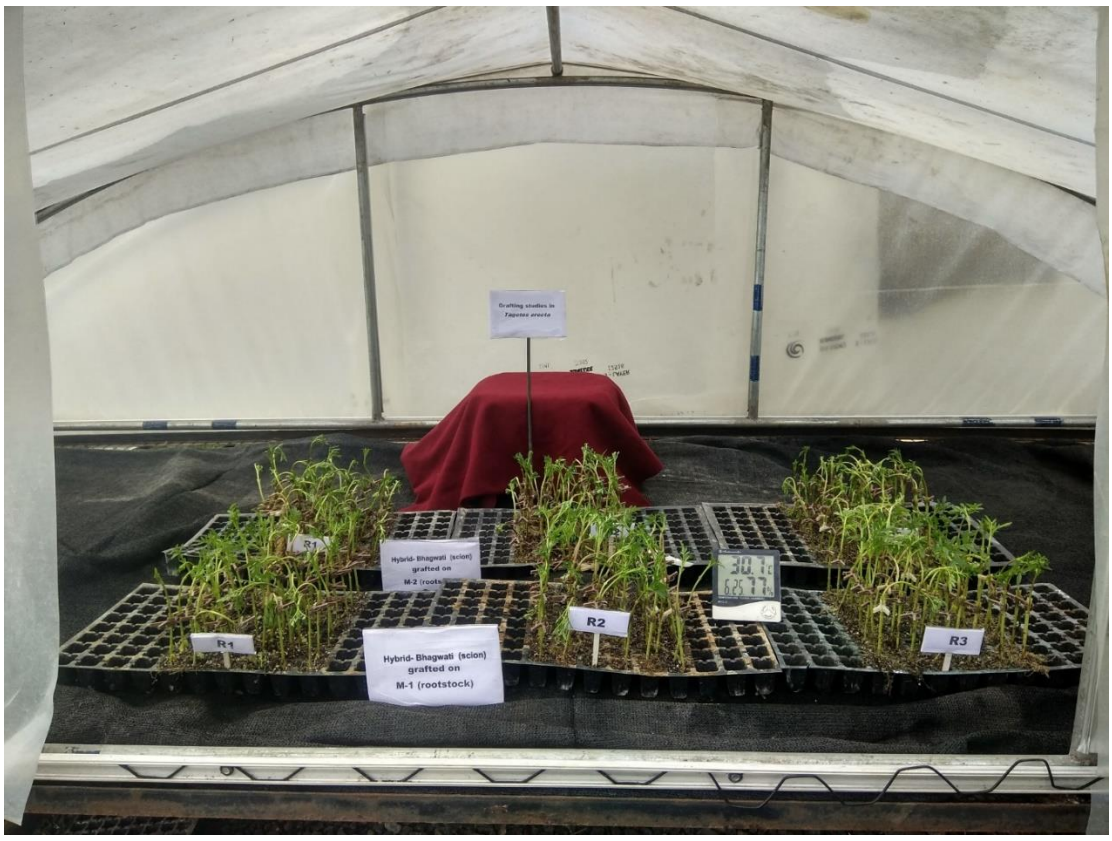


Plate 4. Field view of grafting studies

3.3 Evaluation of rootstocks for *Tagetes erecta* L.

Two genotypes *viz*., M-1 and M-2 that showed complete resistance to bacterial wilt during field evaluation as well as artificial screening studies were used as rootstocks for grafting. nine highly susceptible genotypes which included five Five hybrids (Suvarna orange, Suvarna yellow, Sakura 031, Maria 91, Bhagwati,) and four varieties (Pusa Narangi Gainda, Pusa Basanti Gainda, Double Orange and Double Yellow). Cleft grafting 35 days old scions on 45 days old rootstocks using grafting clips have been followed. Grafted plants were kept in mist chambers for the healing of graft union for 7 days and after they were taken out and acclimatized in a naturally ventilated greenhouse for 7 days before transplanting to pots. The design was FCRD with 18 treatments which were replicated thrice (Plate 4).

Histological studies

Histological studies were conducted to know the anatomy of rootstock and scions at grafting stage. Fresh cut sections were obtained using a sliding microtome of 10 µm. The sections were soaked in 1.0% (w/v) safranin in 25:75 (v/v) HCL-ethanol for 10-15 minutes and these were dehydrated by adding one per cent ethanol. In order to remove the excess stain, 0.2 per cent dimethyl benzene was added. After this, the stained specimens were embedded in paraffin wax and observed and photographed under the stereo binocular microscope under the magnification of 40x.

3.4. Standardization of precision farming techniques in African marigold

Two genotypes, one F_1 hybrid (Bhagwati) and one local collection (M-1) of African marigold were selected for precision farming experiments (Plate 5a). Seeds were sown in protrays filled with a potting mixture comprised of cocopeat, vermiculite, and perlite in the ratio of 3:1:1 and one-month-old seedlings were transplanted in the main field.

The experiment plot was provided with inline drip irrigation with a dripping capacity of 4lph with a facility for venturi mediated fertigation. All the drip irrigated plots were mulched with 30µ silver black polythene sheet. Plots with conventional irrigation and fertiliser application, without mulching were treated as control. A single

pinching was given at 20 DAT and plants were staked at 45 DAT. Weeding the interspaces of beds was done at regular intervals. Need-based plant protection measures were taken during the cropping period. Observations on plant, floral, biochemical and post-harvest parameters were recorded as per the technical programme.

The experiment was carried out in three seasons (Plate 5b) corresponding to summer (January to April 2019), rainy (June to September 2019) and winter (October 2019 to January 2020).

Before starting the experiment in each season, the actual discharge per emitter was measured for computing the duration of irrigation. Irrigation was given daily based on the pan evaporation, at two levels *viz*, I1 (75% Epan) and I2 (100% Epan) during winter and summer.

IIHR recommended dose of fertilizer (RDF) for precision farming in African marigold (90:90:75 NPK kg/ha) was followed for the experiment. Fertilizer dose was fixed based on the soil test data. Full P (based on soil test data) was applied as basal dose. Even though P was in excess as per the soil test data, 25% of the recommended dose was applied to ensure the availability of the nutrient. The source of P was Rajphos. Based on the soil test data, doses of N and K_2O were fixed for the different fertigation levels *viz*., 75%, 100% and 125% RDF. The sources of N and K were urea and potassium nitrate (13:0:45).

Fertigation was given at three days intervals as per the following schedule

1. Establishment stage (upto 21 DAT)	: 20% of N and K (6 doses)
2. Vegetative stage (21- 55 DAT)	: 40% of N and K (12 doses)
3. Flowering stage (55 DAT to completion of harvests)	: 40% of N and K (12 doses)

3.4.1. Precision farming experiment during rainy season

The experiment during rainy season was taken in the month of June to September and laid out in RBD with eight treatments that consisted of two genotypes (Bhagwati-Hybrid and M-1-Local collection) under three fertigation levels *viz.*,

Bhagwati (F_1 Hybrid)

M-1 (Local collection)

Plate 5a. African marigold genotypes selected for precision farming

Plate 5b. General view of precision farming of African marigold

F_1 –75% of RDF, F_2 –100% of RDF and F_3 –125% of RDF and two control treatments. The soil test data in the experimental plots before raising the crop which contained soil organic carbon 1.22 per cent, available phosphorous 196 kg/ha and available potassium 957 kg/ha. The plot size was 4 m x 1m and spacing was adopted was 0.50 m x 0.50 m.

Fertilizer calculation for rainy season:

Based on soil test data and IIHR recommendation, the dose of NPK 75.6:18.75:18.75 kg/ha was fixed and made into 75%, 100%, 125% and Control (conventional application of fertlizers with 100% RDF)

3.4.2. Precision farming experiment during winter and summer seasons

Experiment details:

Month	October – January	January – April
Genotypes	Bhagwati (Hybrid)	Bhagwati (Hybrid)
	M-1 (Local collection)	M-1 (Local collection)
Design	RBD	RBD
No. of treatments	14	14
No. of replications	3	3
Irrigation levels	I_1 - Irrigation at 75% EPan	I_1 - Irrigation at 75% EPan
	I_2 - Irrigation at 100 % EPan	I_2 -Irrigation at 100 % EPan
Fertigation levels	F_1 - 75% of RDF	F_1 - 75% of RDF
	F_2 - 100% of RDF	F_2 - 100% of RDF
	F_3 - 125% of RDF	F_3 - 125% of RDF
Plot size	4.0 m x 1.0 m	4.0 m x 1.0 m
Spacing	0.5 m x 0.5 m	0.5 m x 0.5 m
Soil fertility status (Before crop)		
Soil organic carbon	0.79%	1.30%
Available phosphorous	5.1 kg/ha	242 kg/ha
Available potassium	211 kg/ha	401 kg/ha

Fertilizer calculation for winter and summer

Based on soil test data and IIHR recommendation, the dose of NPK during winter (81.9:87.75:53.25 kg/ha) and during summer (75.6:22.5:18.75 kg/ha) was fixed and made into 75%, 100%, 125% and Control (conventional application of fertilizers as 100% RDF).

Calculation of water requirement

Based on number of emitters present in the plot, the discharging capacity of emitters and daily pan evaporation (Epan) the amount of irrigation to be supplied to the crop was calculated. In the case of control treatment, each plot were given 20 mm water twice in a week.

3.5. Seasonal response of marigold genotypes under precision farming

Response of the two genotypes, in terms of plant and floral characters as well as nutrient uptake, was correlated with weather parameters *viz*., average temperature, average relative humidity, average rainfall, average Epan and the seasonal response in the respective genotypes was analysed.

3.6. Effect of plant growth regulators in African marigold

The effect of growth regulators was studied in two seasons *viz*. rainy (June-September) and winter (October–January). Best performing genotype Bhagwati from the field evaluation experiment was selected for growth regulator studies. Seeds were sown in protrays filled with a potting mixture comprising of cocopeat, vermiculite, and perlite in the ratio of 3:1:1 and one-month-old seedlings were transplanted in the main field. The experiment was laid out in RBD. All the treatment plots were provided with drip irrigation, fertigation and mulched with 30µ silver black polythene.

A single pinching was given at 20 DAT and plants were staked at 45 DAT. Weeding the interspaces of plots was done at regular intervals. Need-based plant protection measures were taken during the cropping period.

Observations on plant, floral, post-harvest as well as biochemical parameters were recorded.

3.6.1. Effect of growth retardants during rainy season

The experiment was conducted during June–September 2019 with seven tretaments replicated thrice. The plot size was 4.0 m x 1.0 m with spacing of 0.50 m x 0.50 m. Plot without plant growth regulators spray was treated as control. Paclobutrazol, CCC and Ethrel were used to control plant height during rainy season.

Treatments:

T_1 : Paclobutrazol 30 mg per liter
T_2 : Paclobutrazol 60 mg per liter
T_3 : CCC 750 mg per liter
T_4 : CCC 1000 mg per liter
T_5 : Ethrel 100 mg per liter
T_6 : Ethrel 200 mg per liter
T_7 : Control (No growth retardant spray)

The required quantity of Paclobutrazol (powder form), Cycocel (CCC) and Ethrel were directly dissolved in distilled water and the prepared solutions were applied as foliar spray at 30 and 45 DAT.

3.6.2. Effect of growth promoters during winter season

The experiment was conducted during October (2019)-January (2020) with seven tretamets replicated thrice. The plot size was 4.0 m x 1.0 m with spacing of 0.50 m x 0.50 m. Plot without plant growth promoter spray was treated as control. Gibberellic acid (GA_3), Alpha-Naphthalene acetic acid (NAA) and Benzyl adenine (BA) was used to enhance the plant growth during winter season.

Treatments:

T_1 : GA_3 200 mg per liter
T_2 : GA_3 300 mg per liter
T_3 : NAA 200 mg per liter
T_4 : NAA 300 mg per liter
T_5 : BA 50 mg per liter
T_6 : BA 75 mg per liter
T_7 : Control (No growth promoter spray)

The required quantity of NAA and BA were dissolved in two to three pellets of sodium hydroxide solution and final volume was made up with distilled water whereas, GA_3 was directly dissolved in distilled water. Growth promoters were applied as foliar spray at 30 and 45 DAT.

3.7. Post-harvest studies

Five flowers per treatment per replication were kept in ambient conditions for recording PLW. The total initial weight of the five flowers was recorded. The loss in weight of flowers was recorded when the flowers showed 25 per cent wilting with faded appearance. Shelf life was also recorded.

3.8. Biochemical analysis

3.8.1. Total carotenoids (mg/g)

Total carotenoids were estimated according to Arnon (1949) method in which the extract was prepared by grinding 200 mg of fresh flower with a pestle and mortar using 10 ml of 80 percent acetone. The homogenate was then filtered in a volumetric flask (25 ml) using Whatman filter paper no.1. The homogenate was washed out 2-3 times with 5 ml of 80 percent acetone each time and the final volume of the filtrate was made up to 25 ml with 80 percent acetone. The filtrate was taken in a cuvette (3/4 volume) and its absorbance was recorded separately at 480 nm and 510 nm using a spectrophotometer (using 80 percent acetone as blank). The carotenoid content was calculated following the formula and expressed in mg/g.

$$\text{Total carotenoids} = [(7.6 \text{ x OD at } 480) - (1.49 \text{ x OD at } 510)] \text{ X} \frac{\text{V}}{1000} \text{ X W}$$

Where,

V- Volume of extract with acetone,

W- Weight of the fresh sample

OD- Absorbance at 480 and 510nm

3.8.2. Flavonoids (A_{300} g^{-1})

The content of flavonoids both in leaves and petals was estimated spectrophotometrically according to Mirecki and Teramara (1984). One gram of plant tissue sample was put in 80 per cent acidified methanol (methanol:water:HCL-79:20:1) and kept overnight in dark. Absorbance was read at a wavelength of 300 nm and flavonoid content was calculated using the following formula and expressed as A_{300} g^{-1} fresh weight of plant sample.

$$Y = 16.05 \text{ X } A_{300}$$

Where,

Y- Concentration of UV-B absorbing compound equivalent to coumaric acid

A- Absorbance at 300 nm

3.8.3. Essential oil (%)

Essential oil content in leaves and petals was estimated. Hundred gram of the sample (leaves/ petals) were submerged in seven times of water and submitted to hydro-distillation in a Clevenger apparatus. When the mixture started boiling, the temperature was maintained at 70^{o}C for 5-6 hours for marigold petals and 3-3.5 hours for marigold leaves during distillation. The distillate was cooled down to room temperature and allowed to settle until the oil layer was clear. The volume was measured and the oil content was calculated and expressed in percentage.

$$\text{Essential oil per cent (V/W)} = \frac{\text{Volume of oil (ml)}}{\text{weight of sample (g)}} \text{X } 100$$

3.9. Plant nutrient analysis

Plant nutrient analysis was done only in the precision farming experiments. The plant samples were subjected to chemical analysis for determining the total N,P,andK content. For this purpose, plant samples from each treatment from the respective replication were dried in an electric hot air oven to constant weight at a temperature of 70^{o}C and passed through a 0.5 mm sieve. The required quantity of sample was weighed

out accurately in an electronic balance and was subjected to acid extraction before subjecting to chemical analysis.

a. Nitrogen content

The nitrogen content in the plant sample was estimated by the modified micro Kjeldahl method (Jackson, 1973).

b. Phosphorus content

The plant sample was subjected to nitric-perchloric (9:4) digestion and phosphorus content in plant samples was determined colorimetrically using Vanadomolybdo phosphoric yellow color method (Jackson,1973). The uptake of phosphorus was calculated by multiplying the phosphorus content of plant sample with the total dry weight of plants and expressed in kg/ha.

c. Potassium content

The plant sample was subjected to nitric- perchloric (9:4) digestion and potassium content in plant samples was determined by flame photometry method (Jackson, 1973). The uptake of potassium was calculated by multiplying the potassium content of plant sample with the total dry weight of plants and expressed in kg/ha.

3.10. Soil analysis

Soil nutrient status of N, P and K was estimated only in precision farming experiments. Representative soil samples were taken from the experimental plots before and after each crop. The air-dried soil samples were passed through 2 mm sieve and were used for the analysis.

a. Organic carbon

The soil organic carbon content before and after each crop was estimated using Walkley and Black's rapid titration method (Jackson,1973) and expressed in per cent.

b. Available Nitrogen

The available N content in soil was estimated using alkaline permanganate method (Subbiah and Asija, 1956) and expressed in kg/ha.

c. Available Phosphorous

The available P content in soil was estimated using Dickman and Bray's molybdenum blue method using Bray No.1 reagent for extraction and estimated using a spectrophotometer (Jackson, 1973) and expressed in kg/ha.

d. Available Potassium

The available K content in soil was determined using neutral ammonium acetate extract and was read in Flame photometer (Jackson, 1973) and expressed in kg/ha.

3.11. Main items of observations

A. Plant characters

a. Plant height

Plant height was measured from base to the tip of the main stem at 30 and 60 DAT. Observations were recorded for five individual plants per genotype per replication and the average height was expressed in cm.

b. Plant spread

The plant spread was recorded East-West and North–South at 30 and 60 DAT for five individual plants of each genotype per replication and the average plant spread was calculated and expressed in cm.

c. Stem girth

Stem girth at 2 cm above collar level was measured at 30 and 60 DAT for five individual plants per genotypes per replication and the average plant stem girth was calculated and expressed in cm.

d. Number of primary branches per plant

The number of primary branches were counted at 30 and 60 DAT for five individual plants per genotype per replication and the average was calculated and expressed in numbers.

e. Stem coloration

The visual difference in stem colour was identified with the help of the Royal Horticultural Society (RHS) colour chart 6th edition 2015.

f. Inter nodal length

This observation was recorded only in the experiment on effect of growth regulators. Inter nodal length of mature five primary branches were measured and the mean inter nodal length was calculated and expressed in cm.

g. Dry matter production per plant

The particular observation was recorded only in precision farming experiments. Three healthy plants at peak flowering stage were selected under each treatment per replication and these plants were uprooted and dried. The dry weight of the plants were recorded and the average was calculated and expressed in gram/plant.

B. Floral characters

a. Days to bud initiation

The number of days taken for first flower bud initiation was recorded by counting the days from the date of planting to the appearance of the first flower bud. This was recorded in all the plants per treatment per replication and the average was worked out.

b. Days to initiation of flower opening

The number of days taken to initiation of flower opening from the day of bud initiation was observed for ten tagged flower buds per treatment per replication and the average number of days was calculated.

c. Days to complete flower opening

The number of days taken to complete flower opening from the initiation of flower opening in the ten tagged flowers per treatment per replication was observed and the average was expressed in days.

d. Days to 50 per cent flowering

The number of days taken for fifty per cent of the plants to produce the first flower in each treatment was computed from the observation item no. a

e. Flower diameter

Ten fully opened individual flowers per treatment per replication were randomly selected from the tagged plants and diameter was measured using scale and the average diameter was expressed in centimeters.

f. Stalk length

Stalk length, of the ten fully opened individual flowers per treatment per replication which were selected for measuring the flower diameter, were measured using scale and the average value expressed in cm.

g. Flower weight

Fresh weight of the ten fully opened individual flowers per treatment per replication that were selected for measuring the flower diameter and stalk length, were recorded using electronic balance and the average was expressed in grams.

h. Weight of ray florets

Weight of ray florets of the ten fully opened individual flowers per treatment and per replication that were selected for recording the fresh weight, were recorded using an electronic balance and the average was calculated and was expressed in grams.

i. Flower colour

The flower colour was identified with the help of the Royal Horticultural Society (RHS) colour chart sixth edition (2015). This observation was recorded in the experiment 3.1.

j. Number of flowers per plant

Counted the number of fully opened flowers totally harvested from the five individual observational plants per treatment per replication and calculated the average and expressed in numbers.

k. Yield per plant

Weight of flowers harvested from the five individual observational plants per treatment per replication was recorded, summed the total weight of flowers for the individual observational plant per treatment per replication and the average weight was calculated to record the yield per plant and expressed in grams.

l. Number of harvests per plant

The total number of pickings of fully opened flowers from the first harvest to the last harvest was counted per treatment per replication, average was worked out and expressed as the number of harvests.

C. Post-harvest studies

a. Shelf life of flowers

The days taken to show more than 25 per cent wilting with faded colour under ambient condition was recorded and expressed as the shelf life of flowers.

b. Physiological loss in flower weight

PLW worked out using the formula

$$\text{PLW} = \frac{\text{Initial weight (g)} - \text{Final weight (g)}}{\text{Initial weight (g)}} \text{X } 100$$

D. Grafting studies

Observations were recorded on percent survival of grafts and the number of days taken for graft union.

a. Percent survival of grafts

The number of grafted plants survived after fifteen days of grafting were observed per treatment per replication and per cent survival was calculated.

b. Number of days taken for graft union

The number of days taken to the union of scion and rootstock was observed per treatment per replication and the average was worked out.

E. Incidence of bacterial wilt

a. Percent Disease Incidence (PDI)

PDI was observed both in the field evaluation and artificial screening studies per treatment per replication and the average PDI was calculated as ratio of number of plants wilted to the total number of plants and expressed as percentage.

b. Days to wilt after planting

The days to show wilt symptoms were observed per treatment per replication and the average days was worked out

F. Biochemical analysis

Total carotenoids in petals, flavonoids and essential oil in leaves and petals were estimated and recorded.

G. Uptake of N, P and K

Uptake of N, P and K was calculated by multiplying the respective contents nutrients in plant samples with the total dry weight of plants and expressed in kg/ha.

H. Water use efficiency (WUE)

Water use efficiency (kg/ha mm^{-1}) was worked out for precision farming experiments during winter and summer. WUE is defined as the relation between yield obtained from one hectare of the crop and the amount of water used. It was worked out by using the following formula.

$$\text{WUE} = \frac{\text{Flower yield (kg/ha)}}{\text{Evapotranspiration(mm)}}$$

I. Incidence of major pests and diseases other than bacterial wilt

Other than the bacterial wilt, the major pests and diseases were observed.

J. Economics of cultivation

Economics of cultivation was worked out for precision farming experiments after taking into account the cost of cultivation and the prevailing market price of marigold flowers. Benefit cost (B:C) ratio was calculated for the treatments.

Benefit-cost ratio worked out using the formula:

$$\text{B: C} = \frac{\text{Gross income per ha}}{\text{Cost of cultivation per ha}}$$

K. Statistical analysis

Statistical analysis was done on different characters using OP-STAT (HAU, Hisar). Analysis of variance studies was engaged to assess the variation among different parameters. In the cases where the effects were found to be significant, the critical difference was calculated at five or one percent probability level and non-significant is denoted as NS. Correlation coefficient analysis studies were analyzed through computer package SPSS v.16 (SPSS, 2007)

Results and Discussion

4. RESULTS AND DISCUSSION

The study entitled "Standardization of production technology for African marigold (*Tagetes erecta* L.) was carried out at the Department of Floriculture and Landscaping, College of Horticulture, Vellanikkara, during the year 2018-2020. The research programme was conducted under the following five experiments;

1 Field evaluation of African marigold genotypes and other *Tagetes* spp. against bacterial wilt

2. Artificial screening against bacterial wilt resistance

3. Evaluation of rootstocks for *Tagetes erecta* L.

4. Precision farming techniques and seasonal response

5. Effect of growth regulators on plant growth and yield in *Tagetes erecta* L.

In this chapter, results and discussion of all the five experiments are furnished.

4.1. Field evaluation of African marigold genotypes and other *Tagetes* species against bacterial wilt

Thirty two marigold genotypes were subjected to field evaluation in a wilt sick plot during rainy and winter seasons during 2018-19. Among the genotypes, there were eight F_1 hybrids, eight varieties, seven local collections of *T. erecta*, eight genotypes of *T. patula* (including three varieties and five local collections) and one genotype of *T. tenuifolia.* Observations were recorded on incidence of bacterial wilt, days to wilt, vegetative, reproductive, post-harvest as well as and biochemical parameters.

A. Bacterial wilt incidence

Data on bacterial wilt incidence, days to wilting of plants and flavonoid content in marigold genotypes and its correlation with bacterial wilt incidence are presented in the Tables 2, 3 and 4, respectively.

a. Per cent Disease Incidence (PDI)

In all the genotypes the percent disease incidence (PDI) were observed during rainy and winter season. Significant difference was recorded with regard to the PDI among the genotypes during both seasons (Table 2). Genotypes M-1 and M-2 did not showed any symptoms of bacterial wilt in both seasons. During rainy season, the maximum PDI was recorded in Coimbatore Local (87.50%) followed by Dharmapuri Local (83.33%), while during winter season, the highest PDI was recorded in Dharmapuri Local (100.00%), followed by Rupa (92.00%) and Pusa Narangi Gainda (91.70%).

Based on PDI, genotypes were classified into resistant [M-1, M-2, Bhagwati and Maria 91], moderately resistant [Arka Agni, Arka Bangara-2, P4, KDA-2 and Madikeri local], moderately susceptible (5), susceptible (10) and highly susceptible (8) types during rainy season. In winter season, 20 genotypes exhibited highly susceptible reaction, eight genotypes susceptible; two moderately susceptible and two resistant types reaction. Except M-1 and M-2, the remaining genotypes had shown reasonably higher susceptibility during winter season when compared to rainy season as evidenced in Table 2. Irrespective of the season, the average PDI was high in *T. erecta* genotypes when compared to genotypes of *T. patula* (except Hisar Jafri 2) and *T. tenuifolia*. Significant variations among the genotypes to bacterial wilt incidence has been reported and this response of the genotypes has been attributed to its genetic make-up in marigold (Umesh *et al.*, 2018; Singh and Singh, 2010). Gopal *et al.* (2005) also reported genetic variation in tomato with respect to susceptibility to bacterial wilt. The thickenings in the cell membrane and cell wall might be a major factor that provides a stronger barrier against bacterial invasion (Kim *et al.*, 2016 and Lohar *et al.*, 2018).

It is also evident from the Table 2 that bacterial wilt incidence was more during winter (69.59%) season compared to rainy season (42.77%). This might be due to the high inoculum present in the soil during winter season (7.40×10^5) as compared to rainy season (5.38×10^5). Besides, there was a sharp fall in humidity just after planting in October (69%), which created a dry climate that might have favoured high bacterial wilt incidence as compared to monsoon when the relative humidity was comparatively high (88%).

Table 2. Bacterial wilt incidence in marigold genotypes during different seasons

Genotypes (Factor A)	Seasons (Factor B)				Average PDI (%) (Factor A)
	Rainy		Winter		
	PDI (%)	Reaction	PDI (%)	Reaction	
Double Orange	62.50 (7.9)	S	87.70(9.4)	HS	75.08
Double Yellow	79.16 (8.8)	HS	71.00(8.4)	HS	75.08
Pusa Narangi Gainda	54.16 (7.3)	S	91.70(9.6)	HS	72.92
Pusa Basanti Gainda	62.48 (7.7)	S	87.70(9.4)	HS	75.08
Suvarna Orange	41.66 (6.4)	S	79.70(9.0)	HS	60.67
Suvarna Yellow	70.83 (8.4)	HS	83.30(9.2)	HS	77.08
Arka Agni	12.50 (3.6)	MR	55.70(7.5)	S	34.08
ArkaBangara 2	20.00 (4.4)	MR	50.00(7.0)	S	35.00
Bhuvana	54.16 (7.5)	S	87.70(9.4)	HS	70.92
Hawaii Orange	33.33 (5.1)	HS	79.30(9.0)	HS	56.33
Rupa	66.60 (8.9)	S	92.00(9.6)	HS	79.33
P-4	16.66 (3.7)	MR	83.70(9.2)	HS	50.17
Bhagwati	4.16 (1.8)	R	58.70(7.7)	S	31.42
Royal Orange	29.16 (5.4)	MS	58.30(6.6)	S	43.75
Sakura 031	41.66 (6.4)	MS	29.30(5.5)	MS	35.50
Maria 91	8.33 (2.7)	R	75.30(8.6)	HS	41.83
M-1	0.00 (1.0)	R	0.0(1.0)	R	0.00
M-2	0.00 (1.0)	R	0.0(1.0)	R	0.00
Dharmapuri Local	83.33 (9.9)	HS	100.0(10.1)	HS	91.67
Coimbatore Local	87.50 (9.3)	HS	83.70(9.2)	HS	85.58
Madikeri Local	20.83 (2.7)	MR	27.70(4.7)	MS	24.25
Nilakottai Local	77.77 (8.7)	HS	62.70(8.0)	S	70.22
TNAU Marigold	54.16 (7.4)	S	87.70(9.4)	HS	79.25
Hisar Jafri 2	70.83 (8.4)	HS	83.30(9.1)	HS	83.42
Pusa Arpita	79.16 (8.9)	HS	83.30 (9.1)	HS	66.67
Red brocade	50.00 (6.9)	S	83.70 (9.2)	HS	68.92
TNAU Dwarf Marigold	50.00 (6.9)	S	66.70 (8.0)	S	58.33
KDA-2	16.66 (4.14)	MR	87.70 (9.4)	HS	52.17
KDA-3	29.16 (5.10)	MS	68.00 (8.3)	S	48.58
KDA-4	25.90 (4.9)	MS	62.70 (7.8)	S	43.83
Chintamani Red	20.83 (4.6)	MS	79.30 (8.8)	HS	50.08
Tagetes tenuifolia	45.83 (6.8)	S	75.30 (8.7)	HS	60.58
Average (Factor B)	**42.77**		**69.59**		
Factors	**C.D (0.05)**		**SE.m±**		
Factor (A)	22.67 (1.74)		0.6		
Factor (B)	5.67 (0.44)		0.2		
Factor (AXB)	32.07(2.47)		0.9		

(Values in the parenthesis are square root transformed)

Genotypes (Factor A)	Days to wilt		
	Season (Factor B)		Average days to wilt (Factor A)
	Rainy	Winter	
Double Orange	51.71	28.63	40.17
Double Yellow	75.13	17.40	46.27
Pusa Narangi Gainda	81.07	28.07	54.57
Pusa Basanti Gainda	63.36	25.67	44.51
Suvarna Orange	72.72	27.57	50.14
Suvarna Yellow	64.08	32.47	48.28
Arka Agni	59.83	21.77	40.80
Arka Bangara 2	71.75	22.23	46.99
Bhuvana	68.50	26.33	47.42
Hawaii Orange	80.83	19.80	50.32
Rupa	65.06	26.60	45.83
P-4	85.75	28.80	57.28
Bhagwati	77.00	27.77	52.38
Royal Orange	76.25	24.87	50.56
Sakura 031	75.80	10.17	42.99
Maria 91	63.00	30.23	46.62
Dharmapuri Local	65.98	27.43	46.71
Coimbatore Local	64.99	26.97	45.98
Madikeri Local	78.33	26.00	52.17
Nilakottai Local	55.66	20.83	38.25
TNAU Marigold	54.90	29.43	42.17
Hisar Jafri 2	68.23	23.77	46.00
Pusa Arpita	61.07	31.07	46.07
Red brocade	69.64	34.00	51.82
TNAU Dwarf Marigold	70.25	26.30	48.28
KDA-2	80.75	37.43	59.09
KDA-3	85.93	22.47	54.20
KDA-4	82.33	31.87	57.10
Chintamani Red	82.50	30.97	56.73
Tagetes tenuifolia	75.33	13.20	44.27
Average (Factor B)	**70.93**	**26.00**	
Factors	CD	SEm±	
A	10.68	3.81	
B	2.76	0.98	
A x B	15.11	5.39	

Table 3. Days to wilt among marigold genotypes

The average temperature during winter season (28.86^0C) was also slightly high when compared to rainy season (26.08^0C) and this might have caused to the high wilt incidence during winter season. Mondal *et al*. (2014) observed a similar trend of increased wilt incidence in marigold in West Bengal just after rain during pre-winter in October.

b. Days to wilt

Both the genotypes and season showed significant influence on days to wilt (Table 3). Early incidence of wilt among the genotypes was observed during winter season (26.00 days) than rainy season (70.93 days). Irrespective of the season, among the genotypes, late wilting was noticed in KDA -2 (59.09 days) which was on par with all the genotypes except the genotypes for which the days to wilt ranged from 38.25-48.28 days.

c. Correlation of flavonoids with bacterial wilt incidence

Flavonoid content in different marigold genotypes and its correlation with PDI are given in Table 4. The highest flavonoid content was recorded in M-1leaves (4.3 A_{300} g^{-1}) and petals (1.7 A_{300} g^{-1}) and M-2 leaves (3.8 A_{300} g^{-1}) and petals (2.0 A_{300} g^{-1}) which were on par with flavonoid content in leaves (3.7 A_{300} g^{-1}) and petals (1.6 A_{300} g^{-1}) of Bhagwati. The flavonoid content was maximum in leaves than petals, which corroborates with the fact that flavonoids are deposited in epidermal cell layers in the cuticle of leaves (Merzylak *et al.,* 2002). Correlation of flavonoid content with PDI (Table 4) and Fig. 1 and 2 showed that the flavonoid accumulation in the leaves (-0.423^*) and petals (-0.587^*) were significantly and negatively correlated with per cent disease incidence. Increased flavonoid content might have induced defence metabolism in genotypes with high flavonoid content and this might have imparted disease resistance in such genotypes. In support to the correlation analysis, the comparative role of the flavonoid content of leaves and petals in different varieties and their response to the bacterial wilt incidence was also analysed by Z-scatter analysis (Fig.3 and 4). The results clearly indicated that genotypes with increased flavonoid content and decreased disease incidence fall on the fourth quadrant in the figure.

