

Effect of pinching and gibberellic acid on growth, flowering and yield of African marigold (*Tagetes erecta* L.) under different seasons

By
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CERTIFICATE - I

This is to certify that this thesis entitled “**Effect of pinching and gibberellic acid on growth, flowering and yield of African marigold (*Tagetes erecta* L.) under different seasons**” submitted for the degree of **Doctor of Philosophy** in the subject of **Horticulture–Floriculture and Landscape Architecture** to the Chaudhary Charan Singh Haryana Agricultural University, Hisar, is a bonafide research work carried out by **Ms. Sonu Kumari, Admission No. 2013A23D** under my supervision and that no part of this dissertation has been submitted for any other degree.

The assistance and help received during the course of investigation have been duly acknowledged.

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CERTIFICATE - II

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ABBREVIATIONS & SYMBOLS

%	percentage
&	and
/	per
@	at the rate of
°	degree
°C	degree celsius
1st	first
2n	diploid chromosome number
AIPH	international association of horticulture producers
APEDA	agricultural and processed food products export development authority
CD	critical difference
Cm	centi meter
cv.	cultivar
dSm ⁻¹	desi simen per meter
E	east
E.C.	electrical conductivity
etc.	et cetera (and other things)
FYM	farmyard manure
G	gibberellic acid
hr	hour
hrs	hours
i.e.	id est (that is)
K ₂ O	potassium oxide
DAT	days after transplanting
DW	distilled water
<i>et al.</i>	<i>et alia</i> (and others)
g	gram
GA ₃	gibberellic acid
ha	hectare
ISTA	international seed testing association
kg	kilogram
L.	linnaeus
m	meter
mg	milligram

ABBREVIATIONS & SYMBOLS

m ²	meter square
MH	maleic hydrazide
ml	milliliter
mm	millimeter
MT	metric ton
N	north
NaHCO ₃	sodium bicarbonate
no.	number
NS	non significant
P	pinching
P ₂ O ₅	diphosphorus pentoxide
pH	potential of hydrogen
ppm	parts per million
q	quintal
Rs.	rupees
S	south
t	tonne
TP	top of the paper
USD	us dollar
USDA	united states department of agriculture
var.	variety
viz.	<i>videlicet</i> (namely)
W	west
WAT	weeks after transplanting

CHAPTER-I

INTRODUCTION

Flowers have always played an important role in human lives. Now, they are playing a vital role and will be of great importance even in the future. In past decades, the floriculture was just a hobby of flower lovers, but now, it has emerged as an economically feasible commercial trade in horticulture. Worldwide business of floriculture products like fresh cut and loose flowers, live plants, fresh bulbs, flower seeds and plantlets is gaining a tremendous momentum day by day. The growth rate of world production of floriculture is 10% per year. Globally, more than 145 countries are involved in floriculture industry and the global floriculture trade is estimated to be at USD 70 billion at present (ICAR Vision 2050). According to International Association of Horticultural Producers (AIPH, 2016), 650,000 ha area was under flower production in different countries of the world. Around 80 % of total flower production is consumed by Germany, USA, UK, Netherlands, France and Switzerland [Global Horticulture (2014 -2018)]. Total world export of floriculture products stands at USD 9,784,525,000 and the Netherlands claims 47.7% of total world exports (ITC Trade Map, 2014). The other major countries are Colombia, Ecuador, Kenya, Ethiopia and Belgium.

At present, India's share in world floriculture trade is about 0.6% (Mishra and Ghosh, 2016). Total export of floriculture products in India during 2015-16 was Rs. 479.43 crores (APEDA, 2015-16). Enormous bio-diversity, favorable agro-climatic conditions such as, fertile land, suitable climate, abundant water supply, low labour cost, versatile human resources, etc., offer India a unique scope for judicious employment of existing resources and exploration of avenues yet untouched. The total area under Indian floriculture is 255.02 thousand hectares with production of 1754.49 thousand MT loose flowers and 542.53 thousand MT cut flowers. In Haryana, the area under floriculture is 6.48 thousand hectares with a production of 65.45 thousand MT of loose flower and 11.26 thousand MT cut flowers, out of which 5.69 thousand hectares is covered under marigold cultivation with a loose flower production of 64.62 thousand MT (Saxena and Gandhi, 2014). Important commercial flower crops grown in India are rose, carnation, orchids, gladiolus, tuberose, chrysanthemum, jasmine, marigold, etc.

Marigold popularly known as *Gainda* is one of the most important and extensively cultivated traditional flower of India due to its hardiness, easy cultivation and high productivity. It belongs to the family Asteraceae. There are about 33 species of the genus *Tagetes* (Neher, 1968). Out of these, mainly two types are grown in India viz., African marigold (*Tagetes erecta* L., 2n = 24) and French marigold (*Tagetes patula* L., 2n = 48) for loose as well as cut flower production. Botanically, the marigold inflorescence is capitulum

with two types of florets, i.e., the peripheral ray floret and the central disc floret. The disc flowers in the centre are perfect having both anthers and pistil. The surrounding ray flowers with strap like petals are pistillate only and are male sterile.

The African marigold is hardy ornamental annual and grows tall (up to 100 cm), with beautiful dark green foliage. It has single to fully double globular flowers. Flower colours varies from lemon yellow to bright yellow, golden yellow, orange and almost white. The French marigold is a dwarf annual and its height varies from 25 to 65 cm. It has smaller single or double flowers of yellow, orange, mahogany, rusty red tangerine, or a combination of these. Marigold is a very hardy and sun loving plant. It can be grown in well-drained soil in almost all the seasons except in very hot weather. In plain areas of the country, marigold seeds can be sown in May-June, August-October and January-February, while in hills marigold is sown during March- April.

Among the various uses of marigold, the flowers are generally used in garlands, social functions and religious offerings, apart from applications in landscaping as flower beds and borders or even as pot plants. It is also widely used as herbal *gulal*, insect and nematode repellent, organic manure, poultry feed, antioxidant in retinotherapy and for *Tagetes oil* extraction (Pramila *et al.*, 2011). Marigold flowers are a very rich source of carotenoids for application in the food industry (Toiu *et al.*, 2008). Production and quality of egg is improved with addition of 550 mg marigold flower extract in per kg diet of hen (Skrivan *et al.*, 2016).

Marigold is traditionally used in treatment of various diseases like ulcers, laxation, kidney troubles and eye diseases. Its leaves and flowers showed a broad spectrum of antibacterial activity (Verma and Verma, 2012). Marigolds releases a chemical substance with a strong pungent odour useful for inhibiting attacks from root-knot nematodes, vine weevils and other insects, fungi, bacteria and viruses. Extracts of marigold also showed a significant herbicidal effect on germination and growth of *Parthenium* (Shafique *et al.*, 2011). Essential oil of marigold has 100% inhibitory effect against Gram-positive bacteria and a 95% inhibitory effect against fungi (Hethelyi *et al.*, 1986). Its flowers possess good mosquitocidal properties (Motiur and Ekramul, 2009).

Pinching is done mostly in annuals and herbaceous perennials to encourage branching and to make the plant bushy. In African marigold, the number of flowers mainly depends on number of branches, which can be manipulated by arresting the vertical growth of plant and encouraging side shoots by removal of apical portion (Rathore *et al.*, 2011). More shoots would provide more scope to bear flower and in turn contributing for higher flower yield. The maximum reduction in plant height was recorded with pinching at 22 DAT followed by pinching done at 15 DAT, however, the number of branches was recorded significantly maximum with pinching done at 15 DAT in African marigold var. African Double Orange (Badge *et al.*, 2014).

In recent years, a number of plant growth regulators have been used in the field of agriculture, especially in horticulture for increasing, reducing or modifying the physiological processes within plant, which ultimately affect the growth, flowering and yield (Ramdevputra *et al.*, 2009). Among all the plant growth regulators, GA₃ is considered as the most potent plant growth regulator in flower crops. It has manifold effects and is generally used to increase plant height by promoting cell elongation and induce flowering in plants. It also affects seed dormancy, seed germination, seed quality and yield. Better plant growth and flower production in marigold was recorded with application of GA₃ (Lal and Mishra, 1986). Significantly maximum plant spread, number of primary branches per plant, number of flowers per plant, flower diameter; weight of flowers per plant and flower yield per plot was obtained in 1st October planting of African marigold cv. Pusa Narangi Gainda (Lakshmi *et al.*, 2014). The earliest bud initiation, opening of first flower and maximum duration of flowering, flower stalk length, number of flowers per plant, fresh weight of flower, weight of flowers per plant and flower yield per hectare were observed with application of GA₃ 300 ppm applied at 30 DAT in African marigold cv. Pusa Narangi Gainda (Kumar *et al.*, 2014).

Marigold requires mild climate for luxuriant growth and profuse flowering. It ceases to grow at high temperature thereby plants remain mostly vegetative with sparse flowering. So flower quantity and quality are adversely affected. Sowing and planting is done during rainy, winter and summer season and hence flowers of marigold can be obtained almost throughout the year. Under North Indian conditions, winter crop of marigold has good potential for better flower and seed yield. However, some of the agro-techniques in the production of marigold under agro-climatic conditions of Haryana has not yet standardized so far. Genetic makeup of the plant is responsible for the production, productivity and quality of flowers. Therefore, there is a tremendous scope of improving yield and quality of marigold flowers. The effect of pinching and GA₃ on various physiological processes and growth is fairly well understood but limited information exists concerning the interactive effect of pinching, GA₃ and seasonal variation on growth, flowering and yield of African marigold under Haryana conditions. This research work will help the commercial growers to increase the number, size, yield and quality of flowers.

Considering the above facts, the present experiment entitled “Effect of pinching and gibberellic acid on growth, flowering and yield of African marigold (*Tagetes erecta* L.) under different seasons” was planned with following objectives:

1. To study the effect of pinching on growth, flowering and yield of African marigold under different seasons
2. To study the effect of gibberellic acid on growth, flowering and yield of African marigold under different seasons
3. To find out the effect of seasons on growth, flowering and yield of African marigold

CHAPTER-II

REVIEW OF LITERATURE

In the recent past, use of plant growth regulators in ornamental crops for modifying their developmental process gained commercial importance for improving more acceptable plant characteristics like compact growth, dwarfness, flower appearance, quality and yield etc. Likewise, manual pinching was also found quite effective in enhancing various growth, flowering and yield attributes of flower crops. Optimum environmental conditions required for successful cultivation of any particular crop is also a prerequisite. But, very little attention has been paid by the scientists towards combined use of pinching and gibberellic acid in African marigold under different seasons. Hence, the pertinent literature available about this flower crop is very meager and scanty. In this chapter, the relevant literature in relation to the proposed work in marigold and other closely related crops like calendula, chrysanthemum, gerbera, etc. was reviewed and presented under following heads.

2.1. Effect of pinching on growth, flowering and yield

Manual pinching is a common floricultural practice (Ecke & Matkin 1976) designed to encourage auxiliary shoot development and greater floral synchrony (Larson 1980). However, pinching is usually aimed at increasing number of flowers for display purposes (Love 1975). It was also ascertained for inducing compact and dwarf growth in African marigold (Pushkar and Singh, 2012).

2.1.1. Growth Parameters

African marigold obtained maximum plant height (71.26 cm) and number of primary branches per plant (18.87) with pinching at 40 DAT, while average plant spread (48.38 cm) was recorded maximum under pinching at 20 DAT (Sharma *et al.*, 2006). Double pinching treatment (30 days after single pinching) significantly recorded maximum plant height (83.14 cm), plant spread (43.30 cm) and number of branches per plant (11.90) followed by single pinching treatment (35 DAT) (81.29 cm), (42.10 cm) and (11.60), respectively in African marigold (Bhat and Shepherd, 2007). The maximum number of primary branches per plant (13.15) was recorded with pinching at 40 DAT followed by pinching at 30 DAT (12.30) and 20 DAT (11.61), while minimum number of primary branches per plant (8.77) was observed with no pinching in African marigold. Similarly, the maximum plant spread (46.65 cm) was recorded with pinching at 30 DAT followed by pinching at 40 DAT (42.96 cm) and 30 DAT (41.13 cm), while minimum (31.95 cm) was recorded in un-pinched plants (Rathore and Dikshit, 2007).

The results obtained by Rathore *et al.* (2011) reveal that un-pinched marigold plants recorded significantly more height (83.22 cm) as compared to the pinched plants (64.40 cm),

while pinched plants recorded significantly more number of primary branches (37.67) as compared to un-pinched plants (33.21). Un-pinched plants obtained the maximum height (89.15 and 95.10 cm, respectively), whereas, minimum (75.46 and 75.52 cm, respectively) was recorded in pinching at 22 DAT followed by pinching at 15 DAT in both the years. Though, the highest number of branches (18.60 and 18.70, respectively) was reported with pinching treatment at 15 DAT followed by pinching at 22 DAT and 30 DAT in both the years in African marigold (Badge *et al.*, 2014). Un-pinched marigold plants significantly recorded higher height (52.97 cm) at maturity while plants double pinched at 60 DAT recorded lower height (47.11 cm) at maturity. In contrast to this, plants double pinched at 60 DAT significantly produced highest number of branches per plant (22.99), while lowest (12.98) was observed in un-pinched plants of marigold (Meena *et al.*, 2015).

2.1.2. Floral Parameters

More number of flowers per plant (19.51) and flowering duration (93.81 days) was observed in plants pinched at 40 DAT in African marigold (Sharma *et al.*, 2006). The minimum days to 1st flowering (47.85 days), maximum number of flowers per plant (63.81) and flower size (5.05 cm) was recorded with double pinching followed by single pinching (48.77 days, 61.50 and 5.01 cm, respectively) in African marigold (Bhat and Shepherd, 2007). Un-pinched marigold plants significantly recorded less number of days to 1st bud emergence (51.25 days) and 1st flowering (60.68 days), while more number of days to 1st bud emergence (60.12 days) and 1st flowering (69.50 days) was recorded with pinching at 40 DAT. The maximum duration of flowering (97.81 days) and number of flowers per plant (53.62) was recorded in plants pinched at 40 DAT followed by pinching at 30 DAT and 20 DAT, while minimum (82.06 days and 42.30, respectively) was recorded in un-pinched marigold plants. However, the maximum flower size (7.44 cm) and pedicel length (8.41 cm) was recorded with pinching at 30 DAT, while minimum flower size (6.12 cm) and pedicel length (6.79 cm) was observed under no pinching treatment (Rathore and Dikshit, 2007).

Marigold plants with pinching treatment significantly recorded more number of flowers per plant (92.04) as compared to less number of flowers per plant (82.22) in un-pinched plants (Rathore *et al.*, 2011). A significant increase in all floral parameters like days to bud initiation, first flower appearance and flowering duration was recorded in marigold plants pinched at 30 DAT, whereas, highest stalk length, duration of flowering and number of flowers per plant were observed in plants pinched at 20 DAT (Pushkar and Singh, 2012). Significantly maximum number of flowers per plant (31.10 and 34.10, respectively) was recorded with pinching done at 15 DAT, whereas, minimum number of flowers per plant (24.53 and 25.01, respectively) was observed with no pinching in both the years in African marigold (Badge *et al.*, 2014). Earliest initiation of flowering (71.35 days) was recorded significantly in P₁ treatment (No pinching), while delayed flowering (94.85 days) was

recorded significantly in P₃ treatment (double pinching at 60 DAT). Marigold plants double pinched at 60 DAT produced maximum number of flowers per plant (34.91) as compared to plants pinched at 30 DAT (31.97) and un-pinched plants (28.90) (Meena *et al.*, 2015).

2.1.3. Yield Parameters

The maximum fresh weight of flowers per plant (157.60 g) and flower yield per hectare (131.48 q) was significantly recorded in marigold plants pinched at 40 DAT (Sharma *et al.*, 2006). The highest fresh weight (308.29 g) and dry weight (65.07 g) of flowers per plant was recorded with pinching at 40 DAT, whereas, lowest (178.61 g) and (39.51 g) was observed in un-pinched plants, respectively. However, the maximum fresh weight of flower (10.14 g) and flower yield per plant (269.57 g), per plot (26.45 kg) as well as per hectare (220.48 q) was recorded with pinching at 30 DAT, while minimum fresh weight of flower (9.15 g), flower yield per plant (130.52 g), flower yield per plot (13.31 kg) and flower yield per hectare (110.93 q) was observed in un-pinched plants of marigold (Rathore and Dikshit, 2007).

Higher fresh (6.60 g) and dry weight of flower (4.50 g) was measured in no pinching treatment as compared to pinching treatment (5.62 g) and (3.48 g), respectively but higher flower yield per hectare (247.57 q) was obtained with pinching at 45 DAT, while lower flower yield per hectare (108.33 q) was found in un-pinched marigold plants (Rathore *et al.*, 2011). The maximum fresh weight and flower yield per plant was reported in marigold plants pinched at 20 DAT (Pushkar and Singh, 2012). Significantly the maximum flower yield per plant (228.30 and 235.31 g), per plot (6.84 and 7.06 kg) and per ha (16.90 t and 17.43 t) was obtained with pinching at 15 DAT followed by pinching at 22 DAT and 30 DAT however, minimum flower yield per plant (184.54 and 180.55 g), per plot (5.53 and 5.41 kg) and per hectare (13.66 and 13.37 t) was recorded in no pinching treatment in both the years, respectively in marigold (Badge *et al.*, 2014).

2.1.4. Seed Parameters

The maximum root length (6.31 cm) and shoot length (4.11 cm) was recorded with single pinching at 35 DAT and minimum (3.77 and 3.98 cm, respectively) as compared to un-pinched plants followed by double pinching at 65 DAT (3.76 and 3.97 cm, respectively). However, higher germination (71.04%) was recorded from un-pinched plants as compared to pinched plants (Bhat and Shepherd, 2007).

African marigold plants double pinched at 60 DAT produced maximum seed yield per flower (0.55 g), while minimum (0.52 g) was recorded from plants pinched at 30 DAT followed by un-pinched plants (0.51 g). Similarly, double pinching at 60 DAT recorded maximum seed yield per plant (19.01 g) and per plot (253.61 g) but minimum seed yield per plant (14.62 g) and per plot (226.91 g) was recorded from un-pinched plants. Furthermore, higher seed yield per plant (17.70 g) was recorded in double pinched plants followed by single pinched plants (11.29 g) as compared to un-pinched plants. However, highest 1000

seed weight (2.88 g) was recorded in un-pinched plants than single and double pinched plants (Meena *et al.*, 2015).

2.2. Effect of gibberellic acid on growth, flowering and yield

Chemical manipulation of plant growth is also receiving increasing attention in floriculture (Davis and Anderson 1989), mainly by use of plant growth regulators to suppress vegetative growth, reduce plant height, alter plant shape, size and form and stimulate early flower initiation and uniformity. Plant growth regulators also play a significant role in flower production, which in small quantity promotes or inhibits or quantitatively modifies growth and development (Kumar *et al.*, 2014). It has been reported that GA₃ regulate the plant growth through both cell division and cell enlargement (Sachs, 1965), whereas its application to the shoot enhances both shoot and root elongation (Fu and Harberd, 2003). In marigold, gibberellic acid was found beneficial in enhancement of plant growth and flower production (Girwani *et al.*, 1990).

2.2.1. Growth Parameters

Significantly maximum plant height (22.25 cm), plant spread (25.88 cm) and number of primary branches per plant (15.49) were observed with foliar spray of GA₃ at 30 DAT in African marigold cv. Cupid (Tyagi and Kumar, 2006). Significantly maximum plant height (89.50 and 74.33 cm) was recorded with GA₃ 300 ppm during both seasons, respectively in African marigold (Swaroop *et al.*, 2007). Significantly maximum plant height (22.59 cm) and number of branches (14.87) per plant were attained by the French marigold sprayed with GA₃ 450 ppm followed by GA₃ 300 ppm (22.15 cm) in case of plant height only, while minimum plant height (19.46 cm) and number of branches (10.07) was observed in control plants (Pandey and Chandra, 2008). The maximum plant height (57.37 & 68.83 cm) and plant spread (49.66 & 53.95 cm) was measured at flower initiation and full bloom stage, respectively with foliar spray of 300 ppm GA₃ in African marigold. Likewise, fresh weight of plant (375.85 g) was also recorded highest at full bloom stage with foliar spray of 300 ppm GA₃ followed by 200 & 100 ppm GA₃ spray, while the maximum number of branches per plant (13.62) was found at full bloom stage with foliar spray of 200 ppm GA₃ (Ramdevputra *et al.*, 2009). The maximum plant height (95.00 cm) was recorded by chrysanthemum cv. Akola Local with GA₃ 200 ppm (Dalal *et al.*, 2009).

Zipri cultivar of chrysanthemum acquired maximum height and number of branches per plant when sprayed with 200 ppm dose of GA₃ (Tannirwar *et al.*, 2011). Shivaprakash *et al.* (2011) in African marigold cv. Orange Double recorded maximum plant height and plant dry weight with 200 ppm GA₃ spray. Significantly maximum plant height (43.73 and 66.96 cm) and number of branches per plant (7.29 and 12.30) was attained by the marigold plant with 350 ppm GA₃ application, while minimum plant height (40.77 and 59.86 cm) and number of branches (7.11 and 12.07) was recorded in control at 45 and 90 DAT, respectively

(Kumar *et al.*, 2011). Daisy cv. Dwarf Pink sprayed with 150 ppm GA₃ obtained higher plant height (30.75 cm) as compared to control (Girisha *et al.*, 2012).

Single spray of GA₃ 150 ppm at 30 DAT recorded significantly higher plant height (83.30 cm) in African marigold (Kanwar and Khandelwal, 2013). Significantly maximum plant height (88.40 and 89.88 cm) and number of branches per plant (19.30 and 18.33) were recorded with GA₃ 300 ppm, while minimum plant height (73.99 and 75.01 cm) and number of branches per plant (15.73 and 16.61) were recorded in control plants of marigold during both years, respectively (Badge *et al.*, 2014).

The maximum plant height (70.50 cm), plant spread (27.20 cm) and number of primary branches per plant (5.47) was recorded with application of GA₃ 300 ppm in chrysanthemum cv. Vasantika (Prakash *et al.*, 2015). In vitro raised hybrid gerbera attained the maximum spread with application of GA₃ 150 ppm followed by 100 & 200 ppm GA₃ (Patra *et al.*, 2015). The highest plant height (58.60 & 46.78 cm) and plant spread (31.79 & 28.56 cm) was recorded significantly when Birbal Sahni and Julia cultivars of chrysanthemum were sprayed with GA₃ 250 ppm, respectively. Application of GA₃ 250 ppm recorded more number of branches per plant (20.87) in chrysanthemum cultivar Julia as compared to cultivar Birbal Sahni (17.22) (Singh and Nigam, 2015). African marigold plant sprayed with GA₃ 100 ppm obtained the maximum height (36.55 cm) and numbers of branches (35.22). Foliar treatment of GA₃ 300 ppm significantly recorded maximum plant height (63.25 cm) at 60 DAT followed by GA₃ 200 ppm (62.78 cm), GA₃ 100 ppm (60.41 cm) and GA₃ 400 ppm (59.61 cm). However, the minimum plant height (53.30 cm) was noticed in control treatment (Palei *et al.*, 2016).

2.2.2. Floral Parameters

The maximum number of flowers per plant (14.00), flower diameter (5.62 cm), stalk length (2.47 cm), fresh weight of flower (6.17 g) and weight of flowers per plant (86.31 g) were recorded significantly with GA₃ 200 ppm at 30 DAT in marigold (Tyagi and Kumar, 2006). Application of GA₃ 250 ppm significantly recorded less time taken to first flower bud appearance and first flower opening over control in chrysanthemum cv. Local (Moond and Gehlot, 2007). The minimum days to bud initiation (80.66 & 70.75) was recorded with application of GA₃ 300 ppm during early summer and early winter planting, respectively but the later planting was found at par with GA₃ 100 ppm (71.74 days) in marigold. However, least days to flowering initiation was reported with GA₃ 100 ppm in early summer planting, while early winter planting recorded fewest days to flowering with GA₃ 300 ppm (91.50 days) (Swaroop *et al.*, 2007).

In French marigold, the earliest flowering initiation (46.52 days) was recorded with GA₃ 450 ppm followed by GA₃ 350 ppm (46.75 days), while late flowering (47.75 days) was observed in control. Similarly, the maximum number of flowers per plant (55.67) was

obtained with GA₃ 450 ppm spray, while minimum number of flowers per plant (42.49) was recorded in control. The maximum flower diameter (3.62 cm) was recorded with 300 ppm GA₃ spray followed by 150 ppm GA₃ spray (3.56 cm) and 450 GA₃ spray (3.53 cm), while minimum flower diameter (3.01 cm) was reported in control (Pandey and Chandra, 2008).

Chrysanthemum cv. Akola Local when sprayed with GA₃ 200 ppm exhibited early flower initiation along with the highest flower diameter and flower stalk length (Dalal *et al.*, 2009). The highest number of flowers per plant (148.73) was noted in Zipri cultivar of chrysanthemum sprayed with GA₃ 200 ppm. Plants treated with GA₃ 200 ppm produced the heaviest flowers per plant (314.53 g) in chrysanthemum cv. Zipri (Tannirwar *et al.*, 2011). Treatment GA₃ 200 ppm significantly recorded more diameter of flower and number of flowers per plant than control in African marigold (Shivaprakash *et al.*, 2011). Early initiation of bud (40.17 DAT), flowering (58.35 DAT) and maximum number of flowers per plant (28.15) were recorded in plants sprayed with GA₃ 350 ppm, while late initiation of bud (43.39 DAT) and flowering (64.46 DAT) along with minimum number of flowers per plant (19.96) was observed in control plants of marigold (Kumar *et al.*, 2011). Application of GA₃ 150 ppm on daisy plants significantly recorded higher spike length (28.88 cm) and rachis length (26.53 cm) than lower in control (19.20 cm) and (18.54 cm), respectively (Girisha *et al.*, 2012).

Significantly maximum flower stalk length (8.95 cm), flower diameter (8.73 cm), number of flowers per plant (60.33) and flowering duration (50.47 days) was recorded significantly with foliar spray of GA₃ 300 ppm in African marigold (Kumar *et al.*, 2014). Similarly maximum number of flowers per plant (31.74 and 33.17, respectively) was also recorded with GA₃ 300 ppm followed by 200 ppm and 100 ppm GA₃ in both the years in African marigold (Badge *et al.*, 2014).

The minimum days taken to bud initiation (55.0 days) and opening of first flower (61.00) was observed in plants treated with 300 ppm GA₃. Same treatment of GA₃ (300 ppm) also recorded longer duration of flowering (33.07 days) as compared to control (24.00 days) in chrysanthemum cv. Vasantika. More number of flowers per plant (59.00) was recorded in plants treated with 300 ppm GA₃ which was at par with 200 ppm GA₃ in chrysanthemum (Prakash *et al.*, 2015). The biggest flowers with longest flower stalk length and more number of flowers per plant were obtained with 100 ppm GA₃ sprayed on gerbera (Patra *et al.*, 2015). Application of GA₃ 200 ppm recorded earlier flowering (87.08 & 90.23 days) and more number of flowers per plant (69.53 & 62.74) as compared to late flowering (96.89 & 98.72 days) and lower number of flowers per plant (48.17 & 42.30) in chrysanthemum cultivars i.e. Julia and Birbal Sahni, respectively (Singh and Nigam, 2015).

African marigold plants treated with GA₃ 100 ppm showed 1st bud on 44.9 DAT and 1st flower on 83.2 DAT, while (61.8, 99.6 DAT) plants sprayed with normal water produced 1st bud on 61.8 DAT and 1st flower on 99.6 DAT. The highest number of flowers per plant

(65.76), flower stalk length (8.93 cm), flower diameter (9.4 cm) and duration of flowering (53.17 days) was also recorded with GA₃ 100 ppm in African marigold (Palei *et al.*, 2016). Earliest bud initiation (30.67 days) and 50 percent flowering (42.13 days) was observed with GA₃ 300 ppm in African marigold (Patil *et al.*, 2016).

2.2.3. Yield Parameters

Application of GA₃ 200 ppm at 30 DAT on African marigold cv. Cupid was found best for significantly increasing the flower yield per hectare (71.92 q) (Tyagi and Kumar, 2006). The maximum fresh weight of flower (6.49 g) and flower yield per plant (359.83 g) was obtained in African marigold plants sprayed with GA₃ 300 ppm during both seasons (Swaroop *et al.*, 2007). According to Moond and Gehlot (2007) the maximum flower yield per plant (815 g) as well as per plot (15.95 kg) was obtained with application of GA₃ @ 150 ppm in chrysanthemum cv. Local.

Significantly maximum flower yield per plant (89.23 g) was recorded in plants treated with GA₃ 450 ppm, while minimum (52.28 g) was noted with control in French marigold (Pandey and Chandra, 2008). Highest flower yield was obtained with 200 ppm GA₃ applied as foliar spray in chrysanthemum (Dalal *et al.*, 2009). Treatment GA₃ 200 ppm significantly recorded highest flower yield per plot (6.45 kg) and per hectare (9.83 t) than control in African marigold (Shivaprakash *et al.*, 2011).

The maximum fresh weight of flower (12.45 g) and flower yield per plant (350.46 g) was recorded in the plants treated with GA₃ at 350 ppm, while minimum fresh weight of flower (8.94 g) and flower yield per plant (178.44 g) was recorded in control plants of marigold (Kumar *et al.*, 2011). The maximum average weight of flower (4.85 g) and yield of flowers per plant (365.23 g) as well as per hectare (132.27 q) was reported with single spray of GA₃ @ 150 ppm at 30 DAT in marigold (Kanwar and Khandelwal, 2013).

Significantly maximum flower yield per plant (239.94 and 235.16 g, respectively), flower yield per plot (7.19 and 7.05 kg, respectively) and flower yield per hectare (17.77 and 17.41 t, respectively) were recorded in marigold plants treated with GA₃ @ 300 ppm, while the minimum flower yield per plant (239.94 and 235.16 g, respectively), flower yield per plot (4.97 and 5.24 kg, respectively) and flower yield per hectare (12.28 and 12.94 t, respectively) was recorded in control treatment during both the years of study (Badge *et al.*, 2014).

Significantly maximum weight of flower (13.13 g) and flower yield per plant (792.13 g) and flower yield per hectare (396.06 q) was recorded with application of GA₃ 300 ppm in African marigold (Kumar *et al.*, 2014). Likely, foliar spray of GA₃ 300 ppm significantly recorded the maximum flower weight (2.75 g) and flower yield per plant (149.39 g) in chrysanthemum cv. Vasantika (Prakash *et al.*, 2015). Maximum flower weight (15.4 g) and flower yield per plant (987.167 g) was recorded significantly with spray of GA₃ 100 ppm on marigold (Palei *et al.*, 2016).

