PERFORMANCE ANALYSIS OF TISSUE CULTURE PLANTLETS OF *Gerbera jamesonii* Bolus. AS INFLUENCED BY MICROBIAL INOCULANTS

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by

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THESIS

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KERALA, INDIA

2016

DECLARATION

I, hereby declare that this thesis entitled **"Performance analysis of tissue culture plantlets of G*erbera jamesonii* Bolus. as influenced by microbial inoculants"** is a bonafide record of research work done by me during the course of research and that the thesis has not previously formed the basis for the award of any degree, diploma, associateship, fellowship or other similar title, of any other University or Society.

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EXTERNAL EXAMINER

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कर्मण्येवाधिकारस्ते मा फलेषु कदाचन ।

मा कर्मफलहेतुर्भूर्मा ते संगोऽस्त्वकर्मणि ।।

(You have the right to work only but never to its fruits.
Let not the fruits of action be your motive, nor let your attachment be to inaction)
Shreemad Bhagawad Geeta
Chapter 2, Verse 47

SHEWTHASHRI MOHANAN
(2014-12-115)

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LIST OF ABBREVIATIONS

%	-	per cent
&	-	and
^{0}C	-	Degree Celsius
AMF	-	Arbuscular Mycorrhizal Fungi
ANOVA	-	Analysis of variance
CD (0.05)	-	Critical difference at 5 % level
cm	-	centimeter
et al.	-	and co-workers/co-authors
Fig.	-	Figure
FYM	-	Farm yard manure
g	-	gram
i.e.	-	that is
kg	-	kilogram
KAU	-	Kerala Agricultural University
klx	-	Kilolux
m^2	-	Square meter
MSL	-	Mean Sea Level
PGPR	-	Plant Growth Promoting Rhizobacteria
RH	-	Relative humidity
sp.	-	Species
Var	-	Variety

Introduction

1. INTRODUCTION

Gerbera is an attractive commercial cut flower native to tropical Asia and Africa comprising 45 species which belongs to the family Asteraceae (Compositae). *Gerbera jamesonii* Bolus. is a widely cultivated species all over the world which ranks fifth in position among cut flowers (Karishma *et al* ., 2013). The change in social fabric of people and increased urban affluence led to a rise in the cut flower production in the country during the past two to three decades where gerbera fetches a prominent position among cut flowers.

Being an important cut flower economic goal in commercial production of gerbera include improvement of quality attributes such as flower size, longevity etc. Profitability and wider adaptability of gerbera among the public had paved way for exploitation of available resources such as soil and agrochemicals for maximization of production. Because of the side effect of different agrochemicals, there is an increasing interest in understanding the co-operative activities of soil microbial population and their application in the field of agriculture.

Beneficial interaction between microbial inoculants and horticultural crops gives enhanced productivity, increased nutrient uptake, less transplanting shock, increased resistance to biotic and abiotic stress etc. Commonly used microbial inoculants include A*rbuscular Mycorrhizal F*ungi (AMF), Phosphate Solubilizing Bacteria *Pseudomonas fluorescence*, Plant Growth Promoting Rhizobacteria (PGPR) etc.

AMF have a prominent role in enhancing the acclimatization of micropropagated plantlets, resistance and regrowth in the main field. Because of this reason AMF are gaining popularity as biofertilizers, bioprotectors and biocontrol agents. *Pseudomonas fluorescens* are non-pathogenic saprophytes that colonizes soil and plant surface which helps to suppress diseases and enhance the crop production. PGPR triggers uptake of bioavailable phosphorus, nitrogen fixation for plant use, sequestration of iron for plants by siderophores, production of plant hormones like auxins, cytokinins and gibberellins and lowering of plant ethylene levels (Glick, 1995).

Microbial inoculants plays a major role in sustaining the soil productivity and reducing the usage of agrochemicals. In this context the present study was undertaken using *Gerbera jamesonii* Bolus. variety Esmara. The aim of the work was to analyse the performance of gerbera treated with different microbial inoculants.

Review of Literature

2. REVIEW OF LITERATURE

Gerbera (*Gerbera jamesonii* Bolus.) is the most popular ornamental flower commercially used both as cut flower and as pot plant and therefore is of ample economic interest. This flower is commonly known as Transvaal daisy or Barberton daisy. The interest of agribusiness involving gerbera as cut flower is evident as demonstrated by continuous increase in the production and commercialization in many countries around the world. It is a perennial herb with silky hairs and deeply lobed leaves arising from a crown. Inflorescence is borne on long stalk. The outer florets (ray florets) are red, orange, pink etc. and the inner florets (disc florets) are greenish yellow or cream. The elegant flowers with sturdy flower stalks , the good array of colours and long vase life make the flowers quite attractive to consumers. Since the flowers are hard and withstand transportation shock, gerbera fetches a good market price. In India, it is fast catching on among the general circles of Indian public (Thomas *et al*., 2004).

Since the usage of different agrochemicals is increasing in the field of agriculture, there is a rising interest in understanding the activities of soil microbial population in the field (Lucy *et al.*, 2004). *Arbuscular mycorrhizal* fungi and phosphate solubilizing bacteria are two major groups of microbial inoculants that act as biofertilizers. In most of the terrestrial plants, AMF is an important symbiotic organism (Parniske, 2008). Plant growth promoting rhizobacteria (PGPR) and Arbuscular mycorrhizal fungi (AMF) are the most important plant interactive microbes (Perotto and Bonfante, 1997). The PGPR have been reported to increase growth and productivity of many commercial crops including rice (Ashrafuzzaman *et al*., 2009), wheat (Khalid *et al*., 2004), cucumber (Maleki *et al*., 2010), maize (Sandhya *et al*., 2010), cotton (Anjum *et al*., 2007), black pepper (Dastager *et al*., 2010) and banana (Mia *et al*., 2010).

Free-living plant growth-promoting rhizobacteria (PGPR) can be used in a variety of ways when plant growth enhancements are required. In agriculture and horticulture, field uses of PGPR has been intensively researched. For the enhanced agricultural production, different commercial formulations of PGPR mixes are available in the market. Forest regeneration, phytoremediation of

contaminated soil etc. are the major research areas including PGPR. In both managed and natural ecosystems, beneficial plant-associated bacteria play a key role in supporting and/or increasing plant health and growth. PGPR, root-colonizing bacteria are known to influence plant growth by various direct or indirect mechanisms. PGPR induces several chemical changes in the soil. It is reported that PGPR can influence the growth, yield, and nutrient uptake by an array of mechanisms (Saharan and Nehra, 2011). The understanding of colonization processes is important to better predict how bacteria interact with plants and whether they are likely to establish themselves in the plant environment after field application as biofertilizers or biocontrol agents (Compant *et al.*, 2010).

PGPR MIX II is a consortium of highly compatible rhizobacteria having broad spectrum of inhibitory property with different mechnanisms. Bacteria promote plant growth and have better ability to multiply and persist in varying soil conditions. PGPR mix I is a compatible consortium of N, P and K biofertilizers and helps to save 25% N, P and K fertilizers. Methods of application and dose are same as that of azospirillium. Fluorescent pseudomonas are a group of bacteria which is found to be effective for disease management and crop growth promotion (KAU, 2009).

2.1 EFFECT OF MICROBIAL INOCULANT TREATMENTS ON SURVIVAL PERCENTAGE

Mohamed and Vidaver (1990) reported that the acclimatized tissue culture plantlets of gerbera inoculated with microbial inoculants showed highest survival percent as that of intact plants. AMF Symbiosis provides a greater resistance to water stress and root pathogens during acclimatization (Vidal *et al*., 1992). Gónzalez-Chávez and Ferrera-Cerrato, R. (1994) found out that AMF inoculation during plantlet acclimatization improves the growth and development of micro propagated plants.

Lovato *et al.* (1995) found out that the application of AMF in horticultural crops enhances the survival and growth rates of plantlets in greenhouse and open conditions. Lovato *et al.* (1996) reported that AMF inoculation is beneficial

during the acclimatization period which helps to colonize the developing root and gains from early symbiosis. According to Vestberg *et al.* (2002) inoculation of AMF enhances the acclimatization of *in vitro* micro propagated plants.

Plantlets of *in vitro* raised chrysanthemum plantlets of cv. Yellow Bangla inoculated with mixed AMF gave the highest survival (94.89%) and root colonization (66.23%) (Kumar *et al.,* 2014).

2.2 EFFECT OF MICROBIAL INOCULANT TREATMENTS ON VEGETATIVE PARAMETERS

Pseudomonas fluorescence strain E6 enhanced growth of sunflower, carnation, and zinnia when inoculated on rooted cuttings (Yuen and Schroth, 1985). They also reported that growth of zinnia, sunflower, stock, vinca and carnation was enhanced with increases averaging from 18-41 per cent over that of untreated controls. Koide (1993) reported that AMF treatments showed better results than non-inoculated treatments with respect to plant length, leaf area, fresh and dry leaf weight, total *in situ* chlorophyll content, root volume, and fresh root weight. Improved root growth with the inoculation of AM fungi can be attributed to growth hormone production and increased nutrient uptake (Azcon-Aguilar and Barea, 1996).

Gaur and Adholeya (2000) reported that mycorrhizal inoculation of seedlings led to marked improvement in both vegetative and reproductive growth of ornamental plants. Shivakumar *et al*. (2002) found out that there was an increase in biomass of geranium plants when inoculated with *P. fluorescence* and AM fungi. Chaitra (2006) also reported an increase in leaf area and flower yield per plant with the application of biofertilizers + vermicompost + 50 per cent recommended dose of NPK fertilizers in China aster.

Vikram (2007) reported that fluorescent pseudomonas, a group of PGPR which has the efficiency to enhance the overall growth of crops. Mortimer *et al*. (2008) reported that AMF have been found to increase plant growth and Banchio *et al.* (2009) reported that sweet basil inoculated with PGPR showed an increase in growth parameters. Amaya-Carpio *et al*. (2009) observed that addition of AMF helps plants to acquire and mobilize nutrients and enhance plant growth.

Schmedit *et al*. (2010) observed higher leaf area in bioinoculant inoculated plants of *Tagetes* which could be the result of increased phosphorus uptake. Magar *et al*. (2010) reported that gerbera Variety Esmara (70.49 cm) recorded maximum plant spread compared to variety Popov. Prasad *et al.* (2012) recorded that mycorrhizal inoculation (*G. mosseae* and *A. laevis*) with *P. fluorescens* enhanced plant height and leaf area in chrysanthemum in comparison to the control.

Karishma *et al.* (2013) found out that inoculation of gerbera with bio inoculants (AMF, *P. fluorescens*) enhanced the leaf number over control. According to Cappellari *et al.* (2013) inoculation of plants with *P. fluorescens* significantly increased the shoot fresh weight. Similar findings were noticed in leaf number and node number. There was an increase of 33 per cent of leaf number in *P. fluorescens* inoculated and co inoculated plants than in control.

Leaf number and area was observed to be maximum in T_4 i.e. mixed AMF inoculated chrysanthemum plantlets. Irrespective of duration and treatment, maximum plant height was observed in plantlets inoculated with T_4 (32.34 cm) (Kumar *et al*., 2014).

2.3 EFFECT OF MICROBIAL INOCULANT TREATMENTS ON FLOWERING CHARACTERS

AMF induces earlier flowering and fruiting in horticultural crops (Lovato *et al*., 1995). Sohan *et al.* (2002) reported that AMF inoculated plants significantly shortened flowering time compared to non-AMF plants. Sohn *et al.* (2003) observed that inoculation of AMF resulted in early flowering in *Chrysanthemum*. Sohan *et al.* (2003) indicated that early inoculation of AMF induced early flowering in Zinnia. Gupta *et al.* (2004) reported that the application of biofertilizers like VAM, *Azospirillum,* Phosphate solubilizing bacteria have registered minimum number of days to first flowering in gladiolus and carnation.

Liang *et al.* (2010) reported that inoculation of efficient strains of AMF resulted in increased number of zinnia flowers. Karishma *et al.* (2013) reported that plants inoculated with *G. mosseae* + *A. laevis* + *P. fluorescens* treatment at

half of recommended dose i.e. lower of superphosphate showed higher number of flowers followed by *G. mosseae* + *P. fluorescens*. Similarly, maximum increment in number of flowers at medium and higher concentration of superphosphate was also observed at *G. mosseae* + *A. laevis* + *P. fluorescens* treatment in comparison to control.

The plantlets of chrysanthemum inoculated with T_3 (*Glomus fasciculatum)* flowered fifteen days earlier than control. T_4 (mixed AMF strains) is also on par with T_3. Maximum numbers of flowers were obtained from mixed AMF inoculated plantlets of gerbera (43.00) (Kumar *et al.,* 2014). AMF inoculated cultivars (3.5 per cent) showed 35 per cent higher flower longevity than control plants in gerbera (Deljou *et al.,* 2014).

2.4 EFFECT OF MICROBIAL INOCULANT TREATMENTS ON FLOWER QUALITY PARAMETERS

Flower diameter is the one of the most important quality of flowers in Asteraceae family. AMF treatments improved flower diameter under drought stress. Since Phosphorus is one of the most essential and effective elements in flowering (Taiz and Zeiger, 2000) increased flower diameter in zinnia could be due to a positive correlation between the flower diameter and P uptake.

Sohan *et al*. (2003), reported that AMF treatments of chrysanthemum increased fresh weight, width and height of flowers. Gupta *et al.* (2004) reported that the application of biofertilizers like VAM, *Azospirillum* and Phosphate solubilizing bacteria have registered maximum plant height in gladiolus . Hasan and Khan (2004) reported that the spike length, number of florets/spike and the floret diameter in gladiolus was increased by the application of neem cake along with VAM fungus (*Glomus fasciculatum*) .

Gupta *et al.* (2004) also reported that the application of bio-fertilizers like VAM, *Azospirillum,* Phosphate solubilizing bacteria have registered , maximum bud and flower size in carnation. The plants treated with PGPR produced flowers with light colour and flowers with more saturated yellow (Griesbach and Austin, 2005). Flores *et al*. (2007) reported that there was an increase in total

inflorescence production in marigold treated with *B. subtilis* and/or *G. fasciculatum* compared to uninoculated controls. There was no significant difference in diameter between inoculated and uninoculated plants but there was an increase in fresh weight of plants inoculated with *B. subtilis* and/or *G. fasciculatum*.

Smith and Read (2008) stated that AMF inoculated plants increased the P, N, Zn, and Cu uptake. The flowers of bioinoculants treated plants showed more yellow and less red hues. Liang *et al.*, (2010) reported that inoculation of efficient strains of AMF resulted in increased size of *Zinnia* flower when inoculated with efficient strain of AMF. Application of AMF significantly increased flower diameter in marigold (*Tagetes erecta*) compared to control plants (Asrar and Elhindi, 2011). AMF inoculation in the soil of *Calendula officinalis* increased the production of flowers (Zaller *et al*., 2011).

In chrysanthemum bigger flowers were recorded in plants treated with mixed AMF strains (6.03 cm) and the flower diameter was found minimum in uninoculated plantlets (7.37 cm) (Kumar *et al*., 2014). Kumar *et al.* (2014) reported that longest flower stalk length was recorded in chrysanthemum treated with AMF strain (4.73 cm) followed by plants treated with *Glomus fasiculatum* (4.26 cm). AMF strain inoculated plants produced flowers having maximum floret number (277.33 cm) in chrysanthemum.

2.5 EFFECT OF MICROBIAL INOCULANT TREATMENTS ON YIELD PARAMETERS

The quality of inflorescences is higher than the stem production in autumn-winter (November-February), which achieves optimal levels in spring-summer in gerbera (Meynet, 1974). Aboul-Nasr (1996) observed that *G. etunicatum* increased number of flowers by 34 per cent in *T. erecta.*Flores *et al.* (2007) reported that inoculation with *B. subtilis* enhanced flower production by 14 per cent in combination with *G. fasciculatum* and 24 per cent when applied alone. Flowering progression was also affected by accelerating the flower maturity and producing more number of mature flowers than *G. fasciculatum*

inoculated plants and control at the same time period. Flores *et al,*(2007) also reported that *G. fasciculatum* inoculated plants did not accelerate flower production but enhanced plant yield since treated plants significantly produced more inflorescence (22 per cent) than uninoculated treatments.

Uptake and transport of calcium, as well as disorders in plants are strongly affected by the climatic conditions, primarily humidity (Sonneveld and Voogt, 2009*).* Cappellari (2013) reported that *P. fluorescens* and other PGPR have the potential for enhancing the productivity of cultivated aromatic plants by the accumulation of secondary metabolites.

In AMF inoculated gerbera plants, flowers harvested per plant was 28.5 percent and 35 percent higher in 'Malibu' and 'Orange Onion' cultivars, respectively. The maximum colonization rate in both cultivars were observed in 3.5 per cent inoculation level, with 64.5 per cent and 72.3 per cent in 'Malibu' and 'Orange onion' cultivars, respectively; while it was zero per cent in non-AMF treatment (Deljou *et al*., 2014).

2.6 EFFECT OF MICROBIAL INOCULANT TREATMENTS ON VASELIFE OF FLOWERS IN DISTILLED WATER

Water balance is a major factor determining quality and longevity of cut flowers. It is influenced by water uptake and transpiration, being the balance between these two processes (Da Silva, 2003). Low water uptake is often due to occlusions located mainly in the basal stem end (He *et al*., 2006), and microbes are a common cause of stem end blockage (van Doorn, 1997).

