Effect of bio-fertilizers on growth, flowering and yield of China aster (*Callistephus chinensis* L.)

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by

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CERTIFICATE - I

This is to certify that the thesis entitled **"Effect of bio-fertilizers on growth, flowering and yield of China aster (*Callistephus chinensis* L.)"** submitted in partial fulfilment 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 (M.P.) is a record of the bona-fide research work carried out by **Mr. SUNIL KUMAR GUPTA,** 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.

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Chairman of the Advisory Committee

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CERTIFICATE- II

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This is to certify that the thesis entitled **"Effect of bio-fertilizers on growth, flowering and yield of China aster (*Callistephus chinensis* L.)"** submitted by **Mr. SUNIL KUMAR GUPTA** to the Rajmata Vijayaraje Scindia Krishi Vishwa Vidyalaya, Gwalior (M.P.) 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.

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Date…/…/……

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Symbol	Abbreviation	Stands for
/	-	Per
@	-	At the rate of
%	-	Percentage
^{0}C	-	Degree Celsius
-	ANOVA	Analysis of variance
-	C.D.	Critical difference
-	Cm	Centimetre
-	cm^2	Centimetre square
-	CRD	Completely Randomized Design
-	CV	Coefficient of Variance
-	cv.	Cultivar
-	DAT	Days after transplanting
-	Df	Degrees of freedom
-	DW	Distilled water
-	EMS	Error Mean Sum of Squares
-	*et al.*	And others/ associates
-	Fig.	Figure
-	G	Gram
-	H	Hour
-	Ha	Hectare
-	*i.e.*	That is
-	K	Potassium
-	Kg	Kilogram
-	L	Litre
-	M.P.	Madhya Pradesh
-	No.	Number
-	Max.	Maximum
-	Mg	Milligram
-	Min.	Minimum
-	Ml	Millilitre

-	Mm	Millimetre
-	MSS	Mean Sum of Squares
-	N	Nitrogen
-	NS	Non significant
-	P	Phosphorus
-	PGR	Plant Growth Regulator
-	Ppm	Parts Per Million
-	R.V.S.K.V.V.	Rajmata Vijayaraje Scindia Krishi Vishwa Vidyalaya
-	S.Ed.	Standard error of difference
-	S.Em ±	Standard error of mean
-	SS	Sum of Squares
-	T	Tonne
-	var.	Variety
-	*Viz.*	Videlicet (Namely)

CHAPTER – I
INTRODUCTION

China aster (*Callistephus chinensis* L.) one of the most admire flowering annuals, is a member of Asteraceae family and is native to China. The present day asters have been developed from a single form of wild species and their plant behaviour is classified as diploid (2n=18). Linnaeus named it *Aster chinensis* at first, but it was renamed to *Callistephus chinensis* by Nees. The single species chinensis belong to the genus Callistephus (Munikrishnappa and Chandrasheker, 2014).

It was first introduced in Europe in 1731 and then spread to other parts of the world (Desai, 1967). The name Callistephus is derivative from two Greek words: Kalistos, which means most attractive and Stephus, which means crown. It symbolizes purity, love, peace, beauty and passion (Naikwad *et al.* 2018).

Aster is a winter seasonal annual flower crop that is half-hardy; free blooming and easy to grow. The plant are erect with leaves are arranged alternately on branches and bear solitary type of flower (Bohra *et al*. 2019).

The plant was around 60 cm tall and single blooming type and branching type. There are two types of florets in an aster bloom: ray florets and disc florets. The bloom type depends mainly upon the relative number of the two kinds of florets and their shapes. The most suitable feature for the classification of China aster is the form of ray florets. Since its arrival to Europe, the plants form, size and colour of bloom have changed significantly (Sindhuja and Prasad, 2018).

In recent times China aster has gained popularity between the farmers as of its easy growing as well as wider adaptability to diverse agro climate region. It is traditionally cultivated in India. Its stunning flower, shining color, straight stalks and long vase life contribute to its big demand in cut flower market, vase arrangement, floral decorations, bouquets making. The China aster has become one of the most popular garden flowers. Among the colours present in all of the many variations are pure white, purple, dark blue, numerous shades of pink, pastel blue, and red. Aster does not have a pure

golden color. Flower with more petals are ideal for use as loose flowers in garlands, buttonholes and veni for hair ornamentation. Aster flower plants are a popular bedding plant in landscape gardening and use as a pot plant, as well as in a mixed herbaceous border and are ideal for window boxes and edging. The China aster is now widely regarded as one of the most beautiful garden flowers (Kirar *et al*., 2009 and Kumar *et al*., 2018).

India's overall floriculture area was 313 thousand hectares 2019-20, with a production of 2865 thousand metric tons of cut and loose flower. In Madhya Pradesh, total area under flower cultivation in 2019-20 was 30.80 thousand hectares, with a total production of 363.83 thousand metric tons of loose and cut flowers (NHB 2nd advance estimate 2019-20).

The China aster is also a popular cut flower of Switzerland, Japan, the United States and Europe. In India, commercial cultivation of China aster is mainly concentrated in Karnataka, Tamil Nadu, Andhra Pradesh, West Bengal and Maharashtra. It ranks next to chrysanthemum and marigold and is grown by small and marginal farmers in India.

China aster cultivation has been found to be a profitable enterprise. Nutrient management is one of the most essential aspects determining flower. Production of high-quality flowers depends largely on well-balanced nourishment at optimum levels. Therefore, attention is needed to apply enough nutritional through appropriate nutrient sources (Khanna *et al.* 2016).

NPK are important nutrients in crop production. As majority of the soils in the world's soil are considered to be weak in the above nutrients, chemical fertilizers will be in high demand to address these nutrient deficiencies. Large scale use of chemical fertilizers affects soil fertility and pollutes water sources.

The fertilizer recommendation for China aster cv. local (180:120:60 kg N:P:K/ha) is extremely high (excluding potassium), which has some negative effects on the physical, chemical and biological characteristics of the soil along with production costs which has a direct impact on the farmers, which is an imminent disaster for the farmers (Sowmya and Prasad, 2017).

Generally we use chemical fertilizers to supply nutrients and if we use some bio-fertilizers along with chemical fertilizers, then the efficiency of chemical fertilizer can be increased so that the crop can perform better (Vanilarasu and Balakrishnamurthy, 2014). Bio-fertilizers are being used to

enhance crop growth and quality of products. Bio-fertilizers are eco-friendly, easily available, cost effective. When bio-fertilizer is added to seed surfaces, plant surfaces or soil, it colonizes the rhizosphere or the plant interior and promotes growth and bioavailability by increasing the supply or availability of primary nutrients to the host plant. They produce phytohormones, enhance plant nutrients and thus help in sustainable crop production through maintenance of soil fertility and productivity. Therefore, emphasis is now being laid on the use of bio-fertilizers such as Azotobacter, Azospirillium and Phosphate soluble bacteria (PSB) in bio-fertilizers.

Some strains of microbes are reported as rhizobacteria that encourage plant growth (PGPR), which can be applied as bio-fertilizer inoculants. Among horticultural crops, the bio-fertilizers that are being used commercially are Azotobacter, Azospirillium, Phosphate soluble bacteria and *Vesicular-arbuscular mycorrhizal*. Azotobacter and Azospirillum are nitrogen fixing bacteria that help plants indirectly improve nitrogen fixation and nutrient availability in the soil. Phosphorus soluble bacteria are used to enhance the accessibility of phosphorus in the soil.

Considering the above benefits, the current study on the "**Effect of bio-fertilizers on the growth, flowering and yield of China aster (*Callistphus chinensis* L.)"** was conducted with the following objectives.

1. To study the effect of bio-fertilizers on the growth of China aster.
2. To study the effect of bio-fertilizers on flower yield and quality of China aster.
3. To derive the best assessment bio-fertilizers for these cultivar of China aster.

CHAPTER – II
REVIEW OF LITERATURE

There is an increasing need for the modification of the traditional processes of nutrient management, to result in higher nutrient concentration and also to reduce environmental pollution. The use of bio-fertilizers like Phosphate solubilizing bacteria (PSB) and Azotobacter along with inorganic fertilizers reduce the cost of production and supplement the secondary and micronutrients to the crops. The information on these bio-fertilizers in combination with inorganic fertilizers on China aster is limited. Hence, the research findings pertaining to these aspects on other crops like chrysanthemum, marigold, zinnia, gaillardia, jasmine, everlasting flower and other related horticultural crops have been reviewed and presented here under, on the following headings.

2.1 Vegetative growth parameters.

China aster

Kaloti (1998) reported that plant height and number of branches per plant significantly increased in treatment receiving Azotobacter + PSB with 75% N and 100% N in China aster.

Kumar *et al*. (2003) observed that application of half N,P + full K + VAM + PSB resulted in the maximum plant height (59.80 cm), maximum number of branches per plant (19.53), maximum number of leaves (277.0) and maximum leaf area (3531.75 cm^2) in China aster (*Callistephus chinensis* L.).

Nandre *et al*. (2005) observed that Azotobacter applied along with 75% N recorded maximum plant height (58.72 cm), stem girth (1.74 cm), number of branches per plant, number of leaves per plant (92.15) and leaf area per plant in China aster (*Callistephus chinensis* L.).

Mogal *et al*. (2006) observed that growth was best in China aster (*Callistephus chinensis* L.) plants receiving FYM at 20t per ha + Azotobacter and PSB at 3kg per h and nitrogen through urea.

Chaitra *et al*. (2007) observed that application of Azospirillum + PSB + FYM + 50% recommended dose of NPK resulted in the greatest plant height

(60.88 cm), number of leaves (103.81), No. of branches (25.08) in China aster.

Kumar and Singh (2007) observed that tallest plant (44.81 cm), highest number of leaves per plant (186.49) and number of branches per plant (9.33), were obtained with 10t. VC per hectare + 5 g VAM per plant in China aster cv. Shashank. The highest plant spread (51.65 cm) was obtained with 10 t. VC + 4 gm VAM per plant. The highest stem diameter (1.63 cm) was obtained with 5 t. VC per hectare + 5 g VAM per plant and 5 t. VC per hectare.

Kirar *et al.* (2009) recorded that Maximum height of plant, maximum stem diameter, maximum date of blooming and full blooming per harvesting of floral heads, maximum number of leaves were significantly increased with 75% NPK + VC + Azotobactor + PSB followed by under treatment 50% NPK + VC + Azotobactor + PSB.

Sharma *et al.* (2009) observed that integrated use of the recommended doses of NPK with VC and triple inoculation with Azotobacter + PSB + VAM give maximum growth of China aster.

Laishram *et al*. (2010) recorded that treatment of 22.5 g per m^2 each of NPK + VC (1kg per m^2) + bio-fertilizes (Azotobacter + PSB + VAM) produced the maximum plant height (81.47 cm), number of side shoots (4.80), length of side shoots (68.49 cm), stem length (58.19 cm) in China aster (*Callistephus chinensis* L.) cultivar Poornima.

Patil and Agasimani (2013) reported that significantly highest plant height (60.88 cm), maximum number of leaves per plant (103.81), higher leaf area (23.16 cm^2), number of primary branches per plant (22.23), maximum number of secondary branches (25.08) were recorded in treatment receiving Azospirillum + PSB + vermicompost + 50 % RDF.

Khanna *et al*. (2016) conducted their experiment and data showed that tallest plant (43.09 cm), maximum plant spread (20.06 cm), highest number of primary branches per plant (12.60), highest number of leaves (43.49) and maximum leaf area (54.63 cm^2) was observed from the plant receiving treatment containing FYM + Forest litter + PSB. From these studies, it could be inferred that combination of FYM (1.5 kg/m^2) + forest litter (1.5 kg/m^2) +

PSB (50 ml/15 L) were to be the best treatment combination for good growth and flowering attributes in China aster.

Pithiya *et al*. (2016) observed that significant variation in vegetative parameters like plant height (59.67 cm), plant spread (396 cm^2), number of primary branches (24.67 cm) were recorded with an application of 50% RDF (180:120:60 kg NPK/ha) + VC @1.5 t/ha + Azotobactor 3 l/ha + PSB @ 2 l/ha. In case of flowering and yield parameters, the variations were found significant.

Bhagat (2017) concluded that role of different treatment combinations was significant on growth. Among different treatments, 100% NPK + Azotobacter was found to be best followed by 100% NPK + PSB.

Singh *et al.* (2017) results revealed that maximum plant height, number of leaves per plant, flowering branches per plant , plant spread were recorded in plants receiving 75% NPK + Azotobacter + PSB at ambient conditions. Plants supplied with 100% NPK + Azotobacter + PSB were noticed with maximum leaf area.

Sowmya and Prasad (2017) result revealed that among the different treatments evaluated, performed better when compared to all other treatments with regard to plant height, the highest plant spread, maximum leaf area was noticed in plants received 100% NPK + Azospirillum + PSB.

Pratap (2018) concluded that treatment received 100% RDF + Azotobactor + PSB gave superior result with respect to plant height, number of branches, Number of leaves, plant spread, number of flowers per plant, weight of single flower, yield per plant, yield per plot, yield per hector.

Bohra *et al*. (2019) observed that maximum number of primary branches, plant spread, number of leaves per plant, from the treatment consisting of FYM @18 ton/ ha (50%) + VC @ 06 ton/ ha (50%)+ PSB @ (50 ml /15L) + Azotobacter @ (30ml/15L).

Krushnaiah *et al.* (2018) observed that highest plant height (64.25 cm), maximum plant spread E-W (34.30 cm), N-S (33.4 cm), maximum number of leaves per plant (198.06), had been recorded in the treatment received RDF 50% + RDF 50% through VC + Azotobactor + PSB). On the basis of results obtained in the investigation, it can be concluded that the application inorganic fertilizers, organic manures along with inoculation of Azospirillum and PSB results in higher flower yield in aster. As a result, the application of 50 percent RDF through inorganic + 50 percent via. VC + Azotobacter + PSB resulted in improved plant growth, flowering and yield.

Marak *et al.* (2020) observed that significant response of organic manures and bio-fertilizers on growth characters. Maximum plant height (63.97 cm) was associated with application of Azospirillum + PSB + VC + 50% RDF followed by Azospirillum + PSB + FYM + 50% RDF (60.33 cm) and PSB + VC + 50% RDF (50.57 cm). The highest plant spread (21.50 cm) was noticed with the application of Azospirillum + PSB + VC + 50% RDF followed by PSB + VC + 50% RDF (19.43 cm) and Azospirillum + VC + 50% RDF (17.83 cm). However, the plant spread with application of Azospirillum + PSB + VC + 50% RDF (21.50 cm) was on par with Azospirillum + PSB + FYM + 50% RDF (21.11 cm).

Marigold

Chandrikapure *et al*. (1999) reported that significantly greater height, in treatment with 100% N + Azotobacter + phosphate solubilizing bacteria and higher flower yield per hectare in treatment with Azotobacter + PSB + 75% compared to uninoculated of bio-fertilizers.

Gupta *et al*. (1999) observed that various combinations of Azotobacter, phosphorus solubilizing bacteria and nitrogen. Treatments were applied to the soil or to seedlings. In general, growth and flower yields were highest after treatment with Azotobacter + phosphorus solubilizing bacteria (applied to soil or seedling) in combination with 75 or 100% nitrogen application.

Rajadurai *et al*. (2000) observed that Application of NPK at 45:45:37.5 mg/kg along with combined inoculation of Azospirillum and VAM exhibited increased growth with respect to plant height (144.50 cm), number of leaves

(156.20) and laterals per plant (28.30). The plants treated with 45 mg N and 45 mg P/kg with combined inoculation of bio-fertilizers recorded a leaf area of 106.70, 55.70, and 96.70 cm^2 at 30, 60 and 90 days after planting, respectively.

Bhaskaran *et al*. (2002) studied that effect of Azotobacter and Azospirillum bio-fertilizers in marigold (*Tagetes erecta*) under different levels of chemical nitrogen. Both bacterial inoculants responded to all levels of chemical nitrogen with an increase in growth as compared to corresponding control. Azospirillum inoculation with low-level chemical nitrogen (50%) significantly increased growth attributes over control.

Gayathri *et al*. (2004) reported that increased plant height, number of leaves, highest number of branches and highest flower yield per plant were obtained with the application of 75% NP + 100% K + VC + Azotobacter + PSB.

Syamal *et al*. (2006) observed that Azotobacter 1.50 kg per hectare recorded maximum plant height, flower yield and number of seeds per flower whereas maximum fresh and dry weight of leaves were recorded in plants treated with 1.00 kg per hectare Azotobacter.

Pushkar *et al*. (2008) conducted that experiment and results revealed that soil application of VAM fungi @ 10 kg per hectare was found to most effective to obtain better growth, floral characters and flower yield of African marigold.

Mittal *et al*. (2010) conducted that experiment with comprised of three bio-fertilizers (Azotobacter, Azospirillum and PSB) three levels of VC (2.0, 3.0 and 4.0 t ha^{-1}) and three levels of NPK (60, 70 and 80% of RDF) including control (RDF). The results revealed that application of 70% RDF + 3 t/ha VC + Azotobacter + Azospirillum + PSB produced significantly maximum plant height, number of branches per plant, plant spread in N-S and E-W directions, as compared to control.

Kumari *et al.* (2013) studied that bio-fertilizers and their application in flower crops. Bio-fertilizers are ready to use live formulates of such beneficial microorganisms which on application to seeds, seedlings or soil, mobilize the availability of nutrients particularly by their biological activity and help to build up the micro-flora and in turn improve the soil health. They are eco-friendly

and play significant role in crop production. Earlier, it is mainly used for field crops but nowadays it is used for flower crops also. Various bio-fertilizers *viz.* Azotobacter, Azospirillum, phosphorus solubilizing bacteria and VAM fungi show their suitability for application in different flower crops such as rose, tuberose, carnation, marigold, aster, jasmine, etc. Bio-fertilizers are able to fix 20-200 kg N/ha/year, solubilize P in the range of 30-50 kg/ha/year and mobilize P, Zn, Fe and Mo to varying extent. These not only help in improving the nutrient uptake by the plants, releasing of growth hormones and antibiotics but also improve the quality of produce along with reduced cost of production. To maximize the beneficial plant growth response, it is essential to identify the best strains of microorganisms, verify their compatibility and combined efficiency before using them in crop production system as a potential candidate for sustainable systems.

Kumar *et al.* (2013) showed that treatment (80% R.D. of NPK (96 kg N, 80 kg P and 80 kg K/ha) + VC (128 q/ha) + Azotobacter (5.28 kg/ha)) was better response to plant growth.

Thumar *et al*. (2013) observed that African marigold (*Tagetes erecta* L.) cv. Pusa Narangi in which 70% RDF + 2t ha^{-1} VC + Azotobacter + Azospirillium + PSB significantly improved growth parameters *viz.*, plant height at full bloom stage (115.45 cm), and number of primary branches per plant at full bloom stage (28.06).

Kumar *et al*. (2017) reported that application of bio-fertilizers and nutrients had left significant response on growth and yield of marigold. Azotobacter + PSB + 75% NPK have resulted maximum plant height, plant spread and number of branches was recorded with the application of Azotobacter + PSB + 75% NPK.

Patel *et al*. (2017) observed that (FYM @ 5 t/ha + 100% RDF (150:100:100 kg NPK/ ha) + Azotobacter + PSB + KMB + 1% foliar spray) showed the maximum plant height and plant spread were observed during 4^{th} month after transplanting.

Sharma *et al.* (2017) showed that integrated use of the recommended doses of NPK with VC and triple inoculation with Azotobacter + PSB + VAM gave maximum growth of African marigold.

Chrysanthemum

Verma *et al.* (2011) reported that treatment comprising Azospirillium, PSB, VC and 50 per cent recommended dose of NPK recorded the highest plant height, number of branches, plant spread, and yield attributes such as number of flowers per plant.

Pandey *et al.* (2010) carried out a study to ascertain the influence of bio-inoculant (Azotobacter and VAM) and vermicompost with different levels of nitrogen, phosphorus and potassium (100%, 75% and 50%) on growth and flowering of chrysanthemum cultivars 'Prof. Harris' and 'Sunil' and results reveal that Cultivar Prof. Harris performed significantly better over cv. Sunil for leaf count, number of lateral shoots, and plant spread. However, plant height, leaf area and flowering duration were maximum in cv. Sunil. Application of 75% recommended dose of fertilizer and vermicompost coupled with dual inoculation of Azotobacter and VAM produced significantly tall plants, higher number of lateral shoots, greater plant spread. Leaf count was maximum with application of 75% dose of N + Azotobacter + VAM + full P and K while, significantly higher leaf area was observed when crop was fertilized with 75% dose of N and P + Azotobacter + VAM + full K compared with 100% recommended dose of fertilizer and other treatment under investigation.

Panchal *et al*. (2010) reported that application of 175 Kg N per hectare + Azospirillum + Azotobacter produced maximum plant height (96.23 cm), number of branches per plant (50.59), plant spread (79.08 cm in north - south direction and 78.79 cm in east - west direction), relative growth rate (0.032 g per day), leaf area index (21.32cm^2) and harvest index (4.32%) in chrysanthemum**.**

Calendula

Mostafa (2002) conducted that experiment on Calendula cv. Muraj and Decklonis and found that bio-fertilizers increased leaf area of cultivar Muraj while plant height and inflorescence diameter of Decklonis.

Shashidhara *et al.* (2002) reported that effects of bio-inoculants (Azotobacter at 200 g/ha and VAM at 15.6 g/plant) with different levels (100, 75, and 50%) of nitrogen and phosphorus. Significantly tall statured plants

(19.60 cm) and high number of branches (8.87/plant) were recorded with the application of 135:90:60 kg N, P_2O_5 and K_2O/ha.

Singh *et al*. (2008) observed that application of Azotobacter + phosphate solubilizing bacteria (PSB) + 75% N/ha was found better with respect to plant growth.