2.2.4. Seed Parameters

More number of seeds per flower (297.50) and seed yield per plant (23.50 g) was recorded with the application of GA₃ at 300 ppm during early winter season in African marigold. Number of seeds per flower (247.00) and seed yield per flower (1.228 g) were recorded maximum when plants were sprayed with GA₃ at 300 ppm during early summer season in African marigold (Swaroop *et al.*, 2007). GA₃ 200 ppm treated seedling showed good shoot length (1.84 cm) as compared to DW (Distilled Water) treated seedling (1.80) and MH 200 ppm treated seedling (1.63 cm) in case of *Calendula officinalis* L (Mankad and Patel, 2012).

Significantly maximum seed yield per plot (994.72 g), seed yield per hectare (14.04 q) and weight of seeds per flower (1.21 g) were obtained with GA₃ 300 ppm followed by GA₃ 200 ppm (991.39 g, 13.99 q and 1.13 g, respectively), GA₃ 100 ppm (907.97 g, 12.81 q and 1.11 g, respectively) and GA₃ 400 ppm (893.45 g, 12.61 q and 1.09 g, respectively). However, the minimum seed yield per plot (589.29 g), seed yield per hectare (8.31 q) and weight of seeds per flower (0.88 g) was measured significantly in control plants of African marigold (Patil *et al.*, 2016).

2.3. Effect of season on growth, flowering and yield

May planting was not found beneficial, as the plants continued vegetative growth for a longer period and the flower yield was very low. On the contrary, September planting was the best for maximizing the yield closely followed by July planting. January and November plantings hastened the appearance of flower bud (Samantarary *et al.*, 1999). Planting time plays an important role for getting higher flower yield and ensuring regular supply to the market (Rajyalakshmi and Rajasekhar, 2014).

2.3.1. Growth Parameters

Late planting time showed better performance in terms of various growth parameters of aster cv. Local as compared to early planting time. Plant height (39.95 cm), plant spread (22.05 cm) and total number of primary branches per plant (18.66) were recorded maximum in aster seedlings planted on 1st November (Dhawale *et al.*, 2008). The maximum plant height (89.29 cm) was significantly recorded on 12th April planting of marigold followed by 10th June, whereas the 12th October planting recorded significantly maximum plant spread (59.30 cm) followed by 10th December (57.41 cm) as compared to other planting dates. Maximum number of primary branches (5.86) and secondary branches (21.69) were recorded from marigold plants planted on 10th August and minimum (3.58 & 13.23) in 10th February planting in influencing number of primary and secondary branches, respectively (Ghosh and Pal, 2008).

Winter conditions are more congenial for aster planting according to Dhawale *et al.* (2008). Significantly tallest plants (90.80 cm) and more number of primary branches (11) were recorded during Kharif season in African marigold (Pramila *et al.*, 2011). Plant height,

branches per plant were significantly higher in the crop which was transplanted in the month of April. Dry matter accumulation in different plant parts was significantly higher in April 26 transplanted crop of *Tagetes minuta* (Kumar *et al.*, 2012b).

The growth parameters viz., plant height, number of branches, as well as fresh and dry yield of plant were significantly responded to planting date in both seasons in Mexican marigold (*Tagetes lucida* L.) (Ismail *et al.*, 2013). In case of French marigold, tallest plants (38.61cm) were recorded during Kharif season (Pramila *et al.*, 2011). The highest plant height of marigold was observed with GA₃ 300 ppm spray in all the three dates of planting, viz., 87 cm in August, 76.67 cm in September and 55.33 cm in October (Rajyalakshmi and Rajasekhar, 2014). Significantly, the maximum number of primary branches per plant (16.89) and plant spread (48.33 cm) was found in 1st October planting of African marigold cv. Pusa Narangi Gaiinda (Lakshmi *et al.*, 2014).

In African marigold highest plant height (57.75 cm) at maturity was recorded significantly from plants transplanted on 15th September whereas, lower plant height (43.75 cm) at maturity was observed in case of 15th November transplanting followed by 15th October transplanting (46.58 cm). Plants transplanted on 15th October recorded higher number of branches per plant (18.79), while lower number of primary branches per plant was reported by 15th September (18.11) transplanting followed by 15th November transplanting (18.34) (Meena *et al.*, 2015).

African marigold cv. Siracole planted on 9th June acquired the maximum height (96.93 cm). The maximum number of primary (5.3) and secondary (14.15) branches per plant, total fresh weight of plant (502.00 g) and dry weight of plant (126.25 g) were recorded from 12th April planting (Joshna and Pal, 2015). Marigold cv. Pusa Narangi Gaiinda planted on 1st May significantly recorded the highest plant (71.12 & 68.02 cm) and number of branches (34.87 & 42.21) in both the years, respectively. The best performance with respect to plant canopy spread (68.73 & 64.41 cm, respectively) was recorded in July planting followed by May planting (65.32 & 59.34 cm, respectively) during both years of experimentation (Singh *et al.*, 2015).

2.3.2 Floral Parameters

Late planting date i.e. 1st November caused early emergence (60.42 days) and opening of flower buds (14.07) in aster cv. Local as compared to 1st August planting which recorded late emergence and opening of flower buds (78.10 & 27.05 days). Peduncle length and flower diameter (30.28 & 7.71 cm) was found maximum in 1st November planting followed by 15th October, 1st October, 15th September, 1st September, 15th August and 1st August planting treatments (Dhawale *et al.*, 2008).

Early bud initiation (35.51 days) was recorded from 10th February planting compared to other planting dates. The maximum flowering duration was recorded in 12th October

planting, while minimum flowering duration was recorded with 10th February and 12th April planting. Crop planted on 12th October produced maximum number of flowers per plant (76.22) as well as per unit area (20.01 kg/5.76 sqm) having larger flower size (5.80 cm) in African marigold (Ghosh and Pal, 2008).

Significantly maximum number of flowers per plant (32) was recorded during Kharif season while maximum flower size (6.55 cm) was recorded during Rabi season in African marigold. The maximum number of flowers per plant (54.90) was recorded during Kharif season (Pramila *et al.*, 2011). The maximum flower diameter and length of flower stalk were recorded in July planting of French marigold (Deshmane *et al.*, 2012). Earliest bud initiation, flower initiation and 50 % flowering were recorded with late transplanting. The crop transplanted on 12th April initiated the bud initiation after 139 days of transplanting, whereas, only 72 days for those transplanted on June 25 in *Tagetes minuta* (Kumar *et al.*, 2012b). The marigold cv. Pusa Narangi Gainda planted on 1st October planting produced the maximum number of flowers per plant (50.10) and flower diameter (6.89 cm) (Lakshmi *et al.*, 2014). Time of planting differed significantly in inducing earlier flowering in African marigold cv. Pusa Narangi Gainda as reported by Meena *et al.*, 2015. He also found that the minimum time (66.70 days) to first flowering was taken by plants planted on 15th September while 15th November planting took maximum time (97.71 days) to first flowering.

The maximum diameter of individual flower (3.99 cm) was recorded from 12th April planting, while the maximum number (7435) of flowers per plot (6.4 m²) along with early appearance of full bloom (20.16 days) was observed in African marigold cv. Siracole planted on 16th May (Joshna and Pal, 2015). Early flowering was observed in the marigold cv. Pusa Narangi when planted on 1st March as compared to other planting dates. First September planting recorded maximum flower diameter (4.56 & 4.67 cm) and number of flowers per plant (51.18 & 54.30) during both the years, respectively (Singh *et al.*, 2015).

2.3.3. Yield Parameters

June planting of French marigold cv. Selection-2 recorded the maximum flower yield per plant (173 g) according to Raju *et al.* (2006). Ramesh and Singh (2008) while studying the planting date effect on growth, development and essential oil productivity of wild marigold planted from 30th July to 9th September at weekly interval in mid hills of Indian western Himalaya in *Tagetes minuta* reported that planting dates had a profound influence on growth and development. *Tagetes* crop transplanted on April 26 recorded significantly higher leaf and herbs yield than other dates of transplanting but remained at par with the crop transplanted on May 11. Delay in transplanting beyond May 11 significantly reduced leaf and herb yields in *Tagetes minuta*. According to Ghosh and Pal (2008) the maximum flower weight (5.29 g) was recorded with 12th October planting in African marigold.

Maximum flower yield per plant (96.49 g) was recorded during Kharif season (Pramila *et al.*, 2011). Crop transplanted on April 26 recorded significantly higher herb yield (635.7 q/ha) (Kumar *et al.*, 2012b). Among the four different dates of planting viz., April, May, June and July, the maximum weight of flower, flower yield per plant and flower yield per hectare was recorded in July planting of French marigold (Deshmane *et al.*, 2012).

Weight of flowers per plant (466.35 g), flower yield per plot (20.97 kg) and flower yield per hectare (25.9 t) were found significantly higher in 1st October planting of African marigold cv. Pusa Narangi Gaiinda (Lakshmi *et al.*, 2014). Heaviest flower (2.55 g) was recorded in 12th October planting of African marigold cv. Siracole (Joshna and Pal, 2015). Marigold crop planted on 1st September produced the maximum weight of flower (4.51 & 4.58 g) and flower yield per plot (19.20 & 19.12 kg) in both the years of study, respectively (Singh *et al.*, 2015).

2.3.4 Seed Parameters

Weight of seeds per hectare was found maximum (155.83 kg) in late planting i.e. 1st November planting followed by 15th October, 1st October, 15th September, 1st September, 15th August and 1st August planting. Significantly maximum number of seeds per plant (165), seed yield per plant (14.51 g) and test weight (2.63 g) were recorded during Kharif season, whereas, significantly highest germination (88.40%), seedling length (12.46 cm), seedling dry weight (0.994 mg), vigour index I (1102) and vigour index II (88) were recorded in Rabi season in case of African marigold. More number of seeds per flower (44.00) and seed yield per plant (4.86 g) were recorded during Kharif season. Whereas, more flower size (4.03 cm) and better seed quality parameters viz., germination (86.30%), seedling length (10.73 cm), seedling dry weight (0.89 mg), vigour index I (928) and vigour index II (77) were recorded during Rabi season in French marigold (Pramila *et al.*, 2011).

The maximum seed yield per flower (0.58 g) was observed in marigold plants transplanted on 15th September, while minimum seed yield per flower (0.46 g) was recorded in plants transplanted on 15th October. Early planting significantly recorded maximum seed yield per plant (17.82 g) from 15th September planting at par with 15th October planting (17.23 g), whereas, minimum seed yield per plant (15.07 g) was recorded from late planting i.e. 15th November planting. Maximum seed yield per plot (254.44 g) was recorded from 15th September planting, whereas, minimum seed yield per plot (213.44 g) was obtained in 15th October planting of African marigold. Significantly maximum (318.12 g) seed yield per plot was recorded with 15th September planting in plants double pinched at 60 DAT, whereas, the minimum (166.68 g) seed yield per plot was recorded with 15th October planting of African marigold (Meena *et al.*, 2015).

2.4. Effect of interaction among pinching, gibberellic acid and season on growth, flowering and yield

Significantly, chrysanthemum cv. IIHR-6 attained the maximum plant spread and number of branches per plant in the treatment combination GA₃ 200 ppm along with pinching at 60 DAT (Shinde *et al.*, 2010). Un-pinched plants of chrysanthemum cultivar IIHR-6 sprayed with 150 ppm GA₃ took minimum days to flower initiation and produced the biggest flower with prolonged duration of flowering. Application of GA₃ @ 200 ppm as foliar spray with pinching at 60 DAT significantly recorded the maximum number of flowers per plant, flower yield per plant as well as per hectare in chrysanthemum cv. IIHR-6 (Shinde *et al.*, 2010).

Pinching and gibberellic acid interaction was found non-significant in influencing various growth parameters like plant height, number of branches per plant, stem diameter and leaf area. Interactional effect of pinching and gibberellic acid was found non-significant in influencing the weight of flower, number of flowers per plant, yield of flower per plant and yield of flower per hectare in African marigold (Badge *et al.*, 2014). November planting of African marigold with single pinching resulted in the maximum seed germination percentage (90.44) and seed vigour index (2098) (Mohanty *et al.*, 2015a).

Planting and pinching time interaction was found significant in influencing the days to first flowering. Earliest first flowering (59.46 days) was recorded in un-pinched plants transplanted in September whereas; delayed first flowering was recorded in double pinched plants planted in November. Fifteen October planting significantly recorded more number of flowers (37.27) per plant compared to September (30.90) and November (27.60) planting. Planting time and pinching interaction was found significant in influencing seed yield per plant and reported maximum seed yield per plant (21.32 g) with P₃ treatment (Double pinching at 60 DAT) from 15th September planting, while minimum (12.83 g) was recorded with P₂ treatment (pinching at 30 DAT) from 15th November planting (Meena *et al.*, 2015).

CHAPTER–III

MATERIALS AND METHODS

The present investigation was carried out at Experimental Orchard of the Department of Horticulture, CCS Haryana Agricultural University, Hisar during 2015-16 to study the effect of pinching and gibberellic acid on growth, flowering and yield of African marigold (*Tagetes erecta* L.) under different seasons and the laboratory studies regarding various seed attributes were carried out at the laboratory of Seed Science and Technology, CCS HAU, Hisar. In this chapter, the experimental details, field and weather conditions, materials used and the methods adopted during the entire course of investigation are presented as under:

3.1. Experimental site

Experimental Orchard of the Department of Horticulture, CCS Haryana Agricultural University, Hisar is situated at 29° 10` North Latitude and 75° 46` East Longitude at an altitude of 215.2 meters above mean sea level.

3.2. Climate

The climate of Hisar region is semi-arid with very hot summers and relatively cool winters. The main characteristics of climate at Hisar are dryness, extremes of temperature, and scanty rainfall. The maximum and minimum temperature show wide degree of fluctuation during summer, while the temperature below freezing point accompanied by frost may also be recorded during winter months (December-January). The maximum day time temperature during summer varies between 40 and 46°C and during winter, from 1.5 to 4°C.

Hisar is located on outer margins of the South-West monsoon region. The rainfall is confined mainly to monsoon season from July to September but light showers of cyclonic rains also occur sometimes during winter and spring months. The average annual rainfall is around 450 mm, most of which occurs during July to September. Dew is observed in December and January. Hot winds, locally known as *loo*, are strong and frequent from May to June. Fog prevails generally in December-January.

The meteorological data for maximum and minimum temperature (°C), total rainfall (mm), relative humidity (%), average wind speed (km/hr) and bright sunshine hours were recorded during the crop season at the meteorological observatory located about 500 meter away from the experimental site in research area of the Department of Agricultural Meteorology, CCS Haryana Agricultural University, Hisar (Annexure-I & II).

3.3. Soil

The physico-chemical analysis of soil was conducted before the start of the experiment and presented in the Table 1. The soil of the experimental field was sandy loam, medium in available phosphorus, nitrogen and organic carbon (0.36%) but high in available potash.

Based on pH and electrical conductivity, the soil was well suited for cultivation of African marigold as well as horticultural crops.

Table 1: Physico-chemical analysis of the experimental field

Sr. No.	Characters	Contents	Methods used for analysis
1.	Texture	Sandy loam	International pipette method (Piper, 1966)
2.	Organic carbon (%)	0.36	Walkley's and Black Rapid Titration method (Jackson, 1973)
3.	pH	7.60	Glass electrode pH meter, 1:2 soil water suspension (Anonymous, 1954)
4.	E.C. (dSm ⁻¹)	0.34	EC meter, 1:2 soil water suspension (Anonymous, 1954)
5.	Available nitrogen (kg/ha)	146.0	Alkaline permanganate oxidation method (Subbaiah and Asija, 1956)
6.	Available phosphorus (kg/ha)	10.0	Olsen's method of extraction with NaHCO ₃ at pH 8.5 (Olsen <i>et al.</i> , 1954)
7.	Available potassium (kg/ha)	470.0	Flame photometer method (Anonymous, 1954)

3.4. Nursery raising

Nursery beds of convenient size (3 m length, 1 m width and 15 cm height) were prepared. Seeds were sown thinly and 2-3 cm deep once in January and again in September 2015 in rows spaced at 6-8 cm and thereafter covered with a thin layer of well decomposed sieved farmyard manure to ensure proper germination. Irrigation was applied immediately after sowing with the help of watering cane. In order to keep the nursery beds moist during entire period, the beds were watered every morning and necessary precautions were taken against insect-pests and diseases.

3.5. Field preparation

The field was prepared well in advance to a fine tilth by repeated ploughing and harrowing. Finally, it was leveled and divided into plots as per the layout. Plots of 1.60×2.00 m size were prepared. A basal dose of FYM (10 kg/plot) was applied uniformly to all the experimental plots and mixed well in to the soil 20 days before transplanting. Full dose of phosphorus (P₂O₅ @ 20 g/m²) and potassium (K₂O @10 g/m²) along with half dose of nitrogen (10 g/m²), was applied before transplanting in the form of single super phosphate, muriate of potash and urea, respectively and the remaining dose of nitrogen (10 g/m²) was applied 30 days after transplanting.

3.6. Transplanting of seedlings

The transplanting of seedlings was done as per the treatment. One month old seedlings having 5-7 leaves were transplanted on 19th February 2015 for summer season crop and again on

16th October 2015 for winter season crop. The spacing between row to row and plant to plant was kept 40 cm each. A light irrigation was given immediately after transplanting for better establishment of seedlings in the field.

3.7. Cultural practices

3.7.1. Gap filling

Gap filling was done five days after transplanting in order to maintain the required plant population in respective plot of each treatment.

3.7.2. Irrigation

Depending upon weather and availability of water, the experimental plots were irrigated at an interval of 5 to 7 days during summer and 10 to 12 days during winter in order to maintain optimum moisture throughout the crop season.

3.7.3. Weeding

Weeds compete with crop plants for nutrients, moisture, space and light, therefore, to keep the experimental field weed free and to conserve the moisture, manual weeding was done at regular interval depending upon weed intensity in crop field.

3.7.4. Staking

Each plant of experimental plot was supported by loosely 75-80 cm long wooden stick by to keep the plants erect after 5 to 6 weeks of transplanting. This wooden stick was tied loosely around the plant stem with a jute string to avoid lodging.

3.7.5. Plant protection

The prophylactic measures were adopted timely and uniformly as and when required to protect the crop against insect-pests and diseases.

3.7.6. Plant tagging

Five plants were selected randomly in each treatment plot and tagged for the purpose of recording data on various parameters.

3.8. Experimental Details

3.8.1. Experiment: Effect of pinching and gibberellic acid on growth, flowering and yield of African marigold (*Tagetes erecta* L.) under different seasons

3.8.2. Experimental plant material

Seeds of African marigold cv. Local Selection (MGH 133-1-2) were taken from previously maintained germplasm at Experimental Orchard of the Department of Horticulture, CCS HAU, Hisar.

3.8.3. Description of genotype

African marigold cv. Local Selection (MGH 133-1-2) is an open-pollinated genotype belonging to *Tagetes erecta*. Plants were tall, vigorous and uniform in growth bearing lemon yellow colour flowers of globular shape.

3.8.4. Treatment details

Crop	African marigold (<i>Tagetes erecta</i> L.)
Cultivar	Local Selection (MGH 133-1-2)
Treatments	
Factor (A)	Pinching levels (P)
P ₁	No pinching
P ₂	Pinching at 2 WAT (Weeks After Transplanting)
P ₃	Pinching at 3 WAT
P ₄	Pinching at 4 WAT
Factor (B)	Gibberellic acid levels (G)
G ₀	Control (water)
G ₁	150 ppm
G ₂	250 ppm
G ₃	350 ppm
Factor (C)	Seasons
S ₁	Winter Season
Sowing	Mid of September
Transplanting:	Mid of October
S ₂	Summer Season
Sowing	Mid of January
Transplanting	Mid of February
Total number of treatments	$4 \times 4 \times 2 = 32$
Statistical design	Randomized Block Design (factorial)
Replications	Three
Total number of plots	96
Time of GA ₃ spray	Four weeks after transplanting

3.8.5. Methods used for treatment application

(a) Pinching

The plants were pinched by removing apical portion as per treatment requirement in order to arrest vertical growth of the plant and to encourage side shoots. Four to five centimeter terminal growing tip consisting of 3-4 pairs of leaves was pinched off as per time mentioned in treatments.

(b) Preparation of chemicals

Solutions of GA₃ viz., 150, 250 and 350 ppm were prepared in 1000 ml volumetric flask by dissolving calculated quantity of chemical in a small quantity of ethyl alcohol and then volume was made up to one litre with distilled water. Foliar spray of GA₃ was done uniformly

with the help of knapsack sprayer pump over the plants at four weeks after transplanting as per treatment combinations, whereas, control plants were sprayed with water.

3.9. Collection of data from the field

For collecting data from the field, five plants were selected randomly and tagged in each treatment leaving the border plants. Observations on growth, flowering, yield and seed parameters were recorded using the tagged plants. The observations recorded during the course of investigation are given below.

3.9.1. Growth parameters

(a) Plant height (cm)

Plant height of representative plants in each plot was measured with the help of meter rod at full bloom stage. It was recorded as the vertical distance from collar region to apical shoot of the plant. The average height was then worked out and expressed in centimeters.

(b) Plant spread (cm)

The plants selected for recording height at random in each plot were also selected for recording plant spread at full bloom stage. The plant spread was recorded with the help of measuring scale as the maximum horizontal distance covered by the plant in East to West and North to South directions. The average plant spread was then worked out and expressed in centimeters.

(c) Number of primary branches per plant

The number of branches arising from the main stem was counted at the time of full bloom on five representative plants in each plot and average values were worked out.

(d) Fresh weight of plant (g)

Fresh weight of five randomly selected plants from each replication was recorded in gram with the help of electronic balance and average fresh weight was calculated.

(e) Dry weight of plant (g)

The plants taken for fresh weight were shade dried until the reduction in weight became constant and then the weight was recorded and expressed in grams.

3.9.2. Flowering parameters

The data pertaining to floral parameters like days to bud initiation, days to 1st flower, Duration of flowering, number of buds per plant, number of flowers per plant, flower stalk length and diameter of flower were recorded.

(a) Days to bud initiation

The number of days taken from transplanting to the appearance of first flower bud in the representative plants of each plot was recorded and the days taken were counted.

(b) Days to first flower:

The number of days taken from transplanting to the appearance of first flower in the representative plants in each plot was recorded and days taken were counted.



Plate 1: General view of African marigold field at flowering stage during summer season



Plate 2: General view of African marigold field at flowering time during winter season

(c) Duration of flowering:

The total number of days taken were counted from the date of first flower opening to the opening of last flower. This constitutes the duration of flowering, which was recorded on representative plants in each plot.

(d) Number of buds per plant

The total number of buds per plant was counted from five randomly selected plants in each plot and their average was worked out.

(e) Number of flowers per plant

The total number of flowers produced by each of the tagged plant was recorded from each plot at full bloom stage. The average number of flowers were taken into consideration for statistical analysis and expressed as number of flowers produced per plant.

(f) Flower Stalk length (cm)

Flower stalk length was measured with the help of a measuring scale from node to the peduncle of flower in each tagged plant of each plot and recorded in centimeters. The data on flower stalk length were recorded and average was taken for statistical analysis.

(g) Flower diameter (cm)

Flower diameter was recorded at full bloom stage by using digital vernier caliper and mean of five flowers from each representative plant in each plot was computed and expressed in centimeters.

3.9.3. Yield parameters

(a) Fresh weight of flower (g)

The mean weight of five flowers plucked randomly from each representative plant was recorded immediately after harvest and their average weight was computed and expressed in grams.

(b) Dry weight of flower (g)

The flowers taken for fresh weight were shade dried until the reduction in weight became constant and then the weight was recorded as mean of five flowers and expressed in grams.

(c) Flower yield per plant (g):

The average fresh weight of a flower multiplied by number of flowers constituted the flower yield per plant and mean was computed and expressed in gram.

(d) Flower yield per plot (kg)

The average flower yield per plant was multiplied by number of plants in the plot and recorded in kilogram.

(e) Flower yield per hectare (t)

The flower yield per plot was converted to hectare basis, which reflected the yield per hectare and expressed in tonnes per hectare (t/ha).

3.9.4. Seed parameters

Seeds from all representative plants of each plot were collected at right stage of development to generate information regarding various seed attributes and the following parameters were studied:

(a) Number of seeds per capitulum

Total five flowers on representative plants of each plot were allowed to be mature. After attaining maturity, the flower capitulum was harvested and seeds were separated. Then, the number of seeds per capitulum was counted and mean was computed.

(b) Number of black seeds per capitulum

The flowers selected for computing number of seeds per capitulum were also taken for counting number of black seeds per capitulum. Then total number of black seeds from each flower was counted manually and their mean was computed.

(c) Seed yield per plant (g)

The mean weight of seeds in five flower capitulum harvested from representative plants was recorded and multiplied by number of flowers from each plant and the weight was recorded in grams.

(d) Seed yield per plot (g)

Seed yield per plot was estimated by multiplying seed yield per plant with number of plants per plot.

(e) Seed yield per hectare (kg)

The seed yield per plot was converted to hectare basis, which reflected the seed yield per hectare and expressed in kilograms.

(f) 1000 seeds weight (g)

The 1000 seeds were counted from each treatment and weighed on analytical balance and the data were recorded in grams per 1000 seeds. Seed samples containing a sum of 1000 seeds from each treatment were weighed and recorded as 1000 seeds weight in gram.

(g) Seed germination (%)

The germination test was performed as per ISTA (Anonymous, 1999). The 100 seeds of each treatment per replication were put on top of the paper (TP) and kept at 20°C. After 14 days, the seedlings were counted and the total number of normal seedlings was recorded.

(h) Seedling root length (cm)

At the time of final count, ten normal seedlings were taken at random and seedling root length was measured. The average of ten seedlings was taken and recorded in centimeters.

(i) Seedling shoot length (cm)

At the time of final count, ten normal seedlings were taken at random and seedling shoot length was measured. The average of ten seedlings was taken and recorded in centimeters.

(j) Seedling dry weight (mg)

The ten normal seedlings randomly selected for measuring seedling root and shoot length was further kept for taking dry weight. These seedlings were dried in a hot air oven at 80°C for 16 hours and the seedlings dry weight was recorded in milligram.

(k) Seed vigor index

The seed vigor index was calculated as per the methods of Abdul Baki and Anderson (1973) given as under:

(i) Seed vigor index-I (based on seedling length)

Seed vigour index-I = Germination percentage × Seedling length (in cm)

(ii) Seed vigor index-II (based on seedling dry weight)

Seed vigour index-II = Germination percentage × Seedling dry weight (in gram)

3.10. Statistical Analysis

The data recorded for growth, flowering, yield and seed characteristics during the course of investigation were subjected to the statistical analysis using factorial Randomized Block Design as suggested by Panse and Sukhatme (1995).

Analysis of variance

The significance of treatment effects was judged by using F test. The critical difference (CD) was worked out at 5% level of significance to judge the significance of difference between two treatment means. Critical difference was calculated only when the 'F' test was found significant.

Analysis of variance

Source	d.f.	S.S.	M.S.S.	F value
Replications	r-1	SS _r	MS _r	MS _r /MS _e
Treatments (T)	t-1	SS _t	MS _t	MS _t /MS _e
Error	(r-1) x (t-1)	SS _e	MS _e	

In order to compare the means of different treatments, the CD was calculated using the following formula:

$$CD = S.E. (d) \times 't' \text{ error d.f.}$$

Where, S.E. is the standard error of difference of means for the treatment means, which was calculated using the following formula:

$$S.E. \text{ for treatment} = \sqrt{\frac{2EMS}{r}}$$

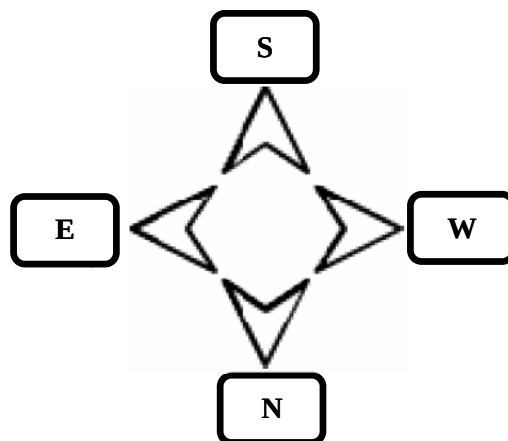
Where,

EMS = Error mean squares

t= tabulated value at 5% level of significance for error degrees of freedom

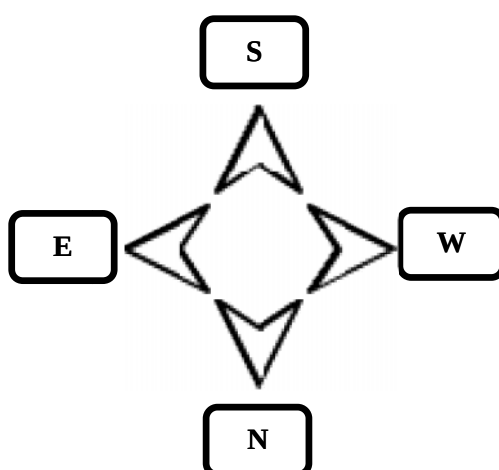
Field layout of winter season

C H A N N E L	$P_2G_0R_1$	$P_3G_1R_3$	C H A N N E L	$P_1G_2R_2$	$P_4G_3R_1$	C H A N N E L	$P_1G_1R_3$
	$P_3G_2R_2$	$P_2G_3R_1$		$P_4G_1R_1$	$P_3G_0R_2$		$P_1G_3R_2$
	$P_2G_2R_1$	$P_3G_1R_2$		$P_2G_0R_2$	$P_4G_2R_1$		$P_2G_1R_3$
	$P_4G_1R_3$	$P_1G_2R_1$		$P_3G_3R_2$	$P_1G_0R_1$		$P_1G_1R_2$
	$P_2G_3R_2$	$P_4G_0R_2$		$P_2G_2R_3$	$P_4G_3R_2$		$P_1G_3R_1$
	$P_4G_2R_3$	$P_3G_1R_1$		$P_3G_2R_1$	$P_1G_3R_3$		$P_1G_0R_2$
	$P_2G_3R_3$	$P_4G_2R_2$		$P_2G_1R_2$	$P_3G_3R_1$		$P_2G_0R_3$
	$P_3G_2R_3$	$P_1G_1R_1$		$P_4G_3R_3$	$P_1G_2R_3$		$P_1G_0R_3$
	$P_4G_0R_1$	$P_2G_2R_2$		$P_3G_0R_3$	$P_4G_1R_2$		N.E.
	$P_3G_3R_3$	$P_4G_0R_3$		$P_2G_1R_1$	$P_3G_0R_1$		N.E.