Gupta *et al.* (2004) reported that the application of bio-fertilizers like VAM, *Azospirillum,* and Phosphate solubilizing bacteria have registered maximum vase life and maximum cost benefit ratio in carnation.

Vase life varied between cultivars, and ranged from 5.6 to 9 days for 'Malibu' and 4.6 to 7.3 days for 'Orange Onion' cultivars of gerbera. The maximum and minimum vase life in both cultivars was observed in 3.5% mycorrhizal colonization and non-mycorrhizal gerberas respectively (Deljou *et al.,* 2014).

2.7 EFFECT OF MICROBIAL INOCULANT TREATMENTS ON ENVIRONMENTAL PARAMETERS (TEMPERATURE IN ^{0}C, RELATIVE HUMIDITY IN %, LIGHT INTENSITY IN LX)

The physiological process of the flowering of *Gerbera jamesonii* H. Bolus ex. Hook F.), is influenced by temperature and light (Roh, 1984). The environmental factors include climate, soil characteristics or the composition or activity of the indigenous microbial flora of the soil. To achieve the maximum growth promoting interaction between PGPR and nursery seedlings it is important to discover how the rhizobacteria exert their effects on plant and whether the effects are altered by various environmental factors, including the presence of other microorganisms. (Bent *et al.,* 2001).

Schnider-Keel *et al.* (2001) reported that *P. fluorescens* can survive under dry conditions. The soil microbes, plant growth promoting rhizobacteria (PGPR), P solubilizing bacteria, mycorrhizal-helping bacteria (MHB) and arbuscular mycorrhizal fungi (AMF) in the rhizosphere of plants growing on trace metal contaminated soils plays an important role in phytoremediation(Khan 2005).

Cristiano *et al*., 2007 reported that there was an increase of 16% in autumn and winter yield for the plants cultivated under supplementary lighting as compared to control in gerbera (14.5 against 12.5 flower/plant).

2.8 PEST AND DISEASE INCIDENCE

Karlik *et al.* (1995) reported that mite infestation in gerbera resulted in reduction of yield and quality of the flower produced. Bodker *et al.* (1998) found that the nutritional superiority of AM plants has been proposed to be a mechanism in reduction of root diseases in gerbera. The biocontrol agents, plant growth promoting rhizobacteria such as *Pseudomonas* spp. and *Bacillus* spp. have shown efficiency in suppressing the fungal infection and promoting growth characteristics (Chen *et al.* 2000).

More than 20 species of arthropods which causes economic injury to gerbera and the two-spotted mite, *Tetranychus urticae* (Acari: Tetranychidae) is considered a key pest of this and other ornamental plants. The species feeds on the

lower leaf surface and sucks cell content resulting in chlorotic symptoms on the leaves, if the infestation is severe, leaves falloff and number of flowers produced may reduce considerably. Mycorrhizal plants are resistant to abiotic stresses and diseases caused by soil borne pathogens (Liu *et al.,* 2004).

In the plant-beneficial rhizosphere bacterium *Pseudomonas fluorescens* CHA0, the GacS/GacAsystem is essential for the production of antibiotic compounds and hence for biological control of root-pathogenic fungi. The differential expression of three small RNAs facilitated the fine tuning of GacS/A-controlled cell population density-dependent regulation in *P. fluorescens (Kay et al.,* 2005).

PGPR enhances plant growth indirectly by reducing the deleterious effects of pathogenic organisms through various mechanisms that include the induction of host resistance to the pathogen (Van Loon, 2007). Matysiak and Falkowski (2010) reported that AMF inoculated plants grown in containers require less fertilizers and pesticide application.

Materials and Methods

3. MATERIALS AND METHODS

The present investigation on "Performance analysis of tissue culture plantlets of *Gerbera jamesonii* Bolus as influenced by microbial inoculants" was carried out at the Department of Pomology and Floriculture, College of Agriculture , Vellayani during 2014-2016. The study was undertaken to study the establishment of tissue culture plantlets of gerbera as influenced by microbial inoculants under rain shelter. This study also aims to analyse the performance of gerbera treated with different microbial inoculants under rain shelter. The details regarding experimental material used and methodology adopted while conducting investigation are presented here.

3.1 LOCATION

The field experiment was conducted at the Department of Pomology and Floriculture, College of Agriculture, Vellayani, Thiruvananthapuram (Plate 1a & 1b), Kerala during 2014-2016. The area is situated at 8^0 30' North latitude and 76 ^{0}54' east longitude at an altitude of 29 m above MSL.

3.2 SOIL

The soil used for carrying out the study was red loam which belongs to Vellayani series which comes under the order Ultisol and sandy soil.

3.3 SEASON

The experiment was conducted from January 2015 to July 2016.

3.4 MATERIALS

3.4.1 Planting Material

Tissue Culture plantlets of *Gerbera jamesonii* Bolus. Var. Esmara were collected for the experiment from Coimbatore

3.4.2 Microbial Inoculants

Microbial inoculants including AMF, *Pseudomonas fluorescens*, PGPR MIX I, PGPR MIX II were collected for the experiment from Department of Agricultural Microbiology, College of Agriculture, Vellayani.

Plate 1a. General view of the experimental area

Plate 1b. General view of the experimental area

3.4.3 Manure

NPK in the form of complex fertilizer (18:18:18) was applied once in two month at the rate of 3g/plant. Dried cowdung was applied at bimonthly interval at the rate of 30g/plant. Application of foliar fertilizer (Green care (13:27:27) @ 500ml/plant) was given at bimonthly interval.

3.5 METHODS

3.5.1 Design and Layout of the Experiment

Variety: Esmara

Design: CRD

No. of Treatments: 9

No. of replication: 4

No. of plants per replication: 4

3.5.2 Preparation of Potting Mixture and Planting

The experiment was carried out in polybags and laid out in completely randomized design. Red loam soil, sandy soil and farm yard manure were mixed in equal proportion (1:1:1 ratio). The polybags were filled with prepared potting mixture leaving some head space. Filled polybags were arranged systematically based on the treatment. Dipping of tissue culture plantlets of *Gerbera jamesonii* Bolus. in Bavistin 0.2% was carried out before planting.

3.5.3 Treatment Details

Treatments were applied in two instalments. Initial application of AMF (5g/plantlet), *Pseudomonas fluorescens* (@ 2% spray and drench), PGPR MIX-I (@ 2% of FYM) and PGPR MIX- II (@ 2% drench and spray) were given at the time of planting. Second application of treatments at same rate were given 3 weeks after planting.

$T_{I:}$ Application of Arbuscular Mycorrhizal Fungi (AMF) at planting (@ 5g/plantlet).

T_2: Application of *Pseudomonas fluorescens* at planting (@ 2% spray and drench).

T_3: Application of PGPR MIX-I at planting (@ 2% of FYM).

T_4: Application of PGPR MIX- II at planting (@ 2% drench and spray).

T_5: Application of AMF twice, first at planting and second after 3 weeks.

T_6: Application of *Pseudomonas fluorescens* twice, first at planting and second after 3 weeks.

T_7: Application of PGPR MIX-I twice, first at planting and second after 3 weeks.

T_8: Application of PGPR MIX-II twice, first at planting and second after 3 weeks.

T_9: Control (without application of microbial inoculants).

3.5.4 After Cultivation

The crop was given regular irrigation and hand weeding throughout the observation period depending upon the intensity of weed growth. Old leaves and flowers were removed periodically. FYM and Greencare were given at bimonthly interval.

3.5.5 Plant protection

The plants were observed frequently for any pest / disease occurrence throughout the crop period. Prophylatic spray of fungicides and insecticides were given periodically. Periodic sprays of acaricide (Oberon 0.4%) were given to control mite infestation.

3.6 OBSERVATIONS

Four replications were maintained for each of the nine treatments. For each replication four plants were maintained. Observations were taken from each plant. Vegetative parameters were taken at bimonthly interval from one month after planting. Floral characters were taken based on flowering from one and a half to two month after planting. Vaselife studies, environmental parameters, pest and disease incidence were recorded for the period of experiment.

3.6.1 Survival Percentage

The observations on number of plants that survived two weeks after planting and number of plants survived four weeks after planting were noticed visually for a period from planting to four week.

3.6.2 Vegetative Parameters

The observation on growth characters were taken from four plants per replication in each treatment from one month after planting for a period of one year and the mean values were recorded

3.6.2.1. Plant Spread (cm)

The plant spread was recorded by measuring the radial length and calculated the perimeter first at one month after planting and thereafter at bimonthly interval and mean was worked out in cm.

3.6.2.2 Number of Leaves per Plant

Number of leaves produced by plant was recorded from each replication by counting the number of leaves first at one month after planting and thereafter at bimonthly interval and the mean was worked out.

3.6.2.3 Leaf Length (cm)

Leaf length was measured from the base of the leaf to the tip of the longest leaf and mean value was recorded

3.6.2.4. Leaf Breadth (cm)

Leaf breadth was measured from the widest part of the leaf and mean value was recorded**.**

3.6.2.5. Number of Suckers per Plant

Number of suckers arising from the mother plant was recorded throughout the crop period.

3.6.3. Flowering Characters

3.6.3.1 Number of Days Taken for Flowering

Days taken for meanflower production was observed and mean calculated.

3.6.3.2 ***Number of Days Taken from Bud Opening to Harvest***

The total number of days taken by the flower from bud opening stage to the freshly harvesting stage was recorded and average number of days were calculated.

3.6.3.3 Total Number of Flowers Produced

Monthly counts were made for estimating number of flowers during July 2015 to May 2016. Total number of flowers produced were observed for one year and the mean values were calculated.

3.6.3.4 Peak Flowering Period

Monthly counts of flowers were taken. Based on the total number of flowers produced the peak flowering period in terms of season was recorded.

3.6.3.5 **Life of Flower in the Plant (days)**

It is the number of days taken from emergence of flower to the days taken for full opening to senescence (Indicated by discolouration of petals).

3.6.4. Flower Quality Parameters

3.6.4.1 Flower Diameter (cm)

Flower diameter was recorded by measuring the spread of the completely opened flower including disc florets and ray florets. Mean values were calculated and recorded.

3.6.4.2 Diameter of the Flower Disc (cm)

Diameter of flower disc were measured in cm and mean values were calculated.

3.6.4.3 Colour of the Flower Disc

Colour of the flower disc was noticed visually and recorded.

3.6.4.4 Number of Ray Florets

Number of ray florets were counted for each flower. The mean was worked out and recorded for all the treatments.

3.6.4.5 Colour of Ray Florets

Colour of the flower ray floret was noticed visually and recorded.

SCORE CARD

Visual appeal of *Gerbera Jamesonii* Bolus. variety Esmara

Sl.no	General appearance					Size of the flower					Colour development					Total score
	1	2	3	4	5	1	2	3	4	5	1	2	3	4	5	
T1																
T2																
T3																
T4																
T5																
T6																
T7																
T8																
T9																

Score distribution

General appearence	Size of the flower	Colour development	Total score
Average (1to 2)	Average (1to 2)	Average (1to 2)	Average (1to 2)
Good (3 to 4)	Good (3 to 4)	Good (3 to 4)	Good (3 to 4)
Very good (5)	Very good (5)	Very good (5)	Very good (5)

3.6.4.6 Length of the Ray Florets (cm)

Length of ray florets was measured from the point of attachment of floret to the disc to the tip of the floret. Mean values were calculated and expressed in cm.

3.6.4.7 Width of Ray Florets (cm)

Width of ray florets was measured in the widest part of ray floret. Mean values were calculated and expressed in cm.

3.6.4.8 Length of Flower Stalk (cm)

Length of flower stalk was measured from the point of emergence from the plant to the base of the flower head , mean calculated and expressed in cm.

3.6.4.9 Girth of Flower Stalk (cm)

Girths of flower stalk (the perimeter) was measured using twine. Average values were taken and expressed in cm**.**

3.6.4.10 Visual Appeal (Scoring based on 3 characters, general appearance, size of flower and colour development)

The visual appeal of flowers was assessed by a panel of 10 judges. Different morphological and visual characters of the flowers were observed and evaluated based on 3 characters *viz,* general appearance, size of flower and colour development. Flowers were categorised in to three groups *viz.* Average (1 to2), Good (3 to4) and Very good(5) in a five point basis.

3.6.5. Yield Parameters

3.6.5.1 Number of Flowers per Plant per Year

Monthly counts were made for estimating number of flowers during July 2015 to July 2016. Total number of flowers produced were recorded and mean value was calculated.

3.6.5.2 Yield of Flowers in Relation to Season or Month of the Year

Monthly counts of flowers were taken. Based on the total number of flowers produced the yield of flowers in terms of season were recorded

3.6.6. Vase Life of Flowers in Distilled Water

Vase life of fully opened flowers were recorded by keeping the flowers in distilled water. Observations were recorded based on the number of days taken for decline in the fresh appearance of the flower.

3.6.6.1 Days Taken for Drooping of Flower Heads

The stalk of fully opened flowers were immersed in distilled water and number of days taken for drooping of flower head was noted.

3.6.6.2 Days Taken for Discoloration of Petals

The stalk of fully opened flowers were immersed in distilled water and number of days taken for discolouration of petal was noted.

3.6.6.3 Days Taken for Petal Fall

The stalk of fully opened flowers were immersed in distilled water and number of days taken for petal fall was noted.

3.6.7 Environmental Parameters (Temperature in ^{0}C, Relative humidity in %, Light intensity in lx)

Temperature in ^{0}C, Relative humidity in %, Light intensity in lux were measured using Thermometer, Hygrometer and Lux meter respectively. Monthly data were collected and mean values were calculated.

5.6.8. Economics of Cultivation

In order to assess the effects of each treatment, the cost of cultivation was worked out. This includes the cost of planting material, the cost of microbial inoculants (AMF, *Pseudomonas fluroscence*, PGPR MIX I and PGPR MIX II) the cost of organic manure (farm yard manure, bone meal, vermicompost), the cost of polybag , potting mixture and other plant protection chemicals taken at existing rates. The labour cost including irrigation, weeding and plant protection etc. during this crop period were worked out. The output from marketable flowers and suckers obtained were taken in to consideration for working out the economics. Based on total cost of cultivation and gross income obtained, benefit cost value was calculated per 1000 m^2 area of rainshelter.

5.6.9. Pest and Disease Incidence

The plants were observed for pest and disease. Need based application of fungicides and plant protection chemicals were given as prophylactic measures.

5.6.9.1 Scoring for Mite Attack

Observation for mite attack was recorded from all the plants. Scoring of pest was done using the scale. The extend of attack was estimated based on the parts of the plant infested. Curling, malformation and complete destruction of leaves were taken in to account for devising the scale. Based on this a 0-4 scale has been devised.

0---- No symptom

1----1-25% leaves/plants showing curling or damage

2----26-50% leaves/plant showing curling-moderately damaged

3----51-75% leaves/plant showing curling-heavily damaged

4----75% leaves/plant showing curling and complete destruction of growing points.

5.6.10 Statistical Analysis

The data collected on different treatments during the crop period was analysed by applying the technique of analysis of variance (ANOVA) for completely randomized design (CRD).

Results

4. RESULTS

The study on "Performance analysis of tissue culture plantlets of *Gerbera jamesonii* Bolus as influenced by microbial inoculants" was carried out in the Department of Pomology and Floriculture, College of Agriculture, Vellayani during the period of 2014-2016. The experiment was undertaken to study the establishment and performance of tissue culture plantlets of gerbera as influenced by microbial inoculants under rain shelter. The results obtained are presented in this chapter.

4.1 EFFECT OF MICROBIAL INOCULANT TREATMENTS ON SURVIVAL PERCENTAGE

The data were collected on survival percentage of tissue culture plantlets of *Gerbera jamesonii* Bolus, two weeks and four weeks after planting. As per the data (Table 1&2, Fig 1&2) cent percent survival of tissue culture plantlets was observed two weeks and four weeks after planting.

4.2 EFFECT OF MICROBIAL INOCULANT TREATMENTS ON VEGETATIVE PARAMETERS

4.2.1 Plant Spread (cm)

Plant spread was recorded at bimonthly interval from one month after planting. The plant spread was found to be significantly different between the treatments (Table 3 & Fig 3). The plants treated with T_4 (application of PGPR MIX- II at planting @ 2% drench and spray) recorded highest value (186.61 cm) which is on par with T_2, T_6, T_7, T_5, T_1 and T_3 which had 183.72, 177.90, 177.84, 168.29, 167.00 and 163.2 cm respectively.

