STANDARDIZATION OF PRECISION PRODUCTION TECHNIQUES TO MAXIMIZE THE YIELD AND QUALITY OF DUTCH ROSE (*Rosa hybrida* var. TAJMAHAL) UNDER GREENHOUSE CONDITIONS

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Thesis submitted in part fulfillment of the requirement for the degree of

Doctor of Philosophy in **Floriculture and Landscape Gardening**

to Tamil Nadu Agricultural University, Coimbatore - 03

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CERTIFICATE

This is to certify that the thesis entitled, **"STANDARDIZATION OF PRECISION PRODUCTION TECHNIQUES TO MAXIMIZE THE YIELD AND QUALITY OF DUTCH ROSE (*Rosa hybrida* var. TAJMAHAL) UNDER GREENHOUSE CONDITIONS "** submitted in partial fulfillment of the requirements for the award of the degree of **DOCTOR OF PHILOSOPHY IN FLORICULTURE AND LANDSCAPE GARDENING** to the Tamil Nadu Agricultural University, Coimbatore is a record of bonafide research work carried out by **Mr. V.VASUDEVAN** under my supervision and guidance and that no part of the thesis has been submitted for the award of any degree, diploma, fellowship or other similar titles. However, part of the thesis work has been published in peer reviewed scientific journal of national/ international repute (copy enclosed)

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Acknowledgement

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"Every rejection of your endeavor is stepping stone for your great success"

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V.VASUDEVAN

Abstract

ABSTRACT

STANDARDIZATION OF PRECISION PRODUCTION TECHNIQUES TO MAXIMIZE THE YIELD AND QUALITY OF DUTCH ROSE (*Rosa hybrida* var.TAJMAHAL) UNDER GREENHOUSE CONDITIONS

By

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An experiment to standardize the precision production techniques for rose under greenhouse conditions was carried out in a private farm of M/s Shiva Sakthi Floritech Pvt Ltd at Hosur, Krishnagiri District, Tamil Nadu during the period from August 2012 – July 2014. The study consisted of two major objectives which were laid as two experiments in Factorial (RBD) and Randomized Block Designs. The objectives include standardization of the bending level and growth regulator interaction to maximize the growth, yield and quality, to standardize optimum level of fertilizer dose and fertigation schedule along with application of micronutrients, bio control agents for foliar disease management with improved growth, yield and quality of rose. Observations were recorded at different stages on growth parameters, physiological traits, yield parameters and post harvest vase life.

In the experiment on standardization of bending practice with growth regulators. B_1G_4 treatment [bending at shoot junction bud (B_1) + BA 200ppm (G_4)] significantly improved the growth parameters *viz.,* plant height, number of compound leaves at the critical stages, number of basal shoots, plant spread, inter nodal length and total number

of shoots after bending. The flowering and yield parameters *viz*., earliness in shoot emergence, flower bud appearance, harvest from flower bud appearance, number of compound leaves per flowering shoot, length of flowering shoot, pedicel length, circumference of flower bud, stem girth, weight of flowering shoot, number of quality grade flowers, number of flowers/plant, cut stem yield/m^2 and vase life.

The physiological parameters *viz.*, total chlorophyll content, IAA oxidase, soluble protein, nitrate reductase activity, total phenolics, peroxidase activity and anthocyanin content were significantly enhanced by this practice of bending with growth regulator interaction. Improvement was also observed in respect of growth parameters *viz.*, plant height at peak vegetative stage (126.29 cm), bud appearance stage (154.81 cm) and flowering stage (165.33 cm), compound leaves stage (83.23), bud appearance (98.07) and peak flowering (104.13), plant spread (45.19 cm^2), inter nodal length (6.13 cm), number of shoots after bending (5.47), flowering and yield parameters *viz*., first shoot emergence (10.87 days), flower bud appearance (26.40 days), harvesting of flowering shoot (48.80 days), length of flowering shoot (86.79 cm), circumference of flower (13.13 cm), weight of flowering stem (91.84 g), number of "A" grade flowers/m^2/year (214.40), cut stems / plant (26.47) and highest yield of flowers / m^2 (317.60) and vase life(12.37 days).

The B_1G_4 treatment also showed improvement in histological parameters *viz.*, width of stomata from 8.18 to 12.13µm, length of stomata from 21.08 to 25.26 µm and sclerenchyma tissue size from 21.01 to 52.78 µm and middle portion of stem cell size from 133.10 to 169.40 µm. The physiological parameters *viz.*, total chlorophyll content (2.552 mg g^{-1}), IAA oxidase activity (22.479 µg of unoxidised auxin g^{-1} h^{-1}), soluble protein content (39.810 mg g^{-1}) and peroxidase activity (1.207 abs min^{-1} g^{-1}) also showed its superiority in B_1G_4 over other treatments. Further, the highest benefit cost ratio (3.70) could be achieved through this treatment (B_1G_4).

The fertigation level, application of 125% of RDF @ 208:104:104 g NPK /m^2 / year through fertigation at weekly intervals + 0.5 % EDTA micronutrient mixture as foliar spray at 10 days interval + *Bacillus megaterium* + *Bacillus amyloliquefaciens* each@ 10 ml/m^2 (T_{19}) significantly improved the quantitative characters of cut rose

(var. Tajmahal) such as vegetative parameters *viz.,* plant height at peak vegetative (128.96 cm), bud appearance stage (153.63 cm) and flowering stage (167.26 cm), number of compound leaves at peak vegetative stage (69.20), bud appearance stage (95.57) and flowering stage (100.33), number of basal shoots (3.45), plant spread (47.82 cm^2) and inter nodal length (6.25 cm). Improvement was also observed in flowering and yield parameters *viz*., days taken for first shoot emergence (11.20 days), minimum duration (26.93 days) for first flower bud appearance, minimum days (49.08) taken for harvesting of flowering shoot, number of compound leaves (16.67), length of flowering shoot (83.77 cm), circumference of flower bud (12.81 cm), girth of flowering stem (0.83 cm), flowering stem weight (90.55 g), number of "A" grade flowers /m^2 (218.47), number of cut stems/ plant (27.07), yield of flowers /m^2 / year (324.84) and vase life (11.50 days).

The treatment T_{19} also registered improvement in physiological parameters *viz.,* total chlorophyll content (2.985 mg g^{-1}), IAA oxidase activity (26.531), soluble protein content (39.082 mg g^{-1}). The soil and plant nutrient status such as, available soil nitrogen content at vegetative stage (207.38 kg ha^{-1}), bud appearance stage (193.04 kg ha^{-1}) and flowering stage (172.63 kg ha^{-1}), available soil phosphorus content at vegetative stage (17.34 kg ha^{-1}), bud appearance stage (15.54 kg ha^{-1}) and flowering stage (14.93 kg ha^{-1}), available potassium content at the critical stages *viz.,* vegetative stage (302.00 kg ha^{-1}), bud appearance stage (283.88 kg ha^{-1}), available nitrogen content in leaf at the critical stages *viz.,* bud appearance (2.69 %) and flowering stage (3.15 %), phosphorus content (0.36 %) at bud appearance and at flowering stage (0.34 & 0.32 %), available potassium content at bud appearance stage (2.62%) and at flowering stage (3.36 %) have been found superior in this treatment (T_{19}).

T_{19} plants also showed improvement in the micronutrient values for copper uptake (30.17 mg $plant^{-1}$ at bud appearance), iron uptake (149.23 mg $plant^{-1}$ and 167.01 mg $plant^{-1}$), zinc uptake (121.12 mg $plant^{-1}$ and147.66 mg $plant^{-1}$) and manganese uptake (82.27 mg $plant^{-1}$and 94.50 mg $plant^{-1}$) both at bud appearance and flowering stage respectively. This treatment (T_{19}) recorded higher microbial populations of bacteria, fungi and actinomycetes in rhizosphere soil. The higher benefit cost ratio of 3.15 could be achieved in this treatment. Thus, the salient findings of the present study on certain

precision production techniques can be recommended for commercial cut rose production under greenhouse conditions.

From the above results, it can be concluded that by doing bending practice at shoot junction bud (B_1) along with the application of BA at 200 ppm (G_4), improvement in plant growth, yield and quality can be achieved for the successful production of greenhouse rose. var. Tajmahal. Hence, this treatment interaction (B_1G_4) can be recommended to obtain increased growth and production of quality flowers in rose. Further, the highest benefit cost ratio of 3.70 could be achieved in this interaction treatment.

The treatment consisting of drip fertigation at 125% of RDF @ 208:104:104 g NPK /m^2 / yr at weekly intervals + 0.5 % EDTA micronutrient mixture as foliar spray at 10 days interval + *B. megaterium* + *B. amyloliquefaciens* each @ 10 ml/m^2 at weekly intervals (75% P as basal soil application) was found to be superior for rose production as it has shown improvement in growth, physiological, nutritional and quality parameters over other treatments. Hence, this treatment can be recommended to obtain increased growth and production of quality flowers in greenhouse rose. var. Tajmahal. With regard to powdery mildew disease management in rose, regular and preventive soil and foliar application of *Bacillus megaterium* + *Bacillus amyloliquefaciens* each @ 10 ml/m^2 at weekly interval was found to promote plant growth and keep the powdery mildew disease incidence under check.

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2.	Effect of fertigation, micronutrients and *Bacillus sp* for maximizing the yield, quality and disease management of rose (*Rosa hybrida* var., Tajmahal) under greenhouse conditions	**1989**	**T072**	**2.74**

ABBREVIATIONS

US	:	United States	viz	:	Namely
%	:	Percent	etc	:	et cetera
et al.,	:	Co-workers	ha	:	Hectare
$	:	US Dollar	PGRs	:	Plant growth regulators
ssp	:	Sub species	var	:	Variety
Pvt	:	Private	Ltd	:	Limited
MSL	:	Mean Sea Level	m	:	meter
kg	:	kilogram	ppm	:	parts per million
EC	:	Electrical conductivity	pH	:	the negative logarithm of Hydrogen ion
dSm^{-1}	:	Deci Siemeans per meter	Zn	:	Zinc
N	:	Nitrogen	Cu	:	Copper
P	:	Phosphorus	Fe	:	Iron
K	:	Potash	Mn	:	Manganese
m^2	:	meter square	Mg	:	Magnesium
GA_3	:	Gibberellic Acid	Bo	:	Boron
BA	:	Benzyl Adenine	Mo	:	Molybdenum
GR	:	Growth Regulator	mm	:	millimeter
RDF	:	Recommened Dose of Fertilizer	cm	:	centimeter
Yr	:	Year	lph	:	litres per hour
g	:	Gram	µ	:	micro
@	:	at the rate of	^0C	:	degree celsius
AMP	:	antimicrobial peptides	hrs	:	Hours

MN	:	Micronutrient	N-S	:	North –South
ml	:	millilitre	E-W	:	East - West
PVC	:	Poly Vinyl Chloride	mg	:	milligram
OD	:	optical difference	IAA	:	Indole Acetic Acid
µg	:	microgram	AMF	:	arbuscular mycorrhizal fungi
g^{-1} h^{-1}	:	gram per hour	PGPR	:	Plant growth promoting rhizobacteria
M	:	molar	cLPs	:	cyclic lipopeptides
pH	:	The negative logarithm of Hydrogen ion	AMP	:	antimicrobial peptides
nm	:	Nanometre	8-HQC	:	Hydroxy quinoline citrate
AAS	:	Atomic Absorption Spectroscopy	$Al_2(SO_4)_3$	:	Aluminum sulphate
UV	:	Ultra violet	PSB	:	phosphate solubilizing bacteria
w/v	:	weight/volume	t	:	tonnes
h^{-1}	:	per hour	EDTA	:	Ethylene diamine tetra acetic acid
cv	:	cultivar	TSS	:	Total soluble soilds
NV	:	Naturally ventilated	Δ	:	delta
LAI	:	Leaf area index	mg g^{-1}	:	milligram per gram
ABA	:	Abscissic acid	µg g^{-1}	:	microgram per gram
nMg^{-1}	:	Nano molar per gram	abs $min^{-1}g^{-1}$	:	absorbance minute per gram
DHZR	:	zeatin-9-glucoside dihydrozeatin riboside	NS	:	Non-significant
ZG	:	zeatin glucoside	Fig.	:	figure
ZR	:	zeatin-9-glucoside	BCR	:	Benefit Cost Ratio
iP	:	isopentenyl adenine	i.e.	:	that is

Z	:	trans-zeatin	SEd	:	Standard error of mean deviation
iPA	:	isopentenyl adenosine	ISR	:	Induced systemic resistance
DAP	:	days after pruning	CD	:	Critical Difference
DAB	:	days after bending	&	:	And
DAT	:	days after transplanting	MH	:	Maleic hydrazide
FUE	:	Fertilizer use efficiency	CKs	:	cytokinins
LPD	:	Liquid pressure defecit	POD		Peroxidase
IW	:	Irrigation water	H_2O_2	:	Hydrogen peroxide
CPE	:	Crop pan evaporation	NO	:	Nitrous oxide
PSM	:	Phosphate-solubilizing microorganisms	PDI	:	Percent Disease Index
PDI	:	Percent disease index	viz	:	namely

Introduction

CHAPTER I

INTRODUCTION

Flowers are symbol of beauty, love and tranquillity. They form the soul of garden and convey the message of nature to mankind. Flowers are greatest gifts of nature forming an integral part of human life and satisfying the basic human aesthetic desire. Roses (*Rosa ssp*.) are one of the most important commercial crops grown for a variety of purposes such as pot plant, garden plant and cut flower production. Among all other cut flowers, roses are being cultivated from ancient times and maintained its position as the "Queen of flowers".

It belongs to the family Rosaceae. The genus *Rosa* consists of about 120 species, out of which only eight species are cultivated viz., *Rosa chinensis* , *Rosa damascena* , *Rosa foetida, Rosa gallica, Rosa gigantea, Rosa moschata, Rosa multiflora* and *Rosa wichuriana*. It enjoys superiority over all other flowers, being commercially grown for loose flower purposes such as pot plant, garden flower for aesthetic value and cut flowers for decoration, add charm to different occasions like marriage ceremonies and symbol of love (Tabassum *et al*., 2002).

Apart from cut flower it is used for making various value added products such as rose oil, rose water, garland, gulkhand, rose attar etc (Azadi *et al*., 2007). However, by virtue of extraordinary qualities, hybrid tea roses have gained the attention of many people all over the world. India being an agricultural country with diverse environmental conditions has a great potential for production of cut flowers. Introduction of green house technology for cultivation of cut flowers in India in the recent years has changed the scenario of Indian floriculture (Ramalingam, 2008).

Global Scenario

Rose ranks first among the top ten cut flowers in the international flower market. The major rose producing countries are Netherlands (65%), Columbia (13%), Israel (8%) and Italy (7%). At global level, flora business is around US$ 176 billion, which is expanding day by day and with an annual average growth rate of 10.3 per cent, is expected to reach US$ 250 billion by 2025 (Global Horticulture Market Outlook, 2015).

Flowers and foliage accounted for around 52.45 per cent, and live plants, bulbs and cuttings accounted for 47.55 per cent of total floriculture products at global trade (APEDA, 2014). Germany is the leading country in floriculture trade with 17.04% share, followed by USA (10.57%) and Netherlands (10%) while India falls on 52nd rank (0.08%). Roses contribute around 16.43% of the total floriculture trade.

Indian Scenario

In Asia, India, China and Thailand are progressively emerging leading countries for flower exports. In our country, flowers are grown in around 0.23 million ha, with the production of loose flowers around 1.73million tonnes and that of cut flowers 76732 lac numbers (NHB, 2013). The area under flower production has increased by 40%, loose flower production by 75% while cut flower production by 60% in last five years, as trend depicted from Tradition of growing flowers is observed in the whole country. Among the cut flowers, cultivation of rose in various states grown in around 28,130 ha, with the production of loose flowers around 75,660 metric tonnes and cut flowers around 19903 lac numbers (NHB, 2013).