Field layout of summer season

C H A N N E L	$P_1G_3R_1$	$P_3G_0R_1$	C H A N N E L	$P_2G_0R_1$	$P_1G_1R_2$	C H A N N E L	$P_4G_3R_1$	$P_3G_1R_1$	C H A N N E L
	$P_2G_1R_1$	$P_1G_2R_2$		$P_4G_1R_1$	$P_3G_2R_1$		$P_2G_2R_1$	$P_4G_3R_2$	
	$P_4G_2R_2$	$P_3G_3R_1$		$P_2G_3R_1$	$P_4G_0R_3$		$P_1G_3R_2$	$P_3G_0R_2$	
	$P_2G_0R_2$	$P_1G_1R_1$		$P_4G_0R_1$	$P_3G_1R_2$		$P_2G_1R_2$	$P_1G_2R_1$	
	$P_1G_1R_3$	$P_3G_2R_2$		$P_2G_2R_2$	$P_1G_3R_3$		$P_4G_2R_1$	$P_3G_3R_2$	
	$P_2G_3R_2$	$P_1G_0R_1$		$P_4G_3R_3$	$P_3G_0R_3$		$P_2G_0R_3$	$P_4G_1R_3$	
	$P_4G_0R_2$	$P_3G_1R_3$		$P_2G_1R_3$	$P_4G_2R_3$		$P_1G_0R_3$	$P_3G_2R_3$	
	$P_2G_2R_3$	$P_1G_0R_2$		$P_1G_2R_3$	$P_3G_3R_3$		$P_2G_3R_3$	$P_4G_1R_2$	



The results of the experiment entitled “Effect of pinching and gibberellic acid on growth, flowering and yield of African marigold (*Tagetes erecta* L.) under different seasons” conducted during 2015-16 at Experimental Orchard of the Department of Horticulture, CCS Haryana Agricultural University, Hisar are presented under following headings:

4.1. Growth parameters**4.2. Flowering parameters****4.3. Yield parameters****4.4. Seed parameters****4.1. Growth parameters****4.1.1. Plant height (cm)**

The data presented in Table 2 showed that season, pinching and gibberellic acid significantly influenced the height of marigold plants. The taller plants (81.58 cm) were observed in summer (S_2) as compared to plants grown in winter (S_1) (70.46 cm) irrespective of pinching and gibberellic acid. Plant height decreased significantly with increasing levels of pinching. The maximum plant height (79.85 cm) was recorded in un-pinched plants (P_1) and minimum (71.84 cm) in plants pinched at four weeks after transplanting (P_4) irrespective of season and gibberellic acid. The plant height increased significantly with the increase in levels of GA_3 up to 250 ppm but thereafter it decreased. The plant height was obtained maximum (83.32 cm) with GA_3 250 ppm, while it was found minimum (66.69 cm) in control (G_0) irrespective of season and pinching.

All the interactions except $S \times G$ were found significant with respect to plant height (Table 2). In case of $S \times P$ interaction, the maximum plant height (84.66 cm) was recorded in un-pinched plants of summer season (S_2P_1), while minimum plant height (65.00 cm) was observed in plants of winter season pinched at 4 WAT (S_1P_4). Likewise, with respect to $S \times G$ interaction, the maximum plant height (88.71 cm) was recorded in plants of summer season sprayed with 250 ppm GA_3 (S_2G_2), while minimum plant height (61.21 cm) was observed in control plants of winter season (S_1G_0). Similarly, $P \times G$ interaction reported that the maximum plant height (88.36 cm) was recorded in un-pinched plants sprayed with GA_3 @ 250 ppm (P_1G_2), while minimum plant height (63.09 cm) was observed in control plants pinched at 4 WAT (P_4G_0).

Season, pinching and gibberellic acid interactions had significant effect on influencing the plant height (Table 2). The maximum plant height (95.15 cm) was recorded

with use of GA₃ at 250 ppm in un-pinched plants of summer season (S₂P₁G₂) and minimum plant height (56.92 cm) was observed in control plants pinched at 4 WAT (S₁P₄G₀) followed by S₁P₃G₀ (59.03 cm).

4.1.2. Plant spread (cm)

The data presented in Table 3 revealed that season, pinching and gibberellic acid played a significant role in influencing plant spread. The widest spread of plant (61.66 cm) was recorded in summer (S₂) as compared to least plant spread (47.98 cm) observed in winter (S₁) irrespective of pinching and gibberellic acid. On the other hand, the maximum plant spread (59.20 cm) was recorded in plants pinched at 2 WAT (P₂) as the minimum plant spread (49.48 cm) was recorded in un-pinched plants (P₁) irrespective of season and gibberellic acid. Plant spread increased significantly with every increase in GA₃ concentration. The maximum plant spread (59.48 cm) was registered with 350 ppm concentration of GA₃ (G₃), though the minimum (48.44 cm) was recorded in control (G₀) irrespective of season and pinching.

S×P, S×G and P×G interactions were found significant in affecting the plant spread (Table 3). In S×P interaction, summer grown plants when pinched at 2 WAT (S₂P₂) attained the widest plant spread (65.05 cm), while least plant spread (40.79 cm) was observed in un-pinched plants of winter season (S₁P₁). With respect to S×G interaction, plants of summer season when sprayed with 350 ppm GA₃ attained the maximum plant spread (65.59 cm) (S₂G₃), whereas the minimum plant spread (40.03 cm) was reported in control plants of winter season (S₁G₀). Further, in relation to P×G interaction the widest plant spread (64.16 cm) was recorded in plants pinched at 2 WAT sprayed with 350 ppm dose of GA₃ (P₂G₃) followed by P₂G₂ (62.79 cm) and P₃G₃ (62.65 cm), respectively while the lowest plant spread (44.65 cm) was observed in un-pinched plants sprayed with water (P₁G₀).

Season, pinching and gibberellic acid interaction (S×P×G) was found non-significant in influencing the plant spread (Table 3). Summer grown marigold plants when pinched at 2 WAT along with foliar spray of 350 ppm GA₃ (S₂P₂G₃) recorded the maximum plant spread (68.82 cm) and minimum plant spread (35.79 cm) was observed in un-pinched plants of winter season when sprayed with water only (S₁P₁G₀).

4.1.3. Number of primary branches per plant

Season, pinching and gibberellic acid had exhibited a significant effect on number of primary branches per plant influenced significantly with different seasons, levels of pinching and gibberellic acid (Table 4). More number of primary branches per plant (12.75) was recorded in winter season (S₁), while less number of primary branches per plant (9.93) was found in summer season (S₂) irrespective of pinching and gibberellic acid. Number of primary branches per plant increased significantly due to all pinching treatments except P₃ (pinching at 3 WAT) and P₄ (pinching at 4 WAT) treatments, which were found at par with each other.

Table 2: Effect of pinching and gibberellic acid on plant height (cm) of African marigold cv. Local Selection in different seasons

Season × Pinching × Gibberellic acid (S x P x G)								
Season→	S ₁				S ₂			
Pinching→ GA ₃ ↓	P ₁ (No pinching)	P ₂ (2 WAT)	P ₃ (3 WAT)	P ₄ (4 WAT)	P ₁ (No pinching)	P ₂ (2 WAT)	P ₃ (3 WAT)	P ₄ (4 WAT)
G ₀ (control)	66.38	62.50	59.03	56.92	74.83	72.97	71.58	69.25
G ₁ (150 ppm)	74.72	70.00	68.36	64.10	81.67	82.25	80.48	78.72
G ₂ (250 ppm)	81.56	80.25	78.34	71.53	95.15	90.60	85.27	83.80
G ₃ (350 ppm)	77.44	75.22	73.50	67.43	86.97	85.16	83.65	82.92
Season x Pinching (S x P)					Season x GA ₃ (S x G)			
Season→ Pinching ↓	S ₁ (Winter)	S ₂ (Summer)	Mean (P)		Season→ GA ₃ ↓	S ₁ (Winter)	S ₂ (Summer)	Mean (G)
P ₁ (No pinching)	75.03	84.66	79.85		G ₀ (control)	61.21	72.16	66.69
P ₂ (2 WAT)	71.99	82.74	77.37		G ₁ (150 ppm)	69.30	80.78	75.04
P ₃ (3 WAT)	69.81	80.25	75.03		G ₂ (250 ppm)	77.92	88.71	83.32
P ₄ (4 WAT)	65.00	78.67	71.84		G ₃ (350 ppm)	73.40	84.67	79.04
Mean (S)	70.46	81.58			Mean (S)	70.46	81.58	
Pinching x GA ₃ (P x G)						CD at 5% level of significance		
Pinching→ GA ₃ ↓	P ₁ (No pinching)	P ₂ (2 WAT)	P ₃ (3 WAT)	P ₄ (4 WAT)	Mean (G)	Season Pinching Gibberellic acid Season × pinching Season × gibberellic acid Pinching × gibberellic acid Season × pinching × gibberellic acid		0.60
G ₀ (control)	70.61	67.74	65.31	63.09	66.69			0.85
G ₁ (150 ppm)	78.20	76.13	74.42	71.41	75.04			0.85
G ₂ (250 ppm)	88.36	85.43	81.81	77.67	83.32			1.20
G ₃ (350 ppm)	82.21	80.19	78.58	75.18	79.04			NS
Mean (P)	79.85	77.37	75.03	71.84				1.70
								2.41
WAT - Weeks After Transplanting								

Table 3: Effect of pinching and gibberellic acid on plant spread (cm) of African marigold cv. Local Selection in different seasons

Season × Pinching × Gibberellic acid (S x P x G)								
Season→	S ₁				S ₂			
Pinching→ GA ₃ ↓	P ₁ (No pinching)	P ₂ (2 WAT)	P ₃ (3 WAT)	P ₄ (4 WAT)	P ₁ (No pinching)	P ₂ (2 WAT)	P ₃ (3 WAT)	P ₄ (4 WAT)
G ₀ (control)	35.79	44.07	41.37	38.88	53.51	59.75	58.53	55.60
G ₁ (150 ppm)	40.07	52.08	50.89	45.72	57.50	63.78	62.38	58.92
G ₂ (250 ppm)	42.86	57.75	55.00	49.69	59.30	67.83	65.35	61.73
G ₃ (350 ppm)	44.42	59.50	57.80	51.77	62.42	68.82	67.50	63.61
Season x Pinching (S x P)					Season x GA ₃ (S x G)			
Season→ Pinching ↓	S ₁ (Winter)	S ₂ (Summer)	Mean (P)		Season→ GA ₃ ↓	S ₁ (Winter)	S ₂ (Summer)	Mean (G)
P ₁ (No pinching)	40.79	58.18	49.48		G ₀ (control)	40.03	56.85	48.44
P ₂ (2 WAT)	53.35	65.05	59.20		G ₁ (150 ppm)	47.19	60.65	53.92
P ₃ (3 WAT)	51.27	63.44	57.35		G ₂ (250 ppm)	51.33	63.55	57.44
P ₄ (4 WAT)	46.52	59.97	53.24		G ₃ (350 ppm)	53.37	65.59	59.48
Mean (S)	47.98	61.66			Mean (S)	47.98	61.66	
Pinching x GA ₃ (P x G)						CD at 5% level of significance		
Pinching→ GA ₃ ↓	P ₁ (No pinching)	P ₂ (2 WAT)	P ₃ (3 WAT)	P ₄ (4 WAT)	Mean (G)	Season Pinching Gibberellic acid Season × pinching Season × gibberellic acid Pinching × gibberellic acid Season × pinching × gibberellic acid		0.59
G ₀ (control)	44.65	51.91	49.95	47.24	48.44			0.84
G ₁ (150 ppm)	48.79	57.93	56.63	52.32	53.92			0.84
G ₂ (250 ppm)	51.08	62.79	60.18	55.71	57.44			1.18
G ₃ (350 ppm)	53.42	64.16	62.65	57.69	59.48			1.18
								1.67
								NS
WAT - Weeks After Transplanting								

Table 4: Effect of pinching and gibberellic acid on number of primary branches per plant of African marigold cv. Local Selection in different seasons

Season × Pinching × Gibberellic acid (S x P x G)								
Season →	S ₁				S ₂			
Pinching→ GA ₃ ↓	P ₁ (No pinching)	P ₂ (2 WAT)	P ₃ (3 WAT)	P ₄ (4 WAT)	P ₁ (No pinching)	P ₂ (2 WAT)	P ₃ (3 WAT)	P ₄ (4 WAT)
G ₀ (control)	9.00	11.59	11.10	10.02	8.22	8.47	9.00	8.56
G ₁ (150 ppm)	10.00	13.33	12.28	11.67	8.67	9.87	9.63	9.48
G ₂ (250 ppm)	12.33	14.56	13.56	12.61	9.08	12.60	10.24	9.83
G ₃ (350 ppm)	14.17	16.50	15.75	15.50	9.66	13.24	11.00	10.22
Season x Pinching (S x P)					Season x GA ₃ (S x G)			
Season→ Pinching ↓	S ₁ (Winter)	S ₂ (Summer)	Mean (P)		Season→ GA ₃ ↓	S ₁ (Winter)	S ₂ (Summer)	Mean (G)
P ₁ (No pinching)	11.38	8.91	10.15		G ₀ (control)	10.43	8.81	9.62
P ₂ (2 WAT)	14.00	11.30	12.65		G ₁ (150 ppm)	11.82	9.41	10.62
P ₃ (3 WAT)	13.17	9.97	11.57		G ₂ (250 ppm)	13.27	10.44	11.86
P ₄ (4 WAT)	12.45	9.52	10.99		G ₃ (350 ppm)	15.48	11.03	13.26
Mean (S)	12.75	9.93			Mean (S)	12.75	9.93	
Pinching x GA ₃ (P x G)						CD at 5% level of significance		
Pinching→ GA ₃ ↓	P ₁ (No pinching)	P ₂ (2 WAT)	P ₃ (3 WAT)	P ₄ (4 WAT)	Mean (G)	Season Pinching Gibberellic acid Season × pinching Season × gibberellic acid Pinching × gibberellic acid Season × pinching × gibberellic acid		0.59
G ₀ (control)	8.61	10.53	10.05	9.29	9.62			0.84
G ₁ (150 ppm)	9.34	11.60	10.96	10.58	10.62			0.84
G ₂ (250 ppm)	10.71	13.58	11.90	11.22	11.86			1.18
G ₃ (350 ppm)	11.92	14.87	13.38	12.86	13.26			1.18
								1.67
								NS
Mean (P)	10.15	12.65	11.57	10.99				
WAT - Weeks After Transplanting								

Table 5: Effect of pinching and gibberellic acid on fresh weight of plant (g) of African marigold cv. Local Selection in different seasons

Season × Pinching × Gibberellic acid (S x P x G)								
Season →	S ₁				S ₂			
Pinching→ GA ₃ ↓	P ₁ (No pinching)	P ₂ (2 WAT)	P ₃ (3 WAT)	P ₄ (4 WAT)	P ₁ (No pinching)	P ₂ (2 WAT)	P ₃ (3 WAT)	P ₄ (4 WAT)
G ₀ (control)	223.45	326.51	298.29	262.50	355.00	515.00	444.44	405.00
G ₁ (150 ppm)	267.35	387.19	346.92	323.23	386.67	552.30	473.33	450.00
G ₂ (250 ppm)	400.57	496.70	464.70	441.69	465.00	616.67	585.00	565.00
G ₃ (350 ppm)	336.05	426.33	397.82	370.52	430.00	570.00	543.33	497.50
Season x Pinching (S x P)					Season x GA ₃ (S x G)			
Season→ Pinching ↓	S ₁ (Winter)	S ₂ (Summer)	Mean (P)		Season→ GA ₃ ↓	S ₁ (Winter)	S ₂ (Summer)	Mean (G)
P ₁ (No pinching)	306.86	409.17	358.01		G ₀ (control)	277.69	429.86	353.77
P ₂ (2 WAT)	409.18	563.49	486.34		G ₁ (150 ppm)	331.17	465.58	398.37
P ₃ (3 WAT)	376.93	511.53	444.23		G ₂ (250 ppm)	450.91	557.92	504.42
P ₄ (4 WAT)	349.49	479.38	414.43		G ₃ (350 ppm)	382.68	510.21	446.45
Mean (S)	360.61	490.89			Mean (S)	360.61	490.89	
Pinching x GA ₃ (P x G)						CD at 5% level of significance		
Pinching→ GA ₃ ↓	P ₁ (No pinching)	P ₂ (2 WAT)	P ₃ (3 WAT)	P ₄ (4 WAT)	Mean (G)	Season		4.94
G ₀ (control)	289.23	420.76	371.37	333.75	353.77	Pinching		6.98
G ₁ (150 ppm)	327.01	469.75	410.13	386.62	398.37	Gibberellic acid		6.98
G ₂ (250 ppm)	432.78	556.69	524.85	503.35	504.42	Season × pinching		9.87
G ₃ (350 ppm)	383.03	498.17	470.58	434.01	446.44	Season × gibberellic acid		9.87
Mean (P)	358.01	486.34	444.23	414.43		Pinching × gibberellic acid		13.96
						Season × pinching × gibberellic acid		19.74
WAT - Weeks After Transplanting								

Plants with pinching done at 2 WAT (P_2) significantly produced the maximum number of primary branches per plant (12.65) and minimum number of primary branches per plant (10.15) was recorded in un-pinched plants (P_1) irrespective of season and gibberellic acid. Foliar spray of GA_3 applied at the rate of 350 ppm (G_3) significantly registered the maximum number of primary branches per plant (13.26), whereas, minimum number of primary branches per plant (9.62) was recorded in control (G_0) irrespective of season and pinching.

All the interactions like $S \times P$, $S \times G$ and $P \times G$ were found significant in increasing the number of primary branches per plant (Table 4). In case of $S \times P$ interaction, winter crop with pinching at 2 WAT (S_1P_2) obtained the maximum number of primary branches per plant (14.00) followed by S_1P_3 (13.17) and minimum number of primary branches per plant (8.91) was observed in un-pinched plants of summer season (S_2P_1) followed by S_2P_4 (9.52) and S_2P_3 (9.97). In relation to $S \times G$ interaction, the maximum number of primary branches per plant (15.48) was reported in winter plants sprayed with 350 ppm GA_3 (S_1G_3), though the minimum number of primary branches per plant (8.81) was observed in control plants of summer season S_2G_0 at par with S_2G_1 (9.41). Application of GA_3 @ 350 ppm over plants pinched at 2 WAT resulted in production of the highest number of primary branches per plant (14.87) (P_2G_3) followed by P_2G_2 (13.58) and P_3G_3 (13.38), which were also at par with each other, while the lowest number of primary branches per plant (8.61) was observed in un-pinched plants sprayed with water only (P_1G_0) followed by P_4G_0 (9.29) and P_1G_1 (9.34) which were also recorded at par with each other.

Season, pinching and gibberellic acid interaction was found non-significant in increasing number of primary branches per plant (Table 4). Winter crop sprayed with 350 ppm dose of GA_3 over plants pinched at 2 WAT recorded the maximum number of primary branches per plant (16.50) ($S_1P_2G_3$), while minimum number of primary branches per plant (8.22) was observed in un-pinched plants sprayed with water only ($S_2P_1G_0$).

4.1.4. Fresh weight of plant (g)

The data shown in Table 5 revealed that season, pinching and gibberellic acid had played a significant role in influencing fresh weight of plant. Summer crop (S_2) recorded more fresh weight of plant (490.89 g) in contrast; winter crop (S_1) produced less fresh weight of plant (360.61 g) irrespective of pinching and gibberellic acid. Plants under P_2 treatment (pinched at 2 WAT) significantly acquired the maximum fresh weight of plant (486.34 g) though minimum fresh weight of plant (358.01 g) was recorded in P_1 treatment (un-pinched plants) irrespective of season and gibberellic acid. Fresh weight of plant increased significantly with increase in concentration of GA_3 up to 250 ppm after that a significant decrease in fresh weight of plant was recorded. The maximum fresh weight of plant (504.42 g) was recorded in G_2 (250 ppm GA_3) treatment, while minimum fresh weight of plant (353.77 g) was recorded in G_0 (control) treatment irrespective of season and pinching.

The interactions of S×P, S×G and P×G were found significant in affecting the fresh weight of plant (Table 5). The maximum fresh weight of plant (563.49 g) was recorded in summer plants pinched at 2 WAT (S₂P₂), although minimum fresh weight of plant (306.86 g) was observed in un-pinched plants of winter season (S₁P₁). Similarly, the maximum fresh weight of plant (557.92 g) was also recorded in plants of summer season (S₂) sprayed with 250 ppm GA₃ (S₂G₂) while minimum fresh weight of plant (277.69 g) was observed in control (G₀) plants of winter season (S₁G₀). Plants pinched at 2 WAT along with GA₃ 250 ppm application (P₂G₂) acquired the maximum fresh weight of plant (556.69 g) and minimum fresh weight of plant (289.23 g) was obtained in un-pinched plants sprayed with water (P₁G₀).

Season, pinching and gibberellic acid interactions (S×P×G) had significant effect on improving the fresh weight of plant (Table 5). The maximum fresh weight of plant (616.67 g) was recorded with 250 ppm GA₃ (G₂) sprayed on plants pinched at 2 WAT in summer season (P₂G₂S₂) while the minimum fresh weight of plant (223.45 g) was observed with control (G₀) in un-pinched plants of winter season (P₁G₀S₁).

4.1.5. Dry weight of plant (g)

The data represented in Table 6 showed that dry weight of plant was significantly affected by season, pinching and gibberellic acid. Summer season (S₂) reported more dry weight of plant (57.47 g) as compared to less dry weight of plant (40.21 g) in winter season (S₁) irrespective of pinching and gibberellic acid. Among pinching treatments, the maximum dry weight of plant (56.26 g) was recorded in plants pinched at 2 WAT (P₂), while the minimum dry weight of plant (41.49 g) was recorded in un-pinched plants (P₁) irrespective of season and gibberellic acid. Dry weight of plant increased significantly with increasing levels of GA₃ up to 250 ppm and thereafter a significant decrease in it was recorded. GA₃ sprayed at the rate of 250 ppm (G₂) produced the maximum dry weight of plant (58.75g), while the minimum dry weight of plant (40.95 g) was recorded in control (G₀) irrespective of season and pinching.

All interactions viz., S×P, S×G, P×G and S×P×G were recorded non-significant in affecting dry weight of plant (Table 6). Although, in case of S×P, the maximum dry weight of plant (64.01g) was recorded with pinching time of 2 WAT in plants of summer season (S₂P₂), while the minimum dry weight of plant (33.74 g) was observed in winter plants without pinching (S₁P₁). Similarly, S×G interaction depicted that the maximum dry weight of plant (66.41 g) was recorded in plants of summer season sprayed with 250 ppm GA₃ (S₂G₂) while minimum dry weight of plant (31.11 g) was observed in control plants of winter season (S₁G₀). Interaction of P×G had further shown that the maximum dry weight of plant (65.39 g) was recorded when 250 ppm GA₃ sprayed over plants pinched at 2 WAT sprayed (P₂G₂), while the minimum dry weight of plant (33.32 g) was observed in un-pinched plants sprayed with water (P₁G₀).

Table 6: Effect of pinching and gibberellic acid on dry weight of plant (g) of African marigold cv. Local Selection in different seasons

Season × Pinching × Gibberellic acid (S x P x G)								
Season →	S ₁ (Winter)				S ₂ (Summer)			
Pinching→ GA ₃ ↓	P ₁ (No pinching)	P ₂ (2 WAT)	P ₃ (3 WAT)	P ₄ (4 WAT)	P ₁ (No pinching)	P ₂ (2 WAT)	P ₃ (3 WAT)	P ₄ (4 WAT)
G ₀ (control)	24.14	39.16	34.81	26.31	42.50	60.00	53.33	47.30
G ₁ (150 ppm)	31.39	45.97	38.24	32.75	44.42	56.67	55.85	51.25
G ₂ (250 ppm)	42.05	60.14	51.59	50.55	58.75	75.63	72.50	63.75
G ₃ (350 ppm)	37.36	48.76	42.53	37.49	51.25	68.75	65.00	57.50
Season x Pinching (S x P)					Season x GA ₃ (S x G)			
Season→ Pinching ↓	S ₁ (Winter)	S ₂ (Summer)	Mean (P)		Season→ GA ₃ ↓	S ₁ (Winter)	S ₂ (Summer)	Mean (G)
P ₁ (No pinching)	33.74	49.23	41.49		G ₀ (control)	31.11	50.78	40.95
P ₂ (2 WAT)	48.51	64.01	56.26		G ₁ (150 ppm)	37.09	52.05	44.57
P ₃ (3 WAT)	41.79	61.67	51.73		G ₂ (250 ppm)	51.08	66.41	58.75
P ₄ (4 WAT)	36.78	54.95	45.87		G ₃ (350 ppm)	41.54	60.63	51.09
Mean (S)	40.21	57.47			Mean (S)	40.21	57.47	
Pinching x GA ₃ (P x G)						CD at 5% level of significance		
Pinching→ GA ₃ ↓	P ₁ (No pinching)	P ₂ (2 WAT)	P ₃ (3 WAT)	P ₄ (4 WAT)	Mean (G)	Season Pinching Gibberellic acid Season × pinching Season × gibberellic acid Pinching × gibberellic acid Season × pinching × gibberellic acid		1.50
G ₀ (control)	33.32	49.58	44.07	36.81	40.95			2.13
G ₁ (150 ppm)	37.91	51.32	47.05	42.00	44.57			2.13
G ₂ (250 ppm)	50.40	65.39	62.05	57.15	58.75			NS
G ₃ (350 ppm)	44.31	58.76	53.77	47.50	51.09			NS
Mean (P)	41.49	56.26	51.73	45.87				NS
WAT - Weeks After Transplanting								

WAT - Weeks After Transplanting

Table 7: Effect of pinching and gibberellic acid on days to bud initiation of African marigold cv. Local Selection in different seasons

Season × Pinching × Gibberellic acid (S x P x G)								
Season →	S ₁ (Winter)				S ₂ (Summer)			
Pinching→ GA ₃ ↓	P ₁ (No pinching)	P ₂ (2 WAT)	P ₃ (3 WAT)	P ₄ (4 WAT)	P ₁ (No pinching)	P ₂ (2 WAT)	P ₃ (3 WAT)	P ₄ (4 WAT)
G ₀ (control)	40.50	42.77	43.63	46.72	41.04	41.80	42.53	43.07
G ₁ (150 ppm)	40.00	41.47	42.47	44.58	39.97	40.20	41.33	42.47
G ₂ (250 ppm)	37.53	41.12	42.12	43.07	38.73	39.07	40.32	41.60
G ₃ (350 ppm)	36.53	39.82	40.20	42.73	38.08	38.98	39.73	40.57
Season x Pinching (S x P)					Season x GA ₃ (S x G)			
Season→ Pinching ↓	S ₁ (Winter)	S ₂ (Summer)	Mean (P)		Season→ GA ₃ ↓	S ₁ (Winter)	S ₂ (Summer)	Mean (G)
P ₁ (No pinching)	38.64	39.46	39.05		G ₀ (control)	43.41	42.11	42.76
P ₂ (2 WAT)	41.30	40.01	40.66		G ₁ (150 ppm)	42.13	40.99	41.56
P ₃ (3 WAT)	42.11	40.98	41.55		G ₂ (250 ppm)	40.96	39.93	40.45
P ₄ (4 WAT)	44.28	41.93	43.11		G ₃ (350 ppm)	39.82	39.34	39.58
Mean (S)	41.58	40.60			Mean (S)	41.58	40.60	
Pinching x GA ₃ (P x G)						CD at 5% level of significance		
Pinching→ GA ₃ ↓	P ₁ (No pinching)	P ₂ (2 WAT)	P ₃ (3 WAT)	P ₄ (4 WAT)	Mean (G)	Season		0.34
G ₀ (control)	40.77	42.29	43.08	44.88	42.76	Pinching		0.48
G ₁ (150 ppm)	39.98	40.84	41.90	43.52	41.56	Gibberellic acid		0.48
G ₂ (250 ppm)	38.13	40.09	41.22	42.34	40.45	Season × pinching		0.34
G ₃ (350 ppm)	37.31	39.40	40.00	41.65	39.58	Season × gibberellic acid		NS
Mean (P)	39.05	40.66	41.55	43.11		Pinching × gibberellic acid		NS
						Season × pinching × gibberellic acid		NS
WAT - Weeks After Transplanting								

Furthermore, $S \times P \times G$ interaction revealed that the maximum dry weight of plant (75.63 g) was recorded due to spray of 250 ppm GA_3 (G_2) on summer plants pinched at 2 WAT ($S_2P_2G_2$), as the minimum dry weight of plant (24.14 g) was observed with water sprayed in un-pinched plants of winter ($S_1P_1G_0$).

4.2. Flowering parameters

4.2.1. Days to bud initiation

It is evident from the data given in Table 7 that days to bud initiation differed significantly because of season, pinching and gibberellic acid application. Plants grown under summer conditions (S_2) significantly recorded the earliest bud initiation (40.60 days) and late bud initiation (41.58 days) was observed in winter (S_1) irrespective of pinching and gibberellic acid. Plants without pinching (P_1) took the minimum days to bud initiation (39.05), whereas plants pinched at 4 WAT recorded the maximum days to bud initiation (43.11) irrespective of season and gibberellic acid. Application of GA_3 @ 350 ppm over plants exhibited the least days to bud initiation (39.58) and control (G_0) plants recorded the highest days to bud initiation (42.76) irrespective of season and pinching.

A significant effect of $S \times P$ interaction on days to bud initiation was reported, however no significant effect of $S \times G$, $P \times G$ and $S \times P \times G$ interactions on days to bud initiation was noticed (Table 7). Bud initiation was reported earliest (38.64 days) in winter plants under no pinching treatment (S_1P_1) and late bud initiation (44.28 days) was noticed in winter plants under pinching treatment given at 4WAT (S_1P_4). With respect to $S \times G$ interaction, the lowest days to bud initiation (39.34) was recorded in plants of summer season sprayed with 350 ppm GA_3 (S_2G_3), while the highest days to bud initiation (43.41) were observed in control plants of winter season (S_1G_0). Further, it was noted that the un-pinched plants treated with 350 ppm GA_3 took the minimum days (37.31) to bud initiation (P_1G_3), while the maximum days (44.88) to bud initiation was observed in control plants with pinching done at 4 WAT (P_4G_0).

In response to $S \times P \times G$ interaction, un-pinched plants of winter season sprayed with 350 ppm concentration of GA_3 ($S_1P_1G_3$) took the minimum days to bud initiation (36.53) and the maximum days to bud initiation (46.72) was observed in control plants of winter season pinched at 4 WAT ($S_1P_4G_0$).