Table 4. Flavonoid content in marigold genotypes and its correlation with bacterial wilt incidence

Genotypes	PDI	Flavonoids (A_{300} g^{-1})	
		Leaves	Petals
Double Orange	62.50 (7.9)	2.2	1.5
Double Yellow	79.16 (8.8)	0.6	0.1
Pusa Narangi Gainda	54.16 (7.3)	1.8	1.6
Pusa Basanti Gainda	62.48 (7.7)	3.0	1.4
Suvarna Orange	41.66 (6.4)	1.5	1.0
Suvarna Yellow	70.83 (8.4)	1.6	1.4
Arka Agni	12.50 (3.6)	2.9	1.4
Arka Bangara 2	20.00 (4.4)	3.3	1.5
Bhuvana	54.16 (7.5)	2.1	0.9
Hawaii Orange	33.33 (5.1)	2.4	1.0
Rupa	66.60 (8.9)	2.7	0.5
P-4	16.66 (3.7)	1.9	1.2
Bhagwati	4.16 (1.8)	3.7	1.6
Royal Orange	29.16 (5.4)	2.6	0.9
Sakura 031	41.66 (6.4)	2.6	1.0
Maria 91	8.33 (2.7)	2.2	1.4
M-1	0.00 (1.0)	4.3	1.7
M-2	0.00 (1.0)	3.8	2.0
Dharmapuri Local	83.33 (9.9)	2.8	0.4
Coimbatore Local	87.50 (9.3)	0.9	0.0
Madikeri Local	20.83 (2.7)	2.7	1.4
Nilakottai Local	77.77 (8.7)	2.8	0.4
TNAU Marigold	54.16 (7.4)	3.5	0.6
Hisar Jafri 2	70.83 (8.4)	2.0	NF
Pusa Arpita	79.16 (8.9)	1.6	NF
Red brocade	50.00 (6.9)	2.8	NF
TNAU Dwarf Marigold	50.00 (6.9)	0.7	0.7
KDA-2	16.66 (4.2)	1.4	0.1
KDA-3	29.16 (5.1)	1.0	0.3
KDA-4	25.90 (4.9)	0.8	1.2
Chintamani Red	20.83 (4.6)	2.0	1.1
Tagetes tenuifolia	45.83 (6.8)	2.4	0.9
C.D (0.01)		0.78	0.65
Correlation		-0.423*	-0.587**

(Values in the parenthesis are square root transformed)

* NF- No flowering was observed

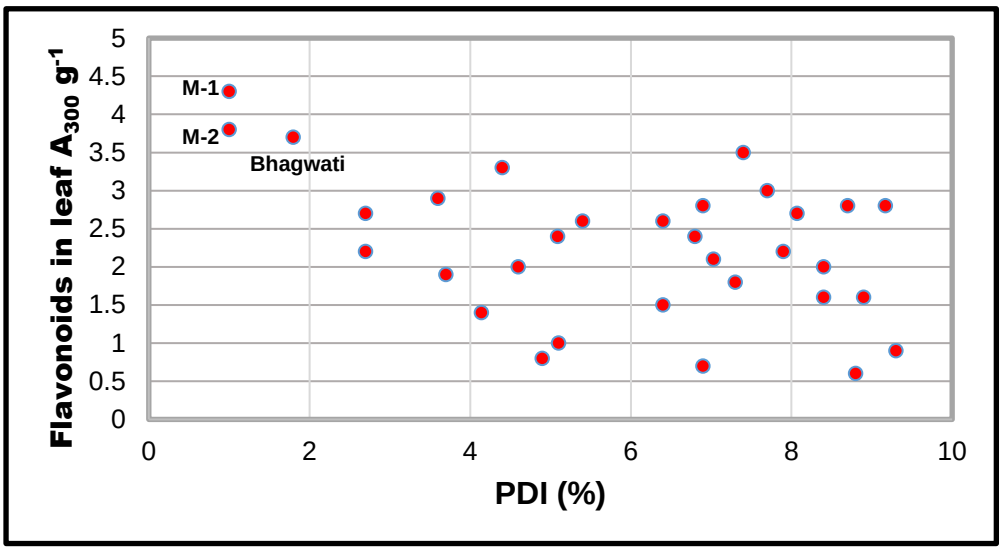


Figure 1. Correlation of flavonoids content in leaf with bacterial wilt incidence

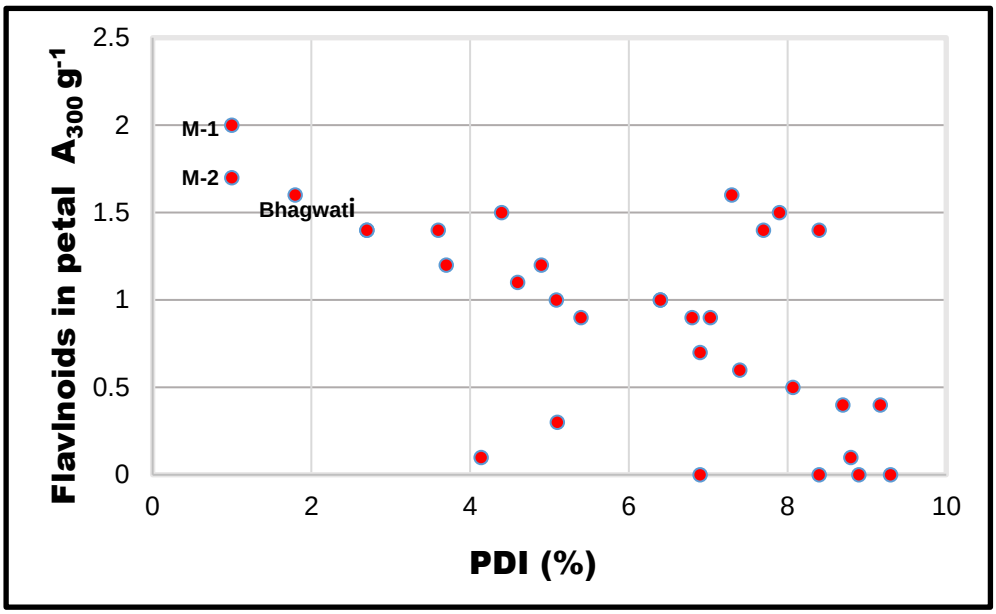


Figure 2. Correlation of flavonoids content in petal with bacterial wilt incidence

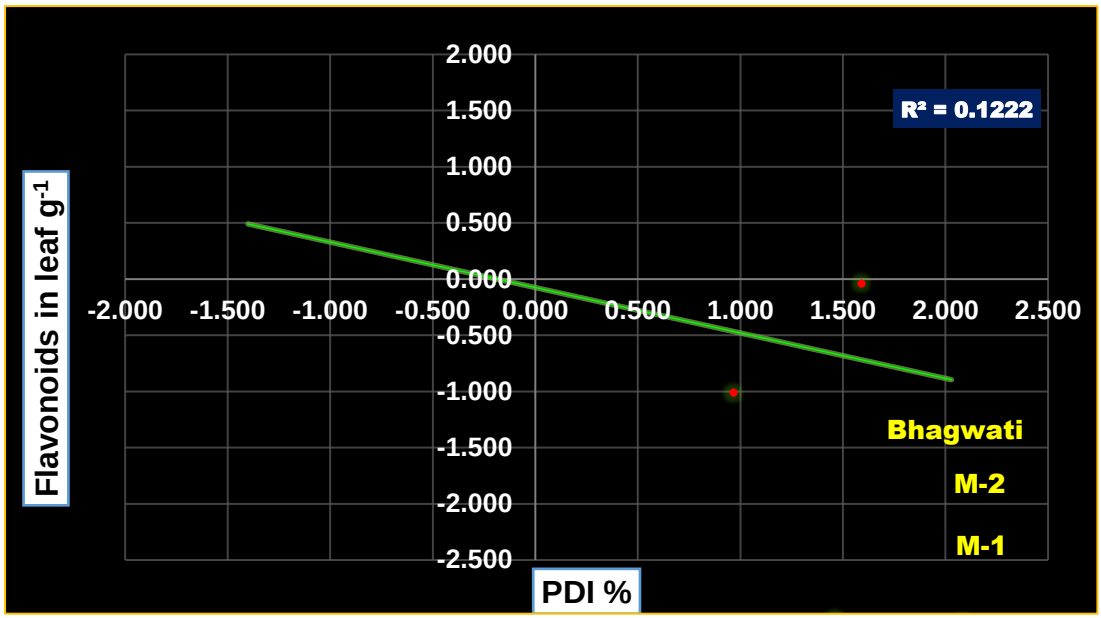


Figure 3. Z-distribution of bacterial wilt incidence and flavonoids content in leaf

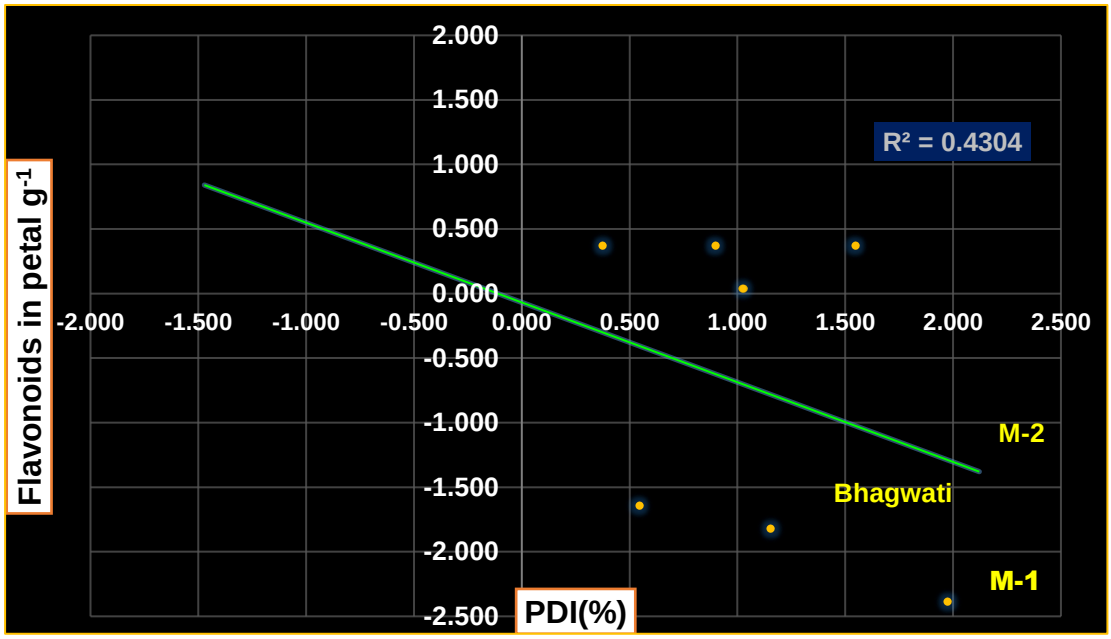


Figure 4. Z-distribution of bacterial wilt incidence and flavonoids content in petal

Flavonoids participate in the mechanisms of plant defence against herbivores and pathogens: fungi, viruses and bacteria. Many flavonoids are toxic to a wide range of pathogenic bacteria and fungi. The rapid synthesis of high concentrations of these compounds in some plants in a relatively short period of time helps to limit the spread of the pathogen. They may also be directly involved in the inhibition of the pathogen's enzymes, especially those digesting the plant cell wall, by chelating metals required for their activity (Treutter, 2005). Defence mechanism of flavonoids is also related to their antioxidant properties and they quench the reactive oxygen species (ROS) generated by pathogens. Moreover, flavonoids can contribute to tightening of the plant structures and tissues by modulating auxin (IAA) activity, which can lead to the differentiation of tissues, promotion of callose and tylose formation and closure of the vascular system to prevent pathogen infection (Beckman, 2000). Studies in *Solanum tuberosum* cv.Agata has revealed an increased flavonoid content in leaves on inoculation with *Ralstonia solanacearum* (Poiatti *et al*., 2009). They have reported the increased flavonoid content as an inducer of defence metabolism in the potato cultivar studied.

C. Symptomatology

Infection was observed as wilting of leaves. On close observation, necrotic lesions were observed at leaf tip which further spread downward the leaves. This was followed by gradual wilting of entire plants. These typical symptoms were observed in the field as well as during artificial inoculation (Plate 6).

a. Cultural characterization of pathogen

The colony characteristics of the pathogen were almost similar in both the isolates collected from the two locations. The size of the colonies varied from 1.5 mm to 5.5 mm and it produced circular colonies with entire, margins which were slightly raised with high fluidity. The two isolates showed similar pigmentation with dark pink coloured colonies-(Plate7).

b. Morphological characterization of pathogen – Scanning electron microscopy

High quality images with the best resolution were obtained at 18.5 µm view field with a magnification of 11.2 kx (Plate 8). Typical rod shaped bacterial cells of size 0.5-0.9 µm x 1.2-1.7 µm were observed.

c. Molecular characterisation of the pathogen

The amplicon size of the PCR products was 1.5 Kbp and amplicons of two isolates were of the same size (Plate 9). The nucleotide sequence data obtained from RGCB, Thiruvananthapuram are given in Appendix I.

d. *In-silico* analysis 16S rDNA sequences

Sequence analysis was carried out using nucleotide basic alignment search tool (BLASTn) to identify the organisms. Both the sample sequences were found to be homogenous to the reported sequences of 16S rDNA gene of *Enterobacter cloacae* in the NCBI database (Plate 10).

The sequence of the both isolates showed 100.00 per cent identity with *Enterobacter cloacae* strain from New Delhi with maximum query cover of 100 per cent. The sequence also showed homology with *Enterobacter cloacae* strains MK811112 from New Delhi. The isolates also showed 100 per cent identity with all the sequences producing significant alignments with an expected 'E' value of zero.

e. Phylogenetic analysis

Phylogenetic analysis was carried out for studying the relationship of the isolates collected during the present study with other isolates of *Enterobacter cloacae* reported from India and elsewhere. The 16S rDNA nucleotide sequence of the two isolates from the two locations were aligned with five sequences each of *R. solanacearum* and *Enterobacter* species 16S rDNA gene retrieved from NCBI database. The sequences were aligned using the Clustal W software and a neighbor joining phylogenetic tree was constructed employing the MEGA X software (Fig.5).

From the all above bioinformatics tools, it is evident that, the rod shaped bacterium obtained from wilted plants of marigold which appeared wider than the

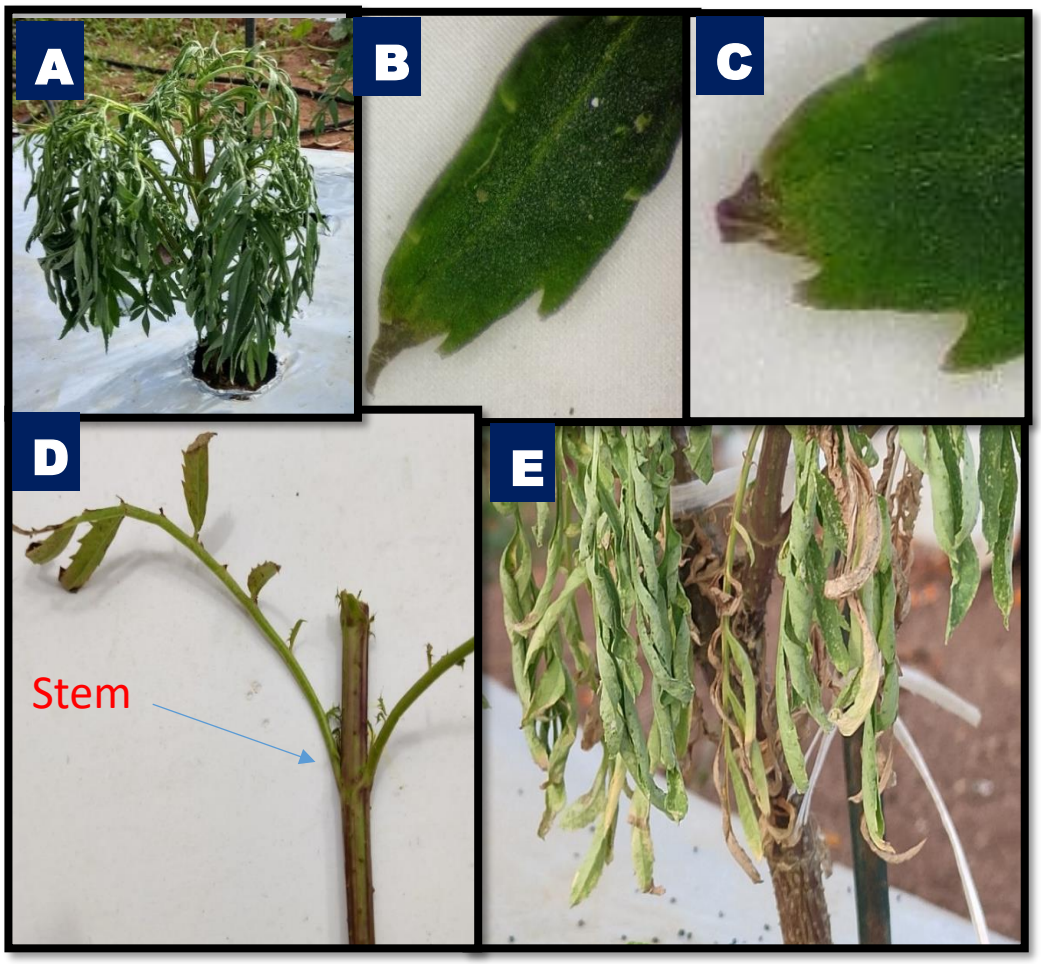


Plate 6. Field level symptoms of bacterial wilt in marigold

A-bacterial wilt infected plant**,** **B**-initiation of necrosis at leaf tips,

C- typical folding of leaf, **D**-elongated irregular lesions on the stem

F-severe wilting and necrosis

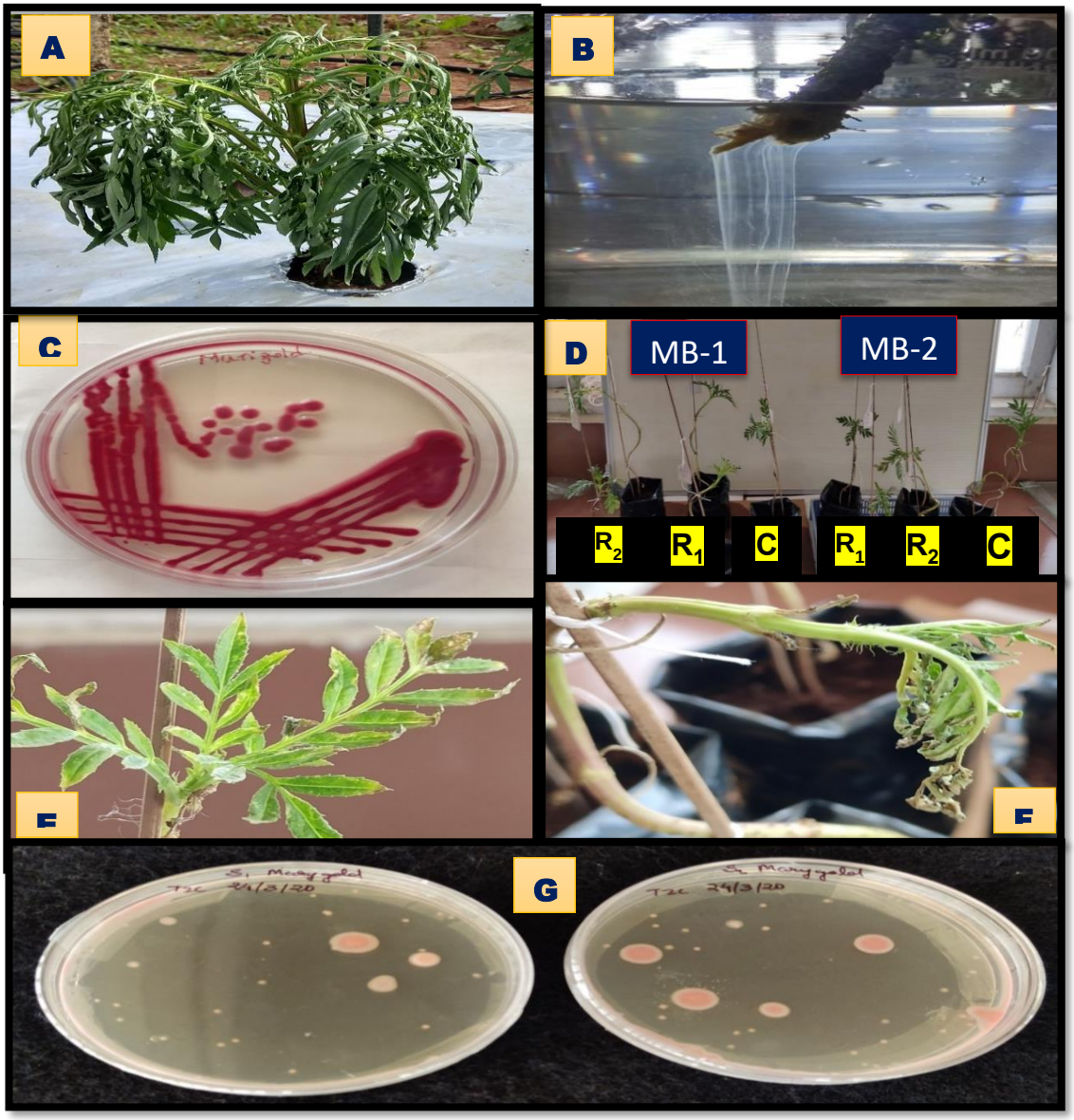


Plate 7. Confirmation of the pathogen through Koch's postulates

A-bacterial wilted marigold plant, **B**- ooze test, **C**- isolation of pathogen on TZC agar, **D**-artificial inoculation, **E**-initial symptoms exhibited on leaves, **F**- pathogenicity from artificially inoculated plants, **G**- isolated pathogen from artificially inoculated plant

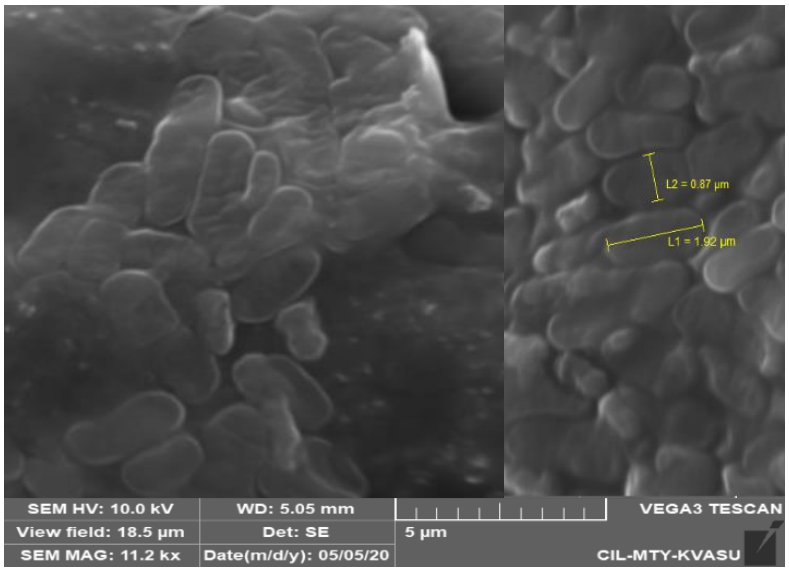


Plate 8. Scanning electron microscope image of *Enterobacter cloacae*

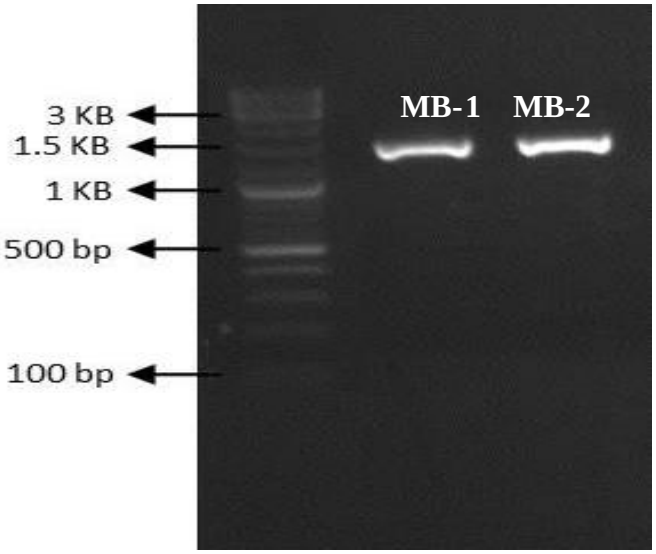
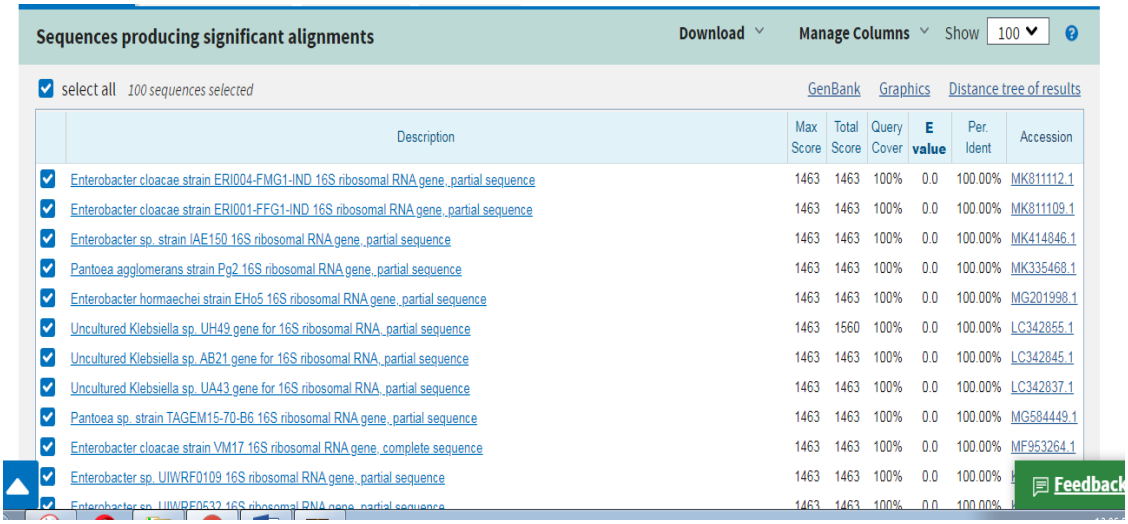


Plate 9. PCR gel profile of 16S rDNA of *Enterobacter cloacae* isolates (MB-1 and MB-2)



Sequences producing significant alignments

Download | Manage Columns | Show 100

select all 100 sequences selected

GenBank | Graphics | Distance tree of results

Description	Max Score	Total Score	Query Cover	E value	Per. Ident	Accession
Enterobacter cloacae strain ERI004-FMG1-IND 16S ribosomal RNA gene, partial sequence	1463	1463	100%	0.0	100.00%	MK811112.1
Enterobacter cloacae strain ERI001-FFG1-IND 16S ribosomal RNA gene, partial sequence	1463	1463	100%	0.0	100.00%	MK811109.1
Enterobacter sp. strain IAE150 16S ribosomal RNA gene, partial sequence	1463	1463	100%	0.0	100.00%	MK414846.1
Pantoea agglomerans strain Pg2 16S ribosomal RNA gene, partial sequence	1463	1463	100%	0.0	100.00%	MK335468.1
Enterobacter hormaechei strain EHo5 16S ribosomal RNA gene, partial sequence	1463	1463	100%	0.0	100.00%	MG201998.1
Uncultured Klebsiella sp. UH49 gene for 16S ribosomal RNA, partial sequence	1463	1560	100%	0.0	100.00%	LC342855.1
Uncultured Klebsiella sp. AB21 gene for 16S ribosomal RNA, partial sequence	1463	1463	100%	0.0	100.00%	LC342845.1
Uncultured Klebsiella sp. UA43 gene for 16S ribosomal RNA, partial sequence	1463	1463	100%	0.0	100.00%	LC342837.1
Pantoea sp. strain TAGEM15-70-B6 16S ribosomal RNA gene, partial sequence	1463	1463	100%	0.0	100.00%	MG584449.1
Enterobacter cloacae strain VM17 16S ribosomal RNA gene, complete sequence	1463	1463	100%	0.0	100.00%	MF953264.1
Enterobacter sp. UIWRF0109 16S ribosomal RNA gene, partial sequence	1463	1463	100%	0.0	100.00%	

Feedback

Plate 10. *In-silico* analysis of *Enterobacter cloacae* isolates (MB-1 and MB-2)

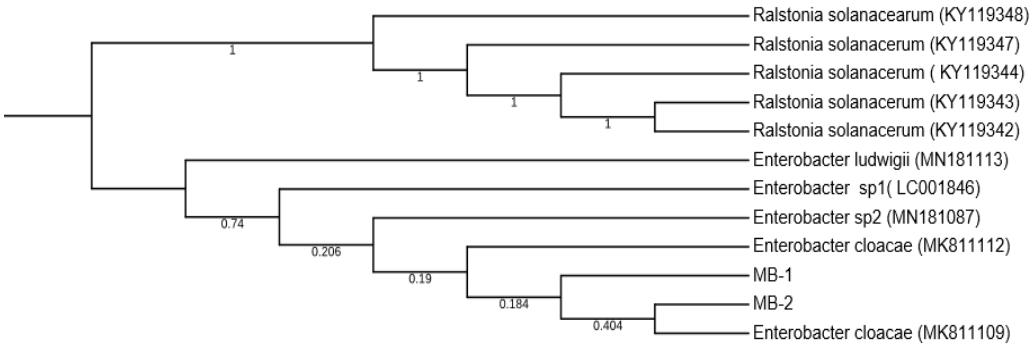


Figure 5. UPGMA dendrogram of *Enterobacter cloacae* isolates

(MB-1 and MB-2)

Ralstonia solanacearum in electron micrograph is different from the bacterial wilt pathogen of solanaceous vegetables and it is similar to *E. cloacae*. The wilt pathogen of marigold identified as *E. cloacae* for the first time in India, is an emerging pathogen in the crop. Association and pathogenicity of the bacterium in wilt of tomato (Sarkar and Chaudhuri, 2015), ginger (Cosmas *et al.*, 2016) and chilli pepper (Garcia-Gonzalez *et al*., 2018) has been reported earlier from West Bengal, Malaysia and Mexico respectively.

D. Vegetative parameters

The thirty two marigold genotypes were evaluated in the field during rainy season and observations were recorded on vegetative parameters *viz.,* plant height, plant spread, stem girth, number of primary branches and stem coloration.

a. Plant height

Data pertaining to the plant height of different marigold genotypes are presented in Table 5. During 30 and 60 DAT, plant height differed significantly among the genotypes.

At 30 DAT, the maximum plant height was recorded in P-4 (44.43 cm) and it was on par with Maria 91 (41.03 cm), Coimbatore Local (40.93 cm), Double orange (40.73cm), Royal orange (39.77 cm), Bhagwati (38.93 cm), Nilakottai Local (38.73 cm), Rupa (37.03 cm), Sakura 031 (35.93 cm), Dharmapuri Local (35.57 cm), Red brocade (35.33 cm), Suvarna Yellow (34.87 cm), Bhuvana (34.70 cm), Hisar Jafri 2 (34.60 cm) and Suvarna Orange (34.17 cm). The lowest plant height was recorded in M-1 (14.23 cm) which was on par with M-2 (19.07 cm). However, at 60 DAT, the greatest plant height was recorded in *T. erecta* genotypes *viz*. Royal Orange (112.90 cm), Maria 91 (111.60 cm), Bhagwati (109.20 cm), Double Orange (101.53 cm) and P-4 (100.87 cm) and these were on par with regard to the parameter. At 60 DAT also, height was lower for *T. erecta* genotypes like M-1 (46.50 cm), M-2 (53.87cm) and *T. patula* genotypes *viz.,* KDA-2 (46.57 cm), KDA-4 (50.23 cm) and KDA-3 (50.33 cm).

b. Plant spread

Among all the genotypes, significant difference could be observed in plant spread at 30 and 60 DAT and the data pertaining to plant spread is depicted in Table 5. The greatest plant spread was recorded in genotypes Pusa Arpita (33.03 cm), Hisar Jafri- 2 (32.37 cm), P-4 (31.47 cm), Maria 91 (29.00 cm), Royal Orange (27.97 cm), Double Orange (27.57 cm), Bhagwati (27.40 cm), Nilakottai Local (27.30 cm), Rupa (26.83 cm), Chintamani Red (26.27 cm), TNAU Dwarf Marigold (25.87 cm) and Suvarna Yellow (24.57 cm) and these were on par with each other at 30 DAT. At 60 DAT also, the widest spread of plant was recorded in genotype *viz.*, Pusa Arpita (54.44 cm) which was on par with P-4 (52.63 cm), Maria 91 (52.25 cm), TNAU Dwarf Marigold (51.86 cm), M-1 (50.83 cm), Royal Orange (50.07 cm), Bhagwati and Chintamani Red (49.58 cm), KDA-3 (49.03 cm), KDA-2 (48.39 cm), Double Orange (48.01 cm), Rupa (47.85 cm) Dharamapuri Local (47.31 cm), KDA-4 (46.28 cm) and Suvarna Orange (46.15 cm).

c. Stem girth

The data on stem girth is presented in Table 6. Genotypes were on par and the value of stem girth ranged from 3.93 cm to 6.20 cm.

d. Number of primary branches

Number of primary branches per plant was significantly different among the genotypes and the data pertaining to this parameter is presented in Table 6. At 30 DAT, more number of branches per plant was recorded in cv. Hisar Jafri-2 and many genotypes which ranged from 7.53 to 9.93 and these were on par. At 60 DAT also the same trend followed and Hisar Jafri-2 recorded maximum number of branches (10.23) which was on par with many genotypes that ranged from 8.13 to 10.23.

e. Stem coloration

Genotypes exhibited the variation in stem coloration (Table 6). The stem colour varied from green to greyed purple. As per RHS colour chart sixth edition (2015)., among the green colour itself, the color ranged from 132-A to 135-C in selected genotypes. Green-132-A was observed in Royal Orange, Bhuvana and TNAU Dwarf

Marigold, whereas Suvarna Yellow, Hawaii Orange and TNAU Marigold expressed Green-132-B while Green-132-C was observed in Suvarna Orange, Rupa, P-4, Sakura 031 and *Tagetes tenuifolia*. Genotype M-1 expressed a stem color of Green -134-A, Coimbatore Local with the coloration of Green N- 134-A, M-2 having Green-134-B, (Dharamapuri Local with Green N- 134-B), Madikeri Local with Green N- 134-C, Double Yellow and Pusa Narangi Gainda having Green -135-A, Arka Bangara 2 with Green -135-B and Green-135-C colour in Double Orange, Arka Agni and Nilakottai Local. Some genotypes showed colour in greyed purple of 183-B series (Hisar Jafri 2, Pusa Arpita, Red brocade and Chintamani Red). The genotypes like Pusa Bsanti Gainda, Bhagwati, Maria 91, KDA-2, KDA-3 and KDA-4 were grouped in the series of greyed purple 187-B.

There was wide variation in plant height among the genotypes and this could be due to individual genotypic growth habit and the genetic constitution might have influenced the parameter. Differences among marigold genotypes with regard to plant height have been reported in earlier studies by Khanvilkar *et al*. (2003);Singh and Mishra (2008);Bharathi and Jawaharlal(2014);Deepa *et al*. (2016);Manik and Sharma (2016);Basheer (2017) and Umesh *et al*. (2018).

Among the species of marigold and their genotypes wide variations with respect to plant spread at 30 and 60 DAT were observed. Variation in plant spread was also observed by Singh *et al*. (2007) on evaluation of 10 genotypes of each of French marigold and African marigold. Plant spread is also a character influenced by the genetic constitution of the plant (Manik and Sharma, 2016). It has also been attributed to the congenial environmental condition that facilitated the expression of the dominant genes as well as the genetic makeup (Patokar *et al*., 2018). From the data (Table 5), it could also be inferred that wider plant spread was recorded for those genotypes with more height and this might be due to the direct relationship between these characters. Umesh *et al*. (2018) also observed the same trend in marigold. Positive correlation between plant height and spread was reported by Raghuvanshi and Sharma (2011).

Table 5. Vegetative parameters of *Tagetes* spp.

Genotypes (Treatments)	Plant height (cm)		Plant spread (cm)	
	30 DAT	60 DAT	30 DAT	60 DAT
Double Orange	40.73	101.53	27.57	48.01
Double Yellow	26.40	69.63	16.77	34.96
Pusa Narangi Gainda	32.00	93.07	20.43	41.86
Pusa Basanti Gainda	23.00	73.90	14.47	37.03
Suvarna Orange	34.17	92.87	24.10	46.15
Suvarna Yellow	34.87	83.90	24.57	40.48
Arka Agni	21.47	65.77	15.70	36.00
Arka Bangara 2	24.57	64.30	17.83	33.57
Bhuvana	34.70	85.07	24.47	40.90
Hawaii Orange	28.10	83.60	16.73	39.19
Rupa	37.03	86.17	26.83	47.85
P-4	44.43	100.87	31.47	52.63
Bhagwati	38.93	109.20	27.40	49.58
Royal Orange	39.77	112.90	27.97	50.07
Sakura 031	35.93	92.30	22.67	44.71
Maria 91	41.03	111.60	29.00	52.25
M-1	14.23	46.50	18.17	50.83
M-2	19.07	53.87	21.90	45.00
Dharmapuri Local	35.57	89.37	22.83	47.31
Coimbatore Local	40.93	92.13	24.20	41.46
Madikeri Local	27.67	76.50	17.70	43.08
Nilakottai Local	38.73	92.53	27.30	46.03
TNAU Marigold	24.43	58.50	21.17	45.32
Hisar Jafri 2	34.60	71.90	32.37	44.67
Pusa Arpita	31.40	82.17	33.03	54.44
Red brocade	35.33	84.43	23.33	40.46
TNAU Dwarf Marigold	28.50	70.80	25.87	51.86
KDA-2	19.60	46.57	18.70	48.39
KDA-3	21.93	50.33	18.40	49.03
KDA-4	22.77	50.23	22.17	46.28
Chintamani Red	28.50	66.13	26.27	49.58
Tagetes tenuifolia	24.27	83.20	15.23	38.63
C.D(0.05)	10.43	19.46	8.75	8.36
SEm±	3.68	6.87	3.09	2.95

Table 6. Vegetative parameters of *Tagetes* spp.

Genotypes (Treatments)	Stem girth (cm)		Primary branches		Stem coloration (RHS colour chart)
	30 DAT	60 DAT	30 DAT	60 DAT	
Double Orange	2.80	5.57	7.53	8.50	Green-135-C
Double Yellow	2.07	4.43	3.87	4.47	Green -135-A
Pusa Narangi Gainda	2.57	5.27	6.53	9.40	Green -135-A
Pusa Basanti Gainda	1.63	4.30	4.80	8.13	Greyed purple-187-B
Suvarna Orange	2.57	5.33	6.77	7.00	Green -132-C
Suvarna Yellow	2.73	5.57	7.60	8.40	Green -132-B
Arka Agni	2.27	4.97	4.40	6.93	Green -135-C
Arka Bangara 2	2.30	5.57	5.30	9.90	Green -135-B
Bhuvana	2.57	5.10	7.50	9.23	Green -132-A
Hawai Orange	2.07	4.47	6.07	8.27	Green- 132-B
Rupa	2.93	5.63	8.57	9.43	Green- 132-C
P-4	3.10	6.00	9.30	10.03	Green- 132-C
Bhagwati	2.90	6.20	7.80	9.33	Greyed purple- 187-B
Royal Orange	2.47	4.83	8.23	8.27	Green- 132-A
Sakura 031	2.70	5.10	7.03	7.23	Green- 132-C
Maria 91	3.10	5.87	9.33	9.80	Greyed purple- 187-B
M-1	2.17	5.70	4.67	5.87	Green- 134-A
M-2	3.90	4.90	4.90	5.73	Green- 134-B
Dharmapuri Local	2.40	5.00	6.30	7.43	Green- N-134-B
Coimbatore Local	2.73	5.13	6.27	9.93	Green- N-134-A
Madikeri Local	2.20	4.70	5.63	6.27	Green- N-134-C
Nilakottai Local	2.70	5.27	6.47	6.30	Green- 135-C
TNAU Marigold	2.10	4.47	5.30	6.90	Green- 132-B
Hisar Jafri 2	3.07	4.57	9.93	10.23	Greyed purple -183-B
Pusa Arpita	3.33	5.77	9.63	10.17	Greyed purple -183-B
Red brocade	4.17	4.33	6.53	6.77	Greyed purple -183-B
TNAU Dwarf Marigold	2.17	3.93	6.17	6.67	Green -132-A
KDA-2	2.10	4.90	5.17	9.40	Greyed purple -187-B
KDA-3	1.93	4.83	4.27	6.43	Greyed purple -187-B
KDA-4	2.30	4.80	5.40	6.80	Greyed purple -187-B
Chintamani Red	2.80	4.47	7.00	7.33	Greyed purple -183-B
Tagetes tenuifolia	2.60	4.87	4.60	6.63	Green-132-C
C.D (0.05)	NS	NS	2.77	2.20	
SEm±	0.44	0.48	0.98	0.78	

The stem girth did not vary significantly among the genotypes. It could be due to that environmental conditions might not have prevailed during experimentation to attain variations in stem girth. Umesh *et al*. (2018) also could not observe significant difference with regard to stem girth of marigold genotypes.

Variations were observed in number of primary branches of marigold genotypes and this was vivid in both *T. erecta* and *T. patula*. Hisar Jafri-2 (*T. patula*) with more primary branches were performing on par with many *T. erecta* genotypes. Hence, it could be concluded that this particular parameter was also highly dependent on the genetic makeup of the genotypes. In marigold this has been reported by many scientists (Nursude *et al*., 2010; Choudhary *et al*., 2014; Mohanty *et al.*, 2015 and Umesh, *et al*., 2018).