Mathivanan (2013) reported that, in India Hosur has the maximum area under rose cultivation with increased productivity. The area under rose flower was 20,801 ha and the production was 1.24 lakhs million tones of loose flowers during 2011-2012. Many hi-tech units with export tie-ups are there in the Tamil Nadu state. The daily average trade of cut flower is over Rs. 2 lakh and loose flower over Rs. 5 lakh in Hosur itself. Area under rose cultivation in Hosur is estimated at 25 ha with production of 53 lakhs cut flowers at an estimated value of Rs. 15 lakh. In recent years the area under rose is fast increasing around Hosur Taluk and Bangalore because of high profits.

Flower exports from India

In view of floriculture exports, major share of exports of flowers by United States (19.8%), Netherland (14.1%), Germany (13.4 %) and United Kingdom (10.8%) from India 2012-13. The exponential growth of floriculture products was being observed in quantity (30.93 and 27.12 million tons) and values of (365.32 and 423.23 crores in (2011-12 and 2012-13) respectively (APEDA, 2014). Overall rise with the establishment of a large number of export oriented cut flower units which has given recognition to Indian flowers in the international market.

Among the cut flowers, cultivation of rose is highly lucrative profession and also has good export potential. The heavy demand for rose cut flowers in the European markets is mainly from November to March due to the shortage of local production because of severe winter. It is pointed out that buyer at international market prefers a very high quality rose cut flowers. Although controlled greenhouse cultivation are expensive, the naturally ventilated structure using polyethylene film as cladding material (polyhouse) are useful to produce quality blooms, year round at comparatively low costs. The main advantages of greenhouse cultivation are the crops can be cultivated successfully throughout the year, getting high productivity with excellent quality, more over it is easy to protect the crops against extreme climatic conditions and incidence of pests and diseases.

Shoot bending technique was progressively replacing the traditional upright growing technique in greenhouse production. This new technique posed new challenges to both cultivation and research (Sarkka, 2004). The fundamental idea behind shoot-bending is that bending down the unmarketable shoots after breaking their apical dominance, thus leading to a heterogeneous canopy structure formed by both upright shoots and horizontally bent-shoots instead of removing unwanted or weak stems by pinching or pruning, these are retained in the canopy so as to maintain foliage area and consequently produce assimilates. The bending technique, first developed in Japan in the late 1980s, has rapidly been adopted by many greenhouse growers as it favours a better quality of the flower shoots (Sarkka and Rita, 1999; Pien *et al.*, 2001; Kim and Lieth, 2004).

Good quality production is required to manipulate growth factors including light and temperature, which is very difficult and expensive. Since, plant growth and flowering depended in PGRs equilibrium, however, it is expected to control the response of plant to hormonal balance changing. Plant growth regulators (PGRs) have been used for more than 60 years to improve plant vigour and enhancing flower production in rose (Asen and Hamner, 1953; CarPenter and Rodriguez, 1971; Mor and Zieslin, 1987.).

Optimal fertigation scheduling of greenhouse crops is very important. Accurate supply of nutrients and water will result in better water use efficiency, avoid stress situations which will enhance the plant growth, consequently increase production and quality (Raviv and Blom, 2001). Fertigation schedule involves the determination of both

timing and quantity of fertilizer and water application. A better understanding of the effects of fertigation frequency on growth, flower production and quality of rose plants can help to propose optimal fertigation scheduling.

In recent days, the area under protected cultivation and open field cultivation of rose is going on increasing in places like Hosur, Krishnagiri and Dharmapuri districts of Tamil Nadu. The major diseases noticed in the rose cultivation are powdery mildew, downy mildew, crown gall, stem blight, die back and black spot. Among various diseases, mildews causes considerable yield loss in terms of number of stems and flower quality. The mildews are managed through the extensive use of fungicides. Repeated application of the fungicides results in the development of resistance among the pathogens and thus, becomes very difficult to manage the disease. In this context, biological control through the use of natural antagonistic micro-organisms has emerged as a promising alternative. Indeed, these bio-agents possess many advantages in term of sustainability, mode of action and less toxicity compared to chemical pesticides. Here, we focus in detail on the versatile utilization of *Bacillus spp* for the management of powdery mildew disease to enhance the growth of cut rose.

Commercial production of rose is a major venture at Hosur region, Tamilnadu in India and highly profitable. There is bright prospect for the expansion of area under cut flowers in the near future. Therefore, it is pertinent and appropriate to study the knowledge level, adoption level and marketing problems of these crops. The above packages of various agro-techniques have significantly increased the yield and export quality of cut rose flowers. Therefore, considering the utility, productivity and quality of the rose, the present investigations were undertaken with the following objectives.

- To study the effect of different levels of bending with growth regulators (GA_3 and BA) to regulate crop growth and quality flower production.
- To standardize the optimum fertigation schedule for cut flower rose along with the application of micronutrients and *Bacillus spp* for improving growth, yield, quality and disease management.
- To work out Cost: Benefit ratio of the above experiments.

Review of Literature

CHAPTER II

REVIEW OF LITERATURE

Rose is one of the most important commercial flower crops, which is gaining popularity in the recent years. Since it is difficult to obtain good quality flowers in the open condition, one has to identify suitable varieties and standardized techniques for protected cultivation to meet out the required quality standards. However, low cost polyhouse technology helps the growers to produce quality cut flowers. Cultivars differ significantly in their performance with respect to yield, quality and vase life, even when grown under protected structures. The literature pertaining to the performance of rose cultivars under cover, influence of growing environment on productivity and quality of flowers and cost economics of growing rose under protected conditions as studied by several workers is reviewed under the following heads.

2.1. EFFECT OF POLYHOUSE

Polyhouse is a framed structure cladded with polythene film, which can provide the favourable climatic conditions for the growth and development of plant in several ways viz., favourable environmental conditions, protection against wind, pest and diseases and other climatic conditions. Most of the flower production in other countries is being done in climatically controlled greenhouse. This has also been identified as thrust area for development in our country. The data of some of the preliminary trials that have been conducted under polyhouse is furnished here under.

Gill (1984) observed flowers grown under modified growing environment of using plastic cover over rose plants during November-February to be of high quality, yield of 1,20,000 cut roses of exportable quality was possible from a hectare by following close density planting. Gowda *et al.* (1979) reported that rose cv. Eiffel Tower produced highest number of marketable flowers (21.50) followed by Jovencelle (16.50) per plant.

Fascella and Zizzo (2005) evaluated four varieties and reported that the cultivar Anastasia produced the higher number of stems (18.7/plant) and longest bud (5.8 cm) and the cultivar Fenice produced the maximum stem length (70 cm).

Sindhu and Rameshkumar (2004) studied the performance of four commercial cut flower rose varieties viz., Konfetti, Novajo, Grandprin and Rakathagandha under unheated polyhouse, Maximum number of flowers/m^2 (10.42) was produced by Novajo followed by Konfetti (8.60) and Rokatgandha (8.22). Length of the cut stem was minimum (47.64cm) in Novajo, Konfetti, Gradprin and Rakthagandha which were at par with each other. Size of the flower and number of petals /flower were observed to be maximum (7.15cm and 21.60cm, respectively) in Grandprin resulting in the longest vase life.

Mandhar and Rathinakumari (2004) reported that naturally ventilated greenhouses of size 32 m length, 6m width and 3.5 m side height and 5 m centre height were designed and constructed for cultivation of rose under Bangalore conditions. Side ventilation of 83 per cent of floor area was provided with insect proof net of zero nylon mesh. The shade net (green colour) of 25 per cent cut off value was provided at a height of 3.5 m. The crops were provided with drip irrigation.

The side ventilation covered with white colour shade net to retain relative humidity and solar radiation. The temperature in rose greenhouse was within ± 2^0C in comparison with the ambient temperature and relative humidity was higher up to 5 per cent above ambient conditions. The percentage of solar radiation maintained inside the greenhouse was 44 to 46 per cent for rose under the above greenhouse microclimate conditions. The yield of rose under such conditions was 160 flowers / m^2.

Malhotra and Kumar (2000) reported the effect of different treatments of overhead shading and polythene covering on rose cv. Rakta Gandha. The maximum plant height and plant spread were observed in plants, which were given 25 per cent summer shading, followed by winter covering. However, maximum number of flowers per plant was observed in plants maintained under 50 per cent shade and polythene covering. Performance was best in plants maintained under 25 per cent shading treatments, as far as number of ‘A’ grade flowers are concerned. The plant produced blooms about 10 days earlier under 25 per cent shading than 50 per cent shaded plants.

Singh and Ramachandran (2002) reported that two types of greenhouses *viz.*, Naturally Ventilated (NV) and fan cum pad cooled system (FP) were compared for growing nine exotic gerbera cultivars (Diablo, Lyonella, Ornella, Sunset, Tara, Thalassa,

Tiramisu, Twiggy and Whitsun) at IIHR, Bangalore during 1989-99. The results revealed that NV greenhouse roses gave better vegetative growth and higher yield of flowers without affecting their quality. The cultivars Diablo, Lyonella and Tiramisu gave higher yield than others.

Jadhav *et al.* (2003) reported that the cultivar First Red had taken minimum number of days (32.08) for flower harvest. It produced maximum bud length (2.30 cm), diameter (2.86 cm) and number of leaves (22.09) per shoot. Patil *et al.* (2003) while comparing the performance of rose cv. Gladiator under fan and pad cooled greenhouse with that of open field cultivation and found that the greenhouse crop outperformed the open field crop in terms of total number of flower production (3897), weight per flower (16.71 g), number of flowers per plant (25.47), number of flowers per unit area (152.82/m^2) and average stalk length (53.00 cm).

Mantur *et al*. (2005) conducted an experiment on bending and pruning on six exotic varieties of roses under naturally ventilated polyhouse and reported that, among the varieties, significantly higher number of flowers were recorded in the variety Sweetness (114.50/m^2), followed by Passion (105.98/m^2). Flower stem length in Polo variety was significantly superior (64.18 cm), followed by First red (59.63 cm), while flower bud diameter was significantly higher in First red (2.62 cm), followed by Polo (2.52 cm).

Teifel *et al.* (2007) compared the greenhouse natural ventilation to fan and pad cooling and revealed that the yield of rose in the naturally ventilated polyhouse was about 26.46 per cent higher and the average stem length was larger in fan and pad method (43.4 cm) than in natural ventilated polyhouse (38.70 cm). Ranpise *et al*. (2008) reported that out of 23 varieties of Dutch roses Passion (33.60), Hollywood (32.20), Poison (27.60), Iceberg (27.20), Mericolour (26.20) and Skyline (26.00) / plant were observed to be better for yield performance under polyhouse condition.

Chandragiri *et al.* (2004) evaluated 20 exotic spay varieties of chrysanthemum for their performance under naturally ventilated greenhouse. Among them, Solomon Impala recorded the highest plant height (132.16 cm) at harvesting stage. Rafel recorded least number of flowers per plant (6.93), while cultivars Shuttle and require recorded maximum

flower diameter (7.93 cm). Caymen recorded the highest number of ray florets per flower head (314.27).

2.2. Effect of bending of shoots on growth and yield

Rose cultivation techniques underwent evolution in the late 20th century. Shoot bending technique was progressively replacing the traditional upright growing technique in greenhouse production. This new technique posed new challenges to both cultivation and research (Sarkka, 2004).

Management of plant architecture plays an important role on the year-round flower production as it greatly determines plant longevity (Marcelis-Van Acker, 1993; Kool *et al*., 1997) and allows controlling both plant development and quality of the flower shoots. In the production of roses under greenhouse conditions, two main management practices are commonly used viz., pruning and bending. The former allows maintaining the rows plantation as a vertical tall hedge by means of periodic pruning (Langhans, 1987), frequently associated to de-budding and de-shooting (Zieslin *et al*., 1975; Zieslin and Mor, 1981a, b).

The latter is based on the technique of bending down the unmarketable shoots after breaking their apical dominance, thus leading to a heterogeneous canopy structure formed by both upright shoots and horizontally bent-shoots which fill in the space between the plants and between the rows. The bending technique, first developed in Japan in the late 1980s, has rapidly been adopted by many greenhouse growers as it favours a better quality of the flower shoots (Okhawa and Suematsu, 1999; Sarkka and Rita, 1999; Pien *et al.*, 2001; Kim and Lieth, 2004).

The advantages provided by the bent shoots are mainly linked to the enhancement of the development and vigour of the basal shoots (Kool and Lenssen, 1997; Le Bris *et al*., 1998), which play an important role in evolution of plant structure and flower production (Marcelis-van Acker, 1993). The supply of carbohydrates to the growing flower shoots especially at the beginning of a growth cycle, improving the quality and vase life of the flowering shoots (Kool *et al*., 1997; Van Labeke *et al*., 2001) and promoting the onset of thicker axillary buds (Marcelis-Van Acker, 1994a). A higher canopy transpiration rate, due

the formation of a higher leaf area per plant and increase in axillary shoots (Cline, 1991) after breaking the shoot apical dominance in bent shoots can be observed.

While knowledge and models of the photosynthetic response of rose canopies managed by classical techniques are available (Gonzalez-Real and Baille, 2000; Kim and Lieth, 2003), only few studies have been addressed until now to investigate the photosynthetic capacity of the bent-shoot leaves (Pien *et al*., 2001; Kim *et al*., 2004). Moreover, no detailed studies are presently available on the distribution of leaf photosynthetic parameters, leaf nitrogen content and intercepted radiation within a rose canopy managed with the bending technique and little is known about the impact of breaking the apical dominance of the bent shoots on their gas exchanges (Kim and Lieth, 2004).

Bending, the curving of non productive shoots (weak stem, short and potential blind shoots) down into the canopy or towards the aisle, became a standard method in cut rose production and is generally done repetitively over the entire growing season. The fundamental idea behind shoot-bending is that instead of removing unwanted or marginal stems by pinching or pruning, these are retained in the canopy so as to maintain foliage area and consequently produce assimilates.

In traditional production, a tall hedge row canopy assures ample foliage area to capture light. With shoot-bending, it becomes possible to maintain the low canopy height without sacrificing foliage area. It has been reported that bending of the primary shoot promotes the formation of axillary shoots by breaking apical dominance (Cline, 1991). Zieslin and Halevy (1978) found that in roses bending the stem caused growth of a strong shoot close to the bend and another strong shoot close to the distal end.

Kool and Lenssen (1996) reported that timing of bending affects the vigor of renewal canes developing from the basal parts of the plant (basal-shoots) and that increased light interception was achieved by bending the primary shoot during the period of basal-shoot formation. The shoot-bending technique, which is called the “arching” method in Japan, has been increasing in popularity for cut rose production in Japan and South Korea, as well as in European countries (Ohkawa and Suematsu, 1999; Sarkka and Rita, 1999). In this technique, some shoots developing in early growth period are bent down and subsequent new basal shoots are grown upright and harvested as cut flowers.

The bent shoots are grown downward or horizontally and are responsible for photosynthesis. This training method results in cut roses of better marketing quality with fewer blind shoots (Sarkka and Rita, 1999). For cut flower yields of roses when using the shoot-bending technique, both growing conditions and architecture of bent shoots must be optimized. In commercial production of the shoot-bending rose in Japan, dense multi-layered canopies are formed commonly because new shoots are bent over old ones intermittently, and consequently lower-layer shoots receive less light. The photosynthetic rate is an essential factor for plant productivity.

Kim and Lieth (2002) reported that the photosynthesis of a bent shoot canopy to find the optimal leaf area in roses. The importance of plant architecture and plant density for rose crop performance has been stressed (Kool, 1997) in traditionally-trained rose canopies and greater plant densities lead to an increased leaf area index (LAI) and dry mass production per square meter (De Vries and Dubois, 1988). Planting density and harvesting methods in shoot-bending roses also greatly affected the cut flower productivity (Dambre *et al.,* 2000; Kool and Lenssen, 1997). To maximize the productivity based on LAI, understanding the characteristics of individual bent shoot layers in the canopy is essential for training plants.

The basal shoots are usually vigorous and act as an important source of flower production (Zieslin and Mor, 1981c). Sarkka and Rita (1999) found that bending resulted in higher quality, fewer blind shoots (aborted flower buds) and higher yield in 'Mercedes' variety. (Palansooriya *et al.,* 2011) reported that shoot height, number of shoot and leaf number did not significantly increase when mother shoot was subjected to bending at 5 weeks after planting. However, there was a significant increase in leaf area (bending: 1861.5; without bending: 1390.4 cm^2) and the flower bud yield (bending: 18.5; without bending: 10 buds /plant) in the bending treatment, determined in all varieties (within the first month).