Dahlia

Sheergojri *et al.* (2013) evaluated that effect of three nitrogen levels (50, 75 and 100 kg ha), two phosphorus levels (100 and 125 kg ha) and three bio-fertilizers (*Bacillus sp., Pseudomonas sp.* and *Azotobacter sp.*) and results revealed that Azotobacter proved superior in improving plant height, length of primary branches per plant. The application of bio-fertilizer along with 75 kg nitrogen / ha + 100 kg phosphorus/ha + Azotobacter. Reported maximum plant height (77.98 cm), number of primary branches plant (10.53), length of primary branches (58.55 cm) and leaf area (88.33 cm^2).

Gaillardia

Deshmukh *et al*. (2008) observed that significantly maximum vegetative growth *viz*., plant height, plant spread, diameter of main stem, 50 percent flowering, diameter of flower, length of flower stalks, number of flowers and yield of flowers per plant and per ha was increased in treatment 75% NPK + seedling inoculation with Azotobacter (500 g) + PSB (500 g) per liter of water in gaillardia.

Anthurium

Srinivasa (2006) results revealed that combined application of Azospirillum along with the split application of NPK at 30:20:40 g/m^2 per year resulted in producing the maximum plant height (38.38 cm), number of leaves (8.69). The one time application of NPK at 30:20:40 g/m^2 per year showed minimum plant height, number of leaves, leaf length and width, canopy height and width, number of suckers.

Tuberose

Yadav *et al.* (2005) reported that effect of N (0, 10, 20 and 30 g/m^2), plant spacing (20x20, 20x25 and 20x30 cm) and bio-fertilizers (Azotobacter, PSB and Azospirillum) on different growth parameters in tuberose. The growth parameters, i.e. plant height, number of leaves per plant, leaf length and area of leaf, significantly increased with increasing N levels, plant spacing and with different bio-fertilizers except plant height, which decreased with increasing plant spacing. Application of 200 kg N/ha at 20x30 cm was observed optimum for the different growth parameters. Among the different bio-fertilizers, Azotobacter was more effective in increasing the different growth parameters.

Kukde *et al*. (2006) observed that tuberose bulbs treated with Azotobacter and PSB at 2.5 g kg^{-1} bulb gave maximum vegetative growth followed by application of vermicompost @ 10 t ha^{-1}.

Chaudhary (2007) observed that Application of bio-fertilizers in combination with N at the rate of 100 Kg per hectare and P at the rate of 50 Kg per hectare proved to be equally effective to N at the rate of 200 Kg/ha and P at the rate of 100 Kg/ha in increasing the plant height, number of leaves per plant and number of bulbs/plant. The higher dose of N and P independently did not affect the growth in tuberose.

Kashyap *et al*. (2014) reported that growth parameters (plant height, number of leaves per plant and days taken for emergence of bulbs) increased significantly with the increasing levels of chemical fertilizers along with the bio-fertilizer applications. Chemical fertilizers N, P and K application @ 15, 11.2 and 9.3 g/m^2 respectively along with the bio-fertilizer was optimum for the growth parameters.

Gladiolus

Kumari *et al*. (2013) observed that application of bio-fertilizer along with NPK fertilizers with VC have shown significantly superior result in both Kharif and Rabi seasons. Cormal parameters such as number of corms/plants, weight of corms, number of cormels, cormel weight, was maximum in VAM + Azospirillum + Trichoderma with 75% RDF and VC treatment in both Kharif and Rabi seasons.

Abdou and Ibrahim (2016) observed that during the two successive seasons of 2013/2014 and 2014/2015, the effect of NPK (0, 50, 75 and 100% of recommended dose) and bio-fertilization (phosphorein and/or E.M.) treatments on growth and flowering of *Gladiolus grandiflorus* cv. White Prosperity. It was found that the use of NPK (75% from the recommended dose) plus phosphorein + E.M. improved the growth and flower production of gladiolus plants compared with the other treatments.

Kumar *et al*. (2016) conducted an experiment and result show that treatment P_2B_2 (Gibberellic acid @ 200 ppm at 60 DAT + Azotobacter @ 0.14ml./m^2 soil application) shown the best result with respect of the appearance of initial spike, width of leaf and diameter of florets were found in P_2 B_1 (Gibberellic acid @ 200 ppm at 60 DAT +Azotobacter @ 0.14ml/liter water (corm treatment) except number of days for corm sprouting and number of leaves per plant.

Baruati *et al*. (2018) observed that maximum growth parameters and the highest yield and yield attributes of gladiolus could be achieved by judicious application of organic manures and bio-fertilizers.

Pansuriya *et al*. (2018) conducted the experiment and results indicated that application of humic acid 0.2% with Azotobacter @ 2.5 ml/plant + PSB @ 2.5 ml/plant + KSB @ 2.5 ml/plant at first spray at 30 DAT, second spray at 45 DAT and third spray at 60 DAT of bio-stimulants and soil application of bio-fertilizers at the time of planting and two month after planting gave higher vegetative growth, parameters in gladiolus.

2.2 Flowering and flower yield

China aster

Kulkarni (1990) observed that application of 75 kg N/ha along with Azotobacter and Azospirillum help in increasing the flower yield of aster.

Mogal *et al*. (2006) reported that best growth in China aster plants received with FYM at 20t. per hectare, Azotobacter and PSB at 3 kg per hectare with 100% nitrogen through urea. The flower quality and vase life were most superior in the plants received with VC, Azotobacter, PSB and 100 percent nitrogen.

Chaitra *et al*. (2007) observed that application of Azospirillum + PSB + vermicompost + 50% recommended N.P.K. resulted in the maximum number of flowers per plant (40.60) and flower yield (11.71t/ha) in china aster.

Thumar *et al*. (2013) reported that 60% RDF+3 t ha^{-1} VC + Azotobacter + Azospirillium + PSB significantly improved flowering parameters *viz*., the shortest number of days taken to first flower opening (53.72 days) and number of pickings (9.12) and the shortest number of days taken for 50% flowering (59.50 days). The maximum diameter of flower (7.30 cm) was recorded with treatment 70% RDF+2 t ha^{-1} VC + Azotobacter + Azospirillium + PSB.

Marak *et al.* (2020) observed that highest flower stalk length (34.00 cm) was noticed with Azospirillum + PSB + VC + 50% RDF (32.20 cm) which was on par with Azospirillum + PSB + 50% RD 'N' and 'P' + 100% RD 'K' (31.50 cm) and Azospirillum + PSB + FYM + 50% RDF (31.51 cm). The lowest flower stalk length was observed in control (27.99 cm). The maximum flower diameter (46.18 cm) was associated with Azospirillum + PSB + VC + 50% RDF (46.18 mm) which was on par with, Azospirillum + PSB + FYM + 50% RDF (46.14 mm) and Azospirillum + PSB + 50% RD 'N' and 'P' + 100% RD 'K' (45.91 mm) Whereas, minimum flower diameter was noticed under control (17.79 cm). The beneficial effect on earliness in flower bud initiation, improving flower stalk length, large sized flower and number of flower buds.

Marigold

Gupta *et al*. (1999) recorded that growth and flower yields were highest with Azotobacter + PSB in combination of 75% to 100% nitrogen in marigold (*Tagetes erecta* L.)

Benjamin and Singh (2003) reported that application of bio-fertilizers in different combinations was found better than single application in marigold.

Shubha (2006) observed that flower bud initiation, flowering duration, flower yield per plant and xanthophyll yield highest plant height, number of leaves, number of branches were obtained with the application of Azospirillum + VC + 75 percent recommended dose of nitrogen and phosphorus in African marigold.

Kumar *et al*. (2006) observed that application of different bio-fertilizers (Azospirillum, Azoctobacter and PSB) in combination with FYM and nutrient content of marigold cv. Pusa Narangi. Yield parameters of plant such as size of flowers, average weight of flowers, fresh weight of flowers per plant (flower yield) and dry weight of flowers per plant were recorded.

Kumar *et al*. (2009) observed that application of Azotobacter + PSB +FYM @ 30 t. per hectare + N @100 kg per hectare and P @ 50 kg per hectare was found to be best for growth, flowering behaviour and yield of cv. African Giant double orange.

Mittal *et al*. (2010) conducted that experiment and results revealed that application of 70% RDF + 3 t/ha vermicompost + Azotobacter + Azospirillum + PSB produced significantly maximum average flower weight, number of flowers per plant, flower yield per plant (g) and flower yield per hectare as compared to control.

Kumar *et al.* (2013) observed that (80% R.D. of NPK (96 kg N, 80 kg P and 80 kg K/ha) + VC (128 q/ha) + Azotobacter (5.28 kg/ha)) showed better response to flowering and yield attributes.

Gladiolus

Dalve *et al.* (2008) conducted that experiment entitled “Effect of bio-fertilizers with reduced doses of nitrogen on growth and flowering of gladiolus” and results revealed that use of bio-fertilizers with reduced doses of nitrogen significantly influenced the vegetative growth and flowering of gladiolus. It was maximum under reduced dose of nitrogenous fertilizer in combination of bio-fertilizers 75%N+ 100% PK ha^{-1} + Azotobacter + Azospirillum and it was found at par with 100% NPK ha-1 + Azotobacter + Azospirillum.

Ali *et al*. (2013) conducted the experiment and results shown that all the reproductive growth accomplished successfully by application of bio-fertilizers. However, the treatment that contain Azospirillum gained highest plant height, spike length, florets, fresh weight and earlier sprouting compare to other treatments.

Pansuriya and Chauhan *et al*. (2015) reported that Application of (FYM @ 20 t/ha + Azotobacter @ 4 kg/ha + PSB @ 4 kg/ha) was yield characters

maximum number of spikes per plant, number of spikes per square meter, length of floret rachis, longevity of spike.

Adhikari *et al*. (2018) observed that treatment 50% RDF + 50% FYM + Azotobacter @ 25 g L^{-1} + *Trichoderma harzianum* @ 20 g m^{-2}. The results also showed that earliness in spike emergence and first floret opening.

Meena *et al*. (2018) showed that application of RDF 75% + Azotobacter + PSB + Mycorrhiza was effective in enhancing vegetative growth and quality of gladiolus.

Rose

Choudhury *et al.* (2009) conducted that experiment and result revealed that application of 50 g N per plant + Azotobacter and Azospirillum each @ 1ml per plant. Produced maximum diameter of flower, number of petals, weight of individual flower, shelf life and yield of flowers as compare to control. The treatment of 25 g N per plant Azotobacter and Azospirillum each @ 1ml per plant produced earliest initiation of first flower bud than control in rose (*Rosa damascena* L.).

Tuberose

Wange and Patil (1994) found that 100kg N per hectare alone or inoculating with Azotobactor + Azospirillum mixtures increased the number of flowers per stalk, bulb yield (rhizome) and number of flowers per stem produced in *Polianthes tuberosa* cv. Single.

Wange *et al*. (1995) observed that cut flower yield were highest with 150 kg N/ha and inoculating with Azospirillum (26.288 dozen per ha) compared with the untreated control (15.871 dozen per ha) in *Polianthes tuberosa* cv. Single.

Munikrishnappa *et al*. (2004) observed that application of 50 percent of recommended dose of fertilizer (RDF) along with vermicompost at 5 tonnes per hectare had improved the flower characters *viz.*, spike length, rachis length, floret diameter, number of florets per spike and flower yield in tuberose (*Polianthes tuberosa* L.).

Kukde *et al*. (2006) studied that effect of organic manures and bio-fertilizers on growth, flowering and yield of tuberose cv. Single and results

revealed that tuberose bulbs treated with Azotobacter and PSB at 2.5 g kg^{-1} bulb gave early opening of first pair of florets, better flower quality, fresh weight of bulb plant and maximum yield of flowers ha^{-1} followed by application of vermicompost @ 10 t ha^{-1}.

Chaudhary (2007) evaluated that combine effect of nitrogen, phosphorus and bio-fertilizers on plant growth and bulb production in tuberose. Treatments comprised of N (0, 50, 100 and 200 Kg/ha) and P (0, 25, 50 and 100 Kg/ha) in combination with bio-fertilizers (no bio-fertilizer, Azotobacter, PSB and VAM). Application of bio-fertilizers with N 100 Kg per ha hectare and P 50 Kg per hectare proved to be equally effective to N 200 Kg/ha and P 100 Kg/ha in increasing the number of bulbs per plant and advancing the sprouting of bulbs. The higher dose of N and P independently did not affect the growth, sprouting of bulbs, and bulb production in tuberose.

Koley *et al*. (2010) observed that highest number of florets/ spike and weight of individual spike were obtained with NPK @ 10:4:10 + Azotobacter in tuberose cv. Prajwal.

Jasmine

Bhavanishankar and Vanangamudi (1999) reported that combined application of 75 percent recommended N as neem cake blended urea + Azospirillum recorded the highest flower yield in *Jasminum sambac* (1.560, 1.739 and 1.779 kg per plant, respectively in 1, 2 and 3 years after fertilizer application) 1 and 2 years after fertilizer application (1.445 and 1.607 kg per plant, respectively).

Jayamma *et al*. (2008) observed that bio-fertilizes application could substitute for the recommended NPK fertilizers to the extent of 50% without affecting various floral characteristics and flower yield in jasmine (*Jasminum sambac).*

CHAPTER- lll
MATERIAL AND METHODS

A field experiment **"Effect of bio-fertilizers on growth, flowering and yield of China aster (*Callistephus chinensis L.*)."** was carried out at Bahadari research farm, K.N.K. College of Horticulture, Mandsaur, (M.P.) during the period of November 2020 to April 2021. The details of the materials and methods pertaining to the present experiment are furnished in this chapter.

3.1 Experimental Site:

The present investigation was carried out during the period of November 2020 to April 2021 at Bahadari farm, K.N.K. College of Horticulture, Mandsaur (M.P.). Mandsaur is situated in Malwa plateau in western part of M.P. at north latitude of 23.45^{o} to 14.13^{o} and 74.44^{o} to 75.18^{o} East longitude and altitude at 435.02 meters above sea levels. This region falls under agro climate zone no.11 of the state.

3.2 Climate of the region:

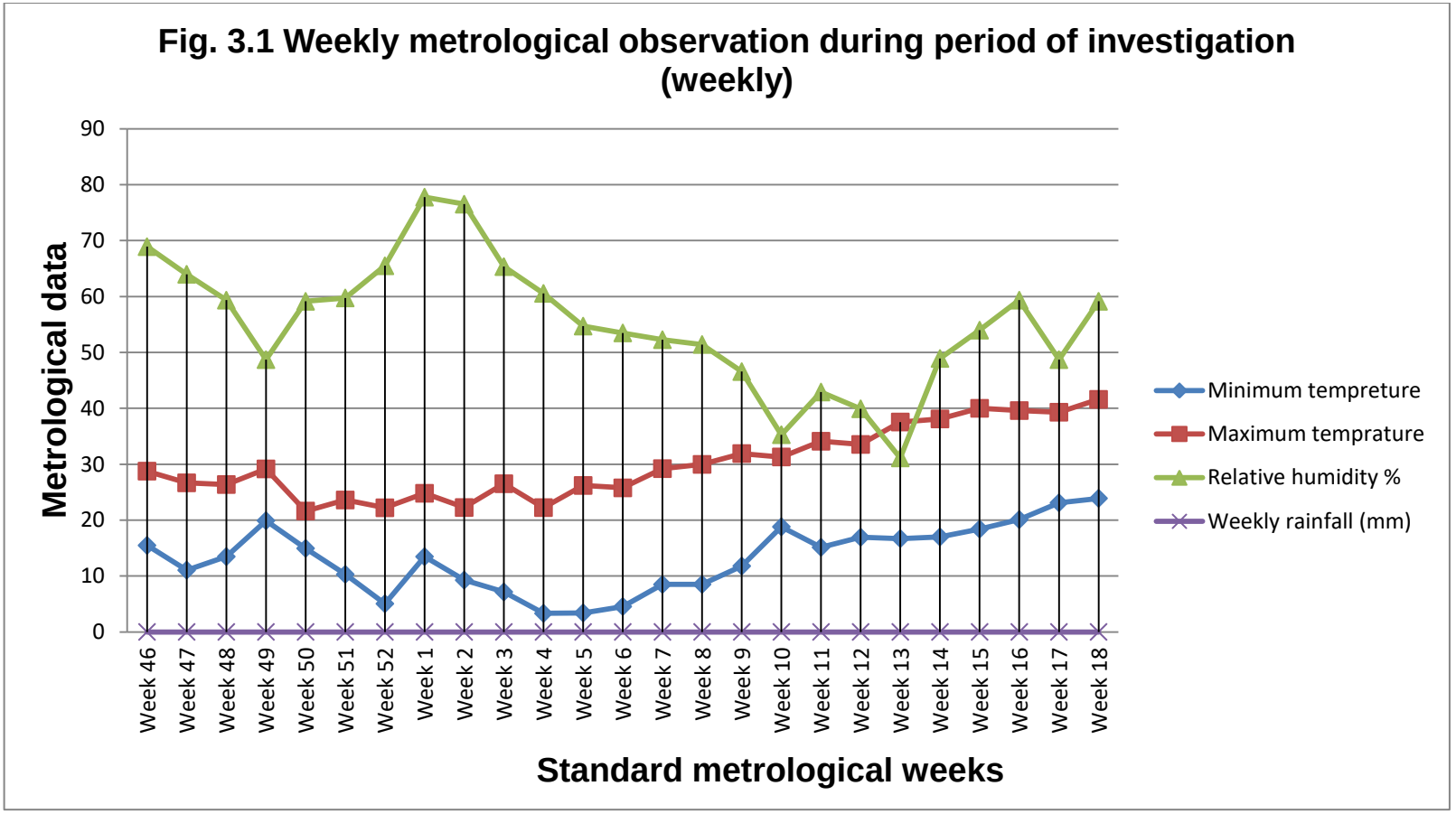
Mandsaur belongs to sub-tropical climate having a mean temperature range of minimum 5^{0}C and maximum 44^{0}C in winter and summer, respectively. In this area, most of the rainfall is received during mid-June to early-October with occasional showers in winter. South-west monsoon is responsible for major part of annual precipitation. The average annual rainfall is 714.8 mm. Meteorological data recorded during the period of investigation are presented in (table 3.1) and are graphically shown in (Fig. 3.1)

Table 3.1: Weekly meteorological data was recorded during the study period (November 2020 - April 2021)

Standards weeks	Duration	Average weekly Temperature (^{0}C)		Relative Humidity (%)	Weekly Rainfall (mm)
		Max. (^{0}C)	Min. (^{0}C)		
Week 46	12/11/20 to 18/11/20	28.76	15.48	68.92	0.0
Week 47	19/11/20 to 25/11/20	26.67	11.05	63.98	0.0
Week 48	26/11/20 to 02/12/20	26.37	13.48	59.35	0.0
Week 49	03/12/20 to 09/12/20	29.16	19.9	48.71	0.0
Week 50	10/12/20 to 16/12/20	21.62	14.95	59.14	0.0
Week 51	17/12/20 to 23/12/20	23.6	10.3	59.75	0.0
Week 52	22/12/20 to 31/12/20	22.21	5.05	65.5	0.0
Week 1	01/01/21 to 07/01/21	24.8	13.47	77.78	0.0
Week 2	08/01/21 to 14/01/21	22.25	9.27	76.52	0.0
Week 3	15/01/21 to 21/01/21	26.51	7.15	65.35	0.0
Week 4	22/01/21 to 28/01/21	22.24	3.32	60.56	0.0
Week 5	29/01/21 to 04/02/21	26.2	3.4	54.71	0.0
Week 6	05/02/21 to 11/02/21	25.77	4.55	53.49	0.0
Week 7	12/02/21 to 18/02/21	29.21	8.49	52.28	0.0
Week 8	19/02/21 to 25/02/21	29.97	8.51	51.42	0.0
Week 9	26/02/21 to 04/03/21	31.91	11.79	46.57	0.0
Week 10	05/03/21 to 11/03/21	31.30	18.81	35.28	0.0
Week 11	12/03/21 to 18/0321	34.11	15.14	42.92	0.0
Week 12	19/03/21 to 25/03/21	33.54	16.94	39.92	0.0
Week 13	26/03/21 to 01/04/21	37.55	16.70	31.13	0.0
Week 14	02/04/21 to 08/04/21	38.1	17.0	48.92	0.0
Week 15	09/04/21 to 15/04/21	40.0	18.4	53.98	0.0
Week 16	16/04/21 to 22/04/21	39.6	20.1	59.35	0.0
Week 17	23/04/21 to 29/04/21	39.3	23.1	48.71	0.0
Week 18	30/04/21 to 06/05/21	41.6	23.9	59.14	0.0

Source: Meteorological observatory, K.N.K. College of Horticulture, Mandsaur (M.P.)

Fig. 3.1 Weekly metrological observation during period of investigation (weekly)



3.3 Soil Characteristics of the Experimental Site

To ascertain physico-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.