Variation of stem colour was noticed among the genotypes. The selected genotypes had showed stem colour ranging from green to greyed purple. Normally, greyed purple colour was predominant in French marigold types, also in some *T. erecta* genotypes with orange colorued flowers *viz.,* Maria-91, Pusa Basanthi Gianda and Bhagwati. Within the green colour, there was great variations in the shades of green as evident from the Table 6. This type of variation was mainly due to inheritance pattern of the particular trait in the genotypes. Differences in stem color of marigold genotypes have been observed by Pramila *et al.* (2011) and Bharathi *et al.* (2014).

E. Reproductive parameters

Data pertaining to various reproductive parameters categorised into three major headings *viz.,* flowering parameters (days to bud initiation, day to initiation of flower opening, days to complete flower opening and days to 50 per cent flowering), floral parameters (Flower diameter, stalk length, flower weight, petal weight and flower colour) and yield parameters (Number of flowers, yield and number of harvests per plant). These parameters were statistically analysed and presented in Tables 7 to 9.

E.1. Flowering parameters

a. Days to flower bud initiation

Among all the genotypes (Table 7), earliest flower bud initiation was observed in KDA-4 (35.50 days) which was on par with Chintamani Red (36.43 days), KDA-3 (37.73 days), Rupa (38.90 days), Arka Agni (38.13 days) , KDA-2 (38.10 days), P-4 (39.93 days), Sakura 031 (39.17 days), Maria 91 (39.13 days), Coimbatore Local (39.10 days), Suvarna Yellow (40.97 days), TNAU Dwarf Marigold (40.77 days), Pusa Narangi Gainda (41.87 days) and Bhagwati (41.13 days). *T. patula* genotypes *viz.,* Hisar Jafri 2, Pusa Arpita and Red Brocade did not flower during June to September whereas, the other *T. patula* genotypes TNAU Dwarf Marigold, KDA -2, KDA-3, KDA -4 and Chintamani Red flowered during the season and these types genotypes are suitable for rainy season cultivation in tropical plains of Kerala. Among all the genotypes, the two wilt resistant genotypes M-1 (77.77 days) and M-2 (68.47 days) were showing very late flowering when planted in June.

b. Days to initiation of flower opening

The data presented in Table 7 shows that the genotype Chintamani Red took the lowest number of days for initiation of flower opening after bud initiation (49.57 days) and this was on par with KDA-4 (53.57 days), KDA-3 (54.67 days), Arka Agni (54.30 days), KDA-2 (54.07 days), Rupa (55.93 days), Maria 91 (55.23 days), Sakura 031 (56.67 days) and Coimbatore Local (56.63 days). Among the genotypes, M-1 had significantly maximum number of days (94.80 days) for initiation of flower opening after bud initiation which was on par with M-2 (90.57 days).

c. Days to complete flower opening

The data pertaining to the parameter is presented in Table 7. All the *T. patula* genotypes except TNAU Dwarf Marigold exhibited lower number of days to complete the opening of a single flower form initiation of flower opening and these *T. patula* genotypes were Chintamani Red (57.67days) KDA-2 (63.47 days), Maria 91 (64.83 days), KDA-3 (65.87 days), KDA-4 (67.17 days) which was on par with *T. erecta* genotypes *viz.,* Coimbatore Local (66.53 days), Sakura 031 (67.80 days)

Arka Agni (67.50 days), Bhagwati (68.70 days), Rupa (68.27 days) and Pusa Narangi Gainda (69.67 days). Among all the genotypes, M-1 significantly took the highest number of days (109.47 days) for complete flower opening which was on par with M-2 (103.20 days).

d. Days to 50 per cent flowering

Days to 50 per cent flowering significantly differed among the genotypes and the data presented in Table 7. The genotype KDA-3 and KDA-4 took the lowest number of days to 50 per cent flowering (34.00 days), which was on par with almost all genotypes except Double Orange, Double Yellow, Pusa Basanti Gainda, Hawaii Orange, Royal Orange, Dharmapuri Local, Madikkeri Local, Nilakottai Local, TNAU Marigold and *T. tenuifolia*. Days to fifty percent flowering was very late in two genotypes *viz.,* M-1 (76.67 days) and M-2 (67.67 days).

E.2. Floral parameters

a. Flower diameter

Table 8 depicts the significant difference recorded for flower diameter among the genotypes. The greatest flower diameter was recorded in the genotype Sakura 031 (9.07 cm) which was on par with Maria 91 and Bhagwati (8.73 cm), P-4 (8.43 cm) and Rupa (7.77 cm). The lowest flower diameter of 4.00 cm in *T. erecta* genotypes was was recorded in genotype Pusa Basanti Gainda which was on par with M-1 (4.77), M-2 (5.60 cm), Bhuvana (5.40), Coimbatore Local (5.07 cm) and *T.patula* genotypes *viz*., TNAU Dwarf Marigold (4.17), Chintamani Red (4.37), KDA-2 (4.43), KDA-3 (4.50) and KDA-4 (4.73).

b. Stalk length

Significant difference was recorded in flower stalk length among the genotypes (Table 8). In general, the stalk length was more in *T.erecta* genotypes compared to *T.patula* genotypes. The longest stalk was recorded in the genotype Bhagwati (13.77 cm), which was on par with genotype *viz.,* TNAU Marigold (13.47cm), P-4 (13.40 cm), Arka Agni (13.00 cm), Hawaii Orange (12.77 cm), Pusa Narangi Gainda (12.57 cm), Maria 91 (12.50 cm), Sakura 031 (12.23 cm), *T. tenuifoila* (11.77 cm) and

TNAU Dwarf marigold and Double Orange (11.07 cm). Shorter flower stalks ranging from 5.50 cm to 8.37 cm were observed in the genotypes M-1, Coimbatore Local, Nilakottai Local, KDA-2, KDA-3, M-2, Suvarna Yellow, Bhuvana, KDA-4, Rupa and Chintamani Red.

c. Flower weight

There was significant difference among the genotypes with respect to flower weight. The greatest flower weight was recorded in Sakura 031 (24.17 g) followed by Bhagwati (17.00 g) which was on par with Rupa, Maria 91 and P-4 (16.40, 15.57 and 15.37 g, respectively). In majority of *T. erecta* genotypes except Pusa Narangi Gainda, the flower weight ranged from 4.77 g to 24.17 g while in the case of *T. patula* genotypes, the flower weight ranged from 2.70 g to 3.53 g.

d. Weight of ray florets

This parameter was varying significantly among the genotypes. In general weight of ray florets was more in *T. erecta* genotypes compared to genotypes of *T. patula* and *T. tenuifolia*. Significantly greatest weight of ray florets was recorded in Sakura 031 (17.93 g) followed by Rupa (12.07 g) which was on par with Bhagwati (11.67g). The lowest weight of ray florets was recorded in KDA-2 (1.23 g) which was on par with Chintamani Red and it was ranged from 1.43 to 4.33 g.

e. Flower colour

Flower colour and different shades of colours observed among the genotypes are presented in Table 8. The flower colour of the genotypes showed wide range of yellow, orange and red among the selected genotypes. As per RHS colour chart (6^{th} edition 2015), in yellow colour 9-A (Double Yellow), Vivid yellow 9-B (Pusa Basanti Gainda, Suvarna Yellow, Arka Bangara-2, Rupa, Sakura 031 and M-1), Light yellow-18-A (Coimbatore Local).

Table 7. Flowering parameters of *Tagetes* spp.

Genotypes (Treatments)	Days taken to			
	Bud initiation	Initiation of flower opening	Complete flower opening	50 % flowering
Double Orange	44.07	63.47	78.60	41.67
Double Yellow	46.73	68.50	83.43	43.00
Pusa Narangi Gainda	41.87	59.20	69.67	40.33
Pusa Basanti Gainda	55.37	74.87	91.90	57.00
Suvarna Orange	45.33	65.40	79.33	41.00
Suvarna Yellow	40.97	59.60	74.03	39.00
Arka Agni	38.13	54.30	67.50	37.00
Arka Bangara 2	45.50	60.10	76.37	40.00
Bhuvana	43.57	65.00	77.57	41.00
Hawaii Orange	43.63	63.17	76.30	42.00
Rupa	38.90	55.93	68.27	36.33
P-4	39.93	59.93	70.67	37.00
Bhagwati	41.13	58.87	68.70	39.00
Royal Orange	46.13	69.50	84.13	43.33
Sakura 031	39.17	56.67	67.80	36.33
Maria 91	39.13	55.23	64.83	36.33
M-1	77.77	94.80	109.47	76.67
M-2	68.47	90.57	103.20	67.67
Dharmapuri Local	53.80	70.07	85.33	53.67
Coimbatore Local	39.10	56.63	66.53	38.33
Madikeri Local	44.10	63.43	77.17	43.67
Nilakottai Local	44.57	60.57	75.37	44.00
TNAU Marigold	46.17	66.70	81.57	45.00
Hisar Jafri 2	NF	NF	NF	NF
Pusa Arpita	NF	NF	NF	NF
Red brocade	NF	NF	NF	NF
TNAU Dwarf Marigold	40.77	59.27	70.93	41.00
KDA-2	38.10	54.07	63.47	36.67
KDA-3	37.73	54.67	65.87	34.00
KDA-4	35.50	53.57	67.17	34.00
Chintamani Red	36.43	49.57	57.67	35.33
Tagetes tenuifolia	45.33	62.40	74.83	45.67
C.D. (0.05)	7.06	9.06	11.68	7.22
SEm±	2.49	3.19	4.11	2.54

* (NF- No flowering was observed)

Table 8. Floral parameters of *Tagetes* spp.

Genotypes (Treatments)	Flower diameter (cm)	Stalk length (cm)	Flower weight (g)	Weight of ray florets (g)	Flower colour (RHS colour chart)
Double Orange	7.17	11.07	12.20	6.87	Vivid orange-28-B
Double Yellow	5.90	8.90	8.80	5.10	Yellow-9-A
Pusa Narangi Gainda	7.23	12.57	8.00	3.73	Strong orange-24-B
Pusa Basanti Gainda	4.00	9.40	3.90	1.50	Vivid yellow-9-B
Suvarna Orange	6.33	9.60	9.73	5.10	Strong orange-24-A
Suvarna Yellow	5.73	7.97	6.03	3.33	Vivid yellow-9-B
Arka Agni	7.27	13.00	13.17	9.53	Strong orange-24-B
Arka Bangara 2	6.80	10.57	10.87	7.67	Vivid Yellow-9-B
Bhuvana	5.40	8.07	6.33	3.43	Light orange-28-C
Hawaii Orange	5.73	12.77	9.00	4.90	Strong orange-24-B
Rupa	7.77	8.27	16.40	12.07	Vivid yellow-9-B
P-4	8.43	13.40	15.37	9.47	Strong orange24-B
Bhagwati	8.73	13.77	17.00	11.67	Strong orange-N-25-A
Royal Orange	6.00	10.03	8.97	5.57	Strong orange-N-24-A
Sakura 031	9.07	12.23	24.17	17.93	Vivid Yellow-9-B
Maria 91	8.73	12.50	15.57	10.27	Strong orange-28-C
M-1	4.77	5.50	6.80	4.27	Vivid yellow-9-B
M-2	5.60	7.93	5.87	4.00	Light orange-28-C
Dharmapuri Local	5.87	10.33	7.17	3.57	Light orange-28-C
Coimbatore Local	5.07	7.00	4.77	1.47	Light yellow-18-A
Madikeri Local	6.43	8.60	10.90	6.00	Strong orange-24-A
Nilakottai Local	6.43	7.27	10.53	7.43	Strong orange yellow-17-A
TNAU Marigold	5.67	13.47	7.90	4.33	Vivid orange yellow 21-A
Hisar Jafri 2	NF	NF	NF	NF	NF
Pusa Arpita	NF	NF	NF	NF	NF
Red brocade	NF	NF	NF	NF	NF
TNAU Dwarf Marigold	4.17	11.07	2.87	1.53	Vivid orange yellow-23-A
KDA-2	4.43	7.33	2.87	1.23	Strong orange-24-A
KDA-3	4.50	7.43	2.70	1.50	Strong reddish orange-31-B
KDA-4	4.73	8.27	3.53	2.00	Strong orange-24-A
Chintamani Red	4.37	8.37	2.83	1.43	Moderate Red-N-34-A
Tagetes tenuifolia	6.97	11.77	7.50	3.93	Strong orange-24-A
C.D(0.05)	1.64	3.09	4.43	3.46	
SEm±	0.58	1.09	1.56	1.22	

* (NF- No flowering was observed)

In orange series, Strong Orange-24-A (Suvarna Orange, Madikeri Local, KDA-2, KDA-4 and *T. tenuifolia*), Strong Orange-N-24-A (Royal Orange), Strong Orange-24-B (Pusa Narangi Gainda, Arka Agni, Hawaii Orange and P-4), Strong Orange-N-25-A (Bhagwati), Vivid Orange -28-B (Double Orange), Strong Orange -28-C (Maria 91), Light Orange -28-C (Bhuvana, M-2 and Dharamapuri Local). Whereas in combination of orange with yellow, Strong Orange Yellow-17-A (Nilakottai Local), Vivid Orange Yellow-21-A (TNAU Marigold), Vivid Orange Yellow-23-A (TNAU Dwarf Marigold). Orange in combination with red and strong reddish orange-31-b was noticed in KDA-3. Chintamani Red was noticed under red colour series which denotes moderate Red-N-34-A.

E.3. Yield parameters

a. Number of flowers per plant

Data regarding number of flowers per plant recorded for the genotypes are given in the Table 9. Among the genotypes, significantly greater number of flowers per plant was recorded in P-4 (59.10) which was on par with Maria 91 (52.07), Bhagwati (51.23), M-2 (47.67) and KDA-3 (44.00).

b. Flower yield per plant

Data pertaining to flower yield per plant are presented in Table 9. Wide variations were observed in yield among the genotypes. *T. erecta* genotypes were showing more yield per plant compared to *T. patula* genotypes. The greatest flower yield was recorded in P-4 (476.50 g/plant) which was significantly superior to all other genotypes. This was followed by Maria 91 (355.17 g/plant) which was on par with Bhagwati (319.73 g/plant). In general, *T. erecta* genotypes recorded more yield compared to *T. patula* genotypes.

c. Number of harvests per plant

Data with respect to number of harvests per plant is given in Table 9. Significantly more number of harvests (5.33) per plant was recorded in, P-4 and Bhagwati, KDA-3 which were on par with KDA-4 and Maria 91 (5.00), Arka Agni (4.33), Sakura 031 and TNAU Marigold (4.00).

Table 9. Yield parameters of *Tagetes* spp.

Genotypes (Treatments)	No. of flowers per plant	Flower yield per plant (g)	No. of harvests
Double Orange	22.77	160.07	3.67
Double Yellow	7.03	40.00	1.33
Pusa Narangi Gainda	11.47	54.70	3.67
Pusa Basanti Gainda	7.90	38.33	1.33
Suvarna Orange	28.77	136.90	3.67
Suvarna Yellow	12.70	68.13	2.00
Arka Agni	24.23	147.73	4.33
Arka Bangara 2	12.90	74.40	3.00
Bhuvana	6.10	34.07	2.00
Hawaii Orange	14.70	67.30	3.67
Rupa	19.33	206.87	3.00
P-4	59.10	476.50	5.33
Bhagwati	51.23	319.73	5.33
Royal Orange	24.57	132.10	3.00
Sakura 031	27.37	284.07	4.00
Maria 91	52.07	355.17	5.00
M-1	17.30	109.30	2.67
M-2	47.67	291.77	3.00
Dharmapuri Local	28.00	216.67	3.00
Coimbatore Local	14.87	63.00	1.67
Madikeri Local	36.77	235.27	3.67
Nilakottai Local	14.07	49.53	2.33
TNAU Marigold	37.37	233.67	4.00
Hisar Jafri 2	NF	NF	NF
Pusa Arpita	NF	NF	NF
Red brocade	NF	NF	NF
TNAU Dwarf Marigold	12.33	38.20	3.00
KDA-2	16.30	49.87	3.33
KDA-3	44.00	93.40	5.33
KDA-4	34.33	69.17	5.00
Chintamani Red	17.57	61.83	3.33
Tagetes tenuifolia	7.97	39.17	2.33
C.D(0.05)	19.40	53.19	1.44
SE(m+/-)	6.83	18.72	0.51

*(NF- No flowering was observed)

F. Correlation among growth and yield attributes in marigold

Correlation among growth and yield attributes of *T. erecta* and *T. patula* were done and data are presented in Appendix I and II.

a. *Tagetes erecta*

Characters like plant spread, flower diameter, stalk length, flower weight, weight of ray florets, number of flowers per plant, number of harvests per plant and total carotenoids showed significant positive correlations with regard to flower yield. However, flowering parameters like days to bud initiation and days to 50 per cent flowering showed negative correlation but not significantly.

b. *Tagetes patula*

Among the characters, only the number of flowers per plant and number of harvests per plant were having significant positive correlation to the flower yield in *T. patula*.

Results of the field evaluation studies on floral characters with respect to day's to bud initiation, days to initiation of flower opening, days to complete flower opening, days to 50 per cent flowering, flower diameter, stalk length, flower weight, petal weight, number of flowers, flower yield per plant and number of harvest per plant are discussed below.

Majority of the genotypes started flower bud initiation 30 days after transplanting. However, there were two exceptional genotypes M-1 and M-2, which initiated buds very late, like 68 to 77 days after transplanting. Other parameters like initiation of flower opening, completion of flower opening and days to 50 per cent flowering also followed the similar trend. The remarkable variation among the genotypes for various flowering parameters is mainly due to the inheritance pattern and response of the genotypes to the prevailing environment. The differences in flowering parameters could be due to the different time period taken by the different genotypes based on their genetic makeup. Variation in flowering parameters has been reported in *T. erecta* by Umesh (2017) and Singh and Singh (2005); Basheer, (2017) in *T. patula.* The study also revealed varied flowering behaviour of *T. patula* genotypes when

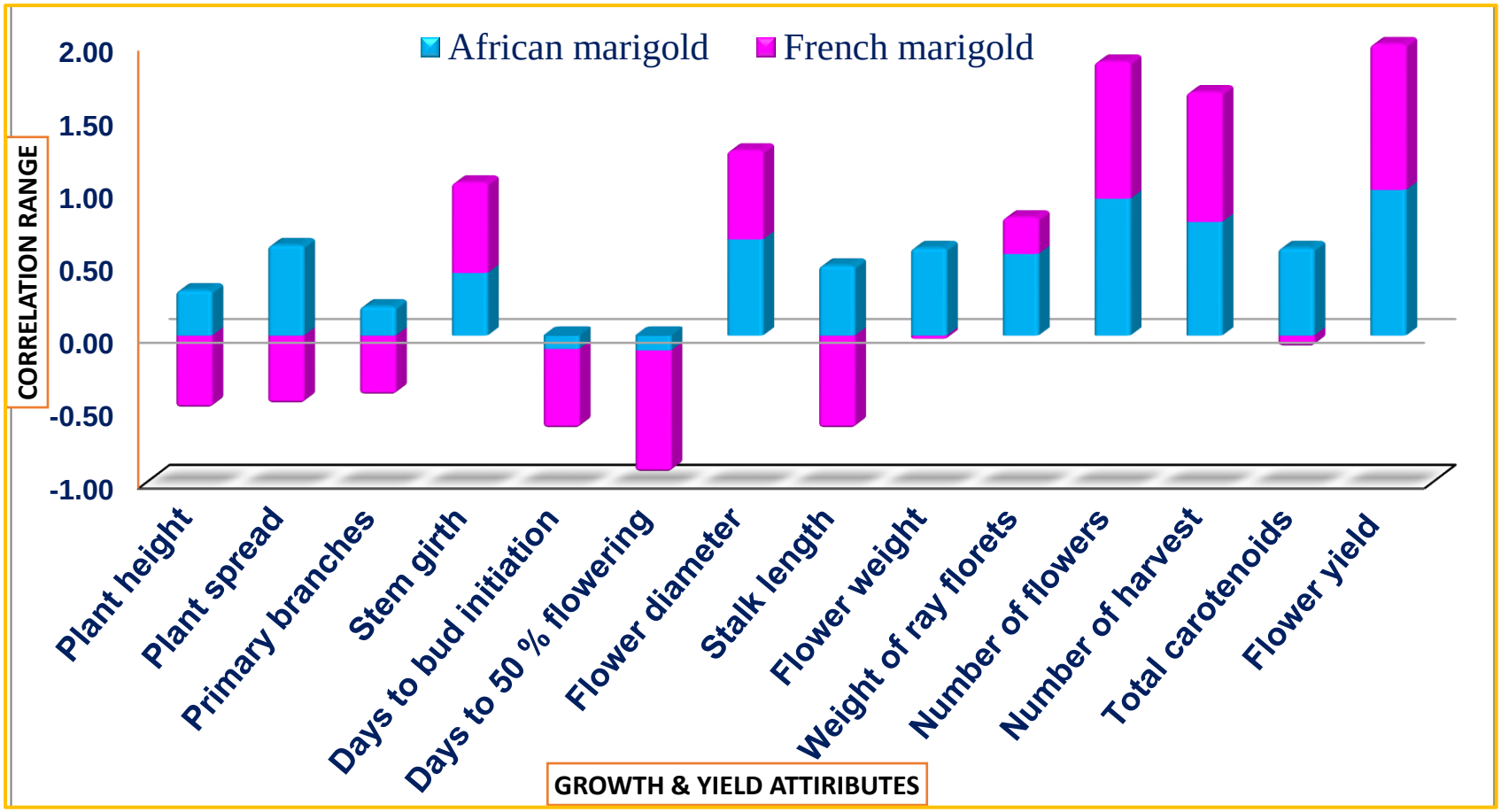


Figure 6. Correlation among growth and yield attributes of *Tagetes* spp.

planted during the rainy season *i.e.* June to September in Kerala. Some *T. patula* genotypes *viz.*, KDA-2, KDA-3, KDA-4, Chintamani Red and TNAU dwarf marigold flowered during the rainy season in Kerala whereas genotypes *viz.*, Hisar Jafri-2, Pusa Arpita and Red brocade did not flower at all during this season. Usually in Kerala, *T. patula* (French marigold) is grown in gardens during winter season from November to February. The variation in flowering response among French marigold genotypes might be due to its genetic behaviour and such variations in photoperiodic requirements among French marigold has been reported by Tsukamoto *et al*. (1968).

The floral parameters *viz.*, flower diameter, stalk length, flower weight and petal weight also differed significantly among the genotypes. Among the genotypes the flower diameter was considerably higher in genotypes Sakura 031 (9.07 cm) which was on par with Maria 91, Bhagwati, P-4 and Rupa. These genotypes which are F_1 hybrids also recorded greater flower weight as well as petal weight. The improved hybrid vigour might have contributed to better floral parameters observed in the study. The reason behind their better performance could be that hybrids are intentionally and carefully crossbred to have particular trait which is stated by Ummyiah *et al*. (2016). The longest stalk was recorded in the genotype Bhagwati (13.77 cm) which was on par with many other F_1 hybrids and varieties evaluated. Variation in flower parameters among different genotypes of marigold might be influenced by the genetic makeup

Yield parameters such as number of flowers, yield per plant as well as number of harvests differed significantly among the genotypes. The greatest number of flowers per plant (59.10), yield per plant (426.80 g) as well as number of harvests (5.33) were recorded in P-4 followed by Maria 91 and Bhagwati. Yield in marigold is mostly dependent on flower size, flower weight, number of flowers and number of harvests. Any genotype with greater values for these parameters will be recording more yield. This might be the reason for better yield in P-4 and Bhagwati. Even though the flower diameter and flower weight was more in Sakura 031, the number of flowers was considerably less in this genotype that resulted in lower yield compared to P-4 and Bhagwati. Variation in floral and yield parameters might be attributed to the genetic makeup. Variation in flower yield of different varieties was also observed in African marigold by many scientists earlier also. The present results are in line with the findings

of Raghuvanshi and Sharma (2011), Panwar *et al.* (2013), Narsude *et al.* (2010), Umesh *et al.* (2018) and Singh *et al.* (2015) in African marigold.

Twenty three genotypes of *Tagetes erecta* and five genotypes of *Tagetes patula* were considered for correlation analysis for desirable traits for commercial exploitation. Among the vegetative paramters of *T. erecta*, plant spread showed significant positive correlation with yield and reproductive parameters, flower diameter, stalk length, flower weight, weight of ray florets, number of flowers per plant and number of harvests per plant showed significant positive correlations with regard to flower yield. However in *T. patula*, only the number of flowers per plant and number of harvests per plant were having significant positive correlation to the flower yield (Fig 6). This is mainly due to genetic nature of the genotypes in respective species. The finding is in accordance with the research findings of Namita *et al.* (2009); Vishnupriya *et al.* (2015); Bharathi *et al.* (2014);Lydia and Ponnuswami, (2019) in marigold.

G. Post-harvest studies

a. Shelf life of flowers

Significant difference was observed among the genotypes for shelf life of the flowers (Table 10). Generally *T. erecta* genotypes shower better shelf life compared to genotypes of *T. patula* and *T. tenuifolia*. Both Sakura 031 and Suvarna Orange had greater shelf life of 3.67 days which was on par with shelf life days of 3.33 (Arka Agni, Arka Bangara-2, P-4, Bhagwati, Maria 91), 3.00 (M-1), 2.67 (M-2, Bhuvana, Hawaii Orange and Double Orange), 2.33 (Double yellow, Pusa Basanti Gainda, Royal Orange, Madikeri Local, TNAU Marigold).

b. Physiological loss in weight (PLW) of flowers

Among the genotypes, significant difference was noticed with respect to physiological loss in weight of flowers and it is presented in Table 10. The lowest PLW was recorded in Maria 91 (9.20%) which was on par with Arka Bangara 2 (9.32%), Arka Agni (10.26%), Suvarna Ornage (10.47%), Bhagwati (10.75%), Suvarna Yellow (11.11%), Double Orange (11.32%), Rupa (11.93%), Double Yellow (12.24%), P-4 (12.50%) and Sakura 031 (12.82%).

Table 10. Post-harvest parameters of *Tagetes* spp.

Genotypes	PLW (%)	Shelf life (days)
Double Orange	11.32	2.67
Double Yellow	12.24	2.33
Pusa Narangi Gainda	14.81	1.33
Pusa Basanti Gainda	16.95	2.33
Suvarna Orange	10.47	3.67
Suvarna Yellow	11.11	2.33
Arka Agni	10.26	3.33
Arka Bangara 2	9.32	3.33
Bhuvana	13.64	2.67
Hawaii Orange	19.35	2.67
Rupa	11.93	1.33
P-4	12.50	3.33
Bhagwati	10.75	3.33
Royal Orange	14.29	2.33
Sakura 031	12.82	3.67
Maria 91	9.20	3.33
M-1	25.00	3.00
M-2	24.56	2.67
Dharmapuri Local	18.92	2.00
Coimbatore Local	17.14	2.00
Madikeri Local	14.63	2.33
Nilakottai Local	21.88	2.00
TNAU Marigold	14.00	2.33
Hisar Jafri 2	NF	NF
Pusa Arpita	NF	NF
Red brocade	NF	NF
TNAU Dwarf Marigold	21.43	2.00
KDA-2	16.67	1.00
KDA-3	15.44	1.00
KDA-4	15.48	1.00
Chintamani Red	16.22	2.00
Tagetes tenuifolia	14.89	2.00
C.D. (0.01)	4.12	1.43
SEm±	1.41	0.50

* (NF- No flowering was observed)

Maximum PLW was recorded in M-1 (25.00%) which was on par with M-2 (24.56%), Nilakottai Local (21.88%) and TNAU Dwarf Marigold (21.43%).

There was significant difference in shelf life and PLW of flowers as influenced by different genotypes and their response to the prevailing environment conditions. Increased shelf life and lower PLW of marigold flower could be due to the higher retention of water in the cells of flowers and lower desiccation rate. Although, all the genotypes experienced the same average temperature (29.5^0C) and relative humidity (92.5%) during shelf life study, variation among these genotypes for these traits might be attributed to their genetic makeup. Similar observations in the shelf life of marigold have been reported by Nimisha (2016); Umesh (2017); Mahantesh *et al.* (2018); Naik *et al*. (2019) in marigold.

H. Biochemical parameters

a. Total carotenoids (mg/g)

Data pertaining to the total carotenoids significantly differed among the genotypes and is presented in Table 11. In general, *T. erecta* genotypes recorded greater carotenoid content compared to genotypes of *T. patula* and *T. tenuifolia*. The highest carotenoids content was recorded in genotype Bhagwati (0.105 mg/g) which was followed by Maria 91 (0.095 mg/g) and P-4 (0.094 mg/g). The lowest carotenoid recorded was 0.010 mg/g in genotype, Suvarna Yellow.

b. Flavonoids (A_{300} g^{-1})

The content of flavonoids both in leaves and petals was significantly varying among the genotypes (Table 11). The highest flavonoid content was recorded in M-1 and M-2, which were on par with Bhagwati (Leaves: 4.3, 3.8 and 3.7 A_{300} g^{-1} leaf; Petals: 1.7, 2.0 and 1.6 A_{300} g^{-1} petal, respectively), whereas, the lowest flavonoids content was recorded in Double yellow, which was on par with Coimbatore Local (Leaves: 0.6, 0.9 A_{300} g^{-1} leaf; Petals: 0.1 A_{300} g^{-1}).

Table 11. Biochemical parameters of *Tagetes* spp.

Genotypes	Total carotenoids (mg/g)	Flavonoids (A_{300} g^{-1})		Essential oil (%)	
		Leaves	Petals	Leaves	Petals
Double Orange	0.048	2.2	1.5	0.31	0.10
Double Yellow	0.025	0.6	0.1	0.26	0.10
Pusa Narangi Gainda	0.039	1.8	1.6	0.22	0.10
Pusa Basanti Gainda	0.054	3.0	1.4	0.20	0.10
Suvarna Orange	0.093	1.5	1.0	0.31	0.15
Suvarna Yellow	0.010	1.6	1.4	0.21	0.15
Arka Agni	0.072	2.9	1.4	0.37	0.20
Arka Bangara 2	0.04	3.3	1.5	0.23	0.25
Bhuvana	0.086	2.1	0.9	0.23	0.15
Hawaii Orange	0.047	2.4	1.0	0.20	0.10
Rupa	0.072	2.7	0.5	0.25	0.13
P-4	0.094	1.9	1.2	0.32	0.10
Bhagwati	0.105	3.7	1.6	0.35	0.20
Royal Orange	0.063	2.6	0.9	0.25	0.15
Sakura 031	0.056	2.6	1.0	0.25	0.15
Maria 91	0.095	2.2	1.4	0.33	0.20
M-1	0.048	4.3	1.7	0.36	0.10
M-2	0.078	3.8	2.0	0.37	0.15
Dharmapuri Local	0.034	2.8	0.4	0.21	0.10
Coimbatore Local	0.034	0.9	0.0	0.10	0.10
Madikeri Local	0.066	2.7	1.4	0.23	0.10
Nilakottai Local	0.025	2.8	0.4	0.10	0.10
TNAU Marigold	0.032	3.5	0.6	0.20	0.10
Hisar Jafri 2	NF	2.0	NF	0.10	NF
Pusa Arpita	NF	1.6	NF	0.10	NF
Red brocade	NF	2.8	NF	0.10	NF
TNAU Dwarf Marigold	0.046	0.7	0.7	0.10	0.10
KDA-2	0.041	1.4	0.1	0.10	0.10
KDA-3	0.043	1.0	0.3	0.10	0.10
KDA-4	0.047	0.8	1.2	0.10	0.10
Chintamani Red	0.051	2.0	1.1	0.10	0.10
Tagetes tenuifolia	0.039	2.4	0.9	0.18	0.10
C.D (0.01)	0.001	0.78	0.65	0.06	NS
SEm+/-	0	0.21	0.25	0.02	0.03

* (NF- No flowering was observed)

c. Essential oil (%)

Table 11 shows the essential oil in leaves and petals of marigold genotypes. Among the genotypes, significant difference was noticed in the essential oil content in leaves but not in petals. The variation in the essential oil content was pronounced in leaves of *T. erecta* genotypes which ranged from 0.21 per cent to 0.37 per cent. The highest essential oil percentage recorded in M-2 and Arka Agni (0.37%) which was on par with M-1 (0.36%), Bhagwati (0.35%), Maria 91 (0.33%), P-4 (0.32%) and Suvarna Orange; Double Orange (0.31%).

Significantly greater content of carotenoids (0.105 mg/g) was recorded in Bhagwati as compared to all other genotypes. The difference in total carotenoids content might be due to colour of flower which is dependent on genetic makeup. The findings are in conformity with the research finding of Sreekala, (2000), Rao *et al.* (2005) and Lohar *et al.* (2018) in African marigold. Flavonoids are referred as secondary metabolites that are polyphenolic in nature and essential oil are the derivatives of terpenoids. The highest flavonoid and also essential oil content was recorded in M-1 and M-2, which were at par with Bhagwati in both leaves and petals. The flavonoid content was maximum in leaves than petals, which corroborates with the fact that flavonoids are deposited in epidermal cell layers in the cuticle of leaves (Merzylak *et al.,* 2002).

4.2. Artificial screening against bacterial wilt resistance

a. Per cent disease incidence

Twelve genotypes which were categorised into resistant as well as moderately resistant in the field evaluation were subjected to artificial inoculation. During artificial inoculation studies, the selected genotypes showed significant variation with respect to diseases incidence and days to wilt (Table 12). The two local collections *viz.,* M-1 and M-2 were completely wilt resistant in the artificial screening studies (Table 12). Among other genotypes, Bhagwati showed a lower PDI of 26.70 per cent. Per cent disease incidence in other nine genotypes ranged from 40 per cent to 60 per cent.

b. Days to wilt

Days to wilt also varied significantly among the genotypes during artificial screening studies. Greater number of days taken to show the wilt symptom was noticed in Bhagwati (13.75 days) which was on par P-4 (13.55 days) with KDA-4 (12.95 days), Arka Agni (12.55 days), Madikeri Local (12.16 days), Chintamani Red (11.92 days) and Maria 91 (11.58 days).

The differential response of marigold genotypes during artificial screening against bacterial wilt incidence has been reported by Umesh (2017). The difference might be due to the genetic makeup. Similar findings were also noticed in brinjal by Bhanwar *et al.* (2019). Santhosha *et al.* (2015) attributed stability of resistance against *Ralstonia solancearum* to various secondary metabolites. Among the secondary metabolites, flavonoids plays an important role in imparting resistance to pathogenic bacteria and fungi. The higher flavonoids content in genotypes M-1, M-2 might have imparted resistance to these genotypes.

Table 12. Bacterial wilt incidence in marigold genotypes during artificial inoculation

Genotypes	PDI (%)	Days to wilt	Reaction
Bhagwati	26.70 (3.6)	13.75	S
Royal orange	46.70 (5.9)	9.90	S
Maria 91	60.00 (7.5)	11.58	S
P-4	40.00 (6.3)	13.55	S
Madikeri Local	40.00 (6.3)	12.16	S
KDA-4	53.33 (7.3)	12.95	S
KDA-2	60.00 (7.5)	9.61	S
Chintamani Red	53.33 (7.3)	11.92	S
M-1	0.00 (1.0)	*	R
M-2	0.00 (1.0)	*	R
Arka Bangara 2	46.60 (6.7)	6.44	S
Arka Agni	46.60 (6.7)	12.55	S
C.D (0.01)	4.33	2.69	
SEm ±	1.46	0.90	

* No wilt incidence; (Values in the parenthesis are square root transformed)

4.3. Evaluation of rootstocks for *Tagetes erecta* L.

Data pertaining to evaluation of rootstocks for *Tagetes erecta* L. are presented in Table 13 and 14.

a. Per cent survival of grafts

Grafting success was depended upon the genotypes of rootstock, scion and their interactions (Table 13). It is also evident from the data that F_1 hybrids recorded better graft survival compared to varieties of African marigold. The greatest survival of grafts was recorded in hybrid scion Bhagwati grafted on M-1 rootstock (60%) and this was on par with Bhagwati grafted on M-2 (54%), Maria 91 grafted on M-1 (54%) and Maria 91 grafted on M-2 (50%). Irrespective of the genotype of scions, M-1 as rootstock recorded better graft survival (34.22%) compared to a survival of 25.56 per cent on M-2 rootstock. The scion genotypes had also great influence on graft survival. Irrespective of the rootstock genotypes, the greatest survival was recorded in Bhagwati (57%) which was on par with Maria 91 (52%).

b. Days to graft union

Days to graft union was depended upon the scion genotypes and the interaction between scion and rootstock types, but not with the genotype of rootstock (Table 14) and (Plate 11b). Earliest graft union was observed in Maria 91(4.0 days) grafted on M-1 and M-2 and this was on par with Bhagwati grafted on M-1 (4.0 days), Suvarna Orange and Suvarna Yellow grafted on M-1, both with 4.50 days for graft union. Irrespective of the rootstock genotypes, Maria 91 and Bhagwati recorded earliest graft union compared to other genotypes. Generally F_1 hybrids took less days for graft union in comparison with varieties of African marigold.

The success rate of grafting depends on well-developed connection between vascular bundles of both scion and rootstock. The cleft grafting method selected for this experiment was found out as the best method by Baburaj *et al.* (2018). F_1 hybrids were showing better graft survival compared to varieties. This might be attributed to the hybrid vigour that might have facilitated faster callus differentiation along the cut surfaces and formation of vascular connection between scion and rootstock. Akhila and

George, (2018) reported formation of necrotic layer in response to wound repair and proliferation of cells of rootstock and scion which is the stage prior to callus formation. Dedifferentiation of the cells and re-differentiation of the callus tissue, followed by rapid vascular connection between rootstock and scion as a requisite for graft success has also been reported by Tamilselvi and Pugalendhi (2017).