Gutierrez Colomer *et al*. (2006) and Kool *et al*. (1996, 1997) stressed the important roles of carbohydrate in cut rose productivity, mutual translocation of assimilates in shoot-bending rose plants is also expected to be clarified. In conclusion, in multi-layered bent shoot canopy of roses, upper-layer shoots contribute primarily to mass

production and cut flower yield of plants through their current photosynthesis with high light interception. On the other hand, lower-layer shoots contribute to cut flower yields by exporting retained assimilates and this shoots should remain on plants until they die spontaneously.

Lieth and Kim (2001) studied the effect of shoot-bending in relation to root media on cut flower production in rose cultivar “Fire and Ice”. The stem length was produced under non-bending technique (51.6 cm & 52.4cm) and shoot-bending practice produced longest stem length (76.1 cm & 73.9 cm) in hydroponics and UC Mix respectively. Shoot-bending resulted in increased dry matter of each part of the shoot in both cultivars

Getachew *et al.*, (2012) studied the combined effect between bending height and flower bud removal in the *Rosa hybrida* .L. cultivar Lovely Jewel. They reported that the highest stem length (66.13 cm), stem thickness (1.01 cm), bud length (4.13 cm) and vase life (16.00 days) was obtained from bending at the junction (BJ) together with flower bud removal (FR) from the bent shoot.

Sarkka and Eriksson (2003) studied the rose production through the use of different bending and harvesting height combinations in a dense plantation (31.25 plants / m^2) with high intensity lighting (220 µmol / m^2 / s) and CO2 (800 ppm). The cultivars Sacha, Indian Femma, Lorena, Frisco and Dream were used and the production time was 5–17 months. Bending above 5 buds and harvesting at different heights (Method 5 B) gave higher yield than bending at base and harvesting above 1 bud (Method B).

2.3. Effect of growth regulators on growth and yield

Good quality production is required to manipulate in growth factors including light and temperature, which is very difficult and expensive. Since, plant flowering and growth depended in PGRs equilibrium, however, it is expected to control the response of plant to hormonal balance changing. Plant growth regulators are one of the most effectiveness PGRs that are exceedingly applied in ornamental plants.

These compounds may increase yield and quality of cut flower via controlling plant height, acceleration of flowering and increasing flower primordia. Gibberellins, especially gibberellic acid (GA_3) play an important role in the growth and development

of plants. Gibberellins are a rather diverse group of plant substances that enhance any physiological or biochemical process in plants. The use of GA_3 for boosting the growth and vigor of various horticultural plants is very old and well documented. GA_3 improves yield and quality of ornamental plants via plant growth initiation and stem elongation.

Plant growth regulators (PGRs) have been used for more than 60 years to stimulate adventitious buds or induce the growth of preformed bud initials at union of the bud and understock or axillary buds of roses improving plant vigor and enhancing flower production (CarPenter and Rodriguez, 1971; Mor and Zieslin, 1987). Non-chemical induction of branching requires manual pinching and pruning (Faber and White, 1977). Inhibition of bud formation was first attributed to auxin after applied 2, 3,5triiodobenzoic acid (TIBA), an auxin transport inhibitor, in a lanolin paste at the base of rose plants to stimulate basal shoots. However, these results have been difficult to repeat (CarPenter and Rodriguez, 1971; Mor and Zieslin, 1987). Increased branching and stimulation of axillary bud formation using PGRs has been extensively studied. Cytokinins, 6-(benzylamino)-9-(2-tetrahydropyran-yl) 9- H-purine (PBA) and N6-benzyladenine (BA) and (2chloroethyl) phosphonic acid (ethephon) are three PGRs that have been demonstrated as effective in promoting bud formation of roses (Mor and Zieslin, 1987).

Carpenter and Rodriguez (1971) observed favourable results using floral foam cubes soaked in PGRs and applied to cut-back rose canes. Axillary bud formation and shoot development increased using these application methods for PBA and BA. When applied in a lanolin paste to the base of the plant, TIBA increased shoot development (Asen and Hamner, 1953). Renewal shoots were not increased by any chemical or application method without TIBA (Carpenter, 1975; Faber and White, 1977; Parups, 1971). This may indicate that TIBA is required for the formation of initials and subsequent growth of the buds is stimulated by cytokinins (Carpenter, 1975; CarPenter and Rodriguez, 1971; Schrock and Hanan, 1980).

If a rose plant is to remain productive, then it must produce one or two renewal canes and new axillary shoots each year (Faber and White, 1977). Renewal shoots are those that originate from bud union and understock from either adventitious or preformed bud initials. Axillary shoots are those that originate from buds in the leaf axils.

Durkin (1960) indicated that renewal (basal) shoots are more common on young rose plants; however, most research has concentrated on the rejuvenation of older greenhouse-grown rose plants.

The ability of a plant to produce canes decreases with age and greenhouse rose growers replace plants every four to six years (Kohl and Smith, 1969). Since plant replacement is expensive due to plant and labour costs (Hulme, 1989) finding a PGR and a method of application that would consistently produce basal and axillary shoots would also benefit greenhouse rose growers. A reliable means of inducing basal and axillary shoots on young rose plants with PGRs would provide growers a means of producing superior plants for retail sale.

Arun *et al.* (2000) studied the effects of different levels of GA_3 on growth and flowering of rose "First red" and found that GA_3 could improve plant and flower neck height, as well flowering stalk. They observed that all treatments increased bud length, flower diameter and produce more cut flowers in an unit area. GA_3 enhances plant growth and inter node length by increasing the cell division and enlargement, also increase cell size, stem height, stem thickness and number of leaves. Other studies on the effect of GA_3 on ornamental plants showed that, GA_3 accelerated flowering and enhanced plant height (Gul *et al*., 2006).

Prashanth *et al.* (2006) studied the effect of growth regulators GA_3 (100 and 200 ppm), BA (100 and 200 ppm), salicylic acid (150 and 200 ppm) and cycocel (1500 and 3000 ppm) and found that GA_3 at 200 ppm increased shoot length (20.66 cm), intermodal length (4.42 cm) while number of laterals (4.62), leaf area (133.12 cm^2) were recorded maximum with cycocel at 1500 ppm. BA at 200 ppm produced more number of leaves per new shoot (56.13).

Muthu Kumar *et al.* (2012) studied the effect of growth regulators gibberellic acid (50 and 100ppm), maleic hydrazide (50 and 100ppm) and salicylic acid (25 and 50ppm) on growth, yield and quality characters of cut rose cv. First Red. They found that gibberellic acid at higher concentration of 100ppm as a pre harvest spray excerted a significant influence on crop growth and recorded highest mean values for plant height (76.18cm), stalk length (60.98cm), stem girth (1.66cm) and total chlorophyll content (1.826mg g^{-1}).

Similarly the application of gibberellic acid at 100 ppm level drastically increased the quality traits viz., mean flower diameter (6.89cm), anthocyanin content (0.1970 OD value) and vase life (2.6 days). Likewise the earliest flowering (40.00 days) was also obtained from preharvest spray of gibberellic acid at 100 ppm. The preharvest application of maleic hydrazide at 100 ppm resulted in the maximum mean number of branches per plant (4.47) and number of flower per plant (16.50) of cut rose cv. First Red.

Hashemabadi and Zarchini **(**2010) Studied the effects of different levels of salicylic acid (50, 100, 150 and 200 mg / l), gibberellic acid (150, 200, 250 and 300 mg /l), and cycocel (500, 1000, 1500 and 2000 mg / l) at pre-harvest stage on the quality, yield and vase life of cut rose (*Rosa hybrida* 'Poison'). The highest record of flower yield was obtained by application of 200 mg /l GA_3 with 192 cut flowers per year per m^2. The highest vase life (12.67 days) was obtained when 150 mg / l salicylic acid applied to cut flowers. The best treatment to increase the stem flower length was application of 300 mg /l GA_3 which produced longest stem (49.33 cm).

2.4. Effect of growth regulators on stomata

Stomata are natural microscopic pores, each surrounded by a pair of guard cells. Stomata are present throughout the leaf epidermis and are also present on other aerial parts of the plant. Guard cells dynamically regulate the size of stomatal apertures and thereby control gas exchange by the plant. The most important function of stomata is to allow entry of sufficient CO_2 for optimal photosynthesis while conserving water as required by the plant. In addition, these specialized structures also play critical roles in the control of leaf temperature by modulating rates of transpirational water loss, and restrict pathogen invasion via stomatal closure. Multiple environmental factors such as drought, CO_2 concentration, light, humidity, biotic stresses and different plant hormones modulate stomatal apertures (Hirayama and Shinozaki, 2007; Israelsson e*t al*., 2006; MacRobbie and Kurup, 2007; Neill *et al*., 2008; Underwood *et al*., 2007).

Recently, important progress has been made in elucidating the roles of other hormones in stomatal function. In addition, the effects of cross talk between and among different hormones on stomatal regulation, particularly the topic of how different plant hormones impact ABA mediated stomatal control.

Cytokinins are adenine-derivative molecules with diverse active forms. Zeatin, dihydrozeatin, and isopentyladenine are important cytokinins found in higher plants (Dello Ioio *et al.*, 2008). Cytokinins play positive roles in germination, shoot development, nodulation, oppose leaf senescence and pathogen invasion (Sakakibara, 2006; To and Kieber, 2008). It has been shown that increased cytokinin concentration in the xylem sap promotes stomatal opening and simultaneously decreases sensitivity to ABA (Wilkinson and Davies, 2002). Water stress leads to reduced synthesis of cytokinin in roots and its transport to shoot (Pospisilova, 2003; Pustovoitova *et al*., 2003).

Stomatal response to exogenous application of cytokinin depends on the concentration and cytokinin species. Both synthetic and natural cytokinins can cause stomatal opening in the grass *Anthephora pubescence* (Jewer and Incoll, 1980) and inhibition of stomatal closure was observed in the amp1-1 cytokinin over producing mutant of Arabidopsis (Tanaka *et al*., 2006), while in the monocot Commelina, inhibition of stomatal opening in response to a high concentration of cytokinin has been reported (Blackman and Davies, 1983).

Recently it has been shown that in darkness, cytokinin induces stomatal opening by decreasing H_2O_2 levels and NO levels within guard cells (She and Song 2006; Song *et al*., 2006). Cytokinins are often considered ABA antagonists in many processes including the regulation of stomatal opening, but the effects are species specific and depend on cytokinin type, concentration and method of application (Pospisilova, 2003). Promotion of stomatal opening induced by application of cytokinin (BA) in *Hosta* 'Undulata Erromena' was in accordance with the results of Rulcova and Pospisilova (2001).

2.5. Concentration of endogenous hormones in rose plant

Most of the rose cultivars used for flower harvest are perennial, self-inductive, year-round flowering plants with terminal flowers on lateral shoots (Halevy, 1972; Zieslin, 1992). The extent of flower production in rose plants depends on formation of renewal shoots from buds concealed in the bark of a callus-like tissue of the plant base, known as a crown, or from buds close to the plant base (Khayat and Zieslin, 1982; Marcelis-Van-Acker, 1993) as well as depends on the number of axillary buds sprouting and flowering along the rose shoots.

Since the work of Kohl and Randle (1974), who showed that the rate of bud-break in rose plants increased following exogenous treatments with cytokinins, numerous reports on the effects of cytokinins have been published (Chmelnitsky *et al*., 2001). Concurrently, activity of endogenous cytokinins was determined in the two upper buds in axils of the five-leaflet leaves which become apical following decapitation of the shoot, in the leaves subtending the buds, in bark of the plant "crown" as well as in the floral organs (Mor and Zieslin, 1987).

Content and structure of cytokinins were measured in axillary buds along shoots of rose plants (*Rosa hybrida* cv. Texas). Three different shoot sections could be distinguished beneath the flower peduncle. The upper section with tri and monofoliate leaves is characterized by lateral shoots from non-inhibited buds growing concomitantly with the growth of terminal flower. The second section from the top is characterized by leaves with five or more leaflets. The third section is characterized by few five-leaflet leaves followed downward by less developed leaves. Isopentenyl cytokinins were the main cytokinins in axillary buds of three-leaflet leaves in the uppermost section and in the buds of the upper five-leaflet leaves in the second section of non-decapitated shoots.

Zeatin and zeatin riboside were the main cytokinins in the lowest buds in axils of five-leaflet leaves of the third section. Three days after decapitation of the shoots above the uppermost five-leaflet leaf (80–90 cm long stems) or above the lowest five-leaflet leaf (10–15 cm long stems) a relatively very high content of zeatin and zeatin riboside was present in the uppermost remaining axillary buds. On the other hand, one week after decapitation the isopentenyl cytokinins were the main cytokinins in the two top axillary buds on the long shoots. The role of isopentenyl cytokinins in ready to sprout, to grow and to flower axillary buds as well as accumulation of root synthesized cytokinins in the lowest buds.

2.6. Drip fertigation

Application of water soluble/ liquid fertilizers through irrigation water is known as fertigation. By definition, fertigation is the precise application of water soluble fertilizer through sprinkler and drip irrigation (Billsegars, 2003). It is an efficient and agronomically sound method of providing soluble plant nutrients directly to the active

plant root zone. The increasing acres of micro-irrigated crops provides an excellent opportunity to explore new methods of providing complete and balanced plant nutrient programs that have the potential to improve plant health and increase yields.

Fertigation permits improved efficiency of irrigation, nutrient use and reduces application costs. It improves plant growth, nutrient uptake and limits nutrient losses. Applying fertilizer through irrigation system has several advantages:

- Nutrients can be applied at any time during the season
- Amount and concentration of nutrients can be as per plants' requirement
- Nutrients are applied uniformly over the field
- Reduced fluctuations of nutrient concentration in the root zone
- Enhanced fertilizer use efficiency and fertilizer saving
- Reduced nutrient leaching
- Increased yield and quality of farm produce
- Saving of time, labour and cost of application
- Uniformity of application
- Crop damage during fertilizer application in minimized (FAO, 2005)

Feigin *et al*. (1982) reported that fertigation is the most efficient method of fertilizer application in celery. This decreases leaching and volatilization losses, improves the Nitrogen utilization efficiency and minimizes ground water contamination in tomato (Papadopoulos, 1985). Drip fertigation enables accurate adjustment of water and nutrient supplies to meet the crop requirement in potato (Papadopoulos, 1988). Drip fertigation permits application of nutrients directly at the site of high concentration of active roots (Sivanappan *et al*., 1987). Drip irrigation with fertigation may reduce the risk of crop damage due to a high water table coupled with heavy rains. Fertigation allows nutrient placement directly into root zone during critical periods of nutrient demand (Kozhushka and Romanets, 1994).

Deshmukh *et al.* (1996) reported that 30 per cent of NPK fertilizer can be saved by the use of liquid fertilizer through drip irrigation system in comparison with recommended fertilizer levels applied conventionally under flood irrigation in sugarcane. Drip fertigation provides an efficient method of fertilizer delivery and if properly managed, reduce overall fertilizers application rate and minimize the adverse environmental impact (Hartz and Hochmuth, 1996). A properly designed drip fertigation system delivers water and nutrients at a rate, duration and frequency, so as to maximize crop water and nutrient uptake, while minimizing leaching of nutrients and chemicals from the root of crops (Gardenas *et al.,* 2005).

2.7. Effect of drip fertigation on growth, yield and quality of rose

Optimal fertigation scheduling is very important to save water and nutrients, while efficient use of water by drip irrigation is becoming increasingly important. Accurate supply of nutrients and water will result in better water use efficiency, avoid stress situations and control production (Raviv and Blom, 2001).

Borrelli (1981) revealed that flower number and stem length increased with increase in irrigation and nitrogen but beneficial effects were much greater when irrigation and N supplies were both combined together. The presence of NH_4 - nitrogen in the nutrient solution increased the flower yield and dry matter production and the cumulative flower yields were the highest with 1: 4 (NH_4 : $N0_3$) ratio (Feigin *et al.,* 1986).

