EFFECT OF GROWTH RETARDANTS ON GROWTH AND YIELD OF AFRICAN MARIGOLD (*Tagetes erecta* L.).

by

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THESIS

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DECLARATION

I, hereby declare that this thesis entitled **"EFFECT OF GROWTH RETARDANTS ON GROWTH AND YIELD OF AFRICAN MARIGOLD (*Tagetes erecta* L.)."**is a bonafide record of research work done by me during the course of research and the thesis has not previously formed the basis for the award to me of any degree, diploma, associateship, fellowship or other similar title, of any other University or Society.

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LIST OF ABBREVIATIONS

%	-	Percent
°C	-	Degree Celsius
CCC	-	Chlormequat Chloride
CD	-	Critical Difference
cm	-	Centimeter
cm^2	-	Centimeter square
DAT	-	Days after transplanting
et al	-	And others
g	-	Gram
ha^{-1}	-	Per hectare
KAU	-	Kerala Agricultural University
Kg	-	Kilogram
mg	-	Milligram
RARS	-	Regional Agricultural Research Station
SEm	-	Standard Error
SCMR	-	SPAD Chlorophyll Meter Reading
SPAD	-	Soil Plant Analysis Development
t	-	tons

INTRODUCTION

INTRODUCTION

African marigold (*Tagetes erecta* L. Family: Asteraceae) is one of the most popular annual flower crop grown on a commercial scale throughout different states of India. Marigold is a native of Central and South America, especially Mexico (Kumari and Choudhary, 2012). The genus *Tagetes* consists of about 33 species. Out of these, *Tagetes erecta, Tagetes minuta, Tagetes patula* and *Tagetes tenuifolia* are commercially exploited for their ornamental value and for oil extraction (Vasudevan *et al.*, 1997).

In India, marigold occupies nearly two-third of total loose flower growing area and the major growing states are Karnataka, Tamil Nadu, Andhra Pradesh, West Bengal and Maharashtra (Majumder *et al.*, 2014). The total area under marigold cultivation is around 55.89 mha of which Karnataka contributes to the maximum in terms of area (9.10 mha) and Madhya Pradesh leads in production of marigold (89 mtons) (NHB Database, 2014).

Marigold is popular among farmers due to ease of cultivation, wider adaptability to thrive in varying agro-climates, shorter duration of crop, pest and disease resistance and its versatile uses. The flowers are mostly marketed as loose as they have great demand during festive seasons and also as cut flowers for decorative purposes. It provides beauty to the landscape by being highly suitable for making flower beds in herbaceous borders and shrubberies. Besides these, the bioactive extracts of different *Tagetes* plant parts exhibit nematicidal, fungicidal and insecticidal activities. They also possess many medicinal properties such as anti-helminthic, analgesic, anti-inflammatory, bronchodialatory, digestive, diuretic, emmanogogue, stomachic and sedative. Nowadays, the importance of marigold flowers is increasing as they are commercially utilized for the extraction of perfumes, natural colours and pigments.

Recently, the demand for marigold flowers is growing, for extraction of perfumes, natural colours and pigments. African marigold is recognized as a potential source of carotenoid pigments such as lutein and zeaxanthin (Jothi,

2008). They are currently used as food colorants, nutritional supplements and poultry feed additives to improve the colour of egg yolk and poultry skin colour (Hadden *et al.*, 1999) and in ophthalmology for the treatment of diseases like cataract and age related macular degeneration (ARMD). Some carotenoids act as precursors of vitamin A and protect the body from damaging reactions by acting as physiological antioxidants and thus improving the immunity of body. They also help to slow down the growth of induced skin tumors, other dermatological diseases and lowering overall risk of cancer in human beings (Gupta, 2014).

Though marigolds are hardy and quick growing plants, because of excessive vegetative growth, the plants become tall and lanky which leads to poor flowering habit and resulting in lower yield. Growth and yield in plants are highly influenced by various agro-techniques. In the recent past use of different agrochemicals in floriculture finds extensive use. Growth regulators find their extensive use in ornamental crops for modifying their developmental process including growth and flowering. Among the different plant growth regulators, some are growth promoters while others are growth retardants. Plant growth retardants are synthetic compounds, which are used to reduce the shoot length of plants in a desired way without changing developmental patterns or being phytotoxic (Rademacher, 2000).

Plant growth retardants are commercially used to retard vegetative growth, suppress apical dominance, induce lateral buds, produce more number of flowers and increase flower yield in various ornamental crops. Growth retardants control excessive vegetative growth by preventing excessive stem elongation and reducing internodal length in plants. Besides controlling plant height, application of growth retardants also helps to increase the number of lateral branches, suppress excessive vegetative growth, resulting in larger number of inflorescences (Latimer and Whipker, 2013).

It has been found that the use of growth retardants such as of Chloremequat chloride and Daminozide were effective in many floricultural crops

to induce lateral branches and to increase flower yield (Bailey and Whipker, 1998 a).

Research on use of plant growth retardants for increasing flower yield in marigold is scanty. Therefore the present study was carried out with an objective to find out the effect of two growth retardants, Alar and Cycocel on growth, yield and carotenoid content in Pusa Narangi Gainda and Maxima Yellow, F_1 varieties of African marigold.

REVIEW OF LITERATURE

2. REVIEW OF LITERATURE

Marigold is a 'flower of common man' with multipurpose uses. It has a great economic potential in loose flower trade. It gains popularity on account of its free flowering habit, short duration, attractive colour, shape and keeping quality. Out of all the commercially grown flower crops, the quantitative demand of marigold is the highest, particularly in North East and South India. The demand for marigold flowers is very high at the time of Dussehra, Diwali and Ugadi festivals in North India and Onam and Pongal in South India (Gothwal *et al.,* 2013). Apart from its significance in ornamental horticulture and landscaping, it has been highly valued as an important source of essential oils and carotenoid pigments. All the plant parts (leaves, root, stem and flowers) are used for the extraction of phytochemicals. In India, marigold occupies two third of total loose flower growing area and South India leads in its production with Karnataka as the leading producer followed by Tamil Nadu, Andhra Pradesh, West Bengal and Maharashtra. To get maximum returns through marigold production, scientific cultivation and agro- techniques for improving productivity are to be adopted.

Commercial floriculturists have been using plant growth regulators for many years as a production tool. Plant growth retardant compounds coming under plant growth regulators are commercially used in floriculture to manipulate plant growth in a desired way. Initially, they were used as a tool to control plant height and to promote rooting. Nowadays, they are being used to serve many fascinating and innovative purposes in the field of floriculture. Growth retardants have been used in the field of agriculture for more acceptable plant characteristics like compact growth, dwarfness, increased number of branches and more number of quality flowers (Song et al, 1990). Primary action of growth retardants is by reducing cell elongation and also by reducing the rate of cell division. Most of the plant growth retardants are antagonistic to gibberellins and auxins, those plant hormones that are primarily responsible for shoot elongation (Bailey and Whipker, 1998 b). Growth retardant treated plants do not ultimately results in stunted or completely suppressed growth and also the rate of development and

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vigor of the plants remain unaffected. In contrast, these compounds suppress apical dominance by inhibiting cell division in the apical meristem.

Alar commonly known as Daminozide, Dazide or B-Nine is one of the most commonly used plant growth retardant in the floriculture industry. It reduces internodal elongation by blocking gibberellin biosynthesis, the plant hormone responsible for cell elongation. Chlormequat chloride commonly known as Cycocel, Citadel or Chlormequat E-Pro is another commonly used plant growth retardant. Cycocel also reduces internodal elongation in plants. But unlike Alar, Cycocel inhibits Gibberellic acid production in the early steps of biosynthesis (Rademacher, 2000).

With respect to the distinct mode of action of the above mentioned growth retardants, their effect on vegetative growth, yield and carotenoid content have been studied on two varieties of African marigold cv. Pusa Narangi Gainda and Maxima Yellow F_1. Available literatures on above aspects in marigold and related species are reviewed here under two headings.

Effect of Alar on plant growth, yield and carotenoid content in ornamentals

Effect of Cycocel on plant growth, yield and carotenoid content in ornamentals

2.1 EFFECT OF ALAR ON PLANT GROWTH, YIELD AND CAROTENOID CONTENT IN ORNAMENTALS

Alar is one of the systemic plant growth retardant and hence has various effects in different plants (Basra, 1994). It belongs to the group of succinic acid. The active ingredients of the retardant are Succinic acid 2,2-dimethyl hydrazide 85.0 % and inert ingredients 15.0 %. Daminozide inhibits Gibberellic acid biosynthesis by being a structural mimic of 2-oxoglutaric acid and interferes with later steps of Gibberellin biosynthesis. At the end of the Gibberellic acid production process Alar renders a key enzyme for making Gibberellic acid production useless, thus reducing gibberellin levels. Alar reduced plant stature by reducing internodal length as a result of compact cells (Read and Hoysler, 1971).

2.1.1 Alar on vegetative growth

2.1.1.1 Plant height

In an experiment conducted by Renu and Srivastava (2013) poinsettia plants treated with Alar 2000 ppm recorded minimum plant height at 30, 60 and 90 days (12.95 cm, 25.63 cm and 35.45 cm respectively) compared with the control plants . Pushkar and Singh (2015) conducted an experiment to study the influence of mechanical pinching and growth retardants on African marigold var. Pusa Narangi Gainda and noticed that minimum plant height (78.13 and 81.29 cm in 2007-08 and 2008-09 respectively) was recorded with Alar 3000 ppm.

Karlovic *et al.* (2004) studied the influence of daminozide on Chrysanthemum cultivar 'Revert' and reported that single foliar application of daminozide at 3000 ppm in the first year and 2000 ppm in the second year was most efficient in reducing plant height (12.56 %) compared with the control. Since there was no significant difference between these two concentrations, lower concentration of daminozide was recommended to 'Revert' Chrysanthemum.

Joshi and Reddy (2006) studied the effect of Cycocel and Alar on growth and flowering parameters in China aster (*Callistephus chinensis* L.Nees). They reported that minimum plant height was recorded with Alar 1200 ppm (32.88 cm). El-Sheibany *et al.* (2007) studied the effect of Alar on some vegetative characters of local cultivar of Chrysanthemum and reported that application of Alar at all concentrations resulted in significant reduction in plant height compared with the control. Anburani and Ananth (2010) evaluated the effect of retardants such as Alar, Cycocel, MH and Ethrel on growth and flowering in nerium. They observed that, all growth retardants effectively controlled plant height and the rate of retardation increased with higher concentrations and minimum plant height (132.06 cm) was recorded with Alar at 1500 ppm.

According to Bhat *et al.* (2011), who studied the effect of Cycocel and B-9 on growth of *Erysimum marshallii*, Alar spray at different concentrations did not show any significant effect in reducing plant height.

Hashemabadi *et al.* (2012) investigated the effect of Cycocel and Daminozide on *Calendula officinalis* and reported that single application of daminozide and combination application along with Cycocel significantly reduced plant height. Interaction effect of Cycocel and Daminozide decreased plant height by 19 % less than that of control.

2.1.1.2 Number of primary and secondary branches per plant

According to a study conducted by Kumari *et al.* (2013), to find out the effect of growth retarding chemicals such as Maleic hyrdrazide and Alar on African marigold cv. Pusa Narangi Gainda, maximum number of primary branches was observed with MH 500 ppm which was statistically significant with all other concentrations of Alar at 500 ppm, 1000 ppm and 1500 ppm except for Alar at 2000 ppm. Renu and Srivastava (2013) also reported that plants sprayed with Alar 2000 ppm were more compact in a study where poinsettias were sprayed with Cycocel and Alar.

In Dahlia, Malik *et al.* (2017) studied the effect of different growth regulators such as Ethephon, Alar and Maleic hydrazide at different concentrations and observed that the number of primary and secondary branches per plant increased with the increase in the concentration of growth regulators. They also observed that among the different growth regulators applied, Alar 3000 ppm recorded the shortest primary branches.

2.1.1.3 Stem girth and internodal length

El-Sheibany *et al.* (2007), in Chrysanthemum, reported that application of Alar at different concentration resulted in differential response as stem thickness was directly proportional to increase in Alar concentration and internodal length was inversely proportional to Alar concentration.

Ghosh and Rao (2015) studied the effect of different growth retardants on quality of pot chrysanthemum production and noticed that application of Alar on pot Chrysanthemum resulted in reduced plant height by reducing internodal length and reduce breakage during shipping.

2.1.1.4 Leaf area and total biomass

According to Joshi and Reddy (2006), gradual increase in leaf area was recorded with increase in concentrations of Alar in China aster. On contrary to this, Bhat *et al.* (2011) reported that, plants sprayed with different concentrations of Alar did not show any significant effect on leaf area, total fresh and dry mass in *Erysimum marshallii.* It was almost comparable with different concentrations of Alar but slightly less as compared to control. Kumari *et al.* (2013) also observed that Alar and MH did not show any significant variation in leaf area, leaf fresh weight and dry weight in African marigold.

2.1.1.5 Leaf chlorophyll

Asrar *et al.* (2014) studied the effect of Alar on Chrysanthemum and observed that Alar sprayed plants recorded significantly higher relative leaf chlorophyll content. Higher values of chlorophyll content were recorded with 1500 ppm Alar over 3000 or 4500 ppm. Application of Alar on pot Chrysanthemum significantly increased leaf chlorophyll content and resulted in deep green colour foliage (Ghosh and Rao, 2015). On contrary, Kazaz *et al.* (2010) reported that chlorophyll *a* and *b* were unaffected by Alar application in Chrysanthemum *morifolium* Ramat.

2.1.2 Alar on flower and yield characters

2.1.2.1 Days to flowering

Pushkar and Singh (2012) reported that spraying Alar at 1500 ppm was found to be very effective in early bud initiation and flowering in African marigold cv. Pusa Narangi Gainda. Similarly, Kumari *et al.* (2013) reported that Alar application at 2000 ppm was effective in attaining earliness in reproductive stage and bud initiation which was statistically on par with MH 750 ppm and Alar 1000 ppm in African marigold. Joshi and Reddy (2006) reported that Alar at lower concentrations of 150 ppm was very effective in inducing early flowering in China aster. In poinsettias, minimum number of days to flowering (58.79 days)

was observed with application of Alar 2000 ppm over control (Renu and Srivastava, 2013).

As reported by Asrar *et al.* (2014), Alar application has also resulted in earliness in flowering but the plant response to the product was not consistent and has resulted in delayed flowering in some cases. According to Malik *et al.* (2017), who studied the effect of different growth regulators in Dahlia, all growth regulators delayed the appearance of first flower bud and colour break. Similar results are reported by Hashemabadi *et al.* (2012) in *Calendula officinalis.*

2.1.2.2 Flower parameters

Singh and Bhattacharjee (1998) reported that preharvest spray of Alar 1000 ppm had a significant influence in improving flower characters like flower bud size, flower diameter and petal size in cut roses 'Rakthagandha'. Hashemabadi *et al.* (2012) reported that spraying plants with Cycocel and Alar had no significant effect on fresh flower weight in *Calendula officinalis.* Similarly, there was no significant effect noticed with the application of different concentrations of Alar and MH on bud diameter and peduncle length in African marigold (Kumari *et al.*, 2013).

Pushkar and Singh (2012) reported that, application of growth retardant treatments significantly reduced the size and weight of individual flowers in African marigold. In Chrysanthemum, Asrar *et al.* (2014) observed that flower parameters varied with different concentrations of Alar. Alar at 1500 ppm recorded the maximum flower diameter and flower weight followed by Alar 3000 ppm and 4500 ppm. On contrary to this, Malik *et al.* (2017) reported that Alar application followed a reverse trend in bud size and bud diameter with increasing concentration, increased fresh flower weight was observed in Dahlia and it was also reported that shortest peduncle length (14.39 cm) was recorded with Alar 3000 ppm.

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2.1.2.3 Number of flowers

In China aster, the plants applied with Alar at 1200 ppm reported significant increased number of flowers per plant (52.84) as reported by Joshi and Reddy (2006). In an experiment conducted by Hashemabadi *et al.* (2012), Cycocel spray at 500 ppm along with Alar 1500 ppm resulted in highest number of flowers per plant in *Calendula officinalis*. The treatments increased the flower number by 150 % over control. In marigold, application of Alar at higher concentrations of 3000 ppm resulted in maximum number of flowers per plant (Kumari *et al.,* 2013). In Dahlia, among the different growth retardants applied, highest flower number was recorded with MH 500 ppm (45.18) followed by Alar 1000 ppm (40.13) as reported by Malik *et al.* (2017).

2.1.2.4 Flower yield

There are many previous studies reporting increased flower yield with application of different growth retardants. It was reported by Joshi and Reddy (2006) that Alar at 1200 was found effective in improving the yield in China aster. According to Pushkar and Singh (2012), spraying of plants with Alar 3000 ppm recorded maximum flower yield per plant in African marigold. In Chrysanthemum, Asrar *et al.* (2014) reported that Alar 1500 ppm recorded the maximum number of flowers per plant followed by Alar 3000 ppm and 4500 ppm.

2.1.2.5 Flowering duration

In an experiment conducted by Pushkar and Singh (2012) Alar at higher concentrations of 3000 ppm recorded maximum duration of flowering (61.86 days) in African marigold. Renu and Srivastava (2013) reported that Alar application at 2000 ppm (97.95 days) significantly influenced flowering duration in poinsettia which was statistically on par with Alar 1000 ppm (95.96 days). In Dahlia, Malik *et al.* (2017) recorded maximum flowering period (63.07 days) with control which was statistically similar to Alar 1000 ppm (61.17 days).

2.1.2.6 Post-harvest longevity of flowers

Preharvest spray of Alar at 1000 ppm significantly improved the vase life of cut 'Rakthagandha' roses (Singh and Bhattacharjee, 1998). According to a study conducted by Pushkar and Singh (2012) in marigold, Alar application at 3000 ppm resulted in maximum vase life of flowers (10.92 days). Kumari *et al.* (2013) also reported that Alar spray at 1000 ppm recorded maximum flower longevity in African marigold.

2.1.3 Alar on carotenoid content

In an experiment conducted by Kazemi *et al.* (2014), the effect of Cycocel and Alar on carotenoid content in pot marigold was studied. They observed that drench application of both the growth retardants was significantly effective in improving the carotenoid content in pot marigold.

2.2 EFFECT OF CYCOCEL ON PLANT GROWTH, YIELD AND CAROTENOID CONTENT IN ORNAMENTALS

Cycocel is one of the well-known plant growth retardant used to produce quality plants. Cycocel is generally used in floriculture crops like geraniums, hibiscus, poinsettias and begonias to control stem elongation resulting in reduced plant height and compact appearance of plants. Cycocel or 2-chloroethyl tri-methyl ammonium chloride is grouped under onuim compounds, i.e. compounds that possess positively charged ammonium, phosphonium or sulphonium groups that block Gibberellic acid biosynthesis directly before ent-Kaurene. Chloremequat chloride is one of the most extensively used plant growth retardant to control shoot growth in many floricultural crops (Davis and Andersen, 1988). It acts as a growth retardant by inhibiting gibberellin biosynthesis in sub apical meristem by preventing the cyclization of geranyl geranyl pyrophosphate to copallyl pyrophosphate (Rademacher, 2000).

2.2.1 Cycocel on vegetative growth

2.2.1.1 Plant height

A study conducted by Joshi and Reddy (2006) in China aster, revealed that application of Cycocel resulted in a reduction in plant height with increasing concentrations. According to Dani *et al.* (2010), foliar spray of Cycocel at 750 ppm 15 days after transplanting resulted in significantly minimum plant height (66.47 cm) and maximum plant spread in African marigold cv. Double Orange.

Bhat *et al.* (2011), reported that reduction in plant height was observed with application of Cycocel at 1000 and 1500 ppm in *Erysimum marshallii* and reduction in plant height increased with increase in Cycocel concentration. Kumar *et al.* (2011), based on the investigation conducted on the effect of Cycocel and GA_3 on African marigold cv. Pusa Narangi Gainda reported that Cycocel in varying levels were highly effective in reducing plant height. Minimum plant height was recorded with Cycocel at 2400 ppm (56.58 cm). Spraying of Cycocel at 2000 ppm resulted in maximum reduction in plant height (12.9% compared with control), in African marigold cv. Pusa Narangi Gainda by Khan *et al.* (2012).

On comparing the effect of different growth regulators (Cycocel, NAA, GA_3, and ethrel) by Rajyalakshmi and Rajasekhar (2014) in African marigold, significantly minimum plant height was recorded with Cycocel 500 ppm in August, September and October dates of planting (70.67 cm, 63.33cm and 40.93cm respectively). According to a study conducted by Vaghasia and Polara (2015) in Chrysanthemum, Cycocel resulted in significant reduction of plant height and increase in plant spread.

2.2.1.2 Number of primary and secondary branches

Cycocel application in China aster was found to be effective in increasing the number of laterals as reported by Joshi and Reddy (2006). Dani *et al.* (2010), reported that plants receiving foliar spray of Cycocel 750 ppm significantly

influenced the number of branches per plant in African marigold cv. Double Orange.

In *Erysimum marshalli,* plants sprayed with Cycocel 1500 ppm recorded maximum number of laterals per plant (Bhat *et al*., 2011). In poinsettia, Renu and Srivastava (2013) reported that Cycocel spray at 3000 ppm recorded maximum number of branches. In African marigold, Rajyalakshmi and Rajasekhar (2014) reported that foliar spray of Cycocel 500 ppm recorded significant increase in number of side shoots in August, September and October dates of planting (16.53, 12.67 and 11.67 respectively).

2.2.1.3 Stem girth and internodal length

According to a study conducted by Renu and Srivastava (2013) on the effect of growth retardants in Poinsettia, minimum internodal length was recorded with increase in concentration of Cycocel. Similar effect was reported by Vaghasia and Polara (2015) in Chrysanthemum.

2.2.1.4 Leaf area and total biomass

In China aster, Joshi and Reddy (2006) reported that Cycocel at 2000 ppm recorded maximum leaf area (597.56 cm^2). According to Naji *et al*. (2015), leaf area Lily cultivar, Brunello increased as a result of spraying with Cycocel.