Among the F_1 hybrids used as scions, Bhagwati and Maria 91 recorded significantly greater graft survival when compared to other genotypes *viz*., Sakura 031, Suvarna Ornage and Suvarna Yellow. Marigold varieties *viz*. Pusa Narangi Gainda, Pusa Basanti Gainda, Double Orange and Double Yellow showed very low per cent graft survival. The reason for poor graft survival in marigold varieties was attributed to their stem anatomy at the stage of grafting (Fig. 7). The cross section of the stem of marigold varieties showed large central hollow portion and this anatomical flaws might have contributed poor vascular connection and successful graft union in varieties. It is also clear from the Plate 11a that the stems of the F_1 hybrids particularly Bhagwati and Maria 91 were very much intact without any central hollowness and this might have promoted early vascular connection between the rootstock and scion which resulted in better graft survival in these hybrids. The anatomical compatibility between rootstock and scion is a determining factor in successful graft union and sometimes anatomical flaws in either in rootstock or scion determine the grafting success has reported by Pérez-Luna *et al*. (2019) in *Pinus engelmannii.* Poor grafts survival in melons due to hollow hypocotyls has been reported by Guan and Zhao (2019). The differential response among the scion genotypes of *Capsicum annuum* has been reported by Soltan *et al*. (2017).

Table 13. Per cent survival of grafts in *Tagetes erecta.* L

Root stocks (Factor A)	Scion genotypes (Factor B)									
	Hybrids					Varieties				Mean A
	Suvarna Orange	Suvarna Yellow	Sakura 031	Maria 91	Bhagwati	Pusa Narangi Gainda	Pusa Basanti Gainda	Double Orange	Double Yellow	
M-1	44	40	42	54	60	30	26	6	6	**34.22**
M-2	42	34	44	50	54	2	4	0	0	**25.55**
Mean B	**43**	**37**	**43**	**52**	**57**	**15**	**6.5**	**3**	**3**	**28.83**
Factors		C.D (0.01)	SEm ±							
Factor (A)		3.64	1.21							
Factor (B)		7.74	2.57							
Factor (AXB)		10.94	3.63							

Table 14. Days to graft union in *Tagetes erecta* L.

Root stocks (Factor A)	Scion genotypes (Factor B)									
	Hybrids					Varieties				Mean A
	Suvarna Orange	Suvarna Yellow	Sakura 031	Maria 91	Bhagwati	Pusa Narangi Gainda	Pusa Basanti Gainda	Double Orange	Double Yellow	
M-1	4.5	4.5	5.0	4.0	4.0	6.0	5.5	5.0	6.0	**4.94**
M-2	5.0	5.0	5.0	4.0	5.0	5.0	5.5	5.5	6.0	**5.05**
Mean B	**4.75**	**4.75**	**5.0**	**4.0**	**4.5**	**5.5**	**5.5**	**5.25**	**6.0**	
Factors		C.D (0.01)	SEm±							
Factor (A)		N	0.07							
Factor (B)		0.50	0.16							
Factor (AXB)		0.70	0.23							

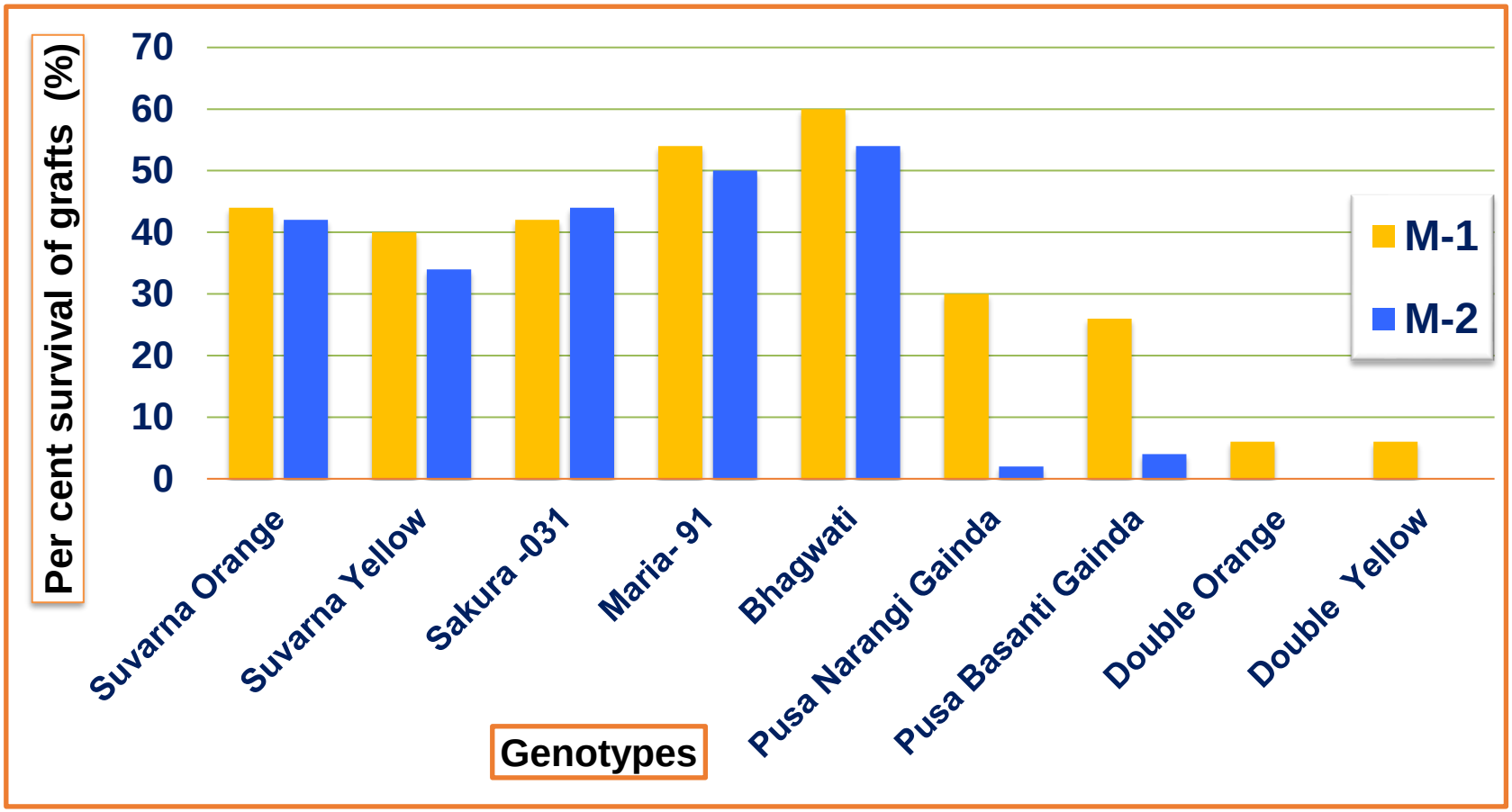
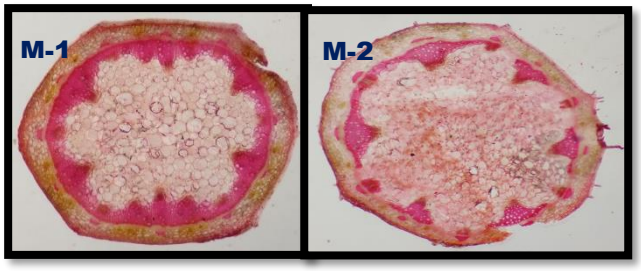
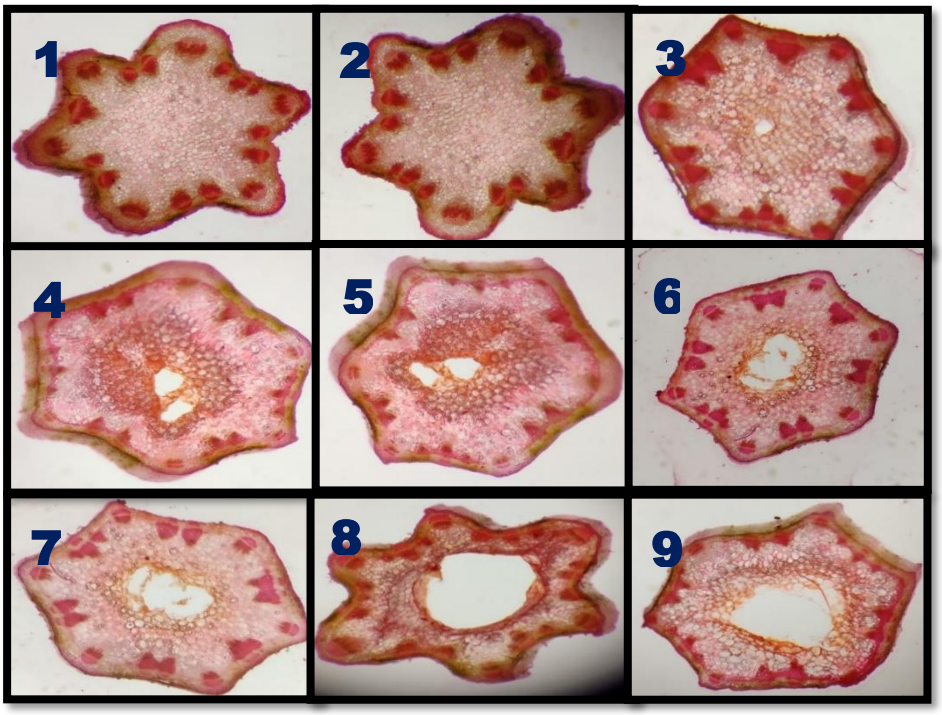


Figure. 7. Survival of grafts in *Tagetes erecta* genotypes



Rootstocks M-1 and M-2



1. Bhagwati, 2. Maria-91, 3. Suvarna Orange 4. Suvarna Yellow,
5. Sakura-031, 6. Pusa Basanti Gainda 7. Pusa Narangi Gainda,
8.Double Orange 9. Double Yellow

Plate 11a. Anatomical view of stem (CS magnified at 40x) of rootstocks and scions at grafting stage

Bhagwati (scion) on M-1(rootstock)

Bhagwati (scion) on M-2(rootstock)

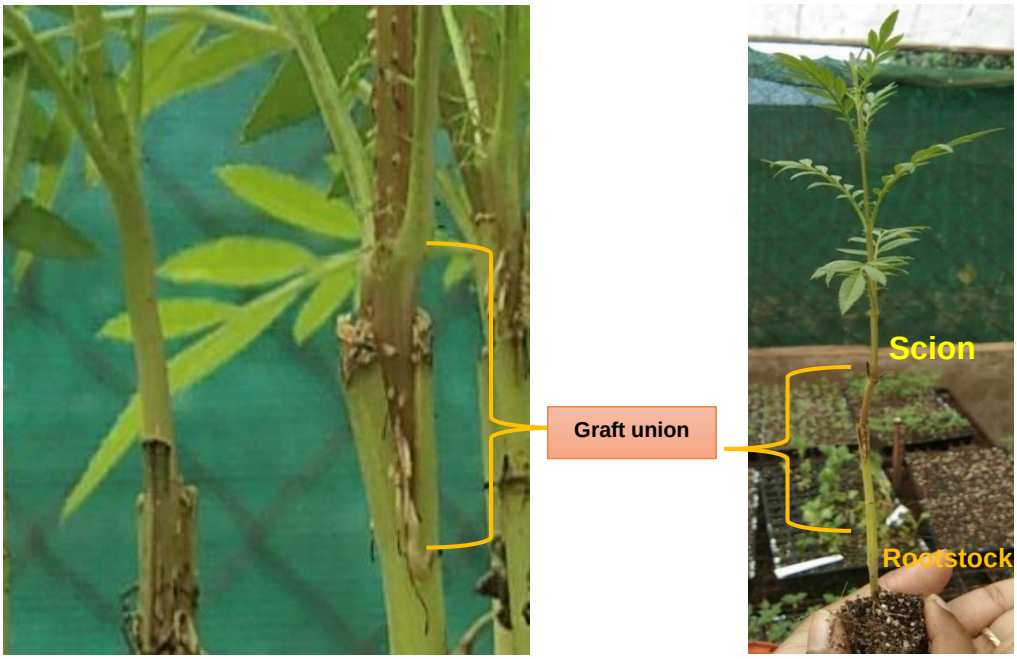


Plate 11b. Grafted marigold plants

4.4. Precision farming techniques and seasonal response of African marigold

Experiments were conducted in three seasons *viz.,* Rainy (June- September), winter (October- January) and summer (January - April) using two marigold genotypes namely, Bhagwati and M-1. The results of the experiments are furnished season wise and discussed hereunder.

4.4.1. Precision farming techniques

A. Vegetative parameters

The data pertaining to vegetative parameters corresponding to rainy, winter and summer seasons are presented in Tables 15, 16 and 17.

a. Plant height

During rainy season (Table 15), at 30 and 60 DAT, hybrid Bhagwati recorded the greatest plant height (60.13 cm and 131.86 cm, respectively) in treatment F_1 (75% RDF), which was followed by a plant height of 50.60 cm and 115.77 cm at 30 and 60 DAT respectively in treatment F_2 (100% RDF). The lowest plant height was recorded in genotype M-1 (control) at both 30 and 60 DAT (9.77 and 41.77 cm, respectively).

During winter season (Table 16), at 30 DAT, hybrid Bhagwati recorded significantly taller plants with a height (56.27 cm) in treatment I_2F_3 which was on par with 55.80 cm in I_2F_1. This was followed by a plant height of 52.87 cm in I_2F_2. At 60 DAT also, the same trend followed with respect to the parameter. Significantly greater plant height (69.80 cm) was recorded in I_2F_3 which was on par with I_2F_2 (67.60 cm) and this was followed by I_2F_1 (61.67 cm) in hybrid Bhagwati. Compared to Bhagwati, plants were shorter in genotype M-1, and the height of this genotype under various levels of irrigation fertigation ranged from 41.30 cm to 55.17 cm. Lowest plant height was recorded in control of the genotype M-1 (36.67 cm). Control treatment showed less plant height in both the genotypes, *viz.,* Bhagwati (45.73 cm) and M-1 (36.67 cm).

Summer season data presented in Table 17 showed that significantly greater plant height (60.77 cm) was recorded in I_2F_2 which was on par with I_2F_3 (59.60 cm), I_2F_1 (59.53 cm) and I_1F_1 (55.40 cm) in hybrid Bhagwati at 60 DAT. During this season

also, the genotype M-1 recorded less plant height compared to Bhagwati and it is evident from the table that height is almost similar in all the treatments including control.

b. Plant spread

Significant difference was found in plant spread among the genotypes. During rainy season, at 30 and 60 DAT, hybrid Bhagwati recorded the highest plant spread (30.18 cm and 61.81cm, respectively) in treatment F_1 (75% RDF), which was followed by F_2 (100% RDF) of 27.55 cm and 53.74 cm, respectively. The control treatments of both genotypes recorded the lower plant spread and it was on par in both Bhagwtai and M-1 at 60 DAT.

During winter season (Table 16), at 60 DAT, plant spread was significantly more in I_2F_3 in both Bhagwati (38.90 cm) and M-1 (36.50 cm). In Bhagwati, the spread in treatments *viz*., I_2F_2 (37.53 cm) and I_2F_1(37.00 cm) were on par with I_2F_3 while in M-1, all other treatments with different levels of irrigation and fertigation recorded significantly lesser plant spread compared to the treatment I_2F_3. In both the genotypes, control showed very low plant spread in comparison with other treatments.

There was significant difference observed among the treatments for plant spread during summer season (Table 17). At 60 DAT, significantly greater plant spread (42.03 cm) was recorded in I_2F_3 which was on par with I_2F_2 (38.90 cm) in hybrid Bhagwati. This was followed by I_2F_1 of 37.37 cm in the same genotype. Plant spread in M-1 was less compared to Bhagwati and it ranged from 30.30 cm to 35.27 cm.

c. Number of primary branches

During rainy season, significant difference could be found in the number of primary branches between the two genotypes at 30 and 60 DAT. At 30 DAT, significantly more number of primary branches was recorded in hybrid Bhagwati (8.60) and M-1 (7.27) fertigated with 75% RDF (F_1), which was on par with treatments F_2 (100% RDF) and F_3 (125% RDF) with 8.07 and 7.40 number of primary branches respectively in Bhagwati. The lowest number of primary branches was recorded in control treatment of both the genotypes. However, at 60 DAT, the treatment F_1

(75% RDF) in Bhagwati recorded the highest number of primary branches (20.58) which was followed by 18.22 branches in F_2 (100% RDF) of the same genotype. Fertigation with 75% RDF also showed better performance with respect to the parameter in M-1. The lowest number of primary branches was recorded in control of M-1(7.63) which was on par with Bhagwati (8.40) at 60 DAT.

During winter season (Table 16), the number of primary branches in Bhagwati was significantly greater in I_2F_3 (11.40) which was on par with I_2F_1 (10.40). In all other treatments, less number of branches were recorded. However, in M-1 the number of primary branches were on par in all the treatments except control and the values of this parameter ranged from 6.60 to 7.60 in M-1. Plants under control showed significantly less number of primary branches in both the genotypes.

Data pertaining to the parameter during summer season is presented in Table 17. At 30 DAT, all the treatments in Bhagwati were showing significantly more number of branches compared to control and it was also on par in M-1 under treatments I_1F_1 and I_2F_1. However at 60 DAT, the primary branches were significantly greater in M-1 under I_2F_3 (8.27) and this was on par with I_2F_1 (7.90), I_2F_2 (7.77) and control (7.57) in Bhagwati.

d. Stem girth

During rainy season, there was significant difference observed for stem girth between the two genotypes at 30 and 60 DAT. Maximum stem girth of 4.67 cm at 30 DAT was recorded in hybrid Bhagwati fertigated with 75% RDF (F_1) which was on par with a stem girth of 4.42 cm in F_2 (100% RDF) in the same genotype. At 60 DAT, the stem girth was significantly more in both genotypes *i.e.* Bhagwati (6.95 cm) and M-1 (6.60 cm) given with fertigation at 75% RDF. This was followed by F_2 (100% RDF) and F_3 (125% RDF) in Bhagwati with a stem girth of 6.12 cm and 5.83 cm, respectively and also by F_1 (75% RDF) in M-1 (5.79 cm). In both the genotypes, control recorded the lowest stem girth.

During winter season, at 30 DAT, hybrid Bhagwati recorded significantly greater stem girth (3.93 cm) in treatment I_2F_3 and it was followed by I_1F_3 (3.29) which was on par with I_1F_1 (3.20 cm), I_2F_3 (3.05 cm); I_2F_2 (3.02 cm) in M-1 genotype. The

lowest stem girth was recorded in control of both genotypes, hybrid Bhagwati (2.43 cm) and M-1 (2.55 cm) which were on par with each other. At 60 DAT, significantly stout stem with a girth of 4.94 cm was recorded in I_2F_3 of M-1 genotype, which was on par with I_2F_3 (4.82 cm) in hybrid Bhagwati. This was followed by I_2F_2 of 4.22 cm which was on par with I_1F_3 of 4.10 cm and I_1F_2 of 3.97 cm in hybrid Bhagwati. The lowest stem girth was recorded in control of both genotypes hybrid Bhagwati (2.90 cm) and it was on par with M-1 (3.03 cm).

Summer season data on this parameter (Table 17.) showed that significantly greater stem girth (5.23 cm) was recorded in I_2F_3 of M-1 genotype. This was followed by I_2F_2 (4.67 cm), control (4.58 cm) in the same genotype and I_2F_2 (4.60 cm) and I_2F_2 (4.53 cm) in hybrid Bhagwati. The lowest stem girth was recorded in Bhagwati (3.27cm) under control.

e. Dry matter production

During rainy season, significantly higher dry matter production was recorded in hybrid Bhagwati under treatment F_1 (75% RDF) (120.14 g/plant) which was followed by F_2 (100% RDF) of 117.50 g/ plant. However, the lowest dry matter production was recorded in treatment control (64.53 g/plant) in genotype M-1, which was on par with control (65.77 g/plant) in hybrid Bhagwati.

Data pertaining to the parameter during winter season is presented in Table 16. Significantly greater dry matter production was recorded in hybrid Bhagwati (78.61 g/plant) and M-1(77.75 g/plant) under treatment I_2F_3 and these were on par also. This was followed by I_2F_2 both in Bhagwati (75.55 g/plant) and M-1 (72.09 g/plant). The lowest dry matter production was recorded in hybrid Bhagwati under control (39.12 g/plant).

During summer season, the greatest dry matter production (76.14 g/plant) was recorded in hybrid Bhagwati in I_2F_3. This was followed by I_2F_2 (70.52 g/plant) and I_2F_1 (68.36 g/plant) in the same genotype. Similar trend also followed in M-1. The lowest dry matter production was recorded under control in both Bhagwati (35.49 g/plant) and M-1 (36.61 g/plant).

Table 15. Effect of fertigation levels on vegetative parameters of African marigold genotypes during rainy season

Season: June – September

Genotypes	Treatments	Plant height (cm)		Plant spread (cm)		Primary branches (No.)		Stem girth (cm)		Dry matter production (g/plant)
		30 DAT	60 DAT	30 DAT	60 DAT	30 DAT	60 DAT	30 DAT	60 DAT	
Bhagwati	F_1(75% RDF)	60.13	131.86	30.18	61.81	8.60	20.58	4.67	6.95	120.14
	F_2 (100% RDF)	50.60	115.77	27.55	53.74	8.07	18.22	4.42	6.12	117.50
	F_3 (125% RDF)	38.93	105.55	23.37	49.67	7.40	14.12	4.23	5.83	115.52
	Control	29.73	86.10	19.07	33.52	5.27	8.40	3.57	4.72	65.77
M-1	F_1(75% RDF)	21.17	61.57	26.65	54.80	7.27	16.81	3.53	5.79	91.99
	F_2(100% RDF)	20.90	54.53	25.38	44.58	7.03	15.17	3.43	6.60	90.22
	F_3 (125% RDF)	18.37	48.60	23.98	37.17	7.03	11.57	3.02	4.93	87.37
	Control	9.77	41.77	23.08	33.77	4.70	7.63	2.88	4.43	64.53
	C.D.(0.05)	3.51	2.72	4.19	2.03	1.42	1.19	0.34	0.44	1.24
	SEm±	1.15	0.89	1.37	0.66	0.47	0.39	0.11	0.14	0.41

Table 16. Effect of irrigation and fertigation levels on vegetative parameters of African marigold genotypes during winter season Season: October – January

Genotypes	Treatments	Plant height (cm)		Plant spread (cm)		Primary branches (No.)		Stem girth (cm)		Dry matter production (g/plant)
		30 DAT	60 DAT	30 DAT	60 DAT	30 DAT	60 DAT	30 DAT	60 DAT	
Bhagwati	I_1F_1	45.07	53.67	23.70	25.73	5.80	8.07	3.20	3.77	61.94
	I_1F_2	49.80	51.53	28.93	31.23	6.40	8.33	3.00	3.97	62.21
	I_1F_3	49.80	54.87	29.37	31.97	6.53	9.33	3.29	4.10	66.43
	I_2F_1	55.80	61.67	33.60	37.00	7.07	10.40	2.87	3.47	68.55
	I_2F_2	52.87	67.60	29.60	37.53	7.27	9.87	3.07	4.22	75.55
	I_2F_3	56.27	69.80	32.07	38.90	7.73	11.40	3.93	4.82	78.61
	Control	40.33	45.73	20.43	23.43	4.60	5.93	2.43	2.90	39.12
M-1	I_1F_1	20.83	41.30	19.28	25.47	5.10	6.70	2.36	3.00	63.34
	I_1F_2	23.57	41.97	24.72	29.35	5.10	6.60	2.83	3.37	63.93
	I_1F_3	23.13	43.80	23.67	28.73	4.60	6.60	2.72	3.60	66.08
	I_2F_1	24.00	44.13	24.72	28.92	6.27	7.53	2.67	3.53	68.14
	I_2F_2	28.70	49.17	29.43	32.77	5.07	6.87	3.02	4.33	72.09
	I_2F_3	31.93	55.17	31.80	36.50	5.30	7.60	3.05	4.94	77.75
	Control	15.20	36.67	17.55	23.97	4.13	6.40	2.55	3.03	43.19
	C.D(0.05)	2.52	3.46	2.48	2.60	0.75	1.09	0.38	0.49	1.17
	SEm±	0.86	1.18	0.85	0.89	0.26	0.37	0.13	0.17	0.40

I_1 = 75 % Epan, and I_2 = 100% Epan; F_1= 75 % RDF, F_2= 100% ,RDF, F_3= 125 % RDF, C= Control through SF with flood irrigation

Table 17. Effect of irrigation and fertigation levels on vegetative parameters of African marigold genotypes during summer season

Season: January – April

Genotypes	Treatments	Plant height (cm)		Plant spread (cm)		Primary branches (No.)		Stem girth (cm)		Dry matter production (g/plant)
		30 DAT	60 DAT	30 DAT	60 DAT	30 DAT	60 DAT	30 DAT	60 DAT	
Bhagwati	I_1F_1	48.73	55.40	27.75	34.47	5.97	6.70	3.28	3.93	58.41
	I_1F_2	45.70	50.50	26.77	35.73	6.27	6.72	3.12	4.00	60.75
	I_1F_3	48.67	51.83	28.28	36.77	6.30	6.97	3.14	3.90	65.25
	I_2F_1	53.40	59.53	31.32	37.37	6.93	7.90	3.52	4.37	68.36
	I_2F_2	51.63	60.77	28.55	38.90	6.27	7.77	3.02	4.60	70.52
	I_2F_3	52.00	59.60	27.50	42.03	6.20	7.17	2.97	4.53	76.14
	Control	45.10	46.10	21.92	28.90	4.87	7.57	2.68	3.27	35.49
M-1	I_1F_1	23.33	39.47	23.05	31.17	6.00	5.63	2.80	4.22	54.77
	I_1F_2	24.87	39.10	26.13	30.30	5.43	5.40	2.87	4.27	51.42
	I_1F_3	24.40	39.93	26.23	32.77	4.77	5.90	2.63	4.48	53.33
	I_2F_1	27.77	41.40	24.07	31.73	6.07	6.70	2.87	4.52	58.37
	I_2F_2	22.90	40.10	23.87	30.67	4.40	6.73	2.93	4.67	60.36
	I_2F_3	27.90	45.53	28.75	35.27	4.77	8.27	3.13	5.23	63.38
	Control	20.03	40.17	18.58	33.33	5.23	6.10	2.40	4.58	36.61
	C.D(0.05)	4.02	5.80	3.51	3.19	1.10	0.76	0.41	0.55	0.32
	SEm±	1.37	1.98	1.20	1.09	0.38	0.26	0.14	0.19	0.11

I_1 = 75 % Epan, and I_2 = 100% Epan F_1= 75 % RDF, F_2= 100% ,RDF, F_3= 125 % RDF, C= Control through SF with flood irrigation

Precision farming experiments during rainy, winter and summer season showed a significant increase in the plant height, plant spread, primary branches, stem girth and dry matter production with the application of different levels of fertigation and irrigation in the two selected genotypes *viz.,* Bhagwati and M-1. Majority of these parameters were excelling under drip fertigation than control during all the three seasons. This can be attributed to the optimum growing conditions facilitated through drip irrigation, fertigation and mulching in which the water and soluble fertilizers were applied to the root zone enabling the plants to grow without much stress. Drip irrigation and fertigation along with mulching might have reduced leaching loss of nutrients, conserved the soil moisture, improved soil structure through reduced soil compaction and lessened the competition from weeds. Better performance in drip fertigation treatments compared to control is also attributed to improved micro climate in the root zone which in turn might have favoured enhanced photosynthesis and metabolic activities and this has been reported by Bhatt *et al*. (2011) and Parmar *et al.* (2013). Enhanced vegetative growth and flowering under drip irrigation and fertigation in African marigold has been reported by Divya *et al*. (2017) and Vashista *et al.* (2020).

It could also be observed that during rainy season, fertigation with 75% RDF showed superior performance compared to the other two fertilizer levels while during winter and summer season, drip irrigation @ 100% Epan along with fertigation @ 125% RDF showed better performance with respect to vegetative and floral parameters. This might be due to the soil nutrient status prior to each crop as well as evapotranspiration prevailed during the cropping seasons. Nutrient status of the soil and plants could be a reminder to the response of the plant to the fertilization and internal content of the nutrients determine the fertilizer requirement and this was stated by Sumangala *et al*. (2018).

Increased plant height in drip fertigation treatments is attributed to the enhanced metabolic activity that might have increased the production of IAA and consequently resultant stimulated cell elongation. The results obtained are in accordance with findings of Vashista *et al.* (2020) in African marigold and Planisamy *et al*. (2015) in gerbera.

The increase in primary branches in marigold plants under drip fertigation might be due to easier and quicker availability of nitrogen in water soluble form at critical stages of plant growth that might have resulted in stimulation of the production and export of cytokinin to the shoots. The increased levels of cytokinin in plants due to optimum dosage nitrogen application at the root zone resulted in well distribution of the hormone to above ground parts and promoted the lateral buds to sprout producing more number of branches. This was reported by Divya *et al*. (2017) in African marigold. These findings are in accordance with the Hemanta *et al.* (2012) and Palnisamy *et al.* (2015) in gerbera.

Plant spread which is depended upon plant height as well as number of branches also showed enhancement under drip fertigation treatments. The optimum doses of fertilizers might have promoted greater cell division and formation of more tissue which resulted in increased stem girth in plants.

Optimum nutrient uptake through drip fertigation could lead to superior growth thereby enhanced the biomass of the plant. Dry matter production is the living indicator of uptake of nutrients from the soil during cropping period. Similar findings were reported by Babu *et al*. (2018) and Acharya and Dashora (2004) in African marigold.

B. Reproductive parameters

Response of the two marigold genotypes under different fertigation and irrigation levels in relation to reproductive parameters is presented in Tables 18, 19 and 20.

a. Days to bud initiation

The data depicted in Table 18 shows that the hybrid Bhagwati under the treatment F_1 (75% RDF) showed earlier flower bud initiation (30.20 DAT) which was significantly different from all other treatments during rainy season. This was followed by 35.60 days in treatment F_2 (100% RDF). The genotype M-1 recorded very late flower bud initiation during rainy season ranging from 63 to 72 days in fertigation treatments and 81 days in control.

During winter season (Table 19), I_2F_3 in the genotype M-1 and control treatment in hybrid Bhagwati recorded the earliest flower bud initiation in 22.17 days. This was followed by I_2F_2 (23.90 days) in M-1. However, control took significantly greater number of days to flower bud initiation (40.17 days) in the genotype M-1.

During summer season (Table 20), the genotype Bhagwati showed earliest bud initiation in all the treatments including control and these were on par also with respect to the parameter. Days to bud initiation in Bhagwati ranged from 24.60 to 27.67days. Compared to Bhagwati, the genotype M-1 showed delayed bud initiation. In this case also, all the treatments were including control were on par and the values for days to bud initiation ranged from 33.07 days to 36.73 days.

b. Days to initiation of flower opening

Days to initiation of flower opening followed the same trend as that of days to bud initiation. During rainy season, (Table 18) the hybrid Bhagwati took the lowest number of days to initiation of flower opening (39.73 days) in the treatment F_1 (75% RDF) which significantly differed from all other treatments. This was followed by F_2 (100% RDF) with 51.63 days for initiation of flower opening. Significantly more number of days to initiation of flower opening was recorded by M-1 (102.80 days) under treatment control.

During winter season, the hybrid Bhagwati took the lowest number of days to initiation of flower opening (31.57 days) in the treatment control, which was on par with I_2F_3 (31.93 days), I_2F_2 ;I_2F_3 (33.00 days) of M-1 genotype, I_1F_2 (32.13 days), I_1F_1 (32.33 days), I_1F_3 (32.40 days) and I_2F_1 32.60 days in hybrid Bhagwati. M-1 under the control treatment took significantly more number of days to (51.97) initiation of flower opening.

During summer season, earliest initiation of flower opening was recorded in Bhagawti in treatments *viz*., I_1F_1 (34.23 days) and I_1F_2 (35.02 days) and I_2F_2 (36.83 days). Compared to Bhagwati, M-1 took more number of days to initiation of flower opening and this was very delayed in M-1 control (48.79 days).

c. Days to complete flower opening

This parameter (Table 18) also followed the similar pattern as that of days to bud initiation and initiation of flower opening. During rainy season, the hybrid Bhagwati took the lowest number of days to complete flower opening (51.57 days) in the treatment F_1 (75% RDF) which was significantly different from all other treatments. This was followed by 68.80 days in F_2 (100% RDF) in the same genotype. However, genotype M-1 under treatment control took significantly more number of days to complete flower opening (120.80 days).

During winter season, the hybrid Bhagwati took the lowest number of days to complete flower opening in the treatment I_1F_3 and control (42.23 days), which was on par with I_1F_3 (42.23 days), I_1F_2 (42.57days), I_1F_1 (42.87 days) and (I_2F_1 43.23 days) in the same genotype and I_2F_2 (42.37 days), I_2F_3 (42.93 days) of M-1 genotype. The control treatment in M-1, took significantly more number of days to (61.60) to complete flower opening.

During summer, all the drip fertigation treatments in Bhagwati showed earlier completion of flower opening ranging from 44.90 days to 49.60 days and these were on par with I_2F_2 (50.63 days) and I_2F_3 (48.07 days) in the genotype M-1. The control of M-1 took maximum number of days taken to complete flower opening (57.60 days).

d. Days to 50 per cent flowering

During rainy season, hybrid Bhagwati in treatment F_1 (75% RDF) showed the earliest 50 per cent flowering (30.00 days) which was followed by 34.33 days in F_2 (100% RDF) in the same genotype. Compared to Bhagwati, M-1 took significantly more number of days to 50 per cent flowering in all the treatments and this was particularly high in M-1 control (82.33 days).

During winter season, the lowest number of days to achieve 50 per cent flowering was recorded in control (22.67 days) of hybrid Bhagwati, which was on par with I_2F_3 (23.00 days), I_2F_2 (24.00 days), I_2F_1 (25.00 days) and I_1F_3 (25.33 days) in M-1 genotype. In Bhagwati, majority of the drip fertigation showed almost similar

number of days to 50 per cent flowering. The greatest number of days to achieve 50 per cent flowering was observed in control treatment of M-1(40.00 days).

In summer, all the treatments including control in hybrid Bagawati recorded earlier 50 per cent flowering the days to which ranged from 26.00 to 27.69. Compared to Bhagwati, M-1 took more number of days to achieve 50 per cent flowering. However, except the control, all other drip fertigation treatments in M-1 were on par with respect to this parameter.

e. Flower diameter

During rainy season (Table 18), hybrid Bhagwati recorded significantly greater flower diameter (10.27 cm) in treatment F_1 (75% RDF). This was followed by F_2 (100% RDF) of 9.33 cm in the same genotype. Flower diameter was the lowest observed in M-1 control (3.22 cm).

Data pertaining to flower diameter during winter season is presented in Table 19. During winter, M-1 genotype had recorded significantly the greatest flower diameter (4.87 cm) in treatment I_2F_3 which was followed by I_2F_2 (4.68 cm) in the same genotype and I_2F_2 (4.59 cm) and I_2F_3 (4.49 cm) in hybrid Bhagwati.

During summer season (Table 20), the greatest flower diameter (7.93 cm) was recorded in treatment I_2F_2 of hybrid Bhagwati which was significantly superior to rest of the treatments. This was followed by I_2F_1 of 7.07 cm in hybrid Bhagwati. The lowest flower diameter was observed in control of genotype M-1 (4.52 cm) which was on par with control of Bhagwati (4.82 cm) and I_1F_3 of M-1 (5.08 cm).

f. Stalk length

During rainy season (Table 18), significantly longer flower stalk was observed in hybrid Bhagwati (14.38 cm) under treatment F_1 (75% RDF), which was on par with 13.28 cm in F_2 (100% RDF) and 13.23 cm in F_3 (125% RDF). The shortest flower stalk was recorded in genotype M-1 under treatment control (4.13 cm).

During winter season (Table 19), significantly greater stalk length was recorded in treatment I_2F_3 (8.08 cm) which was on par with I_2F_2 (7.35 cm) in the hybrid Bhagwati. Genotype M-1 also followed the same trend in stalk length with longer stalks

in I_2F_3 (5.61 cm) and I_2F_2 (5.47 cm). The lowest stalk length was recorded in M-1 control (4.13 cm).

Data presented in Table 20 shows significantly greater stalk length in treatments I_2F_1 (8.33 cm), I_1F_1 (8.30 cm), I_1F_2 (8.17 cm), I_2F_2 (8.13 cm) and I_2F_3 (8.01 cm) in Bhagwati during summer season and these treatments were on par also. Compared to Bhagwati, stalk length was short in M-1. The lowest stalk length was recorded in M-1 control (3.52 cm).

g. Flower weight

The hybrid Bhagwati in the treatment F_1 (75% RDF) recorded the greatest flower weight (28.10 g) which was significantly superior to all the treatments during rainy season (Table 18). This was followed by a flower weight of 25.20 g and 24.80 g in the same genotype in F_2 (100% RDF) and F_3 (125% RDF) respectively and these treatments were on par also. The M-1 genotype under treatment control recorded the lowest flower weight of 6.80 g.

During winter season (Table 19), significantly greater flower weight (7.57 g) was recorded in M-1 in treatment I_2F_2 which was on par with I_2F_3 (7.45 g) of the same genotype and I_2F_3 (6.87 g) in hybrid Bhagwati. This was followed by I_2F_2 (5.87 g) in Bhagwati and I_1F_1 (5.37 g) in M-1. The lowest flower weight was observed control of both genotypes.

Data on flower weight during summer season (Table 20) shows significantly greater weight in I_2F_3 (9.23 g) and I_2F_2 (8.88 g) in hybrid Bhagwati. These two treatments also showed greater flower weight in M-1.

h. Weight of ray florets

During rainy season (Table 18), the hybrid Bhagwati recorded significantly greater weight of ray florets (17.03 g) in the treatment F_1 (75% RDF). This was followed by 16.45 g in F_2 (100% RDF) in the same genotype. The genotype M-1 recorded the lowest flower weight in all fertigation treatments as well as in control.

