“Effect of Plant Growth Regulator on Growth and Flowering of Calendula (*Calendula officinalis* L.)underMalwa Plateau of M.P.”

THESIS

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Rajmata Vijayaraje Scindia Krishi Vishwa Vidyalaya

In partial fulfillment of the requirements for the degree of

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(FLORICULTURE AND LANDSCAPE ARCHITECTURE)

by

KAVITA PATIDAR

Department of Floriculture and Landscape Architecture

Rajmata Vijayaraje Scindia Krishi Vishwa Vidyalaya, Gwalior

K.N.K. College of Horticulture Mandsaur (M.P.) – 458001

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CERTIFICATE - I

This is to certify that the thesis entitled **"Effect of Plant Growth Regulator on Growth and Flowering of Calendula (*Calendula officinalis* L.) under Malwa Plateau of M.P."** submitted in partial fulfillment of the requirements for the Degree of **MASTER OF SCIENCE (AGRICULTURE)** in **HORTICULTURE (Floriculture and Landscape Architecture**) of Rajmata Vijayaraje Scindia Krishi Vishwa Vidyalaya, Gwalior is a record of the bona-fide research work carried out by **Ms. KAVITA PATIDAR** under my guidance and supervision. The subject of the thesis has been approved by the student's Advisory Committee and the Director of Instruction.

No part of the thesis has been submitted for any other degree or diploma or has been published. All the assistance and help received during the course of this investigation has been acknowledged by the scholar.

(Anuj Kumar)

Chairman of the Advisory Committee

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Co-Chairman - Dr. Jyoti Kanwar ……..

Member - Dr. O. P. Singh …….

Member - Dr. G. P. S. Rathore ……..

CERTIFICATE – II

Aadhar No.: 816063317456
ID No.: 19144704

This is to certify that the thesis entitled **"Effect of Plant Growth Regulator on Growth and Flowering of Calendula (*Calendula officinalis* L.) under Malwa Plateau of M.P.''** submitted by **Ms. KAVITA PATIDAR** to the Rajmata Vijayaraje Scindia Krishi Vishwa Vidyalaya, Gwalior, in partial fulfilment of the requirements for the degree of **MASTER OF SCIENCE (AGRICULTURE)** in **HORTICULTURE** in the department of **Floriculture and Landscape Architecture** has been accepted after evaluation by the External Examiner and approved by the Student's Advisory Committee after an oral examination on the same.

Signature

Place: Mandsaur **Anuj Kumar**

Date: Chairman of the Advisory Committee

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Head of the section		……..
Dean of the college		……..
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Place: Mandsaur
Date:...../...../..... ***Kavita Patidar***

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LIST OF SYMBOLS

Symbol	Abbreviation	Stands for
/	-	Per
@	-	At the rate of
%	-	Percentage
°C	-	Degree Celsius
-	ANOVA	Analysis of variance
-	CD	Critical difference
-	Cm	Centimeter
-	cm^2	Centimeter square
-	RBD	Randomized block Design
-	CV	Coefficient of Variance
-	cv.	Cultivar
-	DAP	Days After Planting
-	Df	degrees of freedom
-	DW	Distilled water
-	EMS	Error Mean Sum of Squares
-	*et al.*	et-alia (And others)
-	Fig.	Figure
-	g	Gram
-	H	Hour
-	Ha	Hectare
-	*i.e.,*	That is
-	L	Liter
-	Max.	Maximum

-	mg	Milligram
-	Min.	Minimum
-	ml	Milliliter
-	mm	Millimeter
-	MSS	Mean Sum of Squares
-	NS	Non significant
-	PGR	Plant Growth Regulator
-	PPM	Parts Per Million
-	RVSKVV	Rajmata Vijayaraje Scindia Krishi Vishwa Vidyalaya
-	S.Ed.	Standard error of difference
-	S.Em ±	Standard error of mean
-	SS	Sum of Squares
-	var.	Variety

Chapter – I

INTRODUCTION

Calendula (*Calendula officinalis* L.) is usually referred to as pot marigold, common marigold, English marigold, and garden marigold and belonging to the Asteraceae family. The word Calendula is springs from the L atin word '*Kaendge',* which means the first day of every month, because of its long flowering period (Dheeraj *et al*., 2018).It is free blossoming yearly with excellent crowns, developed for garden design and cut flower. It is a yearly, fragrant, restorative, herbaceous and ornamental herb with yellow and orange blossoms. Centre of origin is Europe and Mediterranean region (Gazim *et al*.,2008).In western medicine, it is most versatile herbs. As an ornamental and medicinal plant, it is mostly cultivated at commercial level in Europe and North America (Mona *et al*., 2006).

Calendula flowers have been produced in ourcountry for medical purposes for many years (Ramayana, 1200-1000 B.C., and Rig-veda, 3000-2000 B.C.), but commercial flower production and floriculture as an industry are relatively recent. Our nation is best in a wide range of agro-climatic zones, from temperate to humid tropics, which allows for the production of all important flower throughout the year.

The country's estimated area under flower cultivation is over 161 thousand hectares, with 870 million tonnes of loose flowers and 4342 million cut flowers produced (Dheeraj *et al*., 2018).

Calendula flower is a winter season and hardly yearly bloom. It is bloosming within the spring-summer seasons for three times per annum, which is developed for loose and cut blossoms, calendula widely developed in beds, containers and boxes.The bloom is found in numerous colours like orange and yellow and utilized in making garlands, bouquets and vase preparations. It uses as a source of colour and landscape (Khudus *et al*., 2017).

Calendula is an annual plant with yellow to orange flowers that are high in lute in, flavoxanthin, rubixanthin, carotenoids, β–carotene, γ-carotene, and lycopene among other pigments (Pintea*et al.,*2003).

Calendula is also used for their medicinal properties. Essential oils are one of the primary components of the active substance in calendula, and the majority of them are generated in the orange petals. Essence include anti-inflammatory, antibiotic, antiviral, antibacterial, and immune-boosting effects. Calendula has traditionally been used to treat skin of flowers is used in both food and medicine. It's also a major source of natural yellow pigments, which are utilised in a various industries and poultry feed (Mona and Colleagues., 2006). Calendula flowers and leaves are utilized in gardening, medicine, cosmetics, perfume, pharmaceutical manufacture, cuisine, and a range of other sectors (Gazim *et al*., 2008).

Calendula is a scented annual herb that grows to 80 cm tall and features a thinly branched lax or straight stem. The leaves are oblong-lanceolate 5-17 cm long, and hairy on each side. It has prolonged flowering time and produces huge yellow or orange single or double flowers with several petals. The flowers are orange, yellow, or golden in colour, with a thick capitulum or flower head 4-7 cm in diameter enclosed by two rows of hairy bracts (Kazemi *et al*., 2014).

Plant growth regulators (PGRs) are small organic molecules that can modify the quality and other features of flowers. They are produced naturally by plants or synthesised. GA_3 plays an important role in growth parameters like (diameter of flower and weight of flower) acting as both a stimulator and an inhibitor depending on its concentration and other intrinsic plant properties (Shrestha *et al*., 2020).

GA_3 is a well-known plant growth regulator that regulates important physiological changes in plants such as cell division and expansion, stem elongation promotion, and flower induction in many herbaceous flower crops (Davies, 2004). Several studies have shown that GA_3 treatment results in high quality flowers (Teszlak *et al*., 2005). Gibberellic acid (GA_3) is thought to improve flower quality and maintain identical in flower size and number (Chen

et al., 2003 and Delvadia *et al*., 2009). It is also thought to encourage plant growth and increase the number of primary and secondary branches, resulting in increased flower production (Azuma *et al*., 2000). Exogenous foliar application of Gibberellic acid (GA_3) encourage flowering, pollination, fertilization, and seed setting to maximize yield (Doddagoudar *et al*., 2004).

GA_3 and NAA have been shown to improve growth and blossoming in calendula, marigold, and lily, respectively. Use of naphthalene acetic acid (NAA) in calendula successfully induced more flowering thereby, facilitating, harvesting. Initially it was thought that this success was due to the role of natural Auxin in flowering but now it is known that the NAA has effect through the excitation of ethylene production (Khudus *et al*., 2017).The application of plant growth regulators has transformed the floriculture industry. It can be used to overcome growth, quality, and yield constraints in order to maximize benefit. Thus, the use of GA_3 in calendula cultivation can encourage flower growers to cultivate calendula within the country in order to meet the growing demand (Shrestha *et al*., 2020).

Keeping in view the above facts and the paucity of research, the present **investigation "Effect of Plant Growth Regulator on Growth and Flowering of Calendula (*Calendula officinalis* L.) under Malwa Plateau of M.P."** has been planned at K.N.K. College of Horticulture, Mandsaur under R.V.S.K.V.V. Gwalior during the year 2020-21.The present investigation is planned with following objectives

- To study the effect of plant growth regulators on the vegetative growth of calendula.
- To study the effect of plant growth regulators on flowering of calendula.
- To find out the best concentration of plant growth regulators for performance of calendula.

Chapter – II

REVIEW OF LITERATURE

The Literature available on **"Effect of Plant Growth Regulator on Growth and Flowering of Calendula (*Calendula officinalis* L.)"and related genera and species** and related aspect in India as well as abroad is reviewed in this chapter under the headings as follows:

1. **Effect of plant growth regulators on growth**
2. **Effect of growth regulators on flowering**

2.1 Effect of plant growth regulators on growth

Delvadia *et al*. (2009) evaluated the effect of different concentration of GA_3 (50, 150, 250 ppm) on growth, flowering and yield in gaillardia (*Gaillardia pulchella* Foug.). Data revealed that GA_3 @ 250 ppm single spray recorded maximum plant height, plant spread and number of branches per plant was highest under double spray of GA_3 at 50 ppm.

Patel *et al*. (2010) conducted a study on effect of different concentrations of GA_3 (50, 100 and 150 ppm), CCC (250, 500 and 750 ppm) and MH (250, 500 and 750 ppm) on growth, flowering and yield of chrysanthemum (*Chrysanthemum morifolium* Ramat.). Result showed that the significantly maximum plant height, plant spread and number of branches per plant were obtained in treatment GA_3 @ 150 ppm.

Sharifuzzaman *et al*. (2011) evaluated the effect of GA_3 (50, 100 and 150 ppm), CCC (400, 600 and 800 ppm) and MH (250, 500 and 750 ppm) on the vegetative growth, yield and quality of chrysanthemum. GA_3 treated plants showed significant increase in plant spread, leave number and leave length. Foliar application of GA_3 @ 150 ppm reported as the best for obtaining better growth of plants.

Ullah *et al.* (2013) investigated the effects of different levels of indolebutyric acid (IBA) and naphthalene acetic acid (NAA) on marigold (*Tagetes erecta* L.). Maximum branches per plant were recorded at 400 ppm

NAA number of leaves per plant, while plant height was observed with @ 100 and 200 ppm NAA concentration.

Palei *et al*. (2016) evaluated the effect of different concentration of GA_3 (25, 50 and 100 ppm), Ethrel (25, 50 and 100ppm) and Naphthalene Acetic Acid (25, 50 and 100 ppm) on growth, flowering and yield attributes of African marigold (*Tagetes erecta* L.). The maximum plant height, number of branches per plant and number of leaves per plant were recorded withGA_3 @ 100 ppm.

Syiemlieh *et al*. (2016) studied the effect of different concentrations of GA_3 (100,150, 200, and 300 ppm), CCC (250, 500, 700 and 800 ppm) and NAA (30, 40, 50 and 60 ppm) on growth and flower yield of Petunia (*Petunia x hybrida*). Data indicate that application of GA_3@ 300 ppm found superior with respect of plant height, plant spread and number of branches.

Benny *et al.* (2017) conducted a study on effect of NAA (100,150 and 200 ppm) and GA_3 (100,150 and 200 ppm) on vegetative, flowering, quality and yield parameters of carnation. Among the treatment, foliar application of GA_3 @ 200 ppm showed the best results with respect of no. of leaves and plant spread.

Choudhari *et al.* (2017) investigated the effect of GA_3 on growth, flowering and quality of cut chrysanthemum. Spraying of GA_3 @ 150 ppm recorded significantly maximum plant height, plant spread and number of leaves per plant.

Khudas *et al.* (2017) conducted an experiment to study the effect of different plant growth regulators on growth and flowering of calendula. Different treatments like GA_3 (100, 200 and 300 ppm), NAA (50,100, 150 and 200 ppm) and CCC (250, 500, 750, 1000 and 1250 ppm) were used. The results showed that application of GA_3 @ 300 ppm was found to be superior in plant height, plant spread, number of branches and number of leaves.