In *Erysimum marshallii,* leaf area, total fresh and dry mass of plants were found to decrease with the application of Cycocel at 1000 and 1500 ppm (Bhat *et al*., 2011). According to Azzaz *et al*. (2007), significant reduction in dry weight of plants was noticed with the application of Cycocel at all concentrations in *Calendula officinalis.*

2.2.1.5 Leaf chlorophyll content

Spraying of plants with Cycocel 2000 ppm resulted in dark green leaves with higher chlorophyll content in China aster (Joshi and Reddy, 2006). In Heliconia plants, Jadhav *et al.* (2015), reported that application of CCC at 100ppm as soil drench resulted in increased chlorophyll content.

2.2.2. Cycocel on flower and yield characters

2.2.2.1 Days to flowering

Cycocel spray at lower concentration of 500 ppm was found to have significant effect in inducing early flowering (50.38 days) in China aster (Joshi and Reddy, 2006). Significantly minimum number of days to first flowering and 50 % flowering were recorded in plants treated with Cycocel 750 ppm at 15 days after transplanting in African marigold (Dani *et al.*, 2010). Cycocel at 1500 ppm recorded minimum number of days to first flowering (51.68 days) and 50 % flowering (60.25 days) as reported by Kumar (2011) in China aster. Pushkar and Singh (2012) studied the effect of different levels of Alar and Cycocel on African marigold cv. Pusa Narangi Gainda and reported that Cycocel at lower concentration of 500 ppm was effective in early initiation of bud and commencement of flowering. This is contradictory to the results of Khan *et al.* (2012), who reported delayed first flower bud appearance (5.81 days) compared with control with the application of Cycocel at 2000 ppm in African marigold.

2.2.2.2 Flower parameters

The spraying of Cycocel was found to decrease the flower diameter in China aster as reported by Joshi and Reddy (2006). In African marigold cv. 'Double orange', Dani *et al.* (2010), reported that Cycocel spray of 750 ppm at 15 days after transplanting resulted in maximum flower diameter and single flower weight. Maximum flower size and individual flower weight was observed with Cycocel spray at 2000 ppm in African marigold by Khan *et al.* (2012).

In Chrysanthemum, Vaghasia and Polara (2015), reported that Cycocel application had significantly influenced flower parameters and resulted in increase in flower weight.

2.2.2.3 Number of flowers

The maximum number of flowers was recorded with Cycocel 2000 ppm in China aster by Joshi and Reddy (2006). According to Dani *et al.*, (2010), plants

treated with Cycocel 750 ppm at 15 days after transplanting significantly increased the number of flowers per plant in African marigold.cv. 'Double orange'. Kumar *et al.* (2011), reported that Cycocel at 2000 ppm was beneficial in African marigold as it resulted in maximum number of flowers per plant. Similarly, in marigold maximum number of flowers per plant (75.22 and 72.37 during 2007-2008 and 2008-2009, respectively) was observed with Cycocel 1000 ppm by Pushkar and Singh (2012).

In African marigold, Rajyalakshmi and Rajasekhar (2014) observed that foliar application of 500 ppm Cycocel recorded maximum number of flowers per plant in August, September and October dates of planting (39.86, 41.30 and 15.45 respectively).

2.2.2.4 Flower yield

Gowda and Gowda (1990), in jasmine, reported that Cycocel at 1000 ppm and 2000 ppm were effective in increasing the flower yield, N, P, K, carbohydrate and chlorophyll content in leaves. According to Suskandari and Prasetya (1998), Cycocel application along with pruning has resulted in increasing flower yield in Jasmine. In an experiment conducted by Dani *et al.*, (2010), to study the effect of growth retardants like Cycocel and Paclobutrazol in African marigold cv. 'Double orange', it was revealed that foliar spray of Cycocel 750 ppm at 15 days after transplanting significantly increased the flower yield per plant. Cycocel at 2000 ppm significantly increased the flower yield in African marigold as reported by Kumar *et al.* (2011). Pushkar and Singh (2012) also reported maximum flower yield in African marigold with Cycocel spray at 1000 ppm. Similarly in African marigold, maximum yield (517.42 g and 548.31 g during both the years of experiment) was recorded with Cycocel 500 ppm during different dates of planting (Rajyalakshmi and Rajasekhar, 2014).

2.2.2.5 Flowering duration

Pushkar and Singh (2012) reported that Cycocel at 1000 ppm recorded maximum duration of flowering (59.26 days, and 58.88 days in 2007-2008 and 2008-2009) in African marigold cv. Pusa Narangi Gainda. According to Renu

and Srivastava (2013), Cycocel application at 3000 ppm recorded maximum duration of flowering (104.23 days) in Poinsettia, which was significantly higher than all other treatments. In Chrysanthemum, Cycocel application significantly increased flowering span as reported by Vaghasia and Polara (2015).

2.2.2.6 Post-harvest longevity of flowers

In African marigold cv. 'Double orange', foliar application of Cycocel 750 ppm at 15 days after transplanting significantly increased longevity and vase life of flowers as reported by Dani *et al.* (2010). According to Pushkar and Singh (2012), maximum vase life of flowers (9.83 days, 10.92 days, 9.19 days, and 9.99 days during 2007-2008 and 2008-2009 respectively) was recorded with higher concentrations of Cycocel at 1000 ppm.

2.2.3 Cycocel on carotenoid content

Bindu (2010) studied the effect of different growth retardants (TIBA and CCC) on carotenoid content in African marigold cv. Pusa Narangi Gainda and reported that growth retardants at all concentrations resulted in more carotenoid content in petals compared with control. Maximum carotenoid per hectare was obtained with CCC at 750 ppm (28.18 kg) and minimum with 1250 ppm (18.13 kg) and the carotenoid yield per hectare was higher with all concentrations of CCC over control (12.76 kg).

According to Azzaz *et al.* (2007), significant increase in carotenoid content was recorded in *Calendula officinalis* with Cycocel at 2000 and 3000 ppm. Similar effect was reported by Kazemi *et al.* (2014), in *Calendula officinalis* with the application of Cycocel application.

MATERIALS AND METHODS

3. MATERIALS AND METHODS

The investigation entitled "Effect of growth retardants on growth and yield of African marigold (*Tagetes erecta* L.)" was conducted at the Department of Pomology and Floriculture, College of Agriculture, Padannakkad, Kasaragod during the period from September 2015 to June 2017. The experimental details are furnished below:

3.1 EXPERIMENTAL SITE:

The experimental study was conducted at the Instructional farm of College of Agriculture, Padannakad. The plot is located in the northern part of Kerala at 12^0 20' 30'' N latitude, 75^0 04' 15'' E longitude and altitude of 20 m above mean sea level.

3.2 CLIMATIC CONDITION:

The monthly meteorological data pertaining rainfall, mean minimum and maximum temperature, relative humidity and sunshine hours during the crop period from May 2016 to May 2017was recorded and are presented in Appendix III.

3.3 SOIL CHARACTERISTICS:

The soil of the experimental field was sandy.

3.4 THE EXPERIMENTAL MATERIAL:

Two varieties of African marigold, namely Pusa Narangi Gainda (V_1) and Maxima Yellow F_1 (V_2), were used in the experiment. The seeds of Pusa Narangi Gainda were obtained from the Division of Floriculture and landscaping, Indian Agricultural Research Institute, New Delhi for the first season and during the second season seeds were purchased from Dr. Yashwant Singh Parmar University of Horticulture and Forestry, Nauni, Solan, Himachal Pradesh. The seeds of Maxima yellow F_1 were obtained from East West Seed Group, Coimbatore, Tamil Nadu during May and December 2016.

3.4.1 Description of variety:

3.4.1.1 Pusa Narangi Gainda

Plants produce deep orange flowers with ruffled florets in 125-135 days after sowing. The variety is a hybrid between Cracker Jack and Golden Jubilee. Plants grow upto a height of 80-85 cm (Shirsath and Bhosale, n.d.). It yields around 25-30 t / ha of fresh flowers and 100-125 kg / ha of seeds. They are widely used for loose flower production as well as in poultry industry, food, pharmaceutical and nutraceutical industries as they are rich in carotenoids (329 mg / 1000 g petals).

3.4.1.2 Maxima Yellow F_1

Plants are medium bushy type with 60-75 cm in height, dense canopy and high flower setting with good adaptability to heat conditions. Flowers are yellow in colour fully double petaled, very compact, 7.5 – 9 cm diameter. Flowers become ready for harvest at 45-50 days after transplanting. It is an all-round outstanding variety suitable for harvesting flowers and also as a pot plant. It yields around 22 t / ha of fresh flowers (Sangamitra *et al.*, 2015).

3.5 LAYOUT OF EXPERIMENT:

The experiment was conducted at College of Agriculture, Padannakkad in two different seasons, viz. monsoon in May 2016 and pre monsoon in January 2017. The seasons were selected based on a previous study conducted by Prakash (2015) at College of Agriculture, Padannakkad, in which standardization of planting seasons on growth, flower yield and post-harvest longevity of African marigold was done. The experimental design was Split Plot with 2 main plots, 7 subplots and 3 replications. Two marigold varieties were treated with 3 different doses of 2 plant growth retardants namely, Alar and Cycocel. The two marigold varieties were the main plots: V_1 – Pusa Narangi Gainda and V_2 – Maxima Yellow F_1. The three different doses of chemical retardants and water spray as control were the 7 subplots.

Plate 1. Varieties used in main plot

a. Pusa Narangi Gainda

b. Maxima Yellow F_1

C_1 : Alar 500 ppm

C_2 : Alar 1000 ppm

C_3 : Alar 1500 ppm

C_4 : Cycocel 1000 ppm

C_5 : Cycocel 1500 ppm

C_6 : Cycocel 2000 ppm

C_7 : Water sprays as control

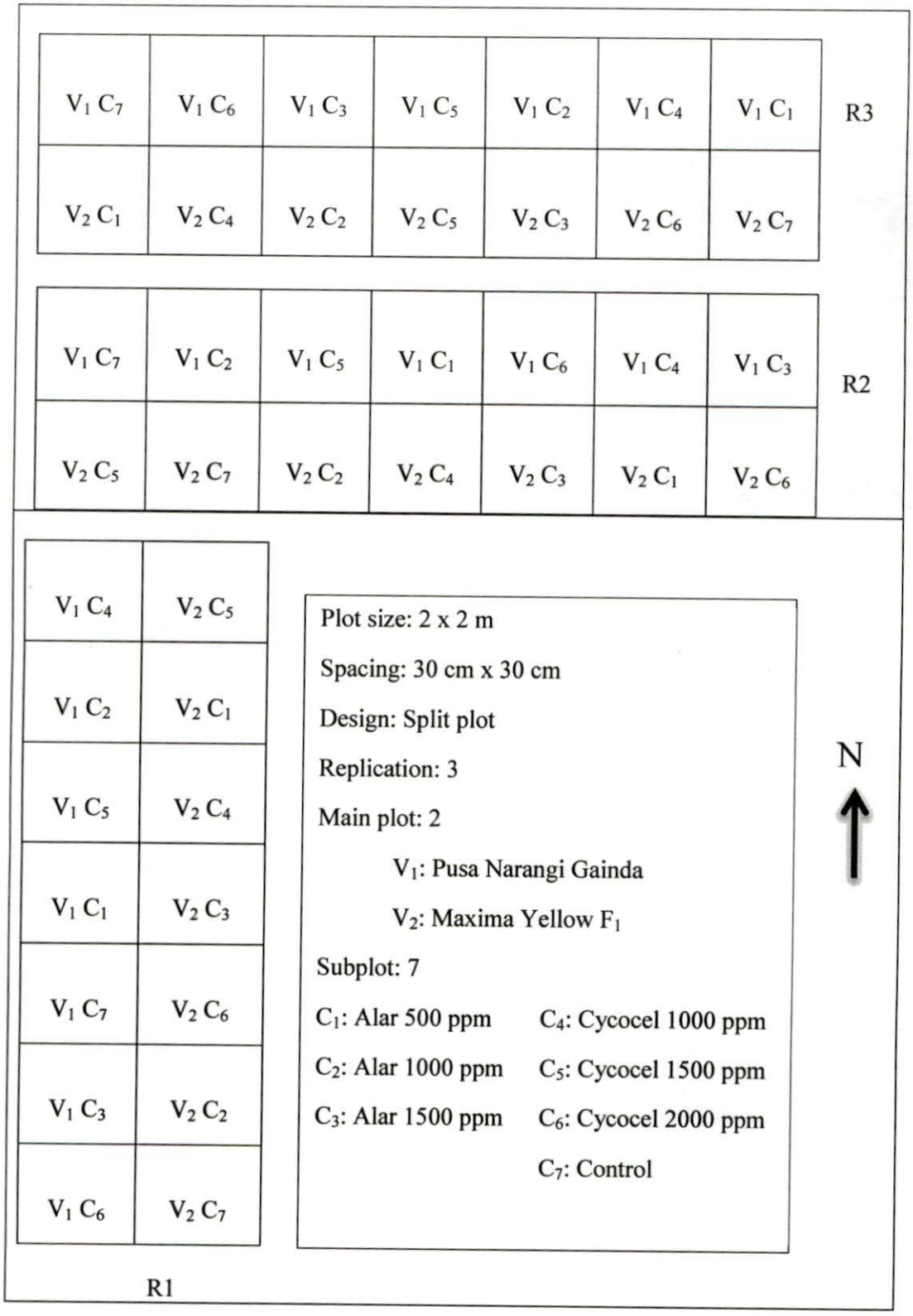
3.5.1 Nursery techniques

Seeds of both the varieties were soaked overnight and sown in pot trays filled with coir pith compost. The seeds were sown one month before transplanting during both monsoon season and pre-monsoon season, in May and January respectively. The pot trays were lightly irrigated daily using rose can. The germination percentage was 94% in Pusa Narangi Gainda and 99% in Maxima Yellow F_1. Towards the end of nursery period, seedlings developed some necrotic spots on leaves due to potassium deficiency. The symptoms disappeared with spray of 2% solution of nutrient 19: 19: 19. There was no serious pest or disease attack observed during the nursery stage.

3.5.2 Transplanting

Seedlings were ready for transplanting 3 weeks after sowing. Land preparation was done one week before transplanting and the land was well ploughed and cleared off weeds. During monsoon season, planting was done on raised beds and during pre-monsoon season ridges and furrows were prepared and planting was done in furrows.

Fig.: Layout of the field experiment



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3.5.3 Crop management

All fertilizers, farm yard manure and lime were given as basal dose as per Kerala Agricultural University, Package of Practices (2011) recommendation. Seedlings were planted at 30 cm X 30 cm spacing and a space of 60 cm was given between each plot. Mulching was done using dry leaves and the crop was irrigated daily during the pre-monsoon season during the first month and then irrigated on alternate days. Sedges and grasses were the most common weeds in the field and hand weeding was done thrice during each crop period.

3.5.4 Imposing of treatments

The plant growth retardants, Alar and Cycocel, at three concentrations and a water spray as control were sprayed 30 days after transplanting. The treatments contained 3 different concentrations of each chemical and a water spray as control. The treatments were allocated randomly within the main plot. Solutions of 500 ppm, 1000 ppm and 1500 ppm of Alar; 1000 ppm, 1500 ppm and 2000 ppm of Cycocel were prepared by dissolving calculated quantity of chemical and making up to 2000 ml so as to cover three replications of each treatment. Spraying was done in the afternoon by covering the plots on four sides using plastic sheets to prevent drifting and a wetting agent was used during monsoon season.

3.5.6 Harvesting

Fully opened flowers were harvested along with stalks during morning hours. The number of flowers and fresh weight were recorded before marketing the flowers.

3.6 COLLECTION OF EXPERIMENTAL DATA:

3.6.1 Sampling procedure:

For recording observations, 5 plants were randomly selected from each subplot per replication and tagged with labels. All biometrical observations were recorded on 40 days and 60 days after transplanting and observations on flowering and yield were also recorded.

3.7 OBSERVATIONS

3.7.1 Plant characters

3.7.1.1 ***Plant height (cm):***

The height of five randomly selected and tagged plants was measured from base of the plant to the growing tip of the main stem. Observations were recorded on 40 and 60 days after transplanting and average height was computed and expressed in centimeters.

3.7.1.2 ***Plant spread (cm):***

The plant spread in East-West and North-South directions were noted for the five tagged plants at 40 and 60 days after transplanting and the averages were worked out and expressed in centimeters.

3.7.1.3 ***Number of primary branches:***

The number of primary branches arising from the main stem was counted at 40 and 60 days after transplanting. The average number of primary branches were worked out and expressed in numbers per plant.

3.7.1.4 ***Number of secondary branches:***

The number of secondary branches arising from the primary branches was counted at 40 and 60 days after transplanting. The average number of secondary branches were worked out and expressed in numbers per plant.

3.7.1.5 ***Leaf area (cm^2):***

The leaf area from all leaves of selected and tagged plants was measured at 40 and 60 DAT and total leaf area was calculated by using portable leaf area meter, LI-COR Model LI-3000A and expressed as square centimeter per plant.

3.7.1.6 ***Internodal length (cm):***

The distance between two adjacent nodes at the bottom, middle and top of the tagged plants were calculated and mean values were computed and expressed in centimeter.

3.7.1.7 ***Stem girth (cm):***

The circumference of main stem of tagged plants was taken at the base just below the first node by using a twine. The mean values for stem girth were calculated for the observations taken at 40 and 60 days after transplanting and expressed in centimeters.

3.7.1.8 ***Incidence of pest and disease:***

Pests and diseases occurred during the crop period was observed and recorded.

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3.7.1.9 ***Total biomass (g):***

Fully flowered sample plants from each replication were dried in oven after tagging the plants till constant weight is obtained. After complete drying, dry weight was recorded and expressed as grams per plant.

3.7.1.10 ***Crop duration (days):***

Total number of days from transplanting to which the crop remained fresh and green were recorded for each treatment and expressed in numbers.

3.7.2 Flower characters:

3.7.2.1 ***Days to first flowering:***

The number of days taken for commencement of first flowering in each treatment were recorded by counting the days from germination to first flower opening and expressed in number of days.

3.7.2.2 ***Days to 50 % flowering:***

The number of days taken for 50 % flowering in each treatment was worked out by counting the days from germination to flowering in 50 % of plants in a plot and expressed in number of days.

3.7.2.3 ***Days to first harvest:***

The number of days taken for first harvest for each treatment was counted from the day of germination to first harvest and expressed in number of days.

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3.7.2.4 ***Flower length (cm):***

The length of 5 randomly selected flowers from each replication was measured was noted from top of the flower head to the stalk end by using scale and the average was worked out and expressed in centimeters (cm).

3.7.2.5 ***Pedicel length (cm):***

Pedicel length of 5 randomly selected flowers from each replication was measured and average was worked out and expressed in centimeters.

3.7.2.6 ***Flower diameter (cm):***

Maximum breadth of 5 randomly selected flowers from each replication was measured by using scale and the average was calculated and expressed in centimeters.

3.7.2.7 ***Mean flower weight (g):***

Individual flower weight of 5 randomly selected flowers from each replication was measured and average was worked out and expressed in grams.

3.7.2.8 ***Number of flowers / plant:***

Total number of flowers per plant harvested at different times was recorded for the tagged plants. Finally, average number of flowers per plant was computed and expressed in numbers.

3.7.2.9 ***Total flower yield / plant (g):***

Fresh weight of flowers harvested at different times from the tagged plants of each replication was recorded and averages were computed and expressed in grams.

3.7.2.10 ***Marketable flower yield / plant (g):***

Fresh weight of flowers suitable for marketing are recorded for flowers harvested at different times from tagged plants and averages were computed and expressed in grams.

3.7.2.11 ***Duration of flowering:***

The number of days taken from first flower opening to last flower opening of tagged plants from each replication was noted and the average was worked out and expressed in number of days.

3.7.2.12 ***Post-harvest longevity of flowers:***

Five flowers from tagged plants were harvested at correct stage of maturity and were kept open in the room temperature. The number of days taken for wilting of 50 % flowers of each replication were recorded and expressed as number of days

3.7.3 Chemical analysis:

3.7.3.1 ***SPAD chlorophyll meter reading (SCMR):***

Chlorophyll content was measured by using SPAD-502 chlorophyll meter, Konica Minolta, Japan and expressed in numbers.

3.7.3.2 ***Carotenoid content of flower (mg / g):***

Total carotenoids were estimated by the method suggested by Arnon (1949). The flower extract was prepared by grinding 200 mg of fresh flower with a pestle and mortar using 10 ml of 80% acetone. The homogenate was then filtered in a volumetric flask (25 ml) using Whatman filter paper no. 1. The homogenate was washed out 2-3 times with 5ml of 80% acetone each time and the final volume was made upto 25 ml with 80% acetone. The filtrate was taken in a cuvette (3/4 volume) and its absorbance was recorded separately at 480, 663 and

645 nm using a spectrometer (using 80% acetone as a blank). The carotenoid content was calculated using the formula

$$\text{Total carotenoids (mg / g)} = \frac{[A_{480} + (0.114 \times A_{663}) - (0.638 \times A_{645})] \times V}{1000 \times W}$$

3.8 Statistical analysis:

The data obtained were subjected to statistical analysis. Statistical analysis was done using OPSTAT software (Sheoran *et al,*. 1998).

RESULTS

4. RESULTS

The study entitled "Effect of growth retardants on growth and yield of African marigold (*Tagetes erecta* L.) was conducted in two seasons namely, monsoon (May sown) and pre-monsoon (January sown). The experimental design was Split Plot. The experimental material comprised of two varieties of African marigold viz., Pusa Narangi Gainda (V_1) and Maxima Yellow F_1 (V_2) as main plots and two plant growth retardants, Alar and Cycocel, at three different doses and a control as subplots *viz.*, C_1: Alar 500 ppm, C_2: Alar 1000 ppm, C_3: Alar 1500 ppm, C_4: Cycocel 1000 ppm, C_5: Cycocel 1500 ppm, C_6: Cycocel 2000 ppm and C_7: Water spray (control). The data obtained were subjected to statistical analysis to find out the effect of different doses of growth retardants on growth, flowering and yield of African marigold varieties and the results obtained are presented in this chapter.