Narayana Gowda (1994) reported that flower yields were optimum with the application of 170 ppm N, 34 ppm P, 158 ppm K, 120 ppm Ca and 12 ppm Mg in the nutrient solution during each watering. Hazan *et al.* (1994) reported that in rose cv. Mercedes grown in 5 cm thick rock wool and supplied with 180 ppm N *via* drip irrigation produced highest cumulative flower yield (1421 flowers / m^2) with longer stalks.

Cabrera *et al.* (1996) reported that in recirculating hydroponic system N in the form of NH_4 or NO_3 had no significant effect on flower yield and quality. A basal application of fertilizers at the rate of 2 kg superphosphate, 1 kg calcium ammonium nitrate and 1 / 2 kg of muriate of potash/m^2 before planting and thereafter 200 ppm each of nitrogen and potash through irrigation system had been reported ideal for roses under greenhouse conditions (Anon, 1996).

Chimonidou-Pavlidou (1996, 1999) reported that drought stress was very damaging to rose plants development, affecting the quantity (up to 70% reduction in production) and quality (reduction in stem length and fresh weight) of the flowering shoots produced.

The influence of various levels and sources of N fertigation on flowering of cut rose cv. First Red was studied under protected conditions (Ashok *et al.*, 1999) and it was observed that Ammonium Nitrate at 150 ppm resulted the highest values for bud circumference (6.09cm), flower diameter (7.33 cm), petal length (4.01cm), petal breadth (3.84 cm) and flower yield (153). Whereas, the effects of aqueous ammonia, nitric acid, ammonium nitrate and urea @ 50, 100 and 150 ppm were studied on rose cv. First Red (Ashok, 1998). Generally, higher N rate resulted in higher fresh weight and dry matter production. Ammonium nitrate @ 150 ppm recorded the longest shoots (67.36cm), maximum number of leaves (13.48) and number of petals (25-41).

Palai *et al*. (2002) reported that application of 300 ppm nitrogen, 300 ppm phosphorus and 200 ppm potassium per week supplied with irrigation water were found optimum for desirable height (114.23 cm) and spread of the plant (96.27 cm). For maximum number of flowers per plant (55.75) nutritional doses of 400 ppm nitrogen, 300 ppm phosphorus and 200 ppm potassium were found ideal under Bhubaneswar conditions in rose cv.Montezuma.

Chaudhari *et al*. (2010) studied the combination of biofertilizers and nitrogen fertilizers for growth and yield of *Rosa damascena*. They found that application of 50 g N/plant + *Azotobacter* and *Azospirillum* each @ 1 ml/plant produced maximum plant height (134.23 cm), number of branches (49.53), plant spread N-S (95.20 cm) and E-W(100.00 cm), stem diameter (2.04 cm), diameter of flower (7.74 cm) and number of petals (41.11).

Viradia and Singh (2004) applied nitrogen at 0, 20, 40 and 60 g / plant to cut rose cv. Gladiator and reported that application of nitrogen at 40g / plant produced number of cut flowers (97.20), number of petals per flower (72.83), flower diameter (10.34).

Gurav *et al.* (2004b) reported that higher levels of nitrogen and phosphorus (400 ppm / plant / week and 200 ppm / plant / week respectively) produced more number of flowers/plant (29.42 and 27.46 respectively) with maximum stalk length (72.86 cm and 62.53 cm respectively). The interaction of treatment of 400:200:200 ppm NPK / plant /

week produced more number of flowers / plant (33.46), flowers with longer stalk length (75.60 cm), more number of flowering shoots / plant (4.40) and larger flower bud size (2.40 cm).

Qasim *et al.* (2008) reported that application of fertilizer through fertigation @ 500 ml of NPK at 2 days interval was produced maximum plant height (65.16 cm), number of branches (7.16), leaves (214), flowers / plant (7.34), petals / flower (28.50), leaf nitrogen (3.53 %), leaf phosphorus (0.31%) and leaf potassium (2.35%) in two hybrid rose cultivars namely, Amalia and Anjleeq.

Singh (2007) found that application of NPK at 50, 40 and 30 g / m^2 recorded maximum number of flowers / plant (26.16), weight of flowers / plant (138.50 g), diameter of flower (9.26 cm) and number of petals / flower (46.00).

Mendhe *et al*. (2011) applied at 100:50:50 kg / ha of NPK with pruning at 60 cm from ground level recorded maximum number of flowers / plant (26.10), length of flower bud (6.50 cm), diameter of flower bud (4.76 cm), pedicel length (8.89 cm), number of petals / flower (66.10), weight of flower (18.20 g) and vase life (8.84 days).

Patil *et al*. (2012) studied the combination effect of fertilizer with microorganism and BA and found that 3/4th dose (56 g of N/plant) +*Azotobacter* 2 g / plant + foliar spray of BA 100 ppm recorded maximum plant spread N-S (81.28 cm) and E-W(87.03 cm), more number of leaves (818.30), total leaf area (63069.38 cm^2), more number of shoots/ plant (62.28), first flower bud initiation after pruning (31.05 days), flower stalk length (73.79 cm), vase life (10.80 days), number of flowers / plant (26.80).

2.8. Effect of drip fertigation on nutrient use efficiency

Fertigation reduces the nutrient loss that would normally occur with conventional methods of fertilizer application and thus permits better availability and uptake of nutrients by crops, leading to higher yield with high fertilizer use efficiency.

Fujiyama and Nagal (1987) opined that nutrient solution along with irrigation water brought about a high nutrient recovery and appeared to be a superior method for supplying nutrient and water. Unlike surface irrigation and conventional fertilizer application, fertigation makes uniform distribution of nutrient solution in the root zone and thereby

increases the fertilizer use efficiency, since the uptake of nutrients by the plant roots depends on their availability to the root system (Rao, 1996). Tumbare *et al.* (1999) concluded that out of 125, 100, 75, 50 and 25 per cent liquid fertilizer (8:8:8 N:P:K), 75 per cent dose applied through trickle irrigation performed better, resulting in 25 per cent saving in fertilizer than band placement of fertilizer in okra.

Patel and Rajput (2000) observed that drip fertigation in onion resulted in 60 per cent saving of fertilizers for achieving the same level of production as compared to conventional method along with higher FUE of 5.28 kg NPK^{-1}.

Singandhupe *et al.* (2002) reported that application of nitrogen through drip irrigation with equal splits at eight days interval saved 20 to 40 per cent nitrogen compared to furrow irrigation in tomato. Lara and Singh (2003) in a greenhouse experiment found that the highest yield (1.68 kg / plant) and higher relative nitrogen recovery were obtained with 160 kg N / ha in chilli.

Vijayselvaraj (2007) reported that highest Nitrogen and Potassium fertilizer use efficiency (48.65 kg ha^{-1} kg of N^{-1}) and (75.74 kg ha^{-1} kg of K^{-1}) were recorded through fertigation with the application of 15 LPD, 75 per cent RDF with mulch in *Jasminum grandiflorum.* Rathore and Singh (2009) reported that nitrogen use efficiency was registered to be 25.42% in the treatment received nitrogen @ 120 Kg ha^{-1} followed by 17.7% in N @ 220 kg ha^{-1} and 13.93 in treatment received N @ 320 kg ha^{-1} in tuberose.

2.8.1. Effect of drip irrigation on soil moisture availability and distribution

Under drip irrigation, when irrigation was applied at every five days, the wetting front reached 60 to 90 cm soil layer. In case of sprinkler irrigation with the same interval and amount of irrigation water, the wetting front did not exceed 30 to 60 cm. Mishra and Pyasi (1993) determined that the moisture distribution under drip irrigation was uniform within a 10 cm radius of the emitter with maximum uniformity at zero, while non uniformity increased with distance from the emitter and also the water front advanced rapidly in the beginning and the rate of advance decreased with time.

Patil (1999) observed that frequent irrigations under drip irrigation has maintained most of the soil in the root zone in a well aerated condition and at a soil moisture content that

does not fluctuate between wet and dry extremes. He also observed that the movement of water in the soil depends on the soil characteristics and the dripper discharge.

Surface irrigation showed steep decline of available soil moisture from 90 to 24 per cent whereas in drip irrigation system, available soil moisture was consistent throughout the irrigation cycle (once in two days) about 87 per cent and it was always nearer to field capacity (Bobade, 1999).

Suresh Kumar (2000) reported that the available soil moisture was almost consistent and nearer to field capacity under drip irrigation system as against wide fluctuation under surface irrigation.

2.8.2. Soil nutrient movement in relation to fertigation

For a successful fertigation system, it is necessary that every emitter delivers the same amount of water and the distribution of nutrients should be such that there are no blockages of fertilizers or chemical deposits. Further, there should be constant and uniform mixing of plant nutrients with the irrigation water and constant water flow throughout the system (Greeff, 1975).

Fertigation permits application of various fertilizer formulations directly at the site of high concentration of active roots and thus improves nutrient uptake efficiency. New approaches of supplying fertilizers through drip or sprinkler systems particularly for high value horticultural crops have been developed.

Greeff (1975) reported the best flower yields with a single tube placed on centre of the bed. The total soluble salts were higher in centre than on edge of the beds with 2 tubes, lower with single tube and no difference was seen with 3 tubes. TSS, Ca, Mg, No_3– N and K levels decreased while P increased with soil depth to 12" regardless of irrigation placement.

Bravdo *et al*. (1994) reported that nitrate - nitrogen (NO_3 - N) content of soil was significantly affected by fertilizer treatments and its concentration increased with depth and distances from the emitter. The soil K significantly increased with K fertigation, but contrary to the NO_3-N distribution, K was mainly concentrated near the emitters.

Fertilizer application based on the need offers the possibility of reducing nutrient element losses associated with the conventional methods that depend on the soil as a reservoir of nutrients, thereby increasing nutrient use efficiency in soil (Greeff, 1975; Khan *et al*., 1996; Rao, 1996; Paul *et al*., 1996).

2.8.3. Nutrient distribution under drip fertigation

Under drip irrigation, the highest reduction in soil NO_3-N was observed in 30 to 60cm deep (18 mg kg^{-1}), while the highest reduction in soil potassium was observed in 0 – 30 cm depth (7.42 mg kg^{-1}) and the soil pH was not affected by drip irrigation (Nightingale *et al*., 1985). The increase in NH_4-N concentration immediately in the vicinity of the emitter is a consequence of the hydrolysis of urea (Haynes, 1990). Papadopoulos (1992) reported that greater phosphorous accumulation occurred in the surface (0-15cm) layer in trickle irrigated potato in agreement with the expected slow movement of phosphorous in the soil.

Chakraborty *et al*. (1998) reported that the distribution of NO_3 – N throughout the soil profile under fertigation was varied both horizontally and vertically from the emitted points. The peak NO_3-N concentration below the emitter was found to be in 30 to 50 cm depth, whereas for locations 15 cm, 30 cm and 45 cm away from the emitter, the peak was within 10 to 20 cm depth. Under the emitter, the NO_3 – N distribution at first decreased steadily up to a depth of 25 cm followed by a sudden increase on the peak concentration in 30–50 cm layer whereas the peak concentration of ammoniacal nitrogen (NH_4 – N) was confined to 0 –10 cm soil depth. Bar-Yosef (1999) stated that drip fertigation with higher dose of N (75 kg ha^{-1}) resulted in higher EC, soluble phosphorus, potassium and NO_3-N in soil compared to lower N doses (39 and 58 kg ha^{-1}).

Bharambe *et al*. (2001) reported that higher amount of available phosphorus was confined at the top 0-15 cm layer just immediately below the emitter. The concentration of phosphorus decreased with increasing depth of soil profile irrespective of planting methods and depth of irrigation water in banana. Hebbar *et al*. (2004) observed that in drip fertigated tomato field, there was lower NO_3-N observed at 30 – 45 cm soil layer (55 kg ha^{-1}) when compared to control (65 kg ha^{-1}). Similar trend was observed in 45 – 60 cm layer

depth also. This shows that drip fertigation decreases leaching fraction of fertilizers applied.

Suganya *et al*. (2007) inferred that the available potassium content was maximum in the surface layer due to the entrance of K ions on soil exchange complex resulting in very small movement to deeper layer. The available nitrogen content was confined to maximum at immediately below the emitter and moved laterally up to 15 cm and vertically up to 15 – 25 cm and thereafter dwindled. The mobility of phosphorous was observed to the highest immediately below the emitter zone, moved laterally and vertically up to 5 cm and thereafter dwindled. As regard to available potassium, it moved both laterally and vertically up to 15 cm and thereafter reduced (Bangar and Chaudhari, 2008).

2.9. Nutrient uptake under drip fertigation

2.9.1. Nitrogen uptake

Anilkumar (2001) reported that nitrogen uptake was significantly higher (108.49 kg ha^{-1}) with 100 per cent water needed at 0.8 IW/CPE ratio than 75 per cent quantity of water. Singandhupe *et al*. (2002) stated that total nitrogen uptake in drip irrigation was 8 -11 per cent higher than that of furrow irrigation at the highest level of applied nitrogen (120 kg N ha^{-1}).

Hebbar *et al*. (2004) reported that fertilizer application through fertigation had an impact on the nitrogen content in stem, leaves and fruits as 0.142, 0.022 and 0.113 mg g^{-1} dry matter respectively when compared to control (0.129, 0.013 and 0.093 respectively) in tomato cv. Arka Abhijit. Senthilvalavan and Kumaresan (2007) observed that application of water soluble fertilizer (Plant starter) along with controlled released fertilizer in chilli var. PKM-1 increased the nitrogen uptake (134.7 kg ha^{-1}) at post harvest stage when compared to control (60.9 kg ha^{-1}).

Vijayselvaraj (2007) reported that in *Jasminum grandiflorum* drip irrigation with 15 LPD, 100 per cent RDF with mulch recorded highest foliar Nitrogen (2.18%) during the peak flowering stage when compared to surface irrigation (1.23%). Qasim *et al*. (2008) reported that the leaf nitrogen percentage was maximum (3.53%) in case of application of compound water soluble fertilizer 17:17:17 @ 2g l^{-1} (500ml) at two days interval in *Rosa*

hybrida cv. Amalia. In marigold hybrid L3 drip fertigation at 125 per cent TRD along with foliar application of 0.2 per cent humic acid leads to increased uptake of nitrogen (0.55 g plant^{-1}) at flowering stage as compared to control (0.30 g plant^{-1}) (Swapna, 2010).

Rathore *et al*. (2010) studied the effect of organic and inorganic fertilizer on growth and yield of Gladiolus. Among the 14 treatments, T_9 treatment (50 kg N from urea and PM) increased the plant height by 64 %, 26% and 23 % and flower yield by 52 %, 39% and 38% as compared to T0, T_4 (100 kg N through poultry manure and T5 (100 kg N through urea) treatments, respectively. The corm and cormels weight was also enhanced by 126%, 68% & 56% and 129%, 66%, 61 % under T_9 treatment over to control (without N), T_4 and T_5 treatments, respectively.

Among the treatments, maximum plant nitrogen uptake (1.78, 1.83, 1.78 and 2.45 g plant^{-1}) was recorded in the treatment (T_3) 100% RDF with humic acid 0.4% + panchagavya 3% spray at all the four stages respectively. Lowest plant nitrogen uptake (1.21, 1.22, 1.22 and 1.42 g plant^{-1}) was recorded in control (100% RDF with soil application of fertilizer and flood irrigation) during all the four stages respectively in *Jasminum sambac* (Bini Sundhar, 2011).

2.9.2. Phosphorus uptake

Raman *et al*. (2000) observed that application of 100 per cent NPK in the form of urea and polyfeed recorded the highest nutrient uptake of 184 kg N, 53 kg P and 325 kg K ha^{-1}. Higher leaf tissue P content in tomato was observed under the application of 75 kg P ha^{-1} through drip fertigation (Carrijo and Hochmuth, 2000). Anilkumar (2001) reported that phosphorus uptake was significantly higher (23.32 kg ha^{-1}) with 100 per cent water needed at 0.8 IW/CPE ratio than 75 per cent quantity of water.