Kumar *et al*. (2017) studied the effect of GA_3 (100,150 and 200 ppm), salicylic acid (50, 100 and 150 ppm), brass inolide (0.5, 1.0 and 1.5 ppm) and triacontanol (1.0, 2.0 and 3.0 ppm) on vegetative and physiological parameters of China aster (*Callistephus chinensis* L.). Spraying of GA_3 @ 150 ppm showed increased plant height, plant spread and number of branches

per plant. Foliar application of GA_3 @ 150 ppm would be effective to improve the growth of China aster.

Sangma *et al*. (2017) studied the effect of GA_3 (50,100,150,200 ppm) and NAA (50, 100, 150, 200 ppm) on growth, yield and flower quality of gerbera (*Gerbera jamesonii* L.). The results revealed that the maximum plant height, number of leaves per plant and plant spread was recorded with GA_3 @ 150 ppm.

Aparna *et al*. (2018) carried out an experiment to study the effect of GA_3 on plant growth, flowering and its role in substituting the artificial light conditions in chrysanthemum cv. Thai Chen Queen. Three different concentrations (200 mg/l, 300 mg/l and 400 mg/l) of GA_3were sprayed. Vegetative growth characteristics like plant height, and leaf number were more superior in higher concentration ofGA_3treated plants.

Biswas *et al*. (2018) conducted an experiment to see the effect of plant growth regulators on growth and flowering of pansy (*Violax wittrockiana*). Plants were treated with foliar application of paclobutrazol, cycocel, ethrel and GA_3. Result indicates that application ofGA_3 showed best results with respect in number of primary branches.

Kumar*et al*. (2018) studied the effect of plant growth regulators on growth and flowering of China aster (*Callistephus chinensis* L.). Plant growth regulators GA_3 (100, 200 and 300 ppm), NAA (50, 100 and 150 ppm) and Ethrel (100, 200 and 300 ppm) were used in this investigation. Maximum plant height, plant spread, number of leaves per plant and number of branches per plant were recorded with the application of GA_3 @ 300 ppm.

Mishra *et al*. (2018) observed the significantly superior plant height, number of primary branches and number of leaves per plant with application of GA_3 @ 100 ppm in China aster.

Sathappan (2018) investigated the effect of GA_3 (50, 100 and 150 ppm), NAA (50, 100 and 150 ppm), MH (250,500 and 750ppm), Alar (200, 400 and 600 ppm) and pinching on growth and flower yield of African marigold (*Tagetes erecta* L.). The plant sprayed with GA_3 @ 150ppm registered the maximum plant height and number of leaves per plant.

Sindhuja *et al*. (2018) investigated the effect of of GA_3, NAA and CCC on vegetative growth, floral yield and vase life of China aster (*Callistephus chinensis* L.).The results of the study revealed that maximum growth attributes like plant height, plant spread, number of leaves per plant and number of branches per plant was recorded with GA_3@ 200 ppm.

Khangjarakpam *et al.* (2019) conducted an experiment to find out the effect of GA_3 on growth, development, yield and biochemical constituents of African marigold cv. 'Pusa Narangi Gainda'. GA_3 @ 250 ppm showed significantly better performance in relation to plant height, number of branches, number of leaves and plant spread.

Pujeri *et al*. (2019) studied the effect of different concentrations of GA_3 (100 and 200 ppm), NAA (100 and 150 ppm), TIBA (100 and 150 ppm) and Ethrel (50 and 100 ppm) on growth and flowering of crossandra (*Crossandra undulaefolia* Salisb). The plants sprayed with the GA_3 @ 200 ppm resulted in maximum plant height, number of branches and plant spread.

Baranidharan *et al*. (2020) investigated the effect of different concentration of gibberellic acid, cycocel, brassinosteroids, and silicic acid on growth and yield of African marigold. The study revealed that foliar application of gibberellic acid @ 150ppm showed a significant improvement in plant height, plant spread and number of primary branches in African marigold.

Acharya *et al.* (2021) conducted an experiment on the effect of different concentrations of GA_3 (50, 100, 150, 200, 250, 300 and 350 ppm) on growth and flowering attributes of African marigold (*Tagetes erecta*). Result showed that the GA_3 @ 250 ppm was found to be most suitable in terms of production perspective.

Deepti *et al*. (2021) conducted a field experiment to study the effect of different concentrations of cycocel (1500 and 1000 ppm), NAA (50 and 100 ppm) and GA_3 (150 and 200 ppm) on growth, flowering, yield and quality of China aster. Data revealed that GA_3 @ 200 ppm performed significantly better with respect of plant height (cm), plant spread (cm), number of primary and secondary branches / plant, number of leaves /plant, leaf area and leaf area index.

2.2 Effect of growth regulators on flowering

Tripathi *et al.* (2003) concluded that the application of GA_3 @ 100, 200 and 400 ppm gave quite beneficial effect on French marigold. Therefore, GA_3 @ 400 ppm increase flower yield/plant and number of flowers/plant.

Dalal *et al*. (2009) conducted an experiment to study the effect of gibberellic acid on growth, flowering, flower yield and flower quality of gerbera. Treatment comprises four levels of gibberellic acid (0, 50, 100 and 150 ppm) and observed that GA_3 @ 150 ppm performed best results with respect of flower yield and quality.

Kumar *et al.* (2010) carried out an experiment to see the effect of different concentration of GA_3 (25, 50, 100 and 200 ppm) and Ethrel (100, 200, 300 and 400 ppm) on growth and flowering of African marigold. Result revealed that the GA_3 @ 200 ppm showed significantly superior result with respect of flower yield per plant and longest duration of flowering.

Kumar *et al.* (2014) studied the effect of different concentration of GA_3 (100, 200 and 300 ppm), Ethrel (200, 300 and 400 ppm) and Maleic hydrazide (200, 300 and 400 ppm) on flowering and yield attribute in African marigold. Among all the treatments, GA_3 @ 300 ppm showed best results with respect of maximum duration of flowering, number of flower per plant and weight of flower.

Sainath *et al*. (2014) studied the effect of different levels of gibberellic acid (100 and 200 ppm), tricontanol (1000 and 500 ppm), cycocel (1000 and 2000 ppm) and Mepiquat chloride (1000 and 2000 ppm) on seed yield and quality attributes in chrysanthemum (*Chrysanthemum coronarium* L.). Spraying of GA_3 @ 200 ppm performed significantly better result with respect of number of capitulum per plant, capitulum diameter and dry weight of capitulum.

Sharma and Joshi (2015) studied the effect of different concentration of NAA (25 and 50 ppm) and GA_3 (150 and 250 ppm) on yield and quality parameters on China aster. Among the treatments, foliar spray of GA_3 @ 250 ppm significantly increased the duration of flowering, improved flower

longevity, flower fresh and dry weight, flower diameter and enhanced flower yield in terms of number of flowers per plant.

Imandi *et al.* (2017) evaluate the effect of plant growth regulators GA_3 (50, 100 and 150 ppm) and NAA (150, 200 and 250 ppm) on vegetative growth, flowering, yield and shelf life of marigold. Among the treatments GA_3 @ 150 ppm was recorded better results for growth, flowering, yield and shelf life of marigold.

Maurya *et al.* (2017) investigated the effect of different levels of GA_3 (75 ppm and 150 ppm), alar (300 ppm and 600 ppm) and Benzyl Adenine (20 ppm and 40 ppm) on flowering and vase life of China aster (C*allistephus chinensis*). Spraying of GA_3 @ 150 ppm resulted in increased number of flowers per plant, fresh weight and dry weight of flowers.

Mishra (2017) investigated the effect of different concentration of GA_3 (100, 200 and 300 ppm), Ethrel (200, 300 and 400 ppm) and Maleic Hydrazid (200, 300 and 400 ppm) on vegetative growth and flowering characters of African marigold (*Tagetes Erecta* L.). Among the treatments, GA_3 @ 300 ppm showed the best results with respect to duration of flowering, number of flower per plant, flower weight and flower diameter.

Kuostu *et al*. (2018) evaluated the effect of different concentrations of GA_3 (50, 100, 150 ppm), MH (200, 250, 300 ppm) and NAA (200, 250, 300 ppm) on growth, flowering, yield and vase life of *Gerbera jamesonii* cv. Red Gem. Results revealed thatGA_3 @ 100 ppm showed the best results with respect to growth and flowering.

Kumar *et al*. (2018) studied the effect of GA_3 (100, 200 and 300), NAA (50, 100, 150 and 200 ppm) and cycocel (250, 500, 750 and 1000 ppm) on flower yield of calendula (*Calendula officinalis* L.). The data revealed that GA_3 @ 300 ppm significantly influenced the different post-harvest attributes in viz., diameter of flower, weight of flowers and number of flower per plant.

Kuri *et al*. (2018) studied the effect of GA_3, NAA and Triacontanol on vegetative, floral and yield characters of China aster (*Callistephus chinensis* L.). The results of the study revealed that GA_3 @ 200 ppm showed the best results with respect of most floral attributes like maximum flower diameter,

flower weight and flower yield per plant. Thus, it can be concluded that application of GA_3 @ 200 ppm can be recommended for commercial cultivation of China aster.

Palekar *et al*. (2018) evaluated the effect of different concentrations ofGA_3 (100, 150 and 200 ppm), IAA (50, 100 and 150 ppm) and NAA (25, 50 and 100 ppm) on growth, flowering and flower quality of China aster. Result showed that the maximum diameter of fully opened flower was recorded with the treatment of GA_3 @ 200 ppm and GA_3 @ 150 ppm concentration recorded maximum weight of flower.

Sarkar *et al*. (2018) investigated the effect of different concentration of GA_3 (50, 100, 150 and 200 ppm) and pinching on growth and physiological characteristics of African marigold. The number of flowers and flower yield per hectare were improved with the application of GA_3 @ 200 ppm.

Arha *et al*. (2019) investigated the effect of different levels of GA_3 (100,150 and 200 ppm), Ethrel (250, 500 and 750 ppm) and MH (250, 500 and 750 ppm) on quality flower production of African marigold. The results revealed that the GA_3 @ 200 ppm was the most potential growth regulator for producing high yield with quality flowers and recorded earlier flowering.

Kaya *et al*. (2019) conducted a study on effects of GA_3 (125, 250 and 500 ppm) and BA (100, 200 and 400 ppm) on yield and quality components of gerbera. GA_3 applications gave good results on yield and quality parameters. It was found that application of GA_3 @ 500 ppm showed the best results with respect of flower diameter.

Reddy *et al*. (2019) studied the effect of NAA (50, 75 and 100 ppm) and GA_3 (50, 75 and 100 ppm), and two plant growth retardants *viz*., CCC (500, 1000 and 1500 ppm) and PBZ (150, 200 and 250 ppm) on flowering behavior of Gaillardia (*Gaillardia pulchella* L.). The treatment GA_3 200 ppm spray was found best with respect to minimum days required for flower initiation, number of flowers per plant and flower yield per plant.

Sidana *et al.* (2019) reported that GA_3 @ 200 ppm resulted in maximum diameter of flower in China aster.

Kadam *et al.* (2020) investigated the effect of different levels of NAA (100 and 200 ppm), GA_3 (100 and 200 ppm), CCC (1500 and 3000 ppm) and PBZ (250 and 500 ppm) on flowering and flower yield in gaillardia (*Gaiilardia pulchella*) cv. Local double. The significantly minimum number of days required for 50% flowering and longest flowering duration were recorded with GA_3 @ 200 ppm.

Kumar *et al*. (2020) conducted a field experiment to determine the effect of different growth regulators and their application time on production of quality flower and seed production of marigold (*Tagetes erecta* L.).The treatments used were different concentrations of GA_3, salicylic acid, benzyl adenine and cycocel. Among the treatments, GA_3 @ 250 ppm showed the best results with respect of seed yield and quality of marigold.

Murugan *et al*. (2020) reported that spraying of NAA @ 150 ppm recorded the maximum number of flowers and flower weight as compare to other treatments in African marigold.

Narute *et al*. (2020) conducted a field experiment to study the effects of plant growth regulators on flowering parameter of marigold. Among the all treatments, GA_3 @ 100 ppm showed best result with respect of flower diameter, flower stalk length, fresh and dry weight of flower.

Shrestha *et al.* (2020) studied the effect of gibberellic acid (GA_3) on quality attributes of calendula (*Calendula officinalis* L.). Result showed that the maximum flower diameter and weight of flower was recorded in GA_3 @ 250 ppm. These results suggest that GA_3 @ 250 ppm was ideal for enhancing the quality of flowers in calendula.