4.1 EFFECT OF GROWTH RETARDANTS ON GROWTH AND YIELD OF AFRICAN MARIGOLD DURING MONSOON SEASON

4.1.1 Morphological characters

4.1.1.1 Plant height

Plant height (cm) was recorded at 40 and 60 DAT and the observations were subjected to statistical analysis. The data obtained are presented in Table 1.

4.1.1.1.1 Varieties

The data analysis on plant height revealed that varieties differed significantly between each other at both 40 and 60 DAT. Between the varieties, variety V_2 exhibited minimum plant height at 40 (53.05 cm) and 60 (77.70 cm) DAT.

4.1.1.1.2 Growth retardants

Significant differences regarding plant height were not noticed at 40 DAT. The plant height differed significantly among the growth retardants at 60 DAT.

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Plate 2. Crop stages during monsoon season

b. Seedling in nursery

a. Transplanted seedlings

d. Vegetative stage

c. Flowering stage

Table 1. Effect of growth retardants on plant height (cm) of African marigold varieties during monsoon season

Treatments	V_1-Pusa Narangi Gainda		V_2-Maxima Yellow F_1		Mean (40 DAT)	Mean (60 DAT)
	At 40 DAT	At 60 DAT	At 40 DAT	At 60 DAT		
C_1 : Alar – 500 ppm	61.07	102.53	51.87	79.00	**56.47**	**90.77**
C_2 : Alar – 1000 ppm	64.33	91.67	51.93	77.93	**58.13**	**84.80**
C_3 : Alar – 1500 ppm	66.47	94.67	50.93	75.53	**58.70**	**85.10**
C_4 : Cycocel – 1000 ppm	62.40	95.13	56.47	83.13	**59.43**	**89.13**
C_5 : Cycocel – 1500 ppm	64.87	94.40	53.13	71.53	**59.00**	**82.97**
C_6 : Cycocel – 2000 ppm	62.47	93.27	53.47	74.53	**57.97**	**83.90**
C_7: Water spray	69.87	103.93	53.53	82.20	**61.70**	**93.07**
Mean	**64.50**	**96.51**	**53.05**	77.70	**56.47**	**87.10**

Comparison	At 40 DAT		At 60 DAT	
	SEm(±)	C. D. (0.05)	SEm(±)	C. D. (0.05)
V	0.76	3.53	0.99	4.56
C	2.14	NS	1.29	2.69
C at same level of V	3.02	NS	1.83	4.98
V at same level of C	2.90	NS	1.96	5.33

At 60 DAT, minimum plant height was noticed in treatment C_5 (82.97 cm), which was statistically similar to treatments C_2 (84.80 cm), C_3 (85.10 cm) and C_6 (83.90 cm).

4.1.1.1.3 Variety x *Growth retardants*

The interaction of varieties and different growth retardant treatments regarding plant height were statistically insignificant at 40 DAT. At 60 DAT, the interaction showed significant difference between each other. Within variety V_1, treatment C_2 resulted in significantly minimum plant height (91.67 cm) which was statistically similar to treatments C_3, C_4, C_5 and C_6. Within variety V_2, significantly minimum plant height (71.53 cm) was recorded in treatment C_5 which was on par with treatments C_3 (75.53cm) and C_6 (74.53 cm). Irrespective of the treatments, all plants of variety V_2 (77.70 cm) were significantly smaller than variety V_1 (96.51 cm) (Table 1).

4.1.1.2 Plant spread

Plant spread (cm) was recorded at 40 and 60 DAT and subjected to statistical analysis. The data obtained are presented in Table 2.

4.1.1.2.1 Varieties

There was no significant difference among the varieties on plant spread observed at 40 and 60 DAT.

4.1.1.2.2 Growth retardants

Significant differences were noticed among the growth retardants on plant spread both at 40 and 60 DAT. Maximum plant spread was observed in treatment both at 40 (26.97 cm) and 60 (36.83 cm) DAT which was statistically similar to C_5 (35.57 cm) and C_2 (35.27 cm) at 60 DAT.

Table 2. Effect of growth retardants on plant spread (cm) of African marigold varieties during monsoon season

Treatments	V_1-Pusa Narangi Gainda		V_2-Maxima Yellow F_1		Mean (40 DAT)	Mean (60 DAT)
	At 40 DAT	At 60 DAT	At 40 DAT	At 60 DAT		
C_1 : Alar – 500 ppm	22.67	34.60	26.33	34.86	**24.50**	**34.73**
C_2 : Alar – 1000 ppm	24.00	36.73	22.53	33.80	**23.27**	**35.27**
C_3 : Alar – 1500 ppm	23.60	34.80	23.26	34.66	**23.43**	**34.73**
C_4 : Cycocel – 1000 ppm	22.53	32.93	23.26	33.53	**23.20**	**33.23**
C_5 : Cycocel – 1500 ppm	26.13	35.20	24.47	35.93	**25.30**	**35.57**
C_6 : Cycocel – 2000 ppm	26.00	37.06	27.93	36.60	**26.97**	**36.83**
C_7: Water spray	24.26	30.46	21.87	32.60	**23.07**	**31.53**
Mean	**24.17**	**34.54**	**24.32**	**34.57**	**24.25**	**34.56**

Comparison	At 40 DAT		At 60 DAT	
	SEm(±)	C. D. (0.05)	SEm(±)	C. D. (0.05)
V	0.534	NS	0.26	NS
C	0.73	1.52	0.91	1.88
C at same level of V	1.03	2.78	1.28	NS
V at same level of C	1.10	2.96	1.22	NS

4.1.1.2.3 Variety x *Growth retardants*

The interaction between varieties and growth retardants on plant spread was found significant at 40 DAT but insignificant at 60 DAT. Within variety V_1, treatment C_5 resulted in significantly maximum plant spread (26.13 cm) which was statistically similar to treatments C_2, C_3, C_6 and C_7. Within variety V_2, significantly maximum plant spread was recorded in treatment C_6 (27.93 cm) which was on par with treatment C_1 (26.33 cm). Within a treatment, significantly higher plant spread was recorded in variety V_2 for treatment C_1 than variety V_1 (Table 2).

4.1.1.3. Number of primary branches per plant

The observations on number of primary branches were recorded at 40 and 60 DAT. The results are presented in Table 3.

4.1.1.3.1. Varieties

The analysis of data on number of primary branches revealed that varieties differed significantly between each other both at 40 and 60 DAT. Maximum mean number of primary branches was observed in variety V_2 at 40 (4.41) and 60 (6.17) DAT.

4.1.1.3.2. Growth retardants

Significant differences were noticed among different growth retardants treatments both at 40 and 60 DAT. Maximum mean number of primary branches was observed in treatment C_5 (4.07) at 40 DAT and was statistically similar to all other treatments except C_1. At 60 DAT, maximum number of primary branches was observed in treatment C_6 (6.37) which was statically similar to C_3 (6.33) and C_5 (6.03).

Table 3: Effect of growth retardants on mean number of primary branches per plant of African marigold varieties during monsoon season

Treatments	V_1-Pusa Narangi Gainda		V_2-Maxima Yellow F_1		Mean (40 DAT)	Mean (60 DAT)
	At 40 DAT	At 60 DAT	At 40 DAT	At 60 DAT		
C_1 : Alar – 500 ppm	2.80	5.60	4.06	6.00	**3.43**	**5.80**
C_2 : Alar – 1000 ppm	2.80	5.53	4.46	6.06	**3.63**	**5.80**
C_3 : Alar – 1500 ppm	3.27	5.87	4.40	6.80	**3.83**	**6.33**
C_4 : Cycocel – 1000 ppm	3.27	5.47	4.40	5.80	**3.83**	**5.63**
C_5 : Cycocel – 1500 ppm	3.53	5.73	4.60	6.33	**4.07**	**6.03**
C_6 : Cycocel – 2000 ppm	3.53	5.93	4.53	6.80	**4.03**	**6.37**
C_7: Water spray	2.80	4.47	4.40	5.40	**3.60**	**4.93**
Mean	**3.14**	**5.51**	**4.41**	**6.17**	**3.78**	**5.84**

Comparison	At 40 DAT		At 60 DAT	
	SEm(±)	C. D. (0.05)	SEm(±)	C. D. (0.05)
V	**0.07**	**0.34**	**0.08**	**0.35**
C	**0.18**	**0.38**	**0.25**	**0.51**
C at same level of V	**0.26**	**NS**	**0.35**	**NS**
V at same level of C	**0.25**	**NS**	**0.33**	**NS**

4.1.1.3.3. Varieties x *Growth retardants*

There was no significant difference between interaction of varieties and growth retardants on number of primary branches both at 40 and 60 DAT.

4.1.1.4. Number of secondary branches per plant

Number of secondary branches was recorded at 60 DAT and the statistically analyzed data are presented in Table 4.

4.1.1.4.1. Varieties

There was no significant difference among varieties on number of secondary branches at 60 DAT.

4.1.1.4.2. Growth retardants

Significant differences were observed among the growth retardants regarding mean number of secondary branches per plant at 60 DAT. Maximum mean number of secondary branches was observed in treatment C_6 (10.82) which was statistically similar to C_1 (10.13), C_2 (9.57) and C_5 (9.8).

4.1.1.4.3. Varieties x *Growth retardants*

There was no significant difference observed between interaction of varieties and growth retardants on number of secondary branches per plant according to the data presented in Table 4.

4.1.1.5. Leaf area

The observation on leaf area (cm^2) was recorded at 40 and 60 DAT and was subjected to statistical analysis. The results obtained are presented in Table 5.

4.1.1.5.1. Varieties

The data regarding leaf area revealed that varieties differed significantly among each other both at 40 and 60 DAT. Maximum leaf area per plant was observed in variety V_2 both at 40 (94.42 cm^2) and 60 (867.15 cm^2) DAT.

Table 4: Effect of growth retardants on secondary branches at 60 DAT in African marigold varieties during monsoon season

Treatments	V_1-Pusa Narangi Gainda	V_2-Maxima Yellow F_1	Mean
C_1 : Alar – 500 ppm	10.53	9.73	**10.13**
C_2 : Alar – 1000 ppm	9.27	9.87	**9.57**
C_3 : Alar – 1500 ppm	8.60	9.07	**8.83**
C_4 : Cycocel – 1000 ppm	7.93	10.20	**9.07**
C_5 : Cycocel – 1500 ppm	9.00	10.60	**9.80**
C_6 : Cycocel – 2000 ppm	12.00	9.63	**10.82**
C_7: Water spray	7.40	8.33	**7.87**
Mean	**9.25**	**9.63**	**9.44**
Comparison	**SEm(±)**	**C. D. (0.05)**	
V	**0.23**	**NS**	
C	**0.80**	**1.67**	
C at same level of V	**1.14**	**NS**	
V at same level of C	**1.08**	**NS**	

Table 5: Effect of growth retardants on leaf area (cm^2) per plant of African marigold varieties during monsoon season

Treatments	V_1-Pusa Narangi Gainda		V_2-Maxima Yellow F_1		Mean (40 DAT)	Mean (60 DAT)
	At 40 DAT	At 60 DAT	At 40 DAT	At 60 DAT		
C_1 : Alar – 500 ppm	84.45	652.18	96.54	865.77	**90.50**	**758.97**
C_2 : Alar – 1000 ppm	89.90	710.46	92.02	866.76	**90.96**	**788.61**
C_3 : Alar – 1500 ppm	88.62	822.77	94.70	816.69	**91.66**	**819.73**
C_4 : Cycocel – 1000 ppm	85.27	853.39	93.29	848.67	**89.28**	**851.03**
C_5 : Cycocel – 1500 ppm	86.38	744.25	94.44	904.63	**90.41**	**824.44**
C_6 : Cycocel – 2000 ppm	88.23	749.88	97.96	871.57	**93.10**	**810.73**
C_7: Water spray	82.35	670.64	91.97	895.98	**87.16**	**783.31**
Mean	**86.46**	**743.37**	**94.42**	**867.15**	**90.44**	**805.26**

Comparison	At 40 DAT		At 60 DAT	
	SEm(±)	C. D. (0.05)	SEm(±)	C. D. (0.05)
V	1.69	7.83	5.04	23.35
C	2.52	NS	30.69	NS
C at same level of V	3.56	NS	43.41	91.84
V at same level of C	3.70	NS	40.50	85.69

4.1.1.5.2. Growth retardants

There was no significant difference observed among the growth retardants treatments on leaf area both at 40 DAT and 60 DAT.

4.1.1.5.3. Varieties x *Growth retardants*

The interaction between varieties and growth retardants was insignificant at 40 DAT. The interaction was found significant at 60 DAT. Within variety V_1, treatment C_4 resulted in significantly maximum leaf area (853.39 cm^2) which was on par with treatment C_3 (822.77 cm^2). Within a treatment, significantly higher leaf area was recorded in variety V_2 for treatments C_1, C_2, C_5, C_6 and C_7 (Table 5).

4.1.1.6. Internodal length

Internodal length (cm) was recorded at 40 and 60 DAT and data was statistically analyzed. The results are presented in Table 6.

4.1.1.6.1. Varieties

The data regarding internodal length revealed that varieties showed significant differences among each other. Minimum internodal length was observed in variety V_2 both at 40 (1.59 cm) and 60 (2.99 cm) DAT.

4.1.1.6.2. Growth retardants

At 40 DAT, the differences among the growth retardants were statistically insignificant. Treatments differed significantly among each other at 60 DAT. Minimum internodal length was observed in treatment C_4 (3.49 cm) at 60 DAT which was statistically similar to C_1 (3.79 cm), C_2 (3.68 cm) and C_6 (3.57 cm).

4.1.1.6.3. Varieties x *Growth retardants*

Significant differences regarding internodal length were not noticed at 40 DAT. Interaction showed significant difference between each other at 60 DAT. Within variety V_1, treatment C_6 resulted in significantly minimum internodal length (4 cm) which was on par with treatments C_3 and C_4. Within variety V_2,

Table 6: Effect of growth retardants on internodal length (cm) of African marigold varieties during monsoon season

Treatments	V_1-Pusa Narangi Gainda		V_2-Maxima Yellow F_1		Mean (40 DAT)	Mean (60 DAT)
	At 40 DAT	At 60 DAT	At 40 DAT	At 60 DAT		
C_1 : Alar – 500 ppm	2.55	4.70	1.77	2.89	**2.16**	**3.79**
C_2 : Alar – 1000 ppm	2.41	4.51	1.70	2.85	**2.06**	**3.68**
C_3 : Alar – 1500 ppm	2.36	4.48	1.82	3.21	**2.09**	**3.85**
C_4 : Cycocel – 1000 ppm	2.34	4.25	1.64	2.72	**1.99**	**3.49**
C_5 : Cycocel – 1500 ppm	2.72	4.85	1.41	2.88	**2.07**	**3.87**
C_6 : Cycocel – 2000 ppm	2.15	4.00	1.52	3.13	**1.84**	**3.57**
C_7: Water spray	2.69	5.14	1.28	3.28	**1.99**	**4.21**
Mean	**2.46**	**4.56**	**1.59**	**2.99**	**2.02**	**3.78**

Comparison	At 40 DAT		At 60 DAT	
	SEm(±)	C. D. (0.05)	SEm(±)	C. D. (0.05)
V	**0.08**	**0.37**	**0.04**	**0.19**
C	**0.16**	**NS**	**0.16**	**0.34**
C at same level of V	**0.23**	**NS**	**0.23**	**0.49**
V at same level of C	**0.23**	**NS**	**0.22**	**0.48**

significantly lower internodal length was recorded in treatment C_4 (2.72 cm) which was on par with all treatments except control C_7. Irrespective of the treatments, plants of variety V_2 recorded significantly minimum internodal length than variety V_1 (Table 6).

4.1.1.7. Stem girth

The results obtained on the effect of growth retardants on stem girth recorded at 40 and 60 DAT are presented in Table 7.

4.1.1.7.1. Varieties

The data regarding stem girth revealed that varieties differed significantly between each other both at 40 and 60 DAT. Maximum stem girth was exhibited by variety V_2 both at 40 (3.04 cm) and 60 (4.12 cm) DAT.

4.1.1.7.2. Growth retardants

Significant difference was observed among the growth retardants on stem girth at 40 and 60 DAT. Maximum stem girth was observed in treatment C_6 both at 40 (3.02 cm) and 60 (4.2 cm) DAT. At 40 DAT, it was statistically similar to treatment C_4 (2.83 cm).

4.1.1.7.3. Varieties x *Growth retardants*

The interaction between varieties and growth retardants on stem girth differed significantly among each other both at 40 and 60 DAT. Within variety V_1, treatment C_6 resulted in significantly maximum stem girth (2.93 cm) which was on par with treatments C_3 (2.88 cm) and C_5 (2.62 cm) at 40 DAT. At 60 DAT, significantly maximum stem girth was reported in treatment C_6 (3.99 cm). Within variety V_2, significantly higher stem girth was recorded in treatment C_1 (3.12 cm) which was similar to all treatments except control at 40 DAT. At 60 DAT, significantly maximum stem girth was reported in treatment C_6 (4.4 cm) which was on par with treatment C_5 (4.3 cm). Irrespective of the treatments,

Table 7: Effect of growth retardants on stem girth (cm) of African marigold varieties during monsoon season

Treatments	V_1-Pusa Narangi Gainda		V_2-Maxima Yellow F_1		Mean (40 DAT)	Mean (60 DAT)
	At 40 DAT	At 60 DAT	At 40 DAT	At 60 DAT		
C_1 : Alar – 500 ppm	2.53	3.23	3.12	4.07	**2.82**	**3.65**
C_2 : Alar – 1000 ppm	2.53	3.10	3.00	4.01	**2.77**	**3.55**
C_3 : Alar – 1500 ppm	2.88	3.28	3.10	4.17	**2.99**	**3.73**
C_4 : Cycocel – 1000 ppm	2.48	3.33	3.19	4.11	**2.83**	**3.72**
C_5 : Cycocel – 1500 ppm	2.62	3.24	2.96	4.33	**2.79**	**3.79**
C_6 : Cycocel – 2000 ppm	2.93	3.99	3.11	4.40	**3.02**	**4.20**
C_7: Water spray	2.57	3.10	2.79	3.74	**2.68**	**3.42**
Mean	**2.65**	**3.33**	**3.04**	**4.12**	**2.84**	**3.72**

Comparison	At 40 DAT		At 60 DAT	
	SEm(±)	C. D. (0.05)	SEm(±)	C. D. (0.05)
V	0.06	0.26	0.03	0.15
C	0.09	0.19	0.07	0.14
C at same level of V	0.13	0.33	0.09	0.22
V at same level of C	0.13	0.33	0.09	0.22

plants of variety V_2 (3.04, 4.12) recorded significantly higher stem girth than variety V_1 (2.65, 3.33) at 40 and 60 DAT respectively (Table 7).

4.1.1.8. Total biomass

The observations on total biomass (g) were recorded from plants at fully flowered stage and the results obtained after statistical analysis are presented in Table 8.

4.1.1.8.1. Varieties

The data regarding total biomass revealed that there was no significant difference noticed among varieties.

4.1.1.8.2. *Growth retardants*

The differences among the growth retardants regarding total biomass were statistically insignificant.

4.1.1.8.3. Varieties x *Growth retardants*

The interaction between varieties and growth retardants on total biomass exhibited no statistical difference between each other.

4.1.1.9. Crop duration

The total crop duration was recorded and the data was statistically analyzed. The results obtained are presented in Table 8.

4.1.1.9.1. Varieties

The data regarding crop duration revealed that there was no significant difference noticed among varieties.

4.1.1.9.2. Growth retardants

The differences among the growth retardants regarding crop duration were statistically insignificant.

Table 8: Effect of growth retardants on total biomass (g) and crop duration (days) of African marigold varieties during monsoon season

Treatments	Total biomass (g)			Crop duration (days)		
	V_1- Pusa Narangi Gainda	V_2-Maxima Yellow F_1	Mean	V_1- Pusa Narangi Gainda	V_2-Maxima Yellow F_1	Mean
C_1 : Alar – 500 ppm	25.84	28.26	**27.05**	152.00	155.00	**153.50**
C_2 : Alar – 1000 ppm	28.70	29.80	**29.25**	153.33	155.33	**154.33**
C_3 : Alar – 1500 ppm	25.54	22.82	**24.18**	154.00	154.00	**154.00**
C_4 : Cycocel – 1000 ppm	25.48	33.60	**29.54**	153.00	156.33	**155.00**
C_5 : Cycocel – 1500 ppm	29.64	22.18	**25.91**	152.66	156.67	**154.67**
C_6 : Cycocel – 2000 ppm	37.66	29.51	**33.59**	154.33	157.67	**156.00**
C_7: Water spray	32.97	26.30	**29.64**	151.33	153.33	**152.33**
Mean	**29.40**	**27.50**	**28.45**	**153.05**	**155.47**	**154.26**
Comparison	**SEm(±)**	**C. D. (0.05)**		**SEm(±)**	**C. D. (0.05)**	
V	**0.62**	**NS**		**1.00**	**NS**	
C	**2.77**	**NS**		**1.15**	**NS**	
C at same level of V	**3.92**	**NS**		**1.63**	**NS**	
V at same level of C	**3.68**	**NS**		**1.81**	**NS**	

4.1.1.9.3. Varieties x *Growth retardants*

The interaction between varieties and growth retardants on crop duration exhibited no statistical difference between each other.

4.1.2. Flower characters

4.1.2.1. Days to first flowering

The number of days taken to first flowering was recorded and the data are presented in Table 9.

4.1.2.1.1. Varieties

The data regarding days to first flowering revealed that varieties differed significantly between each other. Among the varieties, variety V_2 took minimum number of days to first flowering (73 days).

4.1.2.1.2. Growth retardants

The differences among growth retardants regarding the number of days to first flowering were statistically insignificant.