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

Particulars	Value obtained	Method
Physical characters		
Sand%	47%	By international Pipette method (Piper,1950)
Silt%	24%	
Clay%	29%	
Chemical characters		
Soil pH	7.8	Method No. 4 USDA handbook No. 60 (Richards, 1954)
Electrical Conductivity (dsm-1)	0.23	EC Meter
Available Nitrogen (kg N ha^{-1})	214	Alkaline $KMnO_4$ (Subbiah & asija, 1956)
Available phosphorus (kg P_2O_5 ha^{-1})	20.5	Olsen extraction method (Olsen *et al.* 1954)
Available potash (kg K_2O ha^{-1})	241	Flame photometer method (Metson, 1956)

Table 3.3: Experimental Details

Particulars	**Details**
Location	K.N.K. College of Horticulture, Mandsaur (M.P.)
Name of crop	China aster (*Callistephus chinensis* L.)
Name of cultivar	Local
Season	Rabi season 2020-21
Experimental design	RBD (Randomized Block Design)
Number of treatments	10
Number of replication	3
Total number of plot	30
Number of plant per plot	36
Number of plant selected for study	05 per plot
Total number of plant	1080
Planting distance	30 × 30 cm (row to row x plant to plant)
Net plot size	3.24 m^2
Total experimental area	22.5 × 7.4 = 166 m^2
Distance between replication	01 meter
Distance Between Plot	0.5 meter
Date of nursery raising	10^{th} November, 2020
Date of transplanting	25^{th} December, 2020

3.4: Details of layout

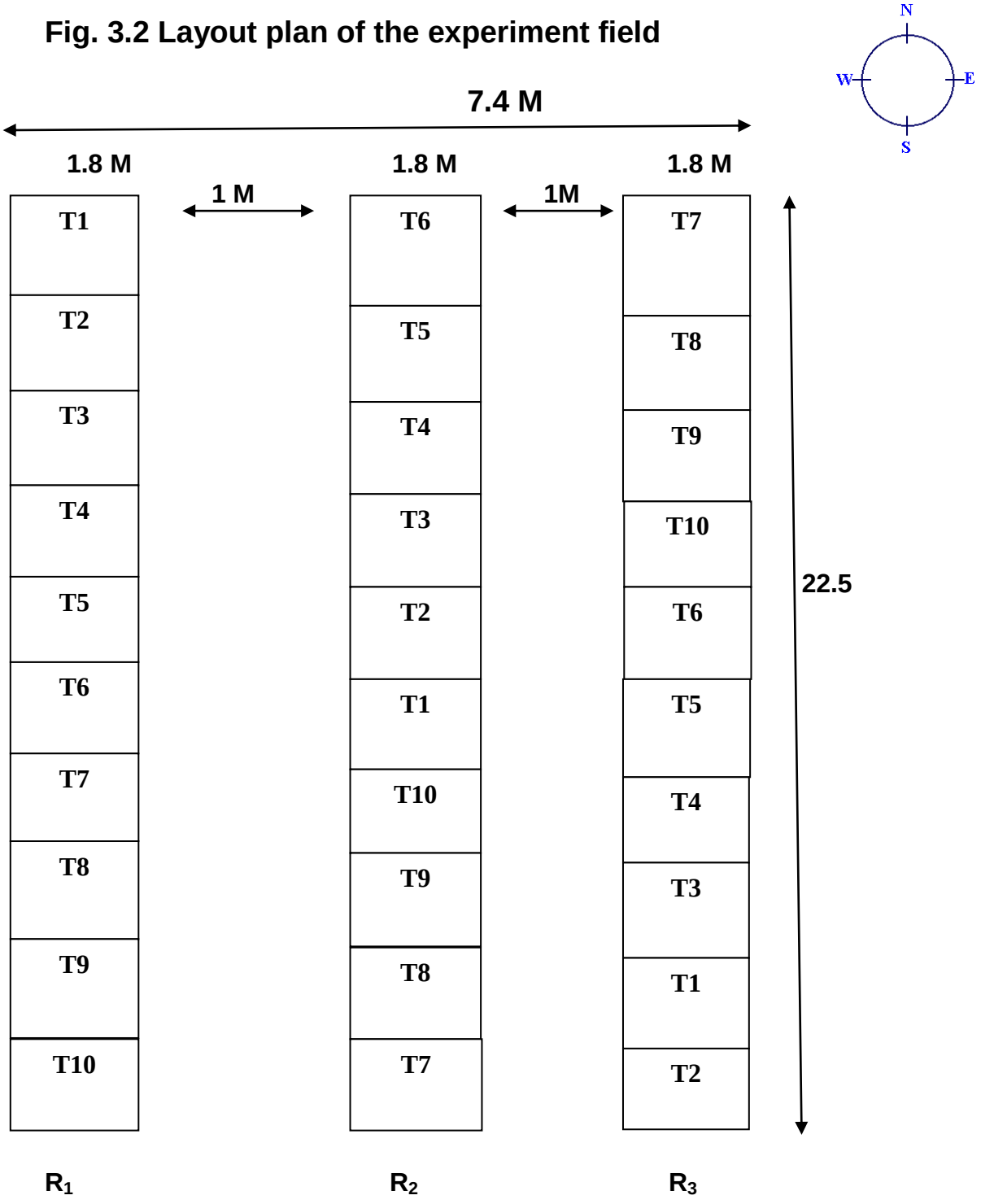
The experiment was laid out in Randomized Block Design (RBD) with different dose of RDF & Bio-fertilizers replicated three times.

Symbols	**Treatments**
T_1	RDF (N: P: K:-180:120:60)
T_2	RDF + Azotobacter
T_3	RDF + PSB
T_4	RDF + Azotobacter + PSB
T_5	85% RDF + Azotobacter
T_6	85% RDF + PSB
T_7	85% RDF + Azotobactor + PSB
T_8	75% RDF + Azotobacter
T_9	75% RDF + PSB
T_{10}	75% RDF + Azotobacter + PSB

Note: RDF – Recommended dose of fertilizer

PSB – Phosphorus solubilizing bacteria

Fig. 3.2 Layout plan of the experiment field



Design: Randomized block design

Plot size: 1.8x1.8 = 3.24 m^2

Distance between plots: 0.5 m

Distance between replication: 1 m

3.4: Agronomical operations:

3.4.1 Nursery raising:

The beds were dug and prepared thoroughly for sowing the seeds of China aster. The soil was well tilled and thoroughly pulverized. Stones, brick pieces, clods and weeds were removed. The seeds were sown in line and covered with a fine mixture of soil and FYM on 12th November, 2020.

First irrigation was given by means of water can immediately after sowing. Subsequently irrigations were done at regular intervals of 6-7 days. Every possible care was taken to get healthy plants of uniform size.

3.4.2 Field preparation:

The experimental area was ploughed twice with the help of tractor drawn implements in both directions and harrowing was done to break the clods and leveling was done.

3.4.3 Layout:

The experimental area was finally leveled and divided into replications, channels, block borders and bunds. The plan of layout as shown in Fig.3.2 was executed on 22th December, 2020.

3.4.4 Manures and fertilizers:

After executing the plan of layout, the calculated quantities of fertilizers were applied to the respective plots marked for giving the nutrient treatments mentioned. The sources of nitrogen, phosphorus and potash were urea (46% N), single super phosphate (16% P_2O_5) and muriate of potash (60% K_2O) respectively. The half dose of nitrogen with full doses of P_2O_5 and K_2O were applied as basal, at the time of transplanting. The remaining dose of N was top dressed at 30 days of transplanting (DAT).

Bio-fertilizers (Azotobacter 5 kg/ha and Phosphorus solubilizing bacteria 5 kg/ha) were applied in furrows just before transplanting of the seedlings as per treatment and thoroughly mixed in soil.

3.4.5 Transplanting:

The 45 days old uniform healthy seedling of local verity was transplanted at a distance of 30 x 30 cm singly in experimental plots on 25th

December, 2020. The operation of transplanting was carried out in evening and followed by a light irrigation with a view to encourage the establishment of seedlings.

3.4.6 Gap filling:

Those seedlings, which died within the first eight days of transplanting, were replaced by new ones to maintain uniform crop stand in all the plots.

3.4.7 Irrigation:

Crop was irrigated periodically. In the initial stage, the irrigation was given at 7 days interval and after one month it was given at 10-12 days interval for maintaining optimum soil moisture.

3.4.8 Weeding and hoeing:

In order to keep the field weed free, hand weeding was done periodically*. Cyperus rotundus, Cyperus iria, Convolvulus arvensis, Cynodon dactylon, Euphorbia heterophylla*, was the major weed. Weeding and hoeing were done manually with the help of hand hoe by digging the plots because of deep roots of this weed. Earthing up was done as and when required to support plants.

3.4.9 Pinching:

Pinching was done after 40 days of transplanting to encourage the emergence of lateral branches.

3.4.10 Plant protection measures:

Spraying of insecticides and fungicides was done as and when required to protect the crop from pests and diseases. Systemic insecticides metasystox and Rogor (@ 2 ml/litre of water) were separately sprayed twice to control the attack of red pumpkin beetle, aphids, thrips and mites. Bavistin @ 0.1% was sprayed as a prophylactic measure against control of blight and leaf spot.

Plate 1:- A view of experimental layout

Table 3.5 Schedule of operations carried out in course of investigation:

Operation	**Date**
Seed sowing	10.11.2020
Field operations	
(a) Ploughing	11.12.2020
(b) Harrowing	16.12.2020
Soil sample collection for physico-chemical studies of the soil before transplanting	17.12.2020
Layout	22.12.2020
Application of basal dose of Urea (50%) S.S.P. and M.O.P. (100%)	24.12.2020
Transplanting of seedlings	25.12.2020
Gap filling	04.01.2021
Application of first dose of nitrogen	25.01.2021
Pinching	03.02.2021
Irrigation	
(a) First	25.12.2020
(b) Second	10.01.2021
(c) Third	21.01.2021
(d) Fourth	01.02.2021
(e) Fifth	12.02.2021
(f) Sixth	24.02.2021
(g) Seventh	05.03.2021
(h) Eighth	14.03.2021
(I) Ninth	20.03.2021
(j) Ten	27.03.2021
(k) Eleven	04.04.2021
(l) Twelve	14.04.2021
(a) Weeding and hoeing I	15.01.2021
(b) Weeding and hoeing II	01.02.2021
(c) Weeding and hoeing III	02.03.2021
Plant protection	
(a) Insecticide and fungicides spray I	10.01.2021
(b) Insecticide and fungicides spray II	15.02.2021

3.5: Observations recorded:

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 all characters given below were recorded on these plants

3.5.1: Growth Parameter:

3.5.1.1: Plant height (cm):

The height of the tagged plant was measured from ground level to the growing tip of the plant and the height was recorded at 60 and 90 days after transplanting. Height was measured with the help of meter scale in cm.

3.5.1.2: Number of leaves/plant:

Number of leaves of the tagged plant was counted from each plot at 60 and 90 days after transplanting and the mean was also determined.

3.5.1.3: Leaf area (cm):

The leaf area of the tagged plant was counted from each plot at 60 and 90 days after transplanting by using the graph paper. Here a leaf is taken and traced over graph paper, and the grids covered by the leaf are counted to give the area.

3.5.1.4: Plant spread (cm):

Plant spread was calculated by measuring the spread of foliage in East-West and North-South direction at 60 and 90 DAT with the help of meter scale in cm and average was determined.

3.5.1.5: No. of branches/plant:

Number of branches per plant was counted at 60 and 90 days after transplanting and average was determined.

3.5.1.6: Stem diameter:

Diameter of the stem was measured at 60 and 90 days after transplanting. This was measured by using vernier calipers and average diameter in mm was computed.

3.5.2 Flowering Parameter:

3.5.2.1: Days taken to 1st flower bud initiation:

In this observation number of days taken for flower bud initiation was counted from the date of transplanting of seedling to the first pea stage flower bud initiation on the plant.

3.5.2.2: Days taken to opening of flower from bud emergence:

In this observation days taken to opening of flower from bud emergence was counted from the first pea stage flower bud formation on the plant to the opening of flower.

3.5.2.3: Blooming period (days):

Blooming period was counted from initiation of first flower on the plant to the last flower on the plant.

3.5.3 Quality Parameter:

3.5.3.1: Flower stalks length (cm):

The length of the flower stalk was taken from the origin of that stalk from the main stem to the neck of the flower and expressed in centimeter. With the help of meter scale and average length in centimeter was computed.

3.5.3.2: Flower diameter (cm):

The diameter (cm) of five flowers per plot in each treatment was measured and the average was calculated.

3.5.3.3: Weight of flower (g):

Flower weight in each of the randomly selected plants was measured in grams with the help of physical balance and mean value was taken as flower weight.

3.5.4. Biochemical parameter:

3.5.4.1: Chlorophyll content in leaves:

Chlorophyll content in each of the randomly selected plant was measured in the help of hand electrical SPAD (PLUS 502) chlorophyll meter.

3.5.5 Yield Parameter:

3.5.5.1: No. of flower / plant:

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

3.5.5.2: Flower yield / plant:

At each plucking, weight of harvested flowers was recorded and summation was done at the end of the season.

3.5.5.3: Flower yield / plot:

Flower yield per plot was calculated on the basis of fresh weight of flower per plant from each experimental plot.

3.6: Statistical Analysis

The data obtained from present experiment were subjected to "Analysis of Variance" as advocated by Panse and Sukhatme (1984). The Skeleton of ANOVA as per design is as follows:

Table 3.6 Skeleton of analysis of variance

Source of variation	Df	SS	MSS	"F" value Calculated	"F" Table Value at 5%
Replication	(r-1)	RSS	RMS	RMS/EMS	
Treatment	(t-1)	TSS	TMS	TMS/EMS	
Error	(r-1) (t-1)	ESS	EMS		
Total	(rt-1)	TSS			

The critical difference (C.D.) was calculated to assess the significance of difference between treatments, whenever the results were found significant through 'F' test, CD at 5 % level of significance was determined. S.Em. and CD are calculated using the following formula.

The standard error of the mean (SEm±) was calculated by using following expression:

$SEm (\pm) = \sqrt{MSE/r}$

The critical difference to test the difference between two mean values was calculated as follows:

CD (P=0.05) = S.Em ± $x\sqrt{2}$ x t value at 5% level of significance at error df

Where,

r = Number of replications

t = Number of treatments

DF = Degrees of freedom

SS = Sum of square

MSS = Mean sum of square

SSR = Sum of square due to replication

EMS = Error mean sum of squares

CD = Critical difference

$t_{5\%}$ = Table value at error degree of freedom

S.Em. ± = Standard error of mean

Fig. Nursery stage

Fig. After Transplanting

Fig. Vegetative growth stage

Fig. Bud initiation stage

Fig. Full blooming stage

Plate2:- A view of different growth stage

CHAPTER- IV
RESULTS

The results of the field experiment entitled **"Effect of bio-fertilizers on growth, flowering and yield of China aster (*Callistephus chinensis* L.) "** was conducted at the College farm, College of Horticulture Mandsaur, during the period of November, 2020 – April, 2021, are presented in this chapter under the data pertaining of various characters were subjected to statistical analysis by using RBD. In support the tabular presentation of the data, graphical presentation has been also presented in this chapter to provide better comprehension of the characters.

4.1. Growth Parameters

4.1.1 Plant height (cm):

The data pertaining to plant height of all treatment have been presented in Table 4.1 and illustrated in Figure 4.1.

It is evident from the data presented in Table 4.1 and Fig 4.1 that the effect of bio-fertilizer on plant height was statistically significant.

Plant height at 60 DAT of different treatment was varied from 36.17 cm to 41.83 cm. Maximum plant height (41.83 cm) was found in T_4 i.e. 100% NPK + Azotobacter + PSB which was statistically at par with treatments T_7 (85% NPK + Azotobacter + PSB) 40.77 cm plant height. In contrast, minimum plant height (36.17 cm) was observed in T_9 (75% RDF + PSB).

The plant height at 90 days after transplanting was varied from 60.13 cm to 66.73 cm. The maximum plant height at 90 days after transplanting (66.73 cm) was recorded by T_4 (100% NPK + Azotobacter + PSB) followed by T_7 (85% NPK + Azotobacter + PSB) and T_{10} (75% NPK + Azotobacter + PSB) which recorded the value of 65.47 cm and 64.93 cm respectively and all of these treatments showed statistically at par with each other. However, the minimum plant height at 60 days (60.13 cm) was recorded by T_9 (75% RDF + PSB).

Table 4.1: Plant height (cm)

Symbol	Treatments	Plant height at 60 DAT (cm)	Plant height at 90 DAT (cm)
T_1	RDF	36.93	61.57
T_2	RDF + Azotobacter	39.27	64.60
T_3	RDF + PSB	38.43	64.20
T_4	RDF + Azotobacter +PSB	41.83	66.73
T_5	85% RDF + Azotobacter	38.43	63.13
T_6	85% RDF + PSB	37.20	62.77
T_7	85% RDF + Azotobacter +PSB	40.77	65.47
T_8	75% RDF + Azotobacter	36.47	61.00
T_9	75% RDF + PSB	36.17	60.13
T_{10}	75% RDF + Azotobacter +PSB	39.91	64.93
SE(m)±		**0.42**	**0.62**
C.D. at 5%		**1.26**	**1.84**

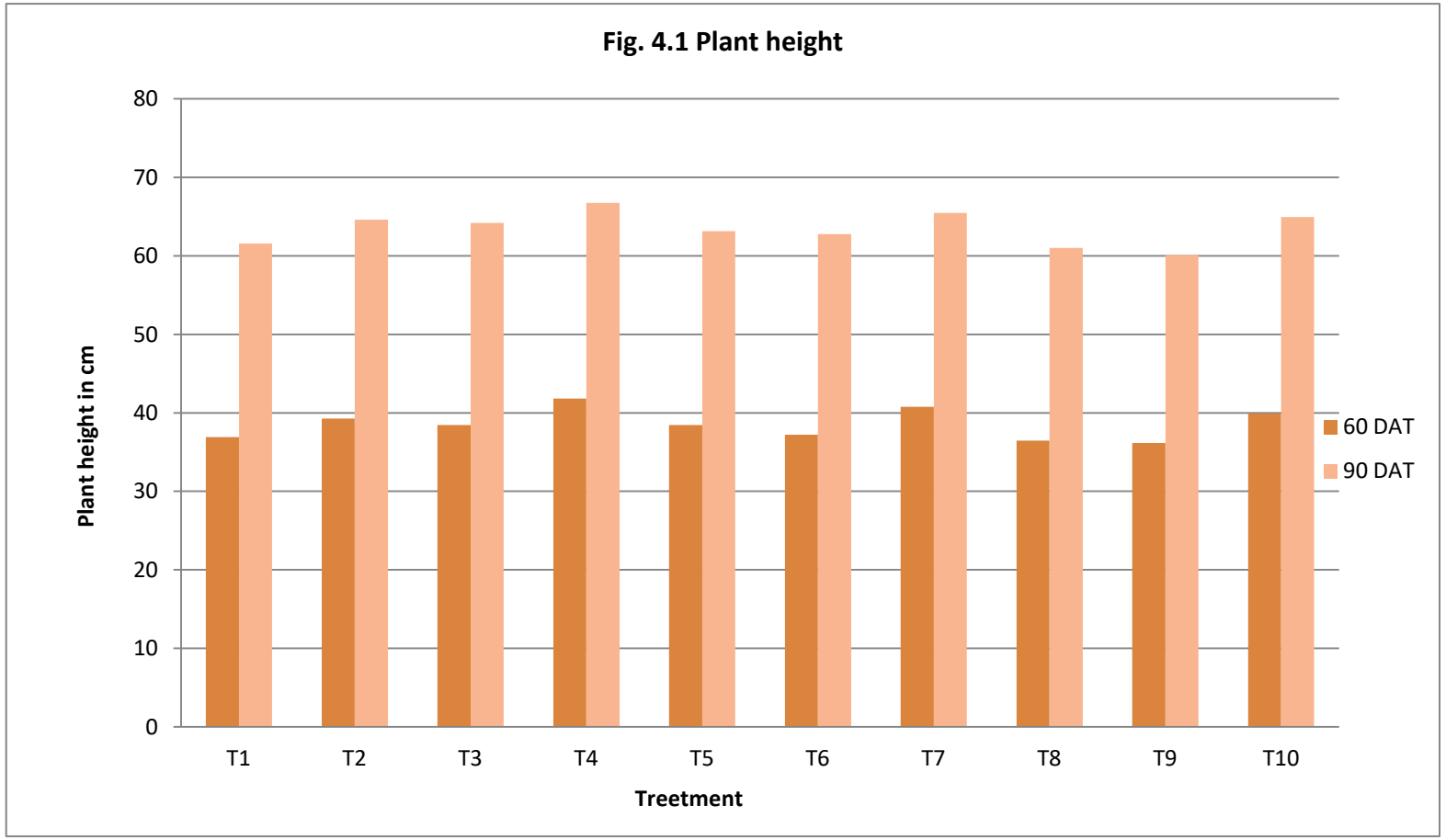


Fig. 4.1 Plant height
80
70
60
50
40
30
20
10
0
Plant height in cm
T1
T2
T3
T4
T5
T6
T7
T8
T9
T10
Treetment
60 DAT
90 DAT

4.1.2 Number of leaves / plant

The data related to number of leaves per plant of different treatment have been presented in Table 4.2 and illustrated in Figure 4.2.

It is evident from Table 4.2 and Figure 4.2 that different treatments have shown significant variation with respect to number of leaves per plant.

The number of leaves at 60 days after transplanting was varied from 83.20 to 96.40. The maximum number of leaves (96.40) was found in T_7 i.e. 85% NPK + Azotobacter + PSB which was statistically at par with the other treatments like T_4 (100% NPK + Azotobacter + PSB) and T_{10} (75% NPK + Azotobacter + PSB) which recorded 95.40 and 93.17 leaves, respectively. In contrast, minimum number of leaves (83.20) was observed in T_8 (75% RDF + Azotobacter).

The number of leaves at 90 days after transplanting was varied from 131.13 to 144.93. The maximum number of leaves (144.93) was found in T_7 i.e. 85% NPK + Azotobacter + PSB which was statistically at par with the other treatments like T_4 (100% NPK + Azotobacter + PSB) and T_{10} (75% NPK + Azotobacter + PSB) which recorded 141.67 and 140.33 leaves, respectively. In contrast, minimum number of leaves (131.13) was observed in T_8 (75% RDF + Azotobacter).