Hebbar *et al*. (2004) reported that fertilizer application through fertigation had an impact on the phosphorous content in stem, leaves and fruits as 0.168, 0.035 and 0.069 mg g^{-1} dry matter respectively) when compared to control (0.158, 0.031 and 0.065 respectively) in tomato cv. Arka Abhijit. Tumbare and Nikam (2004) stated that application of recommended dose of fertilizers at every irrigation (2 days intervals) upto 105 days recorded significantly higher uptake of phosphorus (12.58 kg ha^{-1}) by chilli than surface irrigation (8.53 kg ha^{-1}). Vijayselvaraj (2007) reported that in *Jasminum grandiflorum* drip

irrigation with 15 LPD, 100 per cent RDF with mulch recorded the highest foliar Phosphorous (0.28%) during the peak flowering stage when compared to surface irrigation (0.19%).

Qasim *et al*. (2008) reported that the leaf phosphorous was maximum (0.31%) in case of application of compound water soluble fertilizer 17:17:17 @ 2g l^{-1} (500ml) at two days interval in *Rosa hybrida* cv. Amalia. Swapna (2010) reported that in marigold hybrid L3 drip fertigation at 125 per cent TRD along with foliar application of 0.2 per cent humic acid leads to increased uptake of phosphorous (0.061 g $plant^{-1}$) at flowering stage when compared to control (0.030g $plant^{-1}$).

Bini Sundhar (2011) reported that concerning to the interaction effect, increased plant phosphorous uptake (0.29, 0.27, 0.26 and 0.23 g $plant^{-1}$) was recorded in the interaction (F_3B_3) 125% of RDF with humic acid 0.4% + panchagavya 3% spray during all the four stages respectively. This was followed by (F_2B_3) 100% of RDF with humic acid 0.4% + panchagavya 3% spray (0.27, 0.25, 0.25 and 0.22 g $plant^{-1}$) during all the four stages respectively. Minimum plant phosphorous uptake (0.18, 0.17, 016 and 0.15 g $plant^{-1}$) in all the four stages respectively was recorded in control (100% RDF with soil application of fertilizer and flood irrigation) plants.

2.9.3. Potassium uptake

Tamimi *et al*. (1999) estimated the harvested flower stalks of the cv. Royalty were cut to (45 cm) length and sectioned into 15-cm units, from which blossom, leaf and stem components were separated, weighed and analysed for nutrients. The flower was highest in K (18.4 g kg^{-1}), stem section of (0–15 cm leaf and stem 14.3 and 15.3), stem section of (15–30 cm leaf and stem 16.1, 9.3) and stem section of (30- 45 cm leaf and stem 17, 9.2 g kg^{-1}) of nutrients was presented.

Annual removal of nutrients by 45-cm flower stalks totalled 187.5, kg ha^{-1} assuming 50% recovery of applied N and 80% of K a total annual application of N at 512 kg ha^{-1} and K at 234 kg ha^{-1} of amounts were removed. Annual K removal by the harvested biomass was calculated at 253 kg ha^{-1}. Potassium can be applied as soil analysis dictates. If a 75% to 80% recovery is assumed, an annual rate of 316 to 337 kg ha^{-1} will replace what is removed. Removal rates of other nutrients may be determined by

considering the nutrient uptake. We suggest that periodic soil and tissue tests be used to determine the need for application of all nutrients.

Anilkumar (2001) reported that potassium uptake was significantly higher (105.14 kg ha^{-1}) with 100 per cent water needed at 0.8I W/CPE ratio than 75 per cent quantity of water. Tumbare and Nikam (2004) stated that application of recommended dose of fertilizers at every irrigation (2 days intervals) up to 105 days recorded significantly higher uptake of potash (99.10 kg ha^{-1}) by chilli than surface irrigation (44.60 kg ha^{-1}). Senthilvalavan and Kumaresan (2007) observed that application of water soluble fertilizer (Plant starter) along with controlled released fertilizer in chilli var. PKM-1 increased the potassium uptake (175.9 kg ha^{-1}) at post harvest stage when compared to control (73.5 kg ha^{-1}). Vijayselvaraj (2007) reported that in *Jasminum grandiflorum* drip irrigation with 15 LPD, 100 per cent RDF with mulch recorded highest foliar potassium (1.51%) during the peak flowering stage when compared to surface irrigation (1.31%).

Qasim *et al*. (2008) reported that the leaf potassium percentage was maximum (2.35%) in case of application of compound water soluble fertilizer 17:17:17 @ 2g l^{-1} (500ml) at two days interval in *Rosa hybrida* cv. Amalia. Investigation conducted by Swapna (2010) reported that drip fertigation at 125 per cent TRD along with foliar application of 0.2 % humic acid leads to higher uptake of potassium (0.514 g $plant^{-1}$) at flowering stage when compared to control (0.357 g $plant^{-1}$)in marigold hybrid L3.

Among the three fertilizer levels, highest plant potassium uptake (1.39, 1.36, 1.47 and 1.50 g $plant^{-1}$) was found in the treatment (F_3) 125 % RDF during I, II, III and IV stages respectively. Lowest plant potassium uptake (1.25, 1.28, 1.33 and 1.34 g $plant^{-1}$) was observed in the treatment (F_1) applied with 75% RDF at all the four stages respectively (Bini Sundhar, 2011).

Tamimi *et al*. (1999) studied the weights and concentrations of nutrients in tissue components of cut-flower roses (*Rosa hybrida* L.) were determined to assist in developing a fertilizer management system that sustains a high level of production. Harvested flower stalks of the cv. Royalty were cut to 45-cm length and sectioned into 15-cm units, from which blossom, leaf and stem components were separated, weighed and analysed for

nutrients. The flower represented 28.5%, leaves 46.0%, and stem 25.5% of the total weight of the stalk. Upper leaves had the highest levels (g kg^{-1}) of N (29.3), Ca (21.8) and Mg (3.0) and (mg kg^{-1}) Fe (74) and Mn (71). The flower was highest in K (18.4 gkg^{-1}), P (3.0 g kg^{-1}), Zn (29 mg kg^{-1}), and B (23 mg kg^{-1}). Annual removal of nutrients by 45 cm flower stalks totalled: 256.2, 187.5, 116.3, 30.0, 26.0, and 21.1 kg ha^{-1} of N, K, Ca, P, Mg and S respectively.

2.10. Role of micronutrients on nutrient uptake

Tamimi *et al*. (1999) studied the removal of micronutrients in tissue components of cut flower roses (*Rosa hybrida* L.) per annum totalled 700, 470, 260, 200, and 190 g ha^{-1} of Fe, Mn, Zn, Cu and B respectively. Assuming 50% recovery of applied N and 80% of K, a total annual application of N at 512 kg ha^{-1} and K at 234 kg ha^{-1} may replace the amounts removed. However, actual rates of N and K, as well as other nutrients applied, should be adjusted based on soil and tissue analysis results. Removal of nutrients will be greater if stalks harvested are >45 cm in length, which may necessitate additional nutrient application, depending on soil conditions**.**

Bandyopadhyay *et al.* (1999) reported enhanced zinc uptake in marigold with application of chelated zinc and with combined application of $ZnSO_4.7H_2O$ + $CuSO_4.5H_2O$ in African marigold. Application of zinc alone and in combination with other nutrients increased the concentration of zinc in plants of *Tagetes minuta* (Rajput *et al*., 2003). Application of boron at 1.0 kg per ha + zinc at 5.0 kg per ha recorded higher boron content. Application of nitrogen at 180 kg per ha in combination with foliar spray of 0.5 per cent zinc sulphate + 1.0 per cent ferrous sulphate in crossandra recorded greater uptake of nitrogen, phosphorus and potassium (Aruna, 1999).

2.10.1. Effect of micronutrient mixture in crops

In several studies to overcome deficiency of more than one micronutrient and to improve balanced application, combination sprays of micronutrients have been successfully resorted. Koriesh (1984) found that in chrysanthemum cv. Forester, best flower quality was obtained with foliar spray of Fully Fertile 0.3 per cent, which contains NPK +Fe + Zn and other micronutrients.

Chaturvedi *et al*. (1988) treated gladiolus with single or double sprays of Agromin containing chelated form Zn, Fe, Cu, Mg, B and Mo + N at 1000, 2000, 3000 and 4000 ppm and found out that application at 3000 ppm improved the floret size but delayed spike formation. Double sprays of 4000 ppm were effective for varieties with longer duration of flowering.

Bandyopathyay *et al.* (1999) observed higher flower weight of African marigold with soil application of zinc sulphate at 20 kg per hectare, while increased number of flowers per plant was obtained with combined application of 0.1 per cent mixture of zinc sulphate and copper sulphate solution.

Durga Devi *et al*. (1997) reported that increase in flower yield might be attributed to the fact the application of iron and zinc relieved the plants from chlorosis and produced healthy green leaves which in turn resulted in higher assimilate synthesis and partitioning of the flower growth in *Citrus sinensis.*

In gerbera, higher flower yield per plant, increased flower diameter and plant height was obtained with foliar feeding of plants with ferrous sulphate + zinc sulphate + manganese sulphate at the rate of 0.2 per cent each (Muthumanickam *et al*., 1999).

Aruna (1999) observed that combined application of 180 kg nitrogen per hectare along with foliar spray of 0.5 per cent zinc sulphate + 1 per cent ferrous sulphate significantly increased the plant height in crossandra.

Senthamizhselvi (2000) observed that combined application of 4 g of zinc sulphate and 8 g of ferrous sulphate per plant through soil and 0.5 per cent of zinc sulphate and 1 per cent of ferrous sulphate through foliage during the months of December and June exerted significant influence on plant height, number of shoots, plant spread and leaf area in *Jasminum sambac*.

Rajput *et al.* (2003) in *Tagetes minuta,* reported that application of boron and zinc increased oil yield by 21.2 per cent over the control. Mukesh Kumar *et al*. (2001) reported that soil application of zinc at 15 kg per ha gave best values for number of days taken for flowering, number of flowers per stick and hundred flower weight in tuberose. Nag *et al.* (2003) observed that foliar application of zinc at 0.2 per cent

applied at 10, 20, 30 days after planting appreciably increased the plant height, number of branches and plant spread of African marigold cv. Siracole.

Hardeep Kumar *et al.* (2003) in a pot culture experiment on tuberose observed that application of nitrogen at 150 to 200 ppm along with 7.5 ppm zinc improved plant height, number of branches and leaf area. In gladiolus, Rajiv Kumar *et al.* (2003) reported significant increase in the length of spike, width of the spike and number of florets per spike with foliar application of 0.2 per cent borax and 0.5 per cent calcium sulphate. Similar findings were also reported by Chaturvedi *et al.* (1988); Prabhat Kumar and Arora (2002).

Balakrishnan (2005) studied that foliar application of 0.5 per cent zinc sulphate + 0.5 per cent ferrous sulphate sprayed at 30 and 45 days after planting in marigold significantly increased plant height, stem girth, plant spread, number of branches per plant and dry matter production over the check.

In gladiolus, combined soil application of boron at 2 kg and zinc at 4.5 kg significantly increased the plant height (79.83 cm and 87.61 cm), length of spike (71.2 and 67.33 cm) and floral characters like floret number (12.85 and 12.45 per spike) and floret size (Halder *et al*., 2007). In the same experiment, interaction of B and Zn significantly improved the characters like corm weight and number of cormels and weight of cormels per plant than the other treatments.

Ahmad *et al.* (2010) revealed that foliar application of 0.5 % B + 1.5 % Zn recorded highest plant height (69.80 cm), number of leaves per branch (28.41), leaf area (62.45 cm^2), number of flowers per plant (13.01), flower stalk length (46.73 cm) and leaf Zn content (823.16 ppm) in Rose (*Rosa hybrida* L.)

Jagtap *et al*. (2012) studied the effect of micronutrients (0.1 to 0.3 per cent) viz., $ZnSO_4$, $MnSO_4$, $FeSO_4$ alone and combination treatments. The results indicated that, the vegetative growth in terms of number of primary branches, number of secondary branches, number of leaves per shoot, number of leaves per plant and number of blind shoots, minimum days required for first flower bud initiation and increased the flower yield and quality of flower under 0.3 per cent concentration in each of $ZnSO_4$, $MnSO_4$ and $FeSO_4$, followed by 0.2 per cent concentration in each of $ZnSO_4$, $MnSO_4$ and $FeSO_4$.

Younis *et al*. (2013) in *Rosa hybrida* concluded that application of foliar fertilizer NPK 15:32:7 + chelated micronutrient mix gave the highest values with respect to plant height, number of flowers per plant, bud diameter, flower diameter, fresh and dry weight of flower, flower quality, flower stalk length compared to the application of NPK alone and untreated plants (control)

2.11. Management of diseases and quality improvement by the use of bio-agents

Among various diseases, mildews causes considerable yield loss in terms of number of stems and flower quality. The mildews are managed through the extensive use of fungicides. Repeated application of the fungicides results in the development of resistance among the pathogens and thus, becomes very difficult to manage the disease. In this context, biological control through the use of antagonistic micro-organisms has emerged as a promising alternative. Here, we focus in detail on the versatile utilization of *Bacillus spp* for the management of powdery mildew to enhance the growth promotion of cut rose.

2.11.1. Role of *Bacillus spp* involved in bio-control of plant diseases

The genus *Bacillus* is one of the most utilized bacterial antagonists in the biocontrol of phytopathogens. This genus comprehends a heterogeneous group of Grampositive, aerobic or facultative anaerobic, endospore-forming bacteria. The endospores are thermo tolerant structures, resistant to dryness, to ultraviolet radiation and to organic solvents. These properties, associated to the ability of producing peptide antibiotics, contribute to the utilization of this genus for the bio-control of soil born and foliar diseases (Backman *et al*., 1997; Kloepper, 1997; Melo, 1998). *B. subtilis* and related species have been the object of particular interest because of their widespread distribution in diverse habitats, increased shelf life under adverse conditions and its ability to produce growth promoting substances (Earl *et al*., 2008; Nakkeeran *et al*., 2004 ; Montesinos and Bonaterra, 2009).

2.11.2. Mode of action of *Bacillus spp*

Members of the *Bacillus* genus are often considered as microbial factories for the production of a vast array of biologically active molecules, which are potentially inhibitory to phytopathogens and insects. Their spore-forming ability also makes these bacteria as best

candidates for developing efficient bio-pesticide products. *Bacillus spp* is involved in the control of plant diseases through a variety of mechanisms of action, such as competition, induction of systemic resistance, growth promotion, mobilization of nutrients and antibiotic production. The antibiosis has been shown to be one of the most important mechanisms, which reduce the cost of resistance and results in suppression of both foliar and soil born diseases (Thomashow and Weller, 1996).

B. amyloliquefaciens, B. subtilis, B. cereus, B.licheniformis, B. megaterium, B. mycoides, and *B. pumilus* are known as very efficient producers of antibiotic molecules. Besides, the *Bacillus* spores have a high level of resistance to the dryness, which is a prerequisite for the development of stable products. *B. subtilis*, has 4 -5% of its genome devoted to antibiotic synthesis and has the potential to produce more than two dozen of structurally diverse antimicrobial peptides (AMP). AMPs include cyclic lipopeptides such as fengycin, iturin, bacillomycin and surfactin. These compounds are characterized by broad spectrum action. The intense surfactin activity has been used for the biological control of plant diseases (Stein, 2005). *B. amyloliquefaciens* FZB42 has (8%) of its genome diverted towards antibiotic synthesis (Arguelles- Arias *et al*., 2009; Chen *et al.*, 2009b; Ruckert *et al*., 2011).

2.11.3. Role of bio agents in the control of powdery mildew of flower crops

Moyer and Peres (2008) studied the effect of bio-fungicides for the control of powdery mildew in gerbera. The bio-fungicide product contains [Cease (10 ml of *Bacillus subtilis*) + Biotune (1.3 ml of adjuvant)] sprayed at 28, 37, 44, 51, 58 and 65 days after transplant and the severity of powdery mildew was recorded (0 %, 0.1%, 0.5%, 0.7% and 1%) and 0.1%, 0.3%, 0.8%, 1.6%, 3.1%and 4.2% of severity in untreated plants respectively.