4.1.2.1.3. Varieties x *Growth retardants*

The interaction between varieties and growth retardants on number of days to first flowering was insignificant according to the data presented in Table 9.

4.1.2.2. Days to 50% flowering

The observation on number of days taken for 50 % flowering was recorded and the data subjected to statistical analysis are presented in Table 9.

4.1.2.2.1. Varieties

Significant difference was noticed on the number of days taken to 50 % flowering among the varieties. Minimum number of days to 50 % flowering was observed in variety V_2 (78.38).

Table 9: Effect of growth retardants on days to first flowering and days to 50% flowering of African marigold varieties during monsoon season

Treatments	Days to first flowering			Days to 50% flowering		
	V_1- Pusa Narangi Gainda	V_2-Maxima Yellow F_1	Mean	V_1- Pusa Narangi Gainda	V_2-Maxima Yellow F_1	Mean
C_1 : Alar – 500 ppm	73.33	74.33	**73.83**	82.33	79.67	**81.00**
C_2 : Alar – 1000 ppm	73.33	73.33	**73.33**	80.33	78.67	**79.50**
C_3 : Alar – 1500 ppm	73.67	72.67	**73.17**	81.33	78.00	**79.67**
C_4 : Cycocel – 1000 ppm	73.67	72.33	**73.00**	82.00	77.67	**79.83**
C_5 : Cycocel – 1500 ppm	73.33	72.67	**73.00**	80.67	78.00	**79.33**
C_6 : Cycocel – 2000 ppm	73.33	72.67	**73.00**	81.67	78.00	**79.83**
C_7: Water spray	75.33	73.00	**74.17**	85.00	78.67	**81.83**
Mean	**73.71**	**73.00**	**73.36**	**81.90**	**78.38**	**80.14**
Comparison	**SEm(±)**	**C. D. (0.05)**		**SEm(±)**	**C. D. (0.05)**	
V	**0.17**	**0.71**		**0.41**	**1.89**	
C	**1.33**	**NS**		**1.19**	**NS**	
C at same level of V	**1.87**	**NS**		**1.69**	**NS**	
V at same level of C	**1.74**	**NS**		**1.62**	**NS**	

4.1.2.2.2. Growth retardants

There was no significant difference noticed among growth retardants on the number of days to 50 % flowering.

4.1.2.2.3. Varieties x *Growth retardants*

The interaction between varieties and growth retardants on number of days to 50 % flowering was insignificant according to the data.

4.1.2.3. Days to first harvest

The observation on number of days taken to first harvest was recorded and the data is presented in Table 10.

4.1.2.3.1. Varieties

According to the data presented in Table 10, the varieties did not differed significantly among each other on number of days to first harvest.

4.1.2.3.2. *Growth retardants*

There was no significant difference noticed among the growth retardants on number of days to first harvest.

4.1.2.3.3. Varieties x *Growth retardants*

The data on number of days to first harvest did not show any significant difference due to interaction between varieties and growth retardants.

4.1.2.4. Flower length

The observation on flower length (cm) was recorded and the data are presented in Table 10.

Table 10: Effect of growth retardants on days to first harvest and flower length (cm) of African marigold varieties during monsoon season

Treatments	Days to first harvest			Flower length (cm)		
	V_1- Pusa Narangi Gainda	V_2-Maxima Yellow F_1	Mean	V_1- Pusa Narangi Gainda	V_2-Maxima Yellow F_1	Mean
C_1 : Alar – 500 ppm	85.33	87.33	**86.33**	17.17	13.00	**15.08**
C_2 : Alar – 1000 ppm	86.00	88.33	**87.17**	16.10	13.17	**14.63**
C_3 : Alar – 1500 ppm	86.33	86.67	**86.50**	16.63	11.81	**14.22**
C_4 : Cycocel – 1000 ppm	86.67	87.33	**87.00**	15.40	13.47	**14.43**
C_5 : Cycocel – 1500 ppm	86.00	85.00	**85.50**	17.47	13.00	**15.23**
C_6 : Cycocel – 2000 ppm	84.67	85.00	**84.83**	16.33	13.83	**15.08**
C_7: Water spray	86.67	86.00	**86.33**	17.16	13.82	**15.49**
Mean	**85.95**	**86.52**	**86.24**	**16.61**	**13.16**	**14.88**
Comparison	**SEm(±)**		**C. D. (0.05)**	**SEm(±)**		**C. D. (0.05)**
V	**0.49**		**NS**	**0.66**		**3.04**
C	**1.74**		**NS**	**0.75**		**NS**
C at same level of V	**2.46**		**NS**	**1.05**		**NS**
V at same level of C	**2.33**		**NS**	**1.16**		**NS**

4.1.2.4.1. Varieties

The data analysis on flower length revealed that varieties differed significantly between each other. Among the varieties, minimum flower length was exhibited by variety V_2 (13.16 cm).

4.1.2.4.2. Growth retardants

The differences among the growth retardants with regard to flower length were statistically insignificant.

4.1.2.4.3. Varieties* x *Growth retardants

The interaction between varieties and growth retardants on flower length did not show any statistical difference among each other.

4.1.2.5. Pedicel length

The observation on pedicel length (cm) was recorded and the data was presented in Table 11.

4.1.2.5.1. Varieties

The data regarding pedicel length revealed that varieties differed significantly between each other. Minimum pedicel length was observed in variety V_2 (8.98 cm).

4.1.2.5.2. *Growth retardants*

The differences among the growth retardants with regard to pedicel length were statistically insignificant.

4.1.2.5.3. Varieties* x *Growth retardants

The interaction between varieties and growth retardants on pedicel length did not show any statistical difference among each other.

Table 11: Effect of growth retardants on pedicel length (cm) and flower diameter (cm) of African marigold varieties during monsoon season

Treatments	Pedicel length (cm)			Flower diameter (cm)		
	V_1- Pusa Narangi Gainda	V_2-Maxima Yellow F_1	Mean	V_1- Pusa Narangi Gainda	V_2-Maxima Yellow F_1	Mean
C_1 : Alar – 500 ppm	13.73	9.07	**11.40**	4.77	7.70	**6.23**
C_2 : Alar – 1000 ppm	12.47	8.91	**10.69**	4.83	7.67	**6.25**
C_3 : Alar – 1500 ppm	12.90	7.92	**10.41**	4.73	7.30	**6.02**
C_4 : Cycocel – 1000 ppm	13.17	9.47	**11.32**	4.83	7.33	**6.08**
C_5 : Cycocel – 1500 ppm	14.17	8.93	**11.55**	4.90	7.36	**6.13**
C_6 : Cycocel – 2000 ppm	12.50	9.40	**10.95**	4.93	8.20	**6.57**
C_7: Water spray	14.53	9.17	**11.85**	4.70	6.93	**5.82**
Mean	**13.35**	**8.98**	**11.17**	**4.81**	**7.50**	**6.16**
Comparison	**SEm(±)**	**C. D. (0.05)**		**SEm(±)**	**C. D. (0.05)**	
V	**0.12**	**0.49**		**0.12**	**0.55**	
C	**0.71**	**NS**		**0.26**	**NS**	
C at same level of V	**1.01**	**NS**		**0.37**	**NS**	
V at same level of C	**0.94**	**NS**		**0.36**	**NS**	

4.1.2.6. Flower diameter

The flower diameter (cm) was recorded from flowers at fully grown stage and data subjected to analysis are presented in Table 11.

4.1.2.6.1. Varieties

The data regarding flower diameter revealed that varieties differed significantly between each other. Maximum flower diameter was observed in variety V_2 (7.5 cm).

4.1.2.6.2. Growth retardants

The differences among the growth retardants with regard to flower diameter were statistically insignificant.

4.1.2.6.3. Varieties x *Growth retardants*

The interaction between varieties and growth retardants on flower diameter did not show any statistical difference among each other.

4.1.2.7. Mean flower weight

The mean flower weight (cm) was recorded from flowers at fully grown stage and data are presented in Table 12.

4.1.2.7.1. Varieties

The data regarding mean flower weight revealed that varieties differed significantly between each other. Among the varieties, maximum mean flower weight was observed in variety V_2 (12.99 g).

4.1.2.7.2. Growth retardants

The differences among the growth retardants with regard to mean flower weight were statistically insignificant.

4.1.2.7.3. Varieties x *Growth retardants*

The interaction between varieties and growth retardants on mean flower weight did not show any statistical difference among each other.

4.1.2.8. Number of flowers per plant

The number of flowers per plant was recorded and the data are presented in Table 12.

4.1.2.8.1. Varieties

The data analysis on number of flowers per plant revealed that varieties differ significantly between each other. Maximum number of flowers per plant was observed in variety V_2 (46.5).

4.1.2.8.2. Growth retardants

The growth retardants differed significantly between each other with regard to number of flowers per plant. Among the treatments, maximum number of flowers per plant was exhibited by treatment C_4 (46.86) which was followed by treatments C_3 (42.68) and C_2 (40.75).

4.1.2.8.3. Varieties x *Growth retardants*

According to the data presented in Table 12, the interaction between varieties and growth retardants on number of flowers per plant differed significantly among each other. Within variety V_1, treatment C_4 resulted in significantly higher number of flowers per plant (36.91) which was statistically similar to treatments C_2, C_3, C_5 and C_6. Within variety V_2, significantly higher number of flowers per plant was recorded in treatment C_4 (56.8) which were on par with treatments C_2 (50.13) and C_3 (50.37). Within a treatment, significantly higher number of flowers per plant was recorded in variety V_2 for all treatments except C_5 (Table12).

Table 12: Effect of growth retardants on mean flower weight (g) and number of flowers per plant of African marigold varieties during monsoon season

Treatments	Mean flower weight (g)			Number of flowers / plant		
	V_1- Pusa Narangi Gainda	V_2-Maxima Yellow F_1	Mean	V_1- Pusa Narangi Gainda	V_2-Maxima Yellow F_1	Mean
C_1 : Alar – 500 ppm	5.50	14.13	**9.82**	26.75	43.40	**35.08**
C_2 : Alar – 1000 ppm	5.92	13.60	**9.76**	31.37	50.13	**40.75**
C_3 : Alar – 1500 ppm	5.60	13.17	**9.39**	35.00	50.37	**42.68**
C_4 : Cycocel – 1000 ppm	6.20	12.43	**9.32**	36.91	56.80	**46.86**
C_5 : Cycocel – 1500 ppm	5.40	12.47	**8.93**	32.33	38.67	**35.50**
C_6 : Cycocel – 2000 ppm	4.97	12.70	**8.83**	36.63	41.67	**39.15**
C_7: Water spray	5.13	12.43	**8.78**	26.83	44.50	**35.67**
Mean	**5.53**	**12.99**	**9.26**	**32.26**	**46.50**	**39.38**

Comparison	SEm(±)	C. D. (0.05)	SEm(±)	C. D. (0.05)
V	**1.02**	**4.74**	**1.44**	**6.65**
C	**0.49**	**NS**	**1.91**	**3.96**
C at same level of V	**0.71**	**NS**	**2.70**	**7.32**
V at same level of C	**1.21**	**NS**	**2.88**	**7.81**

4.1.2.9. Total flower yield per plant

The total flower yield per plant (g) was recorded and the data was statistically analyzed and are presented in Table 13.

4.1.2.9.1. Varieties

The data analysis on total flower yield per plant revealed that varieties differed significantly between each other. Among the varieties, variety V_2 exhibited maximum total yield per plant (603.74 g).

4.1.2.9.2. Growth retardants

The total flower yield per plant differed significantly among the growth retardants. Among the treatments, significantly higher total flower yield per plant was noticed in treatment C_4 (469.69 g), which was statistically similar to treatment C_2 (432.50 g).

4.1.2.9.3. Varieties x *Growth retardants*

According to the data presented in Table 13, the interaction between varieties and growth retardants resulted in significant difference among each other on total flower yield per plant. Within variety V_1, significantly higher total yield per plant (229.72 g) was recorded in treatment C_4 which was statistically similar to all treatments except control C_7. Within variety V_2, significantly higher total yield per plant (709.65 g) was recorded in treatment C_4 which was on par with (681.99 g) and C_3 (658.59 g). Irrespective of treatments, variety V_2 (603.74 g) showed significantly higher total flower yield per plant than variety V_1 (177.87 g).

4.1.2.10. Marketable flower yield per plant

The marketable flower yield per plant was recorded and the data are presented in Table 13.

Table 13: Effect of growth retardants on total flower yield per plant (g) and marketable flower yield per plant (g) of African marigold varieties during monsoon season

Treatments	Total yield per plant (g)			Marketable yield per plant (g)		
	V_1- Pusa Narangi Gainda	V_2-Maxima Yellow F_1	Mean	V_1- Pusa Narangi Gainda	V_2-Maxima Yellow F_1	Mean
C_1 : Alar – 500 ppm	147.05	612.61	**379.83**	115.47	487.20	**301.33**
C_2 : Alar – 1000 ppm	183.00	681.99	**432.50**	148.53	571.73	**360.13**
C_3 : Alar – 1500 ppm	195.40	658.59	**427.00**	164.13	521.30	**342.72**
C_4 : Cycocel – 1000 ppm	229.72	709.65	**469.69**	190.86	567.77	**379.32**
C_5 : Cycocel – 1500 ppm	172.37	480.13	**326.25**	142.37	397.33	**269.85**
C_6 : Cycocel – 2000 ppm	181.12	529.53	**355.33**	150.20	440.43	**295.32**
C_7: Water spray	136.40	553.70	**345.05**	113.40	460.57	**286.98**
Mean	**177.87**	**603.74**	**390.81**	**146.42**	**492.33**	**319.38**
Comparison	**SEm(±)**	**C. D. (0.05)**		**SEm(±)**	**C. D. (0.05)**	
V	**22.41**	**103.81**		**27.68**	**128.25**	
C	**19.36**	**40.19**		**18.51**	**38.43**	
C at same level of V	**27.38**	**87.54**		**26.17**	**92.22**	
V at same level of C	**33.83**	**108.18**		**36.79**	**129.64**	

4.1.2.10.1. Varieties

The data analysis on marketable flower yield per plant (g) revealed that varieties differed significantly between each other. Among the varieties, variety V_2 exhibited maximum marketable yield per plant (492.33 g).

4.1.2.10.2. Growth retardants

The marketable flower yield per plant differed significantly among the growth retardants. Among the treatments, highest marketable flower yield per plant was noticed in treatment C_4 (379.32 g), which was statistically similar to treatments C_2 (360.13 g) and C_3 (342.72 g).

4.1.2.10.3. Varieties x *Growth retardants*

According to the data presented in Table 13, the interaction between varieties and growth retardants showed significant difference among each other on marketable flower yield per plant. Within variety V_2, significantly higher marketable yield per plant (571.73 g) was recorded in treatment C_2 which was statistically similar to treatments C_1, C_3 and C_4. Irrespective of treatments, variety V_2 (492.33 g) showed significantly higher marketable yield per plant than variety V_1 (146.42 g) as presented in Table 13.

4.1.2.11. Duration of flowering

The duration of flowering was recorded and the data are presented in Table 14.

4.1.2.11.1. Varieties

The data regarding duration of flowering revealed that differences between the varieties were statistically insignificant.

4.1.2.11.2. Growth retardants

There was no significant difference among the growth retardants on duration of flowering.

Table 14: Effect of growth retardants on duration of flowering (days) and post-harvest longevity (days) of African marigold varieties during monsoon season

Treatments	Duration of flowering			Post-harvest longevity of flowers		
	V_1- Pusa Narangi Gainda	V_2-Maxima Yellow F_1	Mean	V_1- Pusa Narangi Gainda	V_2-Maxima Yellow F_1	Mean
C_1 : Alar – 500 ppm	73.67	76.00	**74.83**	4.33	5.67	**5.00**
C_2 : Alar – 1000 ppm	73.60	76.67	**75.17**	4.33	6.33	**5.33**
C_3 : Alar – 1500 ppm	71.33	75.33	**73.33**	5.33	6.17	**5.75**
C_4 : Cycocel – 1000 ppm	73.00	78.67	**75.83**	4.83	5.33	**5.08**
C_5 : Cycocel – 1500 ppm	72.33	78.67	**75.50**	4.67	6.00	**5.33**
C_6 : Cycocel – 2000 ppm	71.33	78.67	**75.00**	5.17	6.17	**5.67**
C_7: Water spray	71.67	78.33	**75.00**	4.50	6.17	**5.33**
Mean	**72.43**	**77.48**	**74.95**	**4.74**	**5.98**	**5.36**
Comparison	**SEm(±)**		**C. D. (0.05)**	**SEm(±)**		**C. D. (0.05)**
V	**1.27**		**NS**	**0.17**		**0.77**
C	**1.76**		**NS**	**0.27**		**NS**
C at same level of V	**2.49**		**NS**	**0.39**		**NS**
V at same level of C	**2.63**		**NS**	**0.39**		**NS**

4.1.2.11.3. Varieties x *Growth retardants*

The interaction between varieties and treatments on duration of flowering exhibited no statistical difference between each other.

4.1.2.12.2. Growth retardants

The data regarding post-harvest longevity of flowers revealed that the differences between growth retardants were statistically insignificant.

4.1.2.12.3. Varieties x *Growth retardants*

The interaction between varieties and growth retardants on post-harvest longevity of flowers exhibited no statistical difference between each other.

4.1.3. Chemical characters

4.1.3.1. SCMR

SPAD reading was recorded at the time of flowering and the data are presented in Table 15.

4.1.3.1.1. Varieties

The data regarding chlorophyll content revealed that there was no significant difference noticed among varieties.

4.1.3.1.2. Growth retardants

The data regarding leaf chlorophyll content revealed that the differences between growth retardants were statistically insignificant.

4.1.3.1.3. Varieties x *Growth retardants*

The interaction between varieties and growth retardants on chlorophyll content exhibited no statistical difference between each other.

4.1.3.2. Carotenoid content

The carotenoid content (mg / 1000 g) of flowers was recorded and the results obtained are presented in Table 15.

4.1.3.2.1. Varieties

According to the data presented in Table 15, varieties exhibited significant difference between each other on carotenoid content of flower petals. Among the varieties, maximum carotenoid content was observed in variety V_1 (40.35 mg / 1000 g).

4.1.3.2.2. Growth retardants

The growth retardants differed significantly among each other on carotenoid content of flower petals. Among the different treatments, maximum carotenoid content was observed in treatment C_4 (45.15 mg / 1000 g) which was statistically similar to treatments C_3, C_5 and C_6.

4.1.3.2.3. Varieties x *Growth retardants*

The interaction between varieties and growth retardants on carotenoid content was found significant. Within variety V_1, treatment C_4 resulted in significantly maximum carotenoid content (53.13 mg / 1000 g) which was on par with treatment C_5 (49.36 mg / 1000 g). Within variety V_2, significantly maximum carotenoid content was recorded in treatments C_6 (39.27 mg / 1000 g) which was on par with treatments C_3 (39.18 mg / 1000 g) , C_4 (37.17 mg / 1000 g) and C_5 (37. 33 mg / 1000 g). Within a treatment, significantly higher carotenoid content was recorded in variety V_1 for treatments C_4, C_5 and C_6 than variety V_2 (Table 15).

4.1.4 Incidence of pest and disease

During monsoon season, irrespective of varieties and growth retardants, the crops were mildly infested by grasshoppers and hairy caterpillar. Spittle bug attack and thrips attack were observed in variety Pusa Narangi Gainda. In variety Maxima Yellow F_1, bacterial wilt was observed.

Table 15: Effect of growth retardants on SCMR and carotenoid content (mg /1000 g) of African marigold varieties during monsoon season

Treatments	SCMR			Carotenoid content (mg / 1000 g)		
	V_1- Pusa Narangi Gainda	V_2-Maxima Yellow F_1	Mean	V_1- Pusa Narangi Gainda	V_2 - Maxima Yellow F_1	Mean
C_1 : Alar – 500 ppm	50.99	54.05	**52.52**	28.31	23.76	**26.04**
C_2 : Alar – 1000 ppm	48.93	52.66	**50.79**	30.47	28.41	**29.44**
C_3 : Alar – 1500 ppm	49.32	47.92	**48.62**	42.37	39.18	**40.78**
C_4 : Cycocel – 1000 ppm	49.10	52.50	**50.80**	53.13	37.17	**45.15**
C_5 : Cycocel – 1500 ppm	51.24	48.99	**50.12**	49.36	37.33	**43.34**
C_6 : Cycocel – 2000 ppm	48.64	49.04	**48.84**	40.41	39.27	**40.14**
C_7: Water spray	48.81	51.13	**49.97**	38.42	23.47	**31.04**
Mean	**49.58**	**50.90**	**50.24**	**40.35**	**32.57**	**36.56**
Comparison	**SEm(±)**	**C. D. (0.05)**		**SEm(±)**	**C. D. (0.05)**	
V	**0.46**	**NS**		**0.16**	**0.77**	
C	**2.14**	**NS**		**2.25**	**4.67**	
C at same level of V	**3.03**	**NS**		**3.18**	**6.64**	
V at same level of C	**2.85**	**NS**		**2.95**	**6.15**	

4.2. EFFECT OF GROWTH RETARDANTS ON GROWTH AND YIELD OF AFRICAN MARIGOLD DURING PRE-MONSOON SEASON

4.2.1. Morphological characters

4.2.1.1 Plant height

The observations on the effect of growth retardants on plant height (cm) are recorded at 40 and 60 DAT and statistically analyzed data are presented in Table 16.

4.2.1.1.1. Varieties

The data analysis on plant height revealed that varieties differed significantly between each other both at 40 and 60 DAT. Among the varieties, significantly minimum plant height was exhibited by variety V_2 both at 40 (20.95 cm) and 60 (42.12 cm) DAT.

4.2.1.1.2. Growth retardants

The growth retardants varied significantly between each other on plant height both at 40 and 60 DAT. At 40 DAT, minimum plant height was noticed in treatment C_2 (21.37 cm) which is statistically similar to all other treatments except control, C_7. At 60 DAT, significantly minimum plant height was observed in treatment C_3 (50.47 cm) which was on par with treatments C_2 (52.10 cm) and C_4 (52.50 cm).