Table 4.2: Number of leaves /plan

Symbol	Treatments	Number of leaves / plant at 60 DAT	Number of leaves / plant at 90 DAT
T_1	RDF	85.90	132.67
T_2	RDF + Azotobacter	87.47	134.47
T_3	RDF + PSB	88.33	135.73
T_4	RDF + Azotobacter +PSB	95.40	141.33
T_5	85% RDF + Azotobacter	89.20	136.80
T_6	85% RDF + PSB	91.07	137.33
T_7	85% RDF + Azotobacter +PSB	96.40	144.93
T_8	75% RDF + Azotobacter	83.20	131.13
T_9	75% RDF + PSB	84.33	131.80
T_{10}	75% RDF + Azotobacter +PSB	93.17	140.33
SE(m)±		**1.12**	**1.64**
C.D. at 5%		**3.32**	**4.86**

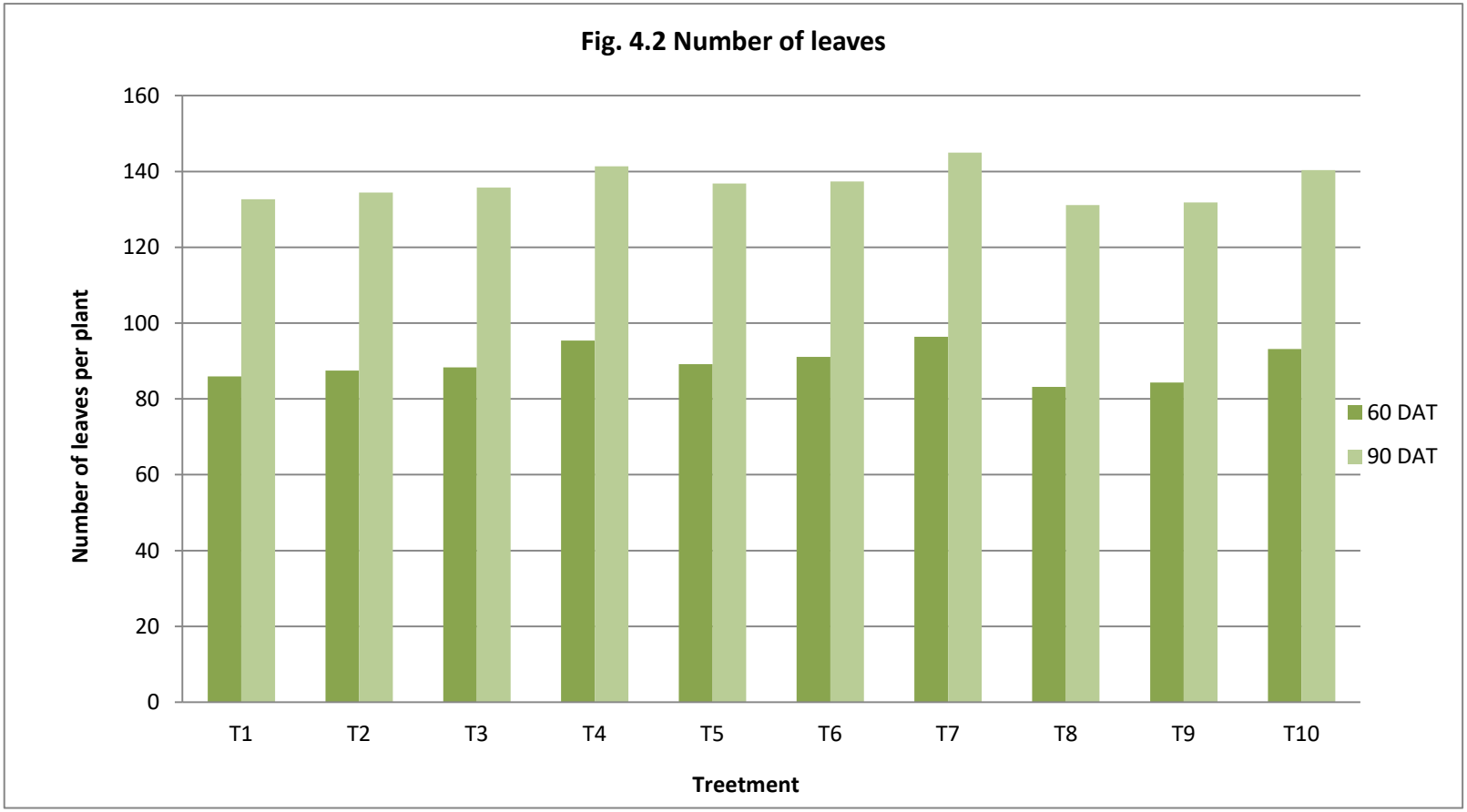


Fig. 4.2 Number of leaves
Number of leaves per plant
160
140
120
100
80
60
40
20
0
T1
T2
T3
T4
T5
T6
T7
T8
T9
T10
Treetment
60 DAT
90 DAT

4.1.3 Leaf area (cm)

The data related to leaf area (cm) per plant of different treatment have been presented in Table 4.3 and illustrated in Figure 4.3.

It is evident from Table 4.3 and Figure 4.3 that different treatments have shown significant variation with respect to leaf area (cm) per plant.

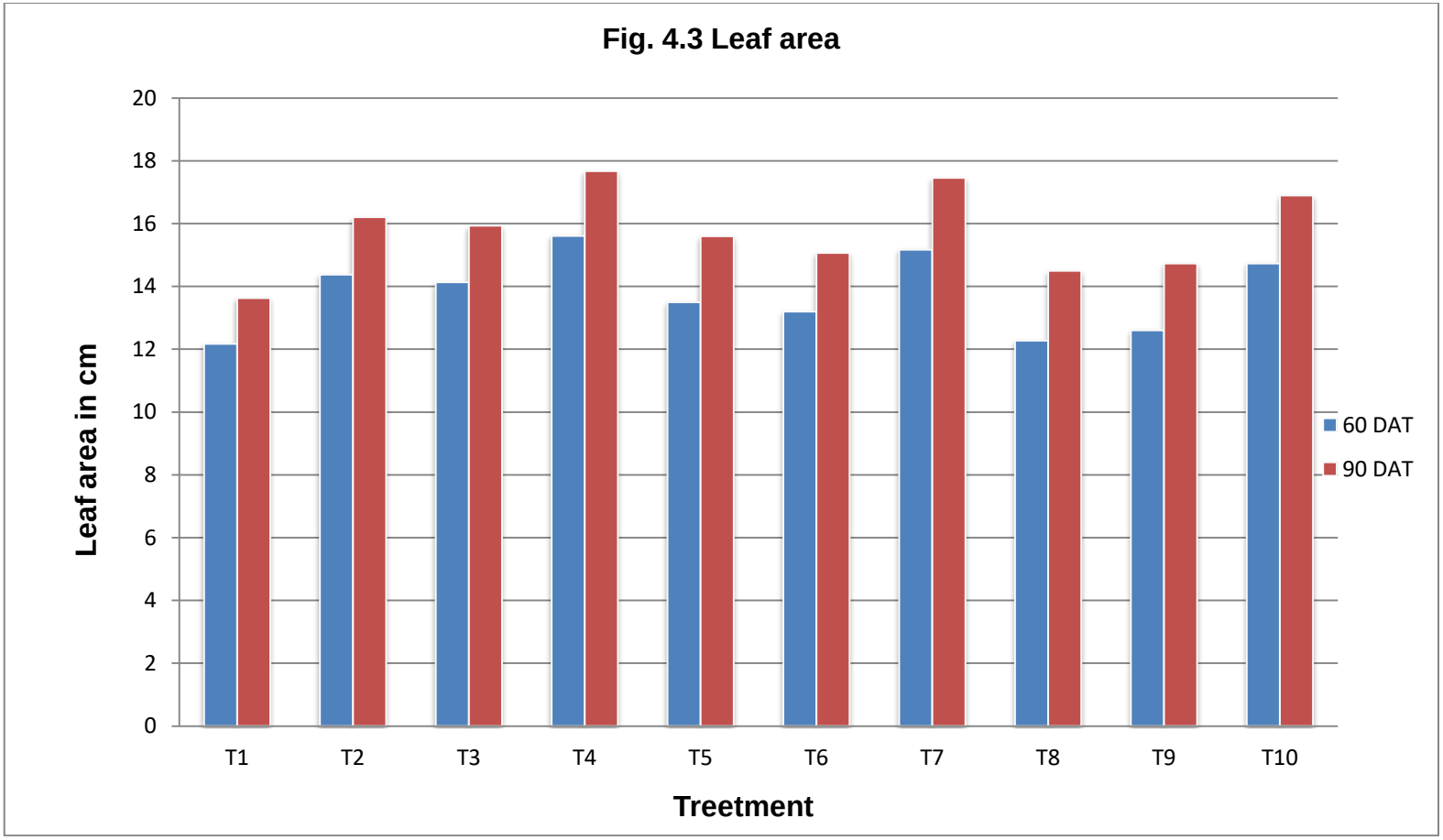
The leaf area per plant at 60 days after transplanting was varied from 12.17 to 15.61 cm. The maximum leaf area per plant (15.61 cm) was recorded by T_4 (100% NPK + Azotobacter + PSB) followed by T_7 (85% NPK + Azotobacter + PSB), T_{10} (75% NPK + Azotobacter + PSB), T_2 (100% NPK + Azotobacter) and T_3 (100% NPK + PSB) which were recorded the value of 15.17 cm, 14.73 cm, 14.37 cm and 14.13 cm respectively and all of these treatments are statistically at par to each other. However, the minimum leaf area per plant (12.17 cm) was recorded by T_1 (RDF).

The leaf area per plant at 90 days after transplanting was varied from 13.63 to 17.67 cm. The maximum leaf area per plant (17.67 cm) was recorded by T_4 (100% NPK + Azotobacter + PSB) followed by T_7 (85% NPK + Azotobacter + PSB) and T_{10} (75% NPK + Azotobacter + PSB) which were recorded the value of 17.46 cm and 16.90 cm respectively and all of these treatments are statistically at par to each other. However, the minimum leaf area per plant (13.63 cm) was recorded by T_1 (RDF).

Table 4.3: Leaf area (cm)

Symbol	Treatments	Leaf area at 60 DAT (cm)	Leaf area at 90 DAT (cm)
T_1	RDF	12.17	13.63
T_2	RDF + Azotobacter	14.37	16.20
T_3	RDF + PSB	14.13	15.93
T_4	RDF + Azotobacter +PSB	15.61	17.67
T_5	85% RDF + Azotobacter	13.50	15.60
T_6	85% RDF + PSB	13.20	15.07
T_7	85% RDF + Azotobacter +PSB	15.17	17.46
T_8	75% RDF + Azotobacter	12.27	14.50
T_9	75% RDF + PSB	12.60	14.73
T_{10}	75% RDF + Azotobacter +PSB	14.73	16.90
SE(m)±		**0.51**	**0.31**
C.D. at 5%		**1.51**	**0.91**

Fig. 4.3 Leaf area



4.1.4 Plant spread (cm)

The data related to plant spread (cm) per plant of different treatment have been presented in Table 4.4 and illustrated in Figure 4.4.

It is evident from Table 4.4 and Figure 4.4 that different treatments have shown significant variation with respect to plant spread (cm) per plant.

On the perusal of data tabulated in Table 4.4 it is evident that plant spread at 60 days after transplanting was varied from 20.67 cm to 25.17 cm. The maximum plant spread (25.17 cm) was observed in treatment T_4 (100% NPK + Azotobacter + PSB) followed by T_7 (85% NPK + Azotobacter + PSB), T_{10} (75% NPK + Azotobacter + PSB), T_2 (100% NPK + Azotobacter) and T_3 (100% NPK + PSB) which recorded the value of 24.90 cm, 24.70 cm, 24.20 cm and 23.90 cm respectively and all of these treatments showed statistically similar to each other. However, the minimum plant spread (20.67 cm) was observed in treatments T_9 (75% RDF + PSB).

On the perusal of data tabulated in Table 4.4 it is evident that plant spread at 90 days after transplanting was varied from 39.75 cm to 44.50 cm. The maximum number of plant spread (44.50 cm) was observed in treatment T_4 (100% NPK + Azotobacter + PSB) followed by T_7 (85% NPK + Azotobacter + PSB), T_{10} (75% NPK + Azotobacter + PSB), T_2 (100% NPK + Azotobacter) and T_3 (100% NPK + PSB) which recorded the value of 44.13 cm, 43.80 cm, 43.55 cm and 43.17 cm respectively and all of these treatments showed statistically at par with each other. However, the minimum plant spread (39.75 cm) was observed in treatments T_9 (75% RDF + PSB).

Table 4.4: Plant spread (cm)

Symbol	Treatments	Plant spread at 60 DAT (cm)	Plant spread at 90 DAT (cm)
T_1	RDF	22.30	41.97
T_2	RDF + Azotobacter	24.20	43.55
T_3	RDF + PSB	23.90	43.17
T_4	RDF + Azotobacter +PSB	25.17	44.50
T_5	85% RDF + Azotobacter	23.40	42.93
T_6	85% RDF + PSB	22.93	42.55
T_7	85% RDF + Azotobacter +PSB	24.90	44.13
T_8	75% RDF + Azotobacter	21.97	41.30
T_9	75% RDF + PSB	20.67	39.75
T_{10}	75% RDF + Azotobacter +PSB	24.70	43.80
SE(m)±		**0.55**	**0.46**
C.D. at 5%		**1.63**	**1.36**

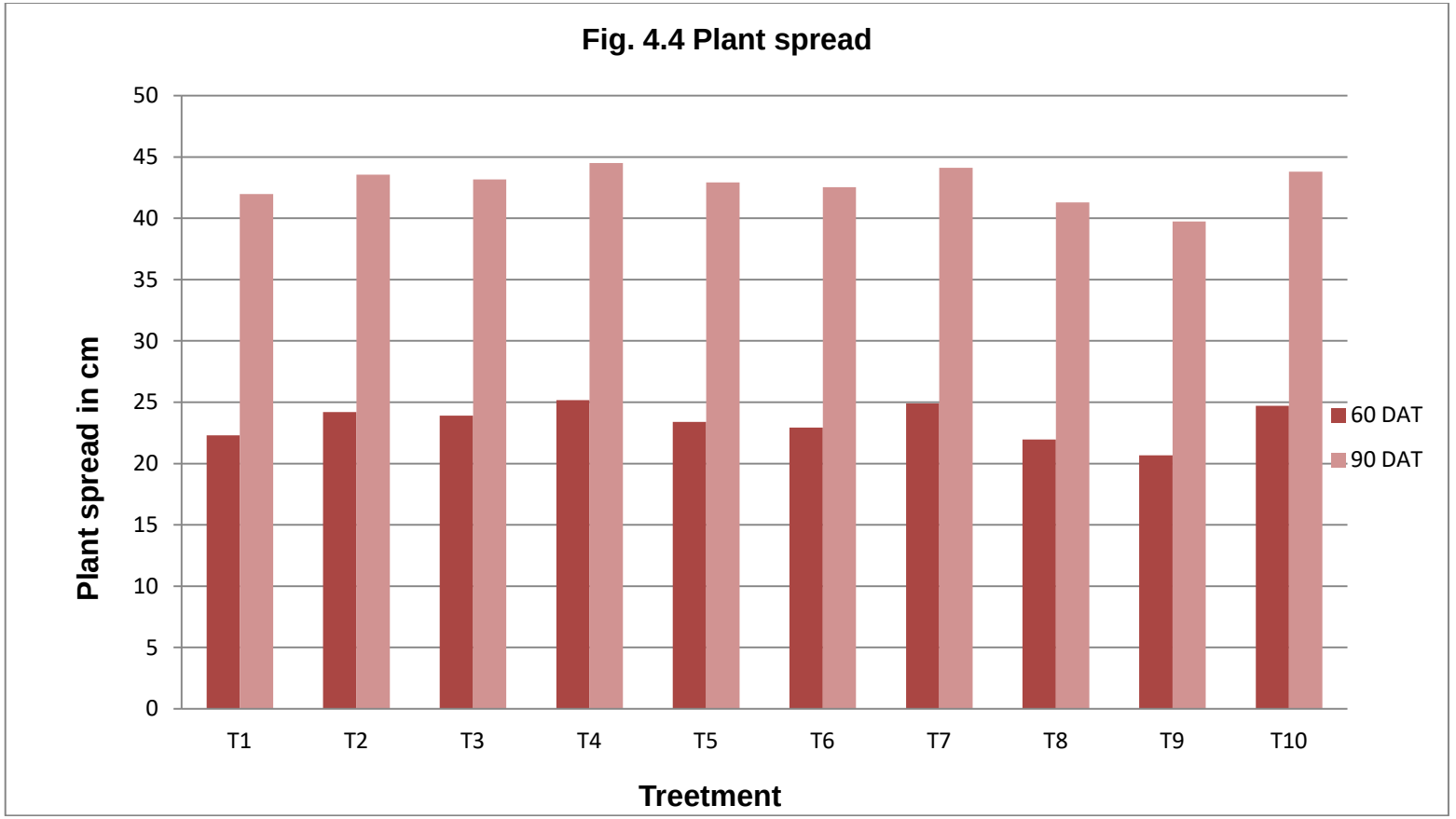


Fig. 4.4 Plant spread
Plant spread in cm
50
45
40
35
30
25
20
15
10
5
0
T1
T2
T3
T4
T5
T6
T7
T8
T9
T10
Treetment
60 DAT
90 DAT

4.1.5 No. of branches / plant

The data related to number of branches per plant of different treatment have been presented in Table 4.5 and illustrated in Figure 4.5.

It is evident from Table 4.5 and Figure 4.5 that different treatments have shown significant variation with respect to number of branches per plant.

The number of branches per plant at 60 days after transplanting was varied from 12.47 to 15.10. The maximum No. of branches / plant (15.10) was found in T_7 i.e. 85% NPK + Azotobacter + PSB which was statistically at par with the treatments T_4 (100% NPK + Azotobacter + PSB) and T_{10} (75% NPK + Azotobacter + PSB) which recorded the value of 14.93 and 14.47 branches per plant respectively and all of these treatments showed statistically at par with each other. In contrast, minimum number of branches (12.47) was observed in T_1 (RDF).

The number of branches per plant at 90 days after transplanting was varied from 16.87 to 19.80. The maximum number of branches per plants (19.80) was recorded by T_7 (85% NPK + Azotobacter + PSB) followed by T_4 (100% NPK + Azotobacter + PSB), T_{10} (75% NPK + Azotobacter + PSB), T_6 (85% NPK + PSB) and T_5 (85% NPK + Azotobacter) which were recorded the value of 19.13, 18.90, 18.87 and 18.63 branches per plant respectively and all of these treatments are statistically at par to each other. However, the minimum number of branches per plants (16.87) was recorded by T_1 (RDF).

Table 4.5: No. of branches /plant

Symbol	Treatments	No. of branches / plant at 60 DAT	No. of branches / plant at 90 DAT
T_1	RDF	12.47	16.87
T_2	RDF + Azotobacter	13.57	18.13
T_3	RDF + PSB	13.90	18.20
T_4	RDF + Azotobacter +PSB	14.93	19.13
T_5	85% RDF + Azotobacter	14.07	18.63
T_6	85% RDF + PSB	14.30	18.87
T_7	85% RDF + Azotobacter +PSB	15.10	19.80
T_8	75% RDF + Azotobacter	12.90	17.40
T_9	75% RDF + PSB	13.13	17.67
T_{10}	75% RDF + Azotobacter +PSB	14.47	18.90
SE(m)±		**0.24**	**0.52**
C.D. at 5%		**0.73**	**1.55**

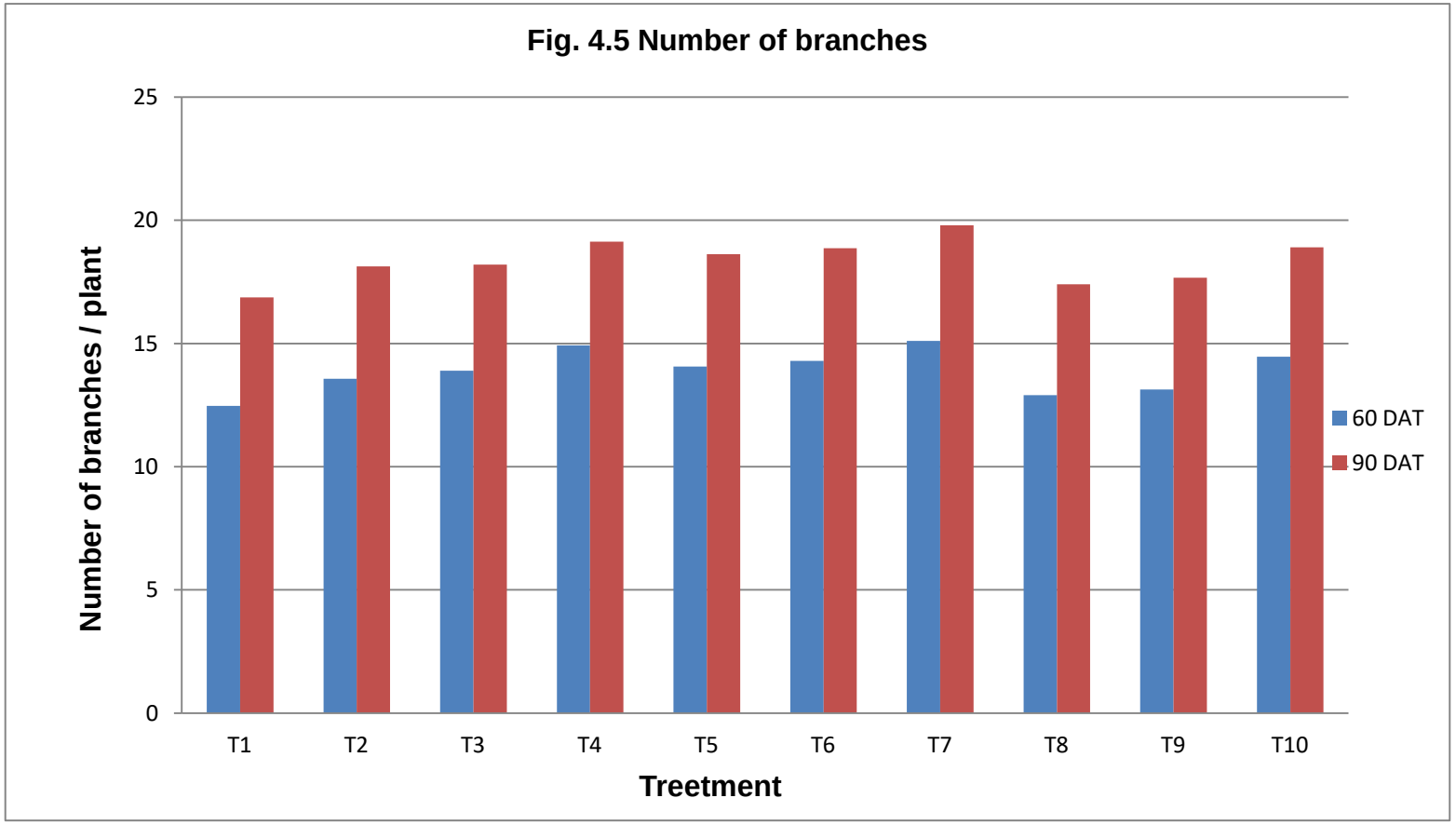


Fig. 4.5 Number of branches
25
20
15
10
5
0
Number of branches / plant
T1
T2
T3
T4
T5
T6
T7
T8
T9
T10
Treetment
60 DAT
90 DAT

4.1.6 Stem diameter

The data related to stem diameter per plant of different treatment have been presented in Table 4.6 and illustrated in Figure 4.6.