4.2.2 Days to first flower

It is apparent from the data presented in Table 8 that season, pinching and gibberellic acid had a significant influence on days to 1st flower. Summer planting (S_2) recorded the fewer days to 1st flower (52.30) in contrast to winter planting (S_1) which reported more days to 1st flower (64.71) irrespective of pinching and gibberellic acid. The earliest appearance of first flower (55.82 days) was observed in un-pinched plants (P_1), though plants pinched at 4 WAT showed late appearance of first flower (60.98 days) irrespective of season and gibberellic acid. Spraying of plants with 350 ppm GA_3 (G_3) resulted in less number of days to 1st flower

(55.77), while plants treated with water only (G_0) reported the more number of days to 1st flower (62.00) irrespective of season and pinching.

Days to first flower reduced significantly as affected by the interactions of season and pinching ($S \times P$), season and gibberellic acid ($S \times G$) and pinching and gibberellic acid ($P \times G$) (Table 8). Summer crop under no pinching treatment (S_2P_1) took the minimum days to 1st flower (50.72) at par with S_2P_2 (51.36 days), whereas the maximum days to 1st flower (67.83) were observed in winter crop under pinching treatment applied at 4 WAT (S_1P_4). GA_3 @ 350 ppm in summer (S_2G_3) recorded the lowest values for days to 1st flower (50.46), although the highest values for days to 1st flower (69.86) were observed in control plants of winter (S_1G_0). GA_3 treatment applied at the rate of 350 ppm sprayed on un-pinched plants registered the minimum days to 1st flower (51.85) (P_1G_3), while the maximum days to 1st flower (63.56) was observed in plants pinched at 4 WAT and sprayed with water (P_4G_0) closely followed by P_3G_0 (62.81 days).

Reduction in days to first flower appearance was significantly occurred due to interaction between season, pinching and gibberellic acid ($S \times P \times G$) (Table 8). Summer raised un-pinched plants showed the earliest appearance of first flower (48.53 days) with 350 ppm GA_3 treatment ($S_2P_1G_3$), while control plants pinched at 4 WAT recorded the late appearance of first flower (71.33 days) in winter season ($S_1P_4G_0$) followed by $S_1P_3G_0$ (70.42).

4.2.3. Duration of flowering (days)

The data depicted in Table 9 revealed that duration of flowering was advanced significantly due to individual effect of season, pinching and gibberellic acid. Longer duration of flowering (56.00 days) was recorded in winter (S_1) in contrary to shorter duration of flowering (34.53 days) as observed in summer (S_2) irrespective of pinching and gibberellic acid. The maximum duration of flowering (50.18 days) was recorded in un-pinched plants (P_1), while the minimum duration of flowering (39.76 days) was recorded in plants pinched at 4 WAT (P_4) irrespective of season and gibberellic acid. GA_3 @ 350 ppm spray (G_3) recorded the maximum duration of flowering (50.31 days), while the minimum duration of flowering (39.94 days) was noticed in control (G_0) irrespective of season and pinching.

($S \times P$) and ($S \times G$) interactions showed a significant influence on duration of flowering, whereas pinching and gibberellic acid ($P \times G$) interaction did not show any significant influence on flowering duration (Table 9). Un-pinched plants raised under winter conditions registered the longest duration of flowering (61.68 days) (S_1P_1), while shortest duration of flowering (30.85 days) was observed in plants pinched at 4 WAT (S_2P_4) in summer season. The maximum duration of flowering (62.68 days) was recorded in plants of winter season sprayed with 350 ppm GA_3 (S_1G_3), while minimum duration of flowering (32.23 days) was observed in control plants of summer season (S_2G_0). Un-pinched plants treated with 350 ppm GA_3 recorded the maximum duration of flowering (54.47 days) (P_1G_3), but control plants pinched at 4 WAT recorded the minimum duration of flowering (33.43 days) (P_4G_0).

Table 8: Effect of pinching and gibberellic acid on days to first flower of African marigold cv. Local Selection in different seasons

Season × Pinching × Gibberellic acid (S x P x G)								
Season →	S ₁ (Winter)				S ₂ (Summer)			
Pinching→ GA ₃ ↓	P ₁ (No pinching)	P ₂ (2 WAT)	P ₃ (3 WAT)	P ₄ (4 WAT)	P ₁ (No pinching)	P ₂ (2 WAT)	P ₃ (3 WAT)	P ₄ (4 WAT)
G ₀ (control)	68.17	69.50	70.42	71.33	52.66	52.87	55.20	55.78
G ₁ (150 ppm)	62.23	65.73	66.86	67.67	51.07	51.67	54.30	54.95
G ₂ (250 ppm)	58.13	61.53	62.78	66.58	50.60	50.64	51.56	53.57
G ₃ (350 ppm)	55.17	60.73	62.68	65.75	48.53	50.27	50.87	52.17
Season x Pinching (S x P)					Season x GA ₃ (S x G)			
Season→ Pinching ↓	S ₁ (Winter)	S ₂ (Summer)	Mean (P)		Season→ GA ₃ ↓	S ₁ (Winter)	S ₂ (Summer)	Mean (G)
P ₁ (No pinching)	60.93	50.72	55.82		G ₀ (control)	69.86	54.13	62.00
P ₂ (2 WAT)	64.37	51.36	57.87		G ₁ (150 ppm)	65.62	53.00	59.31
P ₃ (3 WAT)	65.69	52.98	59.34		G ₂ (250 ppm)	62.26	51.59	56.93
P ₄ (4 WAT)	67.83	54.12	60.98		G ₃ (350 ppm)	61.08	50.46	55.77
Mean (S)	64.71	52.30			Mean (S)	64.71	52.30	
Pinching x GA ₃ (P x G)						CD at 5% level of significance		
Pinching→ GA ₃ ↓	P ₁ (No pinching)	P ₂ (2 WAT)	P ₃ (3 WAT)	P ₄ (4 WAT)	Mean (G)	Season Pinching Gibberellic acid Season × pinching Season × gibberellic acid Pinching × gibberellic acid Season × pinching × gibberellic acid		0.34
G ₀ (control)	60.42	61.19	62.81	63.56	62.00			0.48
G ₁ (150 ppm)	56.65	58.70	60.58	61.31	59.31			0.48
G ₂ (250 ppm)	54.37	56.09	57.17	60.08	56.93			0.69
G ₃ (350 ppm)	51.85	55.50	56.78	58.96	55.77			0.69
								0.97
								1.37
Mean (P)	55.82	57.87	59.34	60.98				
WAT - Weeks After Transplanting								

Table 9: Effect of pinching and gibberellic acid on duration of flowering (days) in African marigold cv. Local Selection in different seasons

Season × Pinching × Gibberellic acid (S x P x G)								
Season →	S ₁ (Winter)				S ₂ (Summer)			
Pinching→ GA ₃ ↓	P ₁ (No pinching)	P ₂ (2 WAT)	P ₃ (3 WAT)	P ₄ (4 WAT)	P ₁ (No pinching)	P ₂ (2 WAT)	P ₃ (3 WAT)	P ₄ (4 WAT)
G ₀ (control)	53.83	49.43	47.21	40.11	36.50	33.67	32.00	26.74
G ₁ (150 ppm)	59.38	57.32	53.25	47.13	38.35	36.64	33.83	30.00
G ₂ (250 ppm)	65.26	62.42	58.17	51.69	39.17	38.16	35.05	32.33
G ₃ (350 ppm)	68.25	65.92	60.82	55.74	40.68	40.30	36.43	34.33
Season x Pinching (S x P)					Season x GA ₃ (S x G)			
Season→ Pinching ↓	S ₁ (Winter)	S ₂ (Summer)	Mean (P)		Season→ GA ₃ ↓	S ₁ (Winter)	S ₂ (Summer)	Mean (G)
P ₁ (No pinching)	61.68	38.68	50.18		G ₀ (control)	47.65	32.23	39.94
P ₂ (2 WAT)	58.77	37.19	47.98		G ₁ (150 ppm)	54.27	34.71	44.49
P ₃ (3 WAT)	54.86	34.33	44.60		G ₂ (250 ppm)	59.39	36.18	47.78
P ₄ (4 WAT)	48.67	30.85	39.76		G ₃ (350 ppm)	62.68	37.94	50.31
Mean (S)	56.00	34.53			Mean (S)	56.00	34.53	
Pinching x GA ₃ (P x G)					CD at 5% level of significance			
Pinching→ GA ₃ ↓	P ₁ (No pinching)	P ₂ (2 WAT)	P ₃ (3 WAT)	P ₄ (4 WAT)	Mean (G)	Season Pinching Gibberellic acid		1.08 1.53 1.53
G ₀ (control)	45.17	41.55	39.61	33.43	39.94	Season × pinching		2.17
G ₁ (150 ppm)	48.87	46.98	43.54	38.57	44.49	Season × gibberellic acid		2.17
G ₂ (250 ppm)	52.22	50.29	46.61	42.01	47.78	Pinching × gibberellic acid		NS
G ₃ (350 ppm)	54.47	53.11	48.63	45.04	50.31	Season × pinching × gibberellic acid		NS
Mean (P)	50.18	47.98	44.60	39.76				
WAT - Weeks After Transplanting								

WAT - Weeks After Transplanting

Season, pinching and gibberellic acid interaction ($S \times P \times G$) could not bring any significant change in the duration of flowering (Table 9). However, the maximum duration of flowering (68.25 days) was recorded with the highest dose of GA_3 (350 ppm) applied in un-pinched plants during winter season ($S_1P_1G_3$), while the minimum duration of flowering (26.74) was observed in control plants with pinching done at 4 WAT during summer season ($S_2P_4G_0$).

4.2.4. Number of buds per plant

An appraisal of the data presented in Table 10 reveal that significant differences in number of buds per plant existed due to individual influence of season, pinching and gibberellic acid. Summer crop (S_2) produced more number of buds per plant (91.76), while less number of buds per plant (70.12) was observed in winter crop (S_1) irrespective of pinching and gibberellic acid. Pinching operation performed at 2 WAT (P_2) recorded the maximum number of buds per plant (89.83), though the minimum number of buds per plant (71.71) was recorded with no pinching (P_1) irrespective of season and gibberellic acid. A gradual increase in number of buds per plant was observed with increasing concentration of GA_3 up to 250 ppm, thereafter it decreased slightly (Table 10). The highest value of number of buds per plant (93.51) was recorded with G_2 treatment (250 ppm GA_3) which was found at par with G_3 treatment (250 ppm GA_3); (88.65), while the lowest value of number of buds per plant (63.86) was recorded in control (G_0) irrespective of season and pinching.

All interactions among season, pinching and gibberellic acid viz., $S \times P$, $S \times G$, $P \times G$ and $S \times P \times G$ were recorded non-significant in enhancing the number of buds per plant as presented in Table 10. However, the maximum number of buds per plant (102.48) was recorded in plants pinched at 2 WAT in summer season (S_2P_2), though minimum number of buds per plant (64.15) was observed in un-pinched plants of winter season (S_1P_1). Foliar application of 250 ppm GA_3 on plants of summer season (S_2G_2) produced the maximum number of buds per plant (105.52), whereas minimum number of buds per plant (53.69) was observed in control plants of winter season (S_1G_0). In similar way, maximum number of buds per plant (102.35) was recorded in 2 WAT pinched plants sprayed with 250 ppm dose of GA_3 (P_2G_2), while minimum number of buds per plant (54.70) was observed in un-pinched plants with foliar spray of water (P_1G_0).

In case of $S \times P \times G$, the maximum number of buds per plant (116.81) was recorded with GA_3 250 ppm applied over plants pinched at 2 WAT of summer season ($S_2P_2G_2$) and minimum number of buds per plant (48.20) was observed in un-pinched plants without any GA_3 spray during winter season ($S_1P_1G_0$).

4.2.5. Number of flowers per plant

Number of flowers per plant was significantly influenced by different levels of season, pinching and gibberellic acid as shown by data presented in Table 11. The crop planted in

summer produced more number of flowers per plant (43.25) (S_2), whereas, less number of flowers per plant (37.82) was observed in winter crop (S_1) irrespective of pinching and gibberellic acid. The highest number of flowers per plant (44.91) was recorded in plants pinched at 2 WAT (P_2), while the lowest number of flowers per plant (35.94) was recorded in un-pinched plants (P_1) irrespective of season and gibberellic acid. Gibberellic acid applied at the rate of 250 ppm (G_2) recorded maximum number of flowers per plant (46.29), although minimum number of flowers per plant (33.05) was recorded in plants without any gibberellic acid spray (G_0) irrespective of season and pinching.

All interactions amidst season, pinching and gibberellic acid like, $S \times P$, $S \times G$, $P \times G$ and $S \times P \times G$ were found significant in influencing the number of flowers per plant as revealed by the data shown in Table 11. More number of flowers per plant (47.70) was obtained by summer plants pinched at 2 WAT (S_2P_2); however less number of flowers per plant (33.86) was reported in un-pinched plants of winter (S_1P_1). Plants raised under summer and sprayed with 250 ppm GA_3 recorded the maximum number of flowers per plant (48.29) (S_2G_2), while minimum number of flowers per plant (28.51) was observed in control plants of winter season (S_1G_0). The maximum number of flowers per plant (51.71) was recorded when plants pinched at 2 WAT and sprayed with GA_3 250 ppm (P_2G_2), though minimum number of flowers per plant (28.89) was observed in un-pinched plants with foliar spray of water (P_1G_0).

With respect to $S \times P \times G$ interaction, GA_3 @ 250 ppm as foliar spray recorded the maximum number of flowers per plant (53.18) in plants pinched at 2 WAT during summer season ($S_2P_2G_2$), while minimum number of flowers per plant (24.69) was observed with water sprayed on un-pinched plants during winter season ($S_1P_1G_0$).

4.2.6. Flower stalk length (cm)

The perusal of data presented in Table 12 showed that pinching and gibberellic acid had significantly advanced the flower stalk length, while season did not have any significant effect on stalk length. However, the longest flower stalk length (9.55 cm) was recorded in summer season (S_2) as compared to shortest flower stalk length (9.44 cm) obtained in winter season (S_1) irrespective of pinching and gibberellic acid. Among different pinching treatments, the maximum flower stalk length (10.38 cm) was recorded in plants pinched at 2 WAT (P_2), whereas, minimum flower stalk length (8.62 cm) was recorded in un-pinched plants (P_1) irrespective of season and gibberellic acid. A significant increase in flower stalk length was noticed as the level of GA_3 rises from 0 to 350 ppm. The maximum flower stalk length (11.13 cm) was recorded with G_3 (350 ppm GA_3), while minimum flower stalk length (7.90 cm) was recorded in control (G_0) irrespective of season and pinching.

The interaction of $S \times P$, $S \times G$ and $P \times G$ had showed a significant effect on flower stalk length (Table 12). In winter, the longest flower stalk length (10.67 cm) was recorded in plants pinched at 2 WAT (S_1P_2), while shortest flower stalk length (8.20 cm) was observed in un-pinched plants (S_1P_1).

Table 10: Effect of pinching and gibberellic acid on number of buds per plant of African marigold cv. Local Selection in different seasons

Season × Pinching × Gibberellic acid (S x P x G)								
Season →	S ₁ (Winter)				S ₂ (Summer)			
Pinching→ GA ₃ ↓	P ₁ (No pinching)	P ₂ (2 WAT)	P ₃ (3 WAT)	P ₄ (4 WAT)	P ₁ (No pinching)	P ₂ (2 WAT)	P ₃ (3 WAT)	P ₄ (4 WAT)
G ₀ (control)	48.20	61.31	54.12	51.13	61.20	83.90	77.47	73.54
G ₁ (150 ppm)	60.25	75.88	70.75	63.83	74.52	98.88	93.00	84.86
G ₂ (250 ppm)	75.61	87.88	82.50	79.95	92.58	116.81	110.09	102.61
G ₃ (350 ppm)	75.52	83.61	79.03	75.29	88.75	110.32	102.38	97.25
Season x Pinching (S x P)					Season x GA ₃ (S x G)			
Season→ Pinching ↓	S ₁ (Winter)	S ₂ (Summer)	Mean (P)		Season→ GA ₃ ↓	S ₁ (Winter)	S ₂ (Summer)	Mean (G)
P ₁ (No pinching)	64.15	79.26	71.71		G ₀ (control)	53.69	74.03	63.86
P ₂ (2 WAT)	77.17	102.48	89.83		G ₁ (150 ppm)	67.68	87.82	77.75
P ₃ (3 WAT)	71.60	95.74	83.67		G ₂ (250 ppm)	81.49	105.52	93.51
P ₄ (4 WAT)	67.55	89.57	78.56		G ₃ (350 ppm)	77.61	99.68	88.65
Mean (S)	70.12	91.76			Mean (S)	70.12	91.76	
Pinching x GA ₃ (P x G)						CD at 5% level of significance		
Pinching→ GA ₃ ↓	P ₁ (No pinching)	P ₂ (2 WAT)	P ₃ (3 WAT)	P ₄ (4 WAT)	Mean (G)	Season		4.12
G ₀ (control)	54.70	72.61	65.80	62.34	63.86	Pinching		5.83
G ₁ (150 ppm)	67.38	87.38	81.88	74.34	77.75	Gibberellic acid		5.83
G ₂ (250 ppm)	84.09	102.35	96.30	91.28	93.51	Season × pinching		NS
G ₃ (350 ppm)	80.64	96.96	90.71	86.27	88.65	Season × gibberellic acid		NS
Mean (P)	71.71	89.83	83.67	78.56		Pinching × gibberellic acid		NS
						Season × pinching × gibberellic acid		NS
WAT - Weeks After Transplanting								

Table 11: Effect of pinching and gibberellic acid on number of flowers per plant of African marigold cv. Local Selection in different seasons

Season × Pinching × Gibberellic acid (S x P x G)								
Season →	S ₁ (Winter)				S ₂ (Summer)			
Pinching→ GA ₃ ↓	P ₁ (No pinching)	P ₂ (2 WAT)	P ₃ (3 WAT)	P ₄ (4 WAT)	P ₁ (No pinching)	P ₂ (2 WAT)	P ₃ (3 WAT)	P ₄ (4 WAT)
G ₀ (control)	24.69	32.89	29.59	26.88	33.09	40.93	39.69	36.59
G ₁ (150 ppm)	33.00	40.37	38.63	35.52	37.08	45.93	43.47	40.34
G ₂ (250 ppm)	40.36	50.25	44.34	42.21	41.94	53.18	51.24	46.81
G ₃ (350 ppm)	37.39	45.00	42.45	41.59	39.93	50.76	47.44	43.55
Season x Pinching (S x P)					Season x GA ₃ (S x G)			
Season→ Pinching ↓	S ₁ (Winter)	S ₂ (Summer)	Mean (P)		Season→ GA ₃ ↓	S ₁ (Winter)	S ₂ (Summer)	Mean (G)
P ₁ (No pinching)	33.86	38.01	35.94		G ₀ (control)	28.51	37.58	33.05
P ₂ (2 WAT)	42.13	47.70	44.91		G ₁ (150 ppm)	36.88	41.71	39.29
P ₃ (3 WAT)	38.75	45.46	42.11		G ₂ (250 ppm)	44.29	48.29	46.29
P ₄ (4 WAT)	36.55	41.82	39.19		G ₃ (350 ppm)	41.61	45.42	43.52
Mean (S)	37.82	43.36			Mean (S)	37.82	43.36	
Pinching x GA ₃ (P x G)						CD at 5% level of significance		
Pinching→ GA ₃ ↓	P ₁ (No pinching)	P ₂ (2 WAT)	P ₃ (3 WAT)	P ₄ (4 WAT)	Mean (G)	Season Pinching Gibberellic acid Season × pinching Season × gibberellic acid Pinching × gibberellic acid Season × pinching × gibberellic acid		0.35
G ₀ (control)	28.89	36.91	34.64	31.74	33.05			0.50
G ₁ (150 ppm)	35.04	43.15	41.05	37.93	39.29			0.50
G ₂ (250 ppm)	41.15	51.71	47.79	44.51	46.29			0.70
G ₃ (350 ppm)	38.71	47.88	44.95	42.57	43.52			0.70
								1.00
								1.41
Mean (P)	35.94	44.91	42.11	39.55				
WAT - Weeks After Transplanting								

Table 12: Effect of pinching and gibberellic acid on flower stalk length (cm) of African marigold cv. Local Selection in different seasons

Season × Pinching × Gibberellic acid (S x P x G)								
Season →	S ₁ (Winter)				S ₂ (Summer)			
Pinching→ GA ₃ ↓	P ₁ (No pinching)	P ₂ (2 WAT)	P ₃ (3 WAT)	P ₄ (4 WAT)	P ₁ (No pinching)	P ₂ (2 WAT)	P ₃ (3 WAT)	P ₄ (4 WAT)
G ₀ (control)	6.64	8.18	8.02	7.57	7.84	8.61	8.42	7.92
G ₁ (150 ppm)	7.54	8.61	8.50	8.27	8.39	9.55	9.42	8.71
G ₂ (250 ppm)	8.93	12.36	10.48	9.76	9.88	10.84	10.16	10.06
G ₃ (350 ppm)	9.68	13.53	11.75	11.15	10.06	11.32	10.83	10.69
Season x Pinching (S x P)					Season x GA ₃ (S x G)			
Season→ Pinching ↓	S ₁ (Winter)	S ₂ (Summer)	Mean (P)		Season→ GA ₃ ↓	S ₁ (Winter)	S ₂ (Summer)	Mean (G)
P ₁ (No pinching)	8.20	9.04	8.62		G ₀ (control)	7.60	8.20	7.90
P ₂ (2 WAT)	10.67	10.08	10.38		G ₁ (150 ppm)	8.23	9.02	8.62
P ₃ (3 WAT)	9.69	9.71	9.70		G ₂ (250 ppm)	10.38	10.24	10.31
P ₄ (4 WAT)	9.19	9.35	9.27		G ₃ (350 ppm)	11.53	10.73	11.13
Mean (S)	9.44	9.55			Mean (S)	9.44	9.55	
Pinching x GA ₃ (P x G)						CD at 5% level of significance		
Pinching→ GA ₃ ↓	P ₁ (No pinching)	P ₂ (2 WAT)	P ₃ (3 WAT)	P ₄ (4 WAT)	Mean (G)	Season Pinching Gibberellic acid		NS 0.21 0.21
G ₀ (control)	7.24	8.39	8.22	7.75	7.90	Season × pinching		0.30
G ₁ (150 ppm)	7.96	9.08	8.96	8.49	8.62	Season × gibberellic acid		0.30
G ₂ (250 ppm)	9.41	11.60	10.32	9.91	10.31	Pinching × gibberellic acid		0.42
G ₃ (350 ppm)	9.87	12.42	11.29	10.92	11.13	Season × pinching × gibberellic acid		0.59
Mean (P)	8.62	10.38	9.70	9.27				
WAT - Weeks After Transplanting								

WAT - Weeks After Transplanting

Table 13: Effect of pinching and gibberellic acid on flower diameter (cm) of African marigold cv. Local Selection in different seasons

Season × Pinching × Gibberellic acid (S x P x G)								
Season →	S ₁ (Winter)				S ₂ (Summer)			
Pinching→ GA ₃ ↓	P ₁ (No pinching)	P ₂ (2 WAT)	P ₃ (3 WAT)	P ₄ (4 WAT)	P ₁ (No pinching)	P ₂ (2 WAT)	P ₃ (3 WAT)	P ₄ (4 WAT)
G ₀ (control)	5.28	4.90	5.02	5.08	5.25	5.03	5.12	5.17
G ₁ (150 ppm)	5.58	5.21	5.29	5.39	5.48	5.24	5.34	5.42
G ₂ (250 ppm)	5.81	5.34	5.49	5.68	5.66	5.44	5.52	5.60
G ₃ (350 ppm)	6.13	5.51	5.61	5.78	5.80	5.52	5.60	5.69
Season x Pinching (S x P)					Season x GA ₃ (S x G)			
Season→ Pinching ↓	S ₁ (Winter)	S ₂ (Summer)	Mean (P)		Season→ GA ₃ ↓	S ₁ (Winter)	S ₂ (Summer)	Mean (G)
P ₁ (No pinching)	5.70	5.55	5.62		G ₀ (control)	5.07	5.14	5.11
P ₂ (2 WAT)	5.24	5.31	5.27		G ₁ (150 ppm)	5.37	5.37	5.37
P ₃ (3 WAT)	5.35	5.40	5.37		G ₂ (250 ppm)	5.58	5.56	5.57
P ₄ (4 WAT)	5.48	5.47	5.48		G ₃ (350 ppm)	5.76	5.65	5.71
Mean (S)	5.44	5.43			Mean (S)	5.44	5.43	
Pinching x GA ₃ (P x G)						CD at 5% level of significance		
Pinching→ GA ₃ ↓	P ₁ (No pinching)	P ₂ (2 WAT)	P ₃ (3 WAT)	P ₄ (4 WAT)	Mean (G)	Season Pinching Gibberellic acid Season × pinching Season × gibberellic acid Pinching × gibberellic acid Season × pinching × gibberellic acid		0.02
G ₀ (control)	5.27	4.97	5.07	5.13	5.11			0.02
G ₁ (150 ppm)	5.53	5.23	5.32	5.41	5.37			0.02
G ₂ (250 ppm)	5.74	5.39	5.51	5.64	5.57			0.03
G ₃ (350 ppm)	5.97	5.52	5.61	5.74	5.71			0.03
Mean (P)	5.62	5.27	5.37	5.48				NS
								NS
WAT - Weeks After Transplanting								

WAT - Weeks After Transplanting

Winter crop sprayed with GA₃ 350 ppm (S₁G₃) recorded the maximum flower stalk length (11.53 cm), while minimum flower stalk length (7.60 cm) was observed in control plants (S₁G₀). Similarly, application of GA₃ 350 ppm on plants pinched at 2 WAT (P₂G₃) resulted in the maximum flower stalk length (12.42 cm), though minimum flower stalk length (7.24 cm) was observed in un-pinched plants sprayed with water (P₁G₀).

The effect of interaction among season, pinching and gibberellic acid was found significant in influencing the flower stalk length (Table 12). The maximum flower stalk length (13.53 cm) was recorded with GA₃ @ 350 ppm applied in winter plants pinched at 2 WAT of season (S₁P₂G₃), while minimum flower stalk length (6.64 cm) was observed with control in un-pinched plants of winter season (S₁P₁G₀).

4.2.7. Flower diameter (cm)

Flower diameter recorded a significant influence of season, pinching and gibberellic acid as revealed by data given in Table 13. Larger flower diameter (5.44 cm) was obtained by winter plants (S₁) closely followed by summer plants (S₂) (5.43 cm) irrespective of pinching and gibberellic acid. Flower diameter declined significantly with various levels of pinching over control. The maximum flower diameter (5.62 cm) was recorded in un-pinched plants (P₁), while minimum flower diameter (5.27 cm) was recorded in plants pinched at 2WAT (P₂) irrespective of season and gibberellic acid. Diameter of flower increased significantly with every rise in level of gibberellic acid. The maximum flower diameter (5.71 cm) was recorded with G₃ (350 ppm GA₃), though minimum flower diameter (5.11cm) was recorded in control (G₀) irrespective of season and pinching.

All interactions except P×G and S×P×G were found significant in influencing the flower diameter as presented in Table 13. The maximum flower diameter (5.70 cm) was recorded in un-pinched plants of winter season (S₁P₁), while minimum flower diameter (5.31 cm) was observed in plants pinched at 2 WAT of summer season (S₂P₂). Plants grown in winter season attained the maximum flower diameter (5.76 cm) when sprayed with 350 ppm GA₃ (S₁G₃), however minimum flower diameter (5.07 cm) was observed in control plants grown in winter (S₁G₀). In relation to P×G interaction, the maximum flower diameter (5.97 cm) was recorded in un-pinched plants sprayed with 350 ppm dose of GA₃ (P₁G₃) and minimum flower diameter (4.97 cm) was observed with water in plants pinched at 2 WAT (P₂G₀). With respect to overall interaction i.e., S×P×G the maximum flower diameter (6.13 cm) was recorded with 350 ppm spray of GA₃ in un-pinched plants of winter season (S₁P₁G₃) and minimum flower diameter (5.03 cm) was noted when control plants pinched at 2 WAT in summer season (S₂P₂G₀).

4.3. Yield parameters

4.3.1. Fresh weight of flower (g)

The data represented in Table 14 reported that a significant effect of season, pinching and gibberellic acid was observed on fresh weight of flower. Winter planting (S_1) recorded more fresh weight of flower (4.57 g), though lower fresh weight of flower (3.15 g) was measured from summer planting (S_1) irrespective of pinching and gibberellic acid. Fresh weight of flower reduced significantly with all pinching treatments as compared to no pinching treatment. The maximum fresh weight of flower (4.06 g) was recorded in un-pinched plants (P_1), while minimum fresh weight of flower (3.69 g) was recorded in pinched plants at 2 WAT (P_2) irrespective of season and gibberellic acid. Fresh weight of flower increased significantly with gradual increase in level of gibberellic acid. The maximum fresh weight of flower (4.13 g) was recorded with G_3 (350 ppm GA_3), whereas, minimum fresh weight of flower (3.45 g) was recorded in control (G_0) irrespective of season and pinching.

All interactions were found significant with respect to fresh weight of flower as presented in Table 14. The maximum fresh weight of flower (4.83 g) was recorded in un-pinched plants of winter season (S_1P_1) and minimum fresh weight of flower (3.02 g) was observed in plants pinched at 2 WAT of summer season (S_2P_2). Further, it was found that the maximum fresh weight of flower (4.91 g) was recorded in plants of winter season sprayed with 350 ppm GA_3 (S_1G_3), while minimum fresh weight of flower (2.87 g) was observed in control plants of summer season (S_2G_0). In case of $P \times G$ interaction, the maximum fresh weight of flower (4.32 g) was recorded in un-pinched plants sprayed with GA_3 350 ppm (P_1G_3), although minimum fresh weight of flower (3.21 g) was observed in plants pinched at 2 WAT sprayed with water (P_2G_0).

Overall interaction between season, pinching and gibberellic acid exerted a significant effect on fresh weight of flower as revealed by data presented in Table 14. The maximum fresh weight of flower (5.14 g) was recorded with GA_3 applied at the rate of 350 ppm in un-pinched plants of winter season ($S_1P_1G_3$) at par with $S_1P_1G_2$ (5.03 g), though minimum fresh weight of flower (2.73 g) was observed in plants pinched at 2 WAT without any GA_3 spray in summer season ($S_2P_2G_0$) followed by $S_2P_3G_0$ (2.80 g).

4.3.2. Dry weight of flower (g)

Statistical analysis of the data presented in Table 15 showed that season, pinching and gibberellic acid had a significant effect on dry weight of flower. Higher values of dry weight of flower (0.52 g) were recorded under winter conditions (S_1) and comparatively, the lower values of dry weight of flower (0.35 g) were observed under summer conditions (S_1) irrespective of pinching and gibberellic acid. Various pinching treatments recorded significant reduction in dry weight of flower over no pinching treatment.