Elmhirst *et al*. (2011) studied the effect of biological control agents for control of powdery mildew in rose. The bio-agent *Bacillus subtilis* (Serenade MAX) sprayed at fortnight interval and recorded lowest percent disease incidence (4.8 and 0.9) in treated plants and (19.8), (20.8) in control during trail1 and trail 2 respectively.

2.11.4. Quality improvement by the use of bio-agents

Biofertilizers are cost effective, eco-friendly and renewable source of plant nutrients in sustainable agriculture system. They are microbial inoculants which enhance crop production through improving the nutrient supply and their availability (Wani and Lee, 2002).

2.11.4.1. Phosphorus solubilizing microorganisms

Evidence of naturally occurring rhizospheric phosphorus solubilizing microorganism (PSM) dates back to 1903 (Khan *et al.,* 2007). Bacteria are more effective in phosphorus solubilization than fungi (Alam *et al.,* 2002). Among the whole microbial population in soil, PSB constitute 1 to 50 %, while phosphorus solubilizing fungi (PSF) are only 0.1 to 0.5 % in P solubilization (Chen *et al.*, 2006). Among the soil bacterial communities, ectorhizospheric strains from *Pseudomonas* and *Bacilli*, and endosymbiotic rhizobia have been described as effective phosphate solubilizers (Igual *et al.*, 2001). *B. megaterium, B. circulans, B. subtilis, B. polymyxa, B. sircalmous* could be referred as the most important strains (Subbarao, 1988; Kucey *et al.*, 1989).

Mohinder *et al.* (2011) reported that the strains of fluorescent *Bacillus spp* isolated from the rhizosphere region of carnation and medicinal plants were screened for the production of plant growth regulators, *viz*. auxins, gibberellins and cytokinins. The continuous interaction between the plant roots and the rhizosphere microorganisms might have influenced plant growth. It improves the plant growth by direct effect on the plant by producing plant growth promoting substances (Lynch, 1976).

Combination of formulated spores of *B. subtilis* strain GB03 as a growth promoting agent and *B. amyloliquefaciens* strain IN937a as an induced systemic resistance (ISR) were used to enhance the growth of several vegetable transplant systems and also induced ISR activity to various foliar pathogens (Kenney *et al.,* 1999; Kloepper *et al.,* 1999).

2.12. Vase life studies

Cut flowers are living, actively metabolizing, heterogeneous organs composed of floral and foliar parts each of which may be at different physiological and developmental stage. The termination of vase life of many cut flowers is characterized by wilting even though they are constantly held in water (Kende and Baumgartner, 1974). The short vase

life of roses is often related to water stress characterized by incomplete bud opening, rapid loss of fresh weight, water deficit and poor maintenance of turgidity. Many studies have been carried out to evaluate the events leading to this phenomenon. The use of preservative solutions to promote the quality and prolong the vase life of cut flowers has been known for many years.

The use of chemical preservatives to extend the shelf life of cut flowers is an age old practice. Water is the prime source for cut flowers. Source of repairable substrate is also very important for longevity of flowers (Rogers, 1973). The importance of water, sugar and various other chemical preservatives to promote the keeping quality of cut flowers has been reported by several workers (Halevy and Mayak, 1981 and Shobha and Gowda, 1993).

Halevy and Mayak (1981) opined that the term vase life should represent the potential useful longevity of the flowers at the final consumer's home. Ferriera and Swardt (1981) reported that flower senescence during vase life is correlated with reduction in sugar content of the flower which results in wilting. Mayak and Dilley (1976) reported that sucrose enhances the effect of cytokinin in delaying senescence of flower and reduced the effect of ethylene in promoting it, thereby, increasing vase life of flowers.

The stage and time of harvest and stem length of the cut flower, effect the vase life (Prince *et al.*, 1980). Graff *et al.* (2008) reported that the cultivar Red giant had more vase life as compared to cultivar Akito, because of more hydraulic conductivity in rose stems. The point of termination of vase life varies from the first sign of wilting and fading (Halevy and Kofranek, 1977) to the total death of all flowers (Salinger, 1975) with all the intermediate values between these points (Molnar and Parups, 1977).

2.13. Mineral solutes

2.13.1. Effect of sucrose on post harvest life of flowers

Sugars play an important role in flower development and opening either as energy source for respiration or as osmotically active substance, which aid in maintaining turgidity of the expanding corolla. However, sugars also maintain higher fresh weight in shoots of cut flowers by inducing stomatal closure in the leaves and thus reducing water loss. The optimum concentration of sugar varies with the treatment and the flowers.

Generally, for a given flower the longer exposure to the chemical solution, the lower concentrations required and vice versa.

Flower senescence during vase life is correlated with reduction in sugar content of the flower (Nowak, 1979; Ferriera and Swardt, 1980) which resulted in wilting (Nicholas, 1973). Supplying cut flower with exogenous sugar, maintaining the respirable substrates in flower (Nicholas, 1973), promotes respiration, encourages protein synthesis (Paulin, 1986), delays the inset of excessive protein degradation and thus extends the longevity of cut flowers (Coorts, 1973 and Rogers, 1973). Sucrose improves water balance in cut flowers (Bravdo *et al*., 1974; Halevy and Mayak, 1974). This was attributed to the effect of sugar on the closure of stomata and reduction of water loss there by, increasing their ability to absorb water and maintain turgidity (Halevy and Mayak, 1979).

Sucrose enhances the effect of cytokinin in delaying senescence of flower and reduced the effect of ethylene in promoting it, thereby, increasing vase life of flowers (Mayak and Dilley, 1976). The supplied sugars may also reduce naturally occurring starch hydrolysis and light degradation in roses (Molnar and Parups, 1977). It prevented on undesirable accumulation of free amino acids in the flower which is a symptom of flower ageing (Ferriera and Swardt, 1980). The main effect of applied sugar in extending the longevity is to maintain mitochondria structure and functions (Kaltaler and Steponkur, 1976). Sucrose in the vase solution is found to increase the vase life of roses (Paulin, 1986).

2.13.2. Effect of aluminium sulphate on post harvest life of flowers

Use of aluminium sulphate as a germicide in floral preservation is recommended by Nowak and Rudnicki (1990), Weinstein (1957) reported that the colour, form and longevity were more in aluminium treated flowers. It has been recommended for maintaining the vase life of several cut flowers (Liao *et al*., 2001) and used as an antimicrobial compound in commercial preservative solutions (Ichimura *et al*., 2006). Aluminium sulphate acidifies vase solution, diminishes bacterial proliferation and enhances water uptake (Tjeerd and Jaap, 2003; Hassanpour Asil *et al*., 2004). Diminished water movement from the vase to different parts of the flower stem may cause water stress to be followed by bent neck, wilting and premature senescence.

Stem plugging is one of the main factors determining longevity of roses and can be caused by physiological occlusion due to plant itself, microorganisms or air embolism (Van Doorn *et al*., 1989). It can decrease the pH of rose petals and stabilizing the anthocyanin pigments and, thereby increase the cut rose flowers vase life (Put Henriette *et al*., 1992; Tjeerd and Jaap, 2003; Hassanpour Asil *et al*., 2004).

Antimicrobial compounds like metal salts prevent and slowdown bacterial growth, ensure proper water uptake and delay senescence (Liao *et al*., 2001; Sarkka, 2005). This compound acts as a bacterial filter by forming Al $(OH)_3$ sediment on the cut surface of stem (Put Henriette *et al*., 1992). Aluminium sulphate (50-100ppm) has been used in many preservative formulations of roses (Halevy, 1978) and other flowers (Aarts, 1957b). Mayak and Bar-Yosef (1972) showed that roses exposed to aluminium for 12 hours only had reduced bent neck and wilting.

According to Rajagopalan and Khader (1993) aluminium sulphate at a concentration of 0.08 to 0.1 per cent reduced the bacterial growth of cut chrysanthemum. Flowers kept in 0.1 per cent aluminium sulphate gave maximum vase life (10 – 11 days) and minimum damage. Sangama (1993) suggested 100 ppm as the optimum concentration for aluminium sulphate for cut roses. When aluminium sulphate (100 ppm) was added to the holding solution containing 8-HQC (200 ppm) and glucose (2%), the vase life was extended (8.5 days).

Tiwari and Singh (2002) reported that more solution uptake was found in flowers kept in aluminium sulphate (25 ml). Variation in solution uptake may be due to disturbance in transpiration pool and bacterial and fungal species gaining predominance in vase solution of aluminium sulphate leading to enhanced solution uptake by acting as anti-bacterial agent.

Singh *et al.* (2004) studied the effect of vase solution on keeping quality of rose and reported that the sucrose 1.5 per cent + aluminium sulphate 300 ppm increased the vase life of flowers to 6.00 days as compared to control (3.33 days). Further, sucrose (1.5%) in combination with aluminium sulphate (300 ppm) considered as suitable treatment for improving vase life of First Red. Effect of $Al_2 (SO_4)_3$ is apparently due to its biocidal nature and also improved water balance of cut roses.

Karki *et al.* (2004) revealed that vase solution of $Al_2(SO_4)_3$ 300 ppm + $AgNO_3$ + sucrose increased the vase life of cvs. Superstar and Happiness. Divya *et al.* (2004) had undertaken an experiment at the Department of Floriculture and Landscaping to improve the post-harvest life of cut rose, Rosa hybrida cv. First Red. The holding solution with sucrose (1.5%) + aluminium sulphate (300 ppm) extended the vase life up to 9.88 days and recorded the highest values for the quality characters *viz.*, flower diameter (7.14 cm), water uptake (18.72 ml), carotenoid content (2.20 g/100 g) and freshness recorded lowest physiological loss in weight (19.94%).

Gupta *et al. (*2007) revealed that sucrose (3%) + Aluminium sulphate (300 ppm) was found to be the best holding solution for improving post harvest quality of cut roses. Madhubala *et al.* (2008) studied the effect of pulsing for enhancing the keeping quality of rose stem. They reported that among the different chemicals tested, pulsing with aluminium sulphate (300 ppm) + sucrose (3%) was found to be most effective with vase life of 9.66 days and volume of solution absorbed per stem was 54.11 ml.

Seyf *et al.* (2012) studied the effect of aluminum sulfate on postharvest life of a cut rose cultivar. Boeing. Flower stems were placed in aluminum sulfate solutions (0, 150 mgl^{-1}, 300 mgl^{-1}, 150 mgl^{-1}+ sucrose 3%, 300 mgl^{-1} +sucrose 3%) until the end of vase life as a standard treatment and distilled water was used as control treatment. Aluminum sulfate treatment (150 and 300 mgl^{-1}) extended the vase life of flowers from 9 days (control) to 12 and 12.3 days respectively. Aluminum sulfate (150 and 300 mgl^{-1}) application resulted in a significant solution uptake until the end of the vase life, higher values of relative fresh weight of flowers and positive effect on flower bud opening and increased flower diameter compared to control.

2.13.3. Effect of stem length on vase life

Roses are graded according to the length of their stem. Laurie *et al*. (1958) reported that the flowers are classified according to stem length and grades are fixed. The longer stem cut roses, had more vase life, it may be due to carbohydrate reserve is more compared to the shorter stem which enables the maintainence of dry matter and respirable substrates, especially in the petals which helps in extending keeping quality (Coorts, 1973).

Rogers (1973) observed that the role of water status in the cut flowers helps in extending the vase life of the flower and depends on the maturity of the stem. Halevy (1976) reported that the translocation of sugar from stem accumulates in the flower, which increases the water uptake and helps to maintain turgidity in the stem thus, extending the vase life of the flowers. The stem possesses high sucrose inversion capacity, which helps to prolong the shelf life (Chin and Sacalis, 1977).

Prince *et al*. (1980) reported that 40 cm length of cut rose stems Cv. Sonia had more vase life and strong consumers acceptance. Mukhopandhyay (1990) reported that blooms with long stems are accepted in export market. In the United States of America, grading of flowers is followed according to stem length. The minimum length of cut rose starts from 25 cm and then the grade increased by 5 cm increment. The long stem blooms have more longevity. A long stem length increased the flower diameter and water uptake, enhancing the shelf life of rose cut flowers. A successive increase in petal area, decreased loss of weight and increased vase life was observed with the increase in stem length. Short-stemmed flowers lasted for a shorter duration (Gothmare, 1993).

2.13.4. Cutting of stems under water

Laurie (1936) reported that cutting of stems of flowers like roses, snapdragons and carnations, which have small conducting vessels under water, was more beneficial when compared to flowers like calendula which have large conducting vessels. He also worked with different types of flowers and using different depths of water ranging from 0.5 to 10 inch and he concluded that the shallow water treatment increased keeping quality by 2 to 3 days, mainly because less surface was exposed to bacterial decomposition in water.

2.13.5. Water relations with vase life

Neck droop of cut rose flower is caused by inadequate water transport through the neck tissue and tends to be varietal characteristic. Hence the water is an important component of cut flower and loss of water without replenishment causes the flower to wilt and droop. However, one cannot exclude the possibility that the antisenescence factor is water and the degradative changes in cut flower are results of water imbalance, an early symptom of senescence in cut flower is loss in fresh weight.

Rogers (1973) reported that the turgidity in plants and flowers is dependent on the rate of absorption and rate of water loss. Increase in fresh weight can occur when the rate of water absorption is more than the rate of transpiration. He also reported that the composition of 'tap water' varies greatly in various locations. This may influence the longevity of the flowers kept in tap water, as well as the efficiency of chemical solutions used for holding, pulsing or bud opening.

In cut flowers, the loss of water from all tissues depends on the environmental factors and immediately after cutting of flower a sharp decrease in water loss occurred due to closure of stomata (Mayak *et al*., 1974). According to Halevy and Mayak (1981) the termination of vase life of many cut flowers is initiated by wilting, even though they are constantly held in water.

The reduction in water uptake coupled with continuous transpiration leads to water deficit, which reduces turgidity in cut flowers. The balance of the two processes affects the fresh weight changes. Shobha and Gowda (1993) related the short post harvest life of rose of water stress, characterized by incomplete bud opening, rapid loss of fresh weight, more water deficit and less turgidity.

2.13.6. Water uptake and vascular blockage

In roses, the loss of petal turgidity and fresh weight was preceded by a decreased rate of water uptake, indicating that reduced uptake rather than excessive water loss is responsible. Since water tension in the flaccid flower is not transmitted to the base of stem a "stem blockage" was suggested within the xylem vessels (Durkin and Kuc, 1996). The reduction in stem conductivity is caused by several factors. Microbial growth paralleled the increase in stem resistance to water flow (Aarts, 1957a).

Therefore, micro-organisms were considered to be one of the main causes of reduced water uptake by cut flower.

Decrease in water conductivity (“stem blockage’’) is not wholly dependent on micro-organism’s population. Durkin and Kuc (1966) suggested that vascular blockage was the result of oxidative processes induced from harvesting injury. A major factor contributing to the rapid senescence of the cut rose flower is a vascular blockage, which begins at the cut ends and move up into the stem with time. Several other, have described the occlusions involved in stem plugging as a gummy substance (Aarts, 1957b). Pectinaceous or carbohydrates in nature (Parups and Molnar, 1972); breakdown products of cell walls (Ramussen and Carpenter, 1974).

This was supported by the fact, that an increase in cellulose activity paralleled the decline in conductivity of cut roses and application of cellulose decreased water uptake (Mayak *et al*., 1974). Lineberger and Steponkur (1976) demonstrated two type of vascular occlusions in rose stems; microbial occlusions were located at the base of the cut stem, while in the second type a gum deposition was found always above the solution level. These oxidative products poison the cells and plug the xylem vessels. Air entering the base of the cut stems during shipment or storage may be a factor disturbing the dehydration of flower (Durkin, 1979 a,b).

Materials and Methods

CHAPTER III

MATERIALS AND METHODS

An experiment on "Standardization of precision production techniques to maximize the yield and quality of Dutch Rose (*Rosa hybrida* var.Tajmahal) under greenhouse condition" was conducted in a private farm of M/s Shiva Sakthi Floritech Pvt Ltd at Hosur, Krishnagiri District, Tamil Nadu during the period from August 2012 – July 2014. The materials used and methods adopted for the experiments are dealt in this chapter.