It is evident from Table 4.6 and Figure 4.6 that different treatments have shown significant variation with respect to stem diameter per plant.

The stem diameter per plant at 60 days after transplanting was varied from 6.87 to 8.73 mm. The maximum stem diameter (8.73 mm) was found in T_4 i.e. 100% NPK + Azotobacter + PSB which was statistically at par with the treatments T_7 (85% NPK + Azotobacter + PSB) recording 8.53 mm. In contrast, minimum stem diameter (6.87 mm) was observed in T_8 (75% NPK+ Azotobacter).

The stem diameter per plant at 90 days after transplanting was varied from 13.77 to 16.33 mm. The maximum stem diameter per plants (16.33 mm) was recorded by T_4 (100% NPK + Azotobacter + PSB) followed by T_7 (85% NPK + Azotobacter + PSB), T_{10} (75% NPK + Azotobacter + PSB) and T_3 (100% NPK + PSB). Which were recorded the value of 15.93 mm, 15.70 mm and 15.57 mm respectively and all of these treatments are statistically at par to each other. However, the minimum stem diameter per plant (13.77 mm) was recorded by T_8 (75% NPK+ Azotobacter).

Table 4.6: Stem diameter

Symbol	Treatments	Stem diameter at 60 DAT (mm)	Stem diameter at 90 DAT (mm)
T_1	RDF	7.47	14.40
T_2	RDF + Azotobacter	8.07	15.40
T_3	RDF + PSB	8.20	15.57
T_4	RDF + Azotobacter +PSB	8.73	16.33
T_5	85% RDF + Azotobacter	7.80	14.93
T_6	85% RDF + PSB	8.93	15.20
T_7	85% RDF + Azotobacter +PSB	8.53	15.93
T_8	75% RDF + Azotobacter	6.87	13.77
T_9	75% RDF + PSB	7.27	14.10
T_{10}	75% RDF + Azotobacter +PSB	8.33	15.70
SE(m)±		**0.09**	**0.29**
C.D. at 5%		**0.27**	**0.86**

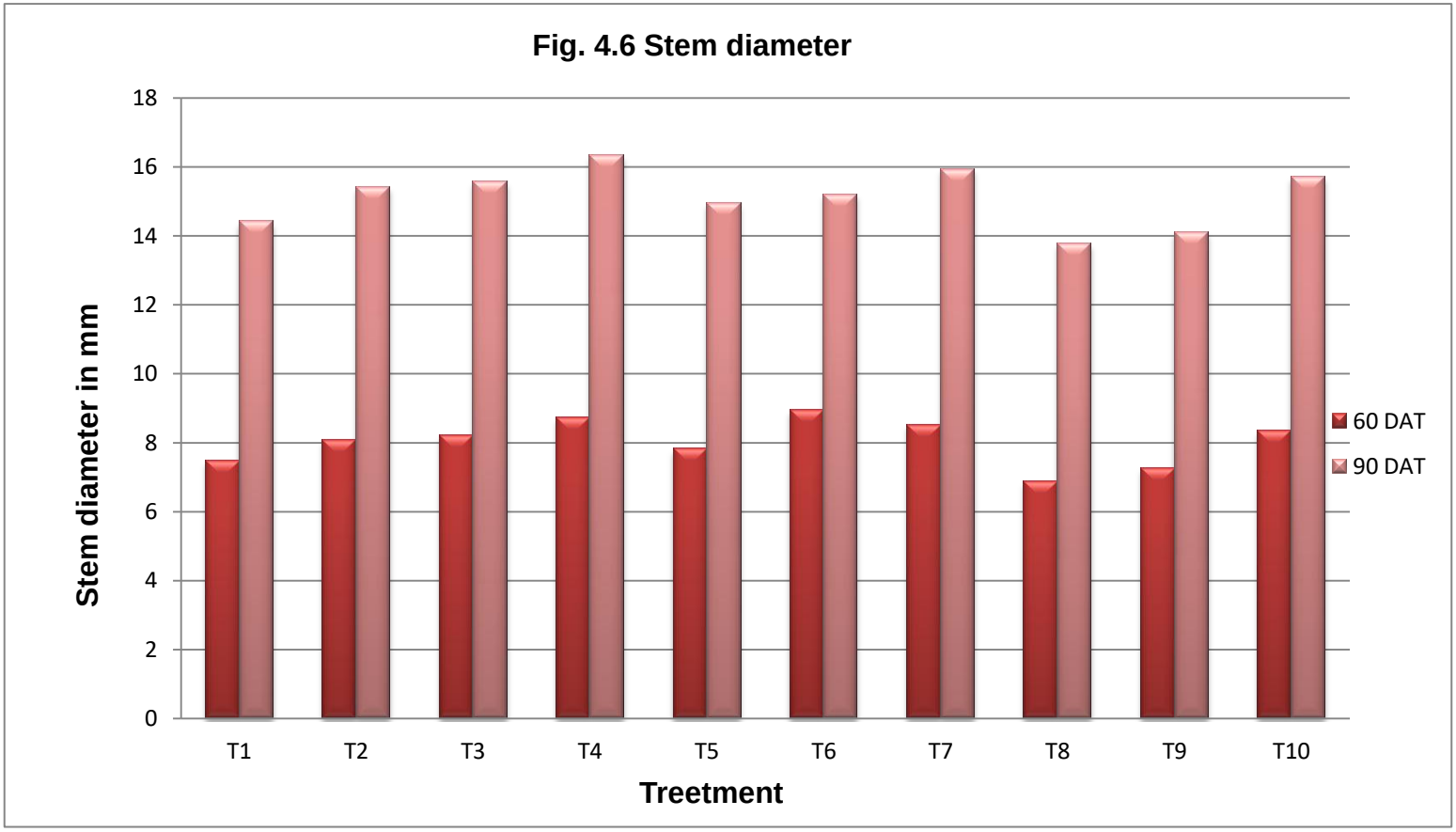


Fig. 4.6 Stem diameter
Stem diameter in mm
18
16
14
12
10
8
6
4
2
0
T1
T2
T3
T4
T5
T6
T7
T8
T9
T10
Treetment
60 DAT
90 DAT

4.2 Flowering Parameters:

4.2.1 Days taken to 1st flower bud initiation:

The data related to days taken to first flower bud appearance of different treatment have been represented in Table 4.7 and illustrated in Figure 4.7.

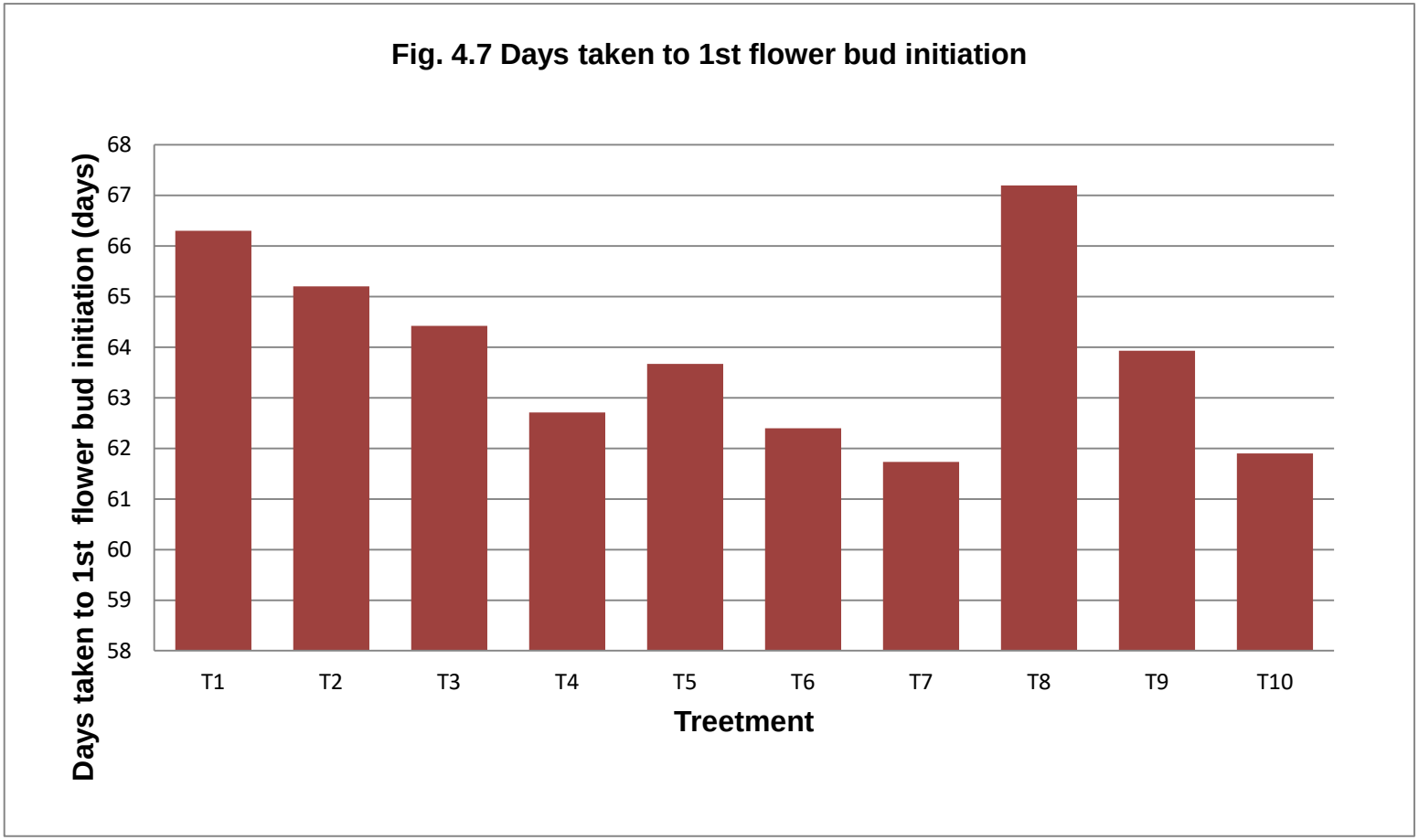
According to Table 4.7 and Figure 4.7 that the different treatment have shown statistically significant variation with respect to days taken to first bud appearance.

The days taken to first flower bud appearance were varied from 61.73 days to 67.20 days. The earliest first flower bud appearance (61.73 days) was recorded by T_7 (85% NPK + Azotobacter + PSB) and first flower bud appearance took place on approximately the same day in T_{10} (75% NPK + Azotobacter + PSB) with 61.90 days. Other treatments like T_6 (85% NPK + PSB) 62.40 days and T_4 (100% NPK + Azotobacter + PSB) 62.71 days were having at par results. Maximum days taken for first flower bud formation (67.20 days) were taken in T_8 (75% NPK + Azotobacter).

Table 4.7: Days taken to 1st flower bud initiation

Symbol	Treatments	Days taken to 1st flower bud initiation
T_1	RDF	66.30
T_2	RDF + Azotobacter	65.20
T_3	RDF + PSB	64.42
T_4	RDF + Azotobacter +PSB	62.71
T_5	85% RDF + Azotobacter	63.67
T_6	85% RDF + PSB	62.40
T_7	85% RDF + Azotobacter +PSB	61.73
T_8	75% RDF + Azotobacter	67.20
T_9	75% RDF + PSB	63.93
T_{10}	75% RDF + Azotobacter +PSB	61.90
SE(m)±		**0.56**
C.D. at 5%		**1.66**

Fig. 4.7 Days taken to 1st flower bud initiation



4.2.2 Days taken to opening of flower from bud emergence

The data related to days taken to opening of flower from bud emergence of different treatment have been represented in Table 4.8 and illustrated in Figure 4.8

According to Table 4.8 and Figure 4.8 that the different treatment have shown statistically significant variation with respect to days taken to opening of flower from bud emergence.

The days taken to opening of flower from bud emergence were varied from 10.07 days to 14.97 days. The number of days taken to first flower opening were minimum (10.07 days) with application of 85% NPK + Azotobacter + PSB i.e. T_7 with the treatments T_{10} (75% NPK + Azotobacter + PSB) and T_6 (85% NPK + PSB). Which were recorded the value of 10.63 and 11.27 days respectively and these two treatments are statistically at par to each other. However, the maximum number of days taken to opening of flower from bud emergence (14.97 days) was recorded by T_8 (75% NPK + Azotobacter).

Table 4.8: Days taken to opening of flower from bud emergence

Symbol	Treatments	Days taken to opening of flower from bud emergence
T_1	RDF	13.37
T_2	RDF + Azotobacter	13.90
T_3	RDF + PSB	12.90
T_4	RDF + Azotobacter +PSB	11.57
T_5	85% RDF + Azotobacter	12.47
T_6	85% RDF + PSB	11.27
T_7	85% RDF + Azotobacter +PSB	10.07
T_8	75% RDF + Azotobacter	14.97
T_9	75% RDF + PSB	14.27
T_{10}	75% RDF + Azotobacter +PSB	10.63
SE(m)±		**0.50**
C.D. at 5%		**1.47**

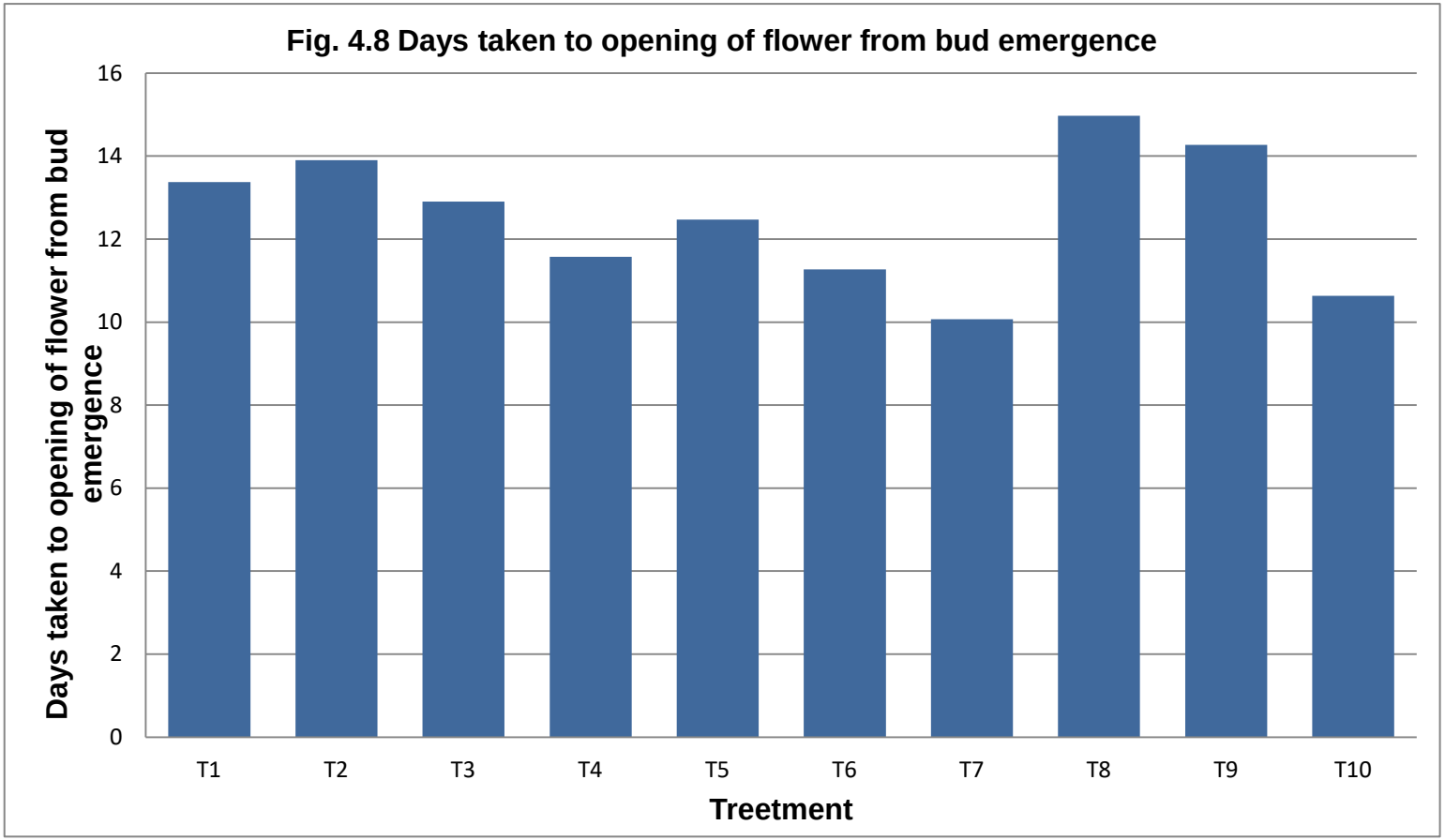


Fig. 4.8 Days taken to opening of flower from bud emergence
Days taken to opening of flower from bud emergence
16
14
12
10
8
6
4
2
0
T1
T2
T3
T4
T5
T6
T7
T8
T9
T10
Treetment

4.2.3 Blooming period (days)

The data related to blooming period of different treatment have been represented in Table 4.9 and illustrated in Figure 4.9

According to Table 4.9 and Figure 4.9 that the different treatment have shown statistically significant variation with respect to blooming period (days).

The blooming period were varied from 24.47 days to 29.93 days. Maximum blooming period (29.93 days) was recorded in plants applied with 85% NPK + Azotobacter + PSB i.e. T_7 and it was found at par with the treatments like T_4 (100% NPK + Azotobacter + PSB) and T_{10} (75% NPK + Azotobacter + PSB) which were recorded the value of 28.27 and 28.13 days respectively and all these treatments are statistically at par to each other. However, the minimum blooming period (24.47 days) was recorded by T_1 (RDF).

Table 4.9: Blooming period (days)

Symbol	Treatments	Blooming period (days)
T_1	RDF	24.47
T_2	RDF + Azotobacter	26.00
T_3	RDF + PSB	26.33
T_4	RDF + Azotobacter +PSB	28.27
T_5	85% RDF + Azotobacter	26.40
T_6	85% RDF + PSB	27.67
T_7	85% RDF + Azotobacter +PSB	29.93
T_8	75% RDF + Azotobacter	25.13
T_9	75% RDF + PSB	26.13
T_{10}	75% RDF + Azotobacter +PSB	28.13
SE(m)±		**0.64**
C.D. at 5%		**1.91**

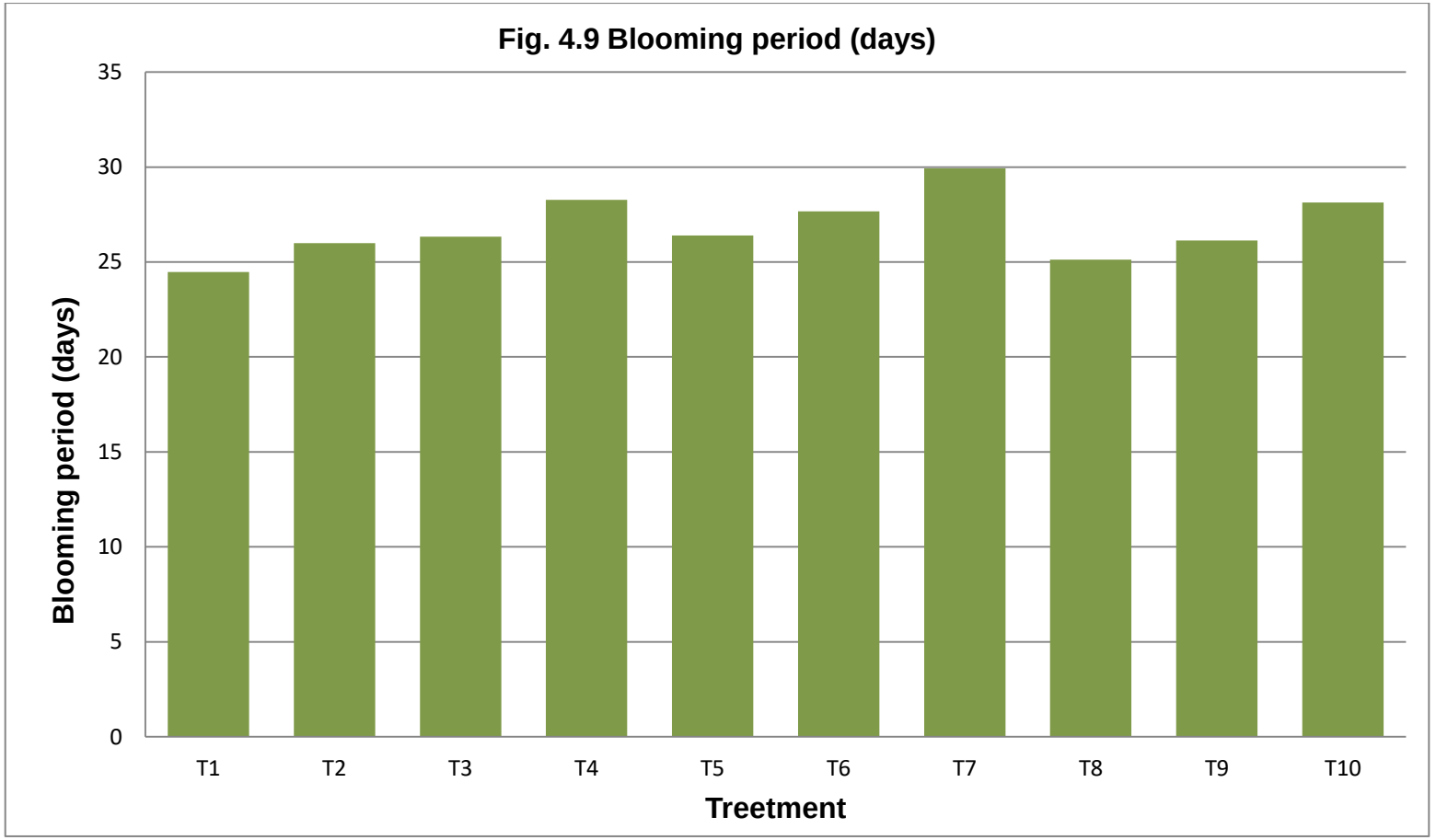


Fig. 4.9 Blooming period (days)
Blooming period (days)
35
30
25
20
15
10
5
0
T1
T2
T3
T4
T5
T6
T7
T8
T9
T10
Treetment

4.3 Quality Parameters:

4.3.1. Flower stalks length (cm):

The data related to flower stalk length of different treatment have been represented in Table 4.10 and illustrated in Figure 4.10

According to Table 4.10 and Figure 4.10 that the different treatment have shown statistically significant variation with respect to flower stalk length.