Chapter - III
MATERIALS AND METHODS

The experimental materials and criteria used for treatment evaluation during the course of investigation are being presented in this chapter. The field experiment entitled **"Effect of Plant Growth Regulator on Growth and Flowering of Calendula (*Calendula officinalis* L.) under Malwa Plateau of M.P."** was conducted during the period from November 2020 to March 2021. Details of the method and techniques utilized in the experiment are given below.

3.1 Experimental Site

The present investigation was carried out during winter season of 2020-2021 at college field of the Department of Floriculture Landscape Architecture, K.N.K. College of Horticulture, Mandsaur, (M.P). Mandsaur is situated in the Malwa plateau in western part of M.P. at North latitude of 23.45 ^{0} to 24.13 ^{0}and 74.44 ^{0} to 75.180 East longitude and an altitude of 435.20 m meters above mean sea level. This region falls under agro climatic zone no.10 of the state.

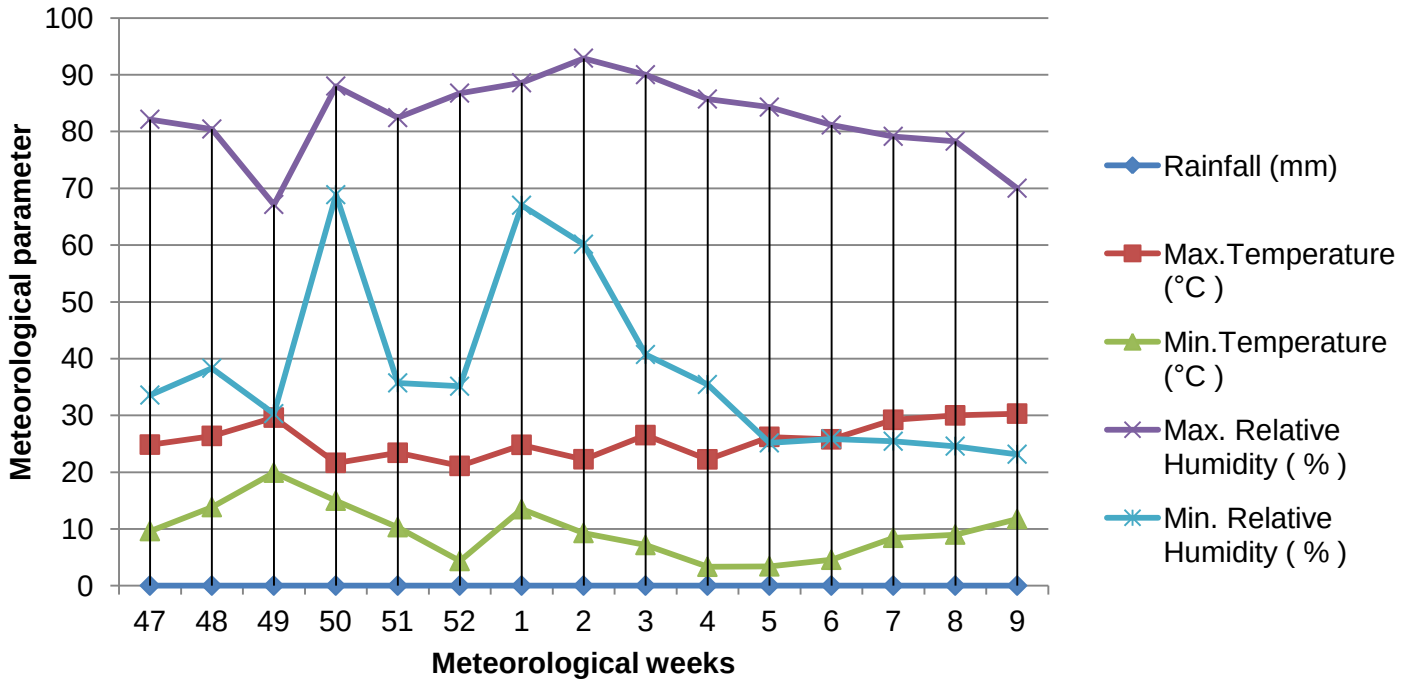
3.2 Climate of the region

Mandsaur belongs to sub-tropical climate having a temperature range of minimum 5^{0}C and maximum 45^{0}C in winter and summer respectively. In this area most of the rainfall is received during mid June to early October with occasional showers in winter. Southwest monsoon is responsible for major portion of annual precipitation. The average rainfall is 714.8 mm. Meteorological data recorded during the period of investigation are presented in (Table 3.1) and graphically shown in (Table 3.1).

Table- 3.1: Weekly meteorological observations during the study period November, 2020 to March, 2021

Period	Standard Metrological Weeks	Average Temperature (°C)		Relative Humidity (%)		Rainfall (mm)
		Max.	Min.	Max.	Min.	
47	19 Nov-25 Nov	24.84	9.61	82.14	33.57	0.0
48	26 Nov-02 Dec	26.37	13.84	80.43	38.29	0.0
49	03 Dec-09 Dec	29.60	19.90	67.14	30.29	0.0
50	10 Dec-16 Dec	21.63	14.96	88.00	68.86	0.0
51	17 Dec-23 Dec	23.40	10.30	82.43	35.71	0.0
52	24 Dec-31 Dec	21.09	4.34	86.75	35.12	0.0
1	01 Jan-07Jan	24.80	13.47	88.57	67.00	0.0
2	08 Jan-14 Jan	22.26	9.27	92.91	60.14	0.0
3	15 Jan-21 Jan	26.51	7.16	90.00	40.71	0.0
4	22 Jan-28 Jan	22.24	3.33	85.71	35.43	0.0
5	29 Feb- 04 Feb	26.20	3.40	84.29	25.14	0.0
6	05 Feb-11 Feb	25.77	4.56	81.14	25.86	0.0
7	12 Feb-18 Feb	29.21	8.43	79.14	25.43	0.0
8	19Feb- 25 Feb	29.99	9.00	78.29	24.57	0.0
9	26 Mar- 04 Mar	30.3	11.73	70.00	23.14	0.0

Fig. 3.1 Meteorological parameter recorded during the experiment (From Nov. 2020 to Mar. 2021)



3.3 Soil Characteristics of the Experimental Site

To ascertain physical-chemical characteristics of the soil during the year of study, soil samples from 0-15 cm depth were taken from different spots of the experimental field before application of fertilizer. A representative composite sample was prepared by processing and mixing them together and the sample was analyzed for physical and chemical properties. The soil of experimental field was medium black to clay texture.

Table 3.2: Physical and chemical composition of the soil sample of experimental site

Particulars	Value obtained	Method
Physical Characters		
Sand%	30%	International Pipette method (Piper,1950)
Silt%	42%	
Clay%	28%	
Chemical Characters		
Soil pH	7.8	Method No. 4 USDA Handbook No. G (Richards, 1954)
Electrical Conductivity (dsm^{-1})	0.40	EC Meter
Available Nitrogen (kg N ha^{-1})	195(Low)	Alkaline $KMnO_4$ (Subbiah & Asija, 1956)
Available phosphorus (kg P_2O_5 ha^{-1})	7.6(Low)	Olsen extraction method (Olsen *et. al.* 1954)
Available potash (kg K_2O ha^{-1})	210(Low)	Flame photometer method Metson, 1956)

3.4 Experimental details

Particulars	Details
Location	: K.N.K. College of Horticulture Mandsaur (M.P.)
Name of crop	: Calendula (*Calendula officinalis* L.)
Season	: *Rabi*, 2020-2021
Design	: Randomized Block Design.
Number of treatments	: 7
Number of replication	: 3
Total number of plots	: 21
Spacing	: 30 x 30 cm
Gross plot size	: 2.7 m^2 (1.8 x 1.5 m)
Total experimental area	: 90 m^2
Net experimental area	: 56.7 m^2
Mode of treatment	: Foliar application at 30 and 45 days after transplanting
Transplanting date	: 24/11/2020

3.5 Treatment Details

Table 3.3: PGR Concentrations:

S.No.	Symbol	Treatments
1	T_1	Control
2	T_2	GA_3 @ 250 ppm
3	T_3	GA_3 @ 300 ppm
4	T_4	GA_3 @ 350 ppm
5	T_5	NAA @ 150 ppm
6	T_6	NAA @ 200 ppm
7	T_7	NAA @ 250 ppm

Different plant growth regulators treatments were applied as foliar spray at 30 and 45 day after transplanting.

3.6 Details of layout

The experiment was laid out in randomized block design (RBD) with 7 treatments for 3 levels each of GA_3, NAA and control, which were replicated 3 times.

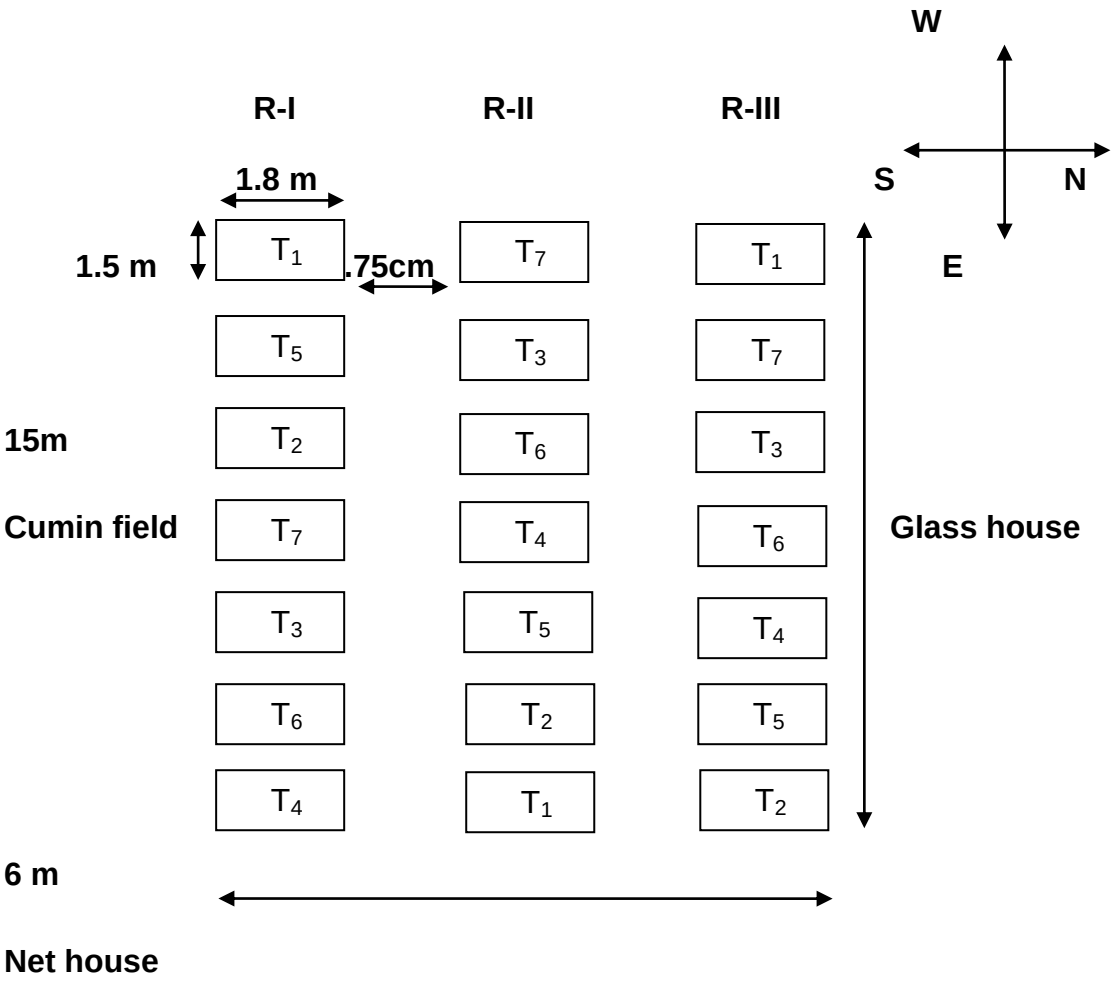


Fig.2 Layout of experimental field of calendula

3.7 Experimental methodology

3.7.1 Seed source

The healthy, disease free, bold and uniform seeds of calendula were obtained from the Department of Floriculture and Landscape Architecture, K.N.K. College of Horticulture, Mandsaur (M.P.).

3.7.2 Nursery raising

The healthy, disease free, bold and uniform size seeds of calendula were sown in the nursery. Each seed was covered with sieved well rotten Farm Yard Manure properly.

3.7.3 Land preparation

The land was brought to the fine tilth with deep ploughing before the transplanting of seedlings. The stones, pebbles, previous crop residues and weeds etc. were removed from the experimental area manually. Then, the raised beds of size 1.8 x 1.5 m were prepared.