4.2.2 Number of Leaves per Plant

The number of leaves per plant was recorded at bimonthly intervals from one month after planting. Significant difference was noticed between the treatments in the number of leaves per plant (Table 3 & Fig 4). The highest value (12.56) was recorded in T_3 (application of PGPR MIX-I at planting @ 2% of

Table1. Effect of microbial inoculants on survival percentage (Two weeks after planting)

Treatment	Survival rate
T_1	100
T_2	100
T_3	100
T_4	100
T_5	100
T_6	100
T_7	100
T_8	100
T_9	100

Table 2.Effect of microbial inoculants on survival percentage (Four weeks after planting)

Treatment	Survival rate
T_1	100
T_2	100
T_3	100
T_4	100
T_5	100
T_6	100
T_7	100
T_8	100
T_9	100

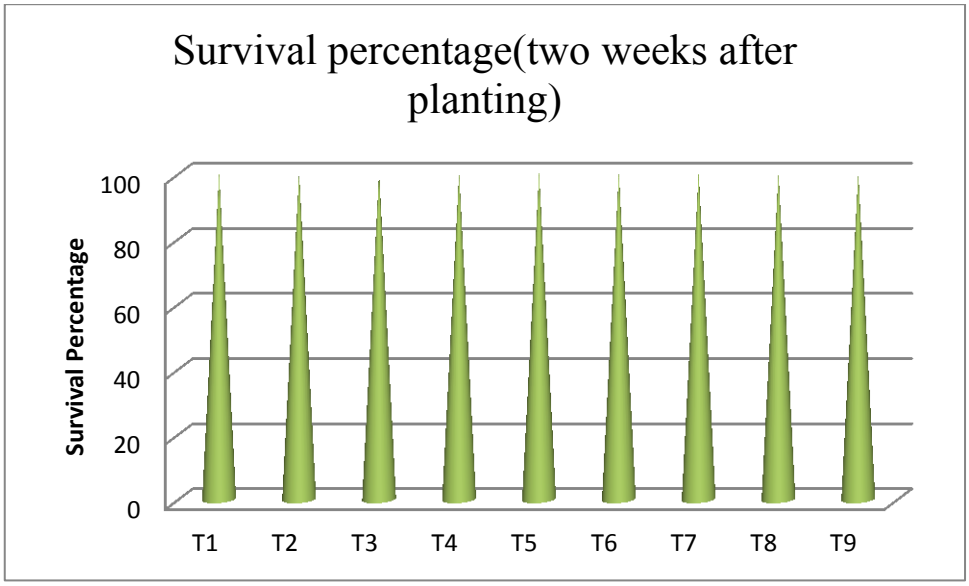


Fig.1 Effect of microbial inoculants on survival percentage two weeks after planting

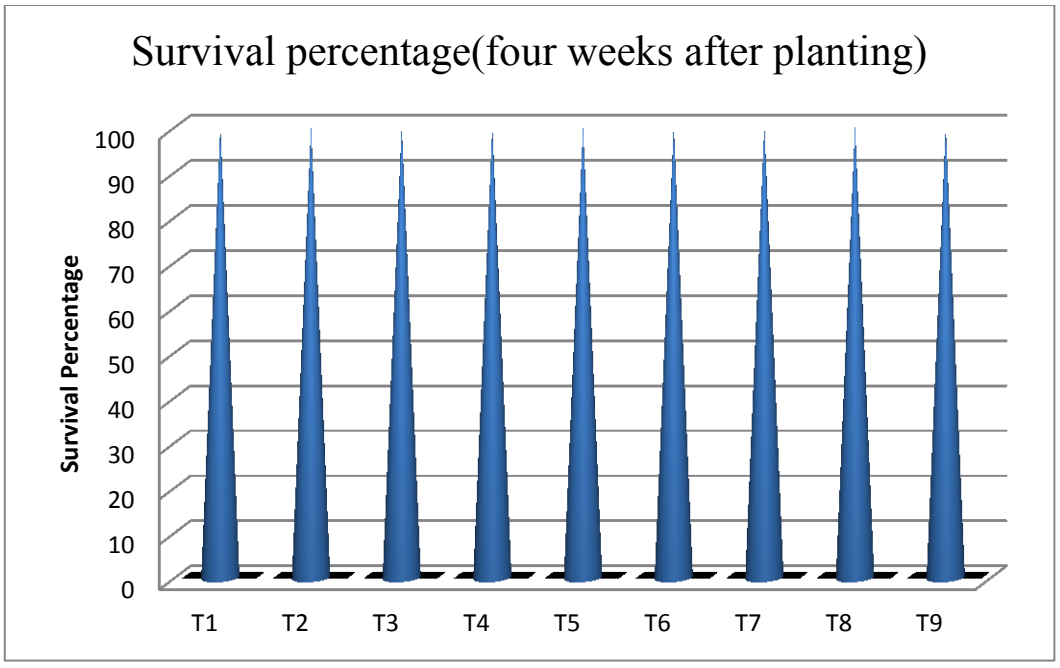


Fig.2 Effect of microbial inoculants on survival percentage four weeks after planting

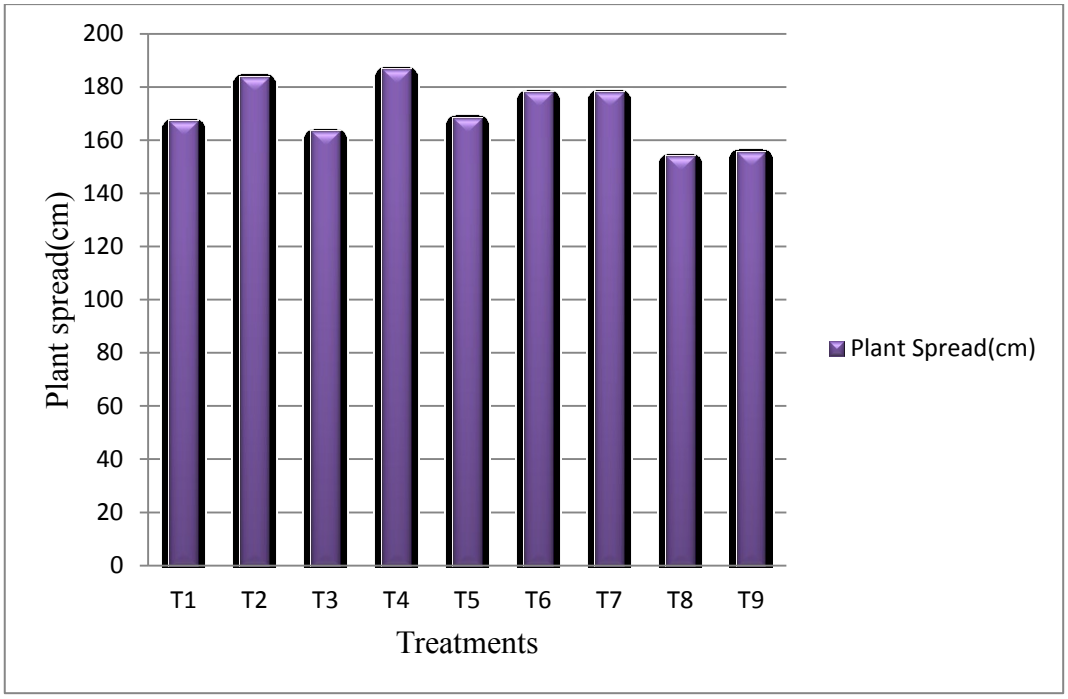


Fig.3 Effect of microbial inoculants on plant spread

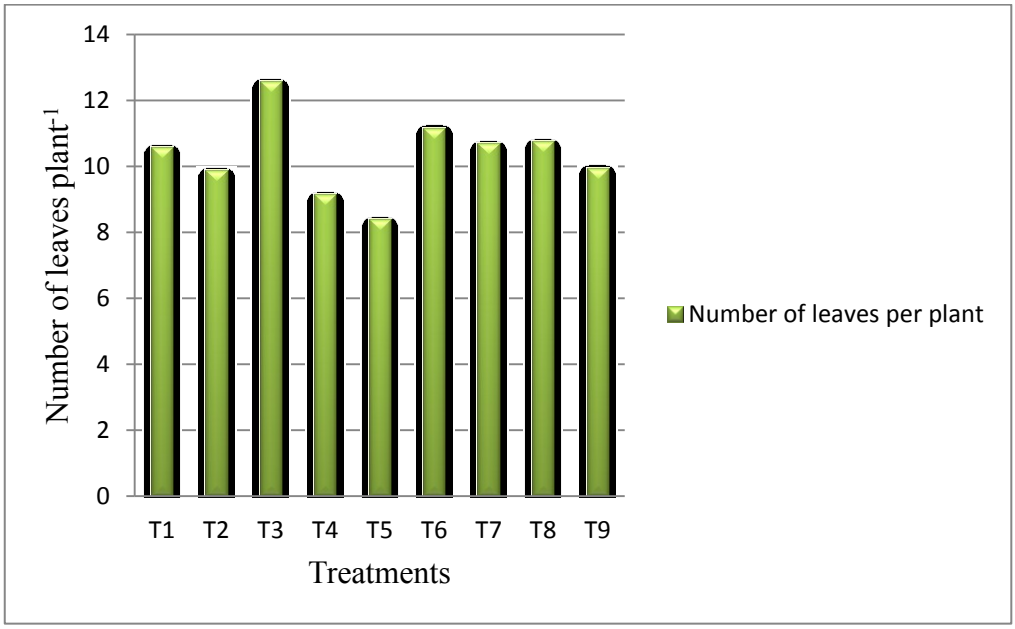


Fig.4 Effect of microbial inoculants on number of leaves per plant

FYM) which was on par with T_6, T_8, T_7, T_1, T_9 and T_2 which had 11.16, 10.75, 10.69, 10.56, 9.94 and 9.88 leaves respectively. The lowest number of leaves was recorded in T_5.

4.2.3 Leaf Length

Leaf length was recorded at bimonthly intervals from one month after planting. There was significant difference in leaf length between the treatments (Table 3 & Fig 5). T_4 (application of PGPR MIX- II at planting @ 2% drench and spray) (29.72 cm) has significantly greater leaf length than T_8 (24.57 cm) and T_9 (24.77 cm) which is on par with T_2, T_6, T_5, T_1, T_3 and T_7 .which had 29.26, 28.34, 26.80, 26.59, 26.00 and 25.82 cm respectively. The lowest leaf length was noticed in T_8.

4.2.4 Leaf Breadth

The leaf breadth was found to be significantly different between the treatments throughout the observation period (Table 3 & Fig 6). At one month after planting T_7 (application of PGPR MIX-I twice, first at planting and second after 3 weeks) showed higher leaf breadth (9.66 cm) which had significantly greater leaf breadth than T_3, T_5, T_6, T_8 and T_9 which had 8.53, 8.15, 8.35, 8.09 and 8.4 cm respectively. T_7 was on par with T_4, T_2 and T_1 which had leaf breadth 9.45, 9.05 and 8.64 cm respectively. Lowest leaf breadth was recorded in T_8.

4.2.5 Number of Suckers per Plant

The number of suckers per plant was recorded throughout the observation period. The number of suckers per plant is significantly different between the treatments (Table 3 & Fig 7). Highest number of suckers was noticed in T_7 (application of PGPR MIX-I twice, first at planting and second after 3 weeks) (4.25) which were significantly higher than T_5, T_9, T_3 and T_4 which had 3.25, 3.25 and 3 numbers of suckers respectively. T_7 was found to be on par with T_9 (4), T_6 (3.94), T_2 (3.88) and T_1 (3.63).

Table 3. Effect of microbial inoculants on vegetative parameters of *Gerbera jamesonii* Bolus.

Treatment	Plant Spread (cm)	Number of leaves per plant	Leaf length (cm)	Leaf breadth (cm)	No: of suckers per plant
T_1	167.00	10.56	26.59	8.64	3.63
T_2	183.72	9.88	29.26	9.05	3.88
T_3	163.20	12.56	26.00	8.53	3.19
T_4	186.61	9.13	29.72	9.45	3.00
T_5	168.29	8.38	26.80	8.15	3.25
T_6	177.99	11.16	28.34	8.35	3.94
T_7	177.84	10.69	25.82	9.66	4.25
T_8	154.00	10.75	24.57	8.09	4.00
T_9	155.54	9.94	24.77	8.34	3.25
CD(0.05)	25.546	3.361	4.441	1.043	0.769

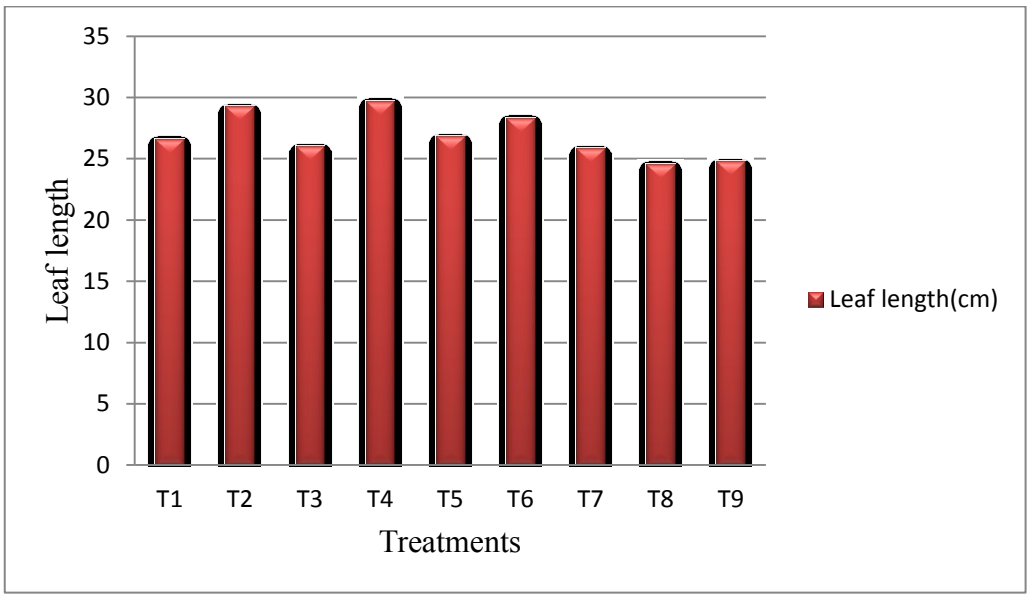


Fig.5 Effect of microbial inoculants on leaf length(cm)

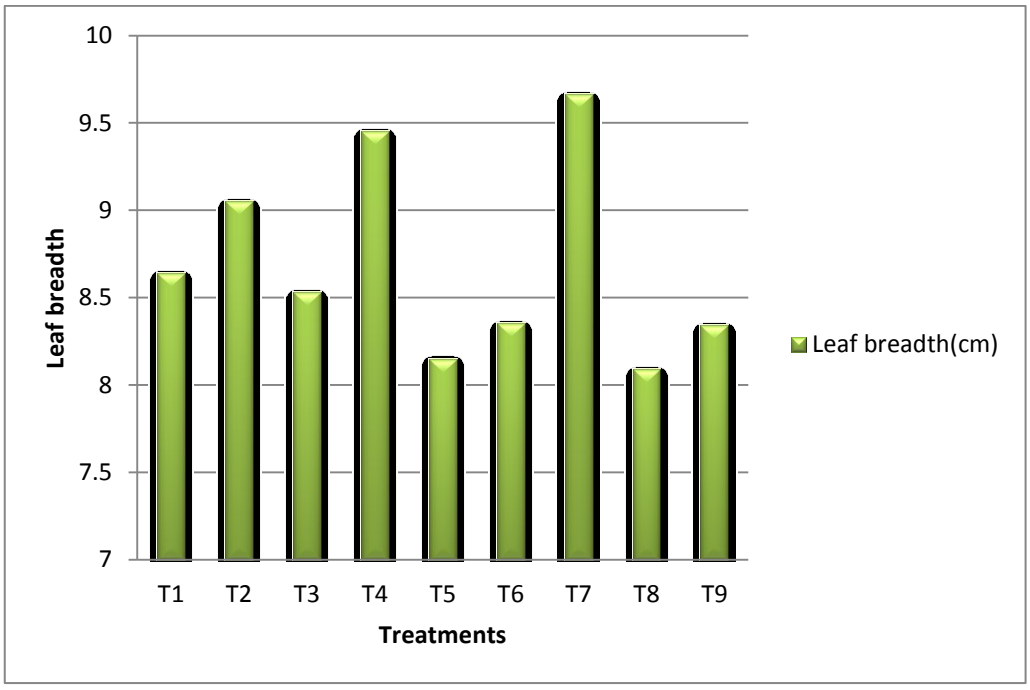


Fig.6 Effect of microbial inoculants on leaf breadth(cm)