The flower stalk length was varied from 25.10 to 30.33 cm. The maximum flower stalk length (30.33 cm) was recorded by T_7 (85% NPK + Azotobacter + PSB) followed by T_4 (100% NPK + Azotobacter + PSB) and T_{10} (75% NPK + Azotobacter + PSB) which were recorded the value of 29.92 and 29.20 cm respectively and these two treatments are statistically at par to each other. However, the minimum flower stalk length (25.10 cm) was recorded by T_1 (RDF).

Table 4.10: Flower stalk length (cm)

Symbol	Treatments	Flower stalk length (cm)
T_1	RDF	25.10
T_2	RDF + Azotobacter	27.53
T_3	RDF + PSB	27.03
T_4	RDF + Azotobacter +PSB	29.92
T_5	85% RDF + Azotobacter	28.50
T_6	85% RDF + PSB	28.00
T_7	85% RDF + Azotobacter +PSB	30.33
T_8	75% RDF + Azotobacter	26.50
T_9	75% RDF + PSB	25.97
T_{10}	75% RDF + Azotobacter +PSB	29.20
SE(m)±		**0.45**
C.D. at 5%		**1.34**

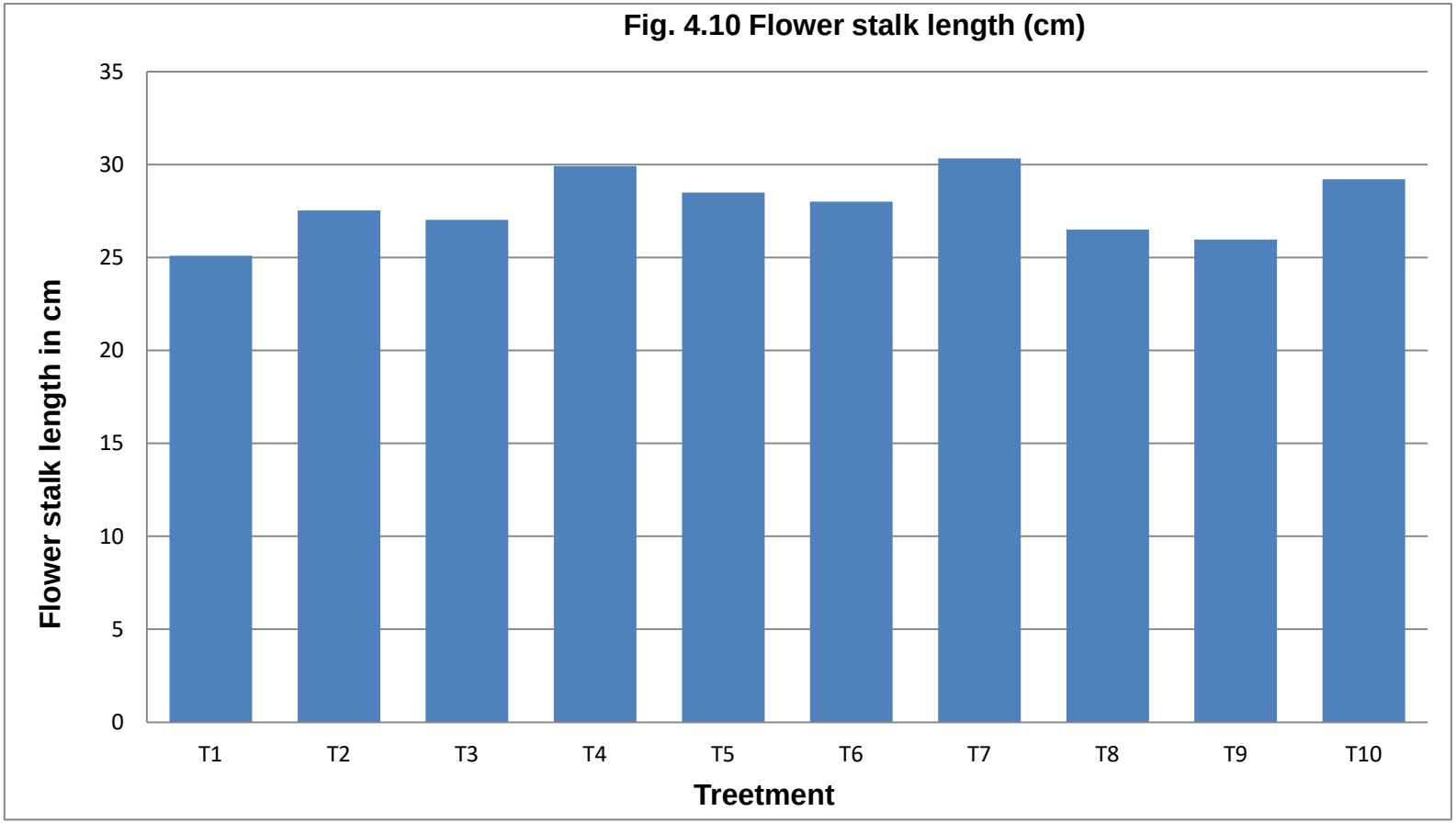


Fig. 4.10 Flower stalk length (cm)
Flower stalk length in cm
35
30
25
20
15
10
5
0
T1
T2
T3
T4
T5
T6
T7
T8
T9
T10
Treetment

4.3.2. Flower diameter (cm):

The data related to flower diameter of different treatment have been represented in Table 4.11 and illustrated in Figure 4.11

According to Table 4.11 and Figure 4.11 that the different treatment have shown statistically significant variation with respect to flower diameter.

The flower diameter was varied from 5.13 cm to 6.90 cm. The maximum flower diameter (6.90 cm) was recorded by T_{10} (75% NPK + Azotobacter + PSB) followed by T_7 (85% NPK + Azotobacter + PSB), T_4 (100% NPK + Azotobacter + PSB) and T_3 (100% NPK + PSB), which recorded values of 6.80, 6.57 and 6.47 cm respectively and all of these treatments are statistically at par to each other. However, the minimum flower diameter (5.13 cm) was recorded by T_1 (RDF).

Table 4.11: Flower diameter (cm)

Symbol	Treatments	Flower diameter (cm)
T_1	RDF	5.13
T_2	RDF + Azotobacter	6.37
T_3	RDF + PSB	6.47
T_4	RDF + Azotobacter +PSB	6.57
T_5	85% RDF + Azotobacter	5.93
T_6	85% RDF + PSB	6.13
T_7	85% RDF + Azotobacter +PSB	6.80
T_8	75% RDF + Azotobacter	5.37
T_9	75% RDF + PSB	5.60
T_{10}	75% RDF + Azotobacter +PSB	6.90
SE(m)±		**0.20**
C.D. at 5%		**0.58**

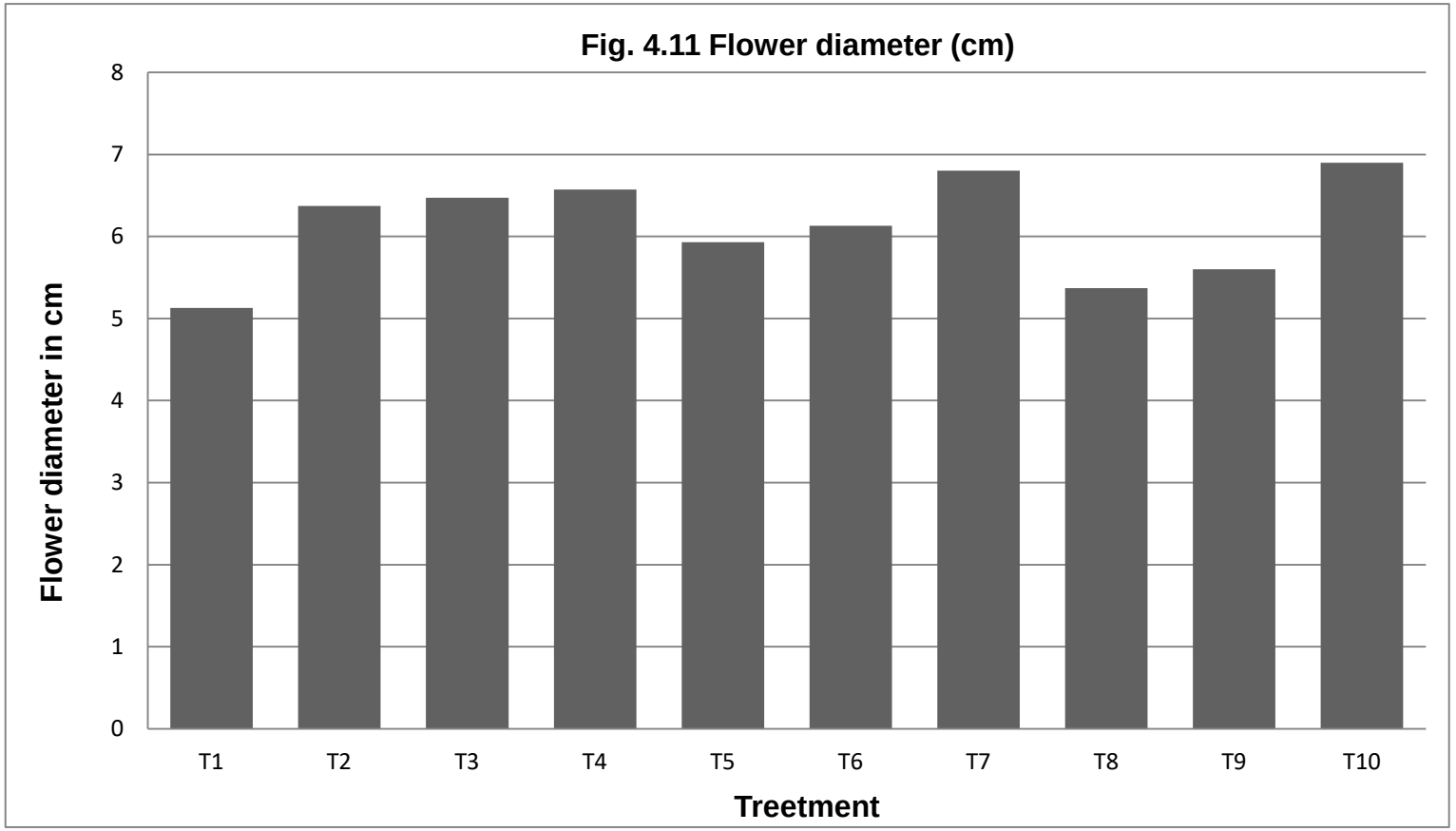


Fig. 4.11 Flower diameter (cm)
Flower diameter in cm
8
7
6
5
4
3
2
1
0
T1
T2
T3
T4
T5
T6
T7
T8
T9
T10
Treetment

4.3.3. Weight of flower (g):

The data related to weight of flower (g) of different treatment have been represented in Table 4.12 and illustrated in Figure 4.12

According to Table 4.12 and Figure 4.12 that the different treatment has shown statistically significant variation with respect to weight of flower (g)

The fresh weight of flower (g) was varied from 2.27 g to 2.90 g. The maximum weight of fresh weight of flower (2.90 g) was recorded by T_{10} (75% NPK + Azotobacter + PSB) followed by T_7 (85% NPK + Azotobacter + PSB), T_4 (100% NPK + Azotobacter + PSB), T_6 (85% NPK + PSB), T_5 (85% NPK + Azotobacter) and T_3 (100% NPK + PSB) which recorded values of 2.83 g, 2.80 g, 2.52 g, 2.47 g and 2.47 g respectively and all of these treatments showed statistically at par with each other. While, the minimum weight of fresh flower (2.27 g) was recorded by T_1 (RDF).

Table 4.12: Weight of flower (g)

Symbol	Treatments	Weight of flower (g)
T_1	RDF	2.27
T_2	RDF + Azotobacter	2.40
T_3	RDF + PSB	2.47
T_4	RDF + Azotobacter +PSB	2.80
T_5	85% RDF + Azotobacter	2.47
T_6	85% RDF + PSB	2.52
T_7	85% RDF + Azotobacter +PSB	2.83
T_8	75% RDF + Azotobacter	2.30
T_9	75% RDF + PSB	2.33
T_{10}	75% RDF + Azotobacter +PSB	2.90
SE(m)±		**0.15**
C.D. at 5%		**0.44**

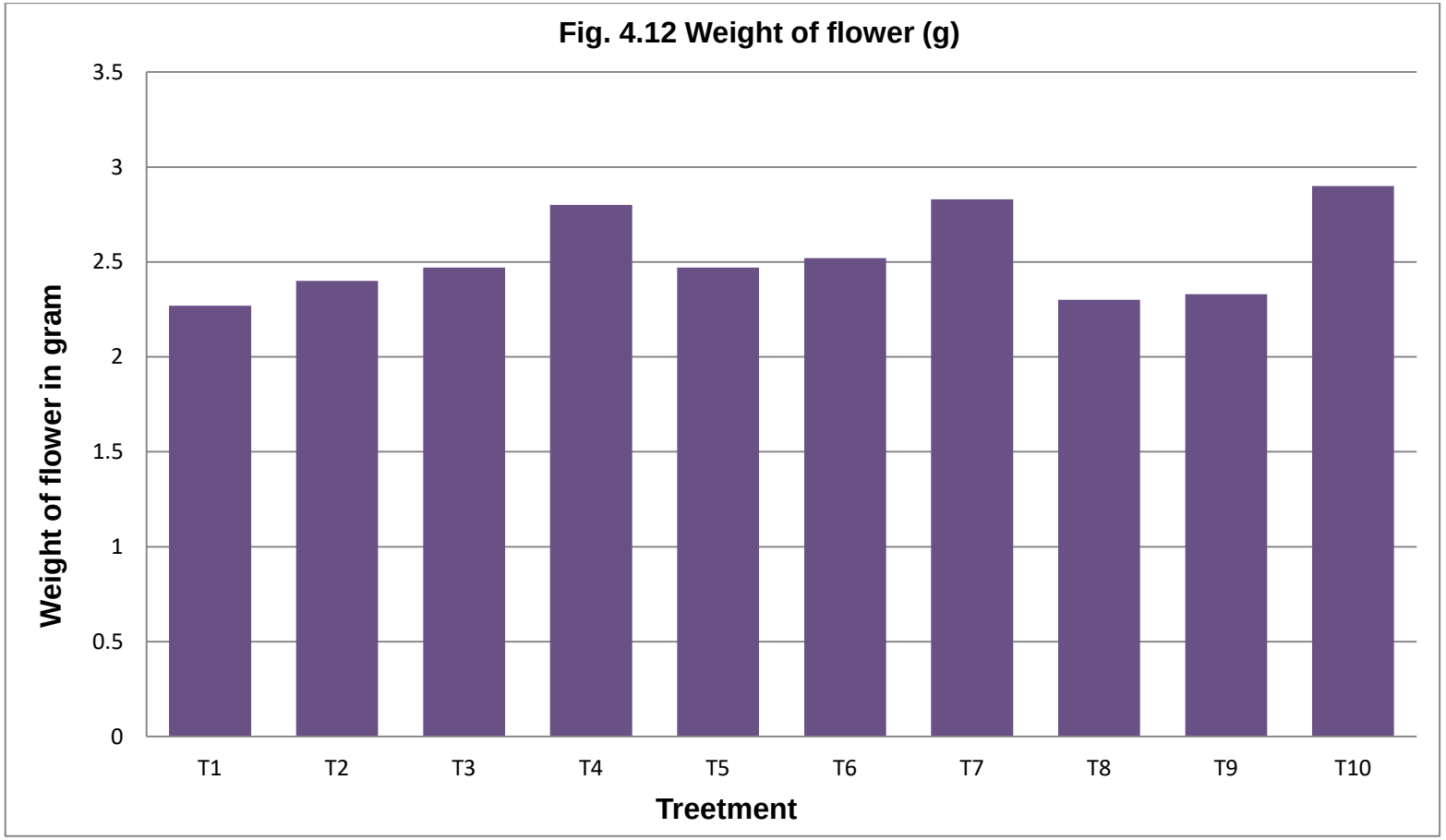


Fig. 4.12 Weight of flower (g)
Weight of flower in gram
3.5
3
2.5
2
1.5
1
0.5
0
T1
T2
T3
T4
T5
T6
T7
T8
T9
T10
Treetment

4.4. Biochemical Parameters:

4.4.1 Chlorophyll content in leaves:

The data related to chlorophyll content in leaves (SPAD VALUE) have been presented in Table 4.13 and illustrated in Figure 4.13

It is evident from Table 4.13 and Figure 4.13 that different treatments have shown statistically non significant variation of chlorophyll content in leaves (SPAD value).

The chlorophyll content in leaves was varied from 58.76 to 64.03. The maximum chlorophyll content in leaves (64.03) was recorded in T_7 (85% NPK + Azotobacter + PSB). However, the minimum Chlorophyll content (58.76) was recorded with T_8 (75% RDF + Azotobacter).

Table 4.13: Chlorophyll content in leaves

Symbol	Treatments	Chlorophyll content in leaves
T_1	RDF	58.76
T_2	RDF + Azotobacter	61.15
T_3	RDF + PSB	61.68
T_4	RDF + Azotobacter +PSB	63.44
T_5	85% RDF + Azotobacter	62.03
T_6	85% RDF + PSB	62.33
T_7	85% RDF + Azotobacter +PSB	64.03
T_8	75% RDF + Azotobacter	59.34
T_9	75% RDF + PSB	59.92
T_{10}	75% RDF + Azotobacter +PSB	62.89
SE(m)±		**1.28**
C.D. at 5%		**3.81**

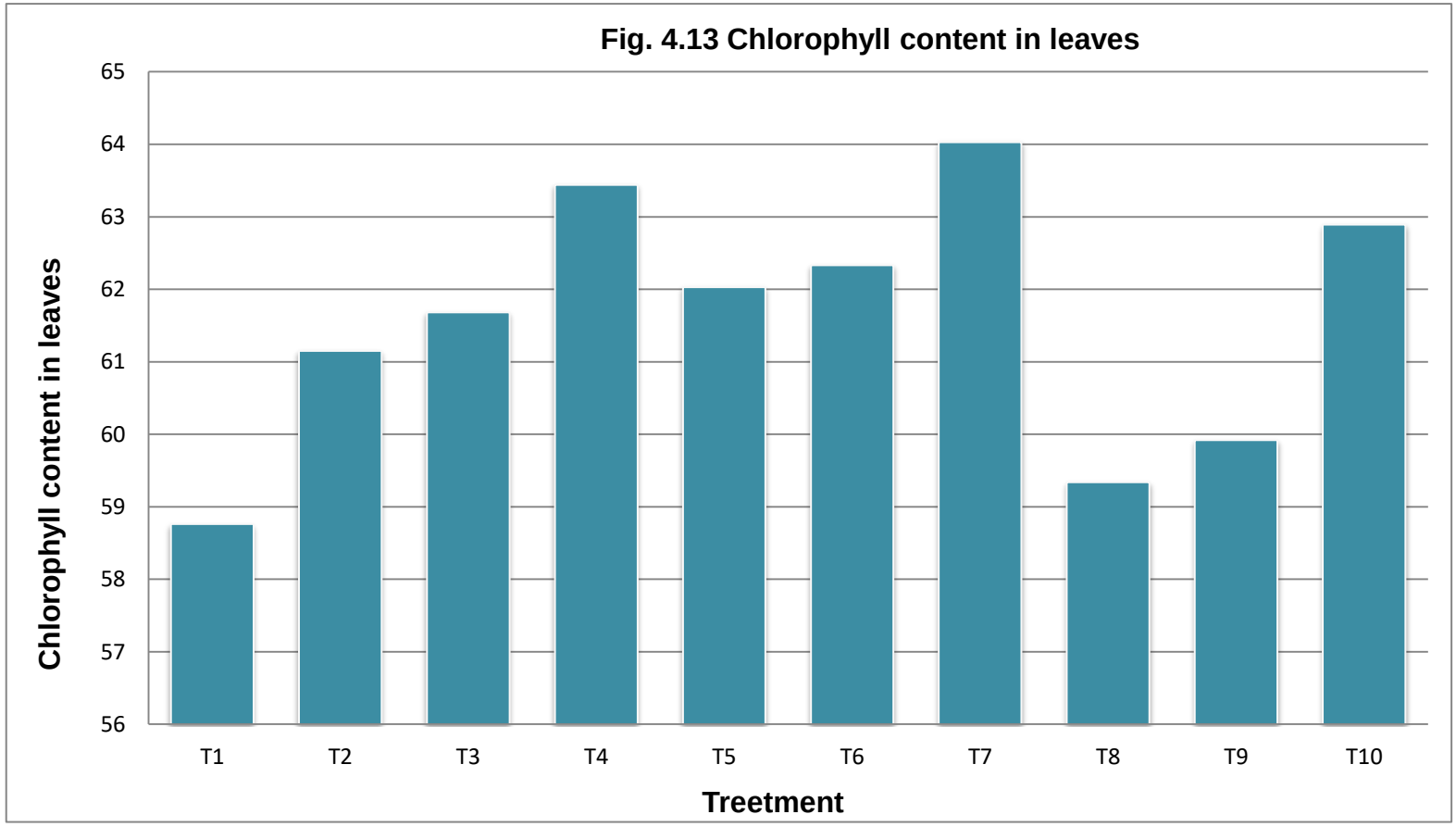


Fig. 4.13 Chlorophyll content in leaves
Chlorophyll content in leaves
65
64
63
62
61
60
59
58
57
56
T1
T2
T3
T4
T5
T6
T7
T8
T9
T10
Treetment

4.5 Yield Parameters:

4.5.1 No. of flower / plant:

The data related to number of flower per plant have been presented in Table 4.14 and illustrated in Figure 4.14

It is evident from Table 4.14 and Figure 4.14 that different treatments have shown statistically significant variation with respect to number of flower per plant.