3.1 Materials

3.1.1. Location of the experimental site

A field trial was conducted inside the polyhouse in a private farm of M/s Shiva Sakthi Floritech Pvt Ltd at Bagalur, Hosur, Krishnagiri District, Tamilnadu **(Plate.1).** Hosur is geographically situated between 12° 43' N latitude and 77^{o} 49' E longitude at an altitude of 942 m above MSL.

3.1.2. Climate and Soil

The meteorological parameters *viz.*, average maximum and minimum temperatures, relative humidity, rainfall, number of rainy days, bright sunshine hours, average daily evaporation, mean wind velocity are furnished in Annexure I.

Annexure –I Physical, chemical and physiochemical properties of the soil

S. No.	Soil properties	Values of sample
I.	**Physical properties**	
1.	Soil texture	Sandy clay loam
II.	**Chemical properties**	
1.	Available Nitrogen	190 kg ha^{-1}
2.	Available Phosphorus	30 kg ha^{-1}
3.	Available Potassium	339 kg ha^{-1}
4.	Organic matter	0.25 %

S. No.	Soil properties	Values of sample
5.	Available Zn	1.82 ppm
6.	Available Cu	1.18 ppm
7.	Available Fe	7.14 ppm
8.	Available Mn	5.16 ppm
III.	**Physio –Chemical properties**	
1.	EC	1.72 dSm^{-1}
2.	pH	6.97

3.2 Methods

3.2.1. Experimental design and layout

Crop : Rose (cut flower)

Variety : Tajmahal

3.2.1.1. Experiment 1: Effect of shoot bending and application of growth regulators in cut rose production

Design : Factorial Randomized Block Design (FRBD)

No. of factors : 2 (Factor-1 - Bending & Factor-2- Growth regulators)

No.of treatments in each factor : 5

No. of treatment combinations : 25 (5 levels of bending and 5 concentrations of growth regulators)

No. of replications : 3

Plot size / replication : 1 m^2

Spacing : 30 x15 cm (Row x Plant)

No. of plants / plot : 12

Planting method : Double row system in raised bed

3.2.1.1.1. Treatment details

Symbols	Factor -1 (Bending)	Symbols	Factor -2 (Growth regulators)
B_1	Bending at shoot junction bud	G_1	GA_3 100 ppm
B_2	Bending above second leaf bud	G_2	GA_3 200 ppm
B_3	Bending above third leaf bud	G_3	BA 100 ppm
B_4	Bending above fourth leaf bud	G_4	BA 200 ppm
B_0	Bending above first leaf bud (Farmers practice)	G_0	Without GR

Treatment combinations

T_1	B_1+G_1 (GA_3 100 ppm)	T_{14}	B_4+G_2 (GA_3 200 ppm)
T_2	B_1+G_2 (GA_3 200 ppm)	T_{15}	B_4 +G_3 (BA 100 ppm)
T_3	B_1 +G_3 (BA100 ppm)	T_{16}	B_4+G_4 (BA 200 ppm)
T_4	B_1+ G_4 (BA 200 ppm)	T_{17}	B_1+ G_0 (without GR)
T_5	B_2+ G_1(GA_3 100 ppm)	T_{18}	B_2 +G_0 (without GR)
T_6	B_2+G_2 (GA_3 200 ppm)	T_{19}	B_3+G_0 (without GR)
T_7	B_2 +G_3 (BA100 ppm)	T_{20}	B_4+ G_0 (without GR)
T_8	B_2+ G_4 (BA 200 ppm)	T_{21}	B_0 + G_0 without GR (control)
T_9	B_3+ G_1 (GA_3 100 ppm)	T_{22}	B_0 + G_1 (GA_3 100 ppm)
T_{10}	B_3+G_2 (GA_3 200 ppm)	T_{23}	B_0 + G_2 (GA_3 200 ppm)
T_{11}	B_3+G_3(BA 100 ppm)	T_{24}	B_0 + G_3 (BA 100 ppm)
T_{12}	B_3+G_4 (BA 200 ppm)	T_{25}	B_0 + G_4 (BA 200 ppm)
T_{13}	B_4+ G_1 (GA_3 100 ppm)		

(GA- Gibberellic acid; BA- Benzyl Adenine)

3.2.1.2. Experiment 2: Optimization of fertigation schedule in cut rose along with the application of micronutrients and *Bacillus spp* for improved growth, yield, quality and disease management

Design : Randomized Block Design (RBD)

No. of treatments : 22

No. of replications : 3

Plot size / replication : 1 m^2

Spacing : 30 x15 cm (Row x Plant)

No. of plants / plot : 12

Planting method : Double row system in raised bed

3.2.1.2.1. Treatment details

T_1	-	75% of RDF @ 125:62.4:62.4 g NPK /m^2 /yr
T_2	-	100% of RDF @ 166.4: 83.2:83.2 g NPK /m^2 / yr
T_3	-	125% of RDF @ 208:104:104 g NPK /m^2 / yr
T_4	-	150% of RDF @ 250:125:125 g NPK /m^2 /yr
T_5	-	T_1 + EDTA – MN + *B. megaterium* each@ 10 ml/m^2
T_6	-	T_2 + EDTA – MN + *B. megaterium* each@ 10 ml/m^2
T_7	-	T_3 + EDTA – MN + *B. megaterium* each@ 10 ml/m^2
T_8	-	T_4 + EDTA – MN + *B. megaterium* each@ 10 ml/m^2
T_9	-	T_1 + EDTA – MN + *B. amyloliquefaciens* each @ 10 ml/m^2
T_{10}	-	T_2 + EDTA – MN + *B. amyloliquefaciens* each @ 10 ml/m^2
T_{11}	-	T_3 + EDTA – MN + *B. amyloliquefaciens* each @ 10 ml/m^2
T_{12}	-	T_4 + EDTA – MN + *B. amyloliquefaciens* each @ 10 ml/m^2
T_{13}	-	T_1 + EDTA – MN + *B. megaterium* + *B. amyloliquefaciens* each@ 5 ml/m^2
T_{14}	-	T_2 + EDTA – MN + *B. megaterium* + *B. amyloliquefaciens* each@ 5 ml/m^2
T_{15}	-	T_3 + EDTA – MN + *B. megaterium* + *B. amyloliquefaciens* each@ 5 ml/m^2
T_{16}	-	T_4 + EDTA – MN + *B. megaterium* + *B. amyloliquefaciens* each@ 5 ml/m^2
T_{17}	-	T_1 + EDTA – MN + *B. megaterium* + *B. amyloliquefaciens* each@ 10 ml/m^2
T_{18}		T_2 + EDTA – MN + *B. megaterium* + *B. amyloliquefaciens* each@10 ml/m^2
T_{19}	-	T_3 + EDTA – MN + *B. megaterium* + *B. amyloliquefaciens* each@ 10 ml/m^2
T_{20}	-	T_4 + EDTA – MN + *B. megaterium* + *B. amyloliquefaciens* each@ 10 ml/m^2
T_{21}	-	Farmers practice's (119: 140: 98 g NPK/ m^2 /yr)
T_{22}	-	Control (without fertilizers)

- (T_1–T_{20} - 75% P as SSP through soil application, EDTA - chelated micro nutrient mixture– 0.5% foliar spray, foliar and soil application of *Bacillus spp.*)
- Spray of *Bacillus spp* once in seven day's interval.
- EDTA – MN - Foliar spray of micronutrient mixture contains (Fe- 4.0%, Zn – 4.0 %, Mn-1.5 %, Cu-1.5 %, B- 0.5%, Mg-9.0%, and Mo-0.1%) were given at ten days interval.
- Source of fertilizers (NPK): Calcium nitrate (15:0:0), All 19 (19:19:19) and Sulphate of potash (0:0:50) respectively.

3.2.1.3. Layout of drip system

Water was pumped through motor and it was conveyed to the main line after filtering through screen filter. From the source line, water was taken to the field through main line of 2'' PVC pipes. Fertigation tank was installed for fertigation. From the main pipes, 1.5" PVC pipes were fixed as sub-main. From which two laterals of 12mm OD were taken for three replications. There were two sub-mains with tap control for imposing drip irrigation and fertigation treatments. Along the laterals, emitters with a discharge rate of 4litres per hour were fixed at a spacing of 30cm.

3.2.1.4. Design data

1. Length of each lateral from sub main (12mm OD LDPE) - 15m
2. Emitter spacing - 30 cm
3. Lateral spacing - 30 cm
4. Emitter type - Inline dripper
5. Emitter discharge rate - 4lph
6. Filter size (screen filter) - 100µ

3.2.1.5. Crop management

3.2.1.5. 1. Details of polyhouse (Naturally Ventilated Polyhouse)

The naturally ventilated polyhouse (NVP) was oriented in East - West direction with central height of 5.7 m. The frame was constructed with galvanized iron pipe.

A rollable low density polyethylene (LDPE) flap was provided on all the sides of the polyhouse to control the ventilation area and to cover the side vents during rainy season to avoid the entry of rainwater and cooling effects inside the polyhouse. Glazing was provided with 200μ (800 gauge) thick ultra violet stabilized low density polyethylene film. The temperature (25 -30^{0}C) and relative humidity (70- 85%) inside the polyhouse were maintained by watering and over head sprinkling.

3.2.1.5. 2. Soil

The soil used for cultivation of rose, has good structure particularly the top layers and is also kept well drained during the entire growing period. Maintaining the correct pH of the soil plays a major role in the root development and uptake of nutrients.

3.2.1.5. 3. Bed Preparation and planting materials

One year old existing rose plants on the raised bed with 1 m width and 30 cm height from the ground level were taken for experiment. Between the two beds a spacing of 45 cm was left for walking space. The plant spacing of 30 x 15 cm and 12 plants / m^2 were maintained.

3.2.1.5. 4. Pruning

The selected plants were pruned for standard height at 50 cm from ground level for both experiments. Randomly five plants were selected and tagged for each replication **(Plate.2** for Experiment -I) and **(Plate.16** for Experiment -I)

3.2.1.5. 5. Fertilizer application through drip irrigation

Drip irrigation system was installed for the complete cropped area. The fertilizer sources for supplying NPK through drip irrigation were Calcium nitrate (15:0:0), All 19 (19:19:19) and Sulphate of potash (0:0:50) respectively. Fertigation was given as per the fertigation schedule for experiment -II (Annexure II).

3.2.1.5. 6. Fertigation techniques

For Rose, based on different treatment doses and stages, the fertilizer was given through fertigation throughout the cropping period through split application. The split doses were given once in a week through fertigation.

3.2.1.5. 7. Bending and application of growth regulators

New vegetative shoots were produced from pruned plants after 30 days. The well grown shoots were selected after attaining pencil thickness size for bending **(Plate 3&4).** The shoots were twisted and gently bent at different levels (B_1 - B_0). The foliar application of plant growth regulators (GA_3 100, 200 ppm and BA 100, 200 ppm) was done immediately after bending. Different concentrations of PGRs were sprayed on one year old plants at fifteen days interval till flowering (2 months) for experiment –I.

3.2.1.5. 8. Application of micronutrients and *Bacillus spp*

The chelated micronutrient mixture contains (Fe- 4.0%, Zn – 4.0 %, Mn-1.5 %, Cu-1.5 %, B- 0.5%, Mg-9.0%, and Mo-0.1%). Foliar application of BA 200 ppm, micronutrient mixture, soil and foliar application of *Bacillus megaterium* and *Bacillus amyloliquefaciens* were done at fifteen days, ten days and seven days interval for experiment – II respectively.

3.2.1.5. 9. Method of preparation of culture media for *Bacillus spp*

In nature, microorganisms exist as mixed populations of many widely differing types. They require suitable nutrients as well as favourable environment for their survival and multiplication. Suitable media required for bacteria growth is nutrient agar (NA) medium. It contains Peptone 5.0 g, Beef extract 3.0 g, Sodium chloride 5.0 g in 1 litre of water with (pH 6.8 to 7.2) mixed thoroughly. This broth culture mixture is kept in autoclave at 121^0C for 30 mins for sterilization. The pure cultures of *Bacillus spp* were transferred to broth media in laminar air flow chamber under sterilized condition. The sterilized media and pure culture of *B.megaterium* (BAC- 4) and *B. amyloliquefaciens* (BSC-7) are mixed in a broth and kept for 24 hrs for multiplication **(Plate.25)**.

3.2.1.5. 10. Inter cultivation

The entire rose beds were kept weed free by hand weeding at regular intervals. The scraping of bed was done once in a month.

3.2.1.5. 11. Irrigation

Application of water through hosepipe was done for plants at two days interval in summer months, to reduce the field heat and to maintain temperature and humidity inside the polyhouse.

3.2.1.5.12. Drip irrigation

It was done once in three days @ 4 lph.

3.2.1.5. 13. Temperature management

To create a favourable environment for plant growth, side ventilation opening was altered depending upon the season, whenever the temperature went high, the rollable polyethylene flap was used to roll up, and sufficient irrigation through hose was given to bring down the temperature. While, under low temperature condition, the rollable polyethylene flap was rolled down in order to conserve the heat inside the polyhouse.

3.2.1.5. 14. Plant protection

Periodical plant protection measures were carried out to control pests and diseases during crop growth as per the schedule.

3.2.1.5. 15. Disbudding and de-shooting

Removal of undesirable axillary buds and shoots was done after development of main bud in the growing shoot. Keeping only the central bud to promote the growth of terminal bud, which led to the production and improve the quality of flower.

3.2.1.5. 16. Bud capping /netting

The nylon made small net like caps were covered to the developing bud to regulate the shape and increase the size of the bud and improve the quality of the flower.

3.2.1.5. 17. Harvesting & grading

The flowering stem was harvested when calyx was reflexed and first petal started opening out (Tight bud stage), leaving two nodes from the base of the shoot. After harvesting, cut stems were pre-cooled and graded based on the length of stem and size of the bud.

3.3. OBSERVATIONS RECORDED

3.3.1. Experiment I & II

Five plants in each replication were selected at random and tagged for recording observations on different traits.

3.3.1.1. Stages of observations

- ✓ Vegetative stage (10-25 days after bending)
- ✓ Flower bud appearance stage (26-35 days after bending)
- ✓ Peak flowering stage (36-45 days after bending)
- ✓ Harvesting stage (46- 60 days after bending)

3.3.2. Growth parameters

3.3.2.1. Plant height (cm)

The plant height was recorded (25, 35 and 45 days after bending) by measuring the length from the base of the plant to the longest tip of shoot. The readings were taken from the tagged plants and the mean values were worked out and expressed in cm.

3.3.2.2. Number of compound leaves per plant

The total number of compound leaves per plant was recorded (25, 35 and 45 days after bending) from the tagged plants.

3.3.2.3. Number of basal shoots per plant

The total number of basal shoots per plant was recorded from the tagged plants.

3.3.2.4. Plant spread (cm^2)

Plant spread was measured in both of the directions i.e. East-West (E-W) and North-South (N-S) and the mean was taken as the actual plant spread. The mean values were expressed in cm.

3.3.2.5. Inter nodal length (cm)

The inter nodal length was measured in-between two compound leaves of flowering shoot and expressed in cm.

3.3.2.6. Total number of shoots per plant after bending

The total number of shoots produced per plant after bending was recorded

3.3.3. Floral parameters

3.3.3.1. Number of days taken for shoot emergence on bent shoots

The number of days taken for first shoot emergence from the day of bending was recorded.

3.3.3.2. Number of days taken for flower bud appearance after bending

The number of days taken for appearance of first flower bud was recorded from grown up shoots after bending

3.3.3.3. Number of days taken for harvest from flower bud appearance

The number of days taken for harvest of flowering stems was recorded from flower bud appearance to date of harvest after bending

3.3.3.4. Number of days taken for harvesting of flowering shoot after bending

The number of days taken for harvesting of flowering shoot was recorded after bending

3.3.3.5. Number of compound leaves per flowering shoot

Number of compound leaves was counted from the harvested flowering shoot grown after bending from each tagged plant.

3.3.3.6. Length of flowering shoot (cm)

The length of flowering shoot was measured from the base of harvested shoot to the tip of the flower bud and expressed in cm.