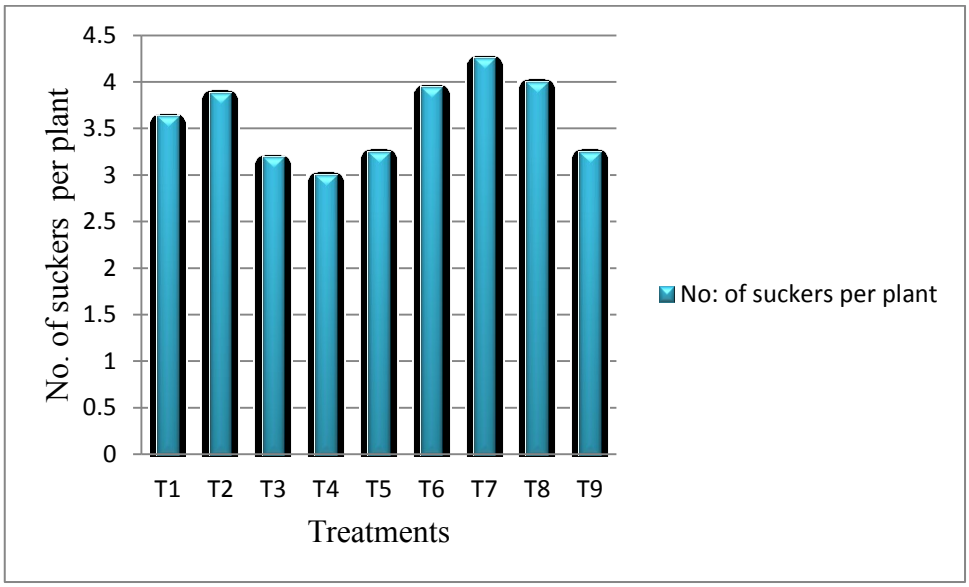


Fig.7 Effect of microbial inoculants on number of suckers per plant

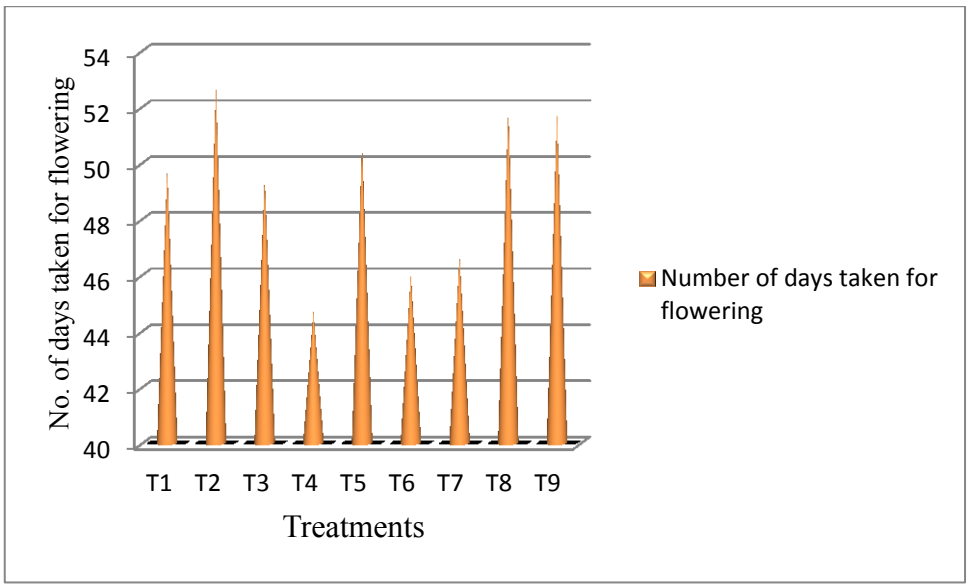


Fig.8 Effect of microbial inoculants on number of days taken for flowering

4.3 EFFECT OF MICROBIAL INOCULANT TREATMENTS ON FLOWERING CHARACTERS

4.3.1 Number of Days Taken for Flowering

Number of days taken for flowering was significantly influenced by the treatments (Table 4 & Fig 8). The lowest number of days taken for flowering was recorded by T_4 (application of PGPR MIX- II at planting (@ 2% drench and spray) (44.69)(Plate 2). T_4 which showed early flowering was on par with T_6, T_7, T_3 and T_1 which had 46, 46.64, 49.44 and 49.69 days respectively. The highest number of days taken for flowering was noticed in T_2 (52.69).

4.3.2 Number of Days Taken from Bud Opening to Harvest

No significant difference was found between treatments for number of days taken from bud opening to harvest.

4.3.3 Total Number of Flowers Produced

The number of flowers produced was recorded every month from one month after planting. Significant difference among the treatments was noticed in total number of flowers produced per plant (Table 4 & Fig 9). The Highest number of flowers was noticed in plants treated with T_8 (application of PGPR MIX-II twice, first at planting and second after 3 weeks)(Plate 3) which was on par with T_7 and T_3. The lowest number of flowers produced per replication was noticed in T_6.

4.3.4 Peak Flowering Period

From the data collected, maximum flower yield was recorded in summer (February, March, April and May) as compared to other seasons (Table 4). In summer season T_8 (17.18) recorded maximum number of flowers per plant. Compared to rainy season, more flowers were recorded in summer season in all the treatments.

4.3.5 Life of Flowers in the Plant

No significant difference was found between the treatments for life of flower on the plant.

4.4 EFFECT OF MICROBIAL INOCULANT TREATMENTS ON FLOWER QUALITY PARAMETERS

Treatment	Number of days taken for flowering	Number of days taken from bud opening to harvest	Total number of flowers produced	Life of flowers in the plant
T_1	49.69	13.31	20.75	6.50
T_2	52.69	12.69	19.25	6.88
T_3	49.44	12.75	21.50	7.56
T_4	44.69	13.56	21.06	6.88
T_5	50.63	13.81	19.19	7.13
T_6	46.00	12.75	19.13	7.31
T_7	46.64	13.13	22.63	7.38
T_8	51.88	12.63	24.00	7.38
T_9	51.69	13.88	19.69	7.00
CD(0.05)	5.698		2.864	

Table 4. Effect of microbial inoculants on flowering characters of *Gerbera jamesonii* Bolus.

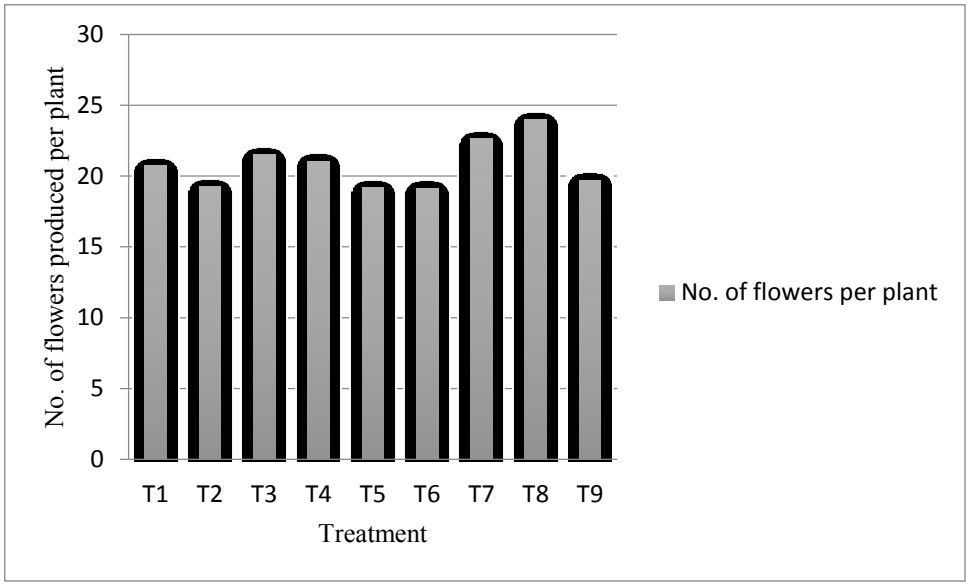


Fig.9 Effect of microbial inoculants on total number of flowers produced (per plant)

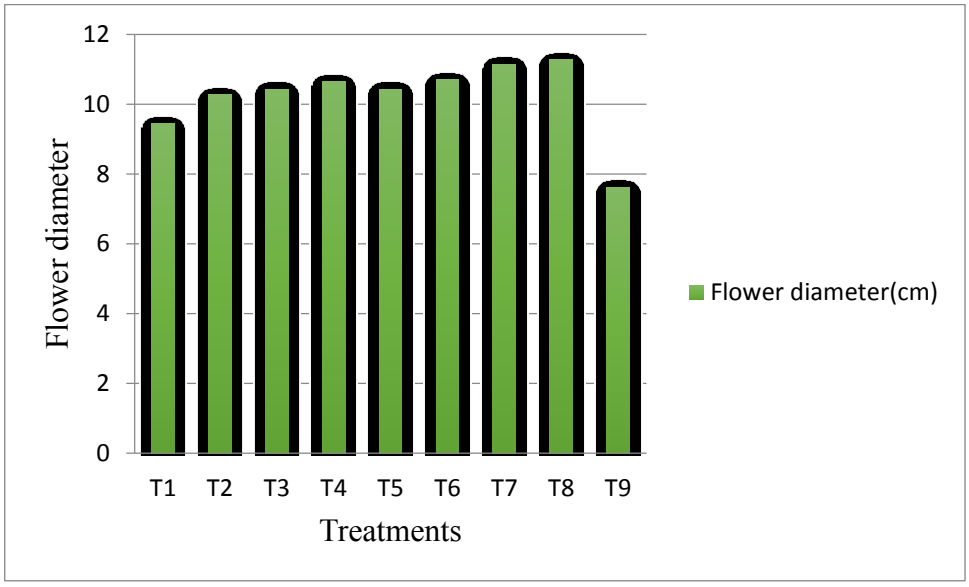


Fig.10 Effect of microbial inoculants on flower diameter (cm)

Plate 2. First flower opening in T_4

Plate 3. Best treatment with highest number of flowers

4.4.1 Flower Diameter (cm)

The data on effect of microbial inoculants on flower diameter are presented in the table 5 & Fig 10. The influence of microbial inoculants on flower diameter was recorded from two month after planting and it was found that there was significant difference among the treatments on the flower diameter throughout the year. The highest value was recorded by T_8 (application of PGPR MIX-II twice, first at planting and second after 3 weeks) (11.46 cm) which is on par with T_3, T_4, T_6 and T_7. The lowest flower diameter was observed in T_9 (7.61).

4.4.2 Diameter of Flower Disc (cm)

There was significant difference among the treatments for the diameter of flower disc (Table 5 & Fig 11). T_8 (application of PGPR MIX-II twice, first at planting and second after 3 weeks) recorded the highest flower diameter and was on par with T_5, T_1, T_6 and T_9 which had 3.84, 3.75, 3.49 and 3.48 cm respectively. T_2 recorded the lowest flower disc diameter.

4.4.3 Colour of Flower Disc

There was no significant difference found between the colour of flower disc among different treatments.

4.4.4 Number of Ray Florets

The number of ray florets was found to differ significantly between the treatments (Table 5 & Fig 12). T_7 (application of PGPR MIX-I twice, first at planting and second after 3 weeks) had significantly more no of ray florets. T_7 was on par with T_8, T_3 and T_6 which had 69.25, 69 and 66.89 number of ray florets respectively. The lowest number of ray florets was recorded in T_1.

4.4.5 Length of Ray Florets (cm)

Data presented in Table 5 & Fig 13 revealed that the length of ray florets (cm) varied significantly among the treatments . The longest ray florets was registered by T_7 (application of PGPR MIX-I twice, first at planting and second after 3 weeks) (5.51) and was found to be on par with T_4 (5.32), T_6 (5.29) and T_2 (5.28). T_7 had significantly higher length of ray florets than T_8 (4.64), T_5 (4.32), T_3 (4.25), T_1 (4.09) and T_9 (3.18).

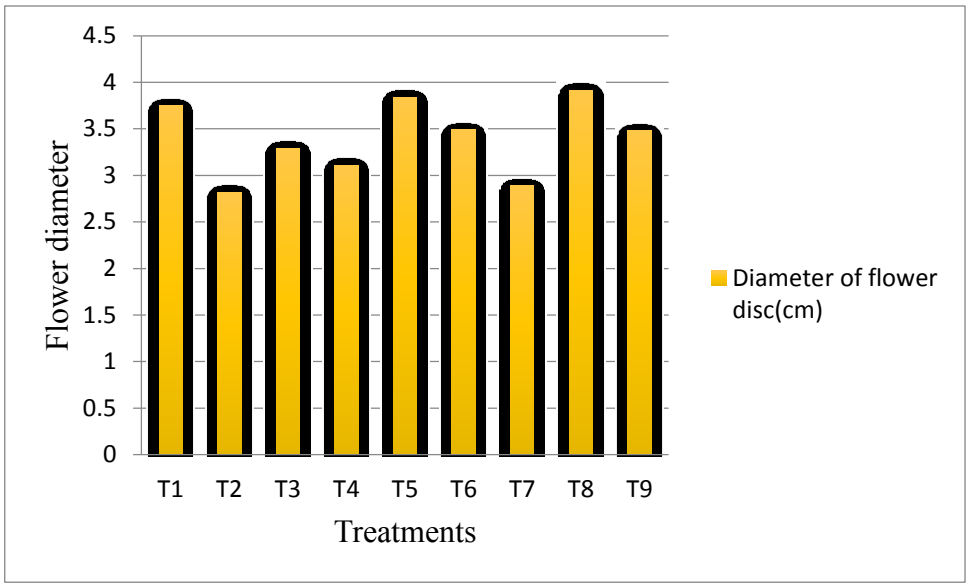


Fig.11 Effect of microbial inoculants on diameter of flower disc(cm)

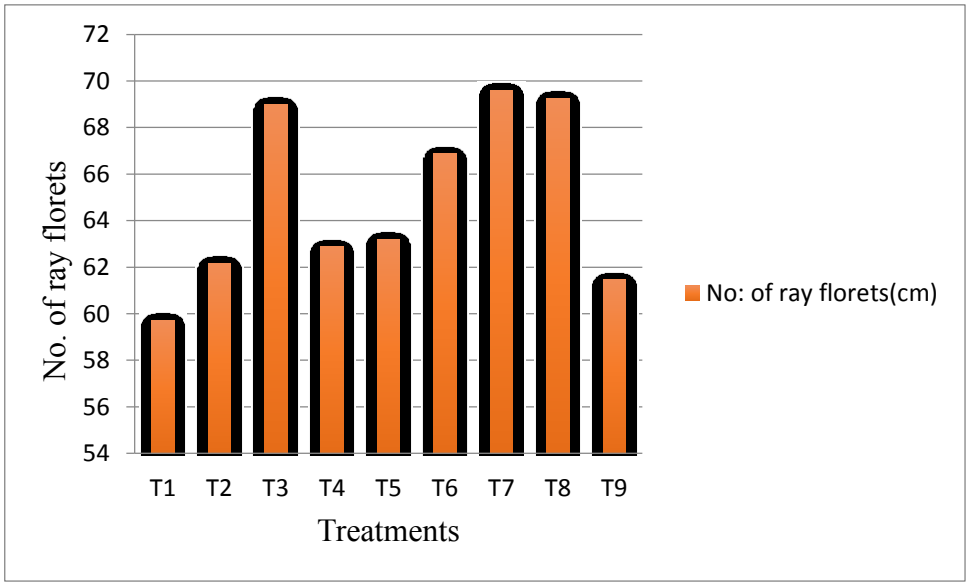


Fig.12 Effect of microbial inoculants on number of ray florets

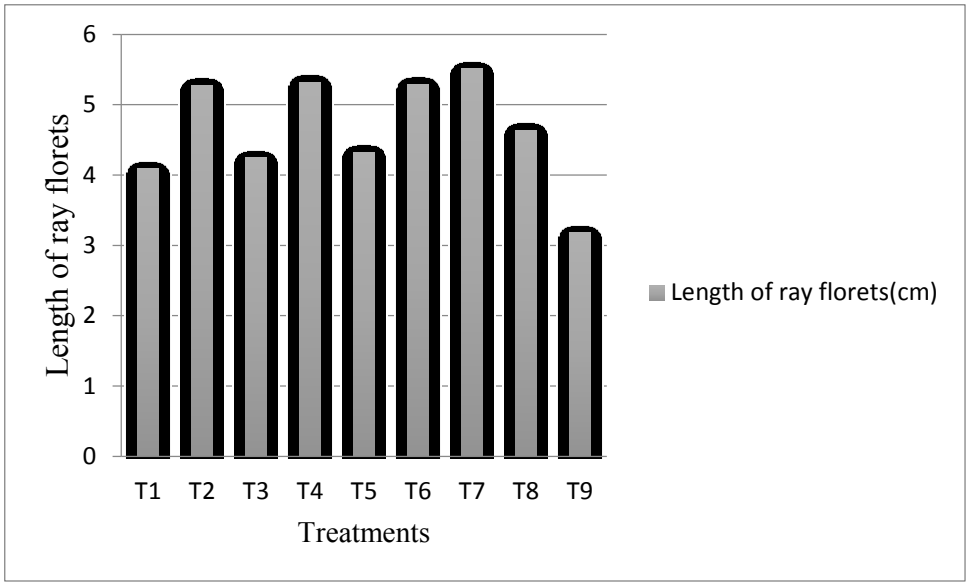


Fig.13 Effect of microbial inoculants on length of ray florets(cm)

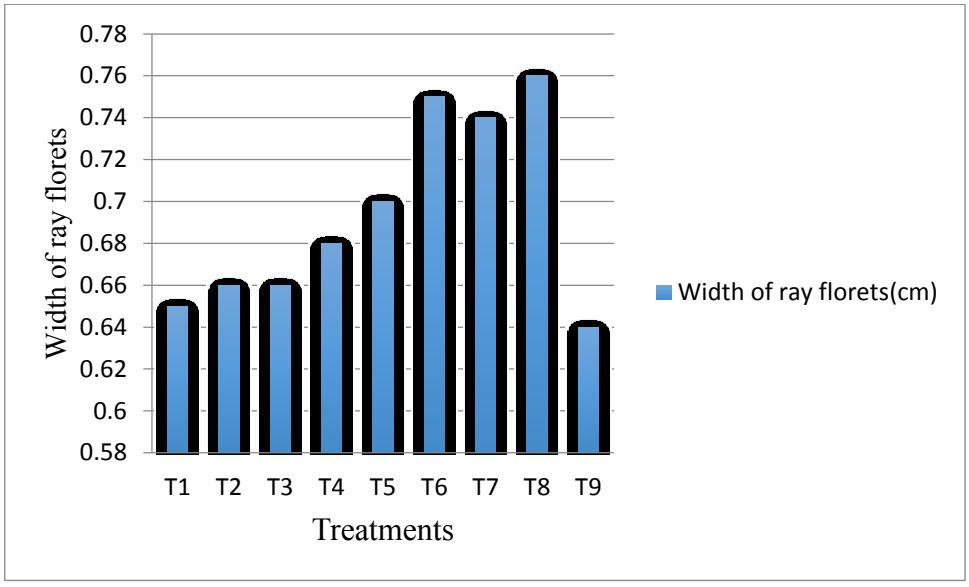


Fig.14 Effect of microbial inoculants on width of ray florets(cm)

4.4.6 Colour of Ray Florets

There was no significant difference found between the colour of ray florets among different treatments.