Table 14: Effect of season, pinching and gibberellic acid on fresh weight of flower (g) in African marigold cv. Local Selection

Season × Pinching × Gibberellic acid (S x P x G)								
Season →	S ₁				S ₂			
Pinching→ GA ₃ ↓	P ₁ (No pinching)	P ₂ (2 WAT)	P ₃ (3 WAT)	P ₄ (4 WAT)	P ₁ (No pinching)	P ₂ (2 WAT)	P ₃ (3 WAT)	P ₄ (4 WAT)
G ₀ (control)	4.37	3.68	3.91	4.11	3.01	2.73	2.80	2.92
G ₁ (150 ppm)	4.78	4.45	4.51	4.65	3.23	2.94	3.03	3.17
G ₂ (250 ppm)	5.03	4.57	4.66	4.75	3.41	3.19	3.28	3.32
G ₃ (350 ppm)	5.14	4.73	4.83	4.94	3.50	3.22	3.32	3.36
Season x Pinching (S x P)					Season x GA ₃ (S x G)			
Season→ Pinching ↓	S ₁ (Winter)	S ₂ (Summer)	Mean (P)		Season→ GA ₃ ↓	S ₁ (Winter)	S ₂ (Summer)	Mean (G)
P ₁ (No pinching)	4.83	3.29	4.06		G ₀ (control)	4.02	2.87	3.45
P ₂ (2 WAT)	4.36	3.02	3.69		G ₁ (150 ppm)	4.60	3.09	3.85
P ₃ (3 WAT)	4.48	3.11	3.80		G ₂ (250 ppm)	4.75	3.30	4.03
P ₄ (4 WAT)	4.61	3.19	3.90		G ₃ (350 ppm)	4.91	3.35	4.13
Mean (S)	4.57	3.15			Mean (S)	4.57	3.15	
Pinching x GA ₃ (P x G)						CD at 5% level of significance		
Pinching→ GA ₃ ↓	P ₁ (No pinching)	P ₂ (2 WAT)	P ₃ (3 WAT)	P ₄ (4 WAT)	Mean (G)	Season		0.03
G ₀ (control)	3.69	3.21	3.36	3.52	3.45	Pinching		0.05
G ₁ (150 ppm)	4.01	3.70	3.77	3.91	3.85	Gibberellic acid		0.05
G ₂ (250 ppm)	4.22	3.88	3.97	4.04	4.03	Season × pinching		0.07
G ₃ (350 ppm)	4.32	3.98	4.08	4.15	4.13	Season × gibberellic acid		0.07
Mean (P)	4.06	3.69	3.80	3.90		Pinching × gibberellic acid		0.10
						Season × pinching × gibberellic acid		0.14
WAT - Weeks After Transplanting								

Table 15: Effect of pinching and gibberellic acid on dry weight of flower (g) of African marigold cv. Local Selection in different seasons

Season × Pinching × Gibberellic acid (S x P x G)								
Season→	S ₁				S ₂			
Pinching→ GA ₃ ↓	P ₁ (No pinching)	P ₂ (2 WAT)	P ₃ (3 WAT)	P ₄ (4 WAT)	P ₁ (No pinching)	P ₂ (2 WAT)	P ₃ (3 WAT)	P ₄ (4 WAT)
G ₀ (control)	0.50	0.45	0.47	0.48	0.31	0.27	0.29	0.30
G ₁ (150 ppm)	0.55	0.49	0.50	0.51	0.36	0.32	0.34	0.35
G ₂ (250 ppm)	0.58	0.50	0.51	0.53	0.38	0.34	0.35	0.37
G ₃ (350 ppm)	0.62	0.52	0.54	0.55	0.42	0.37	0.37	0.39
Season x Pinching (S x P)					Season x GA ₃ (S x G)			
Season→ Pinching ↓	S ₁ (Winter)	S ₂ (Summer)	Mean (P)		Season→ GA ₃ ↓	S ₁ (Winter)	S ₂ (Summer)	Mean (G)
P ₁ (No pinching)	0.56	0.37	0.47		G ₀ (control)	0.47	0.29	0.38
P ₂ (2 WAT)	0.49	0.33	0.41		G ₁ (150 ppm)	0.51	0.34	0.43
P ₃ (3 WAT)	0.51	0.34	0.42		G ₂ (250 ppm)	0.53	0.36	0.45
P ₄ (4 WAT)	0.52	0.35	0.44		G ₃ (350 ppm)	0.56	0.39	0.47
Mean (S)	0.52	0.35			Mean (S)	0.52	0.35	
Pinching x GA ₃ (P x G)						CD at 5% level of significance		
Pinching→ GA ₃ ↓	P ₁ (No pinching)	P ₂ (2 WAT)	P ₃ (3 WAT)	P ₄ (4 WAT)	Mean (G)	Season Pinching Gibberellic acid Season × pinching Season × gibberellic acid Pinching × gibberellic acid Season × pinching × gibberellic acid		0.01
G ₀ (control)	0.41	0.36	0.38	0.39	0.38			0.01
G ₁ (150 ppm)	0.46	0.41	0.42	0.43	0.43			0.01
G ₂ (250 ppm)	0.48	0.42	0.43	0.45	0.45			NS
G ₃ (350 ppm)	0.52	0.45	0.46	0.47	0.47			NS
Mean (P)	0.47	0.41	0.42	0.44				NS
								NS
WAT - Weeks After Transplanting								

The maximum dry weight of flower (0.47 g) was recorded in un-pinched plants (P_1) and minimum dry weight of flower (0.41 g) was recorded in pinched plants at 2 WAT (P_2) irrespective of season and gibberellic acid. A linear increase in dry weight of flower was reported by increasing gibberellic acid concentration. The maximum dry weight of flower (0.47 g) was recorded with G_3 treatment (350 ppm GA_3), whereas, minimum dry weight of flower (0.38 g) was recorded in control (G_0) irrespective of season and pinching.

All interactions were found non-significant in influencing the dry weight of flower as presented in Table 15. However, the maximum dry weight of flower (0.56 g) was recorded in un-pinched plants of winter season (S_1P_1) and minimum dry weight of flower (0.33 g) was observed in plants pinched at 2 WAT of summer season (S_2P_2). Plants planted under winter conditions acquired the maximum dry weight of flower (0.56 g) when they were sprayed with 350 ppm GA_3 (S_1G_3), though minimum dry weight of flower (0.29 g) was observed in control plants planted under summer conditions (S_2G_0). Un-pinched plants sprayed with GA_3 350 ppm produced the maximum dry weight of flower (0.52 g) (P_1G_3), whereas, minimum dry weight of flower (0.36 g) was produced by plants pinched at 2 WAT and sprayed with water (P_2G_0).

Dry weight of flower did not show any significant increase with respect to the interaction between season, pinching and gibberellic acid (Table 15). However, the maximum dry weight of flower (0.62 g) was recorded with GA_3 350 ppm spray in un-pinched plants during winter season ($S_1P_1G_3$) and minimum dry weight of flower (0.27 g) was observed in control plants pinched at 2 WAT during summer season ($S_2P_2G_0$).

4.3.3. Flower yield per plant (g)

The data presented in Table 16 showed that season, pinching and gibberellic acid had played a significant role in influencing flower yield per plant. Winter season (S_1) recorded more flower yield per plant (174.28 g) in contrary to summer season (S_2) which reported less flower yield per plant (136.59 g), comparatively irrespective of pinching and gibberellic acid. The maximum flower yield per plant (165.27 g) was recorded in plants pinched at 2 WAT (P_2), while minimum flower yield per plant (145.46 g) was recorded in un-pinched plants (P_1) irrespective of season and gibberellic acid. Flower yield per plant was increased significantly with increasing levels of gibberellic acid up to G_2 (250 ppm GA_3), after that a small but significant decrease in flower yield per plant was reported. The maximum flower yield per plant (184.42 g) was recorded with G_2 (250 ppm GA_3) and minimum flower yield per plant (110.50 g) was recorded in control (G_0) irrespective of season and pinching.

All interactions except $S \times P$ were found non-significant in influencing the flower yield per plant as shown in Table 16. The maximum flower yield per plant (185.74 g) was recorded in plants pinched at 2 WAT of winter season (S_1P_2) followed by S_1P_3 (175.49 g) and S_1P_4 (170.52 g), which were also at par with each other.

However, the minimum flower yield per plant (125.56 g) was observed in un-pinched plants of summer season (S_2P_1) followed by S_2P_4 (134.12 g) and S_2P_3 (141.87 g), which were also found at par with each other. The maximum flower yield per plant (209.90 g) was recorded in plants of winter season sprayed with 250 ppm GA_3 (S_1G_2), while minimum flower yield per plant (107.16 g) was observed in control plants of summer season (S_2G_0). Plants pinched at 2 WAT sprayed with GA_3 250 ppm (P_2G_2) reported the maximum flower yield per plant (199.57 g) and minimum flower yield per plant (103.61 g) was observed in un-pinched plants sprayed with water (P_1G_0).

The data shown in Table 16 further revealed that season, pinching and gibberellic acid interactions did not exert any significant effect on flower yield per plant. However, the maximum flower yield per plant (229.47 g) was recorded with GA_3 250 ppm spray in plants pinched at 2 WAT of winter season ($S_1P_2G_2$), while un-pinched summer plants without any GA_3 spray ($S_2P_1G_0$) obtained the minimum flower yield per plant (99.43 g).

4.3.4. Flower yield per plot (kg)

The data depicted in Table 17 indicated that season, pinching and gibberellic acid had played a significant role in influencing flower yield per plot. Higher flower yield per plot (3.49 kg) was recorded in winter season (S_1), while lower flower yield per plot (2.73 kg) was observed in summer season (S_2) irrespective of pinching and gibberellic acid. The maximum flower yield per plot (3.31 kg) was recorded in plants pinched at 2 WAT (P_2) followed by P_3 (3.18 kg), which in turn recorded at par with P_4 (3.05 kg), while minimum flower yield per plot (2.91 kg) was recorded in un-pinched plants (P_1) followed by P_4 (3.05 kg) irrespective of season and gibberellic acid. Flower yield per plot was increased significantly up to G_2 level, but thereafter a small decrease in it was observed. The maximum flower yield per plot (3.69 kg) was recorded with G_2 (250 ppm GA_3) at par with G_3 (350 ppm GA_3), while minimum flower yield per plot (2.21 kg) was recorded in control (G_0) irrespective of season and pinching.

Among all interactions, Only $S \times P$ interaction was found significant in affecting the flower yield per plot (Table 17). The maximum flower yield per plot (3.71 kg) was recorded in plants pinched at 2 WAT in winter season (S_1P_2) followed by S_1P_3 (3.51 kg) and S_1P_4 (3.41 kg), while minimum flower yield per plot (2.51 kg) was observed in un-pinched plants of summer season (S_2P_1). In case of $S \times G$ interaction, the maximum flower yield per plot (4.20 kg) was recorded in plots of winter season sprayed with 250 ppm GA_3 (S_1G_2), while minimum flower yield per plot (2.14 kg) was observed in control plots of summer season (S_2G_0). With respect to $P \times G$ interaction the maximum flower yield per plot (3.99 kg) was recorded in plants pinched at 2 WAT and sprayed with GA_3 250 ppm (P_2G_2), while minimum flower yield per plot (2.07 kg) was observed in un-pinched plants sprayed with water (P_1G_0).

Table 16: Effect of pinching and gibberellic acid on flower yield per plant (g) of African marigold cv. Local Selection in different seasons

Season × Pinching × Gibberellic acid (S x P x G)								
Season→	S ₁				S ₂			
Pinching→ GA ₃ ↓	P ₁ (No pinching)	P ₂ (2 WAT)	P ₃ (3 WAT)	P ₄ (4 WAT)	P ₁ (No pinching)	P ₂ (2 WAT)	P ₃ (3 WAT)	P ₄ (4 WAT)
G ₀ (control)	107.78	121.20	115.80	110.52	99.43	111.51	110.83	106.85
G ₁ (150 ppm)	157.82	179.54	174.16	165.02	120.10	134.75	131.55	127.81
G ₂ (250 ppm)	202.72	229.47	206.86	200.53	142.93	169.66	167.93	155.19
G ₃ (350 ppm)	193.08	212.75	205.13	206.01	139.76	163.28	157.18	146.62
Season x Pinching (S x P)					Season x GA ₃ (S x G)			
Season→ Pinching ↓	S ₁ (Winter)	S ₂ (Summer)	Mean (P)		Season→ GA ₃ ↓	S ₁ (Winter)	S ₂ (Summer)	Mean (G)
P ₁ (No pinching)	165.35	125.56	145.46		G ₀ (control)	113.83	107.16	110.50
P ₂ (2 WAT)	185.74	144.80	165.27		G ₁ (150 ppm)	169.14	128.55	148.85
P ₃ (3 WAT)	175.49	141.87	158.68		G ₂ (250 ppm)	209.90	158.93	184.42
P ₄ (4 WAT)	170.52	134.12	152.32		G ₃ (350 ppm)	204.24	151.71	177.98
Mean (S)	174.28	136.59			Mean (S)	174.28	136.59	
Pinching x GA ₃ (P x G)						CD at 5% level of significance		
Pinching→ GA ₃ ↓	P ₁ (No pinching)	P ₂ (2 WAT)	P ₃ (3 WAT)	P ₄ (4 WAT)	Mean (G)	Season Pinching Gibberellic acid		8.28 11.71 11.71
G ₀ (control)	103.61	116.36	113.32	108.69	110.50	Season × pinching		16.56
G ₁ (150 ppm)	138.96	157.14	152.86	146.42	148.85	Season × gibberellic acid		NS
G ₂ (250 ppm)	172.83	199.57	187.40	177.86	184.42	Pinching × gibberellic acid		NS
G ₃ (350 ppm)	166.42	188.02	181.16	176.32	177.98	Season × pinching × gibberellic acid		NS
Mean (P)	145.46	165.27	158.68	152.32				
WAT - Weeks After Transplanting								

WAT - Weeks After Transplanting

Table 17: Effect of pinching and gibberellic acid on flower yield per plot (kg) of African marigold cv. Local Selection in different seasons

Season × Pinching × Gibberellic acid (S x P x G)								
Season→	S ₁				S ₂			
Pinching→ GA ₃ ↓	P ₁ (No pinching)	P ₂ (2 WAT)	P ₃ (3 WAT)	P ₄ (4 WAT)	P ₁ (No pinching)	P ₂ (2 WAT)	P ₃ (3 WAT)	P ₄ (4 WAT)
G ₀ (control)	2.16	2.42	2.32	2.21	1.99	2.23	2.22	2.14
G ₁ (150 ppm)	3.16	3.59	3.48	3.30	2.40	2.70	2.63	2.56
G ₂ (250 ppm)	4.05	4.59	4.14	4.01	2.86	3.39	3.36	3.10
G ₃ (350 ppm)	3.86	4.26	4.10	4.12	2.80	3.27	3.14	2.93
Season x Pinching (S x P)					Season x GA ₃ (S x G)			
Season→ Pinching ↓	S ₁ (Winter)	S ₂ (Summer)	Mean (P)		Season→ GA ₃ ↓	S ₁ (Winter)	S ₂ (Summer)	Mean (G)
P ₁ (No pinching)	3.31	2.51	2.91		G ₀ (control)	2.28	2.14	2.21
P ₂ (2 WAT)	3.71	2.90	3.31		G ₁ (150 ppm)	3.38	2.57	2.98
P ₃ (3 WAT)	3.51	2.84	3.18		G ₂ (250 ppm)	4.20	3.18	3.69
P ₄ (4 WAT)	3.41	2.68	3.05		G ₃ (350 ppm)	4.08	3.04	3.56
Mean (S)	3.49	2.73			Mean (S)	3.49	2.73	
Pinching x GA ₃ (P x G)						CD at 5% level of significance		
Pinching→ GA ₃ ↓	P ₁ (No pinching)	P ₂ (2 WAT)	P ₃ (3 WAT)	P ₄ (4 WAT)	Mean (G)	Season Pinching Gibberellic acid Season × pinching Season × gibberellic acid Pinching × gibberellic acid Season × pinching × gibberellic acid		0.17
G ₀ (control)	2.07	2.33	2.27	2.17	2.21			0.23
G ₁ (150 ppm)	2.78	3.14	3.06	2.93	2.98			0.23
G ₂ (250 ppm)	3.46	3.99	3.75	3.56	3.69			0.33
G ₃ (350 ppm)	3.33	3.76	3.62	3.53	3.56			NS
Mean (P)	2.91	3.31	3.18	3.05				NS
								NS
WAT - Weeks After Transplanting								

WAT - Weeks After Transplanting

Table 18: Effect of pinching and gibberellic acid on flower yield per hectare (t) of African marigold cv. Local Selection in different seasons

Season × Pinching × Gibberellic acid (S x P x G)								
Season→	S ₁				S ₂			
Pinching→ GA ₃ ↓	P ₁ (No pinching)	P ₂ (2 WAT)	P ₃ (3 WAT)	P ₄ (4 WAT)	P ₁ (No pinching)	P ₂ (2 WAT)	P ₃ (3 WAT)	P ₄ (4 WAT)
G ₀ (control)	6.74	7.58	7.24	6.91	6.21	6.97	6.93	6.68
G ₁ (150 ppm)	9.86	11.22	10.89	10.31	7.51	8.42	8.34	7.99
G ₂ (250 ppm)	12.67	14.34	12.93	12.53	8.93	10.60	10.50	9.70
G ₃ (350 ppm)	12.07	13.30	12.82	12.88	8.74	10.21	9.82	9.16
Season x Pinching (S x P)					Season x GA ₃ (S x G)			
Season→ Pinching ↓	S ₁ (Winter)	S ₂ (Summer)	Mean (P)		Season→ GA ₃ ↓	S ₁ (Winter)	S ₂ (Summer)	Mean (G)
P ₁ (No pinching)	10.34	7.85	9.10		G ₀ (control)	7.11	6.70	6.91
P ₂ (2 WAT)	11.61	9.05	10.33		G ₁ (150 ppm)	10.57	8.07	9.32
P ₃ (3 WAT)	10.97	8.90	9.94		G ₂ (250 ppm)	13.12	9.93	11.53
P ₄ (4 WAT)	10.66	8.38	9.52		G ₃ (350 ppm)	12.77	9.48	11.13
Mean (S)	10.89	8.55			Mean (S)	10.89	8.55	
Pinching x GA ₃ (P x G)						CD at 5% level of significance		
Pinching→ GA ₃ ↓	P ₁ (No pinching)	P ₂ (2 WAT)	P ₃ (3 WAT)	P ₄ (4 WAT)	Mean (G)	Season Pinching Gibberellic acid Season × pinching Season × gibberellic acid Pinching × gibberellic acid Season × pinching × gibberellic acid		0.52
G ₀ (control)	6.48	7.28	7.09	6.80	6.91			0.73
G ₁ (150 ppm)	8.69	9.82	9.62	9.15	9.32			0.73
G ₂ (250 ppm)	10.80	12.47	11.72	11.12	11.53			1.04
G ₃ (350 ppm)	10.41	11.76	11.32	11.02	11.13			NS
Mean (P)	9.10	10.33	9.94	9.52				NS
								NS
WAT - Weeks After Transplanting								

WAT - Weeks After Transplanting

Table 19: Effect of pinching and gibberellic acid on number of seeds per capitulum of African marigold cv. Local Selection in different seasons

Season × Pinching × Gibberellic acid (S x P x G)								
Season→	S ₁				S ₂			
Pinching→ GA ₃ ↓	P ₁ (No pinching)	P ₂ (2 WAT)	P ₃ (3 WAT)	P ₄ (4 WAT)	P ₁ (No pinching)	P ₂ (2 WAT)	P ₃ (3 WAT)	P ₄ (4 WAT)
G ₀ (control)	223.75	208.38	215.16	220.14	199.20	156.90	168.40	180.70
G ₁ (150 ppm)	244.50	218.88	222.35	234.49	216.40	185.23	195.60	201.40
G ₂ (250 ppm)	257.91	231.95	240.92	245.61	233.70	203.56	214.80	221.80
G ₃ (350 ppm)	265.73	242.05	249.02	257.08	241.50	213.41	225.30	232.40
Season x Pinching (S x P)					Season x GA ₃ (S x G)			
Season→ Pinching ↓	S ₁ (Winter)	S ₂ (Summer)	Mean (P)		Season→ GA ₃ ↓	S ₁ (Winter)	S ₂ (Summer)	Mean (G)
P ₁ (No pinching)	247.97	222.70	235.34		G ₀ (control)	216.86	176.30	196.58
P ₂ (2 WAT)	225.32	189.78	207.55		G ₁ (150 ppm)	230.06	199.66	214.86
P ₃ (3 WAT)	231.86	201.03	216.44		G ₂ (250 ppm)	244.10	218.47	231.28
P ₄ (4 WAT)	239.33	209.08	224.20		G ₃ (350 ppm)	253.47	228.15	240.81
Mean (S)	236.12	205.64			Mean (S)	236.12	205.64	
Pinching x GA ₃ (P x G)						CD at 5% level of significance		
Pinching→ GA ₃ ↓	P ₁ (No pinching)	P ₂ (2 WAT)	P ₃ (3 WAT)	P ₄ (4 WAT)	Mean (G)	Season Pinching Gibberellic acid Season × pinching Season × gibberellic acid Pinching × gibberellic acid Season × pinching × gibberellic acid		2.05
G ₀ (control)	211.48	182.64	191.78	200.42	196.58			2.90
G ₁ (150 ppm)	230.45	202.06	208.98	217.95	214.86			2.90
G ₂ (250 ppm)	245.81	217.76	227.86	233.71	231.28			4.10
G ₃ (350 ppm)	253.62	227.73	237.16	244.74	240.81			4.10
Mean (P)	235.34	207.55	216.44	224.20				5.80
								8.20
WAT - Weeks After Transplanting								

Interaction of season, pinching and gibberellic acid was found non-significant in influencing the flower yield per plot (Table 17). However, the maximum flower yield per plot (4.59 kg) was recorded with 250 ppm GA₃ sprayed over plants pinched at 2 WAT of winter season (S₁P₂G₂), whereas, minimum flower yield per plot (1.99 kg) was noticed in un-pinched plants sprayed with water during winter season (S₂P₁G₀).

4.3.5. Flower yield per hectare (t)

The data presented in Table 18 showed the significant variation in flower yield per hectare with respect to season, pinching and gibberellic acid. Plants grown in winter season (S₁) obtained more flower yield per hectare (10.89 t), whereas, comparatively, less flower yield per hectare (8.55 t) was recorded from summer grown plants (S₂) irrespective of pinching and gibberellic acid. With respect to pinching treatments, the maximum flower yield per hectare (10.33 t) was recorded in plants pinched at 2 WAT (P₂) which was at par with P₃ (9.94 t) and minimum flower yield per hectare (9.10 t) was recorded in un-pinched plants (P₁) followed by P₄ (9.52 t) irrespective of season and gibberellic acid. P₃ (9.94 t) and P₄ (9.52 t) treatments of pinching were recorded at par with each other in order to influence the flower yield per hectare. Flower yield per hectare increased significantly with increase in dose of GA₃ up to 250 ppm, but thereafter a slight decrease in it was reported. The maximum flower yield per hectare (11.53 t) was recorded with G₂ (250 ppm GA₃) which was found at par with G₃ (350 ppm GA₃) and minimum flower yield per hectare (6.91 t) was recorded in control (G₀) irrespective of season and pinching.

Among various interactions only S×P interaction was found effective in significantly increasing the flower yield per hectare as shown in Table 18. The maximum flower yield per hectare (11.61 t) was recorded in plants of winter season pinched at 2 WAT (S₁P₂) followed by S₁P₃ (10.97 t) and S₁P₄ (10.66 t), respectively which were also found at par with each other and minimum flower yield per hectare (7.85 t) was observed in un-pinched plants of summer season (S₂P₁) followed by S₂P₄ (8.38 t) which in turn was found at par with closely similar values of S₂P₃ (8.90 t) and S₂P₂ (9.05 t), respectively. Similarly, S×G interaction reported that the maximum flower yield per hectare (13.12 t) was recorded in plants of winter season sprayed with 250 ppm dose of GA₃ (S₁G₂), though minimum flower yield per hectare (6.70 t) was observed in control plants of summer season (S₂G₀). The maximum flower yield per hectare (12.47 t) was recorded in plants pinched at 2 WAT along with foliar spray of 250 ppm GA₃ (P₂G₂) and minimum flower yield per hectare (6.48 t) was observed in un-pinched plants sprayed with water (P₁G₀).

Season, pinching and gibberellic acid interaction was found non-significant in influencing flower yield per hectare as depicted in Table 18. The maximum flower yield per hectare (14.34 t) was recorded with 250 ppm GA₃ sprayed on plants pinched at 2 WAT of

winter season ($S_1P_2G_2$), whereas, minimum flower yield per hectare (6.21 t) was observed with control (G_0) in un-pinched plants of summer season ($S_2P_1G_0$).

4.4. Seed parameters

4.4.1. Number of seeds per capitulum

Through statistical analysis it was observed that significant differences occurred in number of seeds per capitulum due to season, pinching and gibberellic acid (Table 19). Statistically, higher number of seeds per capitulum (236.12) was recorded in winter season (S_1) as compared to lower number of seeds per capitulum (205.64) observed in summer season (S_2) irrespective of pinching and gibberellic acid.

A significant reduction in number of seeds per capitulum was recorded with increasing levels of pinching. The maximum number of seeds per capitulum (235.34) was recorded in un-pinched plants (P_1), although minimum number of seeds per capitulum (207.55) was recorded in plants pinched at 2 WAT (P_2) irrespective of season and gibberellic acid. The number of seeds per capitulum increased significantly as the concentration of gibberellic acid increases from 0 ppm to 350 ppm (Table 19). The maximum number of seeds per capitulum (240.81) was recorded with G_3 treatment (350 ppm GA_3), while minimum number of seeds per capitulum (196.58) was recorded in control (G_0) irrespective of season and pinching.

Interactions between $S \times P$, $S \times G$ and $P \times G$ were reported to have a significant influence on total number of seeds per capitulum (Table 19). The maximum number of seeds per capitulum (247.97) was recorded in un-pinched plants of winter season (S_1P_1) and minimum number of seeds per capitulum (189.78) was observed in plants pinched at 2 WAT during summer season (S_2P_2). In reference to $S \times G$ interaction, the maximum number of seeds per capitulum (253.47) was recorded in plants of winter season sprayed with 350 ppm GA_3 (S_1G_3), while minimum number of seeds per capitulum (176.30) was observed in control plants of summer season (S_2G_0). With regard to $P \times G$ interaction, the maximum number of seeds per capitulum (253.62) was recorded in un-pinched plants sprayed with GA_3 350 ppm (P_1G_3), while minimum number of seeds per capitulum (182.64) was observed in control plants pinched at 2 WAT (P_2G_0).

Number of seeds per capitulum recorded a significant increase in its value with respect to the interaction between season, pinching and gibberellic acid (Table 19). The maximum (265.73) number of seeds per capitulum was recorded with GA_3 @ 350 ppm sprayed on un-pinched plants of winter season ($S_1P_1G_3$) followed by $S_1P_1G_2$ (257.91) and minimum (156.90) number of seeds per capitulum was observed with water sprayed on plants pinched at 2 WAT in summer season ($S_2P_2G_0$).

Table 20: Effect of pinching and gibberellic acid on number of black seeds per capitulum of African marigold cv. Local Selection in different seasons

Season × Pinching × Gibberellic acid (S x P x G)								
Season→	S ₁				S ₂			
Pinching→ GA ₃ ↓	P ₁ (No pinching)	P ₂ (2 WAT)	P ₃ (3 WAT)	P ₄ (4 WAT)	P ₁ (No pinching)	P ₂ (2 WAT)	P ₃ (3 WAT)	P ₄ (4 WAT)
G ₀ (control)	129.82	113.21	119.80	123.32	115.93	99.00	106.47	109.87
G ₁ (150 ppm)	142.46	122.63	131.27	138.43	131.86	109.49	116.05	121.16
G ₂ (250 ppm)	153.70	128.07	136.40	144.18	141.00	115.89	124.79	130.43
G ₃ (350 ppm)	159.22	134.00	145.30	151.99	149.23	124.40	131.95	143.63
Season x Pinching (S x P)					Season x GA ₃ (S x G)			
Season→ Pinching ↓	S ₁ (Winter)	S ₂ (Summer)	Mean (P)		Season→ GA ₃ ↓	S ₁ (Winter)	S ₂ (Summer)	Mean (G)
P ₁ (No pinching)	146.30	134.51	140.40		G ₀ (control)	121.54	107.82	114.68
P ₂ (2 WAT)	124.48	112.20	118.34		G ₁ (150 ppm)	133.70	119.64	126.67
P ₃ (3 WAT)	133.19	119.82	126.50		G ₂ (250 ppm)	140.59	128.03	134.31
P ₄ (4 WAT)	139.48	126.27	132.88		G ₃ (350 ppm)	147.63	137.30	142.47
Mean (S)	135.86	123.20			Mean (S)	135.86	123.20	
Pinching x GA ₃ (P x G)						CD at 5% level of significance		
Pinching→ GA ₃ ↓	P ₁ (No pinching)	P ₂ (2 WAT)	P ₃ (3 WAT)	P ₄ (4 WAT)	Mean (G)	Season Pinching Gibberellic acid Season × pinching Season × gibberellic acid Pinching × gibberellic acid Season × pinching × gibberellic acid		2.21
G ₀ (control)	122.88	106.11	113.14	116.60	114.68			3.13
G ₁ (150 ppm)	137.16	116.06	123.66	129.80	126.67			3.13
G ₂ (250 ppm)	147.35	121.98	130.60	137.31	134.31			NS
G ₃ (350 ppm)	154.23	129.20	138.63	147.81	142.47			NS
Mean (P)	140.40	118.34	126.50	132.88				NS
WAT - Weeks After Transplanting								

WAT - Weeks After Transplanting

Table21: Effect of pinching and gibberellic acid on seed yield per plant (g) of African marigold cv. Local Selection in different seasons

Season × Pinching × Gibberellic acid (S x P x G)								
Season→	S ₁				S ₂			
Pinching→ GA ₃ ↓	P ₁ (No pinching)	P ₂ (2 WAT)	P ₃ (3 WAT)	P ₄ (4 WAT)	P ₁ (No pinching)	P ₂ (2 WAT)	P ₃ (3 WAT)	P ₄ (4 WAT)
G ₀ (control)	10.22	12.38	10.96	10.19	9.11	9.89	9.92	9.20
G ₁ (150 ppm)	15.59	16.67	16.29	15.48	12.49	12.93	12.69	12.34
G ₂ (250 ppm)	21.63	23.00	20.98	20.23	15.69	16.84	16.26	15.20
G ₃ (350 ppm)	20.07	21.24	20.33	20.26	15.30	17.14	15.70	15.48
Season x Pinching (S x P)					Season x GA ₃ (S x G)			
Season→ Pinching ↓	S ₁ (Winter)	S ₂ (Summer)	Mean (P)		Season→ GA ₃ ↓	S ₁ (Winter)	S ₂ (Summer)	Mean (G)
P ₁ (No pinching)	16.88	13.15	15.01		G ₀ (control)	10.94	9.53	10.23
P ₂ (2 WAT)	18.32	14.20	16.26		G ₁ (150 ppm)	16.01	12.61	14.31
P ₃ (3 WAT)	17.14	13.64	15.39		G ₂ (250 ppm)	21.46	16.00	18.73
P ₄ (4 WAT)	16.54	13.06	14.80		G ₃ (350 ppm)	20.48	15.91	18.19
Mean (S)	17.22	13.51			Mean (S)	17.22	13.51	
Pinching x GA ₃ (P x G)						CD at 5% level of significance		
Pinching→ GA ₃ ↓	P ₁ (No pinching)	P ₂ (2 WAT)	P ₃ (3 WAT)	P ₄ (4 WAT)	Mean (G)	Season Pinching Gibberellic acid Season × pinching Season × gibberellic acid Pinching × gibberellic acid Season × pinching × gibberellic acid		2.21
G ₀ (control)	9.67	11.14	10.44	9.70	10.23			3.13
G ₁ (150 ppm)	14.04	14.80	14.49	13.91	14.31			3.13
G ₂ (250 ppm)	18.66	19.92	18.62	17.72	18.73			NS
G ₃ (350 ppm)	17.69	19.19	18.02	17.87	18.19			0.67
Mean (P)	15.01	16.26	15.39	14.80				NS
								NS
WAT - Weeks After Transplanting								

WAT - Weeks After Transplanting

4.4.2. Number of black seeds per capitulum

The data depicted in Table 20 reveal that season; pinching and gibberellic acid had played a significant role in affecting number of black seeds per capitulum. More number of black seeds per capitulum (135.86) was recorded in winter season (S_1) as compared to less number of black seeds per capitulum (123.20) observed in summer season (S_2) irrespective of pinching and gibberellic acid. All the pinching levels significantly reduced the number of black seeds per capitulum. The maximum number of black seeds per capitulum (140.40) was recorded in un-pinched plants (P_1), though minimum number of black seeds per capitulum (118.34) was recorded in plants pinched at 2 WAT (P_2) irrespective of season and gibberellic acid. Gradual rise in level of GA_3 resulted in significant increase in the number of black seeds per capitulum. The maximum number of seeds per capitulum (142.47) was recorded with G_3 treatment (350 ppm GA_3), while minimum number of seeds per capitulum (114.68) was recorded in control (G_0) irrespective of season and pinching.