3.7.4 Transplanting of seedlings

The healthy, disease free and stocky seedlings of uniform size and vigour at 3-4 leaf stage were selected and transplanted in the beds of 1.8 x 1.5 m size at spacing 30 x 30 cm on dated 24th November, 2020. Light irrigation was given soon after transplanting of seedlings.

3.7.5 Application and preparation of GA_3 and NAA solutions

The stock solutions of GA_3 and NAA were prepared by taking the required quantity of chemicals and dissolving them initially in a small quantity of absolute alcohol and then stirred it both clockwise and anti clock wise till the powder was completely dissolved. The growth regulators of the respective concentration were sprayed twice at 30 and 45 days after transplanting with the help of hand sprayer. The whole plants were sprayed completely by taking precaution to avoid the mixing of spray from treatment to another.

3.8 Cultural operations followed

3.8.1 Irrigation

The plants were gently watered or irrigated daily and twice a week during winter months in the entire cropping period. The frequency of irrigation was also altered depending on the prevailing water conditions.

3.8.2 Gap filling

The gap filling was done seven days after transplanting for maintaining plant population.

3.8.3 Weeding

Weeds were removed manually as and when they appeared to keep the field free from weeds. Prominent weeds found during cultivation were *Cynodon dactylon* and *Parthenium hysterophorus* etc.

3.8.4 Hoeing

Hoeing was done right after few days from the established of seedlings and practiced when hard crust formed over the soil surface. It was done with the help of khurpi for loosening of the soil surface to ensure optimum air exchange in the root zone and control of weeds as well.

3.9 Plant protection

The plants were sprayed with quinolphos 50% EC and cypermethrin 5% EC @ 1.5 ml/liter water to control the leaf eating caterpillar and to prevent fungal infestation the plants were sprayed with blitox @ 2 gm/liter.

3.10 Harvesting

Fully opened flowers were harvested in the morning.

Plate- 1: View of an experimental plot at full blooming stage.

3.11 Collection of experimental data

To make critical analysis of crop performance as affected by different treatments, five plants were tagged by random method under each plot and all the observations under characters given below were recorded on these plants.

3.11.1 Growth parameters:

3.11.1.1 Plant height (cm)

The height of the tagged plants was measured from ground level to the growing tip of the plant and the height was recorded at 45 and 60 days after transplanting. Height was measured with the help of meter scale in cm.

3.11.1.2 Plant spread (cm)

Plant spread was calculated by measuring the spread of foliage in East-West and North-South direction at 45 and 60 days after transplanting with the help of meter scale in cm. The average was calculated and recorded.

3.11.1.3 Number of leaves

Number of leaves per plant was counted from each plot at 45 and 60 days after transplanting and the mean was also determined.

3.11.1.4 Number of branches / plant

Number of branches per plant was counted from each plot at 45 and 60 days after planting and average was determined.

3.11.2 Flowering parameters:

3.11.2.1 Number of flowers / plant

From the tagged plants, total number of flowers produced / plant was recorded and average number of flowers / plant was calculated.

3.11.2.2 Number of flowers each stem

The total number of flowers produced in each stem was counted and average number of flowers in each stem was calculated.

3.11.2.3 Diameter of flowers (cm)

The diameter of fully opened flowers from each observational plant was measured with the help of vernier caliper and average values were expressed in cm.

3.11.2.4 Fresh weight of flower (g)

The weight of single flower harvested from each observational plant was weighed on electronic balance and average values were calculated and expressed in gram.

3.11.2.5 Dry weight of flower (g)

The fresh fully open flower harvested from each plant was dried in microwave oven and weighed with an electronic balance and average values were expressed in gram.

3.11.2.6 Flowering duration (days)

The number of days taken from date of first flowering to the last flowering constituted duration of flowering. Treatment wise numbers of days taken for flowering was recorded.

3.12Statistical analysis:-

The data recorded was analyzed by using MS-Excel. The mean values of data were subjected to analysis of variance by Panse and Sukhatme (1985) for using Randomized Block Design. Significance of differences among treatments was tested using the following skeleton. The calculated ‘F’ value is compared with table F values at 5% level of significance. If the calculated ‘F’ value was higher than, table value it was considered as significant. All the character which showed significant differences among treatment were further subjected to the analysis for the different parameters.

Table 3.5:- Skeleton of ANOVA

Source of variance	DF	SS	MSS	Fcal	Ftab
Treatment	(t-1)	TrSS	TrMSS	TrMSS/ErSS	
Replication	(r-1)	RSS	RMSS	RMSS/ErSS	
Error	(t-1) (r-1)	ErSS	ErMSS		
Total	rt-1	TSS			

Where,

r = Number of replications

t = Number of treatments

TrSS = Sum of square for Treatments

TSS = Total Sum of Squares

ErSS= Error sum of squares

TrMSS = Mean sum of squares for treatments

ErMSS = Mean sum of squares for error

In order to compare the mean value of treatment, standard error and critical values were calculated as follows:-

Where,

a. Standard Error of mean

$$\mathbf{SEm \pm = \sqrt{EMS / r}}$$

Where,

SEm = Standard error of mean

EMS = Error Mean of square

r = Number of replications

b. Critical Difference

CD = SEd x t Value at 5% at error degree of freedom

$$\mathbf{SEd = \sqrt{2EMS / r}}$$

Where,

SEd = Standard error of difference between two treatment means

EMS = Error Mean of squares

r = Number of replications

Chapter - IV

RESULTS

The current experimental work entitled **"Effect of Plant Growth Regulator on Growth and Flowering of Calendula (*Calendula officinalis* L.) under Malwa Plateau of M.P."** was conducted at the Department of Floriculture and Landscape Architecture, K.N.K. College of Horticulture, Mandsaur (M.P.) during 2020-21. The results obtained for various characters of growth and flowering of calendula as influenced by various concentrations of GA_3 and NAA has been described in this chapter. Data pertaining to various criteria used for evaluation of the treatments were statistically analysed and analysis of variance of these data has been made on the mean basis, highlighting the significant effect of treatments. The results for all treatments are presented in succeeding paragraphs.

4.1 Growth Parameters:

Data on various growth attributes of calendula under the influenced of treatments are presented in Table 4.1 to 4.4 and Fig. 4.1 to 4.4 investigation of variance of each parameter is given in appendix I and II.

4.1.1 Plant height (cm)

It is evident from Table 4.1 and Fig. 4.1 that the plant height was influenced significantly by plant growth regulators at 60 day after transplanting.

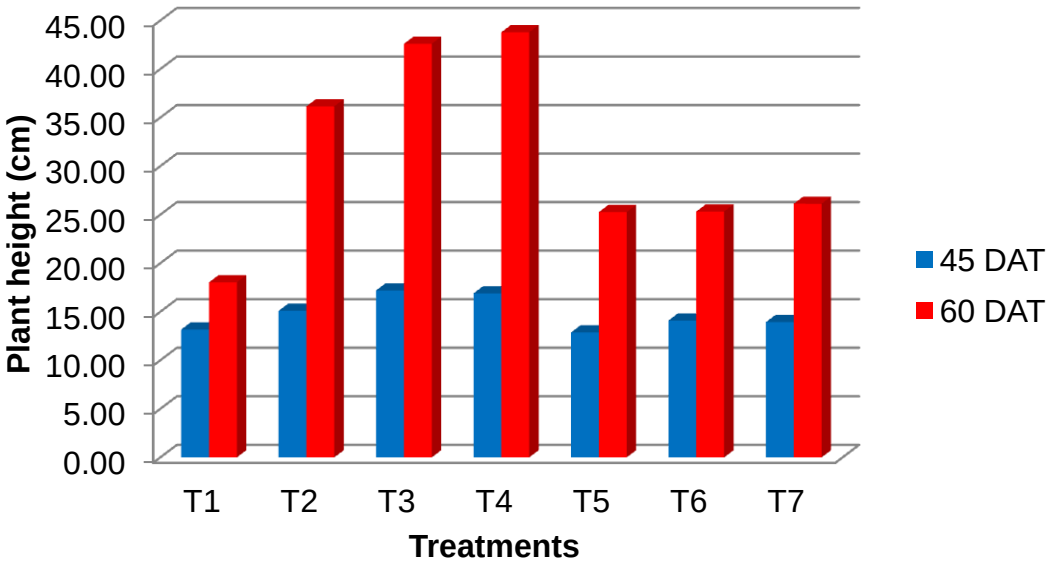
At 45 day after transplanting, T_3 (GA_3 300 ppm) recorded the maximum plant height (17.20 cm) followed by T_4 (GA_3 350 ppm) and T_2 (GA_3 250 ppm) which recorded values of 16.90 and 15.10 cm respectively, while the minimum plant height at this stage (12.87 cm) was reported by treatment T_5 (NAA 150 ppm).

At 60 day after transplanting, T_4 (GA_3 350 ppm) recorded the maximum plant height (43.80 cm) followed by T_3 (GA_3 300 ppm), which recorded value of 42.60 cm and both of these treatments are statistically similar to each other and superior to rest of the treatments except T_2 (GA_3 250 ppm), while the minimum plant height (18.03 cm) was recorded by treatment T_1 (control).

Table 4.1 Effect of plant growth regulators on plant height (cm) in Calendula.

Treatment	Plant height (cm)	
	45 DAT	**60 DAT**
T_1 (control)	13.17	18.03
T_2 (GA_3 at 250 ppm)	15.10	36.17
T_3 (GA_3 at 300 ppm)	17.20	42.60
T_4 (GA_3 at 350 ppm)	16.90	43.80
T_5 (NAA at 150 ppm)	12.87	25.27
T_6 (NAA at 200 ppm)	14.10	25.33
T_7 (NAA at 250 ppm)	13.93	26.13
S.Em.±	**1.04**	**1.95**
C.D. at 5%	**3.23**	**6.02**

Fig. 4.1 Effect of plant growth regulators on plant height (cm) in calendula



T_1 – control, T_2 – GA_3 at 250 ppm, T_3 – GA_3 at 300 ppm, T_4 – GA_3 at 350 ppm, T_5 - NAA at 150, T_6 – NAA at 200 ppm, T_7 – NAA at 250 ppm

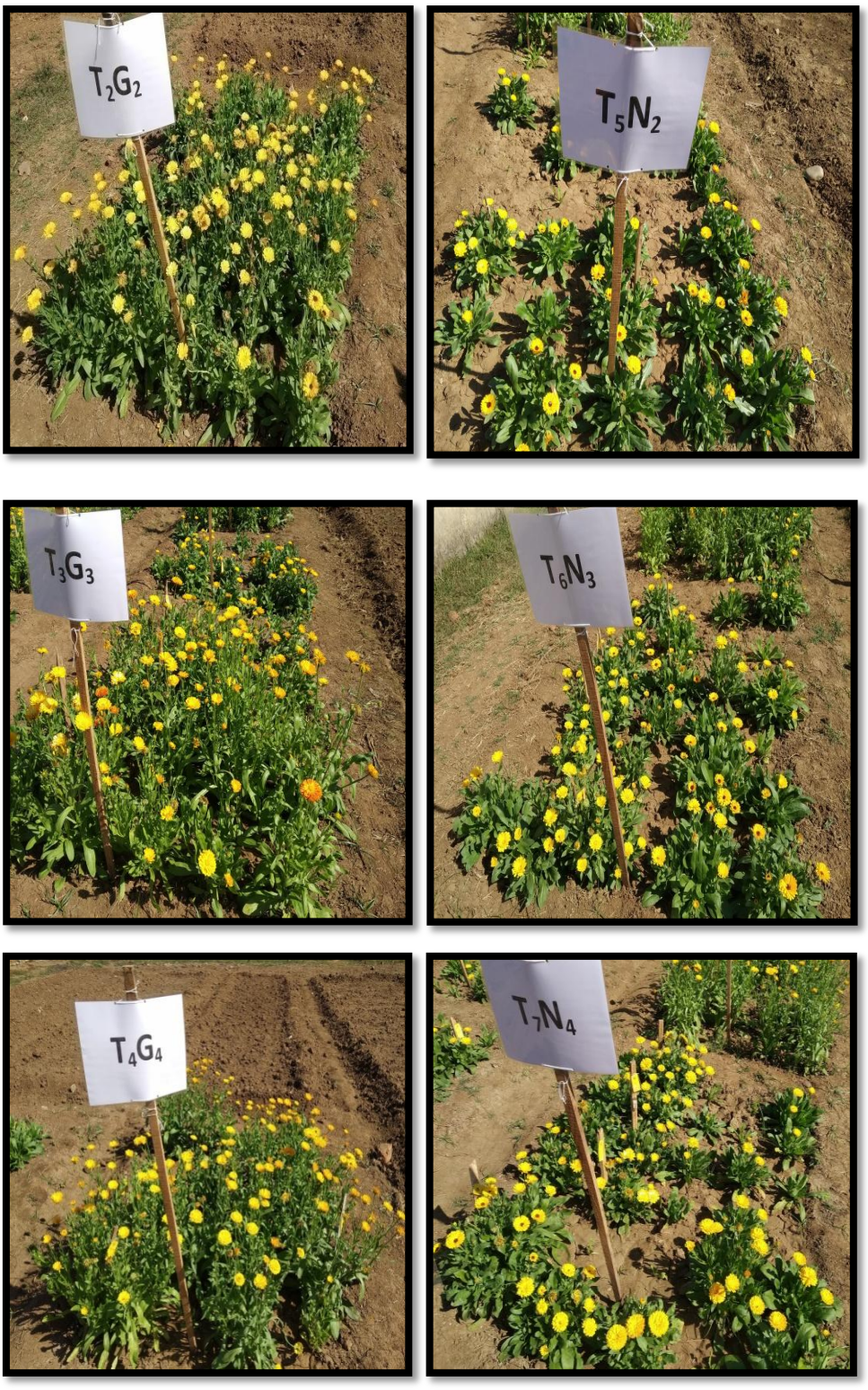


Plate 2:- Effect of plant growth regulators on growth and flowering of calendula.T_2 – GA_3 250 ppm; T_3 – 300 ppm; T_4 – 350 ppm T_5 – NAA 150 ppm ; T_6 – NAA 200 ppm; T_7 – 250 ppm;