4.4.7. Width of Ray Florets (cm)

The width of ray florets was significantly influenced by all the treatments (Table 5 & Fig 14). The maximum width of ray florets was recorded by T_8 (application of PGPR MIX-II twice, first at planting and second after 3 weeks) and was on par with T_6 (0.75), T_7 (0.74) and T_5 (0.70). T_8 had significantly higher width of ray floret than T_4 (0.68), T_2 (0.66), T_3 (0.66), T_1 (0.65) and T_9 (0.64). The lowest width of ray floret was recorded in T_9.

4.4.8. Length of Flower Stalk (cm)

The length of flower stalk was significantly different throughout the observation period (Table 5 & Fig 15). T_7 (application of PGPR MIX-I twice, first at planting and second after 3 weeks) (51.62 cm) recorded the maximum length of flower stalk and was on par with T_8, T_3, T_6, T_4 and T_1 .The minimum length of flower stalk was recorded in T_9 (46.12).

4.4.9 Girth of Flower Stalk (cm)

The data on the girth of flower stalk revealed that there was significant influence among the treatments (Table 5 & Fig 16). The maximum girth of flower stalk was recorded in T_7 (2.45) (application of PGPR MIX-I twice, first at planting and second after 3 weeks.) which had significantly higher girth than all other treatments. The lowest girth of flower stalk was noticed in T_4 (2.01)

4.4.10 Visual Appeal (Scoring based on 3 characters, general appearance, size of the flower and colour development)

The visual appeal was observed based on three characters such as general appearance, size of the flower and colour development. All the treatments showed significant difference among the treatments for the three characters (Table 6 & Fig 17). Comparison of flowers of different treatments with control is given in the plate 4 to 11.

The general appearance of the flower showed significant difference among the treatments.T_8 recorded the highest value for general appearance which was on

Table 5. Effect of microbial inoculants on flower quality parameters of *Gerbera jamesonii* Bolus.

Treatment	Flower diameter (cm)	Diameter of flower disc (cm)	No: of rayflorets (cm)	Length of ray florets (cm)	Width of ray florets (cm)	Length of flower stalk (cm)	Girth of flower stalk (cm)
T_1	9.43	3.75	59.73	4.09	0.65	49.06	2.21
T_2	10.27	2.82	62.18	5.28	0.66	48.15	2.08
T_3	10.70	3.29	69.00	4.25	0.66	50.84	2.02
T_4	11.16	3.11	62.89	5.32	0.68	49.18	2.01
T_5	10.41	3.84	63.21	4.32	0.70	47.75	2.09
T_6	10.68	3.49	66.89	5.29	0.75	49.81	2.15
T_7	11.38	2.89	69.60	5.51	0.74	51.62	2.45
T_8	11.46	3.91	69.25	4.64	0.76	51.15	2.09
T_9	7.61	3.48	61.46	3.18	0.64	46.12	2.12

Table 6. Effect of microbial inoculants on flower quality parameters (Visual appeal) of *Gerbera jamesonii* Bolus

Treatments	General appearance	Size of the flower	Colour development
T_1	3.60	3.20	3.80
T_2	4.00	3.70	4.20
T_3	4.20	4.50	4.10
T_4	4.20	4.50	4.30
T_5	3.90	3.40	4.20
T_6	3.90	4.00	4.10
T_7	4.40	4.40	4.30
T_8	4.60	4.50	4.50
T_9	3.60	3.10	3.90
CD(0.05)	0.545	0.617	0.410

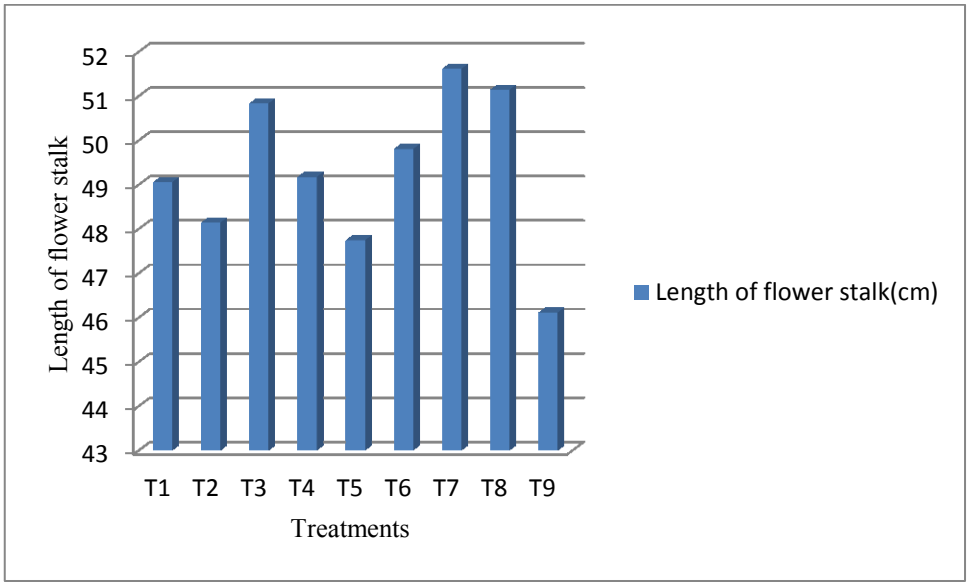


Fig.15 Effect of microbial inoculants on length of flower stalk (cm)

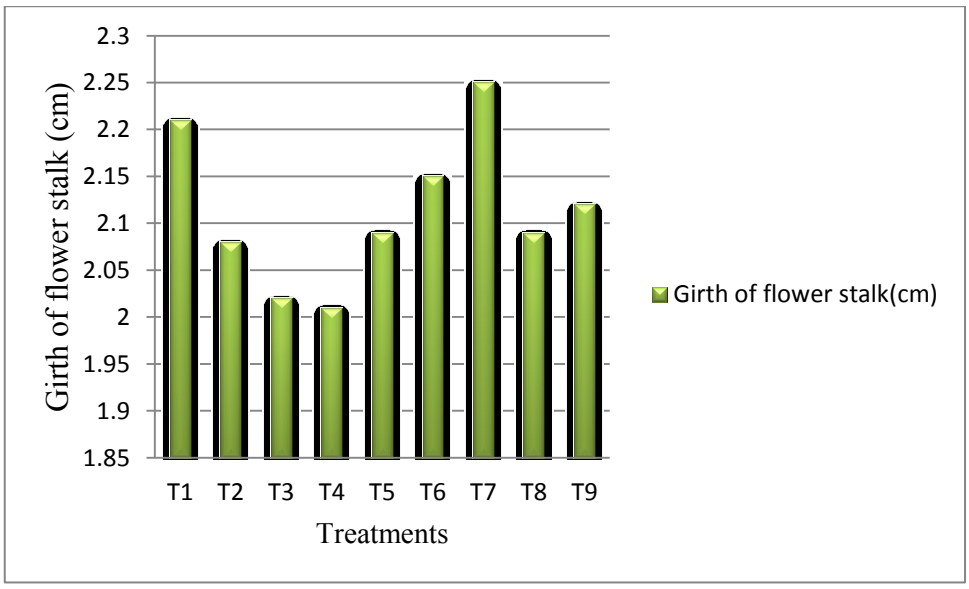


Fig.16 Effect of microbial inoculants on girth of flower stalk(cm)

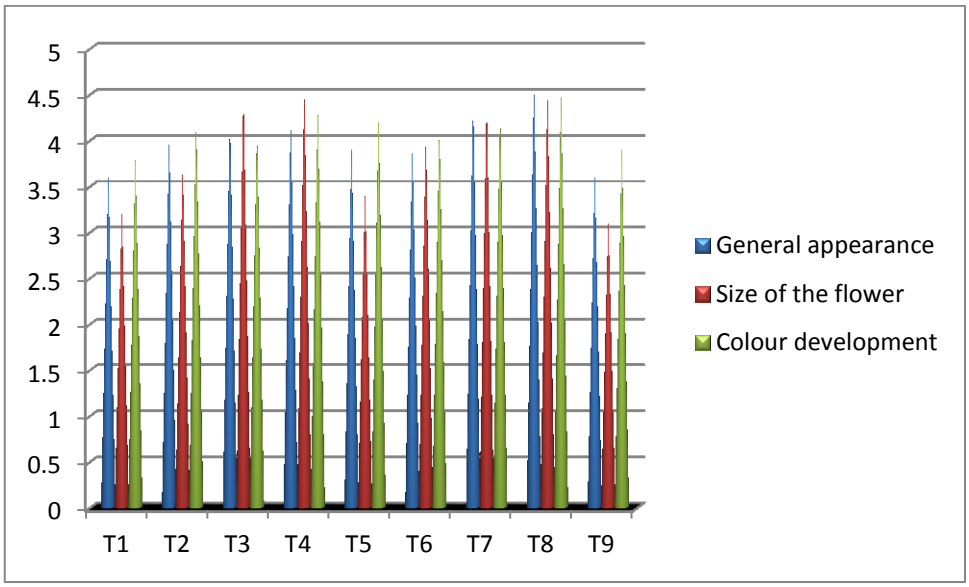


Fig.17 Effect of microbial inoculants on visual appeal

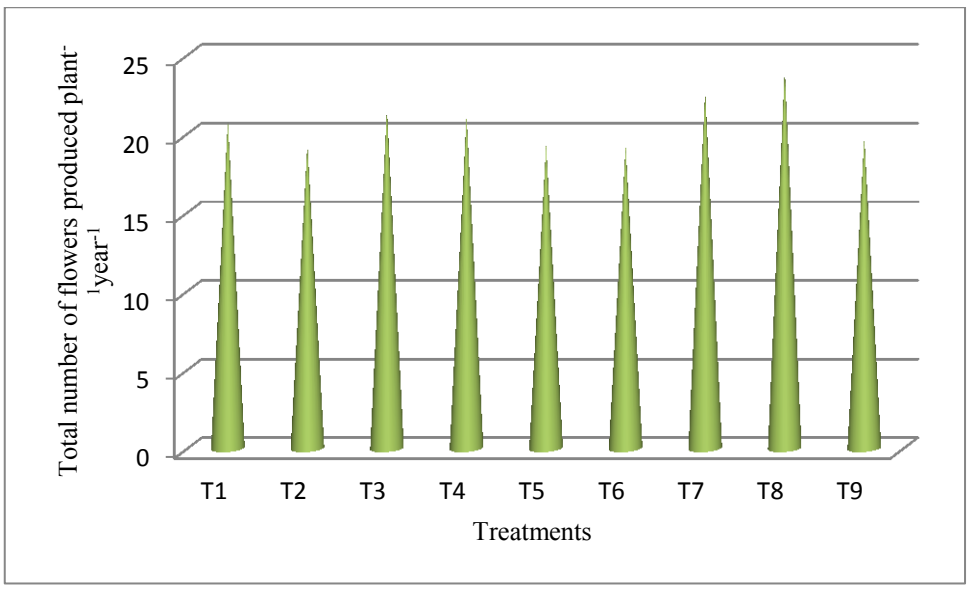


Fig.18 Total number of flowers produced plant^{-1}year^{-1}

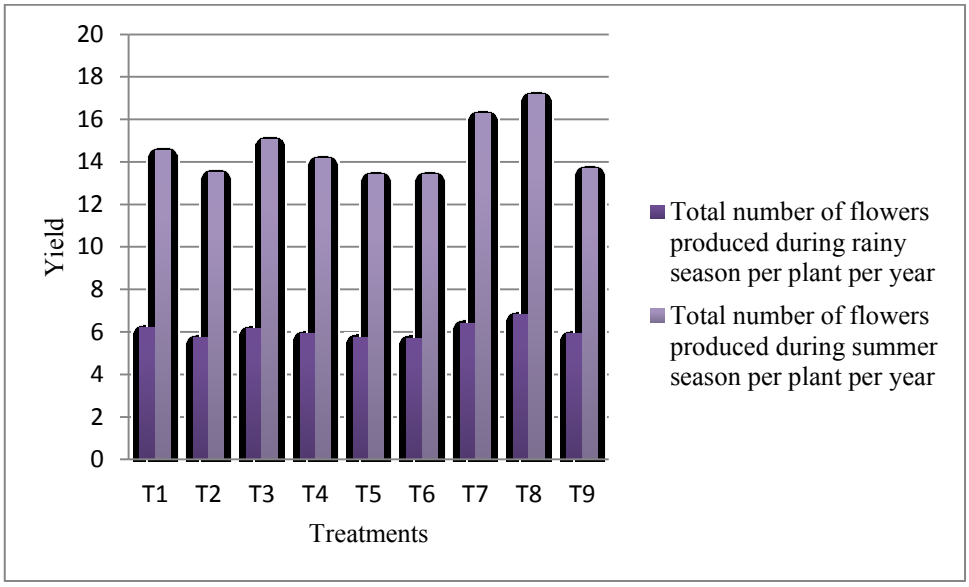


Fig.19 Total number of flowers produced in relation to season

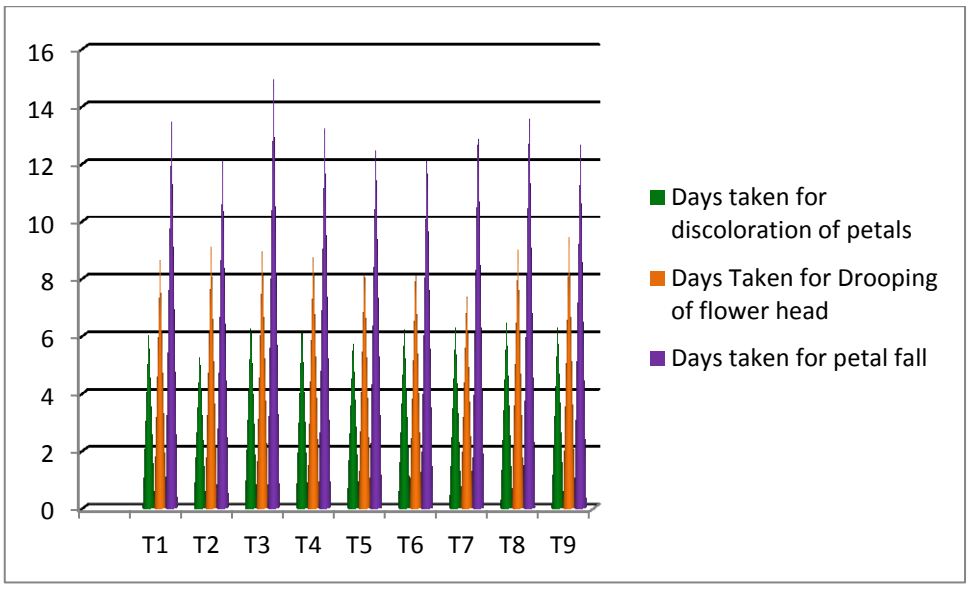


Fig.20 Vase life of flowers in distilled water

Plate 4. Comparison of T_9 and T_1 for visual appeal

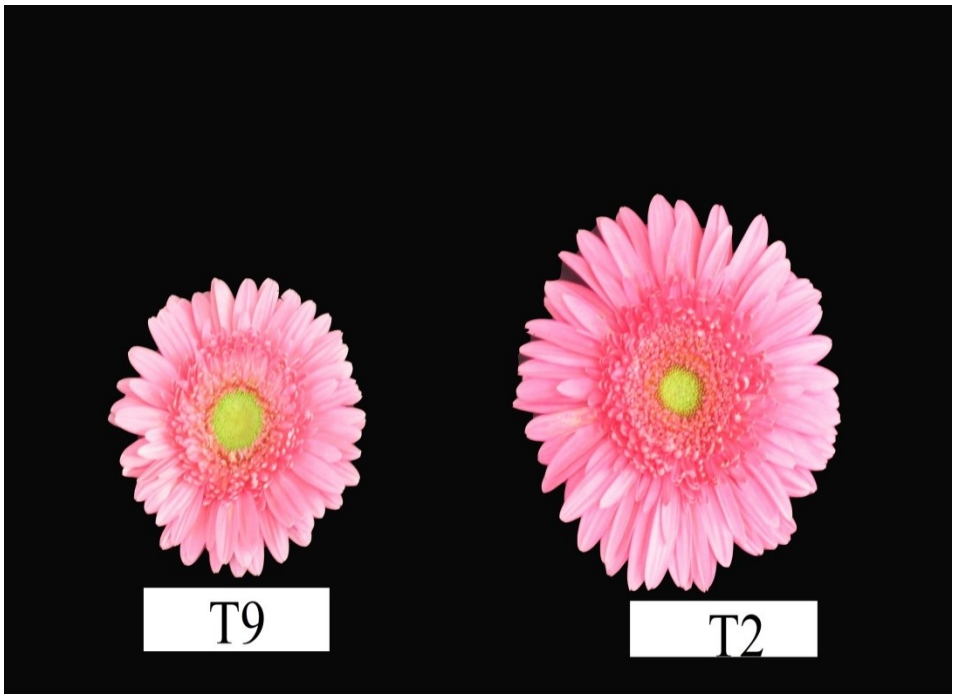


Plate 5. Comparison of T_9 and T_2 for visual appeal

Plate 6. Comparison of T_9 and T_3 for visual appeal

Plate 7. Comparison of T_9 and T_4 for visual appeal

Plate 8. Comparison of T_9 and T_5 for visual appeal

Plate 9. Comparison of T_9 and T_6 for visual appeal

Plate 10. Comparison of T_9 and T_7 for visual appeal

Plate 11. Comparison of T_9 and T_8 for visual appeal

par with T_7, T_3, T_4 and T_2 which had 4.40, 4.20, 4.20 and 4.00 scores respectively. Lowest score was recorded in T_1 (3.6) and T_9 (3.6).