The interaction occurred due to $S \times P$, $S \times G$ and $P \times G$ was found non-significant in increasing the number of black seeds per capitulum (Table 20). However, the maximum number of black seeds per capitulum (146.30) was recorded in un-pinched plants of winter season (S_1P_1), although minimum number of black seeds per capitulum (112.20) was observed in plants pinched at 2 WAT during summer season (S_2P_2). Similarly, $S \times G$ reported that the maximum number of black seeds per capitulum (147.63) was recorded in plants of winter season sprayed with 350 ppm GA_3 (S_1G_3) as minimum number of black seeds per capitulum (107.82) was observed in control plants of summer season (S_2G_0). Likewise, in case of $P \times G$ interaction it was noticed that the maximum number of black seeds per capitulum (154.23) was recorded in un-pinched plants sprayed with GA_3 350 ppm (P_1G_3), while minimum number of black seeds per capitulum (106.11) was observed in plants pinched at 2 WAT sprayed with water (P_2G_0).

Season, pinching and gibberellic acid interactions did not have any significant effect on number of seeds per capitulum (Table 20). However, the maximum number of black seeds per capitulum (159.22) was recorded with GA_3 @ 350 ppm sprayed on un-pinched plants of winter season ($S_1P_1G_3$) and minimum number of black seeds per capitulum (99.00) was observed in control plants pinched at 2 WAT during summer season ($S_2P_2G_0$).

4.4.3. Seed yield per plant (g)

The data presented in Table 21 revealed that seed yield per plant enhanced significantly with respect to various levels of season, pinching and gibberellic acid. The higher seed yield per plant (17.22 g) was recorded in winter season (S_1) as compared to lower seed yield per plant (13.51 g) was observed in summer season (S_2) irrespective of pinching and gibberellic acid. In case of pinching, the maximum seed yield per plant (16.26 g) was recorded in plants pinched at 2 WAT (P_2), while minimum seed yield per plant (14.80 g) was recorded in plants pinched

at 4 WAT (P_4) followed by P_1 (15.01 g) which was also reported at par with P_3 (15.39 g) irrespective of season and gibberellic acid. Seed yield per plant improved significantly with every increase in the level of gibberellic acid up to G_2 , thereafter it decreased significantly. The maximum seed yield per plant (18.73 g) was recorded with G_2 treatment (250 ppm GA_3); while minimum seed yield per plant (10.23 g) was recorded in control (G_0) irrespective of season and pinching.

All interactions except $S \times G$ interaction were found non-significant in influencing the seed yield per plant (Table 21). However, the maximum seed yield per plant (18.32 g) was recorded in plants pinched at 2 WAT of winter season (S_1P_2) and minimum seed yield per plant (13.06 g) was observed in plants pinched at 4 WAT of summer season (S_2P_4). In case of $S \times G$ interaction, the maximum seed yield per plant (21.46 g) was recorded in plants of winter season sprayed with 250 ppm dose of GA_3 (S_1G_2), whereas, minimum seed yield per plant (9.53 g) was observed in control plants of summer season (S_2G_0). The maximum seed yield per plant (19.92 g) was recorded in plants pinched at 2 WAT and sprayed with GA_3 350 ppm (P_2G_2), while minimum seed yield per plant (9.67 g) was observed in un-pinched plants sprayed with water (P_1G_0).

With respect to $S \times P \times G$ interaction, the maximum seed yield per plant (23.00 g) was recorded with GA_3 @ 250 ppm as foliar spray in plants pinched at 2 WAT winter season ($S_1P_2G_2$), though minimum seed yield per plant (9.11 g) was observed with control in un-pinched plants of summer season ($S_2P_1G_0$).

4.4.4. Seed yield per plot (g)

The data presented in Table 22 showed that season, pinching and gibberellic acid exerted a significant influence on seed yield per plot. More seed yield per plot (344.40 g) was recorded in winter season (S_1) as compared to lower seed yield per plot (270.24 g) registered in summer season (S_2) irrespective of pinching and gibberellic acid. Plants pinched at 2 WAT (P_2) recorded the maximum seed yield per plot (325.27 g), while minimum seed yield per plot (295.93 g) was recorded in plants pinched at 4 WAT (P_4) followed by P_1 (300.28 g) which in turn was found at par with P_3 (307.81 g) irrespective of season and gibberellic acid. Seed yield per plot increased significantly up to G_2 level of GA_3 , thereafter a significant decrease in it was recorded. The maximum seed yield per plot (374.58 g) was recorded with G_2 (250 ppm GA_3) and minimum seed yield per plot (204.69 g) was recorded in control (G_0) irrespective of season and pinching.

All interactions except $S \times G$ interaction were found non-significant in influencing the seed yield per plot (Table 22). Though, the maximum seed yield per plot (366.50 g) was recorded in 2 WAT pinched plants of winter season (S_1P_2) and minimum seed yield per plot (261.08 g) was observed in plants pinched at 4 WAT of summer season (S_2P_4).

Table 22: Effect of pinching and gibberellic acid on seed yield per plot (g) of African marigold cv. Local Selection in different seasons

Season × Pinching × Gibberellic acid (S x P x G)								
Season→	S ₁				S ₂			
Pinching→ GA ₃ ↓	P ₁ (No pinching)	P ₂ (2 WAT)	P ₃ (3 WAT)	P ₄ (4 WAT)	P ₁ (No pinching)	P ₂ (2 WAT)	P ₃ (3 WAT)	P ₄ (4 WAT)
G ₀ (control)	204.39	247.67	219.13	203.76	182.24	197.86	198.44	184.01
G ₁ (150 ppm)	311.79	333.46	325.80	309.54	249.89	258.63	253.88	246.80
G ₂ (250 ppm)	432.69	460.02	419.51	404.58	313.84	336.85	325.18	303.99
G ₃ (350 ppm)	401.38	424.84	406.60	405.23	306.01	342.79	313.97	309.53
Season x Pinching (S x P)					Season x GA ₃ (S x G)			
Season→ Pinching ↓	S ₁ (Winter)	S ₂ (Summer)	Mean (P)		Season→ GA ₃ ↓	S ₁ (Winter)	S ₂ (Summer)	Mean (G)
P ₁ (No pinching)	337.56	263.00	300.28		G ₀ (control)	218.74	190.64	204.69
P ₂ (2 WAT)	366.50	284.03	325.27		G ₁ (150 ppm)	320.15	252.30	286.22
P ₃ (3 WAT)	342.76	272.87	307.81		G ₂ (250 ppm)	429.20	319.97	374.58
P ₄ (4 WAT)	330.78	261.08	295.93		G ₃ (350 ppm)	409.51	318.08	363.79
Mean (S)	344.40	270.24			Mean (S)	344.40	270.24	
Pinching x GA ₃ (P x G)						CD at 5% level of significance		
Pinching→ GA ₃ ↓	P ₁ (No pinching)	P ₂ (2 WAT)	P ₃ (3 WAT)	P ₄ (4 WAT)	Mean (G)	Season Pinching Gibberellic acid Season × pinching Season × gibberellic acid Pinching × gibberellic acid Season × pinching × gibberellic acid		6.70
G ₀ (control)	193.32	222.77	208.79	193.89	204.69			9.47
G ₁ (150 ppm)	280.84	296.05	289.84	278.17	286.22			9.47
G ₂ (250 ppm)	373.27	398.44	372.35	354.29	374.58			NS
G ₃ (350 ppm)	353.70	383.82	360.29	357.38	363.79			13.39
Mean (P)	300.28	325.27	307.81	295.93				NS
								NS
WAT - Weeks After Transplanting								

WAT - Weeks After Transplanting

Table 23: Effect of pinching and gibberellic acid on seed yield per hectare (kg) of African marigold cv. Local Selection in different seasons

Season × Pinching × Gibberellic acid (S x P x G)								
Season→	S ₁				S ₂			
Pinching→ GA ₃ ↓	P ₁ (No pinching)	P ₂ (2 WAT)	P ₃ (3 WAT)	P ₄ (4 WAT)	P ₁ (No pinching)	P ₂ (2 WAT)	P ₃ (3 WAT)	P ₄ (4 WAT)
G ₀ (control)	638.72	773.97	684.78	636.76	569.51	618.30	620.14	575.03
G ₁ (150 ppm)	974.34	1042.07	1018.11	967.30	780.92	808.23	793.39	771.25
G ₂ (250 ppm)	1352.15	1437.57	1310.98	1264.31	980.75	1052.65	1016.20	949.98
G ₃ (350 ppm)	1254.31	1327.63	1270.64	1266.34	956.27	1071.22	981.15	967.27
Season x Pinching (S x P)					Season x GA ₃ (S x G)			
Season→ Pinching ↓	S ₁ (Winter)	S ₂ (Summer)	Mean (P)		Season→ GA ₃ ↓	S ₁ (Winter)	S ₂ (Summer)	Mean (G)
P ₁ (No pinching)	1054.88	821.86	938.37		G ₀ (control)	683.56	595.75	639.65
P ₂ (2 WAT)	1145.31	887.60	1016.46		G ₁ (150 ppm)	1000.46	788.45	894.45
P ₃ (3 WAT)	1071.13	852.72	961.62		G ₂ (250 ppm)	1341.25	999.90	1170.57
P ₄ (4 WAT)	1033.68	815.88	924.78		G ₃ (350 ppm)	1279.73	993.98	1136.85
Mean (S)	1076.25	844.52			Mean (S)	1076.25	844.52	
Pinching x GA ₃ (P x G)						CD at 5% level of significance		
Pinching→ GA ₃ ↓	P ₁ (No pinching)	P ₂ (2 WAT)	P ₃ (3 WAT)	P ₄ (4 WAT)	Mean (G)	Season Pinching Gibberellic acid Season × pinching Season × gibberellic acid Pinching × gibberellic acid Season × pinching × gibberellic acid		20.93
G ₀ (control)	604.12	696.14	652.46	605.90	639.65			29.60
G ₁ (150 ppm)	877.63	925.15	905.75	869.28	894.45			29.60
G ₂ (250 ppm)	1166.45	1245.11	1163.59	1107.15	1170.57			NS
G ₃ (350 ppm)	1105.29	1199.43	1125.90	1116.81	1136.85			41.86
								NS
Mean (P)	938.37	1016.46	961.62	924.78				NS
WAT - Weeks After Transplanting								

WAT - Weeks After Transplanting

Likewise, winter plants sprayed with 250 ppm GA₃ (S₁G₂) produced the maximum seed yield per plot (429.20 g), while minimum seed yield per plot (190.64g) was observed in control plants of summer (S₂G₀). Similarly, in case of P×G interaction, the maximum seed yield per plot (398.44 g) was recorded in plants pinched at 2 WAT sprayed with GA₃ 250 ppm (P₂G₂) and minimum seed yield per plot (193.32 g) was observed in un-pinched plants sprayed with water (P₁G₀).

In relation to S×P×G, the maximum seed yield per plot (460.02 g) was recorded with GA₃ @ 250 ppm sprayed on plants of winter season pinched at 2 WAT (S₁P₂G₂), while minimum seed yield per plot (182.24 g) was observed with water sprayed on un-pinched during summer season (S₂P₁G₀).

4.4.5. Seed yield per hectare (kg)

The data presented in Table 23 showed that seed yield per hectare was significantly enhanced by different levels of season, pinching and gibberellic acid. More seed yield per hectare (1076.25 kg) was recorded in winter season (S₁) than summer season (S₂) which recorded comparatively less seed yield per hectare (844.52 kg) irrespective of pinching and gibberellic acid. In relation to pinching treatments, the highest seed yield per hectare (1016.46 kg) was recorded in plants pinched at 2 WAT (P₂), while minimum seed yield per hectare (924.78 kg) was recorded in plants pinched at 4 WAT (P₄) followed by un-pinched plants (P₁) (938.37 kg) which was at par with P₃ (961.62 kg) irrespective of season and gibberellic acid. Linear increase in dose of gibberellic acid up to 250 ppm caused significant increase in seed yield per hectare, but thereafter it decreased significantly. With respect to gibberellic acid, the maximum seed yield per hectare (1170.57 kg) was recorded with G₂ (250 ppm GA₃), while minimum seed yield per hectare (639.65 kg) was recorded in control (G₀) irrespective of season and pinching.

All interactions except S×G were found non-significant in influencing the seed yield per hectare (Table 23). However, the maximum seed yield per hectare (1145.31 kg) was recorded in plants pinched at 2 WAT of winter season (S₁P₂), whereas, minimum seed yield per hectare (815.88 kg) was observed in plants pinched at 4 WAT of summer season (S₂P₄). Similarly, winter plants sprayed with 250 ppm GA₃ (S₁G₂) produced the maximum seed yield per hectare (1341.25 kg), although minimum seed yield per hectare (595.75 kg) was registered in control plants of summer season (S₂G₀). Further, P×G interaction noticed that the higher seed yield per hectare (1245.11 kg) was recorded in plants pinched at 2WAT and sprayed with GA₃ 250 ppm (P₂G₂) as minimum seed yield per hectare (604.12 kg) was observed in un-pinched plants sprayed with water (P₁G₀).

In respect of season, pinching and gibberellic acid interaction (S×P×G), the maximum seed yield per hectare (1437.57 kg) was recorded with GA₃ @ 250 ppm as foliar spray in plants pinched at 2 WAT during winter season (S₁P₂G₂), whereas, minimum seed yield per

hectare (569.51 kg) was reported with water sprayed on un-pinched plants of winter season ($S_1P_1G_0$).

4.4.6. 1000 seeds weight (g)

The perusal of data presented in Table 24 revealed that season, pinching and gibberellic acid had played a significant role in influencing 1000 seeds weight. Higher value of 1000 seeds weight (3.310 g) was recorded in winter season (S_1) though lower value with respect to 1000 seeds weight (2.513 g) was observed in summer season (S_1) irrespective of pinching and gibberellic acid. In case of pinching, the maximum 1000 seeds weight (3.037 g) was recorded in plants pinched at 2 WAT (P_2) and minimum 1000 seeds weight (2.803 g) was recorded in plants pinched at 4 WAT (P_4) irrespective of season and gibberellic acid. By increasing level of GA_3 from 0 to 250 ppm a significant increase in 1000 seeds weight was noticed, but further increase in its level to 350 ppm caused a significant decrease in 1000 seeds weight. Further, it was reported that the maximum 1000 seeds weight (3.034 g) was recorded with G_2 treatment (250 ppm GA_3), while minimum 1000 seeds weight (2.766 g) was recorded in control (G_0) irrespective of season and pinching.

Only interaction which exerted a significant influence on 1000 seeds weight was that of season and gibberellic acid ($S \times G$), all other interactions were failed in their attempt to cause any significant influence on 1000 seeds weight (Table 24). The maximum 1000 seeds weight (3.449 g) was recorded in winter plants pinched at 2 WAT (S_1P_2) as minimum (2.417 g) was observed in summer plants pinched at 4 WAT (S_2P_4). Similarly, plants grown under winter conditions recorded the maximum 1000 seeds weight (3.464 g) when sprayed with 250 ppm GA_3 (S_1G_2), whereas minimum 1000 seeds weight (2.364 g) was observed in control plants grown under summer conditions (S_2G_0). In case of $P \times G$ interaction, the maximum 1000 seeds weight (3.154 g) was recorded in plants pinched at 2 WAT and sprayed with 250 ppm GA_3 (P_2G_2), while minimum 1000 seeds weight (2.681g) was observed in plants pinched at 4 WAT sprayed with water (P_4G_0).

In case of $S \times P \times G$ interaction, the maximum 1000 seeds weight (3.575 g) was recorded with GA_3 @ 250 ppm sprayed on plants pinched at 2 WAT of winter season ($S_1P_2G_2$) and minimum 1000 seeds weight (2.287 g) was observed with control (G_0) in plants pinched at 4WAT during summer season ($S_2P_4G_0$).

4.4.7. Seed germination (%)

The data presented in Table 25 showed that seed germination differed significantly as influenced by season, pinching and gibberellic acid. The higher seed germination (78.71%) was recorded in seeds harvested from summer crop (S_2), whereas, comparatively, lower seed germination (77.82%) was reported in seeds harvested from winter crop (S_1) irrespective of pinching and gibberellic acid.

Table 24: Effect of pinching and gibberellic acid on 1000 seeds weight (g) of African marigold cv. Local Selection in different seasons

Season × Pinching × Gibberellic acid (S x P x G)								
Season→	S ₁				S ₂			
Pinching→ GA ₃ ↓	P ₁ (No pinching)	P ₂ (2 WAT)	P ₃ 3 WAT)	P ₄ (4 WAT)	P ₁ (No pinching)	P ₂ (2 WAT)	P ₃ (3 WAT)	P ₄ (4 WAT)
G ₀ (control)	3.187	3.327	3.088	3.075	2.377	2.443	2.349	2.287
G ₁ (150 ppm)	3.317	3.370	3.213	3.147	2.557	2.610	2.483	2.420
G ₂ (250 ppm)	3.486	3.575	3.468	3.325	2.653	2.733	2.543	2.490
G ₃ (350 ppm)	3.359	3.523	3.295	3.204	2.567	2.715	2.507	2.473
Season x Pinching (S x P)					Season x GA ₃ (S x G)			
Season→ Pinching ↓	S ₁ (Winter)	S ₂ (Summer)	Mean (P)		Season→ GA ₃ ↓	S ₁ (Winter)	S ₂ (Summer)	Mean (G)
P ₁ (No pinching)	3.337	2.538	2.938		G ₀ (control)	3.169	2.364	2.766
P ₂ (2 WAT)	3.449	2.625	3.037		G ₁ (150 ppm)	3.262	2.517	2.890
P ₃ (3 WAT)	3.266	2.471	2.868		G ₂ (250 ppm)	3.464	2.605	3.034
P ₄ (4 WAT)	3.188	2.417	2.803		G ₃ (350 ppm)	3.345	2.565	2.955
Mean (S)	3.310	2.513			Mean (S)	3.310	2.513	
Pinching x GA ₃ (P x G)						CD at 5% level of significance		
Pinching→ GA ₃ ↓	P ₁ (No pinching)	P ₂ (2 WAT)	P ₃ (3 WAT)	P ₄ (4 WAT)	Mean (G)	Season Pinching		0.019
G ₀ (control)	2.782	2.885	2.718	2.681	2.766	Gibberellic acid		0.027
G ₁ (150 ppm)	2.937	2.990	2.848	2.783	2.890	Season × pinching		NS
G ₂ (250 ppm)	3.070	3.154	3.006	2.908	3.034	Season × gibberellic acid		0.038
G ₃ (350 ppm)	2.963	3.119	2.901	2.839	2.955	Pinching × gibberellic acid		NS
Mean (P)	2.938	3.037	2.868	2.803		Season × pinching × gibberellic acid		NS
WAT - Weeks After Transplanting								

Table 25: Effect of pinching and gibberellic acid on seed germination (%) of African marigold cv. Local Selection in different seasons

Season × Pinching × Gibberellic acid (S x P x G)								
Season→	S ₁				S ₂			
Pinching→ GA ₃ ↓	P ₁ (No pinching)	P ₂ (2 WAT)	P ₃ (3 WAT)	P ₄ (4 WAT)	P ₁ (No pinching)	P ₂ (2 WAT)	P ₃ (3 WAT)	P ₄ (4 WAT)
G ₀ (control)	66.67	76.67	73.50	64.00	68.44	78.52	76.44	67.11
G ₁ (150 ppm)	73.33	82.67	78.67	70.67	79.11	82.37	81.33	73.78
G ₂ (250 ppm)	82.67	90.22	86.00	78.67	80.74	87.11	84.15	79.11
G ₃ (350 ppm)	78.67	86.00	82.00	74.67	78.11	83.56	81.63	77.74
Season x Pinching (S x P)					Season x GA ₃ (S x G)			
Season→ Pinching ↓	S ₁ (Winter)	S ₂ (Summer)	Mean (P)		Season→ GA ₃ ↓	S ₁ (Winter)	S ₂ (Summer)	Mean (G)
P ₁ (No pinching)	75.33	76.60	75.97		G ₀ (control)	70.21	72.63	71.42
P ₂ (2 WAT)	83.89	82.89	83.39		G ₁ (150 ppm)	76.34	79.15	77.74
P ₃ (3 WAT)	80.04	80.89	80.47		G ₂ (250 ppm)	84.39	82.78	83.59
P ₄ (4 WAT)	72.00	74.43	73.22		G ₃ (350 ppm)	80.34	80.26	80.30
Mean (S)	77.82	78.71			Mean (S)	77.82	78.71	
Pinching x GA ₃ (P x G)						CD at 5% level of significance		
Pinching→ GA ₃ ↓	P ₁ (No pinching)	P ₂ (2 WAT)	P ₃ (3 WAT)	P ₄ (4 WAT)	Mean (G)	Season Pinching		0.27
G ₀ (control)	67.56	77.59	74.97	65.56	71.42	Gibberellic acid		0.38
G ₁ (150 ppm)	76.22	82.51	80.00	72.22	77.74	Season × pinching		0.38
G ₂ (250 ppm)	81.71	88.67	85.07	78.89	83.59	Season × gibberellic acid		0.54
G ₃ (350 ppm)	78.39	84.78	81.82	76.20	80.30	Pinching × gibberellic acid		0.54
Mean (P)	75.97	83.39	80.47	73.22		Season × pinching × gibberellic acid		0.76
								1.08
WAT - Weeks After Transplanting								

In case of pinching, the maximum seed germination (83.39%) was recorded in plants pinched at 2 WAT (P_2), though minimum seed germination (73.22 %) was recorded in plants pinched at 4 WAT (P_4) irrespective of season and gibberellic acid. Seed germination was significantly increased along with increasing levels of GA_3 except G_2 level which recorded a significant decrease in it. The maximum seed germination (83.59%) was recorded with 250 ppm dose of GA_3 (G_2) and minimum seed germination (71.42 cm) was recorded in control (G_0) irrespective of season and pinching.

The interactions resulted due to $S \times P$, $S \times G$ and $P \times G$ showed a significant influence on seed germination as presented in Table 25. The maximum seed germination (83.89 %) was recorded in plants pinched at 2 WAT in winter season (S_1P_2), while minimum seed germination (72.00%) was observed in plants pinched at 4 WAT in winter season (S_1P_4). In view of $S \times G$ interaction, the maximum seed germination (84.39%) was recorded in plants of winter season sprayed with 250 ppm dose of GA_3 (S_1G_2), whereas, minimum seed germination (70.21%) was also observed in control plants of winter season (S_1G_0). Further in case of $P \times G$ interaction it was noticed that the maximum seed germination (88.67 %) was recorded in plants pinched at 2 WAT along with foliar spray of 250 ppm GA_3 (P_2G_2) and minimum seed germination (65.56 %) was reported in plants pinched at 4 WAT sprayed with water (P_4G_0).

Season, pinching and gibberellic acid interactions had exhibited a significant effect on seed germination (Table 25). The maximum seed germination (90.22%) was recorded in plants pinched at 2 WAT and sprayed with GA_3 @ 250 ppm during winter ($S_1P_2G_2$), while minimum seed germination (64.00%) was noticed with control plants pinched at 4 WAT (P_4) during winter ($S_1P_4G_0$).

4.4.8. Seedling root length (cm)

The data depicted in Table 26 revealed that season, pinching and gibberellic acid recorded a significant increase in seedling root length. Seedling root length (4.00 cm) was recorded superior in winter season (S_1) in contrast to inferior seedling root length (3.70 cm) registered in summer season (S_2) irrespective of pinching and gibberellic acid. Pinching operation performed at 2 WAT (P_2) recorded the maximum seedling root length (4.11 cm) and minimum seedling root length (3.55 cm) was recorded with pinching done at 4 WAT (P_4) irrespective of season and gibberellic acid. Increased seedling root length was recorded with increase in concentration of gibberellic acid up to 250 ppm, thereafter it decreased significantly. The maximum seedling root length (4.18 cm) was recorded with G_2 (250 ppm GA_3), whereas, minimum seedling root length (3.36 cm) was recorded in control (G_0) irrespective of season and pinching.

Interactions between $S \times P$, $P \times G$ except $S \times G$ were found significant in influencing the seedling root length as apparent from the data shown in Table 26. Winter plants pinched at 2

WAT (S_1P_2) recorded the maximum seedling root length (4.29 cm), whereas minimum seedling root length (3.45 cm) was observed in summer planting pinched at 4 WAT (S_2P_4). Further it was found that the maximum seedling root length (4.33 cm) was recorded in plants of winter season sprayed with 250 ppm GA_3 (S_1G_2), while minimum seedling root length (3.22 cm) was noticed in control plants of summer season (S_2G_0). Furthermore, the maximum seedling root length (4.46 cm) was recorded in plants pinched at 2 WAT sprayed with GA_3 250 ppm (P_2G_2) which was at par with P_1G_2 (4.46 cm) and minimum seedling root length (3.20 cm) was reported in plants pinched at 4 WAT sprayed with water (P_4G_0).

Seedling root length was significantly influenced by season, pinching and gibberellic acid interaction ($S \times P \times G$) (Table 26). The maximum seedling root length (4.67 cm) was recorded with GA_3 @ 250 ppm in plants pinched at 2 WAT of winter season ($S_1P_2G_2$) followed by closely similar values of $S_1P_1G_2$ (4.66 cm) and $S_1P_2G_3$ (4.60 cm), respectively and minimum seedling root length (3.11 cm) was found in control plants pinched at 4 WAT during summer season ($S_2P_4G_0$) followed by $S_2P_3G_0$ (3.19 cm).

4.4.9. Seedling shoot length (cm)

The data presented in Table 27 showed that season, pinching and gibberellic acid significantly enhanced the seedling shoot length. Longer seedling shoot length (7.19 cm) was recorded in summer season (S_2) than shorter seedling shoot length (6.51 cm) reported in winter season (S_1) irrespective of pinching and gibberellic acid. Among pinching treatments, the maximum seedling shoot length (7.08 cm) was recorded in plants pinched at 2 WAT (P_2), whereas, minimum seedling shoot length (6.56 cm) was recorded in plants pinched at 4 WAT (P_4) irrespective of season and gibberellic acid. Seedling shoot length increased significantly with increase in level of gibberellic acid up to G_2 level, thereafter it decreased significantly. The maximum seedling shoot length (7.15 cm) was recorded with G_2 treatment (250 ppm GA_3) and minimum seedling shoot length (6.54 cm) was noticed in control (G_0) irrespective of season and pinching.

$S \times P$, $S \times G$ and $P \times G$ interactions were recorded significant in improving the seedling shoot length as depicted in Table 27. Interaction of $S \times P$ reported that the maximum seedling shoot length (7.37 cm) was recorded with pinching done at two weeks after transplanting (2 WAT) in summer season (S_2P_2), though minimum seedling shoot length (6.14 cm) was registered with pinching done at 4 WAT in winter season (S_1P_4). The maximum seedling shoot length (7.46 cm) was recorded in summer season with 250 ppm dose of GA_3 (S_2G_2), although minimum seedling shoot length (6.20 cm) was observed in control (S_1G_0). Likewise, the maximum seedling shoot length (7.49 cm) was recorded with pinching done at 2 WAT along with GA_3 @ 250 ppm (P_2G_2), while minimum seedling shoot length (6.39 cm) was noticed in control along with pinching done at 4 WAT (P_4G_0).