Data presented in Table 19 shows that during winter season, genotype M-1 had significantly greater weight of ray florets (3.22 g) in treatment I_2F_3 which was on par

with I_2F_2 (3.19 g), whereas I_2F_3 (3.10 g) in hybrid Bhagwati. Compared to M-1, petal weight was very less in Bhagwati especially in treatments with irrigation @ 75%Epan.

During summer season (Table 20), significantly greater weight of ray florets was observed in Bhagwati in treatments I_2F_3 (6.13 g) and I_2F_2 (5.95 g). The same trend was followed in genotype M-1, recording I_2F_3 (3.98 g) and I_2F_2 (3.70 g)

i. Number of flowers per plant

There was significant difference recorded among the treatments in number of flowers per plant. During rainy season (Table 18), the hybrid Bhagwati recorded significantly more number of flowers per plant (55.67) in the treatment F_1 (75% RDF). This was followed by 53.60 flowers in F_2 (100% RDF). The M-1 genotype of control treatment recorded the lowest number of flowers per plant (31.00).

The number of flowers per plant significantly greater in treatment I_2F_3 in both genotypes *viz.*, Bhagawti (65.33) and M-1 (63.67) and these were on par also during winter season (Table 19). This was followed by 58.07 flowers in I_2F_2 and 55.23 flowers in I_1F_3 in the M-1 genotype. Control treatment recorded the lowest number of flowers per plant (33.33) in the hybrid Bhagwati and M-1 (38.07).

During summer season (Table 20), the number of flowers per plant followed the similar trend as that of winter season. The highest number of flowers per plant (74.87) recorded in the hybrid Bhagwati in the treatment I_2F_3 which was on par with I_2F_3 (70.90) in M-1. This was followed by I_2F_2 in both Bhagwati (65.13 flowers) and M-1 (59.87 flowers). Control treatment recorded the lowest number of flowers per plant (37.33) in the hybrid Bhagwati and it was on par with M-1control (39.10).

j. Flower yield per plant

Flower yield per plant differed significantly among the treatments. During rainy season (Table 18), significantly higher flower yield per plant (1101.97 g/plant) was recorded in the hybrid Bhagwati in treatment F_1 (75% RDF). This was followed by F_2 (100% RDF) of 975.40 g/plant. As compared to genotype Bhagwati, flower yield per plant was very low in the M-1 genotype and the lowest yield of 243.60 g/plant was observed in control treatment.

Flower yield per plant during winter season (Table 19) showed that significantly greater flower yield of 403.70 g/plant was recorded in I_2F_3 of M-1 genotype. This was followed by a yield of 382.46 g/plant in I_2F_3 of hybrid Bhagwati. All the drip fertigation treatments recorded better flower yield compared to control. The lowest flower yield per plant (150.07 g/plant) was recorded in control treatment of hybrid Bhagwati.

During summer season (Table 20), M-1 recorded significantly greater flower yield (334.63 g/plant) in I_2F_3 which was on par with Bhagwati (314.50 g/plant) in the same treatment. This was followed by I_2F_2 (294.77 g/plant) in M-1. The lowest flower yield per plant (131.70 g/plant) was recorded in control treatment of hybrid Bhagwati.

k. Number of harvests per plant

During rainy season, significantly more number of harvests per plant (9.67) was recorded in the hybrid Bhagwati in treatment F_1 (75% RDF) which was on par with F_2 (100% RDF), (8.69) and F_3 (125% RDF) of 8.65. Even though the number of harvests was less in M-1 compared to Bhagwati, the treatments showed the similar trend as that of Bhagwati. The lowest number of harvests was recorded in control of M-1 genotype (4.67).

Winter season data with respect to the parameter is presented in Table 19. The number of harvests per plant was significantly more in I_2F_3 (6.67) and I_2F_2 (6.33) in the M-1 genotype and these were on par also. This was followed by I_2F_3 of hybrid Bhagwati (6.00). Compared to Bhagwati, the number of harvests more in M-1 during the season.

During summer season, the number of harvests was more in Bhagwati compared to M-1(Table 20). The greater number of harvests per plant was recorded in I_2F_3 (7.67) which was on par with I_2F_2, I_1F_3, I_1F_2 (each with a number of harvests of 7.33) and I_1F_2 (7.00) in hybrid Bhagwati. This was followed by I_1F_1 of (6.00) in the same genotype. The lowest number of harvests was recorded in control (3.87) which was on par with I_1F_1 (5.07) in the M-1 genotype.

Table 18. Effect of fertigation levels on reproductive parameters of African marigold genotypes during rainy season

Season: June – September

Genotypes	Treatments	Days to bud initiation	Days to initiation of flower opening	Days to complete flower opening	Days to 50% flowering	Flower diameter (cm)	Stalk length (cm)	Flower weight (g)	Weight of ray florets (g)	Number of flowers/ plants	Flower yield/ plant (g)	Number of harvests
Bhagwati	F_1 (75% RDF)	30.20	39.73	51.57	30.00	10.27	14.38	28.10	17.03	55.67	1101.97	9.67
	F_2 (100% RDF)	35.60	51.60	68.80	34.33	9.33	13.28	25.20	16.45	53.60	975.40	8.69
	F_3 (125% RDF)	38.30	56.77	74.77	38.67	8.68	13.23	24.80	15.18	51.53	842.90	8.65
	Control	46.27	73.67	97.57	46.00	4.82	8.30	14.80	7.25	41.80	489.67	5.67
M-1	F_1 (75% RDF)	63.53	72.13	84.13	63.00	6.10	8.63	10.78	3.47	44.93	461.73	6.33
	F_2 (100% RDF)	67.90	81.73	96.93	67.67	5.18	7.40	10.07	2.70	39.80	397.93	5.67
	F_3 (125% RDF)	72.40	91.93	108.60	70.33	4.37	6.27	8.20	2.53	38.07	354.53	5.33
	Control	81.30	102.13	120.80	82.33	3.22	4.13	6.80	2.06	31.00	243.60	4.67
	C.D. (0.05)	1.15	2.04	3.59	2.60	0.38	1.15	2.19	0.55	2.02	74.20	1.03
	SE.m ±	0.38	0.67	1.17	0.85	0.12	0.38	0.72	0.18	0.66	24.23	0.34

Table 19. Effect of irrigation and fertigation levels on reproductive parameters of African marigold genotypes during winter season

Season: October- January

Genotypes	Treatments	Days to bud initiation	Days to initiation of flower opening	Days to complete flower opening	Days to 50% flowering	Flower diameter (cm)	Stalk length (cm)	Flower weight (g)	Weight of ray florets (g)	Number of flowers/ plants	Flower yield/plant (g)	Number of harvests
Bhagwati	I_1F_1	24.67	32.33	42.87	26.00	4.06	5.67	4.92	1.69	43.60	197.08	4.00
	I_1F_2	24.70	32.13	42.57	28.00	3.53	6.06	3.91	1.90	46.20	208.24	4.00
	I_1F_3	24.50	32.40	42.23	28.33	3.45	6.33	4.12	1.78	47.53	221.67	4.00
	I_2F_1	25.33	33.60	43.23	26.67	4.06	6.26	4.22	1.77	40.93	185.07	4.00
	I_2F_2	28.50	38.70	48.90	29.67	4.59	7.35	5.87	2.61	54.73	318.66	4.33
	I_2F_3	27.33	36.43	46.00	28.33	4.49	8.08	6.87	3.10	65.33	382.46	6.00
	Control	22.17	31.57	42.33	22.67	3.80	5.33	3.77	1.58	33.33	150.07	4.33
M-1	I_1F_1	28.07	39.63	50.83	28.67	3.68	5.10	5.37	2.25	47.93	238.93	5.00
	I_1F_2	29.33	40.97	52.50	30.33	3.73	4.97	5.17	2.09	51.53	264.73	5.00
	I_1F_3	24.97	37.83	48.67	25.33	3.73	4.45	5.10	2.22	55.23	282.93	5.00
	I_2F_1	25.13	36.00	47.70	25.00	3.23	4.00	4.92	2.30	38.43	194.03	5.00
	I_2F_2	23.30	33.00	42.37	24.00	4.68	5.47	7.57	3.19	58.07	354.63	6.33
	I_2F_3	22.17	31.93	42.93	23.00	4.87	5.61	7.45	3.22	63.67	403.70	6.67
	Control	40.17	51.97	61.60	40.00	3.59	4.63	4.18	1.96	38.07	189.27	5.00
	C.D(0.05)	1.29	2.65	3.01	2.81	0.41	0.76	0.79	0.47	2.10	11.96	0.54
	SEm±	0.44	0.91	1.03	0.96	0.14	0.26	0.27	0.16	0.72	4.09	0.18

I_1 = 75 % Epan, and I_2 = 100% Epan, F_1= 75 % RDF, F_2= 100% ,RDF, F_3= 125 % RDF, C= Control through SF with flood irrigation

Table 20. Effect of irrigation and fertigation levels on reproductive parameters of African marigold genotypes during summer season

Season: January - April

Genotypes	Treatments	Days to bud initiation	Days to initiation of flower opening	Days to complete flower opening	Days to 50% flowering	Flower diameter (cm)	Stalk length (cm)	Flower weight (g)	Weight of ray florets (g)	Number of flowers/ plant	Flower yield/plant (g)	Number of harvests
Bhagwati	I_1F_1	24.60	34.23	44.90	26.27	6.13	8.30	4.73	1.95	46.17	182.73	6.00
	I_1F_2	26.50	35.02	46.70	26.67	6.01	8.17	4.80	2.20	55.30	209.67	7.33
	I_1F_3	26.97	37.16	46.83	26.00	6.67	7.82	5.70	2.57	55.97	206.77	7.33
	I_2F_1	27.47	37.18	49.53	27.10	7.07	8.33	6.72	3.12	54.83	192.43	7.00
	I_2F_2	27.53	36.83	49.23	27.00	7.93	8.13	8.88	5.95	65.13	240.80	7.33
	I_2F_3	27.67	37.27	49.60	27.69	6.70	8.01	9.23	6.13	74.87	314.50	7.67
	Control	25.93	39.16	52.27	26.00	4.85	7.37	4.45	1.82	37.33	131.70	5.33
M-1	I_1F_1	35.13	45.29	54.73	38.33	5.20	4.22	7.47	3.93	50.60	214.97	5.07
	I_1F_2	35.17	44.41	54.10	37.33	5.30	3.77	6.62	3.60	45.53	185.47	4.73
	I_1F_3	35.83	45.13	53.77	38.00	5.08	4.42	6.45	3.45	44.27	181.97	4.67
	I_2F_1	35.30	44.44	52.70	35.33	5.33	4.08	5.73	3.62	54.83	232.70	5.53
	I_2F_2	36.17	43.40	50.63	37.33	5.43	4.10	7.52	3.70	59.87	294.77	4.63
	I_2F_3	36.80	41.99	48.07	38.00	5.82	3.72	7.83	3.98	70.90	334.63	5.33
	Control	39.73	48.79	57.60	45.67	4.52	3.52	4.57	2.92	39.10	176.33	3.87
	C.D(0.05)	2.51	2.72	6.55	3.76	0.66	0.43	0.36	0.23	4.44	21.83	1.29
	SEm±	0.86	0.93	2.24	1.25	0.23	0.15	0.12	0.08	1.52	7.47	0.44

I_1 = 75 % Epan, and I_2 = 100% Epan , F_1= 75 % RDF, F_2= 100% ,RDF, F_3= 125 % RDF, C= Control through SF with flood irrigation

Majority of the reproductive parameters were showing very positive responses under drip fertigation compared to the control treatment during the three seasons studied. During rainy season, all the drip fertigation treatments recorded earliest bud initiation, flower opening and 50 per cent flowering compared to control in both the genotypes. This might be due to the congenial microclimate at the root zone of the plants under these treatments which were also promoted by the mulch provided to these treatments. Especially during rainy season, the plastic mulch might have maintained adequate soil temperature in the root zone which resulted in better uptake of nutrients from the WSF supplied through drip fertigation. The enhanced uptake of nutrients might have favoured accelerated photosynthesis and metabolic activities as reported by Bhatt *et al*. (2011) and Parmar *et al.* (2013). The greater availability of photosynthates might have contributed towards floral primordial initiation at an earlier stage compared to control. Among the fertigation levels tried, bud initiation and flowering was comparatively delayed in higher doses of fertilizers like 100% and 125% RDF compared to the lower dose at 75% RDF in both the genotypes. In this context, the high available nitrogen in the soil prior to the rainy season crop was considered as the reason for earlier flower initiation even at lower doses of fertigation. Plants under this condition might have completed sufficient vegetative growth and put forth the floral primordia earlier. Delayed flowering at higher level of fertigation has been reported by Divya *et al.* (2017) in African marigold.

During rainy season differences were also noticed between the genotypes with regard to bud initiation and flowering. Days to bud initiation and 50 per cent flowering were 46.27 and 46.00 respectively in Bhagwati whereas in M-1, these parameters took almost double the duration *viz.,* days to bud initiation (81.30) and days to 50 per cent flowering (82.33). This was attributed to the differential response of these genotypes due to their genetic makeup.

During winter season, bud initiation as well as 50 per cent flowering showed a different pattern than that of rainy season. In Bhagwati, the control treatment recorded earlier bud initiation and flowering compared to drip fertigation treatments. Bud initiation and flowering was delayed in treatments I_2F_3 and I_2F_2. Earlier bud initiation and flowering in the control treatment of Bhagwati is attributed to the water stress

caused by high evapotranspiration prevailed during this season. Sufficient moisture and fertilisers in both I_2F_3 and I_2F_2 might have contributed to better vegetative growth and delayed flowering in Bhagwati. However, in genotype M-1, entirely the reverse pattern was observed. In M-1, both bud initiation (40.17 days) as well as 50 per cent flowering (40.00 days) was delayed in control whereas in drip fertigation treatments these parameters ranged from 22.17 to 29.33 for days to bud initiation and 23.00 to 30.33 days to 50 per cent flowering. The differential response of the two genotypes was again attributed to their genetic makeup.

During summer season also, differential response due to genetic makeup of the genotypes could be observed with respect to flowering parameters *viz.,* days to bud initiation, initiation of flower opening, days to complete flower opening and days to 50 per cent flowering.

The floral parameters like flower diameter, stalk length, flower weight, petal weight and yield parameters like number of flowers, flower yield as well as number of harvests, were recorded significantly greater in 75% RDF during rainy season. This might be due to the fulfilment of optimum fertiliser requirement of the crop in already rich available nutrients in the soil during rainy season. Fertiliser doses higher than 75% RDF had negative impact on all the floral parameters as well as flower yield in marigold during the season. These results are in conformity to earlier findings of Divya *et al*. (2017) in marigold and Thamara *et al*. (2010) in China aster.

During winter and summer, the treatment I_2F_3 (irrigation @100 Epan along with 125% RDF) recorded better performance with respect to the floral parameters *viz.,* flower diameter, stalk length, flower weight, petal weight as well as yield parameters *viz.,* number of flowers, flower yield and number of harvests in both the genotypes. The requirement of increased fertiliser doses and irrigation at 100% Epan was attributed to the soil nutrient status, prevailing weather conditions like, evapotranspiration and temperature. The higher doses of nutrients along with sufficient irrigation might have increased the uptake of nutrients that might have contributed to enhanced photosynthesis and metabolic activities and this in turn resulted in high dry matter production and translocation of phytohormones to the shoots. The high dry matter as well as the hormonal activity was assigned as the reasons for enhanced floral parameters

as well as flower yield. This was in conformity to the findings of Jawaharlal *et al*. (2013), Divya *et al.* (2017) and Babu *et al.* (2018) in African marigold, Salma *et al.* (2014) in gerbera and in gladilous by Chouhan *et al*. (2014).

C. Post-harvest parameters

Response of the two marigold genotypes *viz.*, Bhagwati and M-1 under different fertigation levels, with respect to the post-harvest parameters is presented in Table 21, 22 and 23.

a. Shelf life of flowers

Significant difference was recorded among the different the treatments for shelf life of the flowers. During rainy season, the hybrid Bhagwati under treatment F_1 (75% RDF) recorded maximum number of shelf life of 5.00 days which was on par with F_2 (100% RDF) and F_3 (125% RDF). The lowest shelf life of 1.00 days was recorded in M-1 genotype in control treatment.

During winter season, all the drip fertigation treatments in hybrid Bhagwati were showing shelf life of flowers ranging from 2.33 to 3.00 days and these were on par also. Compared to Bhagwati, M-1 recorded lower shelf life in all the treatments. The lowest shelf life of 1.33 days was recorded in treatment control of both the genotypes.

The shelf life of flowers during summer season followed almost the same pattern as that of winter. Hybrid Bhagwati in treatment I_1F_3 was recorded maximum shelf life (2.67 days) which was on par with all other treatments (except I_1F_1) in Bhagwati, as well as I_1F_1 (2.00 days) and I_2F_3 (2.00 days) of M-1. The lower shelf life of 1.00 day was recorded in treatment control of M-1 genotype.

Table 21. Effect of fertigation levels on post-harvest parameters of African marigold genotypes during rainy season

Season: June – September

Genotypes	Treatments	PLW (%)	Shelf life (days)
Bhagwati	F_1 (75% RDF)	9.50	5.00
	F_2 (100% RDF)	10.43	5.00
	F_3 (125% RDF)	10.79	5.00
	Control	17.53	2.00
M-1	F_1 (75% RDF)	25.75	2.33
	F_2 (100% RDF)	27.71	2.00
	F_3 (125% RDF)	31.22	2.00
	Control	34.36	1.00
	C.D(0.05)	1.54	0.36
	SEm±	0.50	0.12

b. Physiological loss in weight of flowers

During rainy season, the hybrid Bhagwati under the different doses of fertigation treatments recorded lower PLW compared to other treatments. The loss in weight of 9.50 per cent in the treatment F_1 (75% RDF) was on par with F_2 (100% RDF) and F_3 (125% RDF). The PLW was significantly higher in M-1 genotype particularly under treatment control (34.36 %).

Unlike the rainy season, during winter the lowest PLW (10.88%) was recorded in M-1 in treatment I_2F_3, which was on par with I_2F_2 in M-1 (11.69%) and Bhagwati (11.88%), I_1F_3 (14.08%) in M-1, and I_1F_1 (13.83%) and I_1F_2 (13.86%) of Bhagwati. The control recorded significantly higher PLW in both the genotypes.

Table 22. Effect of irrigation and fertigation levels on post-harvest parameters of African marigold genotypes during winter season

Season: October – January

Genotypes	Treatments	PLW (%)	Shelf life (days)
Bhagwati	I_1F_1	13.83	2.33
	I_1F_2	13.86	2.67
	I_1F_3	14.43	2.67
	I_2F_1	15.47	2.68
	I_2F_2	11.88	2.67
	I_2F_3	11.64	3.00
	Control	20.92	1.33
M-1	I_1F_1	22.13	2.00
	I_1F_2	15.97	2.00
	I_1F_3	14.08	2.00
	I_2F_1	15.38	1.33
	I_2F_2	11.69	2.00
	I_2F_3	10.88	2.00
	Control	24.68	1.33
	C.D(0.05)	3.40	0.75
	SEm±	1.14	0.26

Table 23. Effect of irrigation and fertigation levels on post-harvest parameters of African marigold genotypes during summer season

Season: January - April

Genotypes	Treatments	PLW (%)	Shelf life (days)
Bhagwati	I_1F_1	17.39	1.67
	I_1F_2	17.03	2.00
	I_1F_3	21.82	2.67
	I_2F_1	15.72	2.00
	I_2F_2	14.06	2.61
	I_2F_3	14.73	2.33
	Control	22.39	2.00
M-1	I_1F_1	33.57	2.00
	I_1F_2	33.86	1.33
	I_1F_3	34.52	1.67
	I_2F_1	29.89	1.00
	I_2F_2	27.14	1.67
	I_2F_3	27.38	2.00
	Control	37.95	1.00
	C.D. (0.05)	3.30	0.95
	SE. m±	1.21	0.33

During summer season, treatments *viz.*, I_2F_1, I_2F_2 and I_2F_3 in Bhagwati recorded significantly lower PLW of 15.72%, 14.06%, and 14.73% respectively compared to all other treatments. Compared to Bhagwati, M-1 recorded higher PLW in all the treatments.

Hybrid Bhagwati showed more shelf life and less PLW than M-1, during all the three seasons. This was attributed to the genetic makeup of the two genotypes. During rainy, winter and summer seasons, all the drip fertiagtion treatments in Bhagwati recorded greater shelf life and lesser PLW compared to control. The same trend was also observed in M-1. The longer shelf life and lesser PLW in drip fertigation treatments might be due to the higher initial fresh weight which is an indicator of high dry matter content of flowers in these treatments. This is in accordance with Devi *et al*. (2017) in marigold, Krishnappa and Reddy (2004) in carnation, Talukdar *et al.* (2010) in chrysanthemum.

D. Bio chemical parameters

Performance of the two marigold genotypes under various fertigation levels in relation to the bio chemical parameters is presented in Tables 24, 25 and 26.

a. Total carotenoids (mg/g)

During rainy season, significantly higher total carotenoids of 0.114 mg/g was recorded in hybrid Bhagwati in treatment F_1 (75% RDF), which was followed by 0.107 mg/g carotenoids in F_2 (100% RDF). The genotype M-1 recorded lower carotenoids content ranging from 0.040 mg/g to 0.048 mg/g. .

During winter and summer, significantly higher total carotenoids was recorded in the treatment I_2F_3 (0.095 mg/g, 0.099 mg/g respectively) in Bhagwati and these were on par with I_2F_2 (0.093 mg/g, 0.096 mg/g respectively). During winter and summer season also, M-1 recorded lower carotenoid content compared to Bhagwati and it was the lowest in M-1 control (0.025 mg/g).

b. Flavonoids (A_{300} g^{-1})

During rainy season, the content of flavonoids significantly differed between the genotypes both in leaves and petals under different fertigation levels and the data with

respect to the parameter is presented in Table 24. Significantly higher flavonoid content in leaves (3.36 A_{300} g^{-1}) and petals (1.75 A_{300} g^{-1}) was recorded in hybrid Bhagwati in treatment F_1 (75% RDF). This was followed by F_2 (100% RDF) which was on par with F_3 (125% RDF), with a flavonoid content of 3.17 A_{300} g^{-1} in leaves and 1.64 A_{300} g^{-1} and 1.67 A_{300} g^{-1} in petals.

Table 24. Effect of fertigation levels on biochemical parameters of African marigold genotypes

Season: June- September

Genotypes	Treatments	Total carotenoids (mg/g)	Flavonoids (A_{300} g^{-1})		Essential oil (%)	
			Leaves	Petals	Leaves	Petals
Bhagwati	F_1(75% RDF)	0.114	3.36	1.75	0.58	0.30
	F_2 (100% RDF)	0.107	3.17	1.64	0.51	0.20
	F_3 (125% RDF)	0.100	3.17	1.67	0.44	0.20
	Control	0.097	3.07	1.39	0.27	0.13
M-1	F_1(75% RDF)	0.048	2.82	1.72	0.33	0.27
	F_2(100% RDF)	0.046	2.77	1.57	0.37	0.17
	F_3 (125% RDF)	0.044	2.69	1.51	0.27	0.20
	Control	0.040	2.51	1.26	0.27	0.13
	C.D(0.05)	0.002	0.04	0.10	0.07	0.05
	SEm±	0.001	0.01	0.03	0.02	0.02

Flavonoid content in leaves and petals was higher in genotype M-1 compared to Bhagwati during winter season (Table 25). The highest contents in leaves were recorded in I_2F_3 (3.55 A_{300} g^{-1}) and I_2F_2 (3.52 A_{300} g^{-1}) of M-1. In the case of flavonoid content in petals, significantly greater content was recorded in I_2F_3 (1.63 A_{300} g^{-1}) of M-1 which was followed by I_2F_2 (1.57 A_{300} g^{-1}) in the same genotype. The lowest content of flavonoids in leaves (2.70 A_{300} g^{-1}) and in petals (1.14 A_{300} g^{-1}) was recorded in the control of hybrid Bhagwati during winter season.

During summer season, the highest flavonoid content in leaves was recorded in the treatment I_2F_3 (3.97 A_{300} g^{-1}) in hybrid Bhagwati and this was followed by I_2F_3 (3.93 A_{300} g^{-1}) in M-1 genotype. The lowest flavonoids was recorded in the control (3.41 A_{300} g^{-1}) of the hybrid Bhagwati. In the case of flavonoids in petals, significantly greater flavonoid content was recorded in the treatment I_2F_3 in both M-1 (1.80 A_{300} g^{-1}) and Bhagwati (1.79 A_{300} g^{-1}). This was followed by I_2F_2 (1.73 A_{300} g^{-1}) in hybrid Bhagwati. The lowest flavonoids was recorded in the control (1.23 A_{300} g^{-1}) of Bhagwati.

c. Essential oil (%)

The essential oil content differed significantly between the genotypes both in leaves and petals under different fertigation levels which is presented in Tables 24, 25 and 26. The highest per cent of essential oil was recorded in hybrid Bhagwati in treatment F_1 (75% RDF) in leaves (0.58%) and petals (0.30%) and this was on par with essential oil content of 0.51% in leaves in the same genotype. Compared to petals, more oil content was recorded in leaves.

During winter season, the highest essential oil in leaves was recorded in the treatment of I_2F_2 (0.41%) which was on par with I_2F_3 (0.40%) in M-1 genotype. Compared to M-1, the essential oil content was less in Bhagwati during the season. The lowest essential oil was recorded in the control and I_1F_1 (0.10%) in the hybrid Bhagwati. In the case petals, significantly higher essential oil content was recorded in I_2F_3 (0.23%) followed by I_2F_2 (0.17%) in the hybrid Bhagwati. During the season, the essential oil content was very low in the petals of M-1.

Essential oil quantification during summer season showed that the highest essential oil in leaves was recorded in treatment I_2F_3 (0.47%) in M-1 genotype. This was followed by 0.40 per cent of I_2F_2 (M-1 genotype) and I_2F_3 (0.40%) of hybrid Bhagwati. During the season, essential oil content in petals were on par in all the treatments.

Table 25. Effect of irrigation and fertigation levels on bio chemical parameters of African marigold genotypes during winter season

Season: October – January

Genotypes	Treatments	Total carotenoids (mg/g)	Flavonoids (A_{300} g^{-1})		Essential oil (%)	
			Leaves	Petals	Leaves	Petals
Bhagwati	I_1F_1	0.083	2.76	1.26	0.10	0.10
	I_1F_2	0.081	2.82	1.31	0.13	0.10
	I_1F_3	0.083	2.82	1.32	0.13	0.10
	I_2F_1	0.083	2.81	1.35	0.18	0.13
	I_2F_2	0.093	2.94	1.36	0.20	0.17
	I_2F_3	0.095	2.98	1.40	0.27	0.23
	Control	0.080	2.70	1.14	0.10	0.10
M-1	I_1F_1	0.029	3.30	1.50	0.20	0.01
	I_1F_2	0.031	3.34	1.50	0.27	0.01
	I_1F_3	0.032	3.38	1.53	0.33	0.01
	I_2F_1	0.031	3.44	1.51	0.33	0.01
	I_2F_2	0.034	3.52	1.57	0.41	0.01
	I_2F_3	0.036	3.55	1.63	0.40	0.01
	Control	0.025	3.27	1.25	0.20	0.02
	C.D(0.05)	0.003	0.04	0.04	0.06	0.09
	SEm±	0.001	0.01	0.01	0.02	0.03

Table 26. Effect of irrigation and fertigation levels on bio chemical parameters of African marigold genotypes during summer season

Season:January - April

Genotypes	Treatments	Total carotenoids (mg/g)	Flavonoids (A_{300} g^{-1})		Essential oil (%)	
			Leaves	Petals	Leaves	Petals
Bhagwati	I_1F_1	0.091	3.55	1.54	0.30	0.10
	I_1F_2	0.094	3.63	1.65	0.32	0.16
	I_1F_3	0.094	3.81	1.67	0.27	0.12
	I_2F_1	0.095	3.78	1.69	0.33	0.15
	I_2F_2	0.096	3.85	1.73	0.30	0.10
	I_2F_3	0.099	3.97	1.79	0.40	0.17
	Control	0.082	3.41	1.23	0.30	0.10
M-1	I_1F_1	0.039	3.56	1.58	0.37	0.10
	I_1F_2	0.037	3.06	1.54	0.20	0.10
	I_1F_3	0.039	3.64	1.58	0.30	0.10
	I_2F_1	0.041	3.73	1.54	0.30	0.10
	I_2F_2	0.039	3.81	1.58	0.40	0.10
	I_2F_3	0.050	3.93	1.80	0.47	0.10
	Control	0.036	3.50	1.43	0.20	0.10
	C.D. (0.05)	0.001	0.03	0.02	0.04	NS
	SEm±	0.00	0.01	0.01	0.02	0.05

During the three seasons, the biochemical parameters *viz.,* total carotenoids, flavonoids and essential oil content were higher in the drip fertigation treatments compared to control. This might be due to the high nutrient uptake in drip fertigation treatments. The high nutrient uptake might have promoted greater secondary metabolite production and thus the content of carotenoids, flavonoids and essential oil was more in drip fertigation treatments compared to control. In this context, the vital roles played by two major nutrient elements *viz.*, nitrogen and potassium should be considered. Nitrogen is involved in many physiological processes including photosynthesis and biosynthesis of amino acids and protein, various enzymes, phytohormones and many secondary metabolites. Potassium is an important element in plant metabolism, promoting carbohydrates, fats and protein synthesis, increasing crop yield and improving fresh produce quality. Significant influence of Nitrogen fertilization on many biochemical quality parameters of plants including the content of various secondary metabolites has been reported by Mozafar (1993). Similar findings in marigold was reported by Souri *et al*. (2018). Optimum potassium fertilization increased the essential oil content in pot marigold (Khalid, 2013). It was also found to increase the flavonoid and essential oil in English lavender (Chrysargyris *et al*., 2017). Scheduled irrigation has been found to increase the carotenoids and essential oil contents in pot marigold and sweet basil (Maksimović *et al*., 2018).

E. Nutrient uptake

The results of two marigold genotypes under different fertigation levels with respect to the nutrient uptake are depicted in Tables 27, 28 and 29.

a. Nitrogen content

During rainy season, the nitrogen content was significantly greater in the fertigation treatments compared to control in both the genotypes and it ranged from 1.77 per cent to 1.92 per cent in fertigation treatments whereas in control it was 1.53 to 1.57 per cent.

During winter and summer seasons, the treatment I_2F_3 showed significantly greater nitrogen content in both the genotypes *viz.,* Bhagwati (2.85% and 2.58%

respectively) and M-1 (2.86% and 2.59% respectively). Significant difference was observed between the genotypes.

b. Nitrogen uptake

During rainy season, significantly more uptake of nitrogen (73.82 kg/ha) was recorded in hybrid Bhagwati in treatment F_1 (75% RDF) which was on par the nitrogen uptake of 71.81 kg/ha in F_2 (100% RDF). This was followed by F_3 (100% RDF) in which the nitrogen uptake was 66.28 kg/ha. The uptake of nitrogen in genotype M-1 was low when compared to Bhagwati and it ranged from 50.15 kg/ha to 56.52 kg/ha at different fertigation levels. In both the genotypes, the nitrogen uptake was lowest recorded in the control treatment.

During winter season, the highest nutrient uptake (71.77 kg/ha) was recorded in hybrid Bhagwati of treatment I_2F_3 which was on par with I_2F_3 (71.27 kg/ha) in M-1 genotype and these treatments were significantly superior over other treatments. The lowest uptake of nitrogen was recorded in control treatment of Bhagwati (35.43 kg/ha).

Nitrogen uptake during summer season showed the highest nutrient uptake (62.94 kg/ha) in the hybrid Bhagwati in treatment I_2F_3. In M-1 also, among the treatments, higher nitrogen uptake was recorded in I_2F_3 (52.60 kg/ha). The lowest uptake of nitrogen was recorded in control treatment of Bhagwati (29.08 kg/ha).

c. Phosphorus content

During rainy season, significantly higher phosphorus content was noticed in F_1 (75% RDF) of both genotypes; Bhagwati (0.52%) and M-1 (0.51%).This was followed by F_2 (100% RDF) and F_3 (125%) in both the genotypes. The lowest phosphorus content of 0.40 per cent was recorded in control treatments of both genotypes *viz.*, Bhagwati and M-1.

The phosphorus content differed significantly among the treatments during winter season. The highest phosphorus content (0.69 %) was recorded in I_2F_2 which was on par with I_2F_3 (0.68%), I_1F_1 (0.67%) in hybrid Bhagwati and I_1F_1 (0.67%), I_1F_2 (0.66 %) in M-1 genotype. During summer season also, similar trend was seen in phosphorus content.

d. Phosphorus uptake

During rainy season, higher phosphorus uptake was noticed in all the fertigation treatments compared to control in both the genotypes. The highest uptake of phosphorus (19.86 kg/ha) was recorded in hybrid Bhagwati treated in F_1 (75% RDF) and this was followed by 18.30 kg/ha phosphorus uptake in F_2 (100% RDF) of in the same genotype.

Significantly higher phosphorus uptake during winter (17.24 kg/ha) was recorded in I_2F_3 in the hybrid Bhagwati which was on par with I_2F_2 (16.76 kg/ha) in the same genotype. This was followed by I_2F_3 (14.60 kg/ha) in M-1 genotype. The control treatment of both the genotypes recorded the lowest phosphorus uptake in M-1 (7.07 kg/ha) which was on par with Bhagwati (7.74 kg/ha).

During summer season, the highest phosphorus uptake (13.56 kg/ha) was recorded in the treatment I_2F_3 in Bhagwati. This was followed by I_2F_2 (12.64 kg/ha) in the same genotype. The control treatment of both the genotype, recorded the lowest phosphorus uptake nutrient in Bhagwati (4.96 kg/ha) which was on par with M-1 (5.08 kg/ha).

e. **Potassium content**

During rainy season, significantly higher potassium content was recorded in all the fertigation treatments in both the genotypes and it ranged from 1.81 per cent to 1.85 per cent while in control, the potassium content in Bhagwati was 1.50 per cent whereas in M-1, the content was 1.58 per cent.

The treatment I_2F_3 showed significantly greater potassium content during winter season in both hybrid Bhagwati (1.47%) and M-1 (1.45%) and I_2F_2 (1.46%) in Bhagwati. The lowest potassium content (1.33%) was recorded in control treatment of M-1 which was on par with control of Bhagwati (1.37%). During summer season also, similar trend was noticed in potassium content. I_2F_3 in Bhagwati (1.41%), M-1 (1.38%), I_2F_2 (1.40%) and I_2F_1 (1.39%) in Bhagwati were on par.

f. Potassium uptake

During rainy season, significantly superior uptake of potassium (60.22 kg/ha) was recorded in hybrid Bhagwati in treatment F_1 (75% RDF) which was on par with an uptake of 58.55 kg/ha in F_2 (100% RDF) and 57.20 kg/ha in F_3 (125%) in the same genotype. The genotype M-1 under fertigation showed lower potassium uptake compared to Bhagwati and it ranged from 43.24 kg/ha to 46.10 kg/ha in M-1. Control treatment of both the genotypes recorded very low potassium uptake.

Potassium uptake during winter season showed significantly higher uptake in I_2F_3 (36.98 kg/ha) in hybrid Bhagwati of treatment which was followed by I_2F_3 (35.99 kg/ha) in M-1 genotype. The lowest uptake of potassium was recorded in control treatment of Bhagwati (17.16 kg/ha).

During summer season, potassium uptake was comparatively lower in M-1. The highest potassium uptake (34.27 kg/ha) was recorded in I_2F_3 in Bhagwati, which was followed by I_2F_2 (31.52 kg/ha) in the same genotype. The lowest uptake of potassium was recorded in control treatment of Bhagwati (14.84 kg/ha) which was on par with control M-1(14.88 kg/ha).

During the three seasons studied, better uptake of nutrients was observed in drip fertigation treatments. This was due to the high nutrient contents and dry matter production in these treatments which was facilitated by the judicious application of water and water soluble forms of nutrients through drip irrigation in the root zone that lead to minimum leaching losses under plastic mulching. In this experiment, both nitrogen and potassium were applied as WSF. Nitrogen is a highly mobile element in the plant tissues, its efficient translocation under optimum moisture and nutrient supply from root to leaves could have added to its enhanced accumulation in the leaves (Smith, 1962). Similar results have been observed by Qasim *et al*. (2008) in rose, Prabhu *et al*. (2016) in chilli. High uptake of potassium could be attributed to the fact that the treatments which recorded higher nitrogen and phosphorous improves the K nutrition by synergistic effect and enhanced the uptake of K by the plants, as reported by Polara *et al.* (2014) in marigold.