The size of the flowers in all treatments were observed and the scores are presented in table 6. The size of the flower showed significant difference among the treatments. Highest score was observed in T_2 (4.5), T_3 (4.5) and T_8 (4.5) Lowest score was observed in T_9 (3.1).

Colour development of the flower showed significant difference among the treatments. Good colour development was showed in T_8 with a score of 4.5 which had significantly higher colour development than T_1 (3.8) and T_9 (3.9).

4.5 EFFECT OF MICROBIAL INOCULANT TREATMENTS ON YIELD PARAMETERS

4.5.1 Number of Flowers per Plant per Year

Data in the Table 7 & Fig 18 shows that treatments were significantly different from each other in the total number of flowers produced per plant per year. T_8 (Application of PGPR MIX-II twice, first at planting and second after 3 weeks.) produced maximum number of flowers (24) which was on par with T_7 and T_3. The Lowest number of flowers was noticed in T_6 (19.69).

4.5.2 Yield of Flowers in Relation to Season or Month of the Year

Data presented in Table 7 & Fig 19 shows that more flowers are produced during the summer season (September to July) compared to rainy season in all the treatments. During summer season T_8 (application of PGPR MIX-II twice, first at planting and second after 3 weeks.) (17.18) had recorded more number of flowers per plant per year. T_8 (6.81) had produced maximum number of flowers per plant per year during rainy season

4.6 EFFECT OF MICROBIAL INOCULANT TREATMENTS ON VASE LIFE OF FLOWERS IN DISTILLED WATER

Vaselife studies were carried out in distilled water and following three stages were recorded (Plate 12) .

Table 7. Effect of microbial inoculants on yield parameters of *Gerbera jamesonii* Bolus.

Treatment	Total number of flowers produced per plant per year	Total number of flowers produced during rainy season per plant per year	Total number of flowers produced during summer season per plant per year
T_1	20.75	6.21	14.55
T_2	19.25	5.75	13.48
T_3	21.50	6.15	15.06
T_4	21.06	5.91	14.14
T_5	19.19	5.76	13.4
T_6	19.13	5.71	13.41
T_7	22.63	6.42	16.27
T_8	24.00	6.81	17.18
T_9	19.69	5.93	13.7
CD(0.05)	2.864	0.799	1.892

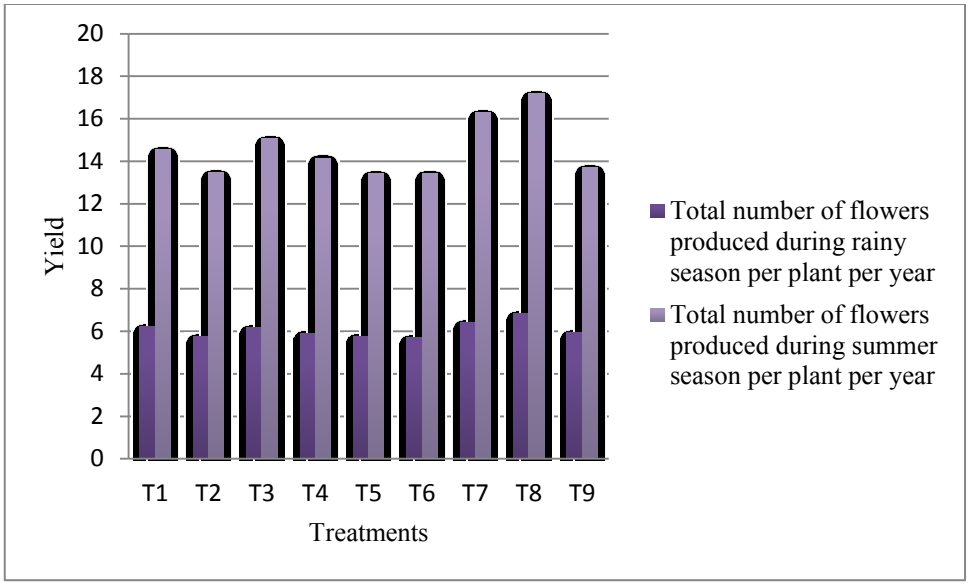


Fig.19 Total number of flowers produced in relation to season

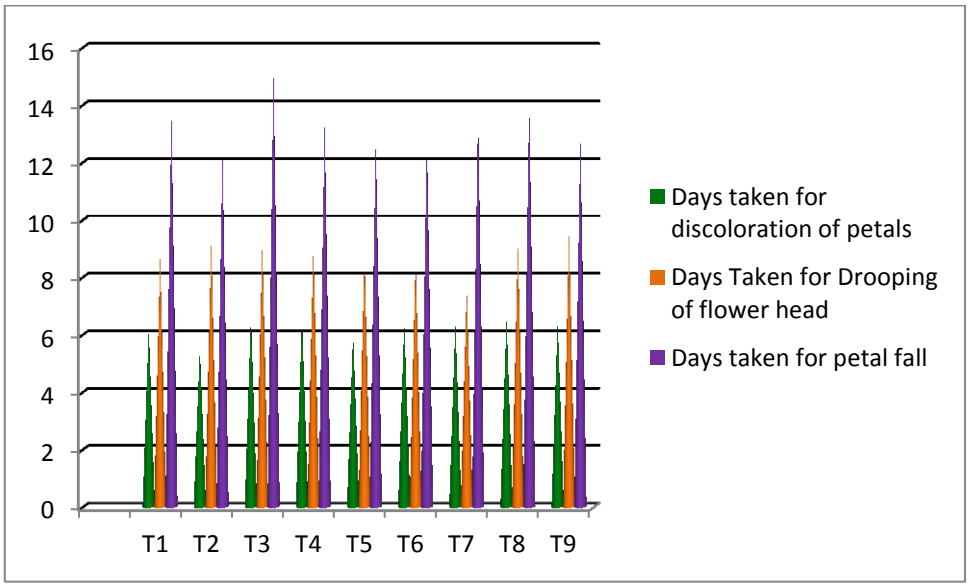


Fig.20 Vase life of flowers in distilled water

4.6.1 Days Taken for Drooping of Flower Head

The data (Table 8 & Fig 20) on drooping of flower head showed that T_9 (9.43) had significantly more number of days than all other treatments except T_7 (7.5). T_7 had recorded lowest number of days taken for drooping of flower head (Plate 13).

4.6.2 Days Taken for Discoloration of Petals

Observations on discoloration of petals were recorded from selected flowers from all the treatments.T_3 remained with good colour for 6.56 days which has significantly higher vase life than T_2 (5.43). T_3 was on par with T_4, T_8, T_6, T_7, T_1 and T_5 which had 6.5, 6.48, 6.31, 6.31, 6.13 and 5.93 days respectively.

4.6.3 Days Taken For Petal Fall

Observations on days taken for petal fall showed that T_3 (14.94) has significantly higher vase life than T_4 (13.25) , T_5 (12.69) , T_9(12.69) , T_6(12.62) and T_2 (12.16) and was on par with T_8, T_7 and T_1 which had taken 13.94, 13.56 and 13.48 days for petal fall respectively.

4.7 ENVIRONMENTAL PARAMETERS (Temperature in ^{0}c, Relative Humidity in %, Light Intensity In lx)

The weather data during the cropping period from May 2015 to May 2016 inside the polyhouse was recorded. In the polyhouse the maximum temperature ranged from 29.33^{0}C to 42.67^{0}C and the minimum temperature ranged from 23.33 ^{0}C to 27.5^{0}C. Light intensity ranged from 62.4 K.lux to 70.1K.lux. Relative humidity ranged from 81% to 94%. Influence of different environmental parameters on flower yield is shown in Fig. 21, 22 and 23.

4.8 ECONOMICS OF CULTIVATION

Gross income per 1000 m^2 for treatment T_8 (Application of PGPR MIX-II twice, first at planting and second after 3 weeks.) was Rs. 720000. BC ratio was

Table 8. Effect of microbial inoculants on vase life of flowers in distilled water

Treatment	Days taken for discoloration of petals	Days Taken for Drooping of flower head	Days taken for petal fall
T_1	6.13	8.62	13.48
T_2	5.43	9.12	12.16
T_3	6.56	9.06	14.94
T_4	6.5	9.00	13.25
T_5	5.93	8.62	12.69
T_6	6.31	8.50	12.62
T_7	6.31	7.50	13.56
T_8	6.48	9.00	13.94
T_9	6.38	9.43	12.69
CD(0.05)	0.778	1.424	1.546

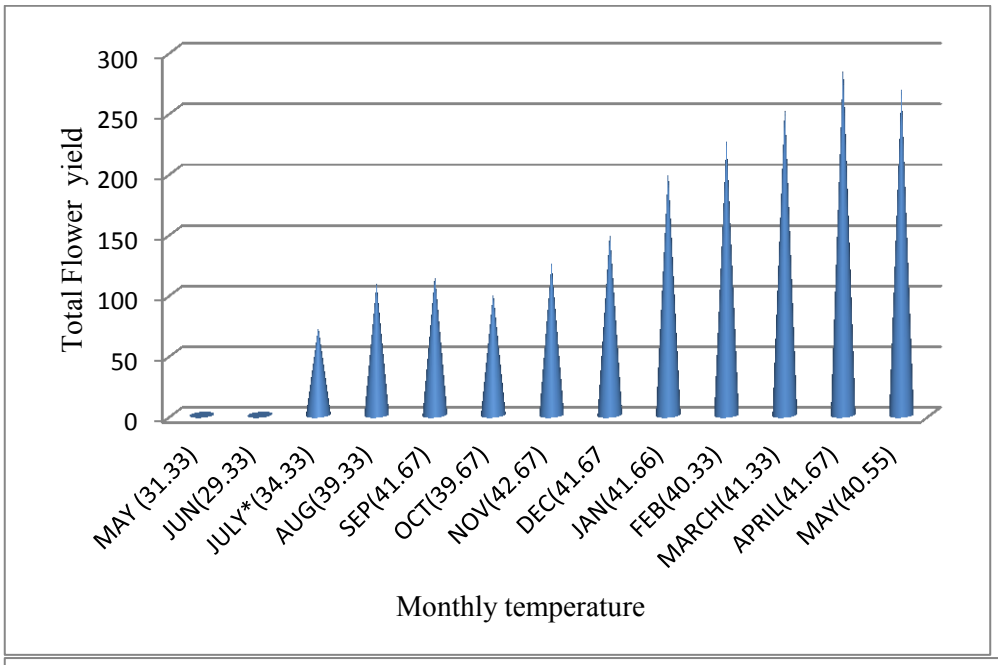
Table 9. Economics of cultivation of *Gerbera jamesonii* Bolus. as influenced by microbial inoculants

Treatments	Cost of cultivation	Gross returns	BC ratio
T_1	402780	622500	1.54
T_2	401880	577500	1.43
T_3	401820	645000	1.60
T_4	401820	631800	1.57
T_5	403980	575700	1.43
T_6	402780	573900	1.42
T_7	402660	678900	1.68
T_8	402660	720000	1.78
T_9	400980	590700	1.47

Table 10. Scoring of mite infestation in experimental plants

Treatment	Score
T_1	2.85
T_2	3.00
T_3	2.46
T_4	2.10
T_5	2.80
T_6	2.90
T_7	2.30
T_8	1.56
T_9	2.75
CD(0.05)	0.441