4.1.2 Plant spread (cm)

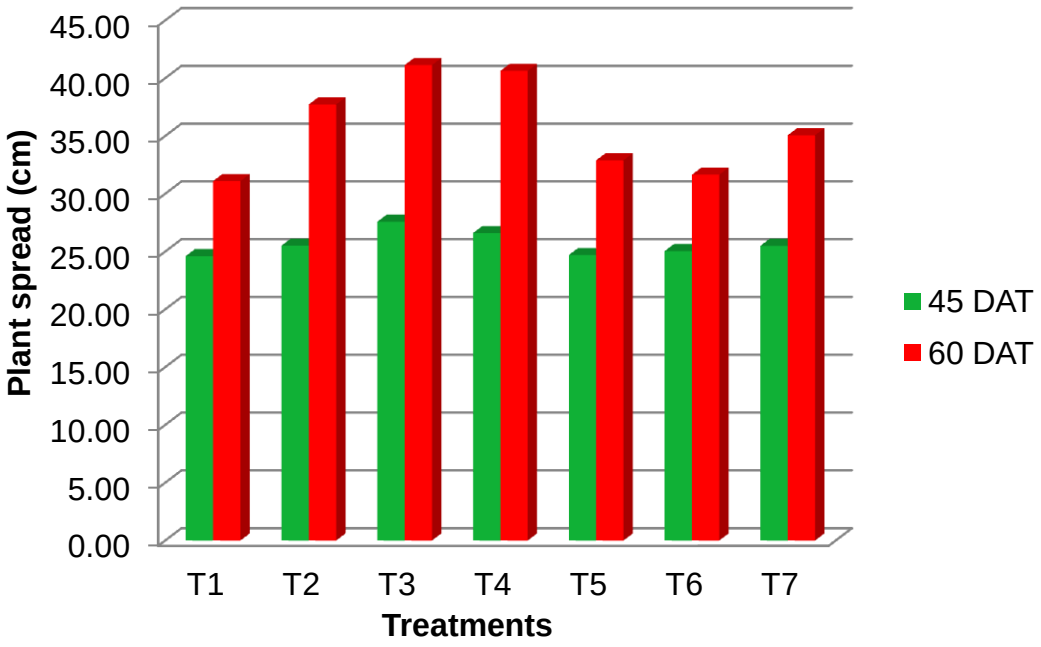
It can be observed from Table 4.2 and Fig. 4.2 that the plant spread was influenced significantly by plant growth regulators at 60 day after transplanting.

The plants sprayed with T_3 (GA_3 300 ppm) attained the maximum plant spread (27.58 and 41.13 cm) followed by T_4 (GA_3 350 ppm) and T_2 (GA_3 250 ppm) which recorded values of 26.60, 40.63 cm and 25.51, 37.10 cm at 45 and 60 day after transplanting respectively. The minimum plant spread (24.61 and 31.10 cm) was recorded by T_1 (control) at 45 and 60 day after transplanting respectively.

Table 4.2 Effect of plant growth regulators on plant spread (cm) in Calendula.

Treatment	**Plant spread (cm)**	
	45 DAT	**60 DAT**
T_1 (control)	24.61	37.10
T_2 (GA_3 at 250 ppm)	25.51	37.73
T_3 (GA_3 at 300 ppm)	27.58	41.13
T_4 (GA_3 at 350 ppm)	26.60	40.63
T_5 (NAA at 150 ppm)	24.70	32.90
T_6 (NAA at 200 ppm)	25.04	31.65
T_7 (NAA at 250 ppm)	25.50	35.07
S.Em.±	**1.08**	**1.57**
C.D. at 5%	**3.33**	**4.83**

Fig. 4.2 Effect of plant growth regulators on plant spread (cm) in calendula.



T_1 – control, T_2 – GA_3 at 250 ppm, T_3 – GA_3 at 300 ppm, T_4 – GA_3 at 350 ppm, T_5 – NAA at 150 ppm, T_6 – NAA at 200 ppm, T_7 – 250 ppm.

4.1.3 Number of leaves

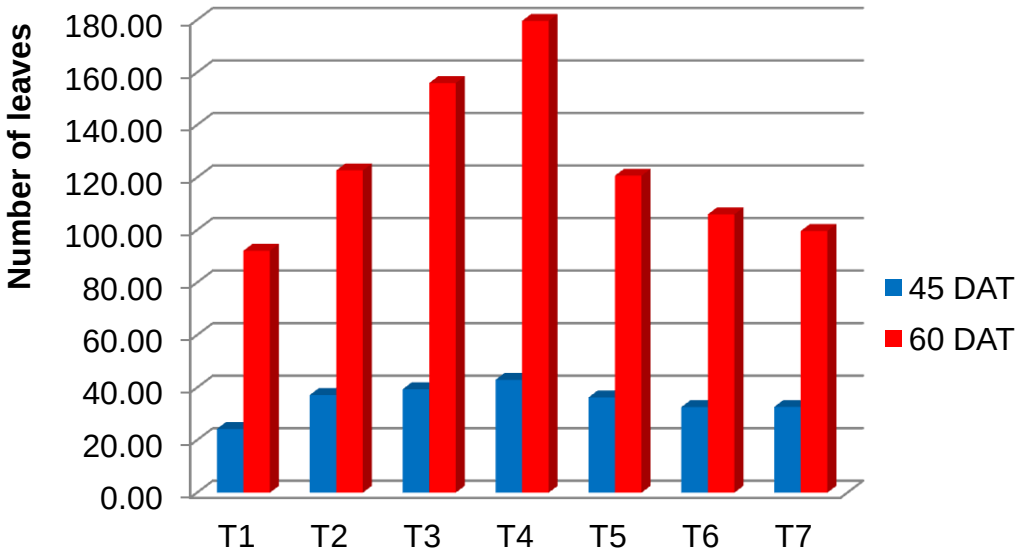
Data can be displayed from the Table 4.3 and Fig. 4.3 that the number of leaves was influenced significantly by plant growth regulators at 60 day after transplanting.

At 45 and 60 day after transplanting, the treatments T_4 (GA_3 350 ppm) exhibited counted the maximum number of leaves (43.00 and 179.67) and it found to be at par with treatments T_3 (GA_3 300 ppm), which recorded values of 39.40 and 156.00 respectively, while the minimum number of leaves (24.27 and 92.13) was recorded withT_1 (control).

Table 4.3 Effect of plant growth regulators on number of leaves in Calendula.

Treatment	**Number of leaves**	
	45 DAT	**60 DAT**
T_1 (control)	24.27	92.13
T_2 (GA_3 at 250 ppm)	37.20	122.73
T_3 (GA_3 at 300 ppm)	39.40	156.00
T_4 (GA_3 at 350 ppm)	43.00	179.67
T_5 (NAA at 150 ppm)	36.27	120.73
T_6 (NAA at 200 ppm)	32.60	106.00
T_7 (NAA at 250 ppm)	32.67	99.67
S.Em. ±	**4.18**	**8.68**
C.D. at 5%	**12.8**	**26.75**

Fig. 4.3 Effect of plant growth regulators on number of leaves in calendula



T_1 – control, T_2 – GA_3 at 250 ppm, T_3 – GA_3 at 300 ppm, T_4 – GA_3 at 350 ppm, T_5 - NAA at 150, T_6 – NAA at 200 ppm, T_7 – NAA at 250 ppm

4.1.4 Number of branches / plant

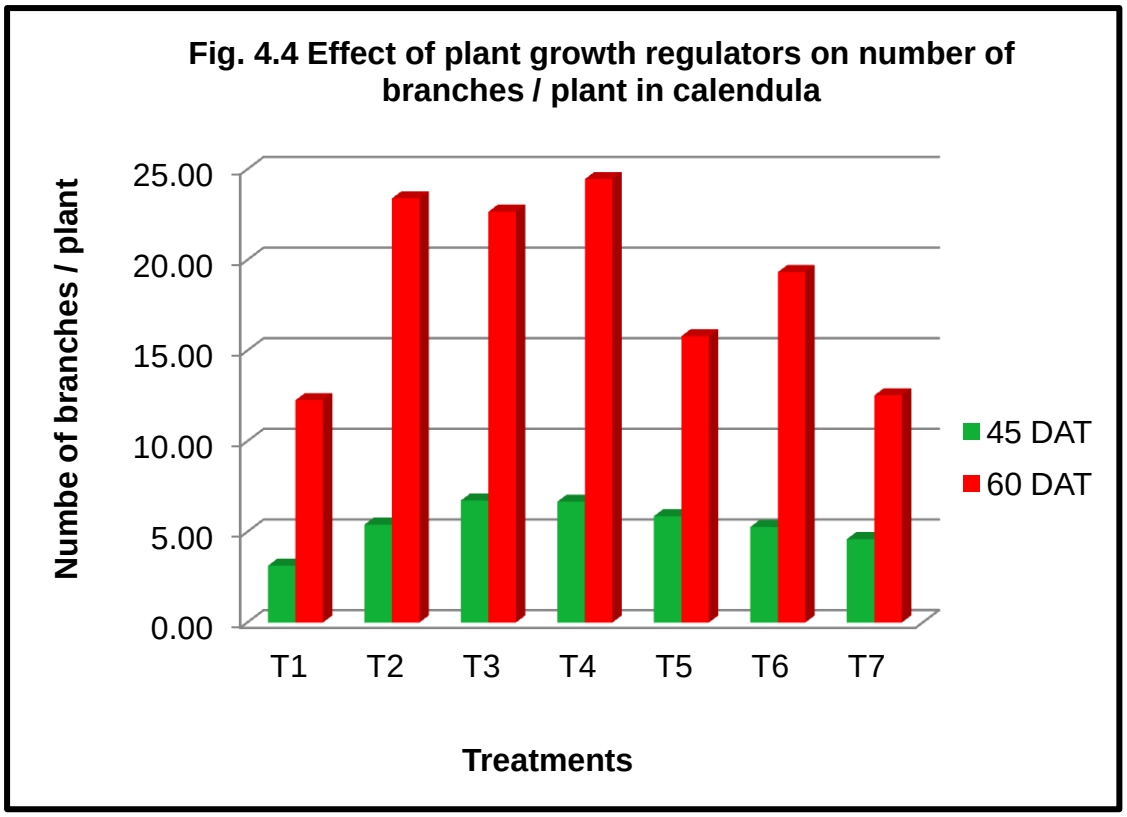
It is clear from Table 4.4 and Fig. 4.4 that the number of branches per plant was influenced significantly by plant growth regulators at 60 day after transplanting.

At 45 day after transplanting, T_3 (GA_3 300 ppm) counted the maximum number of branches per plant (6.73) followed by T_4 (GA_3 350 ppm) and T_5 (NAA 150 ppm) which recorded values of 6.67 and 5.87 respectively, while the minimum number of branches / plant (3.13) was recorded by treatment T_1 (control).

At 60 day after transplanting, T_4 (GA_3 350 ppm) counted the maximum number of branches per plant(24.47) followed by T_2 (GA_3 250 ppm) and T_3 (GA_3 300 ppm) which recorded the values of 23.40 and 22.67 respectively, all of these three treatments are statistically at par to each other and superior over other treatments. The minimum number of branches / plant (12.27) at this stage was recorded by T_1 (control).