Table 27. Effect of fertigation levels on African marigold genotypes for nutrient content and uptake of nutrients

Season: June – September

Genotypes	Treatments	Plant analysis					
		Nitrogen		Phosphorus		Potassium	
		Nutrient content (%)	Nutrient uptake (kg/ha)	Nutrient content (%)	Nutrient uptake (kg/ha)	Nutrient content (%)	Nutrient uptake (kg/ha)
Bhagwati	F_1(75% RDF)	1.92	73.82	0.52	19.86	1.85	60.22
	F_2 (100% RDF)	1.91	71.81	0.49	18.30	1.84	58.55
	F_3 (125% RDF)	1.79	66.28	0.47	17.37	1.82	57.20
	Control	1.57	33.04	0.40	8.49	1.50	28.08
M-1	F_1(75% RDF)	1.90	56.52	0.51	15.21	1.82	46.10
	F_2(100% RDF)	1.88	55.14	0.50	14.05	1.81	44.94
	F_3 (125% RDF)	1.77	50.15	0.42	13.14	1.83	43.24
	Control	1.53	32.42	0.40	8.33	1.58	27.44
	C.D(0.05)	0.16	5.22	0.01	0.30	0.01	9.15
	SEm±	0.05	1.70	0.00	0.10	0.00	2.99

Table 28. Effect of irrigation and fertigation levels of African marigold genotypes for nutrients content and uptake

Season: October – January

Genotypes	Treatments	Plant analysis					
		Nitrogen		Phosphorus		Potassium	
		Nutrient content (%)	Nutrient Uptake (kg/ha)	Nutrient content (%)	Nutrient Uptake (kg/ha)	Nutrient content (%)	Nutrient Uptake (kg/ha)
Bhagwati	I_1F_1	2.83	56.10	0.59	11.78	1.41	28.01
	I_1F_2	2.82	56.14	0.64	12.74	1.42	28.28
	I_1F_3	2.82	59.87	0.63	13.25	1.42	30.17
	I_2F_1	2.84	62.23	0.63	13.89	1.45	31.82
	I_2F_2	2.83	68.50	0.69	16.76	1.46	35.31
	I_2F_3	2.85	71.77	0.68	17.24	1.47	36.98
	Control	2.83	35.43	0.56	7.07	1.37	17.16
M-1	I_1F_1	2.81	56.93	0.67	13.51	1.38	27.90
	I_1F_2	2.79	57.00	0.66	13.43	1.39	28.37
	I_1F_3	2.83	59.77	0.65	13.81	1.37	28.98
	I_2F_1	2.83	61.63	0.59	12.93	1.39	30.24
	I_2F_2	2.85	65.63	0.60	13.84	1.41	32.61
	I_2F_3	2.86	71.27	0.59	14.60	1.45	35.99
	C	2.83	39.20	0.56	7.74	1.33	18.43
	C.D(0.05)	0.02	1.13	0.03	0.64	0.05	0.72
	SEm±	0.01	0.39	0.01	0.22	0.02	0.25

I_1 = 75 % Epan, and I_2 = 100% Epan, F_1= 75 % RDF, F_2= 100% ,RDF, F_3= 125 % RDF, C= Control through SF with flood irrigation

Table 29. Effect of irrigation and fertigation levels on African marigold genotypes for nutrient content and uptake

Season: January - April

Genotypes	Treatments	Plant analysis					
		Nitrogen		Phosphorus		Potassium	
		Nutrient content (%)	Nutrient uptake (kg/ha)	Nutrient content (%)	Nutrient uptake (kg/ha)	Nutrient content (%)	Nutrient uptake (kg/ha)
Bhagwati	I_1F_1	2.56	47.85	0.47	8.72	1.35	25.23
	I_1F_2	2.55	49.57	0.51	9.91	1.32	25.72
	I_1F_3	2.55	53.17	0.50	10.44	1.36	28.39
	I_2F_1	2.57	56.14	0.48	11.01	1.39	30.33
	I_2F_2	2.56	57.85	0.56	12.64	1.40	31.52
	I_2F_3	2.58	62.94	0.55	13.56	1.41	34.27
	Control	2.56	29.08	0.44	4.96	1.31	14.84
M-1	I_1F_1	2.54	44.52	0.54	9.47	1.31	23.03
	I_1F_2	2.52	41.41	0.53	8.72	1.32	21.78
	I_1F_3	2.56	43.63	0.52	8.99	1.31	22.30
	I_2F_1	2.56	47.75	0.45	8.72	1.32	24.72
	I_2F_2	2.58	49.77	0.47	9.14	1.35	26.08
	I_2F_3	2.59	52.60	0.46	9.33	1.38	28.06
	Control	2.56	30.03	0.43	5.08	1.27	14.88
	C.D. (0.05)	0.02	0.45	0.06	0.60	0.04	0.75
	SEm±	0.01	0.16	0.02	0.21	0.01	0.26

I_1 = 75 % Epan, and I_2 = 100% Epan, F_1= 75 % RDF, F_2= 100% ,RDF, F_3= 125 % RDF, C= Control through SF with flood irrigation

Higher uptake of nutrients in drip fertiagtion have been reported by Sumangala *et al*. (2018) in marigold, Singh *et al*. (2015) and Jeevan *et al.* (2016) in tuberose.

g. Soil analysis after the crop

The status of organic carbon, available N, P and K before and after each crop has been given in appendix in soil prior to each season of cropping is furnished in Appendix no. VII.

h. Water use efficiency in African marigold genotypes

Results of the water use efficiency with respect to winter and summer seasons in the two marigold genotypes are presented in Table 30.

h. 1. Water use efficiency during winter season

During winter season, the highest WUE (10.92 kg/ha mm^{-1}) was recorded in I_2F_3 in hybrid Bhagwati which was followed by I_2F_3 (10.11 kg/ha mm^{-1}) in M-1 genotype. The lowest WUE was recorded in control treatment of Bhagwati (3.00 kg/ha mm^{-1}) which was on par with control M-1 (3.36 kg/ha mm^{-1}).

h. 2. Water use efficiency during summer season

The treatment I_2F_3 recorded significantly superior WUE in M-1 (7.02 kg/ha mm^{-1}) and hybrid Bhagwati (6.79 kg/ha mm^{-1}) during summer season. The lowest WUE was recorded in control treatment of Bhagwati (1.95 kg/ha mm^{-1}) which was on par with control M-1(2.14 kg/ha mm^{-1}) in summer season.

Water use efficiency is based on yield per unit area per unit depth of water used. It is evident from the study that WUE was significantly greater in all drip fertigation treatments compared to control in both the genotypes during winter and summer. It could also be observed that among the drip fertigation treatments, WUE was the highest for the treatment I_2F_3 (irrigation @100% Epan along with fertigation @125% RDF) in both the genotypes during both seasons. This might be due to the fact that the higher irrigation and fertigation levels along with black polythene mulching promoted greater uptake of nutrients thereby enhancing yield which led to the remarkable WUE in this treatment.

Table 30. Effect of irrigation and fertigation levels on water use efficiency of African marigold genotypes during winter (October-January) and summer seasons (January –April)

Genotypes	Treatments	Winter			Summer		
		Flower yield/ha	Water applied (mm)	WUE (Kg/ha mm)	Flower yield/ha	Water applied (mm)	WUE (kg /ha mm)
Bhagwati	I_1F_1	6335	840.1	7.51	5847	1112	5.26
	I_1F_2	6644	840.1	7.93	6709	1112	6.04
	I_1F_3	7100	840.1	8.44	6617	1112	5.95
	I_2F_1	5896	1121.3	5.28	6158	1483	4.15
	I_2F_2	9951	1121.3	9.09	7706	1483	5.20
	I_2F_3	12281	1121.3	10.92	10064	1483	6.79
	Control	4809	1600.0	3.00	4214	2160	1.95
M-1	I_1F_1	7691	957.1	7.99	6879	1145	6.01
	I_1F_2	8394	957.1	8.85	5935	1145	5.18
	I_1F_3	9031	957.1	9.46	5823	1145	5.08
	I_2F_1	6219	1277.3	4.86	7446	1525	4.88
	I_2F_2	11344	1277.3	8.88	9433	1525	6.18
	I_2F_3	12963	1277.3	10.11	10708	1525	7.02
	Control	6040	1800.1	3.36	5643	2640	2.14
	C.D. (0.05)			0.36			0.55
	SEm±			0.12			0.19

I_1 = 75 % Epan, and I_2 = 100% Epan F_1= 75 % RDF, F_2= 100% ,RDF, F_3= 125 % RDF, C= Control through SF with flood irrigation

There was also the seasonal differences observed in WUE between winter and summer season. At the same irrigation and fertigation levels, WUE was more during winter compared to summer. This happened due to the increased evapotranspiration during summer which in turn increased the total water used during summer and comparatively low flower yield during summer.

Improved WUE in drip fertigation treatments over control has been reported by Vashista *et al*. (2020) in African marigold, Narayanankutty *et al*. (2017) in Okra, Navyashree *et al.* (2019) in tomato.

4.4.2. Seasonal response of the genotypes in precision farming

Correlation coefficients analysis between genotypes and agro-meteorological parameters is presented in the Appendix-IV, V and VI.

Weather parameters influence all stages of plant growth and thereby affect the crop productivity. Each crop and in particular its varieties, has its own set of optimum and tolerable environmental conditions under which it can grow efficiently. Knowledge about the relationships between crop growth stages and weather parameters is very important to maximize the production by adjusting the crop management practices. For a crop variety to be successful in a specific region, the sequences of its growth phases must fit in the climate of the region to ensure good growth and adequate production. The weather parameters like average temperature, average relative humidity, average rainfall, and average Epan during cropping period of the genotypes in different seasons were considered to assess the response of the genotypes (Bhagwati and M-1) to these agro metrological parameters. The weather parameters were correlated in both genotypes with the vegetative parameters (plant height, plant spread, number of branches and dry matter production), flowering parameters (days to bud initiation and days to 50 per cent flowering), floral parameters (flower weight, weight of ray florets, flower diameter and stalk length), yield parameters (number of flowers/plant, flower yield/plant and number of harvest/plant) and nutrient uptake (N, P and K). The seasonal responses of the two marigold genotypes are presented in Fig.8 to 11.

Hybrid Bhagwati grown during rainy season showed good growth and flower yield compared to M-1.This could be attributed to the adequate vegetative growth

acquired by hybrid Bhagwati at an earlier stage, higher nutrient uptake and high dry matter production compared to M-1. The reason for better growth and yield also could be due to the vigour of the hybrid Bhagwati. One of the flowering parameters *viz.,* days to flower bud initiation was very much delayed in M-1 compared to Bhagwati during rainy season compared to winter and summer seasons. This was attributed to the short day requirement of the genotype M-1 for flowering. Moreover, the performance of the genotypes during the season should be considered in the context of their correlation with weather parameters like average temperature (26.5^{o} C), average relative humidity (87.00%) and average rainfall (19.78 mm). Majority of the parameters expressed positive correlation with temperature and rainfall by both genotypes. However in the case of correlation with relative humidity, only hybrid Bhagwati was showing positive correlation with majority of the parameters while in the case of M-1, most of the parameters were not at all correlated with relative humidity. This also might have contributed to the differential response of the genotypes during rainy season.

During winter season, the genotype M-1 was performing better than hybrid Bhagwati with respect to flower yield. M-1 also showed almost on par performance with Bhagwati in many of other floral as well as vegetative parameters. In this context, the differences in correlation pattern between the two genotypes with average temperature (27.80^{o}C), average relative humidity (69.85%), average rainfall (5.22 mm) and average Epan (3.4) should be considered. During winter season, the genotype M-1 showed positive and significant correlation between temperature and parameters *viz.,* days to bud initiation, flower diameter, flower weight, number of flowers per plant and flower yield while Bhagwati showed negative and significant correlation between temperature and parameters *viz.,* flower diameter, number of flowers per plant and flower yield. The differential behaviour of the genotypes was also attributed to their correlation pattern in temperature with uptake of nutrients. M-1 showed positive correlation between temperature and dry matter production, uptake of the three major nutrients whereas in Bhagwati, a negative correlation was observed between temperature and uptake of nutrients.

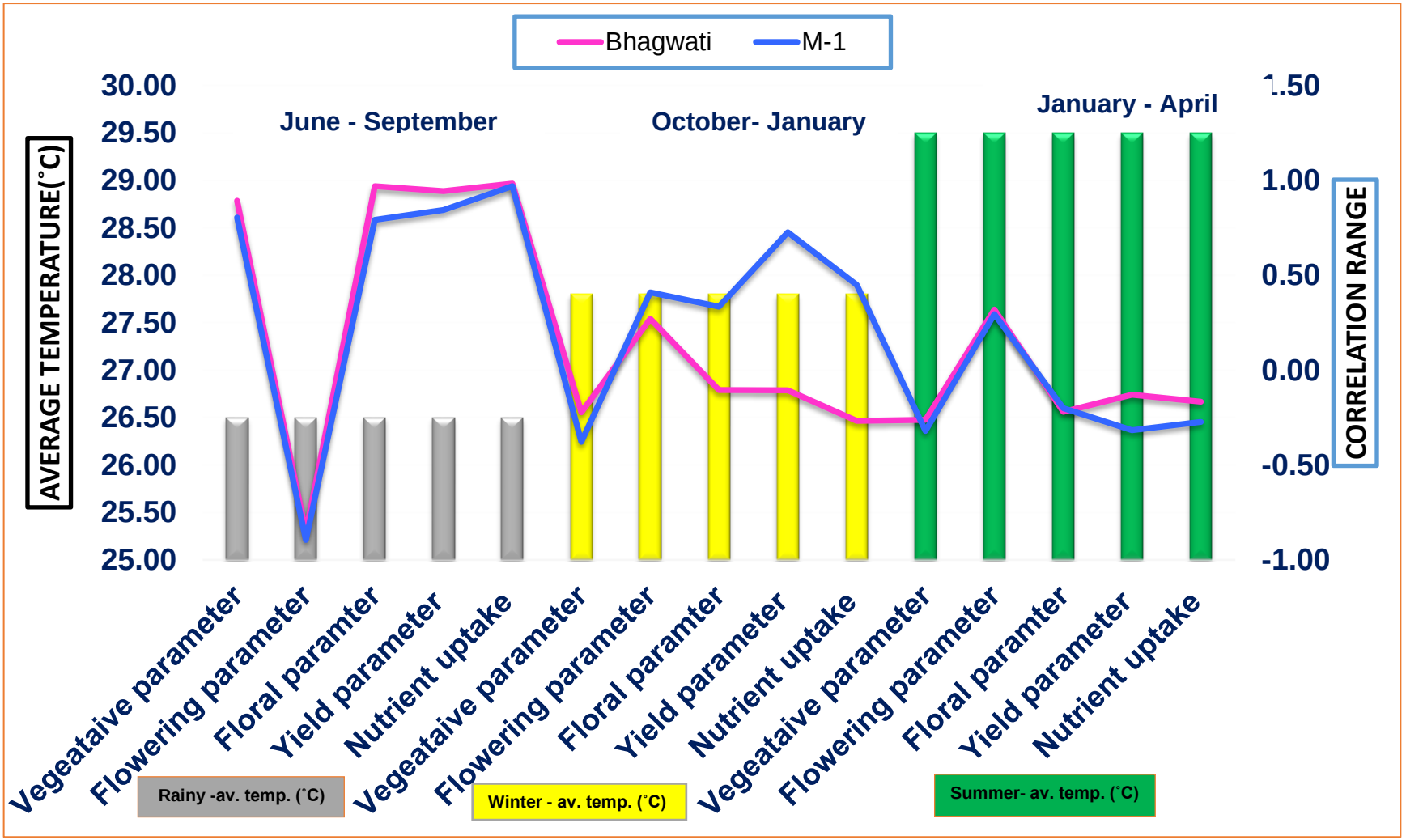


Figure 8. Response of marigold genotypes to average temperature during cropping period

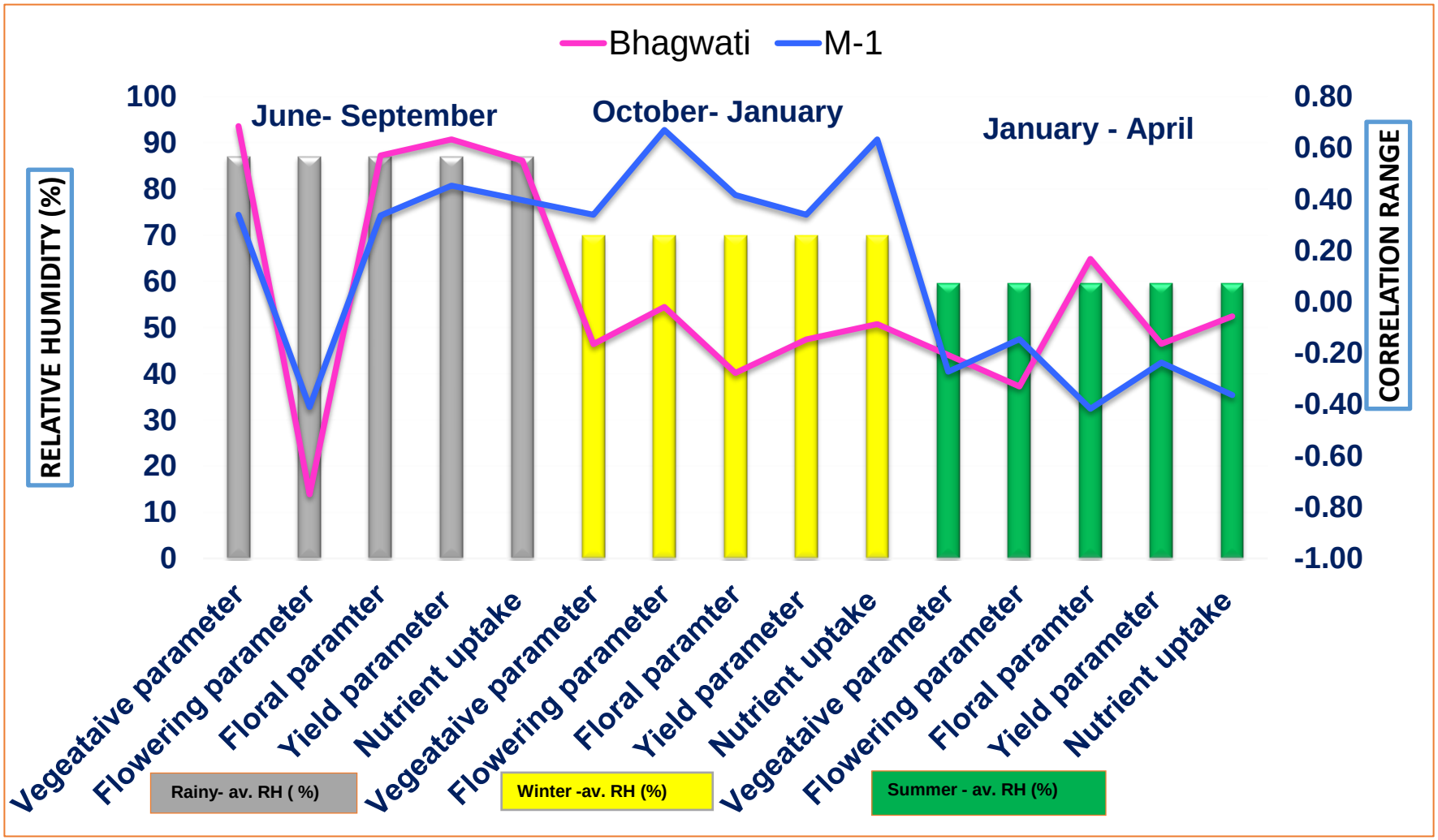


Figure 9. Response of marigold genotypes to average relative humidity during cropping period

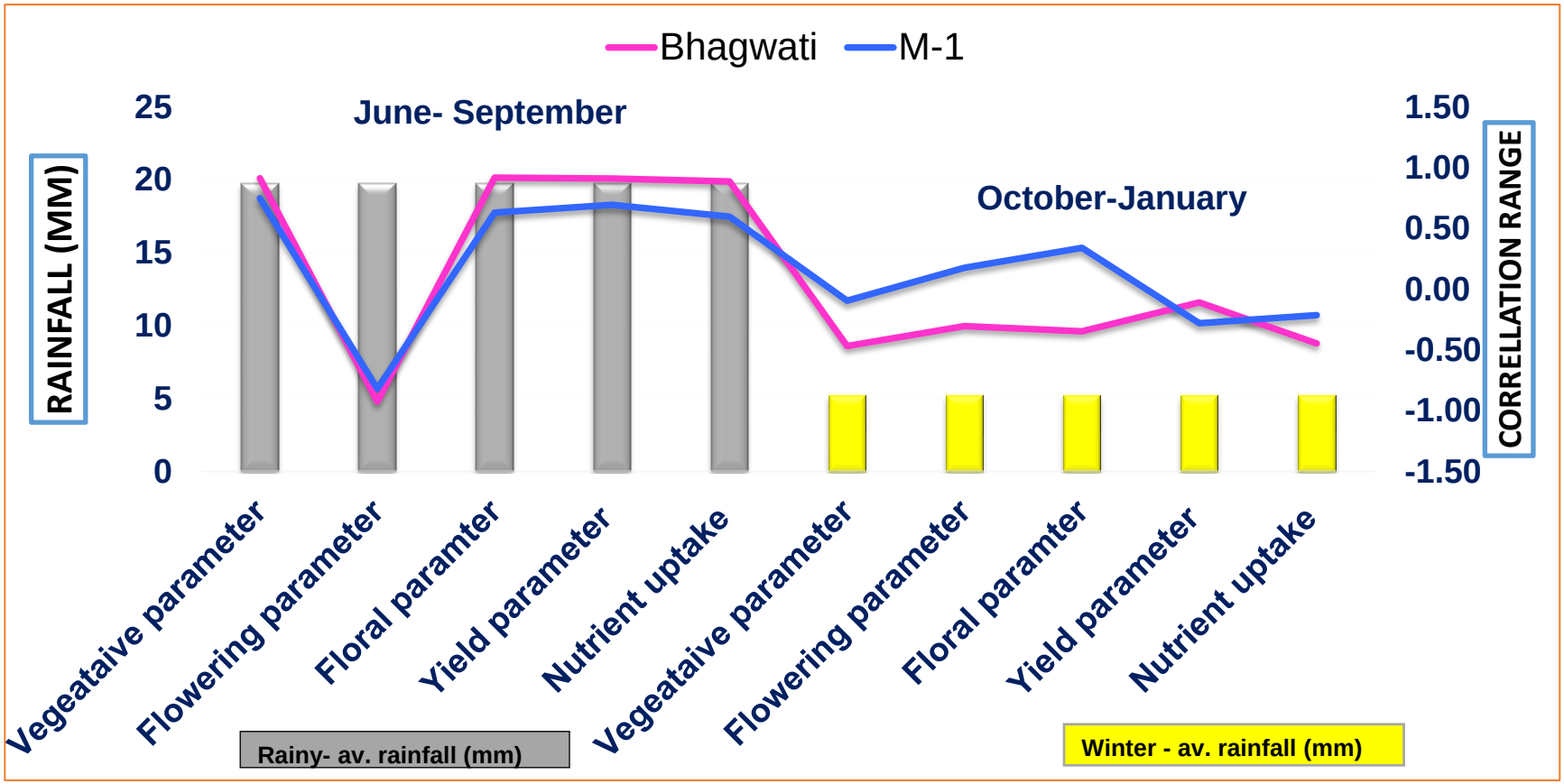


Figure 10. Response of marigold genotypes to average rainfall during cropping period

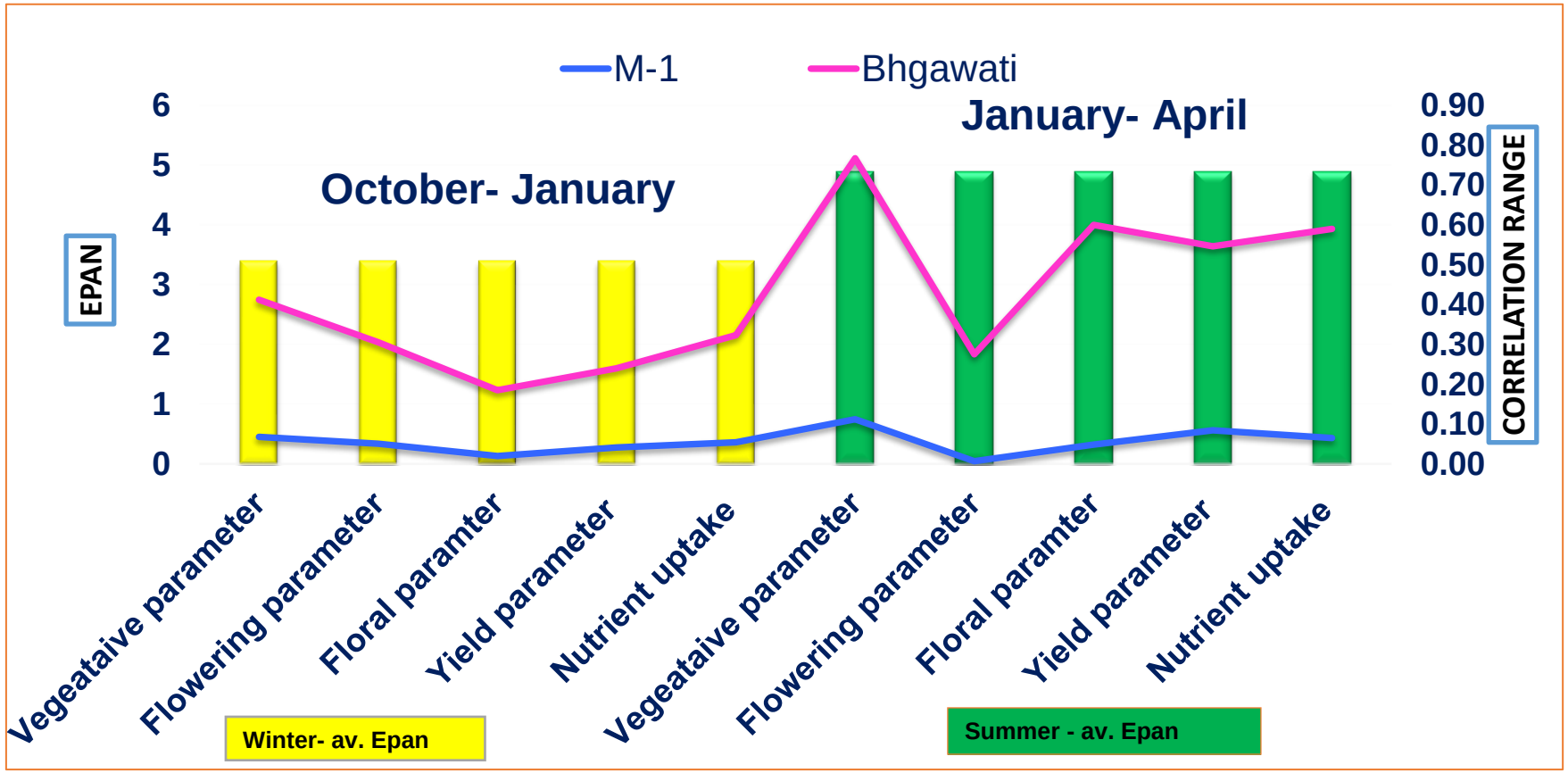


Figure 11. Response of marigold genotypes to average Epan during cropping period

Likewise, relative humidity had positive correlation with plant height, spread, flower diameter, flower weight, number of flowers per plant, dry matter production and uptake of nutrients in M-1 whereas none of the parameters of Bhagwati was correlated with relative humidity during winter season. These factors might have contributed to the better performance of M-1 over Bhagwati during winter season. However average rainfall during winter cropping period did not significantly influenced none of the parameters in both genotypes whereas, average Epan (3.4) was showing significantly positive correlation with vegetative, flowering, yield and nutrient uptake except some floral parameters.

During summer season, both the genotypes was performing on par with respect to yield and number of flowers per plant but significantly differed in many other floral as well as vegetative parameters. The correlation pattern of temperature (29.50^{o}C). With many parameters such as plant height, spread, number of primary branches, flower diameter, flower weight, petal weight, number of flowers per plant, dry matter production, yield as well as uptake of nutrients were showing a negative correlation in both the genotypes. With regard to the effect of relative humidity (59.49%),in Bhagwati many of the vegetative (plant spread), floral and yield parameters (flower diameter, number of flowers/plant, number of harvests/plant and flower yield) were not showing any correlation with relative humidity while in M-1, majority of these parameters were negatively correlated with relative humidity. This might be the reason for the slight differential response between Bhagwati and M-1 during summer season. Likewise during winter season here also same trend has continued with respect to average Epan (4.9) in both the genotypes.

Differential responses of marigold genotypes due to seasonal effects and photoperiodic responses have been reported by Meena *et al.* (2015),Prakash *et al*. (2016), Nimisha (2016); Devi *et al.* (2017), Mohanty *et al*. (2015) and Jyothi *et al*. (2018).

4.4. 8. Economics of precision farming in African marigold genotypes

The cost economics of precision farming of African marigold genotypes during different seasons is presented in Table 31. The cost was calculated taking into consideration all the inputs and its depreciation values. For estimating the returns, the average sale price for Bhagwati flowers was considered as Rs 30/kg and while for M-1 flowers it was considered as Rs 20/kg in all the three seasons.

Rainy season.

During rainy season, the maximum cost benefit ratio (B:C ratio) was obtained for the hybrid Bhagwati (4.35) in the treatment F_1 (75 % RDF). Although the B:C ratio was more than 'one' in M-1, due to the prolonged vegetative phase of the genotype during rainy season, harvesting was not coinciding with the festival season in Kerala during August.

Winter season

During winter season, Bhagwati and M-1 showed a B:C ratio of 1.35 and 1.14 respectively in the treatment I_2F_3 (Irrigation at 100% + 125% RDF). Hence during winter season, both the genotypes can be cultivated economically adopting the treatment I_2F_3.

Summer season

During summer season, hybrid Bhagwati in the treatment I_2F_3 (Irrigation at 100%+125% RDF) showed a B:C ratio of 1.11 and hence the genotype under the mentioned drip fertigation treatment could be recommended.

Based on the cost economics, it could be inferred that marigold cultivation was the most profitable under drip irrigation and fertigation system than the conventional system of cultivation. Regarding the choice of genotypes, hybrid Bhagwati was the best for cultivation during rainy, winter and summer seasons, whereas, the M-1 is economical during winter season.

Table 31. Economics of precision farming in African marigold genotypes

Genotypes	Treatments	Rainy season			Treatments	Winter season			Summer season		
		Total cost Rs.ha^{-1}	Gross income Rs.ha^{-1}	B:C ratio		Total cost Rs. ha^{-1}	Gross income Rs. ha^{-1}	B:C ratio	Total cost Rs.ha^{-1}	Gross income Rs.ha^{-1}	B:C ratio
Bhagwati	F_1	2,42,997.00	10,57,888.00	4.35	I_1F_1	2,42,997.00	1,89,196.80	0.78	2,42,997.00	1,75,424.00	0.72
	F_2	2,64,764.00	9,36,358.40	3.54	I_1F_2	2,64,764.00	1,99,910.40	0.76	2,64,764.00	2,01,280.00	0.76
	F_3	2,71,520.00	8,09,187.20	2.98	I_1F_3	2,71,520.00	2,12,800.00	0.78	2,71,520.00	1,98,496.00	0.73
	C	2,05,142.00	3,52,562.40	1.71	I_2F_1	2,42,997.00	1,77,664.60	0.73	2,42,997.00	1,84,736.00	0.76
					I_2F_2	2,64,764.00	3,05,912.30	1.16	2,64,764.00	2,31,168.00	0.87
					I_2F_3	2,71,520.00	3,67,161.60	1.35	2,71,520.00	3,01,920.00	1.11
					C	2,05,142.00	1,44,067.20	0.70	2,05,142.00	1,26,432.00	0.62
M-1	F_1	2,12,397.00	2,95,498.70	1.39	I_1F_1	2,12,397.00	1,52,921.60	0.72	2,12,397.00	137578.70	0.65
	F_2	2,19,164.00	2,54,679.50	1.16	I_1F_2	2,19,164.00	1,69,429.30	0.77	2,19,164.00	1,18,698.70	0.54
	F_3	2,25,920.00	2,26,884.30	1.00	I_1F_3	2,25,920.00	1,81,088.70	0.80	2,25,920.00	1,16,458.70	0.52
	C	1,63,142.00	1,55,912.50	0.96	I_2F_1	2,12,397.00	1,24,178.70	0.58	2,12,397.00	1,48,928.00	0.70
					I_2F_2	2,19,164.00	2,26,954.20	1.04	2,19,164.00	1,88,650.70	0.86
					I_2F_3	2,25,920.00	2,58,360.00	1.14	2,25,920.00	2,14,165.30	0.95
					C	1,63,142.00	1,21,126.40	0.74	1,63,142.00	1,12,853.30	0.69

I_1 = 75 % Epan, and I_2 = 100% Epan F_1= 75 % RDF, F_2= 100% ,RDF, F_3= 125 % RDF, C= Control through SF with flood irrigation

4.5. Effect of growth regulators on plant growth and yield of *Tagetes erecta* L.

4.5.1. Effect of growth retardants on plant growth and yield of African marigold

Based on the field evaluation results, the F_1 hybrid. Bhagwati was selected to carry out the further investigation using different growth retardants during rainy season.

A. Vegetative parameters

Vegetative parameters of the hybrid Bhagwati treated with various growth retardants during rainy season are presented in Table 32.

a. Plant height

At 30 DAT there was no significance difference noticed among the treatments. However, at 60 DAT, there was significant reduction in plant height (95.34 cm) in plants treated with CCC @ 1000 mg/L and this was followed by CCC @ 750 mg/L which recorded a plant height of 108.17 cm. In the treatment with CCC @ 1000 mg/L there was 24 per cent reduction in height over control. Other treatments did not show any effect on height reduction.

b. Plant spread

Plant spread was significantly influenced by growth retardants. At 30 DAT, the greatest spread of 33.50 cm was observed in PCZ @ 30 and 60 mg/L and these were on par with CCC @ 1000 mg/L (31.87 cm) and Ethrel @ 100 mg/L (32.40 cm). At 60 DAT, plant spread (57.10 cm) was significantly high in CCC @ 1000 mg/L which was followed by Ethrel @ 200 mg/L (53.37 cm) and CCC @ 1000 mg/L (52.83 cm). The lowest plant spread was observed in control (37.50 cm).

c. Number of primary branches

Growth retardants significantly influenced the number of primary branches in marigold. With regard to this parameter also, the effect of CCC @ 1000 mg/L was evident both at 30 and 60 DAT. At 60 DAT, the greatest number of primary branches (23.88) was observed in this treatment. This was followed by CCC @ 750 mg/L (20.92) and Ethrel @ 200 mg/L (18.67).

d. Stem girth

Treatments did not differ significantly at 30 DAT for steam girth. However, at 60 DAT, treatments showed significant influence on stem girth. The stem girth at 60 DAT varied from 6.81 cm to 7.71 cm. The reduced stem girth of 6.85 cm was recorded by application of CCC @ 1000 mg/L and this was on par with control 6.81 cm. The highest stem girth of 7.71 cm was recorded in CCC @ 750 mg/L which was on par with Ethrel @ 200 mg/L (7.67 cm).

e. Inter nodal length

Significantly reduced inter nodal length of 4.69 cm was recorded on application of CCC @ 1000 mg/L. This was followed by CCC @ 750 mg/L (6.00 cm). The greatest inter nodal length of 10.90 cm was recorded in PCZ @ 60 mg /L which was on par with control (10.60 cm).

Growth regulators alter the growth parameters, advance blooming, promote flowering in many ornamental plants, and extend the self-life of many cut flowers. These growth substances will improve the physiological efficiency of the plants by regulating the rate of photosynthesis, transpiration, photorespiration, water and nutrient uptake, leaf senescence and by imparting resistance to various environmental stresses and ultimately this may be increasing the harvest index.

The results of present investigation revealed that there was significant reduction in plant height, stem girth, leaf area and inter nodal length (Plate 12) by spraying growth retardant CCC @ 1000 mg/L on 30 and 45 DAT. This could be due to anti-auxin activity and disturbed carbohydrate metabolism which in turn resulted in inhibition of cell division and elongation of apical meristem in plants treated with CCC. The retarding effect of CCC in marigold has been reported by Barett, (1979 and 1982), Dani *et al.* (2010), Gowda and Jayanthi (1991), Sunita *et al*. (2007), Sunayana *et al.* (2018) in African marigold.

Antagonistic and dwarfing properties of CCC might have inhibited the cell expansion and thereby reduced the stem girth in CCC treated plants. Breakage of apical dominance reduced the plant height through shortening of the distance between two

nodes and this enhanced differentiation of internodes might have taken place when sprayed with CCC. These results are in conformity to the findings of Dani *et al.* (2010) in marigold, and Joshi and Reddy (2006) in Chain aster.

The treatment with CCC however, increased the plant spread and number of primary branches. Greater plant spread and more number of branches per plant might be due to cessation of the apical dominance due to lower level of endogenous auxin production that contributed towards production of more number of lateral branches. Similar results were reported by Patel (1990), Singh and Rathore (1992), Khandelwal *et al*. (2003), Sunita et *al*. (2007) and Sunayana (2017) in African marigold, Joshi and Reddy (2006) in China aster.

B. Reproductive parameters

Performance of the hybrid Bhagwati with respect to reproductive parameters on application of different growth retardants during rainy season is presented in Table 33.

a. Days to bud initiation

The data presented in Table 33 showed that the days to bud initiation ranged from 38.43 to 50.67 days, the greater number of days taken to flower bud initiation of 50.67 days was recorded in CCC @ 1000 mg/L, which was followed by 47.97 days (CCC @ 750 mg/L) and 43.90 days in Ethrel @ 200 mg/L. The plants exhibited an early flower bud initiation on application of Ethrel @ 100 mg/L (38.43 days). All other treatments including control were showing early flower bud initiation the days to which were 38 to 39 days.

b. Days to initiation of flower opening

The days to initiation of flower opening was ranging from 47.33 to 63.40 days. Among the treatments more number of days taken for initiation of flower opening was noticed in CCC @ 1000 mg/L (63.40 days), which was on par with Ethrel @ 200 mg/L (61.57 days). The early initiation of flower opening was recorded in PCZ @ 60 mg/L (47.33 days).