Fig.21 Effect of temperature on flower yield



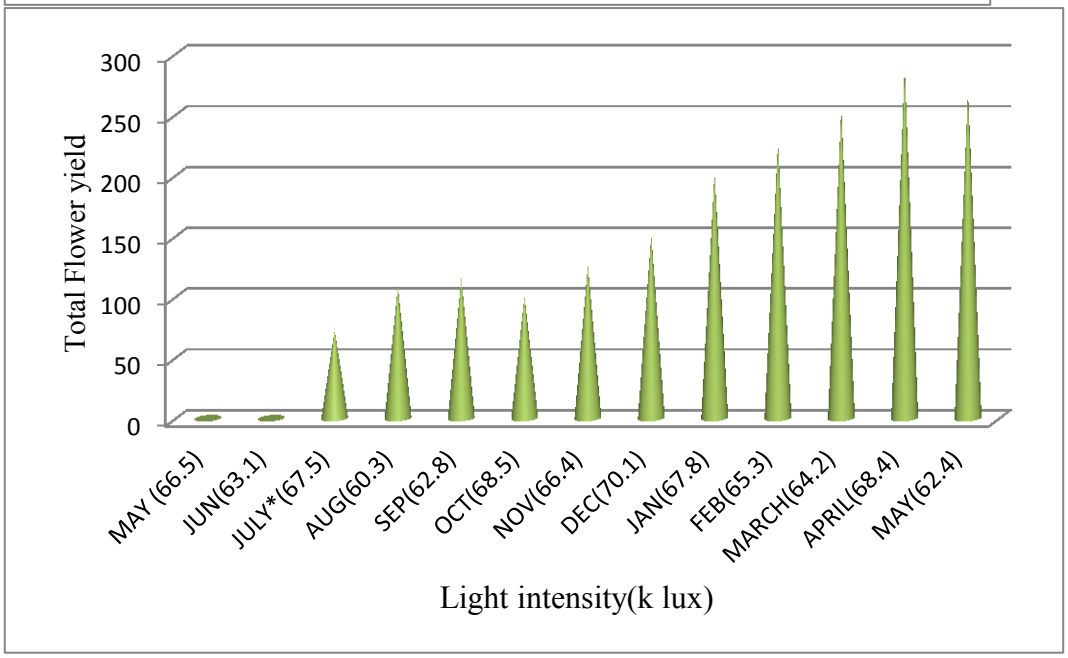


Fig. 22 Effect of light intensity on flower yield

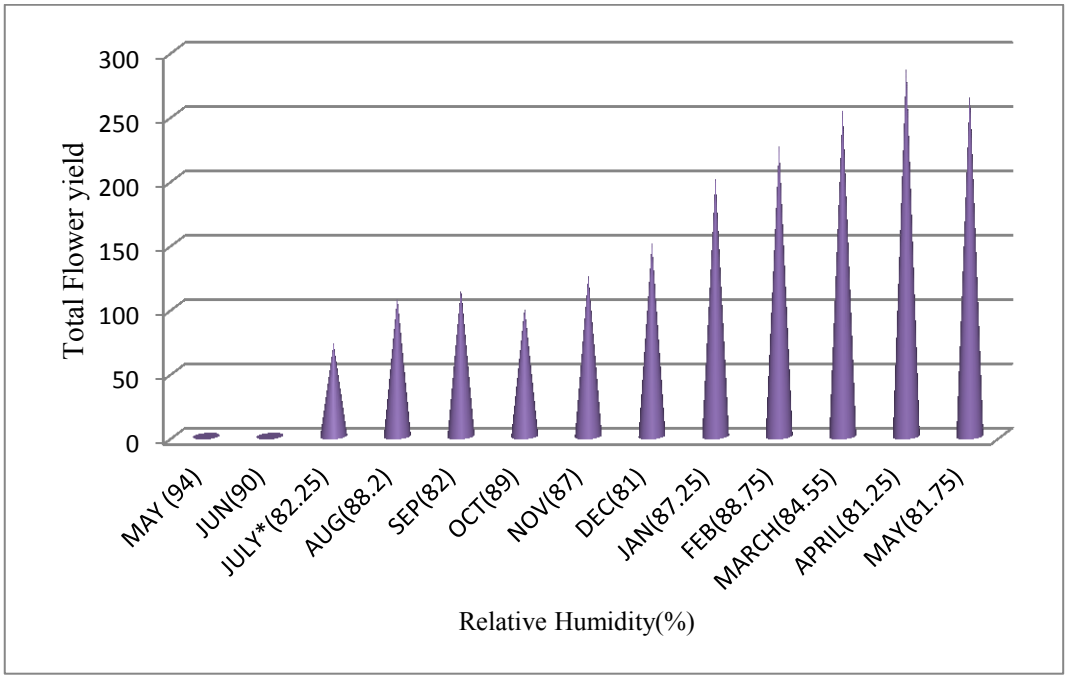


Fig. 23 Effect of Relative Humidity on flower yield

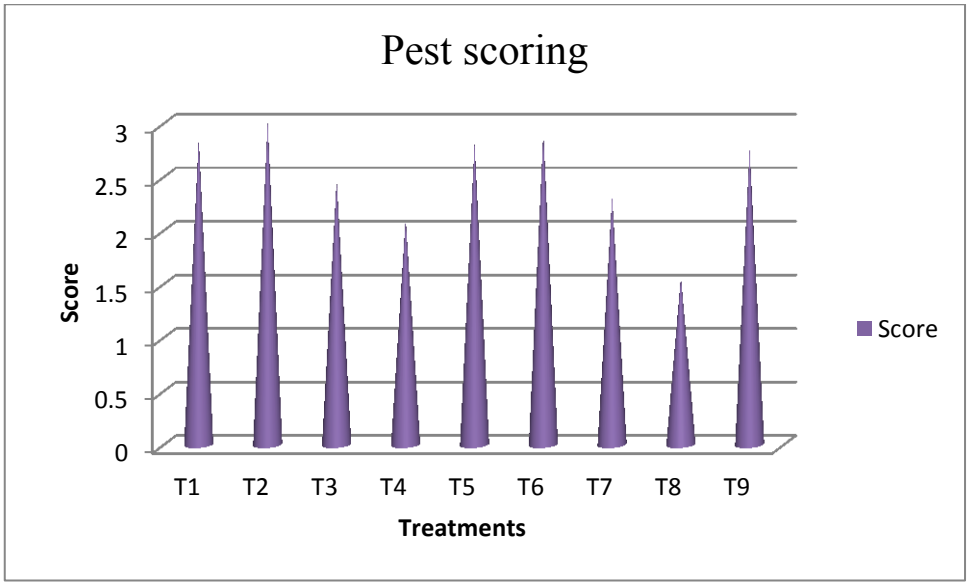


Fig.24 Pest scoring

Plate 12. Vase life study in distilled water

Plate 13. Different stages of flower deterioration in vase

highest (1.78) for same treatment and this was followed by T_7, application of PGPR MIX I twice, first at planting and second after 3 weeks (1.68) (Table 9).

4.9 PEST AND DISEASE INCIDENCE

In the experimental area mite infestation was noticed in plants, two month after planting (Plate 14 & 15). Hence scoring based on devised scale was carried out. The variation in scores in different treatments were observed. Data in the table 10 & Fig 24 shows that treatments significantly differs from each other. T_8 (1.56) showed lowest pest infestation of 1-25% and T_2 (3.00) was recorded with highest pest infestation of 51-75% which was on par with T_1 (2.85), T_6 (2.90), T_5 (2.80) and T_9 (2.75).Minor infestation of snails and thrips were also noticed in the experimental field (Plate 16 & 17).

Plate 14. Mite infested leaves

Plate 15. Mite infested flowers

Plate 16. Snail infestation

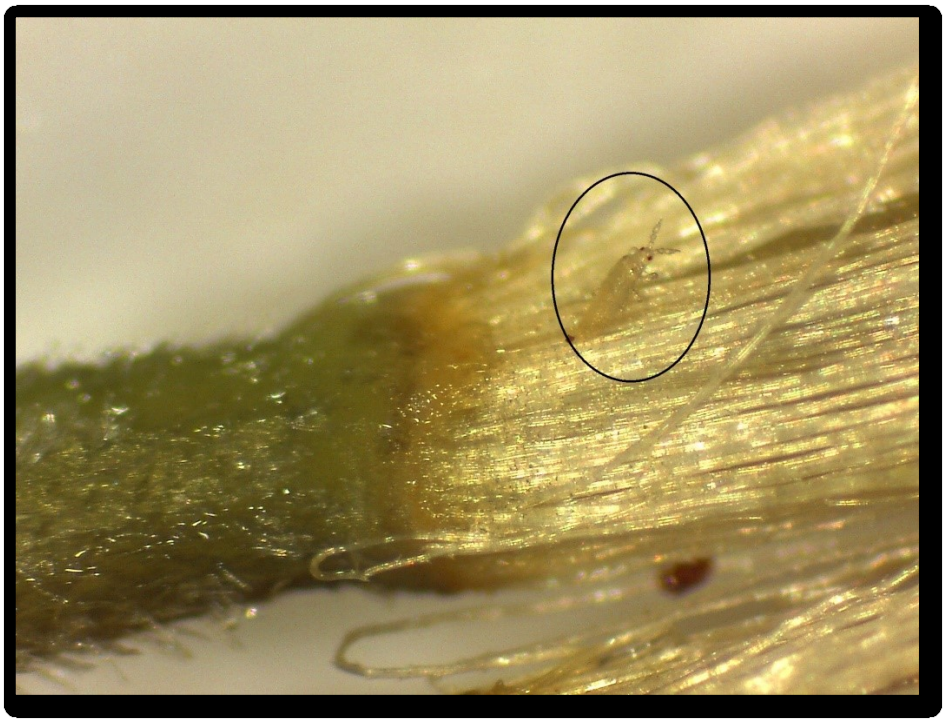


Plate 17. Microscopic view of thrips in gerbera flower

Discussion

5.DISCUSSION

Gerbera is a very popular decorative garden plant with commercial significance and ranks fifth in position in most used cut flower (Anisha, 2009). Increasingly there is a need to enhance the productivity of flower crops in terms of quality. Novel solutions are required to enhance the crop productivity in view of enhancing the quality production.

Application of free living plant growth promoting rhizobacteria and other microbial inoculants improves plant growth and restores environment .PGPR provides protection against pathogenic bacteria, synthesis of fungal cell lysing enzyme and competition with detrimental microorganism in the rhizosphere through indirect mechanisms.

Ornamental crops and high value crops grown under greenhouse conditions lack abundance of free living microorganism in the rhizosphere due to periodic disinfection. So there is a need to enhance the soil microfauna by inoculating different beneficial microbial inoculants which enhance the crop growth and yield in the protected conditions.

Under these circumstances, application of different microbial inoculants in the rhizosphere can be made viable for eco-friendly agricultural practices. Cultivation of gerbera with application of different microbial inoculants are feasible and profitable since gerbera is a high value crop.

Biocontrol agents can activate resistance mechanism in the host, enhance plant growth and increase the yield. Antibiosis, secretion of volatile toxic metabolites, mycotic enzyme parasitism etc. are some of the mechanisms by which biocontrol agents deliver its role. So biocontrol with microbials is an acceptable green approach.

The present study is on " Performance analysis of tissue culture plantlets of *Gerbera jamesonii* Bolus. as influenced by microbial inoculants". The relevance of effect of microbial inoculants on survival percentage, vegetative parameters, floral characters, flower quality parameters, yield parameters, vase life etc. of *Gerbera jamesonii* Bolus. is discussed in this chapter. The study was

carried out at college of Agriculture, Vellayani, Kerala Agricultural University from January 2015 to July 2016.

5.1 EFFECT OF MICROBIAL INOCULANT TREATMENTS ON SURVIVAL PERCENTAGE

In the present investigation all plants treated and un treated with microbial inoculants showed 100% survival rate. This might be due to favourable climatic condition and enhancement of establishment of microbial inoculants. Debergh (1991) reported 100% plantlet survival rate of gerbera in both AMF inoculated and AMF non-inoculated plants. AMF strains can be used as bio hardening agent for micro propagated tissue culture plants by enhancing survival rate and reducing field mortality (Kumar *et al.,* 2014). This report is in conformity with the result in the present study.

5.2 EFFECT OF MICROBIAL INOCULANT TREATMENTS ON VEGETATIVE PARAMETERS

5.2.1 Plant Spread

The plants treated with T_4 (application of PGPR MIX- II at planting (@ 2% drench and spray)) recorded the highest value (186.61 cm). It was observed that PGPR mix II is a consortium of best studied soil microorganisms which enhances the vegetative growth and resistance to pest and diseases. Aryamba (2014) reported that the nutrients and PGPR had greatly influenced the plant spread in Heliconia. This may be due to favourable effect of solubilisation of nutriennts which enhanced nutrient uptake which in turn resulted in better plant growth and increase in yield (Singh *et al*., 2010). The output of any plant is influenced by vigour of the plant where the plant spread along with the plant height play an important role (Nikhil, 2012).

5.2.2 Number of Leaves per Plant

The present study shows that the microbial inoculants had influenced the number of leaves per plant. The highest number of leaves was recorded in T_3 (Application of PGPR MIX-I at planting (@ 2% of FYM). PGPR MIX I and

PGPR MIX II applied at the time of planting and three weeks after planting showed similar results. The application of PGPR MIX I whose favourable effect on solubilization of nutrients favoured increase in number of leaves per plant. The applications of PGPR increased the leaf number and area in apple (Karakurt and Aslantas , 2010).Similar findings were reported by Dasgupta *et al.*(2015) in chickpea.

5.2.3 Leaf Length

The leaf length is influenced by the microbial inoculants especially PGPR MIX II. The increase in leaf length enables them to enhance the photosynthetic efficiency. This might be due to increased availability of microbial inoculants which in turn helped in maintaining higher leaf area. It also leads to increased flower production.

5.2.4 Leaf Breadth

In this study higher leaf breadth has been recorded in plants treated with PGPR MIX-I twice, first at planting and second after 3 weeks. This might be due to increased availability of nutrients and the active role of biofertilizers in enhancing nutrient availability. Gomma and Mohammed (2000) reported that in nutrient contents of leaves which manifested the highest leaf area resulted in more carbohydrate production through photosynthesis and might act as sink.

5.2.5 Number of Suckers per Plant

The study revealed that the microbial inoculants greatly influenced the total number of suckers produced. The maximum sucker production was noticed in T_7 (application of PGPR MIX-I twice, first at planting and second after 3 weeks). This might be due to the increased activity of consortium of microorganisms in PGPR MIX I. The biofertilizers may also trigger the activity of substances like IAA, gibberellins and cytokinin.The beneficial effect of plant growth regulators in enhancing cell divison and cell growth might also have played a crucial role. PGPR inoculants helps to improve nutrient aquisition and phytohormone production which act as biofertilizer and biostimulant respectively (Saharan and Nehra , 2011) .

5.3 EFFECT OF MICROBIAL INOCULANT TREATMENTS ON FLOWERING CHARACTERS

5.3.1 Number of Days Taken for Flowering

The present investigation revealed that early flowering was observed in T_4 (application of PGPR MIX- II at planting (@ 2% drench and spray). Late flowering was noticed in T_2. The early flowering may be due to solubilization of organic acid and inorganic phosphate from soil by the bacteria which releases organic acid and makes the P as well as micronutrients more readily available to the plants. Kumari *et al*. (2015) reported that number of days taken from bud initiation to first flowering was significantly influenced by PGPR (*Pseudomonas sp*. and *Bacillus sp.*) in chrysanthemum. According to Singh *et al*. (2010) number of days taken for spike initiation was reduced by combined application of PGPR (*Pseudomonas sp*. and *Bacillus sp*.) in gladiolus. Barman *et al*. (2003) also reported that application of PGPR (*Bacillus sp.*) resulted in early flowering in tuberose.

5.3.2 Number of Days Taken from Bud Opening to Harvest

Minimum number of days taken from bud initiation to harvest is an indicator of efficiency of microbial plant interaction. This might be due to efficient solubilisation and immobilization of P and micronutrients and synthesis of phytohormones by the PGPR. Kumari *et al*. (2015) reported that the application of *Bacillus* and *Pseudomonas* strains (PGPR) resulted in the minimum number of days taken for full bloom from bud initiation (12.33 days) in chrysanthemum.

5.3.3 Total Number of Flowers Produced

In this study number of flowers per plant per year was found to be the highest in T_8 (application of PGPR MIX-II twice, first at planting and second after 3 weeks). This result is in conformity with the findings of Kaushal *et al.* (2011); Dey *et al*. (2004); Kloepper et *al*. (2004); Herman *et al*. (2008) and Minorsky (2008) . According to their reports PGPR enhances the crop yield and protects the plants from pest and pathogen. . Kumari *et al*. (2015) reported that application of

PGPR enhanced flowering in chrysanthemum. The increase in flower yield might be due to the greater leaf area and more number of leaves per plants well as plant spread which resulted in production and accumulation of maximum photosynthates, resulting the production of more number of flowers with bigger size (Salem *et al.,* 2016). The results are in agreement with the findings of Nair and Medhi (2002) in gerbera under protected condition.

5.3.4 Peak Flowering Period

The study revealed that application of microbial inoculants influenced the flowering in *Gerbera jamesonii* Bolus. var. Esmara . In the present study, summer season (February, March, April and May) had maximum flower yield compared to other seasons. Temperature influences the number of leaves, lateral shoots, flower bud production and therefore the flower production in gerbera as evident in earlier studies by Leffring (1984).

5.3.5 Life of Flower in the Plant (days)

Life of flower in plants might be enhanced due to production of phytohormones like IAA, auxin etc. by the rhizosphere bacteria. Many rhizosphere bacteria including *Bacillus*, *Pseudomonas*, *Azotobacter*, *Azospirillum*, *etc*. were found to have the ability to produce IAA or related auxins (Salma *et al*., 2013). Increase in temperature coupled with less relative humidity and severe pest and disease incidence may result in a significant decline in life of flowers in the plant. The information about the time taken for the flower to lose its fresh appearance helps the farmers in planning the harvesting time of flowers grown under rainshelter.

5.4 EFFECT OF MICROBIAL INOCULANT TREATMENTS ON FLOWER QUALITY PARAMETERS

5.4.1 Flower Diameter (cm)

The flower diameter was influenced by different microbial inoculants. An increase in uptake of nutrients led to production of good quality flowers. T_8 recorded highest flower diameter (application of PGPR MIX-II twice, first at planting and second after 3 weeks). The increased flower diameter in

chrysanthemum might be due to the increased availability of nitrogen and phosphorus for flower development as a result of greater solubility and absorption of nutrients by the PGPR (Kumari et al., 2015). Singh *et al*. (2010) also reported beneficial effect of different biofertilizers and their strains on floret diameter of gladiolus. These findings are in line to that of Pandey *et al.* (2013) who observed that application of *Bacillus subtilis* + vermicompost registered maximum diameter of floret in gladiolus.

5.4.2 Diameter of Flower Disc (cm)

The diameter of the flower disc is directly in proportion with the size of the flower. In the present study the maximum flower diameter was noticed in T_8 (application of PGPR MIX-II twice, first at planting and second after 3 weeks). This increase in flower disc diameter might be due to effect of PGPR on the floral tissues by enhancing availability of nutrients by phosphate solubilisation, nitrogen fixation and siderophore production (Lucy *et al*., 2004)

5.4.3 Colour of Flower Disc

In the present study the colour of flower disc in all treatment was found to be greenish yellow. This might be due to general enhancement of photosynthetic pigments by microbial inoculants.

5.4.4 Number of Ray Florets

In this study number of ray florets was higher in treatment T_7 (Application of PGPR MIX-I twice, first at planting and second after 3 weeks). PGPR comprises of naturally occurring soil bacteria that colonize plant roots and benefit plants by enhancing growth promotion (Saharan and Nehra, 2011). The favourable effect of PGPR MIX I on solubilisation of nutrients might have favoured the increase in number of ray florets in gerbera.

5.4.5 Colour of Ray Florets

The flower colour of gerbera, an important ornamental cut flower, is derived from carotenoids and flavonoids (Tyrach and Horn, 1997).In the present study colour of ray florets is found to be hot pink. The colour is found to be same in all treatments and the bright colour of flowers might be due to quality enhancing property of microbial inoculants.

5.4.6 Length of Ray Florets (cm)

The length of ray florets was influenced by different microbial inoculants. An increase in nutrient availability led to increase in length of ray florets. In the present study highest length of ray florets was noticed in T_7 (application of PGPR MIX-I twice, first at planting and second after 3 weeks). This might be due to increased availability of nutrients for the plant by efficient plant microbe interaction.

5.4.7 Width of Ray Florets (cm)

In this study microbial inoculant treatments influenced the width of ray florets and T_8 (application of PGPR MIX-II twice, first at planting and second after 3 weeks) registered the maximum width of ray floret. This might be because of the better nutrient availability of the plants by the solubilisation of P and other micronutrients

5.4.8 Length of Flower Stalk (cm)

The plants supplied with PGPR MIX-I twice, first at planting and second after 3 weeks recorded highest flower stalk length. An increased growth of PGPR inoculated plants might be due to efficient mobilization of nutrients and water . Length of flower stalk in gerbera was positively and significantly correlated with the content of NPK (%) (Panj *et al.*,2014).