The number of flower per plants was varied from 23.17 to 27.97. The maximum number of flower per plants (27.97) was recorded by T_7 (85% NPK + Azotobacter + PSB) followed by T_4 (100% NPK + Azotobacter + PSB) which recorded value of 27.83 and all of these treatment showed statistically similar to each other. However, the minimum number of flower per plants (23.17) was recorded by T_1 (RDF).

Table 4.14: No. of flower / plant

Symbol	Treatments	No. of flower / plant
T_1	RDF	23.17
T_2	RDF + Azotobacter	24.50
T_3	RDF + PSB	24.67
T_4	RDF + Azotobacter +PSB	27.83
T_5	85% RDF + Azotobacter	25.17
T_6	85% RDF + PSB	25.67
T_7	85% RDF + Azotobacter +PSB	27.97
T_8	75% RDF + Azotobacter	23.67
T_9	75% RDF + PSB	24.17
T_{10}	75% RDF + Azotobacter +PSB	26.33
SE(m)±		**0.54**
C.D. at 5%		**1.61**

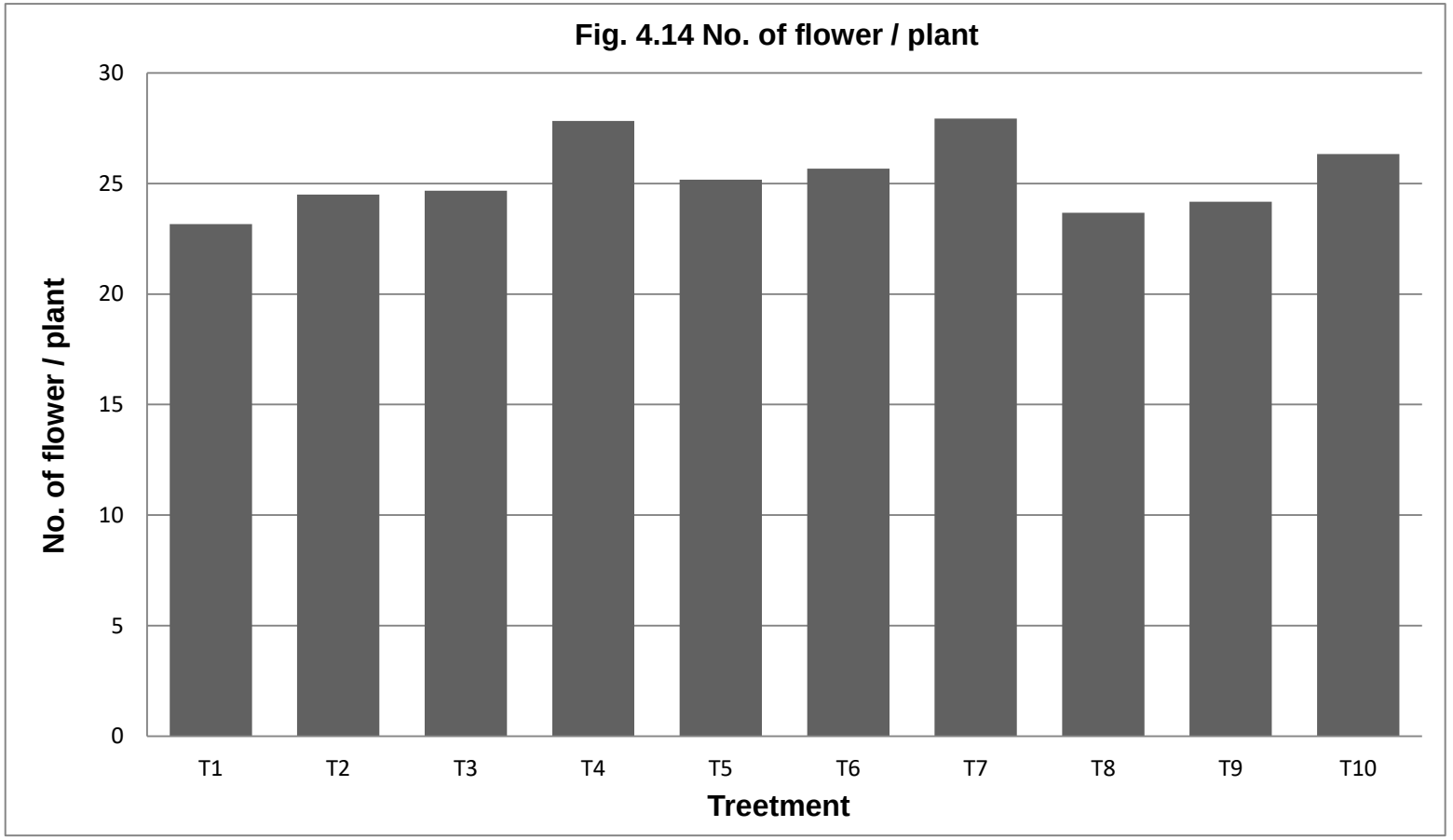


Fig. 4.14 No. of flower / plant
No. of flower / plant
30
25
20
15
10
5
0
T1
T2
T3
T4
T5
T6
T7
T8
T9
T10
Treetment

4.5.2 Flower yield / plant:

The data related to flower yield per plant (g) have been represented in Table 4.15 and illustrated in Figure 4.15

It is evident from Table 4.15 and Figure 4.15 that different treatments have significant variation with respect to flower yield per plant (g).

The flower yield per plant (g) was varied from 52.43 g to 79.13 g. The maximum flower yield per plant (79.13 g) was recorded by by T_7 (85% NPK + Azotobacter + PSB) followed by T_4 (100% NPK + Azotobacter + PSB) and T_{10} (75% NPK + Azotobacter + PSB), which recorded values of 77.90 g and 76.43 g respectively and all of these treatments are statistically at par to each other. However, the minimum flower yield per plant (52.43 g) was recorded by T_1 (RDF).

Table 4.15: Flower yield / plant (g)

Symbol	Treatments	Flower yield / plant (g)
T_1	RDF	52.43
T_2	RDF + Azotobacter	58.83
T_3	RDF + PSB	60.84
T_4	RDF + Azotobacter +PSB	77.90
T_5	85% RDF + Azotobacter	61.92
T_6	85% RDF + PSB	64.57
T_7	85% RDF + Azotobacter +PSB	79.13
T_8	75% RDF + Azotobacter	54.47
T_9	75% RDF + PSB	56.32
T_{10}	75% RDF + Azotobacter +PSB	76.43
SE(m)±		**1.55**
C.D. at 5%		**4.62**

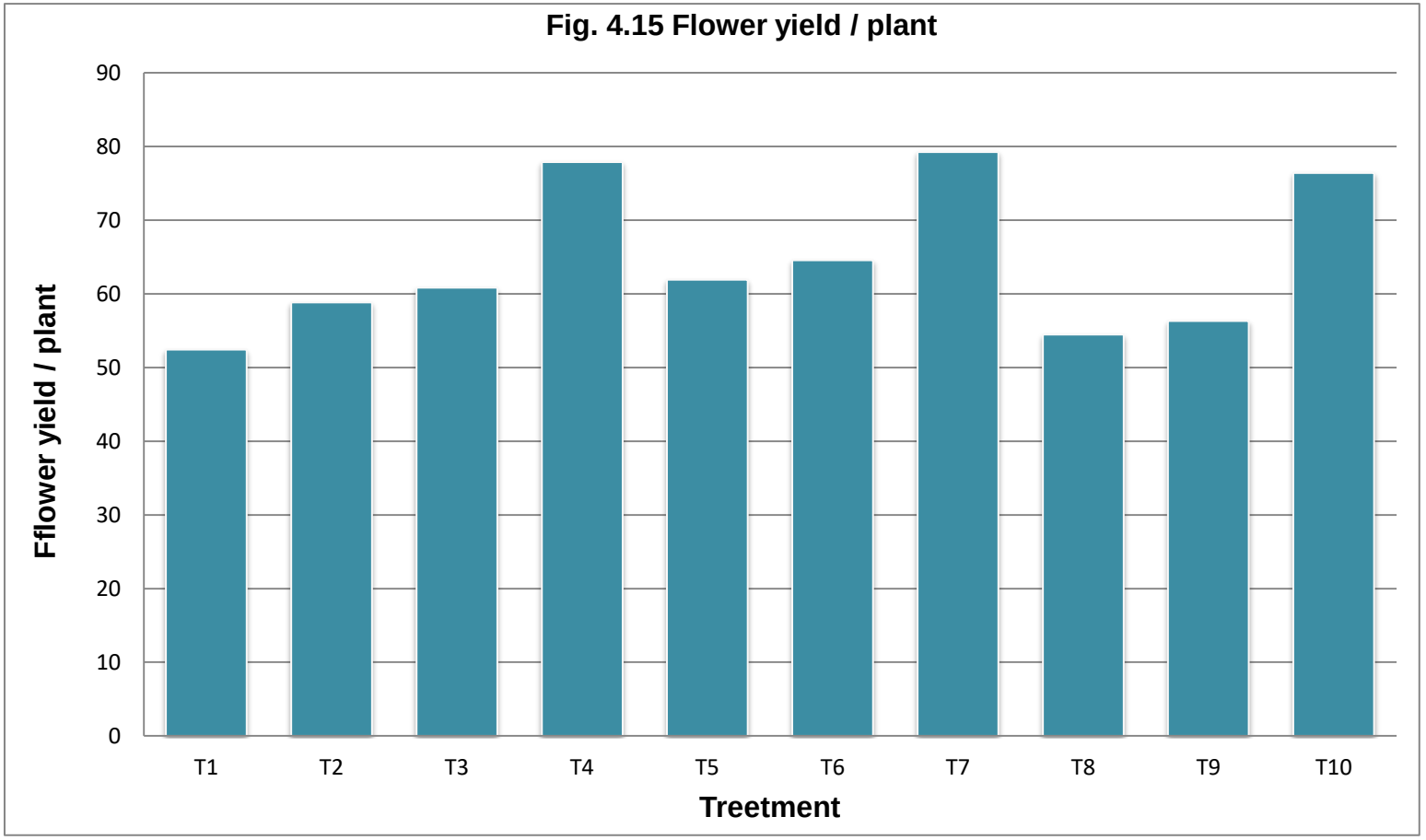


Fig. 4.15 Flower yield / plant
Fflower yield / plant
90
80
70
60
50
40
30
20
10
0
T1
T2
T3
T4
T5
T6
T7
T8
T9
T10
Treetment

4.5.3 Flower yield / plot:

The data related to flower yield per plot (g) have been represented in Table 4.16 and illustrated in Figure 4.16

It is evident from Table 4.16 and Figure 4.16 that different treatments have significant variation with respect to flower yield per plot (g).

The flower yield per plot was varied from 1887.60 g to 2853.64 g. The maximum flower yield per plot (2853.64 g) was recorded by T_7 (85% NPK + Azotobacter + PSB) followed by T_4 (100% NPK + Azotobacter + PSB) and T_{10} (75% NPK + Azotobacter + PSB), which recorded values of 2804.40 g and 2751.60 g respectively. However, the minimum flower yield per plot (1887.60 g) was recorded by T_1 (RDF).

Table 4.16: Flower yield / plot

Symbol	Treatments	Flower yield / plot
T_1	RDF	1887.60
T_2	RDF + Azotobacter	2118.00
T_3	RDF + PSB	2190.24
T_4	RDF + Azotobacter +PSB	2804.40
T_5	85% RDF + Azotobacter	2229.00
T_6	85% RDF + PSB	2324.40
T_7	85% RDF + Azotobacter +PSB	2853.64
T_8	75% RDF + Azotobacter	1960.80
T_9	75% RDF + PSB	2027.40
T_{10}	75% RDF + Azotobacter +PSB	2751.60
SE(m)±		**63.75**
C.D. at 5%		**189.42**

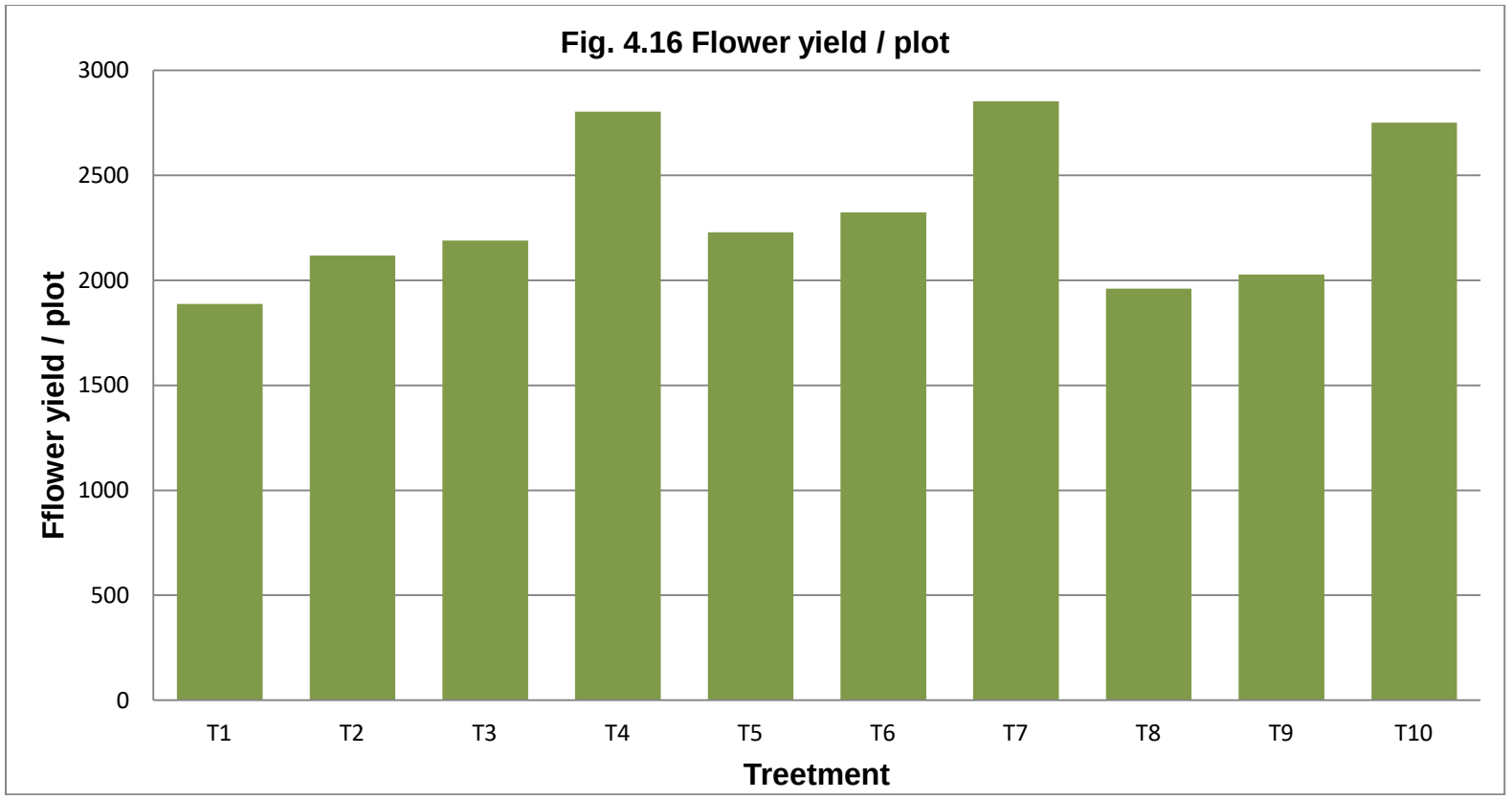


Fig. 4.16 Flower yield / plot
3000
2500
2000
1500
1000
500
0
Fflower yield / plot
T1
T2
T3
T4
T5
T6
T7
T8
T9
T10
Treetment

CHAPTER –V
DISCUSSION

The present investigation entitled: **"Effect of bio-fertilizers on growth, flowering and yield of China aster (*Callistephus chinensis* L.)."** in the prior chapter all the findings which have described the same will be discussed here in detail.

5.1 Growth Parameters

5.1.1 Plant height (cm):

The data in the Table 4.1 is the indication that different bio-fertilizer treatments have shown statistically significant variation with respect to plant height.

The maximum plant height at 60 DAT was found in treatment T_4 (100% RDF + Azotobacter + PSB) followed by T_7 (85% RDF + Azotobacter + PSB) and T_{10} (75% RDF + Azotobacter + PSB). A similar trend was observed in 90 DAT and maximum plant height was found in T_4 (100% RDF + Azotobacter + PSB). The minimum plant height at 60 and 90 DAT were observed with T_9 (75% RDF + PSB).

The use of bio-fertilizers with the recommended fertiliser dose, the solubility and consumption of nutrients, and the production of plant growth regulators such as IAA, GA, and cytokinins, as well as vitamins and organic acids, are all probable reasons for the increase in plant height (Chaudhary *et al.* 2019).

The stimulating and beneficial effects of bio-fertilizers result in better plant nutrition, thereby increasing the activity of photosynthesis. Because nitrogen is a major component of nucleic acids, phosphorus, being a major component of chlorophyll and protoplasm, converts photosynthesis into phospholipids resulting in substantial vegetative growth (Singh *et al.* 2017).

These results were advocated by Chaitra and Patil (2007), Kirar *et al.* (2009) and Bohra *et al*. (2019) in China aster.

5.1.2 Number of leaves / plant:

The data in the Table 4.2 is the evidence that different bio-fertilizer treatments have shown statistically significant variation with respect to number of leaves / plant.

The maximum number of leaves per plant at 60 DAT was recorded with treatment T_7 (85% RDF + Azotobacter + PSB) followed by T_4 (NPK + Azotobacter + PSB) and T_{10} (75% RDF + Azotobacter + PSB). A similar trend was observed in 90 DAT maximum numbers of leaves observed with T_7 (85% RDF + Azotobacter + PSB). The minimum number of leaves at 60 and 90 DAT was observed with T_8 (75% RDF + Azotobacter).

The application of 85% NPK, as well as the inoculation of Azotobacter and PSB, boosted the number of leaves by enhancing cell division and cell enlargement, as well as producing growth promoting hormones like auxins, cytokinins and gibberellins etc (Chaitra and Patil 2007). These findings were consistent with the findings of other researchers, such as Kumar *et al*. (2003), Kirar *et al.* (2009) and Singh *et al.* (2017) in China aster, Kumar *et al*. (2009) in marigold.

5.1.3 Leaf area (cm):

The data in the Table 4.3 is the evidence that different bio-fertilizer treatments have shown statistically significant variation with respect to leaf area (cm).

T_4 (100% RDF + Azotobacter + PSB) had the maximum leaf area per plant at 60 DAT, followed by T_7 (85% RDF + Azotobacter + PSB), T_{10} (75 % RDF + Azotobacter + PSB), T_3 (100% RDF + PSB) and T_2 (100% RDF + Azotobacter). A similar trend was observed in 90 DAT and maximum leaf area observed with T_4 (100% RDF + Azotobacter + PSB). The minimum leaf area at 60 and 90 DAT were observed T_1 (RDF).

Leaf area increased with treatment T_4, which consisted of 100% NPK + Azotobacter + PSB. The use of NPK and bio-fertilizer in combination has improved the availability of nitrogen and phosphate to plants, as well as the production of many growth hormones such as auxins, cytokinins and gibberellins. Because of the bioactive compounds generated by Azotobacter

and PSB the increased leaf area may be linked to enhanced cell division and elongation (Bhagat, R.K., 2017).

These results are confirmed by Singh *et al*. (2017) in China aster and Kumura *et al.* (2019) in African marigold.

5.1.4 Plant spread (cm):

The data in the Table 4.4 is the evidence that different bio-fertilizer treatments have shown statistically significant variation with respect to plant spread.

The maximum plant spread per plant at 60 DAT was recorded T_4 (100% RDF + Azotobacter + PSB) followed by T_7 (100% RDF + Azotobacter + PSB), T_{10} (75% RDF + Azotobacter + PSB) T_2 (85% RDF + Azotobacter), T_3 (85% RDF + PSB). A similar trend was observed in 90 DAT maximum plant spread observed T_4 (100% RDF + Azotobacter + PSB). The minimum plant spread at 60 and 90 DAT were observed T_9 (85% RDF + PSB).

In comparison to other treatments, the findings clearly indicated that combining Azotobacter and PSB with 100 % NPK was beneficial for maximum plant spread. Azotobacter is a free-living bacterium that plays a key role in increasing soil fertility by fixing atmospheric nitrogen. Nitrogen promotes the creation of new cells, cell division, and cell elongation (Panchal *et al*. 2010). It's possible that the maximum plant spread was achieved as a result of the development of new cells in the meristem, which grew in size and produced more cells (Marak *et al.* 2020).

The similar findings have also been reported by Singh *et al.* (2017) and Sowmya and Prasad (2017) in China aster and Krushnaiah *et al.* (2018) in Italian aster.

5.1.5 No. of branches / plant:

The data in the Table 4.5 is the evidence that different bio-fertilizer treatments have shown statistically significant variation with respect to number of branches per plant.