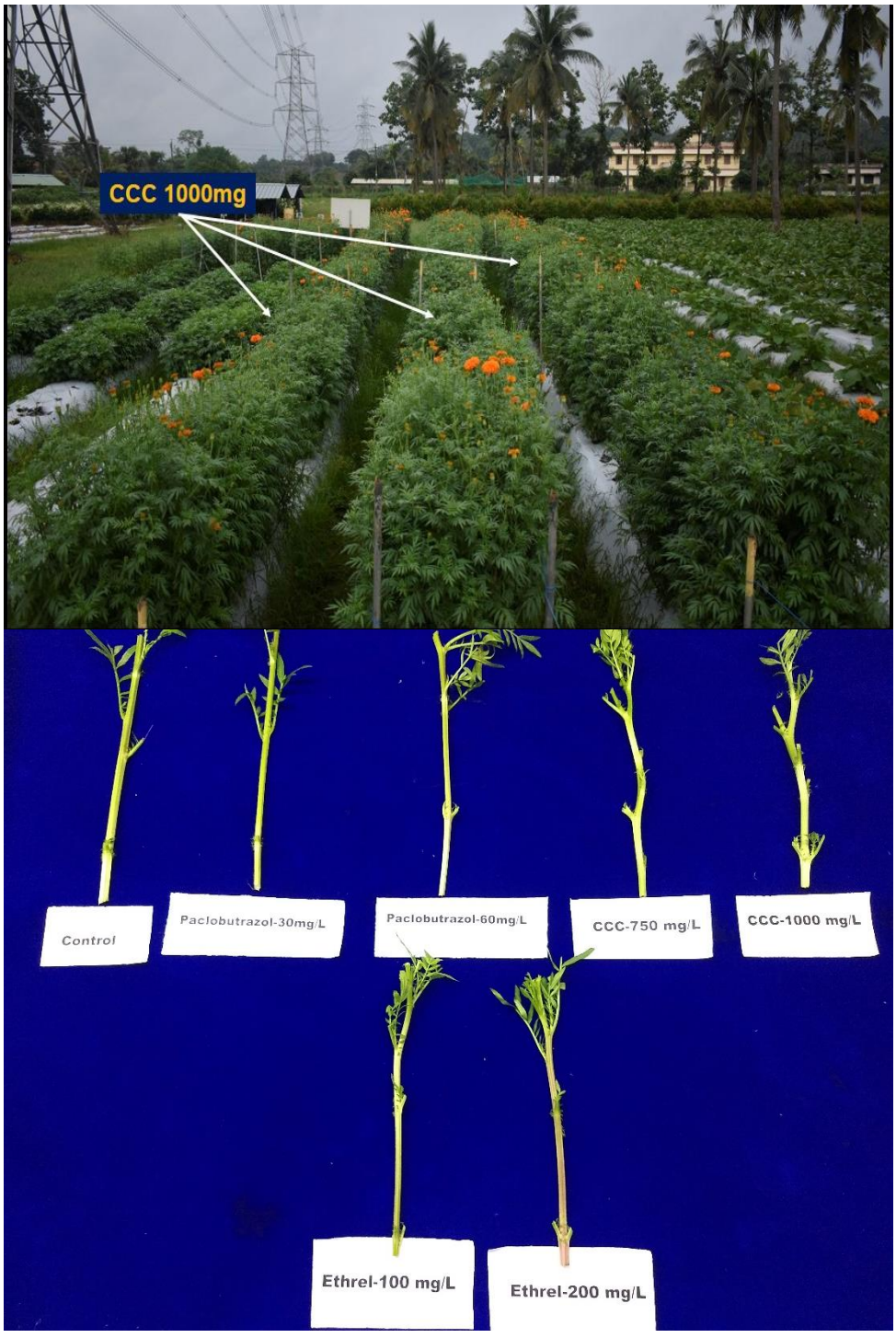


Plate 12. Effect of growth retardants on flowering and internodal length

Table 32. Effect of growth retardants on vegetative parameters of marigold (F_1 hybrid Bhagwati)

Treatments	Plant height (cm)		Plant spread (cm)		Primary branches (No.)		Stem girth (cm)		Inter nodal length (cm)
	30 DAT	60 DAT	30 DAT	60 DAT	30 DAT	60 DAT	30 DAT	60 DAT	
PCZ @ 30 mg/L	53.80	128.59	33.50	42.47	8.29	13.00	4.56	7.21	9.90
PCZ @ 60 mg/L	53.77	138.84	33.50	41.13	8.55	15.88	4.58	7.23	10.70
CCC @ 750 mg/L	51.13	108.17	29.10	52.83	7.50	20.92	4.56	7.71	6.00
CCC @ 1000 mg/L	56.21	95.34	31.87	57.10	8.71	23.88	4.86	6.85	4.69
Ethrel @ 100 mg/L	53.21	127.67	32.40	48.13	8.38	14.19	4.69	7.24	8.99
Ethrel @ 200 mg/L	50.79	112.25	29.70	53.37	7.33	18.67	4.51	7.67	7.90
Control	54.59	126.14	30.77	37.50	7.75	13.24	4.44	6.81	10.60
C.D(0.05)	NS	2.77	2.01	1.68	0.37	1.04	NS	0.33	0.55
SEm±	1.16	0.89	0.65	0.54	0.12	0.34	0.15	0.11	0.18

Table 33. Effect of growth retardants on reproductive parameters of marigold (F_1 hybrid Bhagwati)

Treatments	Days to bud initiation	Days to initiation of flower opening	Days to complete flower opening	Days to 50% flowering	Flower diameter (cm)	Stalk length (cm)	Flower weight (g)	Weight of ray florets (g)	Number of flowers/ plant	Flower yield/plant (g)	Number of harvests
PCZ @ 30 mg/L	38.50	49.80	59.47	38.67	7.32	12.07	18.74	10.99	34.10	670.10	7.33
PCZ @ 60 mg/L	38.90	47.33	57.83	38.33	7.53	15.03	20.03	11.98	34.02	699.50	7.67
CCC @ 750 mg/L	47.97	58.93	71.40	47.67	6.15	6.60	16.94	7.77	41.60	736.40	9.33
CCC @ 1000 mg/L	50.67	63.40	77.47	50.33	5.11	5.88	15.25	6.55	47.47	762.03	10.01
Ethrel @ 100 mg/L	38.43	48.60	58.20	38.67	7.63	16.31	19.27	8.75	35.13	696.90	7.67
Ethrel @ 200 mg/L	43.90	61.57	71.70	44.00	6.75	10.53	18.63	8.88	38.67	736.70	9.04
Control	38.80	50.23	61.13	39.33	6.55	14.97	18.93	10.62	33.33	671.40	8.67
C.D(0.05)	0.77	2.38	3.43	1.14	0.94	1.44	1.40	1.01	1.45	15.10	1.12
SEm±	0.25	0.76	1.10	0.37	0.30	0.46	0.45	0.33	0.46	4.85	0.36

c. Days to complete flower opening

Significant difference was observed in days to complete flower opening among the treatments. Days to complete flower opening ranged from 57.83 to 77.47 days. The greatest number of days taken to complete flower opening was observed in CCC @ 1000 mg/L (77.47 days) which was followed by 71.70 days in Ethrel @ 200 mg/L and 71.40 days in CCC @ 750 mg/L. All other treatments including control took similar number of days to complete flower opening.

d. Days to 50 per cent flowering

This parameter showed the same pattern as that of days to bud initiation. The days to 50 per cent flowering varied from 38.33 to 50.33 days. Significantly more number of days for 50 per cent flowering was recorded on application of CCC @ 1000 mg/L (50.33 days). This was followed by treatments CCC @ 750 mg/L (47.67 days) and Ethrel @ 200 mg/L (44.00 days).Treatments *viz*., PCZ @ 30 mg/L (38.67 days) and 60 mg/L (38.33 days) and control (39.33 days) recorded earlier flowering in the plant population.

e. Flower diameter

Significantly greatest flower diameter of 7.63 cm was recorded in treatment with Ethrel @ 100 mg/L, which was on par with PCZ @ 60 mg/L (7.53 cm), PCZ @ 30 mg/L (7.32 cm) and Ethrel @ 100 mg/L (6.75 cm). However, smaller flowers having an avergage diameter of 5.11 cm was recorded on application of CCC @ 1000 mg/L.

f. Stalk length

There was significant difference observed among the treatments regarding stalk length. Significantly shorter flower stalks were observed in plants treated with CCC @ 1000 mg/L (5.88 cm) and CCC @ 750 mg/L (6.60 cm). Longest flower stalks were observed in Ethrel @ 100 mg/L (16.31 cm) which was on par with PCZ @ 60 mg/L (15.03 cm) and control (14.97 cm).

g. Flower weight

Among the treatments there were significant difference observed with respect to flower weight. Significantly greater flower weight was recorded in PCZ @ 60 mg/L (20.03 g) which was on par with Ethrel @ 100 mg/L (19.27 g), control (18.93 g), PCZ @ 30 mg/L (18.74 g) and Ethrel @ 200 mg/L (18.63 g). Both concentrations of CCC produced flowers with less weight.

h. Weight of ray florets

Significantly highest weight of ray florets (11.98 g) was recorded in PCZ @ 60 mg/L which was on par with PCZ @ 30 mg/L (10.99 g) and this was followed by control (10.62 g).

i. Number of flowers per plant

Spraying CCC @ 1000 mg/L recorded greater number of flowers per plant (47.47) which was significantly superior to all other treatments. This was followed by CCC @ 750 mg/L with 41.60 flowers per plant. The lowest number of flowers was recorded in control (33.33) which was on par with PCZ @ 30 mg/L (34.10) and PCZ @ 60 mg/L (34.02).

j. Flower yield per plant

Significantly superior flower yield was recorded on application of CCC @ 1000 mg/L (762.03 g/plant) and this was followed by CCC @ 750 mg/L (736.40 g/plant). The lowest flower yield of 670.10 g/plant was recorded in PCZ @ 30 mg/L which was on par with control (671.40 g/plant).

k. Number of harvests per plant

Application of CCC @ 1000 mg/L recorded more number of harvests of 10.01, which was on par with CCC @ 750 mg/L (9.33) and Ethrel @ 200 mg/l (9.04). The lowest number of harvests per plant was recorded in PCZ @ 30 mg/L (7.33) which was on par with PCZ @ 60 mg/L and Ethrel @ 100 mg/L both having 7.67 number of harvests.

Results of the growth retardants studies on floral characters with respect to days to bud initiation, days to initiation of flower opening, days to complete flower opening, days to 50 per cent flowering, flower diameter, stalk length, flower weight, petal weight, number of flowers, flower yield per plant and number of harvests per plant are discussed below.

The data depicted in the results revealed that the number of days to flower bud initiation, days to initiation of flower opening, days to complete flower opening and days to 50 per cent flowering were noticed very early on application of paclobutrazol, whereas, CCC @ 1000 mg/L (Plate 12) registered more number of days with respect to all the above flowering parameters. This could be due to the growth retardant effect of CCC that inhibited the endogenous synthesis of gibberellins which is needed for flowering in marigold. Similar results have been reported by Atteya *et al*. (2018); Khobragade *et al*. (2019) in marigold.

Floral parameters like flower diameter, stalk length, flower weight and petal weight were significantly reduced under the treatment of CCC @ 1000 mg/L (Plate 13) because of the antagonistic and dwarfing properties of CCC that inhibited the cell expansion thereby reduced the floral parameters in African marigold.

With respect to yield attributes, the number of flowers (47.47), flower yield (762.03 g/plant) and number of harvests (10.01) were significantly greater in CCC @ 1000 mg/L. The greater number of flowers in CCC treatment might have resulted from the increased number of branches per plant and the resultant enhanced accumulation of photosynthates. This is in agreement with Kumar *et al*. (2011), Naidu *et al*. (2014), in African marigold.

C. Post-harvest parameters

Post-harvest parameters of hybrid Bhagwati under different growth retardants during rainy season is presented in Table 34.

a. Shelf life of flowers

Significant difference was recorded among the treatments with respect to shelf life of the flowers. Application of growth retardants except PCZ @ 30 mg/L, reduced

the shelf life of marigold flowers. PCZ @ 30 mg/L showed a shelf life of 4.05 dayswhich was on par with control (4.00 days) and Ethrel @ 100 mg/L (3.67 days).

Table 34. Effect of growth retardants on postharvest parameters of marigold (F_1 hybrid Bhagwati)

Treatments	PLW (%)	Shelf life (days)
PCZ @ 30 mg/L	9.78	4.05
PCZ @ 60 mg/L	9.14	3.00
CCC @ 750 mg/L	14.13	3.00
CCC @ 1000 mg/L	15.63	3.00
Ethrel @ 100 mg/L	11.16	3.67
Ethrel @ 200 mg/L	16.51	3.33
Control	9.75	4.00
C.D(0.05)	1.53	0.53
SEm±	0.52	0.17

b. Physiological loss in weight of flowers

There was significant difference recorded among the treatments in relation to physiological loss in weight of flowers. Lower PLW was recorded in PCZ @ 60 mg/L (9.14%), control (9.75%) and PCZ @ 60 mg /L (9.78%). The maximum PLW (16.51%) was recorded in Ethrel @ 200 mg/L which was on par with CCC @ 1000 mg/L (15.63%).

The flower quality was comparatively low in the treatment CCC @ 1000 mg/L which recorded low shelf life and high PLW in comparison with other treatments. CCC as an anti-gibberellin might have reduced the gibberellin synthesis resulting in poor shelf life of flowers. This is in conformity findings of Khobragade *et al*. (2019) and Sathappan (2018) in marigold.

D. Bio chemical parameters

Biochemical parameters *viz*., total carotenoids and flavonoids as well as essential oil content as influenced by growth retardant application during rainy season is presented in Table 35.

a. Total carotenoids (mg/g)

Total carotenoids content was not increased by the application of growth retardants as significantly higher total carotenoids was recorded in control (0.104 mg/g) which was on par with PCZ @ 60 mg/L (0.102 mg/g) and Ethrel @ 100 mg/L (0.101 mg/g). The lowest carotenoids of 0.096 mg/g was observed in CCC @ 750 mg/L and 1000 mg/L which was on par with 0.097 mg/g in PCZ @ 60 mg/L and 0.098 mg/g in Ethrel @ 200 mg/L.

b. Flavonoids (A_{300} g^{-1})

Flavonoids content varied significantly among the treatments in both leaves and petals when treated with growth retardants during rainy season. The highest flavonoids content in leaves (3.41 A_{300} g^{-1}) was recorded in Ethrel @ 100 mg/L. This was followed by 3.34 A_{300} g^{-1} in CCC @ 1000 mg/L, whereas, the highest content of flavonoids in petals was estimated 1.66 A_{300} g^{-1} in control. This was followed by 1.54 A_{300} g^{-1} in CCC @ 1000 mg/L which was on par with PCZ @ 30 mg/L (1.53 A_{300} g^{-1}), Ethrel @ 200 mg/L (1.52 A_{300} g^{-1}**)** and CCC @ 750 mg/L (1.51 A_{300} g^{-1}).

c. Essential oil (%)

Essential oil content in leaves was almost similar in all the treatments including control. However, it differed among the treatments in the case of petals. With regard to petals, the highest percentage of essential oil was obtained in control (0.20%) which was on par with CCC @ 1000 mg/L (0.15%). This was followed by CCC @ 1000 mg/L (0.13%) and PCZ @ 30 mg/L (0.13%), PCZ @ 60 mg/L (0.12%) and Ethrel @ 100 and 200 mg/L (0.10%).

Table 35. Effect of growth retardants on biochemical parameters of marigold (F_1 hybrid Bhagwati)

Treatments	Total carotenoids (mg/g)	Flavonoids (A_{300} g^{-1})		Essential oil (%)	
		Leaves	Petals	Leaves	Petals
PCZ @ 30 mg/L	0.102	3.01	1.53	0.27	0.13
PCZ @ 60 mg/L	0.097	3.11	1.50	0.27	0.12
CCC @ 750 mg/L	0.096	3.20	1.51	0.20	0.13
CCC @ 1000 mg/L	0.096	3.34	1.54	0.23	0.15
Ethrel @ 100 mg/L	0.101	3.41	1.46	0.30	0.10
Ethrel @ 200 mg/L	0.098	3.16	1.52	0.27	0.10
Control	0.104	3.16	1.66	0.27	0.20
C.D(0.05)	0.004	0.04	0.03	NS	0.05
SEm±	0.001	0.01	0.01	0.03	0.02

Total carotenoids content was not increased by the application of growth retardants during rainy season. However, in the case of flavonoids, higher contents in leaves were observed in Ethrel @ 100 mg/L and CCC @ 1000 mg/L compared to other treatments. This is in conformity to the findings of Atteya *et al.* (2018) in marigold. In the study, the authors have attributed the increased content of flavonoids due to enhanced chlorophyll(a + b) in CCC applied plants which in turn might have promoted more metabolic activities and finally more content of flavonoids. Similar results of application of CCC has been found to increase the content of leaf flavonoids in *Ginkgo biloba* by Zhang *et al*.(2013) and in mustard leaves by Banerjee *et al* . (2012).

4.5.2. Effect of growth promoters on plant growth and yield of African marigold

The experiment was conducted in hybrid Bhagwati during winter season. The results of the same are presented below.

A. Vegetative parameters

Vegetative parameters of marigold on spraying of different growth promoters during winter season is presented in Table 36.

a. Plant height

At 30 DAT treatments did not show significant difference for plant height. However at 60 DAT, the greatest plant height was observed in GA_3 @ 300 mg/L (80.67 cm). This was followed by GA_3 @ 200 mg/L (77.46 cm). The plant height varied from 67.96 cm to 80.67 cm. significantly higher plant height was recorded on application of during 60 DAT.

b. Plant spread

There was no significant difference among the treatments at 30 DAT with respect to plant spread. At 60 DAT, the maximum plant spread of 44.18 cm was recorded in GA_3 @ 300 mg/L which was on par with 43.20 cm in GA_3 @ 200 mg/L and this was followed by control (39.37 cm).

c. Number of primary branches

At 30 DAT there was no significance difference noticed among the treatments with respect to number of primary branches. However, at 60 DAT, significantly more number of primary branches of 15.38 was observed on application of GA_3 @ 300 mg/L. This was followed by GA_3 @ 200 mg/L (12.54).

d. Stem girth

There was no significance difference found among the treatments regarding stem girth. .

e. Inter nodal length

Significantly greater inter nodal length of 6.85 cm was recorded on application of GA_3 @ 300 mg/L. This was followed by an inter nodal length of 6.13 cm in GA_3 @ 200 mg/L. Minimum inter nodal length of 4.43 cm was recorded in control which was on par with NAA @ 300 mg/L (4.65 cm) and BA @ 50 mg/L (4.96 cm).

Gibberellins are chemically tetracyclic diterpenoids that act at all stages in the plant life cycle. Gibberellins are involved in a number of physiological processes of plants including stem elongation, germination, breaking dormancy, flowering, sex expression, enzyme induction and leaf and fruit senescence, flowering and quality of horticulture produces. In the present study, application of GA_3 @ 300 mg/L played a significant role in enhancing the in plant height (80.67 cm), plant spread (44.18 cm), number of branches (15.38) and increased inter nodal length (6.13 cm). This could be due to enhanced cell division and cell enlargement, promotion of protein synthesis coupled with higher dry matter accumulation in the plants. This view is supported by Dais (1988) in rose, by Kulkarni (2003) in chrysanthemum and Girish (2011) in daisy cv. Dwarf Pink. Similar results on vegetative parameters have been reported by Kumar *et al*. (2011); Mishra (2017); Imandi and Reddy (2017) and Sarkar *et al*. (2018) in African marigold.

B. Reproductive parameters

The reproductive parameters of the hybrid Bhagwati on application of various growth promoters during winter season is presented in Table 37.

a. Days to bud initiation

The data presented in Table 37 showed that the days to bud initiation varied from 33.77 to 35.20 days. Flower bud initiation was earlier in control (33.77 days) which was on par with NAA @ 200 mg/L and GA_3 @ 300 mg/L (34.87 days).

Significantly more number of days taken to flower bud initiation was recorded in GA_3 @ 200 mg/L (35.20 days) and it was on par with BA @ 75 mg/L (35.13 days), NAA @ 300mg/L (35.07 days).

b.Days to initiation of flower opening

All the treatments except the control showed on par effect with respect to this parameter. The days to initiation of flower opening was 45.50 days in BA @ 75 mg/L ,45.00 days in NAA @ 300mg/L, 44.67 days in GA_3 @ 200 mg/L, 44.27 days in NAA @ 200mg/L and 44.23 days in BA @ 50 mg/L. The lowest number

of days was observed in control (42.57 days) and it was on par with GA_3@ 300 mg/L (43.87 days).

c. Days to complete flower opening

There was no significant difference for the parameter among the treatments with respect to days to complete flower opening and 50 per cent flowering.

d. Flower diameter

Significantly larger flowers with diameter of 6.48 cm and 6.16 cm were recorded in GA_3 @ 200 mg/L and GA_3 @ 300 mg/L respectively. Smallest flower diameter was recorded in BA @ 75 mg/L (3.82 cm) which was on par with BA @ 50 mg/L (3.92 cm), control (4.01 cm) and NAA @ 300 mg/L (4.30 cm).

e. Stalk length

Significantly longer flower stalk was recorded in GA_3 @ 300 mg/L (13.18 cm) which was on par with GA_3 @ 200 mg/L (12.20 cm). In all other treatments, the stalk length was much lower than these two treatments.

f. Flower weight

The maximum flower weight (7.97 g) was recorded in GA_3 @ 300 mg/L, which was on par with control (6.96 g). This was followed by GA_3 @ 200 mg/L and BA @ 75 mg/L both with a flower weight of 6.47 g.

g. Weight of ray florets

Significantly greater weight of ray florets was the highest recorded in GA_3 @ 300 mg/L (3.81 g) which was followed by BA @ 50 mg/L (3.33 g) and NAA @ 300 mg/L (3.21 g).

h. Number of flowers per plant

Spraying GA_3 @ 300 mg/L recorded the highest number of flowers per plant (83.47), which was significantly superior among all other treatments. This was followed by GA_3 @ 200 mg/L (78.67 flowers), which was on par with 78.27 and 77.67 flowers

in NAA @ 200 and 300 mg/L respectively. The lowest number of flowers were noticed in control (67.93) and BA @ 50 mg/L (68.13).

i. Flower yield per plant

With regard to flower yield per plant, application of GA_3 @ 300 mg/L produced the greatest flower yield of 475.87 g/plant, which was on par with GA_3 @ 200 mg/L (454.60 g/plant). This was followed by a yield of 428.20 g/plant in NAA @ 200 mg/L and it was on par with NAA @ 300 mg/L (400.73 g/plant). Lowest flower yield was recorded in control (371.37 g/plant).

j. Number of harvests

Significantly more number of harvests was recorded in GA_3 @ 300 mg/L (6.02), which was on par with GA_3 @ 200 mg/L (5.67). The lowest number of harvests (4.00) was recorded in BA @ 50 and 75 mg/L and NAA @ 200 mg/L.

Spraying of GA_3 resulted in significantly early bud initiation, initiation flower opening, completion flower opening and 50 per cent flowering. In general, the plants treated with GA_3 were early to produce first flower than control plants. This might be due the effect of gibberellins, as gibberellins influences florigen hormone which is required for formation of floral buds. These results were in accordance with Doddagoudar *et al.* (2004) in China aster. Early flowering in GA_3 might also be due to increase in the endogenous gibberellin levels in the plants as reported by Singh *et al.* (1991) ; Mithileshkumar *et al.* (2015) in African marigold. Similar findings were reported by Shivaprasad (1995) in China aster, Singh and Bijimol (2001) in tuberose.

Flower quality parameters were the best in the plants sprayed with GA_3 (Plate 14). Enhancement of flower size due to growth regulator could be attributed to increased length of petals. It was opined by Zieslin *et al.* (1974) in rose, that the enlargement of flower size is caused by translocation of photosynthates to the flowers as a consequence of intensification of sink. These views are in confirmation with Kulkarni (2003) in chrysanthemum and Mithileshkumar *et al.* (2015) in African marigold cv. Pusa Narangi Gainda.

Table 36. Effect of grwth promoters on vegetative parameters of marigold (F_1 hybrid Bhagwati)

Treatments	Plant height (cm)		Plant spread (cm)		Primary branches (No.)		Stem girth (cm)		Inter nodal length (cm)
	30 DAT	60 DAT	30 DAT	60 DAT	30 DAT	60 DAT	30 DAT	60 DAT	
GA_3@ 200mg/L	54.25	77.46	29.90	43.20	7.33	12.54	3.56	4.98	6.13
GA_3@ 300mg/L	57.38	80.67	29.63	44.18	6.96	15.38	3.46	5.35	6.85
NAA@ 200mg/L	56.54	70.88	29.70	38.27	7.96	11.38	3.60	4.77	5.20
NAA@ 300mg/L	53.92	70.04	28.43	34.70	7.00	10.67	3.29	4.63	4.65
BA@ 50 mg/L	53.13	67.96	30.47	38.83	6.33	10.96	2.92	4.72	4.96
BA@ 75mg/L	57.34	68.46	27.97	37.93	7.67	11.42	3.65	5.46	5.61
Control	56.17	69.92	28.90	39.37	8.04	11.25	3.36	4.83	4.43
C.D(0.05)	NS	2.52	NS	2.43	NS	1.09	NS	NS	0.53
SEm±	1.22	0.81	0.88	0.78	0.36	0.35	0.16	0.51	0.17

Table 37. Effect of growth promoters on reproductive parameters of marigold (F_1 hybrid Bhagwati)

Treatments	Days to bud initiation	Days to initiation of flower opening	Days to complete flower opening	Days to 50% flowering	Flower diameter (cm)	Stalk length (cm)	Flower weight (g)	Weight of ray florets (g)	Number of flowers/ plant	Flower yield/plant (g)	Number of harvests
GA_3 @ 200mg/L	35.20	44.67	53.20	35.00	6.48	12.20	6.47	3.05	78.67	454.60	5.67
GA_3 @ 300mg/L	34.87	43.87	52.03	34.67	6.16	13.18	7.97	3.81	83.47	475.87	6.02
NAA @200mg/L	34.13	44.27	53.33	34.00	4.36	9.20	6.36	3.08	78.27	428.20	4.00
NAA @300mg/L	35.07	45.00	54.67	35.00	4.30	8.30	5.80	3.21	77.67	400.73	4.33
BA @ 50 mg/L	34.50	44.23	54.53	34.00	3.94	8.33	6.05	3.33	68.13	376.77	4.00
BA @ 75mg/L	35.13	45.50	54.87	35.33	3.82	8.59	6.47	2.96	76.20	416.77	4.00
Control	33.77	42.57	51.87	34.00	4.01	8.25	6.96	2.88	67.93	371.37	4.67
C.D(0.05)	0.91	1.63	NS	NS	0.51	1.31	1.13	0.26	2.05	34.92	0.60
SEm±	0.29	0.52	0.73	0.58	0.16	0.42	0.36	0.09	0.66	11.21	0.19

Favourable effect of application of gibberellins on number of flowers and flower diameter might be due to improved physiological efficiency, selective ion uptake, sufficient water uptake causing high rate of photosynthate accumulation.

Similar results and observations were reported by Rani and Singh (2005) in tuberose. Greater flower weight was recorded with application of GA_3 compared to control and this was attributed to the increased production of photosynthates facilitated by more number of leaves and branches in this treatment. Similar findings were reported by Devadanam *et al.* (2007) in African marigold.

GA_3 application recorded significantly greater yield parameters like number of flowers, flower yield per plant and number of harvests. In this study, GA_3 @ 300 mg/L produced profuse flowers per plant. This could be due to the production of optimum plant stature, increased number of branches, leaf area and plant spread, which in turn enabled them to produce an increased amount of photosynthates, ultimately resulting in accumulation of maximum dry matter resulting in duration of flowering, yield and better quality. Similar findings were also reported by Imandi and Reddy (2017) and Sarkar *et al*. (2018) in African marigold and Kulkarni (2003) in chrysanthemum.

C. Post-harvest parameters

Response of hybrid Bhagwati to the different growth promoters during winter season with respect to post harvest parameters is presented in Table 38.

Shelf life and PLW did not vary significantly with different growth regulators treatments. Significantly greater shelf life of marigold flowers on treatment with GA_3 has been reported by Imandi and Reddy (2017), but in that particular study the concentration of GA_3 used were 100 and 150 mg/L. The concentration used in the present study was slightly more than the earlier study quoted here and perhaps, this might be the reason for the absence of remarkable variation among the treatments.

Table 38. Effect of growth promoters on post-harvest parameters of marigold (F_1 hybrid Bhagwati)

Treatments	PLW (%)	Shelf life (days)
GA_3 @ 200mg/L	11.45	3.00
GA_3 @ 300mg/L	11.84	3.00
NAA @ 200mg/L	14.88	2.33
NAA @ 300mg/L	14.48	2.33
BA @ 50 mg/L	15.64	2.67
BA @ 75mg/L	15.39	2.00
Control	13.23	2.67
C.D(0.05)	NS	NS
SEm±	0.15	0.26

D. Bio chemical parameters

Biochemical parameters of hybrid Bhagwati applied with different growth promoters during winter season are presented in Table 39.

a. Total carotenoids (mg/g)

Significantly higher content of total carotenoids was recorded in GA_3@ 300 mg/L (0.104 mg/g) which was on par with GA_3 @ 200 mg/L (0.102 mg/g). The lowest carotenoids content of 0.096 mg/g was observed in control which was on par with 0.097 mg/g of total carotenoids in BA @ 50 and 75 mg/L and NAA @ 300 mg/L.

b. Flavonoids (A_{300} g^{-1})

The flavonoids content in both leaves and petals differed significantly among the treatments. With regard to leaves, the highest flavonoids content of 3.04 A_{300} g^{-1} was recorded in GA_3 @ 300 mg/L, which was on par with GA_3 @ 200 mg/L (2.99 A_{300} g^{-1}) and control (2.98 A_{300} g^{-1}). The highest content of flavonoids in petals

was 1.44 A_{300} g^{-1} in BA @ 75 mg /L which was on par with 1.41 and 1.40 A_{300} g^{-1} (GA_3 @ 200 and 300 mg/L).

c. Essential oil (%)

The essential oil content was found to be varying in leaves but in petals there was no significant difference among the treatments. With respect to leaves, significantly the highest per cent of 0.30% of essential oil was estimated in GA_3 @ 300 mg/L which was on par with GA_3 @ 200 mg/L (0.27%) and NAA @300 mg/L (0.23%) and in control (0.23%).

Table 39. Effect of growth promoters on biochemical parameters of marigold (F_1 hybrid Bhagwati)

Treatments	Total carotenoids (mg/g)	Flavonoids (A_{300} g^{-1})		Essential oil (%)	
		Leaves	Petals	Leaves	Petals
GA_3@ 200 mg/L	0.102	2.99	1.41	0.27	0.13
GA_3@ 300 mg/L	0.104	3.04	1.40	0.30	0.22
NAA@ 200mg/L	0.099	2.89	1.37	0.20	0.10
NAA@ 300mg/L	0.097	2.92	1.38	0.23	0.17
BA @ 50 mg/L	0.097	2.93	1.38	0.17	0.17
BA @ 75mg/L	0.097	2.89	1.44	0.20	0.17
Control	0.096	2.98	1.34	0.23	0.13
C.D(0.05)	0.002	0.08	0.04	0.08	NS
SEm±	0.001	0.03	0.01	0.03	0.03

Significantly greater total carotenoids was observed in treatment with GA_3. This might be due to the increased chlorophyll content that stimulated the biosynthesis of carotenoids as reported by Giuliano *et al.* (1993). The increased chlorophyll content might have resulted due to the decreased activity of chlorophyllase stimulated by GA_3 application (Jacob-Wilk *et al.,* 1999). Increased carotenoids in marigold due to GA_3 application has been reported by Wadgave (2016).

In the case of flavonoids also, significantly higher content was observed in petals in treatment with GA_3 at both concentrations. Plant growth regulators activate signaling pathways that regulate the expression of genes encoding enzymes related to secondary metabolism, thus increasing the amount or activity of these metabolites (Ghasemzadeh *et al.,* 2012). PGRs also influence carbon partitioning in the plant that increases the number of carbohydrate precursors required for the synthesis of phenolic compounds which includes flavonoids (Singh *et al*., 1991). Similar trend in increasing flavonoids due to application of GA_3 was observed by Machado *et al*. (2014) in pot marigold.

4.6 Incidence of pest and diseases in marigold

During the entire study period, other than the bacterial wilt no major diseases were observed. This might be due to propylatic spraying of fungiicdes at the time of pinching as well as flower bud formation. However, incidence of pests like flower bud borer (*Helicoverpa armigera*), thrips (*Thrips tabaci*), red spider mites (*Tetranychus urticae*) was observed during the cropping seasons. Marigold being a trap crop is easily attracked by these pests. Integrated control measures like installation of yellow sticky traps and timely spraying of both sysytemic and contact insecticides were adopted for management of these pests.

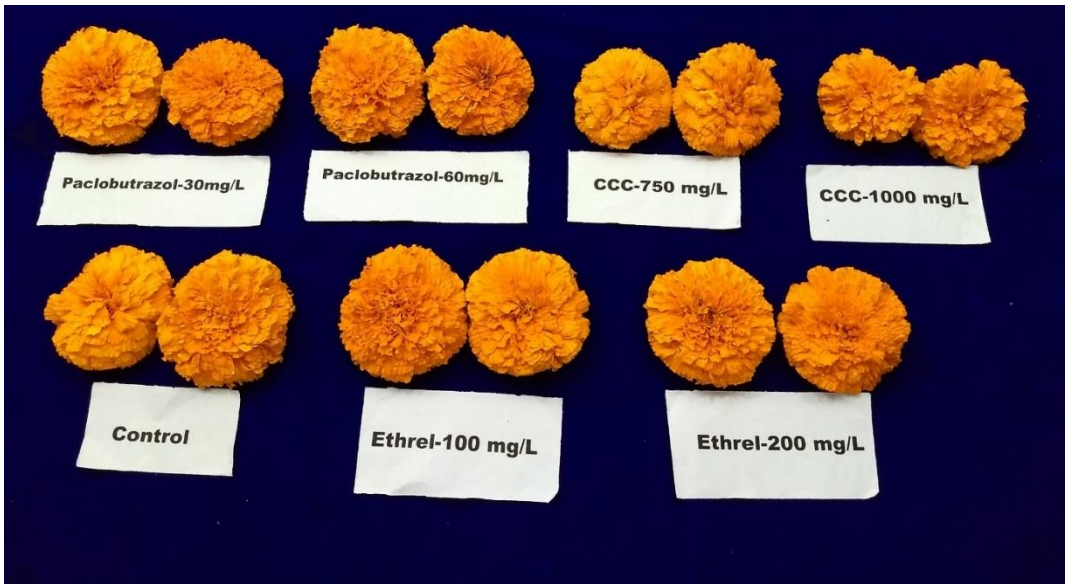


Plate13. Effect of growth retardants on floral parameters in hybrid Bhagwati

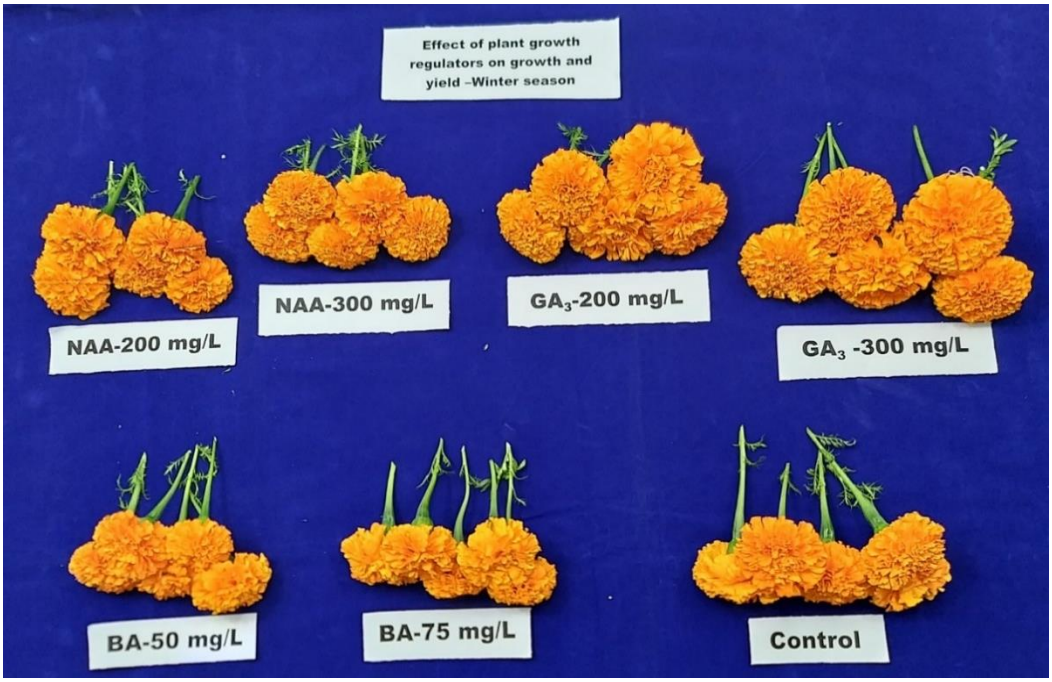


Plate 14. Effect of promoters on floral parameters in hybrid Bhagwati

Summary

5. SUMMARY

The present investigation on "Standardization of production technology for African marigold (*Tagetes erecta* L.)" was conducted in the Department of Floriculture and Landscaping, College of Horticulture, Vellanikkara, Thrissur during the year 2018 to 2020. The silent findings of the present study are summarized in this chapter.