Table 26: Effect of pinching and gibberellic acid on seedling root length (cm) of African marigold cv. Local Selection in different seasons

Season × Pinching × Gibberellic acid (S x P x G)								
Season→	S ₁				S ₂			
Pinching→ GA ₃ ↓	P ₁ (No pinching)	P ₂ (2 WAT)	P ₃ (3 WAT)	P ₄ (4 WAT)	P ₁ (No pinching)	P ₂ (2 WAT)	P ₃ (3 WAT)	P ₄ (4 WAT)
G ₀ (control)	3.55	3.64	3.53	3.29	3.25	3.33	3.19	3.11
G ₁ (150 ppm)	4.12	4.25	3.75	3.66	3.71	3.97	3.53	3.36
G ₂ (250 ppm)	4.66	4.67	4.13	3.85	4.16	4.25	3.95	3..74
G ₃ (350 ppm)	4.57	4.60	3.90	3.78	3.95	4.14	3.89	3.60
Season x Pinching (S x P)					Season x GA ₃ (S x G)			
Season→ Pinching ↓	S ₁ (Winter)	S ₂ (Summer)	Mean (P)		Season→ GA ₃ ↓	S ₁ (Winter)	S ₂ (Summer)	Mean (G)
P ₁ (No pinching)	4.23	3.77	4.00		G ₀ (control)	3.50	3.22	3.36
P ₂ (2 WAT)	4.29	3.92	4.11		G ₁ (150 ppm)	3.95	3.64	3.80
P ₃ (3 WAT)	3.83	3.64	3.74		G ₂ (250 ppm)	4.33	4.02	4.18
P ₄ (4 WAT)	3.65	3.45	3.55		G ₃ (350 ppm)	4.21	3.90	4.06
Mean (S)	4.00	3.70			Mean (S)	4.00	3.70	
Pinching x GA ₃ (P x G)						CD at 5% level of significance		
Pinching→ GA ₃ ↓	P ₁ (No pinching)	P ₂ (2 WAT)	P ₃ (3 WAT)	P ₄ (4 WAT)	Mean (G)	Season Pinching Gibberellic acid Season × pinching Season × gibberellic acid Pinching × gibberellic acid Season × pinching × gibberellic acid		0.02
G ₀ (control)	3.41	3.49	3.36	3.20	3.36			0.03
G ₁ (150 ppm)	3.92	4.11	3.64	3.51	3.79			0.03
G ₂ (250 ppm)	4.46	4.46	4.04	3.81	4.18			0.05
G ₃ (350 ppm)	4.26	4.37	3.90	3.69	4.06			NS
								0.07
Mean (P)	4.01	4.11	3.73	3.55				0.10
WAT - Weeks After Transplanting								

Table 27: Effect of pinching and gibberellic acid on seedling shoot length (cm) of African marigold cv. Local Selection in different seasons

Season × Pinching × Gibberellic acid (S x P x G)								
Season→	S ₁				S ₂			
Pinching→ GA ₃ ↓	P ₁ (No pinching)	P ₂ (2 WAT)	P ₃ (3 WAT)	P ₄ (4 WAT)	P ₁ (No pinching)	P ₂ (2 WAT)	P ₃ (3 WAT)	P ₄ (4 WAT)
G ₀ (control)	6.25	6.30	6.19	6.07	6.92	6.97	6.91	6.70
G ₁ (150 ppm)	6.40	6.41	6.26	6.10	7.20	7.24	7.12	6.88
G ₂ (250 ppm)	7.20	7.26	6.67	6.22	7.57	7.71	7.39	7.17
G ₃ (350 ppm)	7.02	7.16	6.47	6.16	7.39	7.56	7.23	7.12
Season x Pinching (S x P)					Season x GA ₃ (S x G)			
Season→ Pinching ↓	S ₁ (Winter)	S ₂ (Summer)	Mean (P)		Season→ GA ₃ ↓	S ₁ (Winter)	S ₂ (Summer)	Mean (G)
P ₁ (No pinching)	6.72	7.27	7.00		G ₀ (control)	6.20	6.88	6.54
P ₂ (2 WAT)	6.78	7.37	7.08		G ₁ (150 ppm)	6.29	7.11	6.70
P ₃ (3 WAT)	6.40	7.16	6.78		G ₂ (250 ppm)	6.84	7.46	7.15
P ₄ (4 WAT)	6.14	6.97	6.56		G ₃ (350 ppm)	6.70	7.32	7.01
Mean (S)	6.51	7.19			Mean (S)	6.51	7.19	
Pinching x GA ₃ (P x G)						CD at 5% level of significance		
Pinching→ GA ₃ ↓	P ₁ (No pinching)	P ₂ (2 WAT)	P ₃ (3 WAT)	P ₄ (4 WAT)	Mean (G)	Season Pinching Gibberellic acid Season × pinching Season × gibberellic acid Pinching × gibberellic acid Season × pinching × gibberellic acid		0.02
G ₀ (control)	6.59	6.64	6.55	6.39	6.54			0.02
G ₁ (150 ppm)	6.80	6.83	6.69	6.49	6.70			0.03
G ₂ (250 ppm)	7.39	7.49	7.03	6.70	7.15			0.03
G ₃ (350 ppm)	7.20	7.36	6.85	6.64	7.01			0.05
Mean (P)	7.00	7.08	6.78	6.56				0.07
WAT - Weeks After Transplanting								

Table 28: Effect of pinching and gibberellic acid on seedling dry weight (mg) of African marigold cv. Local Selection in different seasons

Season × Pinching × Gibberellic acid (S x P x G)								
Season→	S ₁				S ₂			
Pinching→ GA ₃ ↓	P ₁ (No pinching)	P ₂ (2 WAT)	P ₃ (3 WAT)	P ₄ (4 WAT)	P ₁ (No pinching)	P ₂ (2 WAT)	P ₃ (3 WAT)	P ₄ (4 WAT)
G ₀ (control)	2.62	2.83	2.57	2.47	1.67	1.75	1.60	1.53
G ₁ (150 ppm)	3.09	3.10	2.92	2.78	1.78	1.80	1.73	1.67
G ₂ (250 ppm)	3.28	3.34	3.12	3.00	1.93	2.03	1.88	1.79
G ₃ (350 ppm)	3.18	3.23	3.03	2.90	1.85	2.06	1.81	1.74
Season x Pinching (S x P)					Season x GA ₃ (S x G)			
Season→ Pinching ↓	S ₁ (Winter)	S ₂ (Summer)	Mean (P)		Season→ GA ₃ ↓	S ₁ (Winter)	S ₂ (Summer)	Mean (G)
P ₁ (No pinching)	3.04	1.81	2.43		G ₀ (control)	2.62	1.64	2.13
P ₂ (2 WAT)	3.13	1.91	2.52		G ₁ (150 ppm)	2.97	1.75	2.36
P ₃ (3 WAT)	2.91	1.76	2.34		G ₂ (250 ppm)	3.19	1.91	2.55
P ₄ (4 WAT)	2.79	1.68	2.24		G ₃ (350 ppm)	3.09	1.87	2.48
Mean (S)	2.97	1.79			Mean (S)	2.97	1.79	
Pinching x GA ₃ (P x G)						CD at 5% level of significance		
Pinching→ GA ₃ ↓	P ₁ (No pinching)	P ₂ (2 WAT)	P ₃ (3 WAT)	P ₄ (4 WAT)	Mean (G)	Season		0.03
G ₀ (control)	2.15	2.29	2.08	2.00	2.13	Pinching		0.04
G ₁ (150 ppm)	2.43	2.45	2.33	2.22	2.36	Gibberellic acid		0.04
G ₂ (250 ppm)	2.61	2.69	2.50	2.40	2.55	Season × pinching		0.05
G ₃ (350 ppm)	2.52	2.64	2.42	2.32	2.48	Season × gibberellic acid		0.05
Mean (P)	2.43	2.52	2.33	2.24		Pinching × gibberellic acid		NS
						Season × pinching × gibberellic acid		NS
WAT - Weeks After Transplanting								

Table 29: Effect of pinching and gibberellic acid on seed vigour-I of African marigold cv. Local Selection in different seasons

Season × Pinching × Gibberellic acid (S x P x G)								
Season→	S ₁				S ₂			
Pinching→ GA ₃ ↓	P ₁ (No pinching)	P ₂ (2 WAT)	P ₃ (3 WAT)	P ₄ (4 WAT)	P ₁ (No pinching)	P ₂ (2 WAT)	P ₃ (3 WAT)	P ₄ (4 WAT)
G ₀ (control)	654.02	762.05	714.50	598.48	696.55	809.01	772.06	658.57
G ₁ (150 ppm)	771.49	880.29	787.12	690.31	863.26	922.78	866.20	755.00
G ₂ (250 ppm)	980.43	1076.06	929.25	791.90	954.92	1042.11	953.79	866.02
G ₃ (350 ppm)	911.77	1011.37	850.08	741.91	885.79	977.16	908.00	833.10
Season x Pinching (S x P)					Season x GA ₃ (S x G)			
Season→ Pinching ↓	S ₁ (Winter)	S ₂ (Summer)	Mean (P)		Season→ GA ₃ ↓	S ₁ (Winter)	S ₂ (Summer)	Mean (G)
P ₁ (No pinching)	829.43	850.13	839.78		G ₀ (control)	682.26	734.05	708.16
P ₂ (2 WAT)	932.44	937.77	935.10		G ₁ (150 ppm)	782.30	851.81	817.06
P ₃ (3 WAT)	820.24	875.01	847.63		G ₂ (250 ppm)	944.41	954.21	949.31
P ₄ (4 WAT)	705.65	778.17	741.91		G ₃ (350 ppm)	878.78	901.01	889.90
Mean (S)	821.24	860.27			Mean (S)	821.24	860.27	
Pinching x GA ₃ (P x G)						CD at 5% level of significance		
Pinching→ GA ₃ ↓	P ₁ (No pinching)	P ₂ (2 WAT)	P ₃ (3 WAT)	P ₄ (4 WAT)	Mean (G)	Season Pinching Gibberellic acid Season × pinching Season × gibberellic acid Pinching × gibberellic acid Season × pinching × gibberellic acid		3.57
G ₀ (control)	675.29	785.53	743.28	628.53	708.16			5.05
G ₁ (150 ppm)	817.37	901.54	826.66	722.66	817.06			5.05
G ₂ (250 ppm)	967.67	1059.09	941.53	828.96	949.31			7.14
G ₃ (350 ppm)	898.78	994.27	879.04	787.51	889.90			7.14
Mean (P)	839.78	935.10	847.63	741.91				10.10
								14.28
WAT - Weeks After Transplanting								

Season, pinching and gibberellic acid interactions had significant effect on affecting the seedling shoot length (Table 27). Application of 250 ppm GA₃ along with pinching at 2 WAT reported the maximum seedling shoot length (7.71 cm) during summer season (S₂P₂G₂), though minimum seedling shoot length (6.07 cm) was found in control with pinching at 4 WAT during winter season (S₁P₄G₀) followed by (S₁P₄G₁); (6.10 cm).

4.4.10. Seedling dry weight (mg)

Season, pinching and gibberellic acid registered a significant influence on seedling dry weight as evident from data given in Table 28. Seedling dry weight was recorded higher (2.97 mg) in winter season (S₁) than lower seedling dry weight (1.79 mg) observed in summer season (S₂) irrespective of pinching and gibberellic acid. Similarly, in case of pinching, the maximum seedling dry weight (2.52 mg) was recorded with plants pinched at 2 WAT (P₂), while minimum seedling dry weight (2.24 mg) was recorded in pinched at 4 WAT (P₄) irrespective of season and gibberellic acid. A linear increase in seedling dry weight was registered with increasing levels of GA₃ up to 250 ppm, thereafter it decreased significantly. The maximum seedling dry weight (2.55 mg) was recorded with G₂ (250 ppm GA₃), while minimum seedling dry weight (2.13 mg) was recorded in control (G₀) irrespective of season and pinching.

Seedling dry weight was significantly influenced by S×P and S×G interaction, while P×G interaction did not have any significant effect on seedling dry weight Table 28. The maximum seedling dry weight (3.13 mg) was recorded in winter with pinching done at 2 WAT (S₁P₂) and minimum seedling dry weight (1.68 mg) was observed in summer with pinching done at 4 WAT (P₄) (S₂P₄). The maximum seedling dry weight (3.19 mg) was measured in winter season with application of 250 ppm GA₃ (S₁G₂) and minimum seedling dry weight (1.64 mg) was noticed in control during summer season (S₂G₀). Further, the maximum seedling dry weight (2.69 mg) was reported at 250 ppm dose of GA₃ along with pinching at 2 WAT (P₂G₂), while minimum seedling dry weight (2.00 mg) was registered in control along with pinching done at 4 WAT (P₄G₀).

Season, pinching and gibberellic acid interactions were found non-significant in influencing the seedling dry weight (Table 28). However, the maximum seedling dry weight (3.34 mg) was recorded at 250 ppm GA₃ along with pinching done at 2 WAT during winter season (S₁G₂P₂), while minimum seedling dry weight (1.53 mg) was measured from control treatment applied with pinching done at 4 WAT in summer season (S₂G₀P₄).

4.4.11 Seed vigor-I

The data presented in Table 29 revealed that season, pinching and gibberellic acid had exerted a significant influence on seed vigor-I. The higher seed vigor-I (860.27) was recorded in winter season (S₁) as compared to lower seed vigor-I (821.24) reported in summer season (S₂) irrespective of pinching and gibberellic acid. Plants pinched at 2 WAT (P₂) produced seeds

having the maximum seed vigor - I (935.10) and minimum seed vigor-I (741.91) was recorded in plants pinched at 4 WAT (P_4) irrespective of season and gibberellic acid. Seed vigor-I was significantly influenced with increase in level of GA_3 up to G_2 , after that it decreased significantly. The maximum seed vigor-I (949.31) was recorded with G_2 (250 ppm GA_3) as minimum seed vigor-I (708.16) was recorded in control (G_0) irrespective of season and pinching.

The interactions viz., $S \times P$, $S \times G$ and $P \times G$ were found significant in improving the seed vigor-I (Table 29). The maximum seed vigor-I (937.77) was recorded in plants of summer season pinched at 2 WAT (S_2P_2) closely followed by S_1P_2 (932.44) and minimum seed vigor-I (829.43) was noticed in un-pinched plants of winter season (S_1P_1). In $S \times G$ interaction, the maximum seed vigor-I (954.21) was recorded in plants of summer season sprayed with 250 ppm dose of GA_3 (S_2G_2), though minimum seed vigor-I (682.26) was observed in control plants of winter season (S_1G_0). Similarly, in case of $P \times G$ interaction, plants pinched at 2 WAT when sprayed with GA_3 250 ppm (P_2G_2) recorded the maximum seed vigor-I (1059.09), while control plants pinched at 4 WAT (P_4G_0) registered the minimum seed vigor-I (628.53).

Season, pinching and gibberellic acid interactions had significant effect on influencing the seed vigor-I as revealed by the data shown in Table 29. The maximum seed vigor-I (1076.06) was recorded with GA_3 250 ppm spray (G_2) in plants pinched at 2 WAT of winter season ($S_1P_2G_2$), while minimum seed vigor-I (598.48) was observed in control plants pinched at 4 WAT ($S_1P_4G_0$).

4.4.12. Seed vigor-II

The data presented in Table 30 revealed that seed vigor-II increased significantly in its value with different seasons, levels of pinching and gibberellic acid. Higher seed vigor-II (0.232) was recorded in winter season (S_1) in contrast to lower seed vigor-II (0.141) reported in summer season (S_1) irrespective of pinching and gibberellic acid. Plants pinched at 2 WAT (P_2) recorded the maximum seed vigor-II (0.211) as minimum seed vigor-II (0.164) was recorded in plants pinched at 4 WAT (P_4) irrespective of season and gibberellic acid. Seed vigor-II increased significantly with gradual increase in dose of gibberellic acid up to 250 ppm, thereafter it reduced significantly. Application of gibberellic acid at 250 ppm recorded the maximum seed vigor-II (0.214) as compared to minimum seed vigor-II (0.152) obtained in control (G_0) irrespective of season and pinching.

All interactions except $P \times G$ were found significant in influencing the seed vigor-II as depicted in Table 30. Among various levels of pinching, the maximum seed vigor-II (0.263) was registered in plants pinched at 2 WAT in winter (S_1P_2), though minimum seed vigor-II (0.126) was noticed in plants pinched at 4 WAT in summer (S_2P_4).

Table 30: Effect of pinching and gibberellic acid on seed vigour-II of African marigold cv. Local Selection in different seasons

Season × Pinching × Gibberellic acid (S x P x G)								
Season→	S ₁				S ₂			
Pinching→ GA ₃ ↓	P ₁ (No pinching)	P ₂ (2 WAT)	P ₃ (3 WAT)	P ₄ (4 WAT)	P ₁ (No pinching)	P ₂ (2 WAT)	P ₃ (3 WAT)	P ₄ (4 WAT)
G ₀ (control)	0.175	0.217	0.189	0.158	0.114	0.137	0.122	0.103
G ₁ (150 ppm)	0.227	0.256	0.230	0.196	0.140	0.148	0.141	0.123
G ₂ (250 ppm)	0.271	0.302	0.268	0.236	0.156	0.177	0.158	0.142
G ₃ (350 ppm)	0.250	0.278	0.249	0.217	0.145	0.172	0.148	0.135
Season x Pinching (S x P)					Season x GA ₃ (S x G)			
Season→ Pinching ↓	S ₁ (Winter)	S ₂ (Summer)	Mean (P)		Season→ GA ₃ ↓	S ₁ (Winter)	S ₂ (Summer)	Mean (G)
P ₁ (No pinching)	0.231	0.139	0.185		G ₀ (control)	0.185	0.119	0.152
P ₂ (2 WAT)	0.263	0.159	0.211		G ₁ (150 ppm)	0.227	0.138	0.183
P ₃ (3 WAT)	0.234	0.142	0.188		G ₂ (250 ppm)	0.269	0.158	0.214
P ₄ (4 WAT)	0.202	0.126	0.164		G ₃ (350 ppm)	0.248	0.150	0.199
Mean (S)	0.232	0.141			Mean (S)	0.232	0.141	
Pinching x GA ₃ (P x G)						CD at 5% level of significance		
Pinching→ GA ₃ ↓	P ₁ (No pinching)	P ₂ (2 WAT)	P ₃ (3 WAT)	P ₄ (4 WAT)	Mean (G)	Season Pinching Gibberellic acid		0.002 0.003 0.003
G ₀ (control)	0.145	0.177	0.156	0.131	0.152	Season × pinching		0.004
G ₁ (150 ppm)	0.184	0.202	0.185	0.160	0.183	Season × gibberellic acid		0.004
G ₂ (250 ppm)	0.214	0.240	0.213	0.189	0.214	Pinching × gibberellic acid		NS
G ₃ (350 ppm)	0.197	0.225	0.198	0.176	0.199	Season × pinching × gibberellic acid		NS
Mean (P)	0.185	0.211	0.188	0.164				
WAT - Weeks After Transplanting								

WAT - Weeks After Transplanting

With respect to S×G, the maximum seed vigor-II (0.269) was recorded in plants of winter season sprayed with 250 ppm dose of GA₃ (S₁G₂), although the minimum seed vigor-II (0.119) was observed in control plants of summer season (S₂G₀). In case of P×G interaction, the maximum seed vigor-II (0.240) was recorded in plants pinched at 2 WAT (P₂) along with application of 250 ppm GA₃ (P₂G₂) and minimum seed vigor-II (0.131) was observed in plants pinched at 4 WAT sprayed with water (P₄G₀).

Season, pinching and gibberellic acid interactions were found non-significant in affecting the seed vigor - II (Table 30). However, the maximum seed vigor - II (0.302) was recorded with GA₃ @ 250 ppm in plants pinched at 2 WAT of winter season (S₁P₂G₂), whereas, minimum seed vigor-II (0.103) was reported in control plants pinched at 4 WAT during summer season (S₂P₄G₀).

The present investigation entitled “Effect of pinching and gibberellic acid on growth, flowering and yield of African marigold (*Tagetes erecta* L.) under different seasons” was conducted during 2015-16 at Experimental Orchard of the Department of Horticulture, CCS Haryana Agricultural University, Hisar. With this background, the results obtained in the present investigation are discussed in this chapter by supporting with relevant literature under following headings:

5.1. Growth Parameters

The data depicted in Table 2, 3, 4, 5 & 6 reveal that season, pinching and gibberellic acid significantly increased the plant height, plant spread, number of primary branches per plant, fresh weight and dry weight of plant. Greater plant height (81.58 cm), plant spread (61.66 cm), fresh weight (490.89 g) and dry weight of plant (57.47 g) was recorded in summer season as compared to lower plant height (70.46 cm), plant spread (47.98 cm), fresh weight of plant (360.61 g) and dry weight of plant (40.21 g) in winter season. It might be due to better light intensity and temperature required for plant growth and development during summer season. The higher number of primary branches per plant (12.75) was recorded in winter as compared to summer (9.93). In winter because of less elongation the lateral branches were found more which might be resulted in the formation of more number of branches. The present findings are in accordance with the reports of Rathore *et al.* (2011), Badge *et al.* (2014) and Meena *et al.* (2015) in African marigold.

Pinching treatment reduced the plant height significantly. However, the maximum plant height was recorded in un-pinched plants (79.85 cm). The reduction in plant height in pinched plants might be due to the removal of terminal growing shoot, which broke the apical dominance and diverted the plant metabolites to lateral buds for their growth. The maximum spread (59.20 cm), number of primary branches per plant (12.65), fresh weight of plant (486.34 g) and dry weight of plant (56.26 g) was recorded in plants pinched at 2 WAT (P₂), which might be due to the suppression of vertical growth and expression of horizontal growth in pinched plants caused due to diversion of plant assimilates to lateral buds for their growth. Similar results were quoted by Sharma *et al.* (2006), Rathore *et al.* (2011), Pushkar and Singh (2012), Kumar *et al.* (2012a), Badge *et al.* (2014), Rajyalakshmi and Rajasekhar (2014) and Mohanty *et al.* (2015b) in African marigold.

The marigold plants sprayed with GA₃ 250 ppm (G₂) had the significantly maximum height (83.32 cm), fresh weight (504.42 g) and dry weight of plant (58.75 g), however, plant spread (59.48 cm) and number of primary branches per plant (13.26) were recorded maximum

with GA₃ 350 ppm (G₃), which might be due to the fact that GA₃ increased the inter-nodal length of marigold plants. Here gibberellic acid was responsible for increasing the plant height, fresh and dry weight up to 250 ppm and after that there is a slight decrease with higher concentration this may be because of reason that GA₃ 250 ppm might be optimum for increasing the height, fresh and dry weight. Similar findings were also obtained by Taygi and Kumar (2006), Swaroop *et al.* (2007), Ramdevputra *et al.* (2009), Kumar *et al.* (2010), Shivaprakash *et al.* (2011), Kumar *et al.* (2012), Badge *et al.* (2014), Rajyalakshmi and Rajasekhar (2014), Gahoi and Singh (2015), Meshram *et al.* (2015) and Palei *et al.* (2016) in African marigold.

Various interactions viz. S×P, S×G and P×G had exerted a significant effect on plant spread (Table 3), number of primary branches per plant (Table 4) and fresh weight of plant (Table 5). However, S×P×G interaction did not influence plant spread (Table 3) and number of primary branches per plant (Table 4) but it significantly increased the fresh weight of plant (Table 5). Plant height differed significantly due to the influence of all interactions except S×G interaction (Table 2) but no interaction influenced the plant dry weight (Table 6).

Un-pinched plants in summer season (S₂P₁) recorded maximum plant height (84.66 cm), whereas, the plants in summer when pinched at 2 WAT (S₂P₂) recorded the wider spread (65.05 cm). However, the winter plants pinched at 2 WAT recorded the maximum number (14.00) of primary branches and fresh weight (563.49 g) (S₁P₂). Rathore *et al.* (2011), Badge *et al.* (2014) and Palei *et al.* (2016) also observed similar findings in African marigold. Summer plants attained maximum spread (65.59 cm) and fresh weight (557.92 g) with the application of 350 (S₂G₃) and 250 ppm GA₃ (S₂G₂), respectively, however the maximum number of primary branches per plant (15.48) was recorded with the application of 350 ppm GA₃ on plants in winter season (S₁G₃). Palei *et al.* (2016) also observed similar findings in African marigold.

Un-pinched plants sprayed with GA₃ 250 ppm (P₁G₂) acquired the maximum plant height (88.36 cm). The widest plant spread (64.16 cm) was recorded in plants pinched at 2 WAT and treated with GA₃ 350 ppm (P₂G₃). Spraying of GA₃ 350 ppm over plants pinched at 2 WAT (P₂G₃) resulted in production of the maximum number of primary branches per plant (14.87), while the plants pinched at 2 WAT along with GA₃ 250 ppm (P₂G₂) recorded the maximum fresh weight of plant (556.69 g). Results are in agreement with the findings of Rajyalakshmi and Rajasekhar (2014) and Badge *et al.* (2014) in African marigold.

The significantly maximum plant height (95.15 cm) was recorded when un-pinched plants were treated with foliar spray of 250 ppm GA₃ during summer (S₂P₁G₂). However, the maximum fresh weight of plant (616.67 g) was recorded with foliar spray of GA₃ 250 ppm on plants pinched at 2 WAT in summer season (S₂P₂G₂). The reports of Badge *et al.* (2014) in

African marigold cv. African Double Orange were also found in corroboration with the present study.

5.2. Flowering Parameters

Days to bud initiation, first flower and duration of flowering differed significantly with respect to different seasons and levels of pinching and gibberellic acid (Table 7, 8 & 9). Earlier bud initiation (40.60 days), appearance of first flower (52.30 days) was recorded in summer season as compared to winter season (41.58, 64.71 days, respectively) but longer duration of flowering (56.00 days) was registered in winter season as compared to summer season (34.53 days). Early bud initiation with respect to summer season may be due to earlier completion of juvenile period required for inducing flowering. Summer season conditions were favourable for the formation of early flowers so the first flower was formed early in summer, whereas, during winter flowering time the climatic conditions were congenial, so flower were formed for longer period. The present findings are in harmony with the findings of Swaroop *et al.* (2007), Ghosh and Pal (2008), Singh *et al.* (2015), Mohanty *et al.* (2015b), Palei *et al.* (2016) in African marigold.

Un-pinched plants took less number of days to bud initiation (39.05) and first flower (55.82) along with maximum duration of flowering (50.18 days). Pinching was affected to delay the formation of bud, this might be due to the reason that with the pinching the source of auxin is removed so the plant utilized its energy toward the formation of lateral branches and thus bud initiation was delayed. In pinched plants, newly arised shoot took longer time to become physiologically mature for bearing flowers as the speed of auxiliary shoot growth is slow after pinching and thus resulted in delayed appearance of first flower. Similar results were also reported by Rajhansa *et al.* (2013), Mohanty *et al.* (2015) and Meena *et al.* (2015) in African marigold.

Earliest bud initiation (39.58), visibility of first flower (55.77 days) and maximum duration of flowering (50.31 days) was recorded significantly with G₃ (350 ppm) treatment. GA₃ spray stimulates early flowering due to increase in the endogenous gibberellin levels in the plants, as gibberellins are well known for inducing early flowering in several crop plants. Gibberellins reduces juvenile period and with the termination of juvenile phase, the shoot apical meristem instead of producing leaves and branches start producing flower buds (Palei *et al.*, 2016). Gibberellic acid might have elongated the plant height which has resulted in the flower formation for longer time and hence longer duration of flowering. Results obtained were in conformity with the findings of Swaroop *et al.* (2007), Ramdevputra *et al.* (2009), Kumar *et al.* (2011), Kumar *et al.* (2014) and Palei *et al.* (2016) in African marigold.

All interactions exerted a significant effect on days to first flower (Table 8) but only S×P interaction was found significant in influencing days to bud initiation (Table 7), whereas, S×P and S×G interactions showed a significant effect on duration of flowering (Table 9).

Results are in conformity with the findings of Swaroop *et al.* (2007), Kumar *et al.* (2014) and Palei *et al.* (2016) in marigold.

Summer season un-pinched plants (S_2P_1) took fewer days to first flower (50.72), however, early bud initiation (38.64) along with maximum duration of flowering (61.68 days) was registered in winter season un-pinched plants (S_1P_1). Similar view has also been expressed by Mohanty *et al.* (2015b) in marigold cv. Siracole. The minimum days to first flower (50.46) and maximum duration of flowering (62.68 days) were recorded with GA_3 350 ppm sprayed on summer plants (S_2G_3) and winter plants, respectively (S_1G_3). Patil *et al.* (2016) also reported similar findings in marigold. Application of GA_3 350 ppm as foliar spray on un-pinched (P_1G_3) resulted in earliest days to first flower (51.85 days). Further, it was noticed that early bud initiation and visibility of first flower (48.53) was reported with GA_3 350 ppm spray in un-pinched plants of winter season ($S_1P_1G_3$).

Number of buds per plant, number of flowers per plant and flower diameter differed significantly in relation to different seasons, pinching timings and gibberellic acid doses (Table 10, 11 & 13); while only pinching and gibberellic acid showed a significant influence on flower stalk length and season could not bring any significant change in it (Table 12). Higher number of buds per plant (91.76), number of flowers per plant (43.25) and flower stalk length (9.55 cm) was recorded in summer season as compared to lower (70.12, 37.82 & 9.44 cm, respectively) registered in winter season. However, larger flower diameter (5.44 cm) was obtained in winter season than summer season (5.43 cm). This difference in number of flowers per plant with respect to season may be due to better environmental conditions and more number of branches per plant. These results are in agreement with the findings of Shreekanth *et al.* (2007), Swaroop *et al.* (2007), Ramdevputra *et al.* (2009), Badge *et al.* (2014), Meshram *et al.* (2015) and Mohanty *et al.* (2015) in African marigold.

Un-pinched (P_1) obtained maximum flower diameter (5.62 cm), whereas, plants pinched at two weeks after transplanting produced the maximum number of buds per plant (89.83), number of flowers per plant (44.91) and flower stalk length (10.38 cm). Due to removal of apical dominance by pinching more number of branches per plant was produced that in turn contributed to increase the number of flowers per plant. The increase in number of buds per plant might be due to the fact that it checked apical dominance and diverted extra energy in to the production of more number of branches and flowers (Pushkar and Singh, 2012). Similar results were earlier reported by Tomar *et al.* (2004), Rathore *et al.* (2011), Rajyalakshmi and Rajasekhar (2014), Rajhansa *et al.* (2013) and Mohanty *et al.* (2015b) in African marigold.

The maximum number of buds per plant (93.51) and number of flowers per plant (46.29) was produced as a result of foliar spray of GA_3 250 ppm (G_2) however, the maximum flower stalk length (11.13 cm) and flower diameter (5.71 cm) was reported with use of GA_3

350 ppm. The increase in number of buds and flowers per plant might be because of the reason that gibberelline might have lead to the formation of more buds and also enhanced the internodal length as a result of which the buds were capable of converting in to flowers. This increase in flower diameter might be because of the reason that GA₃ might have given sufficient space for development of flower. Similar results were quoted by Sunitha *et al.* (2007), Pandey and Chandra (2008), Kanwar and Khandelwal (2013), Kumar *et al.* (2014), Meshram *et al.* (2015) and Palei *et al.* (2016) in marigold.