The maximum number of branches per plant at 60 DAT was recorded treatment T_7 (85% RDF + Azotobacter + PSB) followed by T_4 (100% RDF + Azotobacter + PSB), T_{10} (75% RDF + Azotobacter + PSB), T_6 (85% RDF +

PSB) and T_5 (85% RDF + Azotobacter). A similar trend was observed in 90 DAT maximum branches per plant observed with T_7 (85% RDF + Azotobacter + PSB). The minimum number of branches per plant at 60 and 90 DAT were observed T_1 (RDF).

These findings might be explained by role of Azotobacter in nitrogen fixation and the synthesis of growth-promoting substance like IAA and gibberellins, which could lead to the apical dominance being broken and axillary buds sprouting, resulting in a more number of branches per plant (Singh *et al.* 2017).This evidently shows the helpful effect of Azotobacter and PSB with inorganic fertilizers in escalating the number of branches per plant.

These results were advocated by Chaitra and Patil (2007) and Marak *et al.* (2020) in China aster.

5.1.6 Stem diameter

The data in the Table 4.6 is the evidence that different bio-fertilizer treatments have shown statistically significant variation with respect to stem diameter.

The maximum stem diameter per plant at 60 DAT was recorded treatment T_4 (100% RDF + Azotobacter + PSB) followed by T_7 (85% RDF + Azotobacter + PSB), T_{10} (75% RDF + Azotobacter + PSB) and T_3 (100% RDF + PSB). A similar trend was observed in 90 DAT maximum stem diameter per plant observed T_4 (100% RDF + Azotobacter + PSB). The minimum stem diameter at 60 and 90 DAT were observed T_9 (75% RDF + PSB).

Results evidently showed that the joint application of PSB and Azotobacter along with 100% NPK proved to be maximum stem diameter due to vigorous growth of plant as compared to other treatments. This could be because nitrogen and phosphorus with bio-inoculants (PSB and Azotobacter) was found to be beneficial in fixing atmospheric nitrogen and solubilizing fixed phosphorus in soil, as well as secreting growth promoting substances like auxins, which stimulated plant metabolic activities and photosynthetic efficacy, resulting in improved plant growth and development. Similar results have also been investigated by Kirar *et al*. (2009), Marak *et al.* (2020) in China aster, Kumar *et al.* (2009) and Kumura *et al.* (2019) in African marigold.

5.2 Flowering Parameters

5.2.1 Days taken to 1st flower bud initiation:

The data in the Table 4.7 is the evidence that different bio-fertilizer treatments have shown statistically significant variation with respect to days taken to 1st flower bud inititation.

The initial first flower bud appearance was recorded by T_7 (85% NPK + Azotobacter + PSB) and followed by T_{10} (75% NPK + Azotobacter + PSB). Maximum days for first flower bud formation were taken in T_8 (75% NPK + Azotobacter).

Plants that inoculated Azotobacter and PSB with 85% NPK produced the first flower bud due to the emission of growth-promoting substances such as gibberellins, auxin, organic acids and vitamins by bio-fertilizers which accelerated vegetative growth. Phosphorus is a key component and required for initiation of flowering and PSB is known to enhance the accessibility of phosphorus resulting in early flowering. The formation of flower buds was late with the application of 75% NPK+ Azotobacter, which may be due to the fact that the plant's nutritional necessities were not met, so they failed to complete their vegetative stage and flower. Took longer to form buds (Singh *et al*. 2017). Above results were advocated by Singh *et al*. (2017) in China aster, Krushnaiah *et al*. (2018) in Italian aster.

5.2.2 Days taken to opening of flower from bud emergence:

The data in the Table 4.8 is the evidence that different bio-fertilizer treatments have shown statistically significant variation with respect to days taken to opening of flower from bud emergence.

The days taken to opening of flower from bud emergence were minimum application of 85% NPK + Azotobacter + PSB i.e. T_7 followed by T_{10} (75% NPK + Azotobacter + PSB) and T_6 (85% NPK + PSB). However, the maximum days taken to opening of flower from bud emergence was recorded T_8 (75% NPK + Azotobacter).

First flower opening from bud emergence was observed earlier in the plants applied with 85% NPK with Azotobacter and PSB inoculation. The biofertilizers' adequate absorption of nutrients and synthesis of growth-

promoting substances like as gibberellins, auxins, vitamins, and organic acids may be the cause of early blooming. Furthermore, phosphorus is a key component for the initiation of flowering, and PSB have amplified phosphorus availability, resulting in early blooming. Also, the number of days it took the plant to produce a bud may have an effect on the number of days it took for the first flower to open, i.e. the plant that formed the bud first will flower first. Similar variation has also been observed by Chaitra and Patil (2007) and Singh *et al.* (2017) in China aster. The application of 75 percent NPK and Azotobacter, delayed the opening of flowers, which can be attributed to a lack of sufficient nutrition, so the plant to take long time for opening of the flower.

5.2.3 Blooming period (days):

The data in the Table 4.9 is the evidence that different bio-fertilizer treatments have shown statistically significant variation with respect to blooming period.

Maximum blooming period was recorded in plants applied with 85% NPK + Azotobacter + PSB i.e. T_7 followed by T_4 (100 % NPK + Azotobacter + PSB) and T_{10} (75% NPK + Azotobacter + PSB). However, the minimum blooming period was recorded by T_1 (RDF).

Flowers on plants given 85% NPK + Azotobacter + PSB, i.e. T_7, stayed presentable for the longest time. Increased flowering time may be due to the role of NPK in enhancing growth parameters and photosynthate translocation and addition. Similar results were also reported by Singh *et al*. (2017) in China aster, Kumura *et al.* (2019) and Chaudhary *et al*. (2019) in marigold.

5.3 Quality Parameters

5.3.1 Flower stalks length (cm):

The data in the Table 4.10 is the evidence that different bio-fertilizer treatments have shown statistically significant variation with respect to flower stalk length.

The highest flower stalks length was recorded by T_7 (85% NPK + Azotobacter + PSB) followed by T_4 (100% NPK + Azotobacter + PSB) and T_{10}

(75% NPK + Azotobacter + PSB). However, the lowest flower stalk length was recorded by T_1 (RDF).

The plant receiving 85 % NPK + Azotobacter + PSB has the longest flower stem. The high nitrogen and phosphorus absorption from 85% nitrogen and phosphorus, as well as increased nitrogen fixing and phosphorus solubilizing ability and hormone production by the cultures, could explain the large increase in these parameters. Similar variation has also been observed by Kumar *et al.* (2003), Sowmya and Prasad (2017), Singh *et al.* (2017) in China aster and Kumar *et al.* (2009) in marigold.

5.3.2 Flower diameter (cm):

The data in the Table 4.11 is the evidence that different bio-fertilizer treatments have shown statistically important variation with respect to flower diameter.

The maximum flower diameter was observed by T_{10} (75% NPK + Azotobacter + PSB) followed by T_7 (85% NPK + Azotobacter + PSB), T_4 (100% NPK + Azotobacter + PSB) and T_3 (100% NPK + PSB). However, the minimum flower diameter was recorded by T_1 (RDF).

The flower diameter was recorded maximum with treatment T_{10} i.e. 75% NPK + Azotobacter + PSB. This might be due to the plant's proper absorption of nutrients as a result of bio-fertilizer inoculation and improved translocation to the flower. Similar findings as had been observed by Kirar *et al*. (2009), Sowmya and Prasad (2017) and Singh *et al*. (2017) in China aster. The flower diameter in treatments T_4 and T_7 may not have increased any more due to the more flower per plant in these treatments.

5.3.3 Weight of flower (g):

The data in the Table 4.12 is the evidence that different bio-fertilizer treatments have shown statistically significant variation with respect to weight of flower.

The maximum fresh weight of flower was recorded T_{10} (75% NPK + Azotobacter + PSB) followed by T_7 (85% NPK + Azotobacter + PSB), T_4 (100% NPK + Azotobacter + PSB), T_6 (85% NPK + PSB), T_5 (85% NPK +

Azotobacter) and T_3 (100% NPK + PSB). While, the minimum weight of fresh flower was recorded by T_1 (RDF).

Increased fresh weight might be a direct result of organic fertilization, which can effectively stimulate cell growth. (Marak *et al.* 2020). This result got support from Kumar *et al*. (2003), Kirar *et al*. (2009) and Singh *et al.* (2019) in China aster.

5.4 Biochemical Parameters

5.4.1 Chlorophyll content in leaves

The data in the Table 4.13 is the evidence that different bio-fertilizer treatments have shown statistically not significant variation with respect to chlorophyll content in leaves.

The maximum chlorophyll content in leaves was recorded in T_7 (85% NPK + Azotobacter + PSB). However, the minimum Chlorophyll content was recorded T_8 (75% RDF + Azotobacter).

5. Yield Parameters

5.5.1 No. of flower / plant:

The data in the Table 4.14 is the evidence that different bio-fertilizer treatments have shown statistically significant variation with respect to number of flower per plant.

The maximum number of flower per plants was recorded T_7 (85% NPK + Azotobacter + PSB) followed by T_4 (100% NPK + Azotobacter + PSB). However, the minimum number of flower per plants was recorded by T_1 (RDF).

The application of 85% NPK and Azotobacter and PSB inoculation resulted in the highest number of flower per plant. The considerable increase in flowering capacity is likely owing to appropriate NPK absorption from the 85 % NPK in combination with extra nitrogen fixing and phosphorus solubilizing ability, as well as hormone secretion by bio-fertilizers. This result got support from Kumar *et al*. (2003), Chaitra and patil (2007), Kirar *et al*. (2009), Sowmya and Prasad (2017) and Singh *et al.* (2019) in China aster.

5.5.2 Flower yield / plant:

The data in the Table 4.15 is the evidence that different bio-fertilizer treatments have shown statistically significant variation with respect to flower yield per plant.

The highest flower yield per plant was observed T_7 (85% NPK + Azotobacter + PSB) followed by T_4 (100% NPK + Azotobacter + PSB) and T_{10} (75% NPK + Azotobacter + PSB). However, the minimum flower yield per plant was recorded by T_1 (RDF).

T8, i.e. 85% NPK + Azotobacter + PSB, produced the maximum flowers per plant. It might be related to the bio-fertilizers production of phytohormones, which encouraged root development and caused changes in root shape, affecting nutrient absorption. The increase in flower yield per plant might be attributed to the treatment's faster growth characteristics, such as the number of branches, which raised the number of flowers per plant, resulting in a highest yield of flower per plant (Singh *et al.* 2019). Similar result was found by Kumar *et al*. (2003), Chaitra and patil (2007), Kirar *et al*.(2009) and Sowmya and Prasad (2017) in China aster.

5.5.3 Flower yield / plot:

The data in the Table 4.16 is the evidence that different bio-fertilizer treatments have shown statistically significant variation with respect to flower yield per plot.

The maximum flower yield per plot was recorded T_7 (85% NPK + Azotobacter + PSB) followed by T_4 (100% NPK + Azotobacter + PSB) and T_{10} (75% NPK + Azotobacter + PSB). However, the minimum flower yield per plot was observed by T_1 (RDF).

The treatment of 85 % NPK + Azotobacter + PSB (T_7) resulted in the highest flower production per plot. The increased flower yield per plot under the indicated treatment might be attributable to a higher number of flowers per plot and a higher flower yield per plant. Similar results were also obtained by Singh *et al*. (2017) in China aster and Verma *et al*. (2011) in chrysanthemum.

CHAPTER – VI
SUMMARY, CONCLUSIONS AND SUGGESTIONS FOR FURTHER WORK

6.1 Summary

The current experiment permitted **"Effect of bio-fertilizers on growth, flowering and yield of China aster (*Callistephus chinensis* L.)"** was conducted during the phase from November, 2020 to April, 2021 at the Bahadari research farm, Department of Floriculture and Landscape Architecture, College of Horticulture, Mandsaur, R.V.S.K.V.V., Gwalior (M.P.). Ten treatments were layout in a randomized block design (RBD) with three replications.

During the course of study, the observations were recorded on growth characters like, plant height (cm) 60 and 90 DAT, number of leaf per plant 60 and 90 DAT, leaf area (cm) 60 and 90 DAT, number of branches per plant 60 and 90 DAT and stem diameter per plant 60 and 90 DAT. As regards flowering observations on days occupied to 1st flower bud initiation, days taken to opening of flower from bud emergence, blooming period (days). With respect to quality parameters flower stalk length (cm), flower diameter (cm), weight of flower (g). Biochemical parameters chlorophyll content in leaves (SPAD VALUE) and yield parameter number of flower per plant, flower yield per plant, flower yield per plot.

It is clear from the data that all the characters were significantly affected by different bio-fertilizers treatments. The effect of different treatment combinations on various characters of China aster has been summarized below.

A. Growth Parameter

The maximum plant height (cm) 60 and 90 DAT was observed in treatment T_4 (100% RDF + Azotobacter + PSB), whereas, minimum plant height was found in T_9 (75% RDF + PSB).

The maximum number of leaves 60 and 90 DAT was observed in treatment T_7 (85% RDF + Azotobacter + PSB), while, minimum number of leaves was found in T_8 (75% RDF + Azotobacter).

The maximum leaf area (cm) 60 and 90 DAT was observed in treatment T_4 (100% RDF + Azotobacter + PSB), whereas, minimum leaf area (cm) was found in T_1 (RDF).

The maximum plant spread (cm) 60 and 90 DAT was observed in treatment T_4 (100% RDF + Azotobacter + PSB), while, minimum plant spread (cm) was found in T_9 (75% RDF + PSB).

The maximum number of branches per plant 60 and 90 DAT was observed in treatment T_7 (85% RDF + Azotobacter + PSB), while, minimum number of branches (cm) was found in T_1 (RDF).

The maximum stem diameter (mm) per plant 60 and 90 DAT was observed in treatment T_4 (100% RDF + Azotobacter + PSB), while, minimum stem diameter (mm) was found in T_8 (75% RDF + Azotobacter).

B. Flowering Parameter

The earliest first flower bud initiation was recorded by T_7 (85% RDF + Azotobacter + PSB) and the most delayed first flower bud initiation was recorded with T_8 (75% RDF + Azotobacter).

The earliest opening of flower from bud emergence was recorded by T_7 (85% RDF + Azotobacter + PSB) and the most delayed first flower bud initiation was recorded with T_8 (75% RDF + Azotobacter).

The maximum blooming period was recorded with T_7 (85% RDF + Azotobacter + PSB) and minimum blooming period was recorded with T_1 (RDF).

C. Quality Parameter

The maximum flower stalk length was recorded by T_7 (85% RDF + Azotobacter + PSB) and the minimum flower stalk length was recorded with T_1 (RDF).

The maximum flower diameter was recorded by T_{10} (75% RDF + Azotobacter + PSB) and the minimum flower diameter was recorded with T_1 (RDF).

The Maximum weight of flower was recorded by T_{10} (75% RDF + Azotobacter + PSB) and the minimum weight of flower was observed with T_1 (RDF).

D. Biochemical Parameter

The Maximum chlorophyll content in leaves par plant was recorded by T_7 (85% RDF + Azotobacter + PSB) and the lowest chlorophyll content in leaves par plant was observed with T_8 (75% RDF + Azotobacter).

D. Yield Parameter

The maximum number of flower par plant was recorded by T_7 (85% RDF + Azotobacter + PSB) and the lowest number of flower par plant was observed with T_1 (RDF).

The maximum flower yield par plant was recorded by T_7 (85% RDF + Azotobacter + PSB) and the minimum flower yield par plant was recorded with T_1 (RDF).

The maximum flower yield par plot was recorded by T_7 (85% RDF + Azotobacter + PSB) and the minimum flower yield was recorded with T_1 (RDF).

6.2 Conclusions

In the current study, the different combinations of bio-fertilizers and RDF had considerable influence on the growth, flowering and yields parameters of China aster. On the basis of the results obtained by the investigation entitled **"Effect of bio-fertilizers on growth, flowering and yield of China aster (*Callistephus chinensis* L)"** with Azotobacter and PSB inoculation that different treatment T_7 (85% RDF + Azotobacter + PSB), T_4 (100% RDF + Azotobacter + PSB) and T_{10} (75% RDF + Azotobacter + PSB) show the best results with respect of different parameters.

The treatment T_7 (85% RDF + Azotobacter + PSB) proved better than all other treatments with respect of most of the parameters like number of leaves, number of branches, days taken to 1st flower bud initiation, days taken to opening of flower from bud emergence, blooming period (days), flower stalk length (cm), chlorophyll content in leaves, number of flower per plant, flower yield per plant, flower yield per plot.

The treatment T_4 (100% RDF + Azotobacter + PSB) proved better than all other treatments with respect of plant height (cm), leaf area (cm), plant spread (cm), stem diameter. However T_{10} (75% RDF + Azotobacter + PSB) showed the best results with respect of flower diameter (cm) and weight of flower (g). In addition to achieving higher flower yields, the application of prescribed NPK (100% NPK) can be reduced.

As a result, it can be concluded that an 85% NPK treatment combined with Azotobacter and phosphate solubilizing bacteria was shown to be superior in terms of flower production of China aster.

6.3 Suggestions for future work

Based on the results obtained from the present investigation the following future line of work is suggested:

1. Different concentrations of bio-fertilizers can be taken to find out some more results.
2. Similar studies may be conducted on different varieties of China aster.
3. More number of treatment combinations may be tested on growth and yield of China aster with bio-fertilizer.
4. Effect of bio-fertilizer with pinching and plant growth hormones may be tested on the growth and yield of China aster.

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APPENDICES

Appendix- I: Analysis of variance for Plant height (cm)

Source of variation	D.F.	Mean sum of squares	
		Plant height (cm)	
		60 DAT	90 DAT
Replication	2	0.58	2.57
Treatment	9	10.86	13.35
Error	18	0.54	1.15
Total	29		

Appendix- II: Analysis of variance for Number of leaves/plant

Source of variation	D.F.	Mean sum of squares	
		Number of leaves/plant	
		60 DAT	90 DAT
Replication	2	1.93	7.88
Treatment	9	61.07	61.08
Error	18	3.74	8.04
Total	29		

Appendix- III: Analysis of variance for Leaf area (cm).

Source of variation	D.F.	Mean sum of squares	
		Leaf area (cm)	
		60 DAT	90 DAT
Replication	2	0.63	0.99
Treatment	9	4.45	5.24
Error	18	0.78	0.28
Total	29		

Appendix- IV: Analysis of variance for Plant spread (cm)

Source of variation	D.F.	Mean sum of squares	
		Plant spread (cm)	
		60 DAT	90 DAT
Replication	2	1.10	0.24
Treatment	9	6.30	6.23
Error	18	0.90	0.63
Total	29		

Appendix- V: Analysis of variance for No. of branches/plant

Source of variation	D.F.	Mean sum of squares	
		No. of branches/plant	
		60 DAT	90 DAT
Replication	2	0.20	2.50
Treatment	9	2.25	2.33
Error	18	0.18	0.81
Total	29		

Appendix- VI: Analysis of variance for Stem diameter

Source of variation	D.F.	Mean sum of squares	
		Stem diameter	
		60 DAT	90 DAT
Replication	2	0.00	0.67
Treatment	9	1.02	2.06
Error	18	0.03	0.25
Total	29		

Appendix- VII: Analysis of variance for Days taken to 1st flower bud initiation

Source of variation	D.F.	Mean sum of squares
		Days taken to 1st flower bud initiation
Replication	2	0.26
Treatment	9	10.33
Error	18	0.94
Total	29	

Appendix- VIII: Analysis of variance for Days taken to opening of flower from bud emergence

Source of variation	D.F.	Mean sum of squares
		Days taken to opening of flower from bud emergence
Replication	2	0.41
Treatment	9	7.95
Error	18	0.74
Total	29	

Appendix- IX: Analysis of variance for Blooming period (days)

Source of variation	D.F.	Mean sum of squares
		Blooming period (days)
Replication	2	0.80
Treatment	9	8.05
Error	18	1.23
Total	29	

Appendix- X: Analysis of variance for Flower stalk length (cm)

Source of variation	D.F.	Mean sum of squares
		Flower stalk length (cm)
Replication	2	0.42
Treatment	9	8.80
Error	18	0.61
Total	29	

Appendix- XI: Analysis of variance for Flower diameter (cm)

Source of variation	D.F.	Mean sum of squares
		Flower diameter (cm)
Replication	2	0.05
Treatment	9	1.10
Error	18	0.12
Total	29	

Appendix- XII: Analysis of variance for Weight of flower (g)

Source of variation	D.F.	Mean sum of squares
		Weight of flower (g)
Replication	2	0.17
Treatment	9	0.16
Error	18	0.07
Total	29	

Appendix- XIII: Analysis of variance for Chlorophyll content in leaves

Source of variation	D.F.	Mean sum of squares
		Chlorophyll content in leaves
Replication	2	6.89
Treatment	9	9.29
Error	18	4.93
Total	29	

Appendix- XIV: Analysis of variance for No. of flower / plant

Source of variation	D.F.	Mean sum of squares
		No. of flower / plant
Replication	2	0.15
Treatment	9	8.10
Error	18	0.88
Total	29	

Appendix- XV: Analysis of variance for Flower yield/plant

Source of variation	D.F.	Mean sum of squares
		Flower yield/plant
Replication	2	6.06
Treatment	9	300.35
Error	18	7.25
Total	29	

Appendix- XVI: Analysis of variance for Flower yield/plot

Source of variation	D.F.	Mean sum of squares
		Flower yield/plot
Replication	2	4860.24
Treatment	9	391002.60
Error	18	12193.82
Total	29	

VITA

The author of this thesis **Mr. Sunil Kumar Gupta** S/o Mr. Vijay Narayan Gupta and Anita Gupta was born on 5th February 1994 in Village Gopalpur, Post Silphili, Tehsil/District Surajpur, Surguja at Chhatisgarh. He passed High School from Sharda Public Higher Secondary School, Silphili and Higher Secondary School from Govt. Multipurpose Higher Secondary School, Ambikapur (Surguja) (C.G.).

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He is now submitting the thesis after completing the course with 7.18 OGPA out of 10.00-point scale.

(**Mr. Sunil Kumar Gupta**)