1. Field evaluation of African marigold genotypes and other *Tagetes* spp.

Field evaluation for bacterial wilt incidence was done during two seasons *viz*., June–September and October–January whereas the morphological characters were observed only during June-September. Thirty two marigold genotypes were evaluated in an already identified bacterial wilt sick plot. Among the genotypes, there were eight F_1 hybrids, eight varieties, seven local collections of *T. erecta*, eight genotypes of *T. patula* (three varieties as well as five local collections) and one genotype of *T. tenuifolia*.

a. Bacterial wilt incidence

- Genotypes M-1 and M-2 did not show bacterial wilt incidence during both the seasons and these were found to be completely resistant to bacterial wilt.
- During rainy season, the greatest PDI was recorded in Coimbatore Local (87.50%) followed by Dharmapuri Local (83.33%). The genotypes *viz.*, M-1, M-2, Bhagwati and Maria 91 were referred as resistant. However, Arka Agni, Arka Bangara-2, P4, KDA-2 and Madikeri Local were obtained as moderately resistant.
- In winter season, the highest PDI was recorded in Dharmapuri Local (100.00%), followed by Rupa and Pusa Narangi Gainda.
- The resistant genotypes *viz.*, M-1, M-2 and Bhagwati were recorded with greater flavonoid contents in leaves (4.3 A_{300} g^{-1}, 3.8 A_{300} g^{-1}, 3.7 A_{300} $g,^{-1}$respectively) and petals (1.7 A_{300} g^{-1}, 2.0 A_{300} g^{-1}, 1.6 A_{300} $g,^{-1}$ respectively).
- Flavonoid content was significantly and negatively correlated with per cent disease incidence.

b. Identification of the wilt causing bacterium

During the present study, under sick plot conditions marigold plants preliminarily exhibited typical symptoms of leaf wilting. On close observation, necrosis was observed at leaf tip followed by gradual wilting of plants. Cultural, morphological through SEM, PCR gel profile, *In-silico* analysis of 16S rDNA sequences and phylogenetic analysis of the bacterial samples clearly confirmed the bacterium as *Enterobacter cloacae*, causing wilt in marigold. This was first report of *Enterobacter cloacae* in marigold. Received accession numbers *viz.*, MT649902 and MT649903 from NCBI.

c. Vegetative characters

- Field evaluation of marigold genotypes showed significant variations in all the vegetative parameters *viz*., plant height, plant spread, number of primary branches except stem girth. The maximum plant height was recorded in Royal Orange (112.90 cm) which was on par with many other *T. erecta* genotypes. Among the *T. erecta* genotypes primary branches was more for Double Orange, Pusa Basanthi Gainda, Pusa Narangi Gainda Suvarna Yellow, Arka Bangara-2, Rupa, Bhagwati, Maria 91 and Bhuvana. With regard to *T. patula* genotypes primary branches was more in Hissar Jafri-2, Pusa Arpita and KDA-2. The selected genotypes showed stem colour from green to greyed purple.

d. Flowering and yield parameters

- Majority of the genotypes started flower bud initiation at 45 DAT, except two genotypes *viz*., M-1 and M-2, which initiated flower buds very late at 68 to 77 DAT. Other parameters like initiation of flower opening, complete flower opening and days to 50 per cent flowering also followed the similar trend.
- The study also revealed varied flowering behaviour of *T. patula* genotypes when planted during rainy season *i.e.* June to September in Kerala. Some of the *T. patula* genotypes *viz.*, KDA-2, KDA-3, KDA-4, Chintamani Red and TNAU Dwarf Marigold produced flowers during the rainy season in Kerala, whereas

genotypes *viz*., Hisar Jafri-2, Pusa Arpita and Red brocade did not flower at all during this season.

- Among the *T. erecta* genotypes, flower diameter ranged from 4.00 cm to 8.07 cm whereas in *T. patula* genotypes it ranged from 4.17 cm to 4.73 cm. Flower diameter was significantly greater in genotypes Sakura 031 (9.07 cm) which was on par with Maria 91 as well as, Bhagwati (8.73 cm), P-4 (8.43 cm) and Rupa (7.77 cm).
- The flower weight and weight of ray florets was maximum in F_1 hybrids. The maximum flower weight was recorded in Sakura 031 (24.17 g) followed by Bhagwati (17.00 g) which was on par with Rupa, Maria 91, and P-4 (16.40, 15.57 and 15.37 g, respectively). Similar trend was followed in weight of ray florets also.
- The greatest number of flowers per plant (59.10), yield per plant (476.80 g) as well as number of harvests (5.33) were recorded in P-4 followed by Maria 91(355.17 g/plant) on par with Bhagwati (319.73 g/plant).

e. Correlation among plant characters

The two species of *T. erecta* of 23 genotypes and *T. patula* of five genotypes of plant characters were correlated towards flower yield. The important traits *viz.*, vegetative (plant spread, stem girth), floral (flower diameter, stalk length, flower weight, weight of ray florets), yield (number of flowers and harvests/plant) and total carotenoids were positively contributing to the flower yield whereas, days to bud initiation and days to 50 per cent flowering was negative response in African marigold. In case of *T. patula* genotypes with respect to yield parameters (number of flowers and number of harvests/plant) were significantly and positively correlated to flower yield.

f. Post-harvest parameters

Majority of the *T. erecta* genotypes showed better shelf life and lower physiological weight loss compared to *T. patula* and *T. tenuifolia* genotypes.

g. Biochemical parameters

The highest carotenoid content was recorded in the genotype Bhagwati (0.105 mg/g). Among the genotypes, the maximum flavonoids content was recorded in M-1 and M-2 which was on par with Bhagwati. The highest essential oil in leaves was recorded in M-2 and Arka Agni (0.37%) and it was on par with M-1, Maria-91, P-4, Suvarna Orange and Double Orange. However, the essential oil content in petals did not differed significantly.

II. Artificial screening against bacterial wilt resistance

Twelve genotypes which were categorized as resistant and moderately resistant in the field evaluation were subjected to artificial inoculation. The artificial screening studies revealed that genotypes M-1 and M-2 were completely wilt resistance and did not show any wilt symptom during the study. Among other genotypes, Bhagwati showed a lower PDI of 26.70 per cent. Per cent disease incidence in other nine genotypes ranged from 40 per cent to 60 per cent. The maximum number of days taken to show the wilt symptom was noticed in Bhagwati (13.75 days) on par with P-4, KDA-4, Arka Agni, Madikeri Local, Chintamni Red and Maria 91.

III. Evaluation of rootstocks for *Tagetes erecta* L

It is evident from the present study that the F_1 hybrids recorded better survival of grafts compared to varieties of African marigold. The greatest survival of grafts was recorded in hybrid Bhagwati grafted on M-1 rootstock (60%) and this was on par with Bhagwati grafted on M-2 (54%), Maria 91 grafted on M-1 (54%) and Maria 91 grafted on M-2 (50%). Irrespective of the scion genotypes, M-1 as rootstock recorded better graft survival (34.22%) compared to a survival of 25.56 per cent in M-2. Irrespective of the rootstock genotypes, the greatest survival was recorded in Bhagwati (57 %) on par with Maria 91 (52 %).

IV. Precision farming techniques and seasonal response

Precision farming experiments during rainy, winter and summer exhibited a variation in plant height, plant spread, primary branches, stem girth, leaf area and dry matter production with the application of different level of fertigation and irrigation in

the two selected genotypes *viz.*, Bhagwati and M-1. Majority of these parameters were excelling than control during all the three seasons.

- During rainy season, fertigation with 75% RDF (IIHR recommendation) showed superior performance compared to other two fertilizer levels with respect to majority of the vegetative, floral and yield parameters.
- During winter and summer seasons drip irrigation @ 100% Epan along with fertigation @ 125% RDF showed better performance with respect to vegetative, flowering, floral and yield traits.
- The hybrid Bhagwati had more shelf life and less PLW compared to M-1 genotype during all the three seasons. During rainy, winter and summer seasons, all the drip fertigation treatments in Bhagwati recorded greater shelf life and lesser PLW compared to control. The similar trend was observed in M-1 also.
- In all the three seasons, biochemical traits *viz*., total carotenoids, flavonoids, essential oil content and better uptake of nutrients were higher in drip fertigation treatments compared to control.
- Differential response was vivid in marigold genotypes during different seasons. During rainy season, majority of the vegetative, flowering (except days to initiation and fifty per cent flowering) as well as yield parameters, were positively correlated with temperature in both the genotypes, whereas in case of relative humidity only hybrid Bhagwati was showing positive correlation with majority of the parameters.
- During winter, both genotypes showed significant positive correlation with temperature in days to bud initiation. In the case of majority of parameters *viz*., floral, yield as well as nutrient uptake, the genotype M-1 showed positive and significant correlation with temperature while in case of Bhagwati, temperature showed negative correlation. Similar pattern was observed in correlation with relative humidity.
- During summer, temperature and relative humidity showed negative correlation with majority of the parameters in both the genotypes.
- It is evident from the study that WUE was significantly greater in all the drip fertigation treatments compared to the control in both the genotypes during winter and summer seasons. WUE was the highest for the treatment I_2F_3

(Irrigation @100% Epan along with 125% RDF) in both the genotypes during both seasons.

- Based on cost economics, it could be inferred that marigold cultivation was the most profitable under drip irrigation and fertigation system than the convention system of cultivation in all the three seasons. The hybrid Bhagwati recorded the highest returns in all the seasons whereas, the genotype M-1 was remunerative only in winter season.

V. Effect of growth regulators on plant growth and yield in *Tagetes erecta* L.

a. Effect of growth retardants during rainy season

- The result of the present investigation revealed that there was significant reduction in plant height (95.34 cm), plant spread (57.10 cm), stem girth (6.85 cm) and internodal length (4.69 cm) by spraying growth retardant of CCC @ 1000 mg/L on 30 and 45 DAT.
- CCC @ 1000 mg/L delayed flowering by 12 to 15 days.
- Floral parameters like flower diameter (5.11 cm), stalk length (5.88 cm), flower weight (15.25 g) and weight of ray florets (6.55 g) were significantly reduced with the treatment of CCC @ 1000 mg/L.
- Paclobutrazol @ 60 mg/L registered maximum flower weight of 20.03 g with a weight of ray florets 11.98 g.
- With regard to yield attributes, number of flowers (47.47), flower yield (762.03 g/plant) and number of harvests (10.01) were significantly greater in CCC @ 1000 mg/L.
- The flower quality was comparatively low in the treatment (CCC @ 1000 mg/L) recorded the maximum yield of 762.03 g/plant has least number of shelf life (3.00 days) with high PLW (15.63%) in comparison with other treatments.
- Growth retardant application did not increase the total carotenoid content in marigold flowers.
- In the case of flavonoids, higher contents in leaves were observed in Ethrel @ 100 mg/L followed by CCC @ 1000 mg/L. However, in petals, control treatment recorded highest flavonoids.

- The highest percentage of essential oil in petals was obtained in control (0.20%) which was on par with CCC @ 1000 mg/L. However with respect to leaves, the essential oil content did not differ significantly.

b. Effect of growth promoters during winter season

- Study on growth promoters on marigold revealed that application of GA_3 @ 300 mg/L played a significant role in enhancement of plant height (80.67 cm), number of branches (15.38) and increased internodal length (6.85 cm).
- Growth promoters did not induce early bud iniation in marigold.
- Flower weight (7.97 g), weight of ray florets (3.81 g), greater number of flowers (83.47) were significantly superior in GA_3 @ 300 mg/L.
- Flower yield per plant was on par in GA_3 @ 200 mg/L (454.60 g) and GA_3 @ 300 mg/L (475.87 g)
- Growth promoters did not influence the shelf life of marigold flowers.
- The treatment with GA_3 recorded the maximum content of carotenoids (0.104 mg/g), flavonoids in petals (1.40 A_{300} g^{-1}) and essential oil in leaves (0.30%).

Future lines of work

a. Evaluation of more genotypes/new varieties/hybrids for yield, quality and resistance to bacterial wilt disease in the humid tropical conditions of Kerala.
b. Resistance breeding programme utilizing the identified bacterial wilt resistant genotypes.
c. Standardization of temperature and relative humidity for high success of grafting.
d. Optimization of spacing for marigold during rainy, winter and summer season under tropical humid climatic conditions.
e. Elaborate studies on newly identified bacterium in other crops.
f. The effectiveness of paclobutrazol at different concentration through drenching

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Appendices

Appendix I

Nucleotide sequence of 16S rDNA of *Enterobacter clocae*

Sample name: MB -1

(Department of Floriculture and Landscaping, COH Vellanikkara)

GCTACTTTGCCGGCGAGCGGCGGACGGGTGAGTAATGTCTGGGAAACTGC
CTGATGGAGGGGGATAACTACTGGAAACGGTAGCTAATACCGCATAACGT
CGCAAGACCAAAGAGGGGGACCTTCGGGCCTCTTGCCATCAGATGTGCCC
AGATGGGATTAGCTAGTAGGTGGGGTAACGGCTCACCTAGGCGACGATCC
CTAGCTGGTCTGAGAGGATGACCAGCCACACTGGAACTGAGACACGGTCC
AGACTCCTACGGGAGGCAGCAGTGGGGAATATTGCACAATGGGCGCAAG
CCTGATGCAGCCATGCCGCGTGTATGAAGAAGGCCTTCGGGTTGTAAAGT
ACTTTCAGCGGGGAGGAAGGTGTTGAGGTTAATAACCTCAGCAATTGACG
TTACCCGCAGAAGAAGCACCGGCTAACTCCGTGCCAGCAGCCGCGGTAAT
ACGGAGGGTGCAAGCGTTAATCGGAATTACTGGGCGTAAAGCGCACGCA
GGCGGTCTGTCAAGTCGGATGTGAAATCCCCGGGCTCAACCTGGGAACTG
CATTCGAAACTGGCAGGCTAGAGTCTTGTAGAGGGGGGTAGAATTCCAGG
TGTAGCGGTGAAATGCGTAGAGATCTGGAGGAATACCGGTGGCGAAGGC
GGCCCCCTGGACAAAGACTGACGCTCAGGTGCGAAAGCGTGGGGAGCAA
ACAGGATTAGATACCCTGGTAGTCCACGCCGTAAACGATGTCGACTTGGA
GGTTGTGCCCTTGAGGCGTGGCTTCCGGAGCTAACGCGTTAAGTCGACCG
CCTGGGGAGTACGGCCGCAAGGTTAAAACTCAAATGAATTGACGGGGGC
CCGCACAAGCGGTGGAGCATGTGGTTTAATTCGATGCAACGCGAAGAACC
TTACCTACTCTTGACATCCAGAGAACTTAGCAGAGATGGATTGGTGCCTTC
GGGAACTCTGAGACAGGTGCTGCATGGCTGTCGTCAGCTCGTGTTGTGAA
ATGTTGGGTTAAGTCCCGCAACGAGCGCAACCCTTATCCTTTGTTGCCAGC
GGTCCGGCCGGGAACTCAAAGGAGACTGCCAGTGATAAACTGGAGGAAG
GTGGGGATGACGTCAAGTCATCATGGCCCTTACGAGTAGGGCTACACACG
TGCTACAATGGCGCATACAAAGAGAAGCGACCTCGCGAGAGCAAGCGGA
CCTCATAAAGTGCGTCGTAGTCCGGATTGGAGTCTGCAACTCGACTCCAT
GAAGTCGGAATCGCTAGTAATCGTAGA

Sample name: MB -2

(Hi- tech centre, Vellanikkara)

CGGCGGACGGGTGAGTAATGTCTGGGAAACTGCCTGATGGAGGGGGATA
ACTACTGGAAACGGTAGCTAATACCGCATAACGTCGCAAGACCAAAGAG
GGGGACCTTCGGGCCTCTTGCCATCAGATGTGCCCAGATGGGATTAGCTA
GTAGGTGGGGTAACGGCTCACCTAGGCGACGATCCCTAGCTGGTCTGAGA
GGATGACCAGCCACACTGGAACTGAGACACGGTCCAGACTCCTACGGGA
GGCAGCAGTGGGGAATATTGCACAATGGGCGCAAGCCTGATGCAGCCAT
GCCGCGTGTATGAAGAAGGCCTTCGGGTTGTAAAGTACTTTCAGCGGGGA
GGAAGGTGTTGAGGTTAATAACCTCAGCAATTGACGTTACCCGCAGAAGA
AGCACCGGCTAACTCCGTGCCAGCAGCCGCGGTAATACGGAGGGTGCAA
GCGTTAATCGGAATTACTGGGCGTAAAGCGCACGCAGGCGGTCTGTCAAG
TCGGATGTGAAATCCCCGGGCTCAACCTGGGAACTGCATTCGAAACTGGC
AGGCTAGAGTCTTGTAGAGGGGGGGTAGAATTCCAGGTGTAGCGGTGAAA
TGCGTAGAGATCTGGAGGAATACCGGTGGCGAAGGCGGCCCCCTGGACA
AAGACTGACGCTCATGTGCGAAAGCGTGGGGAGCAAACAGGATTAGATA
CCCTGGTAGTCCACGCCGTAAACGATGTCGACTTGGAGGTTGTGCCCTTG
AGGCGTGGCTTCCGGAGCTAACGCGTTAAGTCGACCGCCTGGGGAGTACG
GCCGCAAGGTTAAAACTCAAATGAATTGACGGGGGCCCGCACAAGCGGT
GGAGCATGTGGTTTAATTCGATGCAACGCGAAGAACCTTACCTACTCTTG
ACATCCAGAGAACTTTCCAGAGATGGTTTGGTGCCTTCGGGAACTCTGAG
ACAGGTGCTGCATGGCTGTCGTCAGCTCGTGTTGTGAAATGTTGGGTTAAG
TCCCGCAACGAGCGCAACCCTTATCCTTTGTTGCCAGCGGTCCGGCCGGG
AACTCAAAGGAGACTGCCAGTGATAAACTGGAGGAAGGTGGGGATGACG
TCAAGTCATCATGGCCCTTACGAGTAGGGCTACACACGTGCTACAATGGC
GCATACAAAGAGAAGCGACCTCGCGAGAGCAAGCGGACCTCATAAACTG
CGTCGTAGTCCGGATTGGAGTCTGCAACTCGACTCCATGA

Appendix II

Correlation matrix among growth and yield attributes of African marigold (*T. erecta*) genotypes

Parameters	1	2	3	4	5	6	7	8	9	10	11	12	13	14
1. Plant height	1	0.50*	0.52*	0.32NS	-0.65**	-0.64**	0.51*	0.45*	0.38NS	0.29NS	0.33NS	0.41*	0.27NS	0.31NS
2. Plant spread		1	0.11NS	0.60**	0.12NS	0.11NS	0.40NS	0.02NS	0.35NS	0.31NS	0.63**	0.48*	0.47*	0.62**
3. Primary branches			1	0.37NS	-0.49*	-0.49*	0.27NS	0.44*	0.12NS	0.07NS	0.16NS	0.33NS	0.17NS	0.20NS
4. Stem girth				1	-0.14NS	-0.19NS	0.60**	0.09NS	0.44*	0.43*	0.40NS	0.48*	0.39NS	0.43*
5. Days to bud initiation					1	0.99**	-0.56**	-0.49*	-0.47*	-0.40NS	-0.04NS	-0.30NS	-0.09NS	-0.09NS
6. Days to 50 % flowering						1	-0.59**	-0.49*	-0.50*	-0.44*	-0.05NS	-0.32NS	-0.12NS	-0.10NS
7. Flower diameter							1	0.61**	0.91**	0.87**	0.56**	0.77**	0.46*	0.66**
8. Stalk length								1	0.50*	0.44*	0.46*	0.77**	0.31NS	0.48*
9. Flower weight									1	0.98**	0.44*	0.66**	0.42*	0.60**
10. Weight of ray florets										1	0.40NS	0.60**	0.40NS	0.56**
11. No. of flowers/ plant											1	0.80**	0.624**	0.94**
12. No. of harvest/ plant												1	0.60**	0.78**
13. Total carotenoids													1	0.60**
14. Flower yield/ plant														1

Appendix III

Correlation matrix among growth and yield attributes of French marigold (*T. patula*) genotypes

Parameters	1	2	3	4	5	6	7	8	9	10	11	12	13	14
1.Plant height	1	0.79^{NS}	-0.40^{NS}	-0.94*	0.47^{NS}	0.65^{NS}	-0.74^{NS}	0.83^{NS}	-0.25^{NS}	-0.06^{NS}	-0.57^{NS}	-0.60^{NS}	0.66^{NS}	-0.50^{NS}
2.Plant spread		1	-0.17^{NS}	-0.83^{NS}	0.85^{NS}	0.80^{NS}	-0.97**	0.70^{NS}	-0.69^{NS}	-0.55^{NS}	-0.54^{NS}	-0.63^{NS}	0.10^{NS}	-0.47^{NS}
3.Primary branches			1	0.38^{NS}	-0.06^{NS}	0.06^{NS}	-0.05^{NS}	-0.41^{NS}	-0.12^{NS}	-0.61^{NS}	-0.48^{NS}	-0.47^{NS}	-0.44^{NS}	-0.41^{NS}
4.Stem girth				1	-0.68^{NS}	-0.83^{NS}	0.79^{NS}	-0.96**	0.19^{NS}	0.02^{NS}	0.59^{NS}	0.61^{NS}	-0.43^{NS}	0.62^{NS}
5.Days to bud initiation					1	0.89*	-0.84^{NS}	0.66^{NS}	-0.53^{NS}	-0.45^{NS}	-0.48^{NS}	-0.53^{NS}	-0.34^{NS}	-0.55^{NS}
6.Days to 50 % flowering						1	-0.85^{NS}	0.83^{NS}	-0.27^{NS}	-0.31^{NS}	-0.76^{NS}	-0.77^{NS}	-0.05^{NS}	-0.84^{NS}
7. Flower diameter							1	-0.65^{NS}	0.69^{NS}	0.62^{NS}	0.71^{NS}	0.789^{NS}	-0.06^{NS}	0.61^{NS}
8. Stalk length								1	0.01^{NS}	0.16^{NS}	-0.53^{NS}	-0.51^{NS}	0.35^{NS}	-0.64^{NS}
9. Flower weight									1	0.85^{NS}	0.18^{NS}	0.32^{NS}	0.22^{NS}	-0.03^{NS}
10. Weight of ray florets										1	0.46^{NS}	0.57^{NS}	0.36^{NS}	0.25^{NS}
11. No. of flowers/ plant											1	0.98**	-0.19^{NS}	0.94*
12. No. of harvest/ plant												1	-0.18^{NS}	0.89*
13. Total carotenoids													1	-0.08^{NS}
14. Flower yield plant														1

Appendix. IV

Correlation of growth and yield attributes of African marigold genotypes with agro meteorological parameters (rainy season)

Season: June (2019) – September (2019)

Weather parameters	Temperature ^{O}C		Relative humidity (%)		Rain fall (mm)	
Characters / genotypes	**Bhagwati**	**M-1**	**Bhagwati**	**M-1**	**Bhagwati**	**M-1**
1. Plant height	0.82*	0.77*	0.76**	0.36	0.93*	0.84*
2. Plant spread	0.90**	0.63	0.69*	0.33	0.88*	0.76*
3. Primary branches	0.86*	0.84*	0.80**	0.26	0.98**	0.85*
4. Days to bud initiation	-0.86**	-0.87**	-0.72*	-0.37	-0.94**	-0.80*
5. Days to 50% flowering	-0.85**	-0.92**	-0.78*	-0.45	-0.91**	-0.84*
6. Flower diameter	0.96*	0.81*	0.62*	0.42*	0.92**	0.68*
7. Stalk length	0.98*	0.86*	0.52*	0.38	0.94*	0.59
8. Flower weight	0.96*	0.79*	0.56*	0.21	0.98**	0.63
9. Weight of ray florets	0.98*	0.71	0.58*	0.52	0.83*	0.62
10. No. of flowers / plant	0.96*	0.86*	0.64*	0.50	0.89*	0.69*
11. No. of harvest/ plant	0.96*	0.80*	0.54*	0.44*	0.91*	0.62
12. Dry matter production/plant	0.99**	0.98**	0.49	0.41	0.86*	0.54
13. Nitrogen uptake	0.98*	0.96*	0.58*	0.35	0.91*	0.62
14. Phosphorous uptake	0.98*	0.96*	0.57*	0.43	0.90*	0.63
15. Potassium uptake	0.99**	0.99**	0.50	0.41	0.85*	0.54
16. Flower yield / plant	0.91**	0.87*	0.72*	0.42	0.93*	0.77

Appendix. V

Correlation of growth and yield attributes of African marigold genotypes with agro meteorological parameters (winter season)

Season: October (2019)- January (2020)

Weather parameters	Temperature ^{O}C		Relative humidity (%)		Rain fall (mm)		Epan	
Characters/ genotypes	**Bhagwati**	**M-1**	**Bhagwati**	**M-1**	**Bhagwati**	**M-1**	**Bhagwati**	**M-1**
1. Plant height	-0.25**	-0.75**	-0.32	0.35*	-0.56	-0.12	0.39*	0.42*
2. Plant spread	-0.20*	-0.72**	-0.08	0.25*	-0.54	-0.28	0.53**	0.57**
3. Primary branches	-0.16	-0.51*	-0.18	0.15	-0.35	0.23	0.37*	0.41*
4. Days to bud initiation	0.36**	0.42*	0.10	-0.67**	-0.33	0.18	0.32*	0.34*
5. Days to 50% flowering	0.18	0.40	-0.14	-0.67**	-0.28	0.17	0.29*	0.33*
6. Flower diameter	-0.44**	0.74**	-0.47	0.32*	-0.46	-0.35	0.17	0.38*
7. Stalk length	-0.06	-0.66**	-0.17	0.41*	-0.35	-0.40	0.29*	-0.20
8. Flower weight	0.13	0.62**	-0.34	0.52*	-0.28	-0.37	0.13	0.15
9. Weight of ray florets	-0.05	0.64**	-0.13	0.42*	-0.30	-0.24	0.15	0.20
10. No. of flowers / plant	-0.20*	0.68**	-0.05	0.42*	-0.18	-0.32	0.26*	0.28
11. No. of harvest/ plant	0.18	0.75**	-0.23	0.24	0.14	-0.22	0.17	0.22
12. Dry matter production/plant	-0.28	0.47*	-0.08	0.61**	-0.42	-0.21	0.36*	0.40*
13. Nitrogen uptake	-0.27*	0.50*	-0.09	0.59*	-0.42	-0.18	0.37*	0.40*
14. Phosphorous uptake	-0.27*	0.32*	-0.07	0.73**	-0.48	-0.25	0.26*	0.28
15. Potassium uptake	-0.26*	0.53*	-0.10	0.58*	-0.44	-0.21	0.34*	0.40*
16. Flower yield / plant	-0.30*	0.75**	-0.16	0.36*	-0.29	-0.30	0.29*	0.32*

Appendix VI

Correlation of growth and yield attributes of African marigold genotypes with agro meteorological parameters (summer season)

Season: January (2019) – April (2019)

Weather parameters	Temperature ^{O}C		Relative humidity (%)		Epan	
Characters/ genotypes	**Bhagwati**	**M-1**	**Bhagwati**	**M-1**	**Bhagwati**	**M-1**
1. Plant height	-0.47**	-0.47**	-0.32*	-0.27*	0.75**	0.90**
2. Plant spread	-0.12	-0.24*	-0.04	-0.39*	0.68*	0.83**
3. Primary branches	-0.29*	-0.31*	-0.37*	-0.12	0.85**	0.79**
4. Days to bud initiation	0.57**	0.40**	-0.22	-0.41*	0.08*	0.19
5. Days to 50% flowering	0.07	0.19	-0.44*	0.12	0.47	-0.10
6. Flower diameter	-0.32*	-0.56**	-0.04	-0.26*	0.56*	0.60
7. Stalk length	-0.15*	0.50	0.22*	-0.45*	0.65*	-0.18
8. Flower weight	-0.27*	-0.37*	0.23*	-0.54*	0.69*	0.46*
9. Weight of ray florets	-0.14*	-0.37*	0.26*	-0.52*	0.50*	0.42*
10. No. of flowers / plant	-0.22*	-0.38*	-0.01	-0.23*	0.62**	0.68**
11. No. of harvest/ plant	0.11	-0.25*	-0.30*	-0.33*	0.25	0.37
12. Dry matter production/plant	-0.17*	-0.26*	-0.10	-0.31*	0.79**	0.47*
13. Nitrogen uptake	-0.18*	-0.26*	-0.08	-0.31*	0.62**	0.50*
14. Phosphorous uptake	-0.11*	-0.24*	-0.03	-0.48**	0.41	0.28
15. Potassium uptake	-0.21*	-0.32*	-0.06	-0.30*	0.74**	0.52*
16. Flower yield / plant	-0.28*	-0.32*	-0.18	-0.15	0.77**	0.64**

* In the cropping period of summer months did not received rainfall

Appendix VII

Effect of irrigation and fertigation levels on soil available nutrients

	OC (%)			Available nitrogen (kg/ha)			Available phosphorous (kg/ ha)			Available potassium (kg/ ha)		
	Rainy	**Winter**	**Summer**	**Rainy**	**Winter**	**Summer**	**Rainy**	**Winter**	**Summer**	**Rainy**	**Winter**	**Summer**
Initial status	1.22	0.79	1.30	-	-	-	195.8	5.16	242.0	956.48	210.11	400.74
After the crop												
Bhagwati	0.36	0.17	0.18	239.13	203.50	221.03	18.43	12.88	13.60	248.20	208.39	215.30
	0.39	0.17	0.19	245.53	193.02	204.67	19.67	11.80	12.50	250.47	190.73	204.83
	0.42	0.14	0.15	258.33	180.50	198.63	20.30	11.08	11.80	252.43	185.99	192.33
	0.11	0.15	0.15	175.60	194.08	186.33	8.60	10.19	10.90	168.43	173.67	205.93
		0.14	0.16		147.57	183.70		8.78	9.50		171.05	159.43
		0.13	0.12		165.55	179.93		7.39	8.10		167.30	177.37
		0.04	0.11		131.37	135.50		5.31	6.07		122.89	143.23
M-1	0.32	0.15	0.18	237.14	205.11	225.73	18.39	13.56	14.29	242.15	213.09	216.92
	0.35	0.14	0.18	242.55	194.60	208.06	19.62	12.48	13.19	248.42	195.43	206.43
	0.44	0.14	0.16	256.38	182.12	203.33	20.26	11.76	12.49	255.41	190.69	193.93
	0.09	0.13	0.15	172.52	195.67	191.01	8.52	10.87	11.59	162.49	178.37	207.52
		0.12	0.13		149.15	188.38		9.46	10.19		175.75	161.01
		0.11	0.14		167.14	184.64		8.07	8.80		172.00	178.97
		0.05	0.06		132.38	140.22		5.99	6.74		127.59	144.82
C.D(0.05)	0.02	0.02	0.03	2.92	27.04	21.08	0.06	1.12	2.81	5.50	23.57	27.05
SEm±	0.00	0.01	0.01	0.96	9.25	7.88	0.02	0.35	0.91	1.84	7.88	9.26

Appendix VIII

Monthly meteorological data for the experimental period (2018-2020) recorded at the KAU, Vellanikkara

Month	Average temperature (^{0}C)	Average relative humidity (%)	Average rainfall (mm)	Average Epan
June-2018	27.2	81	14.8	2.6
July -2018	26.2	82	24.1	2.2
Aug-2018	25.9	88	34.5	1.6
Sep-2018	26.2	86	24.0	2.3
Oct-2018	26.5	68	23.5	2.5
Nov-2018	27.1	69	11.8	3.2
Dec-2018	27.9	62	0.0	3.5
Jan-2019	26.7	60	0.0	3.9
Feb-2019	29.3	59	0.0	5.1
Mar-2019	30.8	64	0.0	4.8
April-2019	30.8	70	2.5	4.7
May-2019	29.8	74	1.6	4
June-2019	27.8	83	10.8	2.8
July -2019	26.6	86	21.1	2.4
Aug-2019	25.7	89	31.5	1.9
Sep-2019	26.6	85	14.0	2.5
Oct-2019	26.9	79	13.5	2.7
Nov-2019	27.3	71	6.8	3.4
Dec-2019	27.2	63	0.1	4.5
Jan-2020	27.2	62	0.0	4.7
Average	**27.5**	**74.1**	**11.7**	**3.3**

STANDARDIZATION OF PRODUCTION TECHNOLOGY FOR AFRICAN MARIGOLD (*Tagetes erecta* L.)

by

JEEVAN U.

(2017-22-002)

ABSTRACT OF THE THESIS

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ABSTRACT

Marigold (*Tagetes* spp.), one of the commercially grown flower crops in India, is of multipurpose uses in floriculture, pharmaceutical, cosmetic and dye industries. The present investigation entitled "Standardization of production technology for African marigold (*Tagetes erecta* L.) was undertaken in the Department of Floriculture and Landscaping, during the year 2018-2020. The research programme consisted of five experiments.

The first experiment was 'Performance evaluation of African marigold and evaluation of other *Tagetes* spp. against bacterial wilt'. Thirty two marigold genotypes from three different species of *Tagetes viz*., *T. erecta*, *T. patula* and *T. tenuifolia* were evaluated in a wilt sick plot, for assessing bacterial wilt incidence during rainy (June-September) and winter (October–January) seasons. Genotypes of *T. erecta* M-1 and M-2 did not show bacterial wilt incidence during both seasons and these genotypes were categorised as completely resistant to bacterial wilt. Wilt incidence in other genotypes ranged from 4.16 per cent to 87.50 per cent during rainy season while during winter, it ranged from 27.7 per cent to 100.00 per cent. Compared to rainy season (43.00%), bacterial wilt incidence was more severe during winter season (70.00%). Days to wilt was also very early during winter (26.00 days) than rainy season (71.00 days). Significant negative correlation was observed between flavonoid content (leaves and petals) and bacterial wilt incidence. The causal organism of marigold wilt was characterized and identified as *Enterobacter cloacae* and this is first report of the bacterium in marigold. The 16SrDNA sequence data were deposited in NCBI (MT649902 and MT649903).

From the performance evaluation, it could be observed that the genotypes *viz*., Bhagwati, Royal Orange, Maria-91, Rupa and P-4 were superior with respect to morphological characters. These F_1 hybrids also recorded greater flower weight as well as petal weight. Genotypes P-4, Maria 91 and Bhagwati recorded significantly greater number of flowers per plant (59.10, 52.07, 51.23, respectively), and yield per plant (476.80g, 355.17g, 319.73g respectively). The highest carotenoid content was recorded in the genotype Bhagwati (0.105 mg/g).

In the second experiment, twelve genotypes which were categorized as resistant as well as moderately resistant during field evaluation, were subjected to artificial inoculation studies. The genotypes M-1 and M-2 were found to be completely wilt resistant in artificial screening. Among other genotypes, Bhagwati showed a lower bacterial wilt incidence of 26.00 per cent.

The third experiment was conducted with the objective to evaluate rootstocks for *T. erecta*. Two resistant genotypes *viz.,* M-1 and M-2 were used as rootstocks for grafting nine susceptible genotypes which consisted five F_1 hybrids (Bhagwati, Maria 91, Sakuara 031, Suvarna Orange and Suvarna Yellow) and four varieties (Pusa Narangi Gainda, Pusa Basanti Gainda, Double orange and Double Yellow). F_1 hybrids recorded better graft survival compared to varieties. Significantly greater graft survival was recorded in Bhagwati and Maria 91, grafted on M-1 rootstock (60% and 54%, respectively) and M-2 rootstock (54% and 50%, respectively).

The fourth experiment was conducted during rainy, winter and summer seasons under precision farming system using two selected genotypes *viz.,* Bhagwati and M-1. Irrigation was given @ 75 and 100 per cent Epan and fertigation was given at 75, 100 and 125 per cent of IIHR recommendation (90:90:75 kg/ha) for marigold. During rainy season, fertigation @ 75 per cent RDF (F_1) recorded a yield of 35.00 t/ha for Bhagwati and 13.00 t/ha for M-1 which were double the yield in the control treatments of respective genotypes. During winter and summer seasons, irrigation @ 100 per cent Epan along with fertigation @ 125 per cent RDF (I_2F_3) recorded the greatest yield of 12.50 and 10.00 t/ha respectively in Bhagwati. WUE was the highest in the treatment I_2F_3 for Bhagwati and M-1 during winter (10.92 kg/ha mm^{-1}, 10.11 kg/ha mm^{-1}) and summer (6.79 kg/ha mm^{-1}, 7.02 kg/ha mm^{-1}) seasons.

The fifth experiment was conducted to study the effect of growth regulators on plant growth and yield by using F_1 hybrid Bhagwati during rainy and winter season. Spraying growth retardant CCC @ 1000 mg/L during rainy season at 30 and 45 days after transplanting (DAT), was proved to be the best treatment for reducing the plant height (24%) and improvement of yield (14%). CCC @ 1000 mg/L delayed flowering by 12 days compared to control. During winter, spraying growth promoter GA_3 @ 300

mg/ L (30 and 45 DAT) was the best for enhancing vegetative growth and yield (28.00%) over control.

The study could identify a new wilt causal organism of bacterial wilt in marigold and it was identified as *Enterobacter cloacae*. Among the thirty two genotypes evaluated, two genotypes *viz.*, M-1 and M-2 were identified as bacterial wilt resistant types. With regard to *Tagetes erecta*, among the F_1 hybrids, Bhagwati, Maria- 91, P-4, Sakura 031 showed better performance in terms of flower yield whereas among the varieties, Double Orange, and Arka Agni and Arka Bangara-2 showed better performance with respect to floral parameters and flower yield. F_1 hybrids with good yield but highly susceptible to bacterial wilt can be grafted on resistant rootstock genotypes. F_1 hybrids showed better graft survival compared to varieties. Greater graft survival (60%) was recorded for Bhagwati on M-1 rootstock. During rainy season 75 % RDF (90:90:75) was the best with respect to the yield and quality parameters. During winter and summer I_2F_3 (100% Epan along with 125% RDF) was performing best. Hybrid Bhagwati was performing well during all the seasons studied, with the highest B:C ratio. Genotype M-1 can be suggested as an alternate variety during winter season. During rainy season spraying CCC @ 1000 mg/L (30 and 45 DAT) was found the best treatment for reduction in plant height (24%) and increased yield (14%) over control. CCC @ 1000 mg/L can also be used for delaying flowering in marigold. During winter, spraying GA_3 @ 300 mg/L or 200 mg/L (30 and 45 DAT) enhanced the plant height (15%, 11% respectively) and yield per plant (28%, 22% respectively) over control.