4.2.1.1.3. Varieties x *Growth retardants*

The data on plant height did not show any significant difference between interaction of varieties and growth retardants upto 40 DAT. At 60 DAT, the interaction of varieties and treatments showed significant variation. Within variety V_1, significantly minimum plant height was noticed in treatment C_4 (61.60 cm) which was on par with treatments C_2 (61.87 cm) and C_3 (61.93 cm). Within variety V_2, significantly lower plant height was observed in treatment C_3 (39 cm)

Plate 3. Crop stages during pre-monsoon season

b. Seedling in nursery

a. Transplanted stage

d. Vegetative stage

c. Flowering stage

Table 16: Effect of growth retardants on plant height (cm) of African marigold varieties during pre-monsoon season

Treatments	V_1-Pusa Narangi Gainda		V_2-Maxima Yellow F_1		Mean (40 DAT)	Mean (60 DAT)
	At 40 DAT	At 60 DAT	At 40 DAT	At 60 DAT		
C_1 : Alar – 500 ppm	24.33	68.13	19.87	42.13	**22.10**	**55.13**
C_2 : Alar – 1000 ppm	22.53	61.87	20.20	42.33	**21.37**	**52.10**
C_3 : Alar – 1500 ppm	22.53	61.93	20.33	39.00	**21.43**	**50.47**
C_4 : Cycocel – 1000 ppm	22.86	61.60	20.80	43.40	**21.83**	**52.50**
C_5 : Cycocel – 1500 ppm	25.13	67.87	22.13	42.16	**23.63**	**55.02**
C_6 : Cycocel – 2000 ppm	25.26	71.33	20.86	40.60	**23.07**	**55.97**
C_7: Water spray	30.33	74.20	22.46	45.20	**26.40**	**59.70**
Mean	**24.71**	**66.70**	**20.95**	**42.12**	**22.83**	**54.41**

Comparison	At 40 DAT		At 60 DAT	
	SEm(±)	C. D. (0.05)	SEm(±)	C. D. (0.05)
V	0.69	3.23	0.88	4.09
C	1.37	2.85	1.55	3.21
C at same level of V	1.94	NS	2.19	5.43
V at same level of C	1.93	NS	2.21	5.48

which is similar to all other treatments except control, C_7. Irrespective of the treatments, plants of variety V_2 were significantly smaller than variety V_1.

4.2.1.2 Plant spread

The observations on plant spread (cm) were recorded at 40 and 60 DAT and results obtained after statistical analysis are presented in Table 17.

4.2.1.2.1. Varieties

According to the data presented in Table 17, varieties did not significantly influenced plant spread both at 40 and 60 DAT.

4.2.1.2.2. Growth retardants

The treatments did not show any significant influence on plant spread at 40 DAT. Thereafter, plant spread was significantly influenced by treatments. At 60 DAT, significantly higher plant spread was noticed in treatment C_6 (26.77cm) which was on par with treatments C_2 (25.37 cm) and C_5 (25.57 cm).

4.2.1.2.3. Varieties x *Growth retardants*

Significant difference was not noticed regarding plant spread at 40 DAT. Interaction of varieties and growth retardants caused significant differences in plant spread at 60 DAT. Within variety V_1, significantly higher plant spread was recorded in treatment C_6 (28.67 cm) which was statistically similar to treatment C_5 (26.13 cm). Within variety V_2, significantly more plant spread was recorded in treatment C_2 (25.27 cm) which was also similar to treatments C_1, C_4, C_5 and C_6. Within a treatment, significantly higher plant spread was recorded in variety V_1 for treatments C_6 and C_7 than variety V_2.

4.2.1.3. Number of primary branches per plant

The number of primary branches per plant was recorded at 40 and 60 DAT and the results are presented in Table 18.

Table 17: Effect of growth retardants on plant spread (cm) of African marigold varieties during pre-monsoon season

Treatments	V_1-Pusa Narangi Gainda		V_2-Maxima Yellow F_1		Mean (40 DAT)	Mean (60 DAT)
	At 40 DAT	At 60 DAT	At 40 DAT	At 60 DAT		
C_1 : Alar – 500 ppm	12.60	25.33	14.13	22.80	**13.37**	**24.07**
C_2 : Alar – 1000 ppm	13.33	25.47	13.40	25.27	**13.67**	**25.37**
C_3 : Alar – 1500 ppm	11.93	20.67	14.53	22.00	**13.23**	**21.33**
C_4 : Cycocel – 1000 ppm	12.40	22.80	13.87	24.20	**13.13**	**23.50**
C_5 : Cycocel – 1500 ppm	13.33	26.13	13.60	25.00	**13.47**	**25.57**
C_6 : Cycocel – 2000 ppm	14.40	28.67	14.07	24.87	**14.23**	**26.77**
C_7: Water spray	12.33	25.33	13.00	21.93	**12.67**	**23.63**
Mean	**12.90**	**24.91**	**13.80**	**23.72**	**13.35**	**24.32**

Comparison	At 40 DAT		At 60 DAT	
	SEm(±)	C. D. (0.05)	SEm(±)	C. D. (0.05)
V	0.33	NS	0.50	NS
C	0.69	NS	0.87	1.79
C at same level of V	0.97	NS	1.22	3.06
V at same level of C	0.96	NS	1.24	3.09

4.2.1.3.1. Varieties

There was no significant variation observed between varieties on number of primary branches both at 40 and 60 DAT.

4.2.1.3.2. Growth retardants

Growth retardants did not show any significant variation on number of primary branches at 40 DAT. At 60 DAT, treatments varied significantly between each other. Significantly more number of primary branches per plant was recorded in treatment C_6 (10.87) which were on par with treatment C_5 (9.75).

4.2.1.3.3. Varieties x *Growth retardants*

The data regarding number of primary branches per plant exhibited no significant interaction between varieties and growth retardants both at 40 and 60 DAT.

4.2.1.4. Number of secondary branches per plant

The number of secondary branches was recorded at 60 DAT and the results are presented in the Table 19.

4.2.1.4.1. Varieties

The varieties differed significantly between each other on the number of secondary branches per plant. The variety V_2 recorded significantly more number of secondary branches per plant (9.58).

4.2.1.4.2. Growth retardants

The growth retardants differed significantly among each other on the number of secondary branches per plant. Among the treatments, significantly more number of secondary branches was recorded in treatment C_5 (10.13) which were statistically similar to all other treatments except C_3.

Table 18: Effect of growth retardants on primary branches per plant of African marigold varieties during pre-monsoon season

Treatments	V_1-Pusa Narangi Gainda		V_2-Maxima Yellow F_1		Mean (40 DAT)	Mean (60 DAT)
	At 40 DAT	At 60 DAT	At 40 DAT	At 60 DAT		
C_1 : Alar – 500 ppm	3.87	7.87	3.67	8.00	**3.77**	**7.93**
C_2 : Alar – 1000 ppm	4.47	8.07	4.00	8.73	**4.23**	**8.40**
C_3 : Alar – 1500 ppm	3.80	8.33	4.00	7.93	**3.90**	**8.13**
C_4 : Cycocel – 1000 ppm	3.93	8.33	3.80	8.13	**3.87**	**8.23**
C_5 : Cycocel – 1500 ppm	4.73	11.00	4.67	8.50	**4.70**	**9.75**
C_6 : Cycocel – 2000 ppm	4.53	12.60	5.07	9.13	**4.80**	**10.87**
C_7: Water spray	4.13	10.53	4.20	7.80	**4.17**	**9.17**
Mean	**4.21**	**9.53**	**4.20**	**8.32**	**4.20**	**8.93**

Comparison	At 40 DAT		At 60 DAT	
	SEm(±)	C. D. (0.05)	SEm(±)	C. D. (0.05)
V	0.21	NS	0.99	NS
C	0.46	NS	0.55	1.13
C at same level of V	0.65	NS	0.77	NS
V at same level of C	0.64	NS	1.23	NS

4.2.1.4.3. Varieties x *Growth retardants*

The interaction of varieties and growth retardants significantly affected the number of secondary branches per plant. Within variety V_1, treatment C_6 recorded significantly higher number of secondary branches per plant (10.67) which was statistically similar to treatments C_1, C_2 and C_7. Within varietyV_2, treatment C_5 recorded significantly higher number of secondary branches per plant (12.2) which was on par with treatment C_4 (10.73). Within a treatment, significantly higher number of secondary branches was recorded in treatments C_4 and C_5 of variety V_2.

4.2.1.5. Leaf area

The leaf area (cm^2) was recorded at 40 and 60 DAT and results obtained are presented in the Table 20.

4.2.1.5.1. Varieties

According to the data, varieties did not show any significant influence on leaf area upto 40 DAT. Thereafter, at 60 DAT, significant difference was noticed between varieties. Significantly higher leaf area was observed in variety V_2 (654.85 cm^2).

4.2.1.5.2. Growth retardants

The data on leaf area revealed that growth retardants varied significantly between each other both at 40 and 60 DAT. At 40 DAT, significantly higher leaf area was recorded in treatment C_6 (76.14 cm^2). At 60 DAT, maximum leaf area was observed in C_3 (772.95 cm^2), which was on par with C_2 (755.6 cm^2).

4.2.1.5.3. Varieties x *Growth retardants*

The interaction of varieties and growth retardants on leaf area was found statistically insignificant at 40 DAT. At 60 DAT, the interaction significantly influenced leaf area. Within variety V_1, treatment C_2 recorded maximum leaf area (765.7 cm^2) which was statistically similar to treatments C_3, C_4 and C_5. Within

Table 19: Effect of growth retardants on secondary branches per plant at 60 DAT in African marigold varieties during pre-monsoon season

Treatments	V_1-Pusa Narangi Gainda	V_2-Maxima Yellow F_1	Mean
C_1 : Alar – 500 ppm	9.47	9.20	**9.33**
C_2 : Alar – 1000 ppm	8.60	9.13	**8.87**
C_3 : Alar – 1500 ppm	6.47	8.47	**7.47**
C_4 : Cycocel – 1000 ppm	7.80	10.73	**9.27**
C_5 : Cycocel – 1500 ppm	8.06	12.20	**10.13**
C_6 : Cycocel – 2000 ppm	10.67	9.13	**9.90**
C_7: Water spray	9.27	8.20	**8.73**
Mean	**8.62**	**9.58**	**9.10**
Comparison	**SEm(±)**	**C. D. (0.05)**	
V	**0.11**	**0.52**	
C	**0.74**	**1.53**	
C at same level of V	**1.04**	**2.19**	
V at same level of C	**0.97**	**2.05**	

Table 20: Effect of growth retardants on leaf area (cm^2) of African marigold varieties during pre-monsoon season

Treatments	V_1-Pusa Narangi Gainda		V_2-Maxima Yellow F_1		Mean (40 DAT)	Mean (60 DAT)
	At 40 DAT	At 60 DAT	At 40 DAT	At 60 DAT		
C_1 : Alar – 500 ppm	67.70	587.92	67.84	491.03	67.77	539.48
C_2 : Alar – 1000 ppm	68.38	765.70	72.30	745.50	70.34	755.60
C_3 : Alar – 1500 ppm	76.32	707.52	70.61	838.38	73.47	772.95
C_4 : Cycocel – 1000 ppm	69.06	678.41	66.80	734.76	67.93	706.59
C_5 : Cycocel – 1500 ppm	69.23	676.50	68.97	724.01	69.10	700.26
C_6 : Cycocel – 2000 ppm	75.22	518.46	77.05	705.21	76.14	611.83
C_7: Water spray	67.02	450.33	64.79	345.05	65.91	397.69
Mean	70.42	626.41	69.77	654.85	70.09	640.63

Comparison	At 40 DAT		At 60 DAT	
	SEm(±)	C. D. (0.05)	SEm(±)	C. D. (0.05)
V	0.47	NA	1.24	5.72
C	1.22	2.53	31.13	64.62
C at same level of V	1.72	NS	44.02	91.49
V at same level of C	1.66	NS	40.77	84.74

variety V_2, treatment C_3 recorded significantly higher leaf area (838.38 cm^2). Within a treatment, significantly higher number of secondary branches was recorded in treatments C_1 and C_7 of variety V_1 and treatments C_3 and C_6 of variety V_2.

4.2.1.6. Internodal length

The internodal length (cm) was recorded at 40 and 60 DAT and the results are presented in Table 21.

4.2.1.6.1. Varieties

The varieties differed significantly between each other on the internodal length both at 40 and 60 DAT. The variety V_2 recorded significantly lower internodal length both at 40 (1.37 cm) and 60 (2.55 cm) DAT.

4.2.1.6.2. Growth retardants

The growth retardants differed significantly between each other on the internodal length at both 40 and 60 DAT. At 40 DAT, significantly lower internodal length was recorded in treatment C_6 (1.69 cm) which was statistically similar to treatments C_1, C_3, C_4 and C_5. At 60 DAT, treatment C_3 (3.05 cm) resulted in minimum internodal length which was on par with treatments C_2 (3.17 cm) and C_6 (3.33 cm).

4.2.1.6.3. Varieties x *Growth retardants*

The interaction of varieties and growth retardants on internodal length was found insignificant at 40 DAT. At 60 DAT, the interaction significantly influenced internodal length. Within variety V_1, treatment C_2 recorded minimum internodal length (3.69 cm) which was statistically similar to treatments C_1, C_3 and C_4. Irrespective of all the treatments, internodal length was found significantly lower in variety V_2.

Table 21: Effect of growth retardants on internodal length (cm) of African marigold varieties during pre-monsoon season

Treatments	V_1-Pusa Narangi Gainda		V_2-Maxima Yellow F_1		Mean (40 DAT)	Mean (60 DAT)
	At 40 DAT	At 60 DAT	At 40 DAT	At 60 DAT		
C_1 : Alar – 500 ppm	2.44	4.19	1.30	2.54	**1.87**	**3.36**
C_2 : Alar – 1000 ppm	2.60	3.69	1.52	2.65	**2.06**	**3.17**
C_3 : Alar – 1500 ppm	2.24	3.72	1.25	2.39	**1.75**	**3.05**
C_4 : Cycocel – 1000 ppm	2.13	4.06	1.37	2.72	**1.75**	**3.39**
C_5 : Cycocel – 1500 ppm	2.50	4.70	1.34	2.51	**1.92**	**3.60**
C_6 : Cycocel – 2000 ppm	2.10	4.29	1.27	2.37	**1.69**	**3.33**
C_7: Water spray	2.60	4.86	1.53	2.65	**2.06**	**3.75**
Mean	**2.37**	**4.21**	**1.37**	**2.55**	**1.87**	**3.38**

Comparison	At 40 DAT		At 60 DAT	
	SEm(±)	C. D. (0.05)	SEm(±)	C. D. (0.05)
V	0.06	0.29	0.08	0.35
C	0.13	0.27	0.14	0.29
C at same level of V	0.19	NS	0.19	0.49
V at same level of C	0.18	NS	0.20	0.49

4.2.1.7. Stem girth

The stem girth (cm) was recorded at 40 and 60 DAT and the results are presented in Table 22.

4.2.1.7.1. Varieties

Varieties differed significantly between each other on stem girth at 40 DAT. Among the varieties, significantly higher stem girth was recorded in treatment V_2 (2.27 cm). There was no significant variation observed between varieties on stem girth at 60 DAT.

4.2.1.7.2. Growth retardants

According to the data presented in Table 22, growth retardants varied significantly between each other on stem girth both at 40 and 60 DAT. Significantly higher stem girth was recorded in treatment C_6 both at 40 (2.33 cm) and 60 (3.23 cm) DAT. The observation was on par with treatments C_4 and C_5 at 40 DAT and with treatment C_5 at 60 DAT.

4.2.1.7.3. Varieties x *Growth retardants*

The interaction of varieties and treatments on stem girth was found insignificant both at 40 and 60 DAT.

4.2.1.8. Total biomass

The observations on total biomass (g) were recorded and the results obtained are presented in Table 23.

4.2.1.8.1. Varieties

The varieties differed significantly between each other on total biomass. Among the varieties, significantly higher total biomass was recorded in variety V_1 (28. 25 g).

Table 22: Effect of growth retardants on stem girth (cm) of African marigold varieties during pre-monsoon season

Treatments	V_1-Pusa Narangi Gainda		V_2-Maxima Yellow F_1		Mean (40 DAT)	Mean (60 DAT)
	At 40 DAT	At 60 DAT	At 40 DAT	At 60 DAT		
C_1 : Alar – 500 ppm	1.50	2.42	2.20	3.08	**1.85**	**2.75**
C_2 : Alar – 1000 ppm	1.50	2.55	2.20	2.95	**1.85**	**2.75**
C_3 : Alar – 1500 ppm	1.80	2.57	2.23	2.95	**2.02**	**2.76**
C_4 : Cycocel – 1000 ppm	1.63	2.58	2.36	3.03	**2.00**	**2.81**
C_5 : Cycocel – 1500 ppm	1.90	2.94	2.30	2.96	**2.10**	**2.95**
C_6 : Cycocel – 2000 ppm	2.06	3.04	2.60	3.42	**2.33**	**3.23**
C_7: Water spray	1.80	2.72	2.00	2.85	**1.90**	**2.79**
Mean	**1.74**	**2.69**	**2.27**	**3.04**	**2.01**	**2.86**

Comparison	At 40 DAT		At 60 DAT	
	SEm(±)	C. D. (0.05)	SEm(±)	C. D. (0.05)
V	0.07	0.33	0.18	NS
C	0.14	0.29	0.14	0.28
C at same level of V	0.19	NS	0.191	NS
V at same level of C	0.19	NS	0.25	NS

4.2.1.8.2. Growth retardants

The growth retardants varied significantly between each other on total biomass. Significantly higher total biomass was recorded in treatment C_6 (27.54 g) which was on par with treatment C_5 (27.21 g).

4.2.1.8.3. Varieties x *Growth retardants*

The interaction between varieties and growth retardants did not show any significant influence on total biomass.

4.2.1.9. Crop duration

The total crop duration was recorded and the results obtained are presented in Table 23.

4.2.1.9.1. Varieties

The varieties differed significantly between each other on crop duration. Among the varieties, significantly higher crop duration was recorded in variety V_2 (139.10 days).

4.2.1.9.2. Growth retardants

The growth retardants varied significantly between each other on crop duration. Significantly higher crop duration was recorded in treatment C_6 (140 days) which was on par with treatments C_1, C_2, C_3 and C_5.

4.2.1.9.3. Varieties x *Growth retardants*

The interaction between varieties and growth retardants did not show any significant influence on crop duration.

Table 23: Effect of growth retardants on total biomass (g) and crop duration (days) of African marigold varieties during pre-monsoon season

Treatments	Total biomass (g)			Crop duration (days)		
	V_1- Pusa Narangi Gainda	V_2-Maxima Yellow F_1	Mean	V_1- Pusa Narangi Gainda	V_2-Maxima Yellow F_1	Mean
C_1 : Alar – 500 ppm	27.58	20.70	**24.14**	137.00	139.67	**138.33**
C_2 : Alar – 1000 ppm	27.27	19.51	**23.39**	136.00	141.00	**138.50**
C_3 : Alar – 1500 ppm	25.23	19.46	**22.35**	136.67	139.33	**138.00**
C_4 : Cycocel – 1000 ppm	28.40	18.60	**23.50**	134.33	137.33	**135.83**
C_5 : Cycocel – 1500 ppm	31.75	22.66	**27.21**	136.67	142.00	**139.33**
C_6 : Cycocel – 2000 ppm	30.44	24.63	**27.54**	139.00	141.00	**140.00**
C_7: Water spray	27.06	17.82	**22.44**	133.00	134.67	**133.83**
Mean	**28.25**	**20.48**	**24.37**	**136.29**	**139.1**	**137.69**

Comparison	SEm(±)	C. D. (0.05)	SEm(±)	C. D. (0.05)
V	**0.78**	**3.60**	**0.48**	**2.24**
C	**1.60**	**3.33**	**0.81**	**1.68**
C at same level of V	**2.27**	**NS**	**1.144**	**NS**
V at same level of C	**2.24**	**NS**	**1.164**	**NS**

4.2.2. Flower characters

4.2.2.1. Days to first flowering

The number of days taken for first flowering was recorded and the data are presented in Table 24.

4.2.2.1.1. Varieties

The data regarding days to first flowering revealed that varieties differed significantly between each other. The variety V_2 took significantly minimum number of days to first flowering (58.19 days).

4.2.2.1.2. Growth retardants

The effect of growth retardants on number of days to first flowering was found statistically insignificant.

4.2.2.1.3. Varieties x *Growth retardants*

The interaction between varieties and growth retardants did not show any significant influence on days to first flowering.

4.2.2.2. Days to 50% flowering

The observation on number of days taken for 50 % flowering was recorded and the results are presented in Table 24.

4.2.2.2.1. Varieties

According to the data presented in Table 24, the varieties differed significantly between each other on days to 50 % flowering. Among the varieties, significantly minimum number of days to 50 % flowering was recorded in variety V_2 (62.57 days).

Table 24: Effect of growth retardants on days to first flowering and days to 50 % flowering of African marigold varieties during pre-monsoon season

Treatments	Days to first flowering			Days to 50 % flowering		
	V_1- Pusa Narangi Gainda	V_2-Maxima Yellow F_1	Mean	V_1- Pusa Narangi Gainda	V_2-Maxima Yellow F_1	Mean
C_1 : Alar – 500 ppm	65.67	58.33	**62.00**	73.00	63.00	**68.00**
C_2 : Alar – 1000 ppm	66.00	58.00	**62.00**	73.33	62.67	**68.00**
C_3 : Alar – 1500 ppm	64.67	58.00	**61.33**	73.00	62.67	**67.83**
C_4 : Cycocel – 1000 ppm	69.33	58.33	**63.83**	75.67	62.33	**69.00**
C_5 : Cycocel – 1500 ppm	69.33	56.67	**63.00**	76.00	60.67	**68.33**
C_6 : Cycocel – 2000 ppm	66.00	58.67	**62.33**	73.67	62.67	**68.17**
C_7: Water spray	69.00	59.33	**64.17**	76.67	64.00	**70.33**
Mean	**67.14**	**58.19**	**62.67**	**74.48**	**62.57**	**68.52**

Comparison	SEm(±)	C. D. (0.05)	SEm(±)	C. D. (0.05)
V	**0.55**	**2.54**	**0.58**	**2.68**
C	**1.18**	**NS**	**1.40**	**NS**
C at same level of V	**1.66**	**NS**	**1.98**	**NS**
V at same level of C	**1.64**	**NS**	**1.93**	**NS**

4.2.2.2.2. Growth retardants

The effect of growth retardants on number of days to 50 % flowering was found insignificant.