Table 4.4 Effect of plant growth regulators on number of branches / plant in calendula.

Treatment	Number of branches / plant	
	45 DAT	**60 DAT**
T_1 (control)	3.13	12.27
T_2 (GA_3 at 250 ppm)	5.40	23.40
T_3 (GA_3 at 300 ppm)	6.73	22.67
T_4 (GA_3 at 350 ppm)	6.67	24.47
T_5 (NAA at 150 ppm)	5.87	15.80
T_6 (NAA at 200 ppm)	5.27	19.33
T_7 (NAA at 250 ppm)	4.60	12.53
S.Em.±	**0.88**	**1.12**
C.D. at 5%	**2.73**	**3.47**



T_1 – control, T_2 – GA_3 at 250 ppm, T_3 – GA_3 at 300 ppm, T_4 – GA_3 at 350 ppm, T_5 - NAA at 150, T_6 – NAA at 200 ppm,T_7 – NAA at 250 ppm

4.2 Flowering Parameters:

Data on various flowering attributes of calendula under the influence of treatments are presented in Table 4.5 to 4.10 and Fig. 4.5 to 4.10 Analysis of variance of each parameter is given in appendix III, IV and V.

4.2.1 Number of flowers / plant

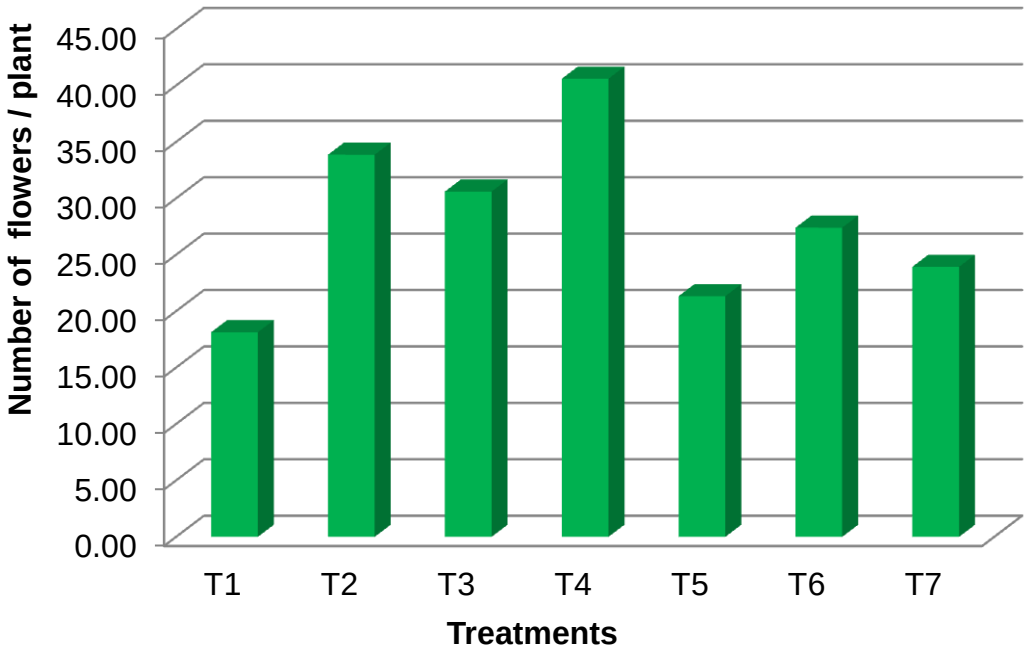
It is showed from Table 4.5 and Fig. 4.5 that the number of flowers / plant was influenced significantly by plant growth regulators as compare to control.

The maximum number of flowers per plant (40.60) was recorded in T_4 (GA_3 350 ppm) and it was statistically superior over other treatments examined here. Minimum number of flowers per plant (18.13) was recorded in T_1 (control).

Table 4.5 Effect of plant growth regulators on number of flowers per plant in Calendula.

Treatment	Number of flowers / plant
T_1 (control)	18.13
T_2 (GA_3 at 250 ppm)	33.87
T_3 (GA_3 at 300 ppm)	30.60
T_4 (GA_3 at 350 ppm)	40.60
T_5 (NAA at 150 ppm)	21.33
T_6 (NAA at 200 ppm)	27.40
T_7 (NAA at 250 ppm)	23.93
S.Em.±	**6.59**
C.D. at 5%	**2.13**

Fig. 4.5 Effect of plant growth regulators on number of flowers / plant in calendula



T_1 – control, T_2 – GA_3 at 250 ppm, T_3 – GA_3 at 300 ppm, T_4 – GA_3 at 350 ppm, T_5 - NAA at 150, T_6 – NAA at 200 ppm, T_7 – NAA at 250 ppm

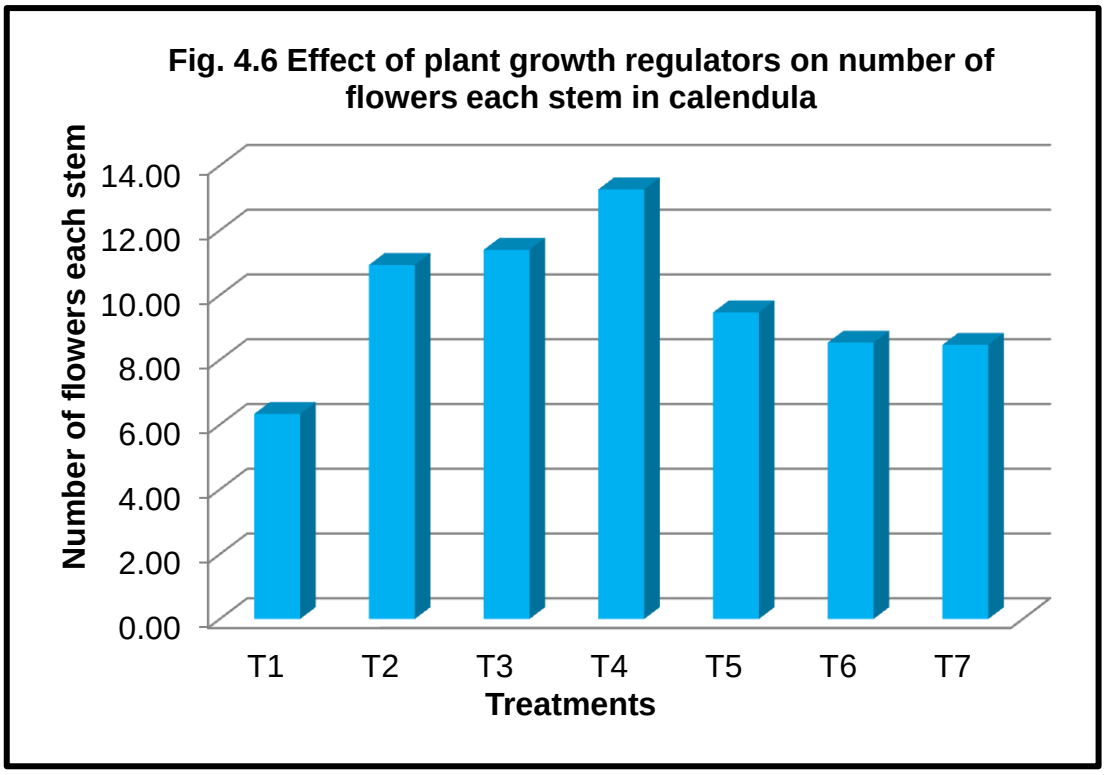
4.2.2 Number of flowers each stem

Data pertaining to the number of flowers each stem presented in the Table 4.6 and Fig. 4.6 indicate that the number of flowers each stem was influenced significantly by plant growth regulators as compare to control.

Maximum number of flowers each stem (13.27) was recorded in T_4 (GA_3 350 ppm) followed by T_3 (GA_3 300 ppm), which recorded value of 11.40. Among the treatments, T_4 (GA_3 350 ppm) was statistically superior over rest of the treatments except T_3 (GA_3 300 ppm). The minimum number of flowers each stem (6.33) was noted in T_1 (control).

Table 4.5 Effect of plant growth regulators on number of flowers each stem in Calendula.

Treatment	**Number of flowers each stem**
T_1 (control)	6.33
T_2 (GA_3 at 250 ppm)	10.93
T_3 (GA_3 at 300 ppm)	11.40
T_4 (GA_3 at 350 ppm)	13.27
T_5 (NAA at 150 ppm)	9.47
T_6 (NAA at 200 ppm)	8.53
T_7 (NAA at 250 ppm)	8.47
SE.m.±	**2.25**
C.D. at 5%	**0.73**



T_1 – control, T_2 – GA_3 at 250 ppm, T_3 – GA_3 at 300 ppm, T_4 – GA_3 at 350 ppm, T_5 - NAA at 150, T_6 – NAA at 200 ppm, T_7 – NAA at 250 ppm

4.2.3 Diameter of flowers

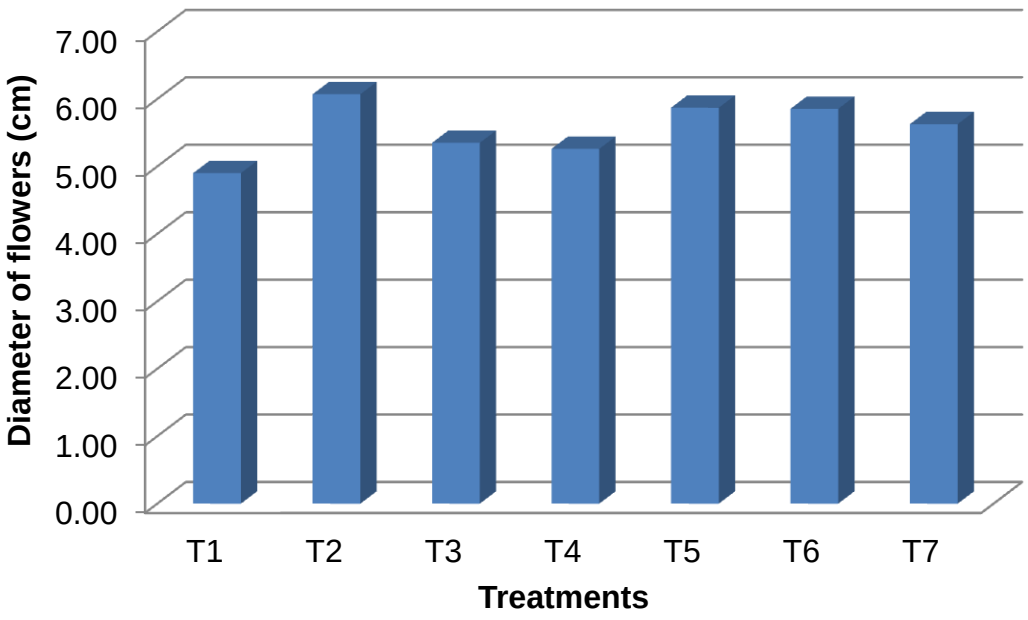
It is cleared from Table 4.7 and Fig. 4.7 that the diameter of flowers was influenced significantly by plant growth regulators.

Among the growth regulators spray, T_2 (GA_3 250 ppm) recorded the maximum diameter of flowers (6.07 cm) followed by T_5 (NAA 150 ppm) andT_6 (NAA 200 ppm), which recorded the values of 5.87 and 5.85 cm. The minimum diameter of flowers (4.90 cm) was obtained by T_1 (control).

Table 4.7 Effect of plant growth regulator on diameter of flowers (cm) in Calendula.