All interactions had a significant influence on number of flowers per plant and flower stalk length (Table 11&12) but no interaction had any significant effect on number of buds per plant (Table 10), whereas, S×G and S×P interactions exerted a significant effect on flower diameter (Table 13). Plants with pinching at 2 WAT obtained the maximum number of flowers per plant (47.70) and flower stalk length (10.67 cm) in summer (S₂P₂) and winter season, (S₁P₂) respectively. However, the maximum flower diameter (5.70 cm) was recorded in un-pinched plants of winter season (S₁P₁). These results are in consonance with the reports of Badge *et al.* (2014) in marigold.

The maximum number of flowers per plant (48.29) was recorded with GA₃ 250 ppm sprayed on summer plants (S₂G₂), while winter application of GA₃ 350 ppm (S₁G₃) registered maximum stalk length of flower (11.53 cm) and flower diameter (5.76 cm). Swaroop *et al.* (2007), Ramdevputra *et al.* (2009), Kumar *et al.* (2014), Badge *et al.* (2014) and Meshram *et al.* (2015) observed similar findings in marigold. The maximum number of flowers (51.71) and flower stalk length (12.42 cm) was registered in plants pinched at 2 WAT with foliar spray of GA₃ 250 ppm (P₂G₂) and GA₃ 350 ppm (P₂G₃), respectively. Current findings are in agreement with the reports of Badge *et al.* (2014). The highest number of flowers per plant (53.18) was observed with GA₃ 250 ppm sprayed on summer plants pinched at 2 WAT (S₂P₂G₂). However, winter season plants pinched at 2 WAT and sprayed with 350 ppm GA₃ (S₁P₂G₃) produced longest stalk length of flower (13.53 cm).

5.3. Yield Parameters

Season, pinching and gibberellic acid had exerted a significant influence on fresh weight of flower, dry weight of flower, flower yield per plant, per plot as well as per hectare as apparent from the data shown in Table (14, 15, 16, 17 & 18). Higher fresh weight of flower (4.57 g), dry weight of flower (0.52 g), flower yield per plant (174.28 g), per plot (3.49 kg) as well as per hectare (10.89 t) was recorded in winter season in contrary to lower recorded in summer season (3.15, 0.35, 136.59 g, 2.73 kg & 8.55 t, respectively). Similar results were also reported by Swaroop *et al.* (2007), Ghosh and Pal (2008), Rathore *et al.* (2011), Rajyalakshmi and Rajasekhar (2014), Mohanty *et al.* (2015b), Joshna and Pal (2015) and Palei *et al.* (2016) in African marigold.

Un-pinched plants (P_1) attained the maximum fresh weight of flower (4.06 g) and dry weight of flower (0.47 g), whereas, maximum flower yield per plant (165.27 g), per plot (3.31 kg) as well as per hectare (10.33 t) was recorded in plants pinched at 2 WAT (P_2). It may be due to the fact that pinched treatment increased the number of flowers per plant hence; the developing flowers might have been supplied with comparatively lesser quantities of plant bioregulators and food reserve and resulting ultimately in reduction of fresh and dry flower weight. The increase in yield of flowers under pinching treatments may be due to the fact that pinching checked the apical dominance and diverted extra metabolites into the production of more number of flowers. These results are in the harmony with the findings of Rathore *et al.* (2011), Kumar *et al.* (2012a), Badge *et al.* (2014), Rajyalakshmi and Rajasekhar (2014), Mohanty *et al.* (2015b) in African marigold.

Fresh weight of flower (4.13 g) and dry weight of flower were recorded maximum (0.47 g) with GA_3 350 ppm but plants sprayed with GA_3 250 ppm significantly obtained the highest flower yield per plant (184.42 g), plot (3.69 kg) as well as per hectare (11.53 t). This increase in fresh weight of flower can be attributed to better translocation of plant assimilates from source to sink due to enhanced reproductive efficiency and photosynthesis, whereas, increase in flower yield might be due to better crop growth; more number of branches thus increased the number of flowers per plant and ultimately increased the flower yield. Present results are in conformity with the findings of Kumar *et al.* (2010), Kumar *et al.* (2011), Kanwar and Khandelwal (2013), Kumar *et al.* (2014), Gahoi and Singh (2015), Meshram *et al.* (2015) and Palei *et al.* (2016) in marigold.

All interactions had exerted a significant influence on fresh weight of flower as revealed by data shown in Table 14 but only $S \times P$ interaction showed a significant effect on flower yield per hectare (Table 18). A significant increase in flower yield per plant and flower yield per plot was also recorded because of $S \times P$ interaction (Table 16 & 17). These results are in harmony with the findings of Swaroop *et al.* (2007), Kanwar and Khandelwal (2013) and Badge *et al.* (2014) in marigold.

Winter season registered maximum fresh weight of flower (4.83g), dry weight of flower (0.56 g) in un-pinched plants (S_1P_1), while it recorded the maximum flower yield per plant (185.74 g), plot (3.71 kg) as well as per hectare (11.61 t) with plants pinched at 2 WAT (S_1P_2). Rathore *et al.* (2011) also noticed similar results in marigold cv. Pusa Narangi Gaiinda. Winter season plants recorded maximum fresh weight of flower (4.91 g) and flower yield per hectare (13.12 t) when sprayed with GA_3 350 ppm (S_1G_3) and GA_3 250 ppm (S_1G_2), respectively. Swaroop *et al.* (2007), Kumar *et al.* (2014) and Meshram *et al.* (2015) also observed similar findings in African marigold. Un-pinched plants attained the maximum fresh weight of flower (4.32 g) with GA_3 350 ppm (P_1G_3), whereas, maximum flower yield per plot (3.99 kg) as well as per hectare (12.47 t) was recorded with foliar spray of 250 ppm GA_3

spray in plants pinched at 2 WAT (P_2G_2). Current results are in agreement with the findings of Badge *et al.* (2014) in African marigold.

In relation to $S \times P \times G$ interaction, the maximum fresh weight of flower (5.14 g) was noted with GA_3 350 ppm on un-pinched plants of winter season ($S_1P_1G_3$). However, the maximum flower yield per plant (229.47 g), per plot (4.59 kg) as well as per hectare (14.34 t) was recorded when plants pinched at 2 WAT were sprayed with 250 ppm GA_3 during winter season ($S_1P_2G_2$).

5.4. Seed Parameters

Significant influence of season, pinching and gibberellic acid on number of seeds per capitulum, number of black seeds per capitulum and seed yield per plant, per plot as well as per hectare was recorded as depicted in Table 19, 20, 21, 22 & 23. The statistically higher value of number of seeds per capitulum (236.12) and number of black seeds per capitulum (135.86), seed yield per plant (17.22 g), per plot (344.40 g) and per hectare (1076.25 kg) was recorded in winter season (236.12) than lower value (205.64, 123.20, 13.51, 270.24 g and 844.52 kg, respectively) in summer season. Similar results were quoted by Pramila *et al.* (2011) and Mohanty *et al.* (2015a) in African marigold. This difference in number of seeds per capitulum with respect to season may be occurred due to favourable environment conditions for seed development.

Un-pinched plants (P_1) produced maximum number of seeds per capitulum (235.34), number of black seeds per capitulum (140.40), while plants pinched at 2 WAT reported the maximum seed yield per plant (16.26 g), plot (325.27 g) as well as per hectare (1016.46 kg). This reduction in number of seeds per capitulum might be due to the fact that more number of branches per plant arised from main shoots in pinching treatment which in turn produced more number of flowers per plant having reduced flower diameter comparatively and ultimately resulted in to less number of seeds per capitulum. These results are in the conformity with the findings of Sunitha *et al.* (2007), Rajhansa *et al.* (2013), Mohanty *et al.* (2015a) and Patil *et al.* (2016) in marigold.

Plants treated with GA_3 350 ppm significantly recorded the maximum seed yield per plant (10.23 g), per plot (374.58 g) as well as per hectare (1170.57 kg), while plants sprayed with GA_3 350 ppm significantly recorded the maximum number of seeds per capitulum (240.81) and number of black seeds per capitulum (142.47). This increase in seed yield per plant were might be due to increased plant growth and increased concentration of carbohydrates, which resulted in efficient translocation from leaves to flowers and ultimately seeds (Arun *et al.*, 1994). The present results are in conformity with the reports of Swaroop *et al.* (2007) and Patil *et al.* (2016). Similar results were also reported by Rajhansa *et al.* (2013) in African marigold.

All interactions had a significant effect on number of seeds per capitulum (Table 19), whereas, no interaction increased the number of black seeds per capitulum (Table 20). Only S×G interaction exhibited a significant influence on seed yield per plant, per plot as well as per hectare (Table 21, 22 & 23). Mohanty *et al.* (2015a) also noticed similar results in marigold. The maximum number of seeds per capitulum (247.97) was recorded in un-pinched plants of winter season (S₁P₁). Similarly, the maximum number of seeds per capitulum (253.47) was recorded at 350 ppm GA₃ applied on winter plants (S₁G₃). However, the maximum seed yield per plant (21.46 g), per plot (429.20 g) as well as per hectare (1341.25 kg) was recorded with 250 ppm GA₃ sprayed on winter plants (S₁G₂). Un-pinched plants sprayed with GA₃ 350 ppm (P₁G₃) produced the maximum number of seeds per capitulum (253.62) and it was also found maximum (265.73) when GA₃ 350 ppm sprayed on un-pinched plants during winter (S₁P₁G₃).

Various seed quality parameters like, 1000 seed weight (test weight), seed germination, seedling root length, seedling shoot length, seedling dry weight, seed vigour-I and seed vigour-II affected significantly due to influence of season, pinching and gibberellic acid as apparent from the data shown in Tables 24, 25, 26, 27, 28, 29 & 30. More test weight (3.310 g) seedling root length (4.00 cm), seedling dry weight (2.97 mg), seed vigour-I (860.27) and seed vigour-II (0.233) was recorded in seeds harvested from winter season crop as compared to summer (2.513 g, 3.70 cm, 1.79 mg, 821.24, 0.142, respectively). However, higher seed germination (78.71%) was recorded in seeds collected from summer than of winter season (77.82 %). More seeds weight, seedling length, seedling dry weight and seed vigour in winter may be due to the favourable temperature for the growth and development of seed in the flower. On the other hand, better seed germination in summer season might be due to high temperature suitable for process of germination. Results obtained were in harmony with the findings of Sunitha *et al.* (2007) and Pramila *et al.* (2011) in African marigold.

Seeds obtained from plants pinched at 2 WAT registered the maximum test weight (3.037 g), seed germination (83.39 %), seedling root length (4.11cm), seedling shoot length (7.08 cm), seedling dry weight (2.52 mg), seed vigour-I (935.11) and seed vigour-II (0.211). Pinching might have lead to reduction in vegetative growth and thus plant photosynthates might have been utilized for the development of better seeds as a result of all seed qualitative parameters increased. Similar findings were reported by Bhat and Shepherd (2007), Sunitha *et al.* (2007) and Mohanty *et al.* (2015a).

The highest test weight (3.034 g), seed germination (83.59 %), seedling root length (4.18 cm), seedling shoot length (7.15 cm), seedling dry weight (2.55 mg), seed vigour-I (949.31) and seed vigour-II (0.214) was significantly recorded at G₂ (250 ppm) treatment. With GA₃ application germination percentage was improved, this may be because of the reason that GA₃ might have helped the hydrolysis of reserve food material in the seed and

thus enhanced the germination percentage. As seed vigour index is a multiplication of seedling growth so that also might have been improved. Results are in agreement with the findings of Sunitha *et al.* (2007) and Patil *et al.* (2016) in African marigold.

All interactions were found significant in affecting seed germination, seedling shoot length and seed vigour-I (Table 25, 27 & 29), whereas, only S×G interaction was found significant in influencing 1000 seeds weight (Table 24). The interaction effect of all interactions except S×G was found significant in influencing seedling root length (Table 26). S×P and S×G interaction showed a significant effect on seedling dry weight and seed vigour-II (Table 28 & 30). Sunitha *et al.* (2007) also noticed similar results in marigold.

The maximum seed germination (83.89 %), seedling root length (4.29 cm), seedling dry weight (3.13 mg) and seed vigour-II (0.263) was recorded in seeds harvested from plants pinched at 2 WAT in winter (S₁P₂), while maximum seedling shoot length (7.37 cm) and seed vigour-I (937.77) was recorded in plants pinched at 2 WAT in summer season (S₂P₂). In case of S×G interaction, the maximum test weight (3.464 g), seed germination (84.39 %), seedling dry weight (3.19 mg) and seed vigour-II (0.269) was recorded with GA₃ @ 250 ppm in winter (S₁G₂). However, summer season plants sprayed with 250 ppm GA₃ (S₂G₂) recorded the longest seedling shoot length (7.46 cm) and seed vigour-I (954.21). Plants pinched at 2 WAT when treated with GA₃ @ 250 ppm (P₂G₂) produced the seeds having maximum seed germination (88.67%), seedling root length (4.46 cm), seedling shoot length (7.49 cm), seed vigour-I (1059.09)

The highest seed germination (90.22%), seedling root length (4.67 cm), seed vigour-I (1076.06) was recorded with GA₃ 250 ppm spray in plants of winter season pinched at 2 WAT plants (S₁P₂G₂). However, the maximum seedling shoot length (7.71 cm) was recorded with GA₃ 250 ppm spray in plants of summer season pinched at 2 WAT plants (S₂P₂G₂).

The present investigation was carried out at Experimental Orchard, Department of Horticulture, CCS Haryana Agricultural University, Hisar during 2015-16 in factorial Randomized Block Design with three replications. Analysis of various seed parameters were done in laboratory of Seed Science & Technology, CCS Haryana Agricultural University, Hisar. The salient findings of the present investigation are summarized and concluded as below:

Season, pinching and gibberellic acid had played a significant role in influencing all the growth parameters. Summer grown plants attained the maximum plant height, plant spread, fresh and dry weight of plant, while more number of primary branches per plant was observed in winter. Un-pinched plants significantly acquired the maximum plant height, whereas, plants pinched at two weeks after transplanting (WAT) significantly attained the maximum spread, number of primary branches per plant, fresh and dry weight of plant. Application of GA₃ 250 ppm significantly recorded the maximum plant height, fresh and dry weight of plant, while plant spread and number of primary branches per plant were reported significantly maximum with GA₃ 350 ppm spray.

All interactions except S×G exhibited a significant effect on plant height but no interaction influenced the dry weight of plant. Plant spread, number of primary branches per plant and fresh weight of plant increased significantly with respect to S×P, S×G and P×G interactions. However, S×P×G interaction did not influence plant spread and number of primary branches per plant but it exerted a significant effect on fresh weight of plant.

Marigold plant pinched at 2 WAT when sprayed with GA₃ 350 ppm recorded highest spread and number of primary branches in summer (S₂P₂G₃) and winter (S₁P₂G₃), respectively. In summer season, GA₃ 250 ppm recorded the maximum plant height from un-pinched plants (S₂P₁G₂), while it recorded the maximum fresh and dry weight of plant with pinching at 2 WAT (S₂P₂G₂).

All floral parameters except flower stalk length differ significantly with respect to season. Early bud initiation was reported in winter season, while early appearance of first flower was recorded in summer season. Largest flower having longer duration of flowering was reported in winter, whereas, longer flower stalk length, more number of buds and number of flowers per plant was observed in summer. Different pinching and GA₃ treatments had a significant influence on all floral parameters. Un-pinched plants showed earliest bud initiation, first flower appearance and larger diameter of flower having longer duration of flowering as compared to pinched plants. However, the plants pinched at 2 WAT produced

maximum number of buds per plant, number of flowers per plant and flower stalk length. On the other hand, GA₃ @ 350 ppm significantly recorded the earliest bud initiation, 1st flower appearance along with the largest flower having the longest flower stalk length and duration of flowering but maximum number of buds and flowers per plant was observed in plants sprayed with 250 ppm GA₃.

All floral parameters except number of buds per plant enhanced significantly by interaction of season with pinching (S×P) and GA₃ (S×G), respectively. Pinching and GA₃ interaction (P×G) significantly influenced the days to first flower, number of flowers per plant and flower stalk length. Similarly, interaction among season, pinching and GA₃ (S×P×G) had a significant influence on days to first flower, flower stalk length and number of flowers per plant.

During winter season, GA₃ 350 ppm application recorded early bud initiation, maximum flower diameter and flowering duration in un-pinched plants (S₁P₁G₃), while it recorded longest flower stalk length in plants pinched at 2 weeks after transplanting (S₁P₂G₃). Similarly, un-pinched plants sprayed with GA₃ 350 ppm recorded the least days to first flower (S₂P₁G₃) but when GA₃ 250 ppm sprayed on plants pinched at 2 WAT produced the highest number of buds and flowers per plant in summer season (S₂P₂G₃).

All yield parameters were significantly enhanced by individual effects of season, pinching and gibberellic acid. Winter season significantly recorded higher fresh and dry weight of flower, flower yield per plant, per plot as well as per hectare as compared to summer. With respect to pinching, un-pinched plants produced the maximum fresh and dry weight of flower, while plants pinched at 2 WAT obtained maximum flower yield per plant, per plot as well as per hectare. Further, it was noticed that GA₃ 350 ppm recorded maximum fresh and dry weight of flower, while the maximum flower yield per plant, per plot as well as per hectare was recorded in plants sprayed with GA₃ 250 ppm.

All interactions viz., S×P, S×G, P×G and S×P×G had exerted a significant influence on fresh weight of flower but no interaction affected the dry weight of flower. However, only season and pinching interaction (S×P) significantly influenced the flower yield per plant, per plot as well as per hectare. Un-pinched plants sprayed with GA₃ 350 ppm produced the maximum fresh weight of flower during winter season (S₁P₁G₃).

All seed parameters differed significantly due to individual effect of season, pinching and GA₃. Winter planting recorded maximum number of seeds per capitulum, number of black seeds per capitulum, 1000 seeds weight, seed yield per plant, per plot as well as per hectare, seedling root length, seedling dry weight and seed vigour-II however, the maximum seed germination, seedling shoot length and seed vigour-I was observed in summer. Un-pinched plants produced the highest number of seeds per capitulum and number of black seeds per capitulum, while plants pinched at 2 WAT recorded maximum 1000 seeds weight,

seed yield per plant, per plot as well as per hectare, seed germination, seedling root length, seedling shoot length, seedling dry weight and seed vigour-I&II. Application of GA₃ 350 ppm recorded maximum number of seeds per capitulum and number of black seeds per capitulum. However, the maximum 1000 seeds weight, seed yield per plant, per plot as well as per hectare, seed germination, seedling root length, seedling shoot length, seedling dry weight and seed vigour-I & II was noticed with foliar spray of 250 ppm GA₃.

All interactions had exhibited a significant effect on number of seeds per capitulum but no interaction increased the number of black seeds per capitulum. Season and pinching interaction (S×P) was found significant in increasing all seed qualitative parameters except 1000 seeds weight. Season and GA₃ (S×G) was only interaction which exerted a significant effect on seed yield (per plant, per plot as well as per hectare) and 1000 seeds weight.

Seed germination, seedling shoot length, seedling dry weight and seed vigour-I&II were also influenced significantly due to season and GA₃ (S×G) interaction. Likewise, effect of pinching and GA₃ (P×G) interaction significantly enhanced seed germination, seedling root length, seedling shoot length and seed vigour-I. Significant increase in number of seeds per capitulum, seed germination, seedling shoot length, seedling root length and seed vigour-I was recorded due to effect of season, pinching and GA₃ (S×P×G) interaction.

Un-pinched plants of winter sprayed with GA₃ 350 ppm (S₁P₁G₃) produced the maximum number of seeds per capitulum. Application of GA₃ 250 ppm with pinching at 2 WAT significantly recorded maximum seed germination, seedling root length and seed vigour-I in winter (S₁P₂G₂), while longest seedling shoot length was recorded in summer plants pinched at 2 WAT with GA₃ 250 ppm (S₂P₂G₂).

CONCLUSION

From the present investigation it may be concluded that application of GA₃ 250 ppm on plants pinched at two weeks after transplanting showed better results in terms of growth, flowering and yield of African marigold. The maximum fresh & dry weight of plant, number of buds and flowers per plant and seedling shoot length was observed with GA₃ @ 250 ppm and pinching at two weeks after transplanting in summer season, whereas, maximum flower yield per plant and per hectare, 1000 seeds weight, seed yield per plant and per hectare, seed germination, seedling root length, seedling dry weight and seed vigour-I&II was observed in winter season.

It was also found that earliest appearance of 1st flower observed in un-pinched plants of summer season sprayed with GA₃ 350 ppm, whereas, earliest bud initiation, maximum flower diameter, duration of flowering, fresh & dry weight of flower, number of seeds and number of black seeds per capitulum were recorded in un-pinched plants of winter season .

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Annexure-I: Weekly meteorological data prevailing during crop growth period in summer season of 2015-16

Standard Week No.	Duration	Mean Temperature (⁰ C)		Relative Humidity (%)		Average Wind Speed (Km/hr)	Bright Sunshine (hrs)	Rainfall (mm)
		Maximum	Minimum	Morning	Evening			
1	01 January – 07 January	16.1	7.6	97	81	3.3	1.8	0.4
2	08 January – 14 January	14.9	6.3	98	77	4.0	2.8	0.6
3	15 January – 21 January	18.6	4.8	99	62	3.0	5.9	0.4
4	22 January – 28 January	14.7	7.2	98	83	4.0	0.8	0.9
5	29 January – 04 February	18.8	6.0	88	59	4.4	5.5	1.2
6	05 February – 11 February	21.9	6.2	92	46	3.2	8.2	0.0
7	12 February – 18 February	24.3	9.5	90	53	6.6	6.6	0.0
8	19 February – 25 February	25.9	14.4	97	63	5.1	4.5	0.5
9	26 February – 04 March	22.4	9.2	87	57	5.1	6.0	5.8
10	05 March – 11 March	23.5	8.3	93	58	4.0	8.2	2.5
11	12 March – 18 March	24.8	11.8	94	57	4.9	6.0	7.0
12	19 March – 25 March	29.4	13.9	92	43	2.7	9.1	0.0
13	26 March – 01 April	32.4	17.5	88	45	6.0	7.4	2.0
14	02 April – 08 April	29.9	17.2	88	45	6.4	8.0	9.7
15	09 April – 15 April	32.1	17.9	79	40	4.2	8.5	0.8
16	16 April – 22 April	36.0	20.0	67	30	4.6	9.5	1.6
17	23 April – 29 April	38.0	21.6	56	27	8.7	9.8	0.9
18	30 April – 06 May	39.2	20.9	63	20	5.5	9.6	0.0
19	07 May – 13 May	40.5	24.3	58	29	6.5	8.6	0.0
20	14 May – 20 May	38.2	22.8	66	32	6.1	8.3	0.0
21	21 May – 27 May	42.6	22.9	44	18	7.1	9.6	0.0
22	28 May – 03 June	40.3	24.0	60	34	7.8	8.9	0.0

Source: Department of Agricultural Meteorology, CCS Haryana Agricultural University, Hisar

Annexure-II: Weekly meteorological data prevailing during crop growth period in winter season of 2015-16

Standard Week No.	Duration	Mean Temperature (⁰ C)		Relative Humidity (%)		Average Wind Speed (Km/hr)	Bright Sunshine (hrs)	Rainfall (mm)
		Maximum	Minimum	Morning	Evening			
36	03 September – 09 September	36.8	22.6	73.6	34.7	5.4	9.9	0.0
37	10 September– 16 September	37.9	23.3	73.7	35.6	4.4	9.8	0.0
38	17 September – 23 September	33.9	23.4	87.1	55.3	7.3	4.7	1.3
39	24 September – 30 September	34.1	20.7	79.3	43.9	5.0	9.1	1.5
40	01 October – 07 October	36.6	19.3	82.0	30.4	3.4	9.7	0.0
41	08 October – 14 October	36.7	20.1	67.6	28.4	4.6	9.3	0.0
42	15 October – 21 October	35.2	20.1	84.9	33.1	3.9	7.7	0.0
43	22 October – 28 October	32.3	16.7	80.1	34.6	4.8	8.4	1.0
44	29 October – 04 November	28.0	14.2	93.6	38.3	2.3	4.9	0.0
45	05 November – 11 November	27.4	15.5	94.3	51.4	3.8	3.6	0.4
46	12 November – 18 November	29.1	12.8	85.9	36.3	2.7	7.5	0.0
47	19 November – 25 November	27.7	9.0	90.6	36.1	1.2	7.7	0.0
48	26 November – 02 December	25.3	9.5	95.1	50.1	2.5	4.2	0.0
49	03 December – 09 December	25.5	8.8	97.3	51.4	2.2	5.5	0.0
50	10 December – 16 December	21.4	7.1	94.6	45.3	3.4	5.2	0.0
51	17 December – 23 December	21.0	3.5	98.1	44.0	2.0	6.2	0.0
52	24 December – 31 December	21.0	4.0	93.0	42.0	2.0	6.4	0.0
1	01 January – 07 January	22.7	6.4	97.3	57.9	2.1	4.9	0.0
2	08 January – 14 January	22.4	8.4	95.1	58.6	2.7	4.9	0.0
3	15 January – 21 January	15.3	6.1	89.7	75.3	2.9	2.2	0.0
4	22 January – 28 January	16.4	5.5	97.4	66.3	3.4	4.2	0.0
5	29 January – 04 February	22.3	7.7	94.7	52.6	2.6	6.2	0.0

Source: Department of Agricultural Meteorology, CCS Haryana Agricultural University, Hisar

ABSTRACT

Title of Thesis : **Effect of pinching and gibberellic acid on growth, flowering and yield of African marigold (*Tagetes erecta* L.) under different seasons**

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Admission No. : 2013A23D

Title of Degree : Doctor of Philosophy

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Year of Award of Degree : 2017

Major Subject : Horticulture–Floriculture and Landscape Architecture

Total No. of pages in the thesis : 89+v+II

No. of words in the abstract : 289

Key word: African marigold, season, pinching, gibberellic acid, growth, flowering and yield.

The present experiment entitled “**Effect of pinching and gibberellic acid on growth, flowering and yield of African marigold (*Tagetes erecta* L.) under different seasons**” was conducted at Experimental Orchard of Department of Horticulture, CCS Haryana Agricultural University, Hisar during the crop season of 2015-16. Treatments comprised of four levels each of pinching (P₁ - No pinching, P₂ - Pinching at 2 WAT, P₃- Pinching at 3 WAT and P₄ - Pinching at 4 WAT) and gibberellic acid (G₀ - Control, G₁ - 150 ppm, G₂ - 250 ppm and G₃ - 350 ppm) with two different seasons i.e. winter and summer. This experiment comprising sixteen treatments in each season was laid out as factorial Randomized Block Design with three replications. Five competitive plants were randomly selected from each treatment to record data on growth, flowering, flower yield and seed parameters. Statistical analysis of data revealed that application of GA₃ 250 ppm on plants pinched at two weeks after transplanting showed better results in terms of growth, flowering and yield of African marigold.

In summer season, maximum fresh & dry weight of plant, number of buds and flowers per plant and seedling shoot length was observed with application of GA₃ 250 ppm and pinching at 2 week after transplanting while, maximum flower yield, 1000 seeds weight, seed yield, seed germination, seedling root length, seedling dry weight and seed vigour-I&II observed in winter season. It was also recorded that earliest appearance of 1st flower was observed in un-pinched plants sprayed with GA₃ 350 ppm during summer season, however, earliest bud initiation, maximum flower diameter, duration of flowering, fresh & dry weight of flower, number of seeds and number of black seeds per capitulum were recorded in un-pinched plants of winter season.

MAJOR ADVISOR

SIGNATURE OF STUDENT

HEAD OF THE DEPARTMENT

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Degree	University/ Board	Year of passing	Percentage/ Grades	Subjects
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M. Sc. (Horticulture)	CCS HAU, Hisar	2013	75.20	Horticulture
PhD (Horticulture)	CCS HAU, Hisar	2017	78.60	Horticulture

- (k) **Co-curricular activities** : Listening music, reading books and cooking
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- (m) **List of publications** :

Research papers published : 07

From M.Sc. research work : 04

1. Sonu Sheoran, O.P. Dudi, B.S. Beniwal and R.P.S Dalal, 2015. Effect of nitrogen and spacing on flowering and yield of tuberose (*Polianthes tuberosa* L.) cv. Prajwal *Annals of Biology*, **31**(2): 270-274.
2. Sonu Sheoran, B.S. Beniwal, O.P. Dudi and R.P.S. Dalal, 2015. Effect of nitrogen and spacing on growth and yield of tuberose (*Polianthes tuberosa* L.) cv. Prajwal *Annals of Agri-Bio Research*, **20**(2): 212-215.
3. Sonu Sheoran, B.S. Beniwal, O.P. Dudi, O.P. Sheoran and R.P.S. Dalal, 2016. Effect of nitrogen and spacing on flower yield and bulb production of tuberose cv. Prajwal *Annals of Agri-Bio Research*, **21**(2): 155-159.
4. Sonu Sheoran, B.S. Beniwal, O.P. Dudi and Sheena Nain, 2016. Effect of nitrogen and spacing on nutrient content of tuberose (*Polianthes tuberosa* L.) cv. Prajwal *Annals of Biology*, **32**(2): 224-227.

Abstracts published : 10

From current research work : 02

1. Sonu Sheoran, B.S. Beniwal and R.P.S. Dalal, 2016. Regulation of plant growth by pinching and GA₃ application in African marigold (*Tagetes erecta* L.) under different seasons. In: 7th Horticulture Congress 2016, Doubling Farmers income through Horticulture jointly organized by ICAR, Horticultural Society of India & Ministry of Agriculture & Farmers Welfare, New Delhi held on 15-18 November, 2016, pp. 284-285.
2. Sonu Sheoran, B.S. Beniwal and R.P.S. Dalal, 2017. Floral and yield attributes of African marigold as influenced by pinching and gibberellic acid. In: National Conference on Advances in Indian Floriculture with Focus on North-East & Hill Region jointly organized by CIH, Medziphema (Dimapur), Nagaland & ISOH, ICAR-IARI, New Delhi & Department of Horticulture, Nagaland held on 13-15 January, 2017, pp. 63-64.

I, hereby, declare that all the information given in the resume is true to the best of my knowledge.

Date:

Place:

Sonu Kumari

UNDERTAKING OF COPY RIGHT

I, **Sonu Kumari**, Admission No. **2013A23D** undertake that I give copy right to the Chaudhary Charan Singh Haryana Agricultural University, Hisar of my thesis entitled, **“Effect of pinching and gibberellic acid on growth, flowering and yield of African marigold (*Tagetes erecta* L.) under different seasons”**.

I also undertake that, patent, if any, arising out of the research work conducted during the program shall be filed by me only with due permission of the competent authority of CCS HAU, Hisar.

Sonu Kumari