4.2.2.2.3. Varieties x *Growth retardants*

The interaction between varieties and growth retardants did not show any significant influence on days to 50 % flowering.

4.2.2.3. Days to first harvest

The observation on number of days taken to first harvest was recorded and the data are presented in Table 25.

4.2.2.3.1. Varieties

According to the data presented in Table 25, the varieties varied significantly among each other with respect to number of days to first harvest. The variety, V_2 took significantly minimum number of days to first harvest (70.76).

4.2.2.3.2. Growth retardants

The growth retardants significantly influenced number of days taken for first harvest. Minimum number of days to first harvest was observed in treatment C_3 (72.33 days), which was similar to treatments C_1, C_2, C_5 and C_6.

4.2.2.3.3. Varieties x *Growth retardants*

The interaction of varieties and growth retardants on days to first harvest was found insignificant as presented in Table 25.

4.2.2.4. Flower length

The observation on flower length (cm) was recorded and the results are presented in Table 25.

Table 25: Effect of growth retardants on days to first harvest and flower length (cm) of African marigold varieties during pre-monsoon season

Treatments	Days to first harvest			Flower length (cm)		
	V_1- Pusa Narangi Gainda	V_2-Maxima Yellow F_1	Mean	V_1- Pusa Narangi Gainda	V_2-Maxima Yellow F_1	Mean
C_1 : Alar – 500 ppm	75.00	70.00	**72.50**	15.96	10.03	**13.00**
C_2 : Alar – 1000 ppm	76.67	70.00	**73.33**	15.10	9.59	**12.35**
C_3 : Alar – 1500 ppm	73.33	71.33	**72.33**	15.27	10.30	**12.78**
C_4 : Cycocel – 1000 ppm	78.33	71.00	**74.67**	16.33	10.77	**13.55**
C_5 : Cycocel – 1500 ppm	77.67	70.00	**73.83**	16.33	10.90	**13.62**
C_6 : Cycocel – 2000 ppm	74.00	71.00	**72.50**	16.10	10.80	**13.45**
C_7: Water spray	78.33	72.00	**75.17**	17.50	10.77	**14.13**
Mean	**76.19**	**70.76**	**73.48**	**16.08**	**10.45**	**13.27**
Comparison	**SEm(±)**	**C. D. (0.05)**		**SEm(±)**	**C. D. (0.05)**	
V	**0.59**	**2.76**		**0.40**	**1.87**	
C	**0.96**	**1.99**		**0.56**	**NS**	
C at same level of V	**1.36**	**NS**		**0.79**	**NS**	
V at same level of C	**1.39**	**NS**		**0.83**	**NS**	

4.2.2.4.1. Varieties

The data on flower length presented in Table 25 revealed that the varieties varied significantly among each other. Significantly lower flower length was recorded in variety V_2 (10.45 cm).

4.2.2.4.2. Growth retardants

The effect of growth retardants did not show any significant influence on flower length.

4.2.2.4.3. Varieties x *Growth retardants*

The interaction between varieties and growth retardants did not show any significant effect of on flower length.

4.2.2.5. Pedicel length

The observation on pedicel length (cm) was recorded and the data are presented in Table 26.

4.2.2.5.1. Varieties

According to the data presented in Table 26, varieties differed significantly between each other on pedicel length. Among the varieties, significantly lower pedicel length was recorded in variety V_2 (7.44 cm).

4.2.2.5.2. Growth retardants

The effect of growth retardants on pedicel length was found statistically insignificant.

4.2.2.5.3. Varieties x *Growth retardants*

The interaction between varieties and growth retardants did not show any significant influence on pedicel length.

Table 26: Effect of growth retardants on pedicel length (cm) and flower diameter (cm) of African marigold varieties during pre-monsoon season

Treatments	Pedicel length (cm)			Flower diameter (cm)		
	V_1- Pusa Narangi Gainda	V_2-Maxima Yellow F_1	Mean	V_1- Pusa Narangi Gainda	V_2-Maxima Yellow F_1	Mean
C_1 : Alar – 500 ppm	12.97	6.89	**9.93**	3.37	5.59	**4.48**
C_2 : Alar – 1000 ppm	12.00	6.95	**9.48**	3.34	5.66	**4.50**
C_3 : Alar – 1500 ppm	12.13	7.60	**9.87**	3.63	5.65	**4.64**
C_4 : Cycocel – 1000 ppm	13.03	7.57	**10.3**	3.33	6.19	**4.76**
C_5 : Cycocel – 1500 ppm	13.57	7.87	**10.72**	3.67	5.57	**4.62**
C_6 : Cycocel – 2000 ppm	13.12	7.37	**10.24**	3.90	6.03	**4.97**
C_7: Water spray	14.80	7.85	**11.33**	3.30	5.45	**4.37**
Mean	**13.09**	**7.44**	**10.27**	**3.51**	**5.73**	**4.62**
Comparison	**SEm(±)**	**C. D. (0.05)**		**SEm(±)**	**C. D. (0.05)**	
V	**0.30**	**1.39**		**0.02**	**0.08**	
C	**0.55**	**NS**		**0.18**	**NS**	
C at same level of V	**0.78**	**NS**		**0.25**	**NS**	
V at same level of C	**0.78**	**NS**		**0.23**	**NS**	

4.2.2.6. Flower diameter

The flower diameter was recorded from flowers at fully grown stage and results are presented in Table 26.

4.2.2.6.1. Varieties

The data regarding flower diameter presented in Table 26 revealed that the varieties differed significantly between each other. Significantly higher flower length was recorded in variety V_2 (5.73 cm).

4.2.2.6.2. Growth retardants

The effect of growth retardants on flower diameter was found statistically insignificant.

4.2.2.6.3. Varieties x *Growth retardants*

The interaction between varieties and growth retardants did not show any significant influence on flower diameter.

4.2.2.7. Flower weight

The mean flower weight (g) was recorded from flowers at fully grown stage and data are presented in Table 27.

4.2.2.7.1. Varieties

The data regarding mean flower weight revealed that varieties differed significantly between each other. Among the varieties, maximum mean flower weight was observed in variety V_2 (8.09 g)

4.2.2.7.2. Growth retardants

There was no significant difference noticed among the growth retardants on mean flower weight.

Table 27: Effect of growth retardants on flower weight (g) of African marigold varieties during pre-monsoon season

Treatments	Flower weight (g)			Number of flowers per plant		
	V_1- Pusa Narangi Gainda	V_2-Maxima Yellow F_1	Mean	V_1- Pusa Narangi Gainda	V_2-Maxima Yellow F_1	Mean
C_1 : Alar – 500 ppm	5.11	7.50	**6.30**	13.83	35.57	**24.70**
C_2 : Alar – 1000 ppm	5.29	7.52	**6.41**	12.89	35.67	**24.28**
C_3 : Alar – 1500 ppm	5.07	8.57	**6.82**	15.10	34.67	**24.88**
C_4 : Cycocel – 1000 ppm	4.90	8.41	**6.66**	15.20	34.32	**24.76**
C_5 : Cycocel – 1500 ppm	4.90	8.53	**6.72**	15.17	33.99	**24.58**
C_6 : Cycocel – 2000 ppm	5.23	8.66	**6.95**	17.30	36.27	**26.78**
C_7: Water spray	4.62	7.41	**6.01**	12.67	30.57	**21.62**
Mean	**5.02**	**8.09**	**6.55**	**14.59**	**34.44**	**24.51**

Comparison	SEm(±)	C. D. (0.05)	SEm(±)	C. D. (0.05)
V	**0.14**	**0.63**	**1.27**	**5.87**
C	**0.29**	**NS**	**0.83**	**1.72**
C at same level of V	**0.42**	**NS**	**1.17**	**NS**
V at same level of C	**0.42**	**NS**	**1.67**	**NS**

4.2.2.7.3. Varieties x *Growth retardants*

The interaction between varieties and growth retardants on mean flower weight did not show any statistical difference among each other.

4.2.2.8. Number of flowers per plant

The number of flowers per plant was recorded and the data are presented in Table 27.

4.2.2.8.1. Varieties

The data analysis on number of flowers per plant revealed that varieties differ significantly between each other. Significantly higher number of flowers per plant was observed in variety V_2 (34.44).

4.2.2.8.2. Growth retardants

The growth retardants differed significantly between each other on number of flowers per plant. Among the treatments, significantly maximum number of flowers per plant was exhibited by treatment C_6 (26.78).

4.2.2.8.3. Varieties x *Growth retardants*

According to the data presented in Table 27, the interaction between varieties and growth retardants on number of flowers per plant did not differed significantly among each other.

4.2.2.9. Total flower yield per plant

The total flower yield per plant was recorded and the data was statistically analyzed and are presented in Table 28.

4.2.2.9.1. Varieties

The varieties differed significantly between each other on total flower yield per plant. The variety V_2 recorded significantly higher total flower yield per plant (279.40 g).

4.2.2.9.2. Growth retardants

The growth retardants significantly influenced total yield per plant. Significantly higher total flower yield per plant was observed in treatment C_6 (202.41 g), which was similar to treatments C_3, C_4 and C_5.

4.2.2.9.3. Varieties x *Growth retardants*

The interaction of varieties and growth retardants on total flower yield per plant was found insignificant as presented in Table 28.

4.2.2.10. Marketable flower yield per plant

The marketable flower yield per plant was recorded and the data are presented in Table 28.

4.2.2.10.1. Varieties

The varieties differed significantly between each other on marketable flower yield per plant. The variety V_2 recorded significantly higher marketable flower yield per plant (188.5 g).

4.2.2.10.2. Growth retardants

The growth retardants significantly influenced marketable flower yield per plant. Significantly higher marketable yield per plant was observed in treatment C_6 (143.29 g), which was similar to treatments C_3, C_4 and C_5.

4.2.2.10.3. Varieties x *Growth retardants*

The interaction of varieties and growth retardants on marketable flower yield per plant was found insignificant as presented in Table 28.

4.2.2.11. Flowering duration

The duration of flowering was recorded and the results are presented in Table 29.

Table 28: Effect of growth retardants on total yield per plant (g) and marketable yield per plant (g) of African marigold varieties during pre-monsoon season

Treatments	Total yield per plant (g)			Marketable yield per plant (g)		
	V_1- Pusa Narangi Gainda	V_2-Maxima Yellow F_1	Mean	V_1- Pusa Narangi Gainda	V_2-Maxima Yellow F_1	Mean
C_1 : Alar – 500 ppm	70.68	268.01	**169.35**	50.34	158.53	**104.44**
C_2 : Alar – 1000 ppm	67.98	270.42	**169.20**	45.54	180.15	**112.84**
C_3 : Alar – 1500 ppm	77.24	297.4	**187.32**	56.10	200.25	**128.18**
C_4 : Cycocel – 1000 ppm	74.34	289.43	**181.88**	52.27	199.13	**125.70**
C_5 : Cycocel – 1500 ppm	74.39	289.61	**182.00**	53.14	206.72	**129.93**
C_6 : Cycocel – 2000 ppm	90.68	314.15	**202.41**	70.02	216.56	**143.29**
C_7: Water spray	58.31	226.76	**142.53**	41.52	158.15	**99.83**
Mean	**73.37**	**279.40**	**176.39**	**52.70**	**188.50**	**120.60**
Comparison	**SEm(±)**	**C. D. (0.05)**		**SEm(±)**	**C. D. (0.05)**	
V	**12.49**	**57.86**		**10.28**	**47.59**	
C	**13.46**	**27.94**		**10.75**	**22.33**	
C at same level of V	**19.03**	**NS**		**15.21**	**NS**	
V at same level of C	**21.59**	**NS**		**17.43**	**NS**	

4.2.2.11.1. Varieties

The data regarding flowering duration revealed that varieties differed significantly between each other with the parameter. Among the varieties, significantly higher flowering duration was displayed by variety V_2 (68.71).

4.2.2.11.2. Growth retardants

The growth retardants differed significantly among each other on flowering duration. Significantly higher flowering duration was recorded in treatment C_6 (67.33) which were statistically similar to treatments C_1, C_3 and C_5.

4.2.2.11.3. Varieties x *Growth retardants*

According to the data presented in Table 29, the interaction of varieties and growth retardants exhibited significant difference among each other on flowering duration. Within variety V_1, significantly higher flower duration was recorded in treatment C_6 (64.67) which were on par with treatment C_1 (61.33). Within variety V_2, treatment C_5 resulted in maximum flowering duration (72.33) which was on par with treatments C_3 (69.67) and C_6 (70.00). Irrespective of all treatments, variety V_2 recorded significantly higher flowering duration.

4.2.2.12. Post-harvest longevity of flowers

The data on post-harvest longevity was recorded and are presented in Table 29.

4.2.2.12.1. Varieties

The data regarding post-harvest longevity of flowers revealed that varieties differed significantly between each other. Significantly higher post-harvest life was recoded in variety V_2 (3.74).

4.2.2.12.2. Growth retardants

The growth retardants varied significantly among each other on post-harvest longevity of flowers. Among the treatments, C_6 recorded significantly

Table 29: Effect of growth retardants on duration of flowering and post-harvest longevity of African marigold varieties during pre-monsoon season

Treatments	Duration of flowering			Post-harvest longevity		
	V_1- Pusa Narangi Gainda	V_2-Maxima Yellow F_1	Mean	V_1- Pusa Narangi Gainda	V_2-Maxima Yellow F_1	Mean
C_1 : Alar – 500 ppm	61.33	69.00	**65.17**	2.83	3.83	**3.33**
C_2 : Alar – 1000 ppm	60.00	68.00	**64.00**	3.17	3.67	**3.42**
C_3 : Alar – 1500 ppm	62.00	69.67	**65.83**	3.17	3.83	**3.50**
C_4 : Cycocel – 1000 ppm	56.67	67.33	**62.00**	3.00	3.50	**3.25**
C_5 : Cycocel – 1500 ppm	58.33	72.33	**65.33**	3.50	4.00	**3.75**
C_6 : Cycocel – 2000 ppm	64.67	70.00	**67.33**	3.58	4.16	**3.88**
C_7: Water spray	56.00	64.67	**60.33**	2.33	3.17	**2.75**
Mean	**59.86**	**68.71**	**64.29**	**3.08**	**3.74**	**3.41**
Comparison	**SEm(±)**	**C. D. (0.05)**		**SEm(±)**	**C. D. (0.05)**	
V	**0.218**	**1.011**		**0.066**	**0.307**	
C	**1.163**	**2.414**		**0.237**	**0.492**	
C at same level of V	**1.644**	**3.498**		**0.335**	**NS**	
V at same level of C	**1.538**	**3.272**		**0.317**	**NS**	

higher post-harvest longevity (3.88) which was statistically similar to treatments C_2, C_3 and C_5.

4.2.2.12.3. Varieties x *Growth retardants*

The interaction of varieties and growth retardants on post-harvest longevity was found statistically insignificant.

4.2.3. Chemical characters

4.2.3.1. SCMR

SPAD reading was recorded at the time of flowering and the data are presented in Table 30.

4.2.3.1.1. Varieties

There was no significant difference noticed among the treatments on SPAD reading.

4.2.3.1.2. Growth retardants

The growth retardants differed significantly between each other on chlorophyll content. Among the treatments, maximum chlorophyll content was exhibited by treatment C_5 (51.36) which was statistically similar to treatments C_1, C_2, C_3 and C_6.

4.2.3.1.3. Varieties x *Growth retardants*

The interaction of varieties and growth retardants varied significantly between each other on chlorophyll content as per the data presented in Table 30. Within variety V_1, treatment C_5 recorded maximum leaf chlorophyll content which was similar to all treatments except control C_7. Within variety V_2, treatment C_5 recorded maximum chlorophyll content which was on par with treatments C_1, C_2 & C_6. Within a retardant treatment, variety V_1 resulted in significantly maximum leaf chlorophyll content with treatment C_3.

4.2.3.2. Carotenoid content

The carotenoid content of flowers was recorded and the data was subjected to statistical analysis. The results obtained are presented in Table 30.

4.2.3.2.1. Varieties

The varieties differed significantly between each other on carotenoid content in flower petals. Between the varieties, significantly higher carotenoid content was recorded in variety V_1 (74.28 mg / 1000 g).

4.2.3.2.2. Growth retardants

The growth retardants varied significantly among each other on carotenoid content. Significantly higher carotenoid content was recorded in treatment C_3 (58.20 mg / 1000 g) which was on par with C_6 (55.65 mg / 1000 g).

4.2.3.2.3. Varieties x *Growth retardants*

According to the data presented in Table 30, the interaction of varieties and growth retardants exhibited significant difference between each other on carotenoid content.

Within variety V_1, treatments C_3 and C_6 resulted in significantly maximum carotenoid content (85.57 mg / 1000 g) which was on par with treatment C_5 (78.46 mg / 1000 g). Within variety V_2, significantly maximum carotenoid content was recorded with treatment C_3 (30.54 mg / 1000 g) which was on par with treatment C_6 (25.56 mg / 1000 g). Irrespective of all the treatments, carotenoid content was found significantly higher in variety V_1 (Table30).

4.2.4. Incidence of pest and disease

During pre-monsoon season, the variety Maxima Yellow F_1 was severely affected by bacterial wilt. In variety, Pusa Narangi Gainda, flower bud rot was observed towards the end of flowering season. Irrespective of varieties and growth retardant treatments, mild incidence of mite attack was also observed.

Table 30: Effect of growth retardants on SCMR and carotenoid content (mg / 1000 g) of African marigold varieties during pre-monsoon season

Treatments	SCMR			Carotenoid content (mg / 1000 g)		
	V_1- Pusa Narangi Gainda	V_2-Maxima Yellow F_1	Mean	V_1- Pusa Narangi Gainda	V_2-Maxima Yellow F_1	Mean
C_1 : Alar – 500 ppm	52.86	47.89	**50.37**	68.48	16.30	**42.49**
C_2 : Alar – 1000 ppm	52.40	46.17	**49.28**	73.36	22.85	**48.10**
C_3 : Alar – 1500 ppm	55.27	43.84	**49.57**	85.57	30.54	**58.20**
C_4 : Cycocel – 1000 ppm	50.62	43.46	**47.04**	68.32	16.67	**42.49**
C_5 : Cycocel – 1500 ppm	50.73	51.98	**51.36**	78.46	21.38	**49.92**
C_6 : Cycocel – 2000 ppm	52.02	46.49	**49.26**	85.74	25.56	**55.65**
C_7: Water spray	47.02	44.19	**45.60**	60.64	13.73	**37.18**
Mean	**51.56**	**46.29**	**48.93**	**74.28**	**21.08**	**47.72**
Comparison	**SEm(±)**	**C. D. (0.05)**		**SEm(±)**	**C. D. (0.05)**	
V	**1.450**	**NS**		**3.65**	**16.94**	
C	**1.676**	**3.479**		**1.56**	**3.24**	
C at same level of V	**2.370**	**6.761**		**2.21**	**8.90**	
V at same level of C	**2.630**	**7.503**		**4.19**	**16.86**	

Fig 1: Effect of growth retardants on plant height during two seasons

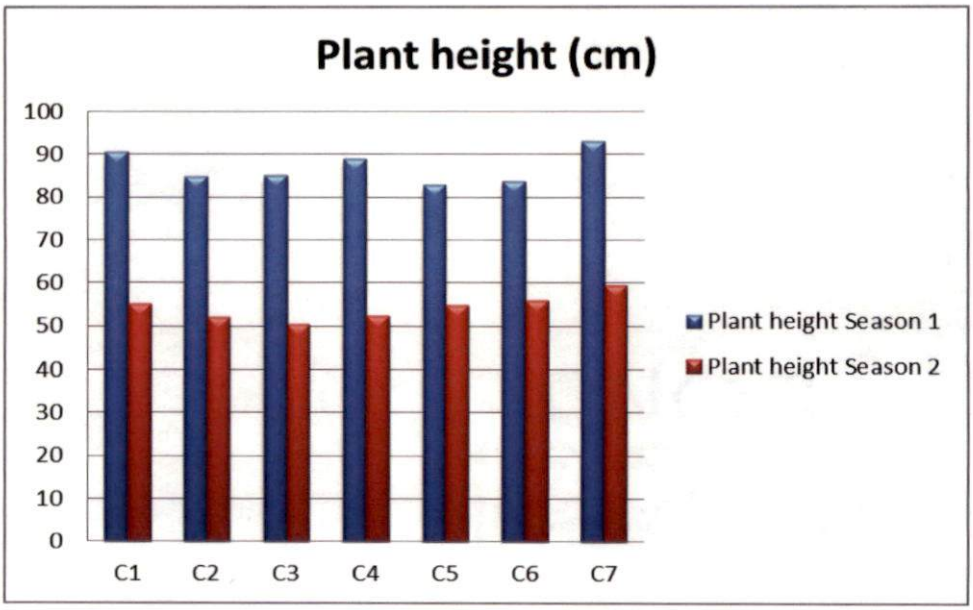


Fig 2: Effect of growth retardants on internodal length during two seasons

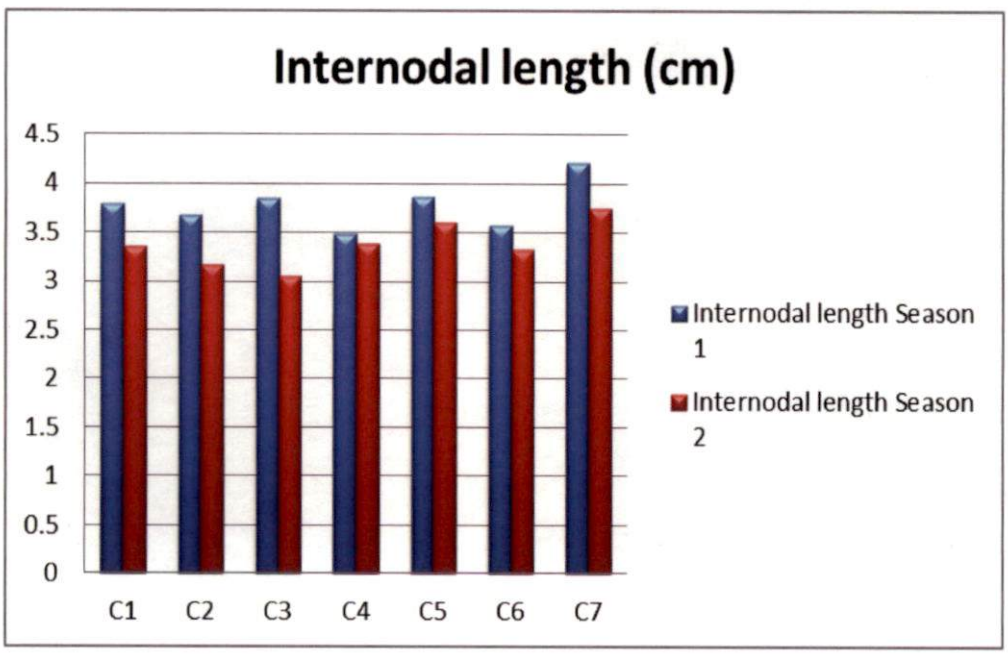


Fig 3: Effect of growth retardants on number of flowers / plant during two seasons