Treatment	**Diameter of flowers (cm)**
T_1 (control)	4.90
T_2 (GA_3 at 250 ppm)	6.07
T_3 (GA_3 at 300 ppm)	5.35
T_4 (GA_3 at 350 ppm)	5.26
T_5 (NAA at 150 ppm)	5.87
T_6 (NAA at 200 ppm)	5.85
T_7 (NAA at 250 ppm)	5.63
S.Em.±	**0.52**
C.D. at 5%	**0.16**

Fig. 4.7 Effect of plant growth regulators on diameter of flowers (cm)



T_1 – control, T_2 – GA_3 at 250 ppm, T_3 – GA_3 at 300 ppm, T_4 – GA_3 at 350 ppm, T_5 - NAA at 150, T_6 – NAA at 200 ppm, T_7 – NAA at 250 ppm

Plate-3: Effect of plant growth regulators on diameter of flowers (cm)

T_2 – 250 ppm; T_5 – NAA 150 ppm; T_1 – control

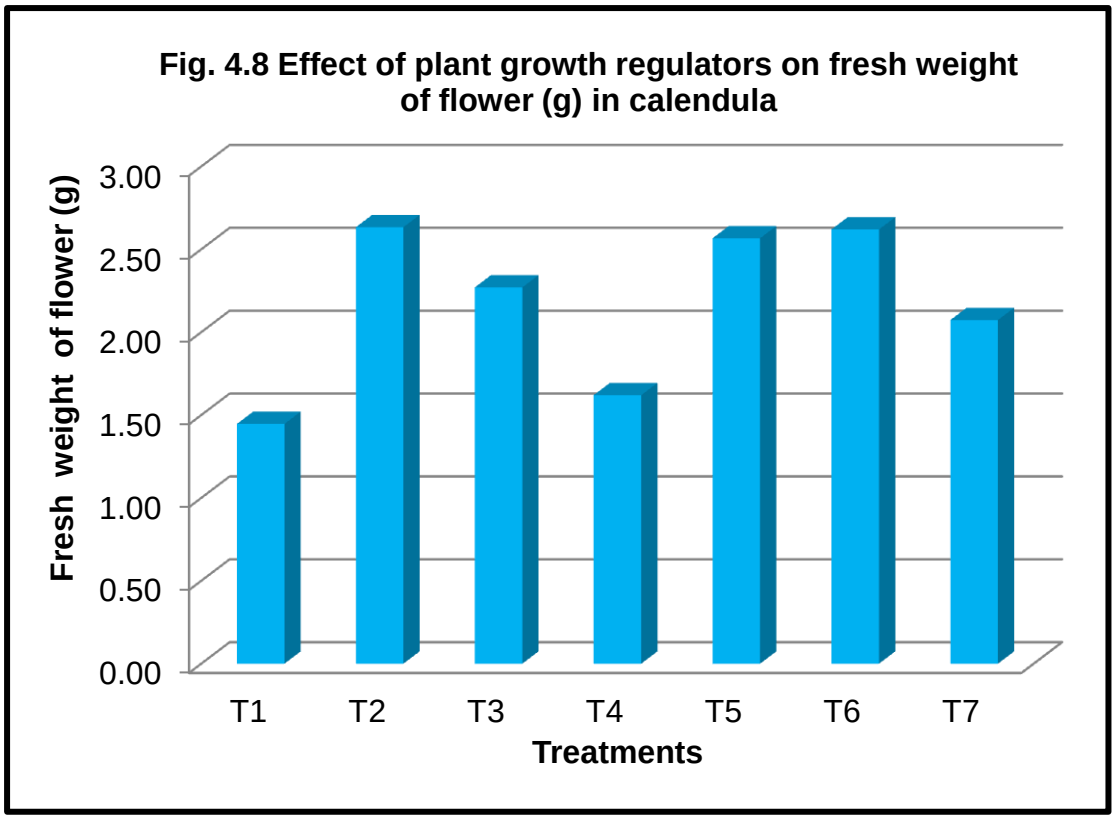
4.2.4 Fresh weight of flower

A close review of data Table 4.8 and Fig. 4.8 indicate that the fresh weight of flower (g) was influenced significantly by plant growth regulators as compare to control.

The maximum fresh weight of flower (2.63 g) was recorded with T_2 (GA_3 250 ppm) followed by T_6 (NAA 200 ppm), which recorded the value 2.62 g and both of these are statistically at par to each other and superior over control. The minimum fresh weight of flower (1.45 g) was recorded with T_1 (control).

Table 4.8 Effect of plant growth regulators on fresh weight of flower (g) in Calendula.

Treatment	**Fresh weight of flower (g)**
T_1 (control)	1.45
T_2 (GA_3 at 250 ppm)	2.63
T_3 (GA_3 at 300 ppm)	2.27
T_4 (GA_3 at 350 ppm)	1.62
T_5 (NAA at 150 ppm)	2.57
T_6 (NAA at 200 ppm)	2.62
T_7 (NAA at 250 ppm)	2.07
SE.m.±	**0.53**
C.D. at 5%	**0.17**



T_1 – control, T_2 – GA_3 at 250 ppm, T_3 – GA_3 at 300 ppm, T_4 – GA_3 at 350 ppm, T_5 - NAA at 150, T_6 – NAA at 200 ppm, T_7 – NAA at 250 ppm

4.2.5 Dry weight of flower

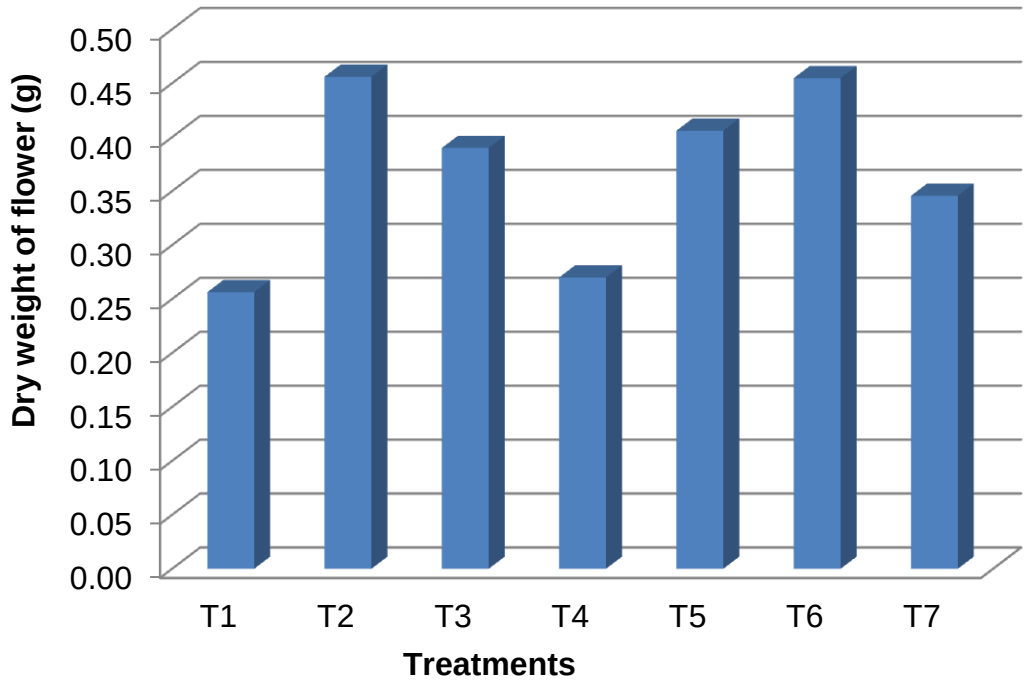
It is presented from Table 4.9 and Fig. 4.9 that the dry weight of flower (g) was influenced significantly by plant growth regulators.

The treatments T_2 (GA_3 250 ppm) produced maximum dry weight (0.46 g) as compared to other treatments and it was found to be at par with the treatments T_6 (NAA 200 ppm) and T_7 (NAA 250 ppm), which recorded the values of 0.45 and 0.41 g respectively, while the minimum dry weight of flower (0.26 g) was recorded with the treatment T_1 (control).

Table 4. Effect of plant growth regulators on dry weight of flower (g) in Calendula.

Treatment	**Dry weight of flower (g)**
T_1 (control)	0.26
T_2 (GA_3 at 250 ppm)	0.46
T_3 (GA_3 at 300 ppm)	0.39
T_4 (GA_3 at 350 ppm)	0.27
T_5 (NAA at 150 ppm)	0.41
T_6 (NAA at 200 ppm)	0.45
T_7 (NAA at 250 ppm)	0.35
S.Em.±	**0.10**
C.D. at 5%	**0.03**

Fig. 4.9 Effect of plant growth regulators on dry weight of flower (g) in calendula



T_1 – control, T_2 – GA_3 at 250 ppm, T_3 – GA_3 at 300 ppm, T_4 – GA_3 at 350 ppm, T_5 - NAA at 150, T_6 – NAA at 200 ppm, T_7 – NAA at 250 ppm

4.2.6 Flowering duration (days)

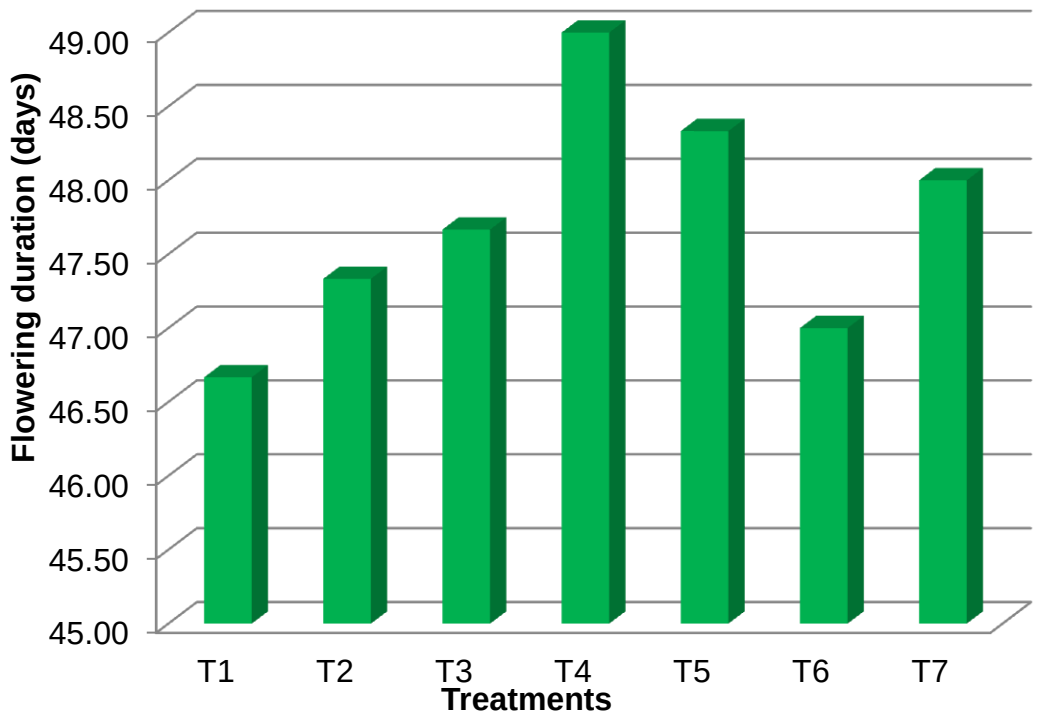
It can be observed from Table 4.10 and Fig. 4.10 that the effect of plant growth regulators on flowering duration was statistically non - significant

The longer flowering duration (49.00 days) was recorded in T_4 (350 ppm GA_3) and it was found statistically at par with the treatments T_5 (NAA 150 ppm) and T_7 (NAA 250 ppm), which revealed the values of 48.33 and 48.00 days respectively, while the minimum flowering duration (46.67 days) obtained by the treatment T_1(control).

Table 4.10 Effect of plant growth regulators on flowering duration (days) in Calendula.

Treatment	**Flowering duration (days)**
T_1 (control)	46.67
T_2 (GA_3 at 250 ppm)	47.33
T_3 (GA_3 at 300 ppm)	47.67
T_4 (GA_3 at 350 ppm)	49.00
T_5 (NAA at 150 ppm)	48.33
T_6 (NAA at 200 ppm)	47.00
T_7 (NAA at 250 ppm)	48.00
S.Em.±	**4.317**
C.D. at 5%	**1.401**

Fig. 4.10 Effect of plant growth regulators on flowering duration (days) in calendula



T_1 – control, T_2 – GA_3 at 250 ppm, T_3 – GA_3 at 300 ppm, T_4 – GA_3 at 350 ppm, T_5 - NAA at 150, T_6 – NAA at 200 ppm, T_7 NAA at 250 ppm

Chapter-V
DISCUSSION

In the course of presenting the results of experiment entitled **"Effect of Plant Growth Regulator on Growth and Flowering of Calendula (*Calendula officinalis* L.) under Malwa Plateau of M.P."** significant variation in the criteria used for evaluating the treatments have been described. In this chapter, it is endeavored to discuss the significant results or those assuming a definite pattern in various parameters in the light of available evidence in literature.

5.1 Growth parameters:

Growth parameters viz., plant height (cm), plant spread (cm), number of leaves, number of branches per plant was observed at 45 and 60 day after transplanting. All the parameters of growth indicated significant influenced by plant growth regulators.

5.1.1 Plant height (cm)

The plant height was shown to be significantly influenced by the different plant growth regulators treatments in the current study. GA_3 300 ppm showed the maximum plant height at 45 day after transplanting and GA_3 350 ppm at 60 day after transplanting. The minimum plant height was noted with the NAA 150 ppm at 45 day after transplanting and control at 60 day after transplanting.