5.4.9 Girth of Flower Stalk (cm)

The plants supplied with PGPR MIX-I twice, first at planting and second after 3 weeks recorded highest flower stalk girth. This might be due to increased solubilisation and mobilization of nutrients by consortium of microorganisms with in PGPR MIX I. Panj *et al.* (2014) reported that girth of flower stalk was significantly and positively correlated with E.C. (dsm-1), Organic carbon (%) content, available N, P, K (%) in gerbera.

5.4.10 Visual Appeal

In a commercial flower like gerbera visual appeal of flowers is the single most important critical factor determining its commercial value. The visual appeal of flowers was observed based on three characters such as, general appearance, size of the flower and colour development. The highest score for general

appearance and colour development of the flower was recorded in plants treated with PGPR MIX-II twice, first at planting and second after 3 weeks. This might be due to resistance imparted by PGPR MIX II against pest infestation and proper utilization of nutrients by the plant. Size of the flower was found to be highest in plants treated with *Pseudomonas fluorescens* at planting (@ 2% spray and drench), PGPR MIX-I at planting (@ 2% of FYM) and PGPR MIX-II twice, first at planting and second after 3 weeks. Kumari *et al*. (2015) reported that the maximum flower size was noticed with PS3 strain of *Pseudomonas* (P20) in chrysanthemum.

5.5 EFFECT OF MICROBIAL INOCULANT TREATMENTS ON YIELD PARAMETERS

5.5.1 Number of Flowers per Plant per Year

The plants supplied with PGPR MIX-II twice, first at planting and second after 3 weeks recorded more number of flowers per plant per year . This might be due to resistance imparted by the microorganism against pest infestation in PGPR MIX II treated plants. The selected bacterial strains are feasible to be used for development of plant growth promoting or biocontrol inoculants, together with other plant growth promoting microbes (Evalaslo *et al.*, 2012). Plants inoculated with consortium of PGPR (*G. mosseae + A. laevis + P. fluorescens)* recorded higher number of flowers in gerbera (Karishma *et al.,* 2013). Kumari *et al*. (2015) reported that the interaction effects of PGPR (*Pseudomonas* and *Bacillus* strains) showed maximum number of flowers in chrysanthemum.

5.5.2 Yield of Flowers in Relation to Season or Month of the Year

The maximum number of flowers was noticed during summer season (February, March, April and May) . The increased temperature and high light intensity might be the reason for higher flower production during the summer season. Pearson *et al*. (1993) reported that effective temperature and light intensity have a linear effect on flowering in chrysanthemum.

5.6 EFFECT OF MICROBIAL INOCULANT TREATMENTS ON VASELIFE OF FLOWERS IN DISTILLED WATER

In the present study flowers from plants treated with PGPR MIX I at the time of planting recorded maximum vase life. This might be because of the flower quality enhancement property of PGPR MIX I by providing nutrients for maintaining freshness even after harvest. The scapes of cut gerbera flowers often bend and break when they are placed in water (Steinitz, 1984).

5.7 ENVIRONMENTAL PARAMETERS

Garner and Allard (1920) reported that flowering induction, initiation and development are photoperiodic in ornamental herbaceous plants. In the present study environmental parameters have an influence on crop growth and flowering of gerbera. In the initial stage the acclimatization of plantlets were favoured with less temperature and high relative humidity. Later during the flowering period high temperature and more light intensity favoured vigorous flowering in gerbera. From this study it can be concluded that the temperature and light intensity have immense effect on flowering, since more flowering was recorded in the summer season. Less humidity during flowering season reduced the disease incidence in gerbera.

Zaidi *et al.* (2009) reported that climatic variations have an effect on efficacy of PGPR. Plants treated with AM fungi are resistant to environmental stresses such as drought, chilling, salinity and have capacity to resist and survive pathogen attacks (Rodrigues and Rodrigues, 2014).

5.8 ECONOMICS OF CULTIVATION

Good quality flowers and suckers were found to attribute to higher B:C ratio.Benefit cost analysis showed that the treatment T_8 (Application of PGPR MIX-II twice, first at planting and second after 3 weeks.) recorded high B:C ratio (1.78).

5.9 PEST AND DISEASE INCIDENCE

In the present study severe infestation of mite was noticed in gerbera which affected the flower production. Plants treated with PGPR MIX II twice showed lowest pest infestation ranging from one to twenty five percent. Vinale *et al*. (2008) reported that growth-promoting microorganism protects plants against pathogens by evolving various mechanisms such as antagonism, competition and induced systemic resistance (ISR). PGPR as biofertilizers is an efficient consortium of microorganism to replace chemical fertilizers and pesticides (Kumari *et al.* 2015). These reports are in conformity with results in the present investigation.

CONCLUSION

In the present study treatments which contain PGPR MIX I and PGPR MIX II showed best results for vegetative parameters, flowering characters, flower quality parameters, yield parameters and resistance to pest and diseases. T_4 (Application of PGPR MIX- II at planting (@ 2% drench and spray)) was found to be significantly superior in plant spread (186.61 cm), leaf length (29.72 cm) , number of days taken for flowering (44.69 days). T_7 (Application of PGPR MIX-I twice, first at planting and second after 3 weeks) was found to be significantly superior in leaf breadth (9.66 cm), number of suckers per plant (4.25), number of ray florets (69.60), length of ray florets (5.51 cm) and girth of flower stalk (2.45 cm). T_8 (Application of PGPR MIX-II twice, first at planting and second after 3 weeks) was found to be significantly superior in characters like total number of flowers produced per plant (24), flower diameter (11.46 cm), diameter of flower disc (3.91 cm), width of ray florets (0.76 cm), length of flower stalk (51.62 cm) , visual appeal and least pest infestation. T_3 (Application of PGPR MIX-I at planting (@ 2% of FYM)) recorded maximum vaselife comparing to other treatments.

For the large scale production of good quality gerbera flowers, along with manures PGPR MIX I and PGPR MIX II can be applied as biostimulants and biocontrol agents. From the present study it is clear that the application of PGPR

MIX I and PGPR MIX II enhanced the production and quality of the flowers. Application of these bioinoculants can enhance the microbial population in soil, enhance plant microbe interaction and ultimately help to produce good quality flowers for commercial purpose. This treatments can be recommended for large scale production of *Gerbera jamesonii* Bolus. var. Esmara under protected environment

FUTURE LINE OF WORK

Gerbera jamesonii Bolus var. Esmara is variety which performs well in Kerala condition. Standardization of different combination of microbial inoculants in open field conditions of Kerala can be done with a view of enhancing the flower production and for efficient use of gerbera as a landscape plant. Future line of work maybe enhancement of yield and quality of flower through nutrient application and scheduling with microbial inoculant treatments in gerbera. Studies on root parameters and survival of microbial inoculants after inoculation and microbial inoculant treatment of gerbera in open and protected conditions can be taken up based on the result obtained in the present study .

Summary

6. SUMMARY

The present study on "Performance analysis of tissue culture plantlets of *Gerbera jamesonii* Bolus. as influenced by microbial inoculants" was carried out at the Department of Pomology and Floriculture, College of Agriculture ,Vellayani during 2014-2016.The experiment was laid out in completely randomized design consisting of nine treatments and four replications. The treatments consisted of application of AMF, *Pseudomonas fluorescence,* PGPR MIX I and PGPR MIX II at planting and first at planting and three weeks after planting. The study was undertaken is to study the establishment of tissue culture plantlets of gerbera as influenced by microbial inoculants under rain shelter. This study also aims to analyse the performance of gerbera treated with different microbial inoculants under rain shelter.

The salient findings of the above studies are summarized in this chapter.

- The plants treated with AMF, *Pseudomonas fluorescence,* PGPR MIX I and PGPR MIX II first at planting and a second application three weeks after planting showed 100% survival percent in two and four weeks after planting.
- The plants supplied with PGPR MIX II once at the time of planting (T_4) was found to be significantly superior in vegetative parameters such as plant spread and leaf length.
- Treatment T_7 (Application of PGPR MIX-I twice, first at planting and second after 3 weeks) recorded highest number of suckers per plant and maximum leaf breadth .Treatment T_3 (Application of PGPR MIX-I at planting (@ 2% of FYM)) showed maximum number of leaves per plant.
- The flowering characters i.e., number of days taken for first flowering and total number of flowers produced per plant, was found to differ significantly with the treatments. Minimum number of days taken for flowering was noticed in plants treated with PGPR MIX II once at the time of planting(T_4)

- Maximum number of flowers produced per replication was recorded in T_8 (Application of PGPR MIX-II twice, first at planting and second after 3 weeks).
- The flower quality parameters were found to differ significantly among treatments. The parameters such as diameter of flower disc and flower, width of ray florets and length of flower stalk was found to be maximum in plants treated with treatment T_8 (Application of PGPR MIX-II twice, first at planting and second after 3 weeks).
- Number of ray florets, length of ray florets, length of flower stalk and girth of flower stalk was found to have significantly superior values in treatment T_7 (Application of PGPR MIX-I twice, first at planting and second after 3 weeks).
- The colour of ray florets and disc florets was found to be hot pink and greenish yellow respectively, irrespective of the treatments.
- Data on visual appeal revealed that treatment T_8 (Application of PGPR MIX-II twice, first at planting and second after 3 weeks) scored highest values in general appearance, size of flower and colour development.
- There was significant difference in number of flowers produced per plant per year between the treatments. Highest number of flowers produced per plant per year was recorded in T_8 (Application of PGPR MIX-II twice, first at planting and second after 3 weeks). During the observation period maximum number of flowers were produced during summer season compared to rainy season.
- The vase life of flowers was found to differ significantly among the treatments. Maximum number of days taken for discoloration of petal and petal fall was recorded in T_3 (Application of PGPR MIX-I at planting (@ 2% of FYM)).
- Environmental parameters like Temperature in ^{0}C, Relative humidity in %, Light intensity in lx influenced the vegetative and floral parameters. Increased temperature enhanced flower production and variation in relative humidity affected the pest infestation during the crop period.

- The benefit cost ratio was highest for T_8 (Application of PGPR MIX-II twice, first at planting and second after 3 weeks.)(1.78) and lowest was by T_6 (1.42)(Application of *Pseudomonas fluorescens* twice, first at planting and second second after 3 weeks.)
- There was a major infestation of mite during the crop period. Data on scoring of pest reveals that minimum infestation was noticed in T_8 (Application of PGPR MIX-II twice, first at planting and second after 3 weeks).

FUTURE LINE OF WORK

Gerbera jamesonii Bolus var. Esmara is variety which performs well in Kerala condition. Standardization of different combination of microbial inoculants in open field conditions of Kerala can be done with a view of enhancing the flower production and for efficient use of gerbera as a landscape plant. Future line of work maybe enhancement of yield and quality of flower through nutrient application and scheduling with microbial inoculant treatments in gerbera. Studies on root parameters and survival of microbial inoculants after inoculation and microbial inoculant treatment of gerbera in open and protected conditions can be taken up based on the result obtained in the present study .

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Appendices

APPENDIX – I

Visual appeal of flowers (Score card)

Sl. No	General Appearance										Size of the flower										Colour development									
	1	2	3	4	5	6	7	8	9	10	1	2	3	4	5	6	7	8	9	10	1	2	3	4	5	6	7	8	9	10
T_1	3	4	3	4	4	4	3	3	4	4	3	4	4	4	4	3	3	3	5	2	4	4	3	4	4	3	4	3	4	5
T_2	4	4	4	3	4	4	4	4	4	5	4	4	4	3	4	4	3	4	4	3	5	4	4	4	4	4	4	4	4	5
T_3	5	4	4	4	4	4	5	4	5	3	5	5	5	4	5	4	4	4	5	4	4	4	4	5	4	4	4	4	4	4
T_4	5	3	4	4	4	5	4	5	4	4	5	5	5	4	5	4	3	4	5	5	4	4	4	4	4	4	4	5	5	5
T_5	5	4	4	4	5	3	3	3	5	3	3	4	3	4	4	2	4	3	4	3	5	4	4	4	4	4	5	4	4	4
T_6	4	5	3	4	4	4	4	3	4	4	4	5	4	4	4	5	4	2	5	3	4	4	4	5	4	4	4	4	4	4
T_7	4	4	5	4	5	5	4	4	5	5	4	5	4	4	5	5	4	5	4	4	5	4	4	4	4	4	4	4	5	5
T_8	5	5	5	5	5	4	5	5	4	4	5	4	5	5	4	4	4	5	5	4	4	4	4	5	4	4	5	5	5	5
T_9	4	4	4	4	3	4	4	3	4	3	4	3	4	4	3	3	3	2	3	3	4	4	4	3	4	4	4	4	4	4

Score distribution

Average - 1 to2

Good - 3 to4

Very good – 5

APPENDIX - II

Weather data in poly house during the cropping period (May 2015 – May 2016)

Month	Temperature (^{0}C)		Relative humidity (%)	Light intensity (K. lux)
	Max. temp	Min. temp		
May 2015	31.33	25.33	94.00	66.5
June	29.33	25.33	90.00	63.1
July	34.33	27	82.25	67.5
August	39.33	25.67	88.20	60.3
September	41.67	27.5	82.00	62.8
October	39.67	24.33	89.00	68.5
November	42.67	24.33	87.00	66.4
December	41.67	24	81.00	70.1
January	41.66	25.67	87.25	67.8
February	40.33	24.33	88.75	65.3
March	41.33	24	84.55	64.2
April	41.67	23.33	81.25	68.4
May2016	39.55	24	91.25	62.4

Abstract

PERFORMANCE ANALYSIS OF TISSUE CULTURE PLANTLETS OF *Gerbera jamesonii* Bolus AS INFLUENCED BY MICROBIAL INOCULANTS

by

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Abstract of the

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ABSTRACT

The present investigation on "Performance analysis of tissue culture plantlets of *Gerbera jamesonii* Bolus. as influenced by microbial inoculants" was carried out in the Department of Pomology and Floriculture, College of Agriculture, Vellayani during 2014-2016. The objective was to study the establishment of tissue culture plantlets of gerbera variety Esmara as influenced by microbial inoculants and to analyse the performance of gerbera treated with different microbial inoculants under rain shelter. The treatment consisted of AMF, *Pseudomonas fluorescence,* PGPR MIX - I and PGPR MIX – II applied in two sets: first at planting , first at planting + second application 3 weeks after planting. The experiment was laid out in completely randomized design consisting of nine treatments and four replications.

All the treatments showed 100 per cent survival after two weeks and four weeks of planting. Considering the vegetative parameters, the highest value for plant spread (186.61 cm) and leaf length (29.72 cm) was recorded in T_4 (application of PGPR MIX- II at planting @ 2% drench and spray). Maximum number of leaves per plant (12.56) was recorded in T_3 (application of PGPR MIX-I at planting @ 2% of FYM). The leaf breadth (9.66 cm) and number of suckers per plant (4.25) was highest in T_7 (application of PGPR MIX-I twice, first at planting and second after 3 weeks).

Regarding the flowering characters, the lowest number of days taken for flowering (44.69 days) was noticed in T_4. There was no significant difference found between the treatments for number of days taken from bud opening to harvest and life of flowers in the plant. Total number of flowers produced (24) was found to be significantly superior in T_8 (application of PGPR MIX-II twice, first at planting and second after 3 weeks). Peak flowering period was recorded during summer season, in which T_8 produced highest number of flowers (17.18).

In flower quality parameters highest diameter of flower (11.46 cm), flower disc diameter (3.91 cm) and width of ray florets (0.76 cm) was recoded in T_8 .The colour of ray florets and disc florets was found to be hot pink and greenish yellow respectively for all the treatments. Other flower quality parameters such as number of ray florets (69.60), length of ray florets (5.51 cm), length of flower stalk (51.62 cm) and girth of flower stalk (2.45 cm) was found to be maximum in T_7. The visual appeal of flowers were assessed based on three characters, in which T_8 recorded highest value for general appearance (4.60), size of the flower (4.50) and colour development (4.50).

In yield parameters, the highest number (24) of flowers per plant per year was recorded in T_8 and the yield of flowers were highest during summer season (17.18) in the same treatment. The vase life studies showed that the highest number of days for discoloration of petal (6.56 days) and petal fall (14.94 days) was recorded in T_3 (application of PGPR MIX-I at planting @ 2% of FYM). The number of days taken for drooping of flower head was found to be highest (9.43 days) in T_9 (control).

Environmental parameters (temperature (^{0}C), relative humidity (%) and light intensity (lx)) inside the rain shelter during the growing period was recorded and an increase in flower yield was noticed with an increase in temperature and light intensity. Highest benefit cost ratio was recorded in T_8 (1.78) and the plants were comparatively tolerant to mite infestation compared to other treatments.

The establishment of tissue culture plantlets of gerbera under rain shelter was100 per cent two and four weeks after planting. Application of PGPR MIX-II twice, first at planting and second after 3 weeks (T_8) was the best treatment in terms of flower quality parameters, yield parameters and less pest incidence and benefit cost ratio followed by application of PGPR MIX-I twice first at planting and second after 3 weeks (T_7), application of PGPR MIX- II at planting(T_4) and application of PGPR MIX-I at planting (T_3).

Future line of work maybe enhancement of yield and quality of flower through nutrient application and scheduling with microbial inoculants. Studies on root parameters and survival of microbial inoculants after inoculation and microbial inoculant treatment of gerbera in open and protected conditions can be taken up based on the result obtained in the present study .