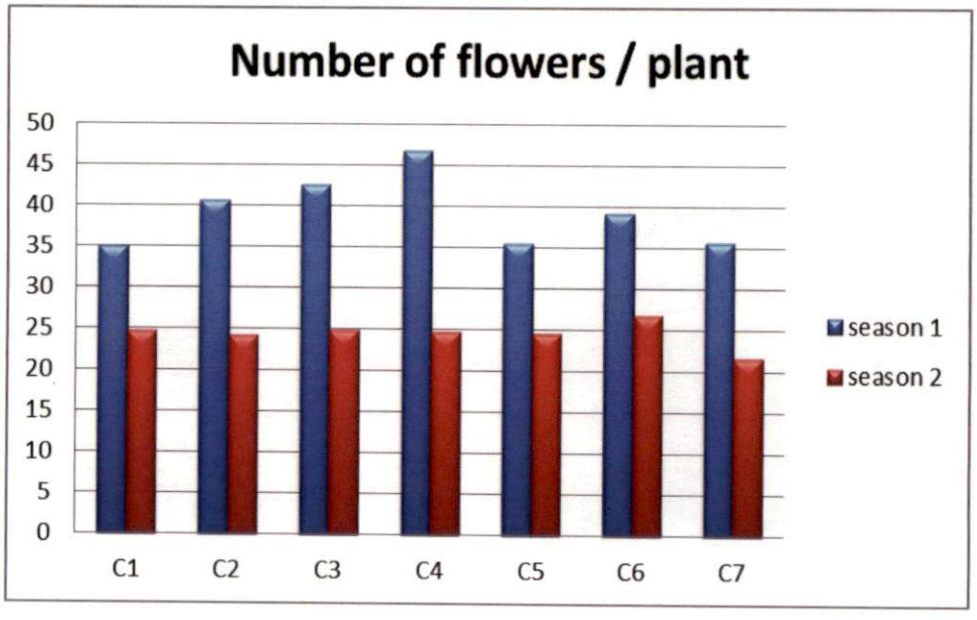
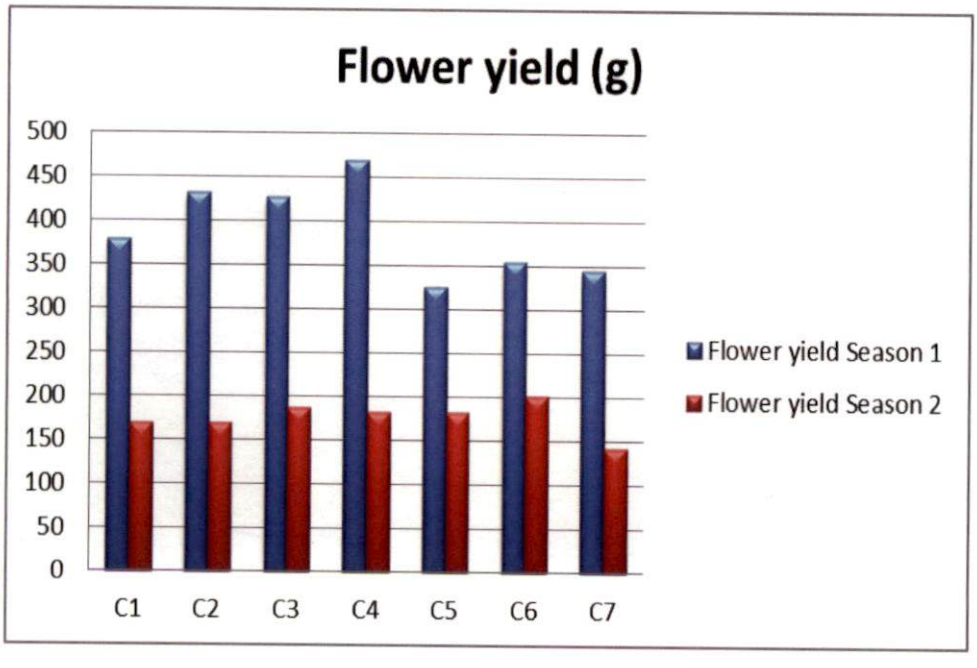


Fig 4: Effect of growth retardants on flower yield during two seasons



DISCUSSION

DISCUSSION

Marigold is one of the most popular annual flower crop commercially cultivated under different agro-climatic conditions in India. Even though Marigold is having year round demand in Kerala, its cultivation is very limited due to lack of proper technical know-how on scientific care and cultural practices as well as limited open space available for cultivation. Hence, a standardized package of practice needs to be recommended to carry out marigold cultivation in a more profitable manner irrespective of all the limiting factors. Among different plant growth retardants, Alar and Cycocel are eminent for production of quality floricultural crops. Therefore, an attempt has been made to study the effect of Alar and Cycocel on growth, yield and carotenoid content in Pusa Narangi Gainda and Maxima Yellow F_1 varieties of African marigold. The results obtained in the present experiment are briefly discussed in this chapter.

5.1 EFFECT OF GROWTH RETARDANTS ON GROWTH AND YIELD OF AFRICAN MARIGOLD DURING MONSOON SEASON

5.1.1. MORPHOLOGICAL CHARACTERS

The primary objective of using plant growth retardants is to regulate plant height and vegetative growth without any formative effects. In the present study, the effect of growth retardants on plant height are not pronounced at 40 DAT, as it was too early to get a visible impact (10 days after application of growth retardants). Significant reduction in plant height was noticed at 60 DAT with the application of both Alar and Cycocel. In Pusa Narangi Gainda, maximum retardation in plant height was observed with Alar 1000 ppm (8.9 % over control) which was on par with Cycocel 1000 ppm. In Maxima Yellow F_1, minimum plant height was noticed in plants treated with Cycocel 1500 ppm (12.98 %). The reduction in plant height with the application of Alar might be due to inhibition of Gibberellic Acid biosynthesis caused due to structural mimicking of 2-oxo glutaric acid and of Cycocel may be attributed to the presence of a quaternary ammonium group in its structure that block the biosynthesis of GA (Rademacher,

2000). The results are in conformity with the findings of Bindu (2010), Pushkar and Singh (2015) and Kumari *et al.* (2013) in African marigold. Naidu (2011) also reported that significant reduction in plant height was observed with increase in concentration of Cycocel in marigold. This was confirmed in potted roses (Hallikeri, 1985), in Chrysanthemum (Dutta *et al.,* 1998, Talukdar and Paswan, 1998), in marigold (Girwani *et al.*, 1990, Naik *et al.*, 2004). Between the two varieties, the effect of growth retardants was more pronounced in variety, Maxima Yellow F_1 (12.98 % reduction) than Pusa Narangi Gainda.

In the present study, maximum plant spread and higher number of primary and secondary branches was recorded in Pusa Narangi Gainda and in Maxima Yellow F_1 with Cycocel 2000 ppm. The possible reason for this could be that Cycocel interrupts the basipetal flow of auxin and inhibits apical dominance and induces the sprouting of auxillary buds and enhance the production of more number of lateral branches as reported by Rajyalakshmi and Rajasekhar (2014) in marigold. The increase in plant spread and number of lateral branches by Cycocel was previously reported by Naidu (2011) in marigold, Joshi and Reddy (2006) in China aster and Saiyed *et al.,* (2009) in Gaillardia.

Increase in leaf area was recorded with the application of both Alar and Cycocel. There was no significant effect noticed on leaf area and leaf chlorophyll content with the different treatments of growth retardants. On contrary to this Joshi and Reddy (2006) reported that, leaf area gradually increased with the increase in concentration of Alar in China aster. The increase in leaf area with the application of Alar might be due to its action as anti-gibberellin by which apical growth was arrested and stimulates more number of branches which in turn results in increased leaf area. Increase in leaf area with application of Cycocel might be attributed to increase in number of leaves due to reduction of plant height and increase in number of branches per plant.

There was marked difference noticed in internodal length with growth retardant spray. Among the treatments, minimum internodal length was recorded

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with Cycocel 1000 ppm which was on par with Alar 500 ppm. In Pusa Narangi Gainda, Cycocel 2000 ppm resulted in 22.17 % reduction over control in internodal length over control and in Maxima Yellow F_1, minimum internodal length was recorded with Cycocel 1000 ppm (17.07 %). Aswath (1991) also reported that minimum internodal length was obtained with Alar and Cycocel sprays in China aster. The reduction in internodal length as affected by growth retardant spray was attributed to the suppression of apical dominance by inhibiting cell division in the apical meristem and thereby resulting in shorter internodes (Cathey, 1964). El-Sheibany *et al.* (2007) also reported that internodal length was inversely proportional to Alar concentration, especially with the increasing time of growing in Chrysanthemum. The possible reason for reduction in plant height might be also attributed to shortened internodes in plants treated with Cycocel as reported by Vaghasia and Polara (2015) in Chrysanthemum.

The effect of growth retardants on stem girth was found significant in which maximum stem girth was recorded with Cycocel 2000 ppm both at 40 DAT (12.69%) and 60 DAT (22.80 %). In Pusa Narangi Gainda, significantly higher stem girth was obtained with Cycocel 2000 ppm which was on par with Alar 1500 ppm and Cycocel 1500 ppm at 40 DAT. In Maxima yellow F_1, all chemical treatments showed significantly higher stem girth over control. The result was in accordance with El-Sheibany *et al.* (2007) in Chrysanthemum. The increase in stem girth might be due to transverse cell expansion and division in sub apical tissues as reported by Barras-Ali (2002) in Chrysanthemum. Fepas *et al.* (2014) reported daminozide application significantly increased stem diameter in Chrysanthemum at short day condition.

Among the different growth parameters considered, total biomass and total crop duration failed to exhibit significant effect as influenced by the application of growth retardants. These are in line with the observations made on total biomass by Fepas *et al.* (2014) in Chrysanthemum treated with daminozide. On contrary, Cycocel treated plants exhibited reduction in total biomass and increased total

crop duration in pot marigold as reported by Azzaz *et al.* (2007). This might be due to effect of environmental and varietal characteristics.

5.1.2. FLOWERING AND YIELD PARAMETERS

Among the two varieties tried, significantly minimum flower length and pedicel length, maximum flower diameter and higher individual flower weight were recorded in Maxima Yellow F_1. In the present study, even without showing significant effect on the initiation of flower bud and commencement of flowering, the number of flowers per plant was significantly affected by different growth retardant treatments. Maximum number of flowers per plant was recorded with Alar and Cycocel at 1000 ppm. In both the varieties, Cycocel 1000 ppm exhibited significantly higher number of flowers (37.57 % and 27.64 % increase over control respectively in Maxima Yellow F_1) which was on par with Alar 1000 and Alar 1500 ppm. Of the two varieties tried, flower production was higher in Maxima Yellow F_1 (44.14 % higher) compared with Pusa Narangi Gainda. Higher number of flowers was recorded in African marigold with different doses of Alar and Cycocel. Similar results were reported by Kumari *et al.* (2013), Bindu (2010) in marigold, Anburani and Ananth (2010) in Nerium, Hashemabadi *et al.* (2012) in Calendula. The increase in number of flowers with the application of growth retardants might be attributed to the enhanced the production of lateral branches and more leaf area at initial stage of crop growth and accumulation of carbohydrates for proper flower bud differentiation. The increase in yield with the application of Cycocel might be attributed to utilization of the reserve food material for reproductive purpose with restriction on vegetative growth due to anti-gibberellic action of Cycocel as reported by Ramesh *et al.,* (2001). Kumar *et al.* (2011) also reported maximum number of flowers per plant in marigold with Cycocel 2000 ppm. Further, this could be ascribed due to increased mobilization of biomass to flowers from sources. Increased number of flowers with the application of Alar might be explicated as part of the increased number of branches per plant and inhibition of apical dominance.

The present investigation indicates that the flower yield per plant; both total yield and marketable yield, was significantly influenced by various concentrations of Alar and Cycocel. Among the varieties, Maxima Yellow F_1 recorded maximum flower yield per plant. Cycocel 1000 ppm resulted in significantly higher total and marketable flower yield per plant (36.12 % and 32.18 % over control respectively in Maxima Yellow F_1) which was statistically on par with Alar 1500 ppm in both the varieties. The results are in conformity with the work of Pushkar and Singh (2012) in marigold and Patil *et al.* (2013) in China aster. This might be attributed to the initiation of more number of auxiliary buds in accordance with the cessation of terminal bud growth. The possible reason for increase in yield with the application of Cycocel might be attributed to increase in total chlorophyll content due to increase in cytokinins in xylem sap that delays senescence of leaves and improve nutrient translocation as reported by Bindu (2010) in marigold.

Among the varieties, Maxima Yellow F_1 recorded higher post-harvest flower longevity. The effect of treatments and their interactions with varieties was found insignificant with regard to flowering duration and post-harvest longevity of flowers. This was contradictory to the results obtained by Joshi and Reddy (2006) in China aster who reported extended flower longevity with the application of alar. It might be due to environmental and plant differences.

5.1.3. CAROTENOID CONTENT

The data pertaining to carotenoid content reveals that varieties, treatments and their interactions varied significantly among each other. Among the two varieties, Pusa Narangi Gainda recorded maximum carotenoid content (25 % more than Maxima Yellow F_1) in flower petals. This might be attributed to the orange colour of the variety that possesses higher content of carotenoid pigment. Cycocel spray at 1000 ppm resulted in maximum carotenoid content in flower petals (45.16 % increase over the control) which was on par with Alar 1500 ppm, Cycocel 1500 ppm and Cycocel 2000 ppm. Carotenoid content was found significantly higher with different concentrations of Cycocel. The increase in

carotenoid content might be due to overall effect of increase in flower yield associated with growth retardant application. This result is in agreement with that obtained by Kazemi *et al.* (2014) and Azzaz *et al.* (2007) in pot marigold. This could be also ascribed to the enhanced production of cytokinins with growth retardant spray which in turn increases the carotenoid pigments as reported by Fletcher *et al.* (2010).

5.2 EFFECT OF GROWTH RETARDANTS ON GROWTH AND YIELD OF AFRICAN MARIGOLD DURING PRE-MONSOON SEASON

5.2.1. MORPHOLOGICAL CHARACTERS

The results of the present study revealed that different concentrations of plant growth retardants exhibited significant effect on vegetative characters. Plant growth retardants at all concentrations significantly resulted in reduction in plant height. Alar 1500 ppm resulted in significantly minimum plant height which was on par with Alar 1000 ppm and Cycocel 1000 ppm. Cycocel 1000 ppm resulted in minimum plant height in variety Pusa Narangi Gainda, i.e., 16.98 % less than control. In Maxima Yellow F_1, all chemical treatments significantly reduced plant height less than control (13.71 %). There are several studies reporting effectiveness of Alar and Cycocel in retarding plant height. The possible reason for height reduction by Cycocel might be due to the inhibition of cell division and elongation of sub-apical meristem. Kazemi *et al.* (2014) reported that all concentrations of Daminozide and Cycocel caused reduction in plant height in *Calendula officinalis*. The results are in line with that obtained by Dani *et al.* (2010) in African marigold, Hashemabadi *et al.* (2012) in pot marigold, Rajyalakshmi and Rajasekhar (2014) in African marigold.

Plant spread differed significantly among different treatments from 60 DAT. Maximum plant spread was recorded with Cycocel 2000 ppm (16.80 % over control) which was on par with Cycocel 1500 ppm and Alar 1000 ppm. Increase in plant spread might be attributed to inhibition of apical dominance with growth retardant spray that resulted in more number of primary and secondary

branches which increased plant spread in both the directions as reported by Vaghasia and Polara (2015) in Chrysanthemum. The results are in line with the findings of Parmar and Singh, (1983) and Naik *et al.,* (2004) in marigold, Nair *et al.,* (2002) in gerbera, Saiyed *et al.,* (2009) in Gaillardia. Number of primary and secondary branches increased significantly with the application of Cycocel. The maximum number of lateral branches was recorded with Cycocel 2000 ppm in Pusa Narangi Gainda and with Cycocel 1500 ppm in Maxima Yellow F_1 which was on par with Cycocel 1000 ppm. Similar effect of Cycocel on number of branches was observed by Dani *et al.* (2010) in marigold and Saiyed *et al.,* (2009) in Gaillardia.

Increased leaf chlorophyll content was observed with application Alar and Cycocel over control. Maximum leaf chlorophyll content was recorded with Cycocel 1500 ppm which was similar to all treatments of Alar and Cycocel at 2000 ppm. Asrar *et al.* (2014) also reported increase in total leaf chlorophyll content with increasing concentrations of Alar. Cycocel 2000 ppm recorded significantly higher leaf area (15.52 % over control) at 40 DAT and Alar 1500 ppm recorded maximum leaf area (94.35 %) at 60 DAT which was on par with Alar 1000 ppm. Joshi and Reddy (2006) reported that Cycocel 2000 ppm resulted in dark green foliage with maximum leaf area in China aster. Increase in leaf area with Cycocel application might be attributed to thicker mesophyll tissues in leaves related with higher chlorophyll content which makes the leaves photosynthetically more active for longer period resulting in enhanced production of carbohydrates. The gradual increase in leaf area with increasing concentration of Alar might be due to increase in leaf thickness, more number of palisade tissue and number of chloroplast and starch grains in spongy cells.

Significantly shorter internodes and greater stem girth was recorded with Cycocel 2000 ppm which was on par with other higher doses of retardants in both the varieties. Among the varieties evaluated, Maxima Yellow F_1 recorded more number of lateral branches and shorter internodes. Gowda and Jayanthi, (1991) also reported reduction in internodal length with the application of Cycocel in

African marigold. Reduction in plant height in turn might contribute to shortening of internodes in Cycocel treated plants (Vaghasi and Polara, 2015).

Total biomass was noticed higher with Cycocel 2000 ppm which was similar to Cycocel 1500 ppm. The application of both the retardants significantly extended crop duration over control. Maximum crop duration was displayed by Cycocel 2000 ppm which was similar to all treatments of Alar and Cycocel at 1500 ppm. It has been reported that exogenous application of Alar has shown to minimize chlorophyll loss and delay senescence and protect plants against environmental stress (Asrar *et al.,* 2014).

5.2.2. FLOWERING AND YIELD PARAMETERS

The experiment regarding the application of plant growth retardants in different concentrations significantly influenced various flowering and yield parameters. Within the two varieties considered, Maxima Yellow F_1 recorded minimum number of days to first flowering, 50 % flowering and days to first harvest as well. Considering the different treatments, Alar 1500 ppm took minimum days to first harvest even without affecting the commencement of first flowering, which was on par with Alar 500 ppm and Cycocel 1500 ppm. The varieties differed significantly on flower characters like flower length, pedicel length, flower diameter and mean flower weight to which Maxima Yellow F_1 gave preferable results. The treatments and interaction between varieties and treatments did not influence flower length, pedicel length, flower diameter and mean flower weight significantly.

Maximum number of flowers per plant (23.87 %) and significantly higher yield per plant (42.02 %) was recorded with Cycocel 2000 ppm which was on par with Cycocel 1000 ppm. Joshi and Reddy (2006) also reported that Cycocel 2000 ppm resulted in maximum number of flowers in China aster. The increase in flower number and yield might be due to increased translocation of assimilates to flowers from sources. The increase in flower yield with the application of Cycocel might be due to retardation of plant height by inhibiting terminal bud

growth and the available auxin might be in turn utilized for production of flowers. The formation of more number of branches per plant and maximum plant spread with the treatment might have resulted in accumulation of more carbohydrates which were used for production of more number of flowers eventually increasing the flower yield (Dani *et al.*, 2010).

Cycocel spray at 2000 ppm significantly increased flowering duration and vase life in both the varieties, which was on par with Alar at 1500 ppm and Cycocel at 1500 ppm. The improvement in flower longevity by Cycocel and Alar might be due to maintaining higher levels of chlorophyll, protein and the RNA content of leaves at a higher level for a longer duration delaying the senescence as reported by Joshi and Reddy (2006) in China aster. Asrar *et al.* (2014) also reported that total flowering period significantly increased with the application of Alar at different concentrations in Chrysanthemum. Similar effect of Cycocel on flowering span was reported by Vaghasia and Polara (2015) in Chrysanthemum which might be due to availability of more photosynthates for a longer time thereby prolonging the reproductive phase. Khan and Tewari (2003) reported that Cycocel at 4000 ppm resulted in maximum shelf-life in Dahlia.