Increased plant height could be attributed to faster cell multiplication and cell elongation due to higher concentration of $GA_{3,}$ which may have stimulates plant growth and, as a result increased plant height (Benny *et al*., 2017).

Promotive effect of gibbrellin on growth may be due to increasing auxin level in the tissues or enhancement of the conversion of tryptophane to IAA which caused the cell division and cell elongation. as a result increased plant height (Mishra *et al*., 2017)

These findings were in conformity with the findings of Palekar *et al.* (2018) in China aster.

5.1.2 Plant spread (cm)

The plant spread was found significantly influenced due to application of GA_3 300 ppm and showed the maximum plant spread at 45 and 60 day after transplanting, while the minimum plant spread during all these stages of observation was reported in control.

GA_3 caused a hyper elongation of internodal length, which resulted in plant height extension, while an increase in the total number of main axis led in an increase in the number of latent dormant buds from which main branches developed, resulting in optimal plant spread (Acharya *et al.*, 2021).

These results are confirmed by the finding of Sindhuja *et al*. (2018) and Kumar *et al*. (2018) in China aster.

5.1.3 Number of leaves per plant

In the recently investigation, it was observed that number of leaves was significantly influenced by application of GA_3 350 ppm and observed the maximum number of leaves at 45 and 60 day after transplanting, while the minimum number of leaves during all these stages of observation was recorded under control.

The production of more number of leaves with the application of GA_3 might have been due to quick development and differentiation, resulting more number of leaves (Benny *et* al., 2017).

The results are confirmed with the findings of Sindhuja *et al.* (2018) and Kuri *et al*. (2018) in China aster.

5.1.4 Number of branches per plant

The number of branches per plant was shown to be significantly influenced by the various plant growth regulators treatments in the recent study. GA_3 300 ppm recorded the maximum number of branches per plant at 45 day after transplanting and GA_3 350 ppm at 60 day after transplanting. The minimum number of branches per plant was found in control during both the stages of observation.

Maximum number of branches per plant with spray of GA_3 might be due to the fact that, GA_3 is well known for its prominent translocation and

transcription mechanism of protein synthesis, as well as stimulation of cell division and cell elongation, while increasing the flexibility of cell wall and the synthesis of energy - rich phosphates, results in enlarged more number of productive branches (Deepti *et al.* 2021)

Increase in the number of branches with GA_3 treatment may be due to the hyper elongation of internodal length and a resultant increase in nodal count on the main axis. Consequently these nodes increased number of dormant buds from where the primary branches may have originated (Delvadia *et al.* 2009)

Present study was in line with the findings of Palekar *et al.* (2018) and Sidana *et al.* (2019) in China aster.

5.2 Flowering parameters:

Flowering parameters viz., number of flowers / plant, number of flowers each stem, diameter of flowers (cm), fresh weight of flower (g), dry weight of flower (g) flowering duration (days) were observed. All the parameters of growth indicated significant influenced by plant growth regulators.

5.2.1 Number of flowers per plant

In the present study the number of flowers per plant increased significantly by plant growth regulators treatments as compared to control. Treatment GA_3 350 ppm recorded the maximum number of flowers per plant and the minimum number of flowers per plant was noted in control.

The enlargement in number of flower per plant could be due to possible production of more laterals at prior phase of development, and giving it more time for carbohydrate accumulation for flower bud differentiation due to improved reproductive effectiveness of the plant (Kumar *et al*., 2018).

The above results are in conformity with the findings Shrestha *et al.* (2020) in calendula, Kumar *et al.* (2014) in African marigold, Arha *et al.* (2019) in African marigold.

5.2.2 Number of flowers per stem

In the current study the number of flowers each stem increased significantly by plant growth regulators treatments as compared to control. The maximum number of flowers each stem was recorded in treatment GA_3 350 ppm, whereas the minimum number of flowers each stem was reported in control.

The increasing in number of flowers each stem could be due to possible production of more laterals at prior phase of growth, and giving it more time for carbohydrate accumulation for flower bud differentiation due to improved reproductive effectiveness of the plant (Sathappan *et al.,* 2018).

These results are confirmed with the findings of Mishra *et al.* (2017) in African marigold and Delvadia *et al.* (2009) in gaillardia.

5.2.3 Diameter of flowers (cm)

Plant growth regulators had a significantly influenced on diameter of flowers in the current investigation. The maximum diameter of flowers was measured by treatment GA_3 250 ppm, whereas the minimum diameter of flowers was measured in control.

The increase in diameter of flowers might be related to the flowers cell elongation. Gibberellins have also been revealed to increase the sink strength of actively developing portions (Kuri *et al*., 2018).

The parallel results were also noted by Sindhuja *et al.* (2018) and Kuotsu *et al.* (2018) in gerbera.

5.2.4 Fresh weight of flower (g)

Effect of plant growth regulators on fresh weight of flower was statistically significantly. The maximum fresh weight of flower was noted with GA_3 250 ppm, while the minimum fresh weight of the flower was measured in control.

Increase in fresh weight of flower in GA_3 treated plants may be attributed to the fact that GA_3 promote the plants effectiveness in terms of photosynthetic activity, absorption of nutrients and their translocation, and

improved partitioning of assimilates into reproductive organs (Sindhuja *et al.*, 2018).

Similar findings were obtained by Palekar *et al*. (2018) in China aster and Maurya *et al*. (2017) in China aster.

5.2.5 Dry weight of flower (g)

Effect of plant growth regulators on dry weight of flower was statistically significantly. The maximum dry weight of flower was recorded with GA_3 250 ppm, while the minimum dry weight of flower was recorded with control.

5.2.6 Flowering duration (days)

In the recently investigation it was observed that flowering duration was non-significantly influenced by plant growth regulators. Treatment GA_3 350 ppm recorded the maximum flowering duration, and the minimum flowering duration was reported in control.

Chapter– VI

SUMMARY, CONCLUSION AND SUGGESTIONS FOR FUTURE WORK

6.1 Summary:

A field experiment entitled **"Effect of Plant Growth Regulator on Growth and Flowering of Calendula (*Calendula officinalis* L.) Under Malwa Plateau of M.P."** was conducted at Floriculture Research Field, College of Horticulture, Mandsaur (M.P.), during rabi season 2020-21. The research experiment was laid out in randomized block design in three replications from November 2020 to February 2021. Plant growth regulators at three concentration of GA_3 (250, 300 and 350 ppm) and NAA (150, 200 and 250 ppm) were tested. All the parameters were recorded at different growth and flowering stages. The salient findings of the investigations are summarized here:-

6.1.1 Effect of plant growth regulators

6.1.1.1 Growth parameters:

The observation on plant height (cm), plant spread (cm), number of leaves and number of branches / plant were recorded at 45 and 60 day after transplanting. It was clear from the results that growth regulators indicated significant differences for growth attributes under the experiment. The effect of different treatment on various characters of calendula has been summarized below.

1. The Maximum plant height was found in T_3 (GA_3 300 ppm) at 45 day after transplanting and in T_4 (GA_3 350 ppm) at 60 day after transplanting. The minimum plant height was observed inT_5 (NAA 150 ppm) at 45 day after transplanting and in T_1 (control) at 60 day after transplanting.
2. The maximum plant spread was recorded with T_3 (GA_3 300 ppm) at 45 and 60 day after transplanting, while the minimum plant spread was recorded in case of T_1 (control).

3. The maximum number of leaves was recorded in T_4 (GA_3 350 ppm) at 45 and 60 day after transplanting, while the minimum number of leaves was recorded in T_1 (control).
4. The maximum number of branches per plant was recorded in T_3 (GA_3 300 ppm) at 45 day after transplanting and in T_4 (GA_3 350 ppm) at 60 day after transplanting. The minimum number of branches per plant was found in T_1 (control) at 45 and 60 day after transplanting.

6.1.1.2 Flowering parameters:

The number of flowers / plant, number of flower each stem, flower diameter (cm), fresh weight of plant (g), dry weight of plant (g), flowering duration(days) were significantly influenced by various treatments of plant growth regulators.

1. The maximum number of flowers per plant and each stem were recorded in T_4 (GA_3 350 ppm), while minimum number of flowers were recorded with T_1 (control) .
2. The maximum diameter of flowers (cm) was recorded in T_2 (GA_3 250 ppm), while minimum was recorded in T_1 (control).
3. The maximum fresh and dry weight of flower (g) were recorded in T_2 (GA_3 250 ppm), while minimum was recorded in T_1 (control).
4. The maximum flowering duration (days) was recorded in T_4 (GA_3 350 ppm), while minimum was recorded in T_1 (control).

6.2 Conclusions

The different plant growth regulators had significant influenced on the growth and flowering parameters of calendula in the current study.

On the basis of the results obtained by the investigation entitled **"Effect of Plant Growth Regulator on Growth and Flowering of Calendula (*Calendula officinalis* L.) under Malwa Plateau of M.P."** it may be reported that an application of GA_3 at 350 ppm proved better than all other treatments with respect of various attributes related to the plant height (cm), number of leaves, number of branches per plant and flowering parameters also as it recorded the maximum number of flowers per plant, number of flowers each stem and flowering duration (days). However, T_3 (GA_3 300 ppm) showed best

results with plant spread and T_2 (GA_3 250 ppm) with fresh and dry weight of flower (g) and diameter of flowers (cm).

6.3 Suggestions for future work

Following future line of work is suggested for obtaining improved growth, flowering and flower quality of Calendula for benefit to growers.

The following suggestions are made for further research work.

1. The experiment may be repeated to confirm the findings of current research.
2. Different types of plant growth regulators should be tried for finding best regulator for individual and overall factor of growth and flowering for Malwa region of M.P.
3. Same experiment can be repeated in various locations.

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APPENDICES

Appendix- I: Analysis of variance for plant height (cm) and plant spread (cm)

Source of variation	D.F.	Mean sum of squares			
		Plant height (cm)		Plant spread (cm)	
		45 DAP	60 DAP	45 DAP	60 DAP
Treatment	6	8.94	290.94	3.51	51.87
Error	12	3.30	11.48	3.50	7.39
Total	20				

Appendix- II: Analysis of variance for number of leaves and number of branches / plant

Source of variation	D.F.	Mean sum of squares			
		Number of leaves		Number of branches / plant	
		45 DAP	60 DAP	45 DAP	60 DAP
Treatment	6	4.69	79.63	108.095	3027.62
Error	12	2.35	3.82	52.4933	226.16
Total	20				

Appendix- III: Analysis of variance for number of flowers / plant and number of flowers each stem.

Source of variation	D.F.	Mean sum of squares	
		Number of flowers / plant	Number of flowers each stem
Treatment	6	179.31	15.68
Error	12	13.73	1.6
Total	20		

Appendix- IV: Analysis of variance for diameter of flowers (cm) and fresh weight of flower (g)

Source of variation	D.F.	Mean sum of squares	
		Diameter of flowers (cm)	Fresh weight of flower (g)
Treatment	6	0.50	0.70
Error	12	0.086	0.089
Total	20		

Appendix- V: Analysis of variance fordry weight of flower (g) and flowering duration (days)

Source of variation	D.F.	Mean sum of squares	
		Dry weight flower (g)	Flowering duration (days)
Treatment	6	0.020	1.80
Error	12	0.0036	6.05
Total	20		

VITA

The author of this thesis **Ms. KAVITA PATIDAR** was born on 2th may. 1996 at Village- Suri, Tehsil & District - Mandsaur (M.P).

She passed her high school examination from govt. H.S. school, suthi Mandsaur (M.P) with 74.60% in year 2012 and passed her Higher Sec. School Suthi in year 2014 with 71.20 from same school.

He took admission for B.Sc. (Ag.) in College of Agriculture, Tikamgarh (M.P.) in year 2015. He has successfully completed her graduation with 71.20 out of 10 point scale in the year 2019.

For further study, he got admission in M.Sc. Agriculture in Horticulture (Floriculture and landscape Architecture) at K.N.K college of Horticulture, Mandsaur, (M.P.). Where successfully completed entire course requirement for master's degree with OGPA 7.45 out of 10 point scale.

For the partial fulfillment of the master's degree, he carried out the experiment entitled, **"Effect of Plant Growth Regulators on Growth and Flowering of Calendula (*Calendula officinalis* L.) under Malwa Plateau of M.P."** which has been completed and presented in this thesis.

Permanent Address:

Kavita Patidar

D/o Nageshwar Patidar

Village :- Suri

post :- Lodh

Teh & Distt. :- Mandsaur (M.P.)

Pin:- 458895

Kaviptdr21@gmail.com

Kavita Patidar