5.2.3. CAROTENOID CONTENT

The experimental results showed that varieties, treatments and their interaction were significant on the carotenoid content of flower petals. Among the varieties tried, maximum carotenoid content was recorded in Pusa Narangi Gainda. Maximum carotenoid content in flowers was obtained with Alar at 1500 ppm and Cycocel at 2000 ppm (41.66 % more in Pusa Narangi Gainda and 130 % more in Maxima yellow F_1). Rao *et al.*, (2005) also reported that the cultivar Pusa Narangi Gainda produced higher carotenoid content per gram of fresh weight of flower petals while screening African marigold cultivars for carotenoid content. The study showed positive effect of growth retardants on increasing the carotenoid content of flower petals. Kazemi *et al.* (2014) also reported that effect of Cycocel, Alar and their combinations were significant on carotenoid content of flower petals in pot marigold. Significant increase yield per hectare was obtained

with Cycocel spray in marigold by Bindu (2010). This might be due attributed to increase in carotenoid content in petal and flower yield. There were earlier reports supporting the results of increasing pigment content in plants with the application of different plant growth regulators as reported by Sardoei (2014) in some indoor ornamentals and Rajalekshmi *et al.* (2009) in some medicinal plants like *Plectranthus aromaticus* and *Plectranthus vettiveroids*.

Conclusion

As per the results obtained in the present study, it could be concluded that growth retardants significantly influenced marigold with regard to different morphological, flowering, yield and carotenoid content during both monsoon and pre-monsoon seasons. Among the varieties, Maxima Yellow F_1 performed well during both the seasons when compared with Pusa Narangi Gainda (Appendix I).

The best treatment with respect to flower quality and yield parameters, which are the important economic characters regarding a flower crop, was observed with Cycocel 1000 ppm during monsoon season and Cycocel 2000 ppm during pre-monsoon season. In general, highest Benefit Cost Ratio was recorded with Cycocel 1000 ppm during both the seasons (Appendix II). Plants produced during pre-monsoon season were more compact than those during monsoon season. The total flower yield in plants was reported to be higher during monsoon season than pre-monsoon season and total carotenoids in flower petals was recorded to be maximum during pre-monsoon season than monsoon season.

The effect of growth retardants was more pronounced during pre-monsoon season than monsoon season.

SUMMARY

SUMMARY

African marigold can be called as a flower of common man with versatile uses. Besides being an important crop for landscaping, it is commercially grown for loose flowers, cut blooms, oil and pigment extraction, perfumery and cosmetics as well as for medicinal purposes. Nowadays, the demand for dwarf varieties with improved presentability for decorations and landscapes are growing. Along with the development of suitable varieties or cultivars, new production techniques have huge impact on producing such desirable traits. Plant growth retardants are growth regulating chemical substances that find extensive use in the field of floriculture for modifying plant growth and development. Alar and Cycocel are two well-known growth retardants used for producing quality plants that are now being tried in African marigold. Alar, as a growth retardant inhibits GA biosynthesis and produce plants with reduced height, increased branching and flowering. Cycocel slows down stem elongation and results in compact plants with improved flowering and quality.

The present study entitled "Effect of growth retardants on growth and yield of African marigold (*Tagetes erecta* L.)" was conducted at the Department of Pomology and Floriculture, College of Agriculture, Padannakkad during the period 2015 to 2017 *viz*., monsoon in May 2016 and pre-monsoon in January 2017. The experiment was laid out in Split plot design with two varieties of African marigold (*Tagetes erecta* L.) as main plots, *viz.,* Pusa Narangi Gainda and Maxima Yellow F_1 and growth retardants treatments as subplots and there were three replications. The treatments comprising Alar @ 500, 1000 and 1500 ppm, Cycocel @ 1000, 1500 and 2000 ppm and distilled water as control were applied as foliar spray at 30 days after transplanting. The seedlings were transplanted to the main field, 30 days after germination, at a distance of 30 x 30 cm. Observations on growth, flowering and yield parameters and carotenoid content were recorded from five randomly selected and tagged plants per replication from each treatment.

The salient findings of the present study are summarized below:

- From the study, it was revealed that, among the two varieties, Maxima Yellow F_1 (V_1) performed better for different growth parameters *viz.*, minimum plant height and internodal length, maximum plant spread, number of lateral branches, stem girth. From farmer's point of view, for flowering and yield attributing characters like days to first flowering, days to 50 percent flowering, flower length, pedicel length, flower diameter, single flower weight, number of flowers per plant and flower yield per plant Maxima Yellow F_1 performed better than Pusa Narangi Gainda.
- The different concentrations of growth retardants significantly influenced various growth parameters during both the seasons. During monsoon season, minimum plant height and minimum internodal length was recorded in plants treated with Cycocel 1500 ppm and Cycocel 1000 ppm respectively. Alar 1500 ppm and Cycocel 1000 ppm recorded minimum plant height and internodal length during pre-monsoon season.
- Maximum plant spread, number of primary branches and stem girth was observed in plants treated with Cycocel 2000 ppm during both seasons.
- The total biomass and crop duration was not significantly influenced by growth retardant application during monsoon season. However, during pre-monsoon season, Cycocel at 2000 ppm significantly increased the total biomass and crop duration.
- The flowering characters like number of days to first flowering, days to 50 % flowering, and flower parameters including flower length, pedicel length, flower diameter and single flower weight were not significantly influenced by growth retardant application during both seasons.
- Growth retardants did not significantly influenced duration of flowering and post-harvest longevity of flowers during monsoon season. However, during pre-monsoon season, Cycocel 2000 ppm recorded significantly higher flowering duration and post-harvest longevity of flowers.

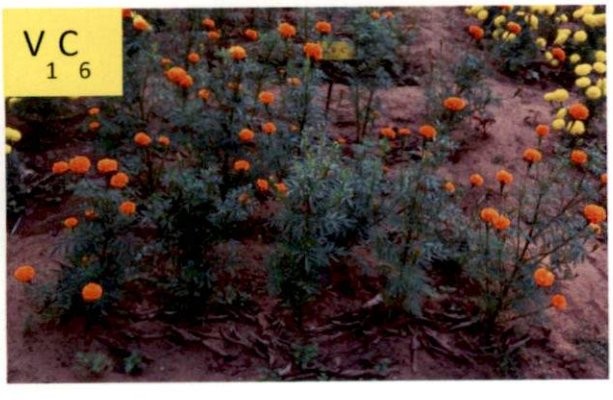
- The yield attributing characters like number of flowers per plant, total yield and marketable yield per plant were found to be maximum in plants treated with Cycocel 1000 during monsoon season and Cycocel 2000 ppm during pre-monsoon season.
- Leaf chlorophyll content was unaffected by growth retardant application during monsoon season. During pre-monsoon season, Cycocel 1500 ppm recorded significantly higher chlorophyll content.
- Carotenoid content of flower petals were significantly influenced by growth retardant application during both the seasons. Maximum carotenoid content was recorded in plants treated with Cycocel 1000 ppm during monsoon season and with Cycocel 2000 ppm during second season.
- From economic point of view, better performance with respect to growth and yield were observed in African marigold variety Maxima Yellow F_1 with the application of Cycocel at 1000 ppm during both monsoon season and pre-monsoon season (Appendix II).

From the present study and perusal of the available literatures on the application of growth retardants on various floriculture crops, it could be inferred that using suitable growth retardants in flower crops at appropriate concentrations can bring about desirable changes in growth, yield and pigment content depending upon the grower's interest. Early spraying, multiple sprays and combination of chemicals could be more advantageous depending upon the species, cultivars and seasons. With respect to varying varietal responses, better production methods and agro-techniques might be developed for Maxima Yellow F_1, of which many studies are not reported. Hence, further studies on these aspects may be initiated in future.

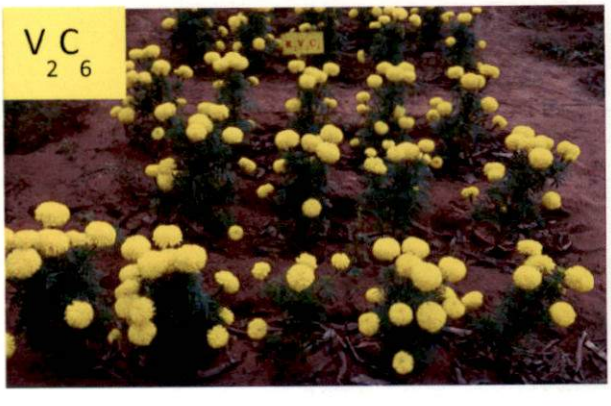
Plate 4.Best growth retardant treatments on marigold varieties

a. Cycocel 1000 ppm in Pusa Narangi Gainda

b. Cycocel 1000 ppm in Maxima Yellow F_1



c. Cycocel 2000 ppm in Pusa Narangi Gainda



d. Cycocel 2000 ppm in Maxima Yellow F_1

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EFFECT OF GROWTH RETARDANTS ON GROWTH AND YIELD OF AFRICAN MARIGOLD (*Tagetes erecta* L.).

by

SUNAYANA S

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Abstract of the Thesis

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ABSTRACT

The study entitled "Effect of growth retardants on growth and yield of African marigold (*Tagetes erecta* L.)" was conducted at College of Agriculture, Padannakkad during 2015-2017 with the objective to assess the response of marigold in terms of growth, yield and carotenoid content as influenced by foliar application of growth retardants Alar and Cycocel. The experiment was laid out in split plot design during two seasons *viz.*, monsoon and pre-monsoon. The data was subjected to statistical analysis to find out the effect of growth retardants on different parameters.

The experimental material comprised of Pusa Narangi Gainda and Maxima Yellow F_1 varieties of African marigold and their response to growth retardants was evaluated with treatments *viz.*, C_1 : Alar 500 ppm, C_2 : Alar 1000 ppm, C_3 : Alar 1500 ppm, C_4 : Cycocel 1000 ppm, C_5 : Cycocel 1500 ppm, C_6 : Cycocel 2000 ppm and C_7 : Water spray (control). The analysis of data regarding different plant characters revealed that the varieties and growth retardants resulted in significant differences with vegetative, floral and yield characters and pigment contents in flowers.

Growth retardants significantly influenced plant height, plant spread, number of branches, internodal length, and stem girth, number of flowers, flower yield and carotenoid content. There was no significant difference noticed on days to first flowering, days to 50 % flowering, flower length, pedicel length, flower diameter and flower weight. The effects of growth retardants on leaf area, SCMR, total biomass, crop duration, flowering duration and post-harvest longevity varied with seasons.

On comparing the two varieties during two seasons, Maxima Yellow F_1 performed better for most of the growth and floral characters and recorded highest flower yield in monsoon season. From economic point of view, Maxima Yellow F_1 can be recommended during monsoon season in Kerala to meet the high demand of flowers during Onam. Among the growth retardants, Cycocel 1000

ppm can be recommended for better growth, higher yield and carotenoid content in Pusa Narangi Gainda and Maxima Yellow F_1 varieties of African marigold during monsoon season and pre-monsoon seasons.

സംക്ഷിപ്തം

കേരളത്തിലെ പുഷ്പവിപണിയിൽ വളരെയധികം പ്രാധാന്യം അർഹിക്കുന്ന ഒരു പുഷ്പമാണ് ചെണ്ടുമല്ലി. ചെണ്ടുമല്ലിപ്പൂക്കളുടെ പരിപാലനവുമായി ബന്ധപ്പെട്ട് വ്യത്യസ്ത വളർച്ചാനിയന്ത്രണ ഹോർമോണുകൾ ഉപയോഗിച്ച് ചെടിയുടെ വളർച്ച, പൂക്കളുടെ ഉൽപ്പാദനം എന്നിവയിൽ വളർച്ച നിയന്ത്രണ ഹോർമോണുകളുടെ സ്വാധീനം തിരിച്ചറിയുന്നതിനായ് 2015 - 17 കാലയളവിൽ കാർഷിക കോളേജ്, പടന്നക്കാടിൽ വെച്ച് ഒരു പരീക്ഷണം നടത്തുകയുണ്ടായി. 2016 കാലവർഷവും (മെയ് മാസം), 2017 ശീതകാലവും (ജനുവരി മാസം) പ്രസ്തുത പരീക്ഷണത്തിനായി തെരഞ്ഞെടുത്തു. പുസ നാരംഗി ഗൈന്ദ , മാക്സിമ യെൽലോ എഫ് 1 എന്ന രണ്ടിനം ചെണ്ടുമല്ലിയിൽ വ്യത്യസ്തങ്ങളായ വളർച്ചാനിയന്ത്രണ ഹോർമോണുകൾ പല വീര്യത്തിൽ ഉപയോഗിക്കുകയുണ്ടായി. അവ യഥാക്രമം 500 ppm, 1000 ppm,1500 ppm വീര്യമുള്ള Alar 1000 ppm,1500 ppm, 2000 ppm വീര്യമുള്ള Cycocel എന്നിവയായിരുന്നു.

മേൽപ്പറഞ്ഞ വളർച്ചാനിയന്ത്രണ ഹോർമോണുകളുടെ ഉപയോഗത്താൽ ചെടികളുടെ ഉയരം, വ്യാപ്തി, രണ്ട് മുട്ടുകൾ തമ്മിലുള്ള അകലം എന്നിവ ഗണ്യമായി കുറയുന്നതായും, പൂക്കളുടെ എണ്ണം, വിളവ് എന്നിവ ഗണ്യമായി വർദ്ധിക്കുന്നതായും കണ്ടെത്തി. മേൽപ്പറഞ്ഞ ഇനങ്ങളിൽ മാക്സിമ യെൽലോ എഫ് 1 വളർച്ചയുടെയും പൂവുൽപ്പാദനത്തിന്റെയും എല്ലാ ഘട്ടത്തിലും മികവ് പുലർത്തുന്നതായും കണ്ടെത്തി.

ചെണ്ടുമല്ലിയുടെ മികച്ച വളർച്ചയ്ക്കും പൂവുൽപ്പാദനത്തിനും, കരോട്ടിനോയിഡ് ഉൽപ്പാദനത്തിനും 1000 ppm Cycocel കാരണമാകുന്നതായി ഈ പരീക്ഷണം തെളിയിച്ചു.

APPENDICES

Appendix 1

Comparing parameters of two seasons

Varieties	Plant height		Internodal length		Flower yield		Carotenoid content	
	Season 1	Season 2	Season 1	Season 2	Season 1	Season 2	Season 1	Season 2
V_1	96.51	66.70	4.56	4.21	177.87	73.37	40.35	74.28
V_2	77.70	42.12	2.99	2.55	603.74	279.40	32.57	21.08
SEm (±)	**0.99**	**0.88**	**0.04**	**0.08**	**22.41**	**12.49**	**0.16**	**3.65**
C. D. (0.05)	**4.56**	**4.09**	**0.19**	**0.35**	**103.81**	**57.86**	**0.77**	**16.94**
Growth retardants								
C_1	90.77	55.13	3.79	3.36	379.83	169.35	26.04	42.49
C_2	84.80	52.10	3.68	3.17	432.50	169.20	29.44	48.10
C_3	85.10	50.47	3.85	3.05	427.00	187.32	40.78	58.20
C_4	89.13	52.50	3.49	3.39	469.69	181.88	45.15	42.49
C_5	82.97	55.02	3.87	3.60	326.25	182.00	43.34	49.92
C_6	83.90	55.97	3.57	3.33	355.33	202.41	40.14	55.65
C_7	93.07	59.70	4.21	3.75	345.05	142.53	31.04	37.18
SEm(±)	**1.29**	**1.55**	**0.16**	**0.14**	**19.36**	**13.46**	**2.25**	**1.56**
C. D. (0.05)	**2.69**	**3.21**	**0.34**	**0.29**	**40.19**	**27.94**	**4.67**	**3.24**

Appendix II

a. BCR during monsoon

Particulars	V_1							V_2						
	C_1	C_2	C_3	C_4	C_5	C_6	C_7	C_1	C_2	C_3	C_4	C_5	C_6	C_7
Seeds	1000	1000	1000	1000	1000	1000	1000	99000	99000	99000	99000	99000	99000	99000
Nursery	5000	5000	5000	5000	5000	5000	5000	45000	45000	45000	45000	45000	45000	45000
Land preparation	25000	25000	25000	25000	25000	25000	25000	25000	25000	25000	25000	25000	25000	25000
Transplanting	4800	4800	4800	4800	4800	4800	4800	4800	4800	4800	4800	4800	4800	4800
FYM	8000	8000	8000	8000	8000	8000	8000	8000	8000	8000	8000	8000	8000	8000
Fertilizers	15000	15000	15000	15000	15000	15000	15000	15000	15000	15000	15000	15000	15000	15000
Growth retardants	70000	140000	210000	40000	60000	80000	0	70000	140000	210000	40000	60000	80000	0
Spraying	1000	1000	1000	1000	1000	1000	-	1000	1000	1000	1000	1000	1000	-
Irrigation	2500	2500	2500	2500	2500	2500	2500	2500	2500	2500	2500	2500	2500	2500
Weeding	7500	7500	7500	7500	7500	7500	7500	7500	7500	7500	7500	7500	7500	7500
Plant protection	1000	1000	1000	1000	1000	1000	1000	10500	10500	10500	10500	10500	10500	10500
Staking	-	-	-	-	-	-	5000	-	-	-	-	-	-	5000
Harvesting	10000	10000	10000	10000	10000	10000	10000	20000	20000	20000	20000	20000	20000	20000
Transportation	18000	18000	18000	18000	18000	18000	18000	25000	25000	25000	25000	25000	25000	25000
Total cost (in Lakh)	1.68	2.38	3.08	1.38	1.58	1.78	1.02	3.33	4.03	4.73	3.03	3.23	3.43	2.67
Gross returns (in Lakh)	4.31	4.70	5.09	7.05	6.66	6.27	3.92	12.05	14.70	14.11	15.28	12.05	12.34	10.29
Net returns(in Lakh)	2.62	2.31	2.00	5.66	5.07	4.48	2.89	8.72	10.66	9.37	12.25	8.82	8.91	7.61
BCR	2.55	1.96	1.65	5.08	4.19	3.50	3.81	3.61	3.64	2.98	5.04	3.72	3.59	3.84

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b. BCR during pre-monsoon

Particulars	V_1							V_2						
	C_1	C_2	C_3	C_4	C_5	C_6	C_7	C_1	C_2	C_3	C_4	C_5	C_6	C_7
Seeds	1000	1000	1000	1000	1000	1000	1000	99000	99000	99000	99000	99000	99000	99000
Nursery	5000	5000	5000	5000	5000	5000	5000	45000	45000	45000	45000	45000	45000	45000
land preparation	25000	25000	25000	25000	25000	25000	25000	25000	25000	25000	25000	25000	25000	25000
Transplanting	4800	4800	4800	4800	4800	4800	4800	4800	4800	4800	4800	4800	4800	4800
FYM	8000	8000	8000	8000	8000	8000	8000	8000	8000	8000	8000	8000	8000	8000
Fertilizers	15000	15000	15000	15000	15000	15000	15000	15000	15000	15000	15000	15000	15000	15000
Growth retardants	70000	140000	210000	40000	60000	80000	0	70000	140000	210000	40000	60000	80000	0
Spraying	1000	1000	1000	1000	1000	1000	-	1000	1000	1000	1000	1000	1000	-
Irrigation	5000	5000	5000	5000	5000	5000	5000	5000	5000	5000	5000	5000	5000	5000
Weeding	3000	3000	3000	3000	3000	3000	3000	3000	3000	3000	3000	3000	3000	3000
Plant protection	1000	1000	1000	1000	1000	1000	1000	15000	15000	15000	15000	15000	15000	15000
Staking	-	-	-	-	-	-	5000	-	-	-	-	-	-	-
Harvesting	10000	10000	10000	10000	10000	10000	10000	15000	15000	15000	15000	15000	15000	15000
Transportation	7500	7500	7500	7500	7500	7500	7500	10000	10000	10000	10000	10000	10000	10000
Total cost (in Lakh)	1.56	2.26	2.96	1.26	1.46	1.66	0.90	3.15	3.85	4.55	2.85	3.05	3.25	2.44
Gross returns (in Lakh)	2.11	1.84	2.19	2.27	2.19	3.13	1.72	7.91	8.27	8.62	8.78	8.50	9.01	6.50
Net returns (in Lakh)	0.55	-0.42	-0.76	1.01	0.73	1.47	0.82	4.76	4.41	4.06	5.92	5.44	5.75	4.05
BCR	1.35	0.81	0.74	1.80	1.50	1.88	1.91	2.50	2.14	1.89	3.07	2.78	2.76	2.65

Appendix III

Weather data during the crop period

Standard week	Temperature (°C)		Relative humidity (%)		BSS hours	Rainfall (mm)	Evaporation (mm)
	Max	Min	7.22 am	2.20 pm			
May-2016	33.93	25.11	86.74	64.45	4.25	1.87	5.51
June-2016	29.73	23.43	94.00	78.33	1.62	31.24	2.16
July-2016	28.68	23.10	96.03	82.30	0.85	28.54	1.82
August-2016	29.50	23.04	96.03	76.55	2.10	14.35	2.71
September-2016	28.82	22.34	94.20	77.96	1.33	4.69	2.78
October-2016	29.95	22.03	89.48	70.32	2.16	0.69	4.15
November-2016	31.28	21.87	89.63	66.20	2.20	2.92	3.20
December-2016	31.47	19.59	89.96	70.40	2.54	0.60	2.82
January-2017	31.57	18.70	89.16	55.13	2.78	0.00	3.61
February-2017	32.20	20.53	89.39	60.92	2.47	0.00	4.07
March-2017	33.05	22.23	86.25	63.35	2.24	0.03	4.57
April-2017	33.19	24.78	85.83	66.10	3.49	0.94	5.43
May-2017	32.89	23.62	85.29	64.35	3.85	4.00	4.37