3.3.3.7. Length of flower bud at harvest (cm)

The length of the flower bud was measured from the base of the bud to the tip of the bud and expressed in cm.

3.3.3.8. Pedicel length (cm)

The length of pedicel was measured from the base of the pedicel to the base of the bud and expressed in cm.

3.3.3.9. Circumference of flower bud at harvest (cm)

The circumference of the flower bud was measured using Vernier caliper and expressed in cm

3.3.3.10. Stem girth (cm)

The girth of the flowering stem was measured using Vernier caliper and expressed in cm

3.3.3.11. Weight of flowering shoot at harvest (g)

The flowering shoot along with flower was cut at the peak flowering stage and weighed and the mean was expressed in gram

3.3.3.12. Number of quality grade flowers/m^2

The number of quality grade flowers/m^2 was calculated with the below mentioned stem length and the mean was expressed as A, B and C grade

Stem length (cm)	Grade
> 65	A
50 to 65	B
40 to 50	C

3.3.3.13. Yield of cut stems / plant /year

The number of stems harvested per plant per year was counted and expressed in numbers for yield per plant

3.3.3.14. Yield of flowers /m^2 / year

The number of flowers harvested per square meter area was counted and expressed in numbers for yield / m^2

3.3.3.15. Vase life (days)

After harvest, the flower stems at equal length of 35cm were kept in aluminum sulfate 100ppm +1% sucrose solution for vase life study at room temperature. Vase life was evaluated daily by observing the physiological changes and counting the number of days taken for the symptom of shriveling and wilting of petals (Halevy and Mayak, 1979) and expressed in days

3.3.4. Histological studies for experiment -I

3.3.4.1. Microtome

In order to study the ultra structural change in the leaf stomata and in the structure of xylem and phloem before and after bending of shoots

3.3.4.2. Fixing

The leaf specimens (stomata) were fixed by using quick fix. The quick fix was applied at the lower surface of the leaf. The size of fixed leaf (0.5 cm^2) portion was kept under Scanning Electron Microscope (SEM) for stomatal aperture measurement and observation.

3.3.4.3. Sectioning

The stem specimens were sectioned with the help of sharp blades. The thickness of the section was 1mm. Then it was kept under Scanning Electron Microscope (SEM) for observation.

3.3.5. Physiological analysis of plants for experiment – I & II

The plant samples were collected (5th compound leaf below bud on the flowering stem during flowering stage) for both experiments (Michelle McGinnis, 2012).

3.3.5.1. Chlorophyll content (mg/g)

Fresh leaves were collected and chlorophyll 'a', 'b' and the total chlorophyll contents in the leaves were determined by the following method of Yoshida *et al.* (1971) and expressed in mg g^{-1} of fresh weight of fresh tissue.

Chlorophyll 'a' = (12.7 X OD at 663) – (2.69 X OD at 645) X V/ (1000 X W)

Chlorophyll 'b' = (22.9 X OD at 645) – (4.68 X OD AT 663) X V / (1000 X W)

Total chlorophyll = [(OD at 652 X 1000)] / 34.5) X (V / 1000 X W)

Where

V = Final volume of chlorophyll extract (ml)

W = Fresh weight of tissue extracted (g)

OD = Optical density

3.3.5.2. IAA oxidase (µg/g/hr)

The IAA oxidase activity in the leaf sample was determined colorimetrically at 540 nm as per the method of Parthasarathi *et al*. (1970). The OD values were referred to a standard curve using auxin (IAA – 10 to 100 µg /l) and expressed as µg $g^{-1}h^{-1}$ of fresh sample.

3.3.5.3. Soluble protein (mg/g)

The soluble protein content was estimated with tricarboxylic acid extract of leaf sample following the method of Lowery *et al*. (1957) and expressed as mg g^{-1} of fresh weight.

3.3.5.4. Nitrate reductase activity (NO_2/g/hr)

The nitrate reductase activity was estimated as per the method suggested by Nicholas *et al*. (1976). A known quantity (250 mg) of leaf was cut into small bits and placed in a test tube containing 10 ml of ice cold assay medium (phosphate buffer). The enzyme was extracted by suction using a vacuum evaporator for 5 minutes in darkness. Then the solution was kept in darkness for one hour for the enzyme reaction. After one hour, 2 ml of the aliquot was taken and 1 ml of Zinc acetate (1 M) and 2 ml of 70 % ethanol were added. The precipitate was filtered and to which 1 ml of 1% Sulphanilamide in 1.5 N HCl and 1 ml of 0.02% 1–Naphthyl ethylene diamine dihydrochloride was added. The pink colour developed was read at 540 nm in colorimeter. KNO_3 was used to plot a standard graph against which the sample was referred. Standards ranged between 20 and 100µg were prepared and plotted in a graph. The nitrate reductase activity (expressed in µg of NO_2 g^{-1} h^{-1}) was calculated by the following formula.

NRase = Conc. (µg) / 2ml x vol. (10 ml) / W (250 mg) x 1000 mg

Enzyme stability (%) = NRase (moisture stress) / NRase (normal condition) x 100

3.3.5.5. Total phenolics (µg/g)

Total phenolics content was estimated by Folin ciocalteau method (Malik and Singh, 1980). A leaf sample of 500 mg was taken and cut into bits and shaked in 5 ml of 80 per cent ethanol and then kept in the water bath for 10 minutes and then cooled. The sample was then macerated with 80 % ethanol and centrifuged at 5000 rpm for 10 minutes. One ml of supernatant was taken and added with one ml phenol reagents (Folin ciocalteau) and 2 ml of Na_2CO_3 and kept in water bath for 5 to 10 minutes. Then the colour intensity was read at 660 nm. Catechol was used as standard. Phenol content was expressed as mg equivalent of pyrocatechol per 100g fresh tissue.

3.3.5.6. Peroxidase activity (OD at 430nm /min/g)

Peroxidase activity was determined by adopting the procedure of (Hammerschmidt *et al.,* 1982). 0.5 gram of leaf sample was macerated with 10 ml of phosphate buffer (pH 7.0). The content was centrifuged at 5000 rpm for 15 minutes. A known volume (1ml) of extract was transferred to the test tube and added 3 ml of pyrogallol. The known content was added with 0.5 ml of hydrogen peroxide solution as a substrate to the cuvette and records the enzyme activity change in the OD value absorbance at 430 nm for 2 minutes with every 30 seconds interval. The enzyme activity was expressed as change in the OD value at 430nm /min/g.

3.3.5.7. Anthocyanin content

The anthocyanin content was estimated with alcohol extract of the sample is treated with HCI in aqueous methanol followed by anthocyanin reagent. The colour intensity is measured calorimetrically at 525nm. The anthocyanin content estimation method was described by Swain and Hillis (1959) and expressed as A_{525} values.

3.3.6. Observations on nutrient analysis

3.3.6.1. Nutrient analysis of soil & plant sample for experiment -II

Soil & plant samples were analyzed for available nutrient contents at critical stages of crop growth.

3.3.6.2. Collection and processing of samples

Soil samples were drawn at critical stage of the crop growth. The collected soil samples were dried under shade and made into power using wooden mallet; sieved through a 2mm sieve and then it is subjected to chemical analysis.

3.3.6.3. Available soil nitrogen

The available nitrogen content in soil was estimated by alkaline permanganate method (Subbaiah and Asija, 1956) and expressed as kg ha^{-1}.

3.3.6.4. Available soil phosphorus

The method described by Olsen's *et al.* (1954) was adopted for estimating the available phosphorus of the soil and expressed as kg ha^{-1}.

3.3.6.5. Available soil potassium

The available potassium was estimated using flame photometer (Stanford and English, 1949) and expressed as kg ha^{-1}.

3.3.7. Plant sample analysis

Fifth leaflet leaf below the bud on the flowering stem was collected and oven dried at 65^0C till constant dry weight was obtained. The dried samples were powdered and used for analysis.

3.3.7.1. Total nitrogen content

The nitrogen content in the plant sample was estimated by micro Kjeldhal method (Humphries, 1956), content was calculated and expressed in %.

3.3.7.2. Total phosphorus content

The phosphorus content was estimated in triple acid extract by adopting Vanado molybdate phosphate yellow colour method (Jackson, 1973) and content was calculated and expressed in %.

3.3.7.3. Total Potassium content

The potassium content was estimated by reading in the flame photometer values of triple acid extract (Jackson, 1973) and content was calculated expressed in %.

3.3.7.4. Plant sample analysis for micronutrients

One gram of plant sample was weighed and put in a 25 ml conical flask and 12 ml of triple acid extract mixture (nitric, sulphuric and perchloric acid in the ratio of 9:2:1) was added and kept overnight for cold digestion. The next day it was digested for 1 hour until clear white solution was obtained. After the digestion was over, the content was made up to 50 ml with double distilled water and transferred to 'Corning' vials and fed in to the Atomic Absorption Spectrophotometer (Make: Varian Techron, Model-Spectrometer AA 10/20 BQ for micronutrient analysis).

Methods of analysis

S.No	Estimation	Author	Methods
1.	Micronutrients (Cu, Fe, Zn, Mn)	Jackson, 1973	Triple acid extract (Nitric, Sulphuric, Perchloric acid- 9:2:1) using AAS with their respective cathode lamps

3.3.8. Soil enzyme analysis for experiment -II

3.3.8.1. Dehydrogenase

Five grams of fresh soil was taken in a 100 ml beaker. To that 0.05 g of calcium carbonate was added and mixed thoroughly. One ml of 3 per cent aqueous solution of 2, 5 tri phenyl tetrazolium chloride and 2.5 ml distilled water were added. The soil was completely saturated so that a thin film of free liquid just appears at the surface after mixing. The contents were mixed well at the surface after mixing. The contents were mixed well with a glass rod and covered with aluminium foil to make it air tight. It was then incubated for 24 hrs at 37 ^{0} C. The reddish colour of Triphenyl Formazan (TPF) was extracted by transferring the soil with the aid of methanol form each beaker to a funnel plugged with absorbent cotton. The extract was collected till all the filtrate ran colourless. The final volume was made up to 100 ml with methanol and the colour intensity was determined using Varian Cary 50 spectrophotometer at a wavelength of 485 nm with methanol as blank. A standard graph was drawn using Triphenyl Formazan (TPF) in methanol.

2, 3, 5 Triphenyl Tetrazolium Chloride (TTC) + 2H ⟶ Triphenyl Formazan + HCl

The dehydrogenase activity was expressed as ▲in OD at 480 nm of Triphenyl Formazan (TPF) formed per gram of soil per 24 hours (Cassida *et al*., 1964).

3.3.8.2. Acid Phosphatase

One gram of the soil was placed in 1000 ml Erlenmeyer flask, 4ml of 0.25 per cent p- nitrophenyl phosphate in 0.2 M Borax – NaOH buffer (pH 9.4) (Tatabai and Bremner, 1969) was added to it. After mixing the contents the flasks were tightly stoppered and incubated at 35 ± 1 ^{0}C for one hour. After incubation 1 ml of 0.5 M $CaCl_2$ and 4 ml of 0.5 M NaOH were added. The soil suspension was filtered through Whatman No. 42 filter paper and the volume was made up to 25 ml with distilled water. The intensity of the yellow colour was measured immediately in UV- spectrophotometer at 420 nm (Rao *et al*., 1990). The p-nitrophenyl phosphate g^{-1}dry soil min^{-1} at 35 ± 1 ^{0}C at pH 5.4.

3.3.8.3. Urease

Urease activity was determined by the release of ammonium after incubating10 g of soil with 20ml of 0.2 M Citrate buffer (pH 6.7) and urea solution (10 ML, 10% w/v) at 27^0 C for 3 hours. At the end of incubation, 70 ml of distilled water was added, the mixture filtered and the sediment washed once. 1 ml of aliquot of the filtrate was mixed with phenol-sodium reagent and the intensity of the colour was read spectrophotometrically after 20 minutes at 630 nm and expressed as mg NH_4 –N $100g^{-1}$ soil h^{-1} (Hoffmann and Teicher, 1961).

3.3.9. Enumeration of rhizosphere soil microbial population for experiment -II

The rhizosphere soil sample from rose was analyzed for bacteria, fungi and actinomycetes.

3.3.9.1. Serial dilution

One grams of rhizosphere soil was transferred to 9 ml of sterile distilled water to get 10^{-1}dilution. After thorough mixing, one ml of this dilution was transferred to 9 ml water blank to get 10^{-2} dilution. Likewise, sample was diluted serially with 9 ml water blanks till appropriate dilution was obtained (Parkinson *et al*., 1971).

3.3.9.1.1. Bacteria

The total bacterial population was enumerated by planting one ml of 10^{-6} dilution in sterile Petri plates using soil extract medium. The bacterial colonies appearing on the plates after 48 hrs of incubation at 30°C were counted and expressed as colony forming units per g of dry weight of the soil.

3.3.9.1.2. Fungi

For the enumeration of fungal population, one ml of 10^{-4} dilution of the soil sample was plated in sterile plate with potato dextrose agar medium. After 72 hrs of incubation the fungal colonies were counted and expressed per g dry weight of soil.

3.3.9.1.3. Actinomycetes

The total actinomycetes population was enumerated by plating 1 ml of 10^{-5} dilution with starch casein nitrate agar medium. The powdery colonies of actinomycetes appearing after 5 days were counted and expressed per gram dry weight of soil.

3.3. 10.Percent Disease Index

The incidence of powdery mildew was assessed based on the symptoms expressed in cut rose var. Tajmahal at (25 days after pruning), (35 days after pruning) and (45 days after pruning) of plants in an area of $1m^2$ per replication. Each treatment was replicated thrice. The powdery mildew incidence was assessed using by following formula:

Disease rating scale:-

Disease rating	Disease severity description
0	No symptoms on leaf area
1	Irregular white patches covering < 5 % of compound leaf area
3	Irregular white patches covering 6 to 10 % of compound leaf
5	Irregular white patches covering 11 to 25 % of compound leaf
7	Irregular white patches covering 26 to 50 % of compound leaf
9	Irregular white patches covering > 50 % of compound leaf

$$\textbf{Percent Disease Index (PDI)} = \frac{\text{Sum of all numerical ratings}}{\text{Total number of leaves observed} \times \text{maximum rating}} \times 100$$

3.4. Benefit cost ratio

3.4.1. Cost of cultivation

The cost of cultivation of cut rose under polyhouse was worked out based on the prevailing market price of various inputs and wages paid to the labours at M/s Shiva Sakthi Floritech Pvt Ltd at Hosur Taluk.

3.4.2. Gross return

The total income obtained from the crop was worked out, considering the prevailed market price during the experimentation.

3.4.3. Net return

It was calculated by subtracting the corresponding cost of cultivation of cut rose from the respective gross returns.

3.4.4. Benefit cost ratio (BCR)

The benefit cost ratio was worked out by using the formula suggested by Palaniappan (1985).

$$BCR = \frac{\text{Gross return (Rs. ha}^{-1})}{\text{Total cost of cultivation (Rs. ha}^{-1})}$$

3.5. Meteorological observations

3.5.1. Temperature

The temperature is expressed in terms of degree Celsius (^{0}C).

3.5.2. Relative humidity (RH)

Average daily relative humidity was expressed as percentage. Temperature and humidity were measured using thermo hygrometer.

3.6. Statistical analysis

The experimental data were statistically analyzed as per the method suggested by Panse and Sukhatme (1985). The critical differences were worked out for 5 per cent (0.05) probability. The mean differences were compared using LSD test for both the experiments. The treatment differences that were not significant were denoted by “NS”.

Experimental Results

CHAPTER IV

EXPERIMENTAL RESULTS

An experiment on "Standardization of precision production techniques to maximize the yield and quality of Dutch rose (*Rosa hybrida* var.Tajmahal) under greenhouse conditions" was conducted in a private farm of M/s Shiva Sakthi Floritech Pvt Ltd at Bagalur, Hosur, Krishnagiri District, Tamil Nadu during the period from August 2012 – May 2014. The data of various observations on growth parameters, flowering parameters, yield parameters, physiological attributes, nutrient contents and quality aspects were recorded and documented during the conduct of two greenhouse experiments. The data so obtained were statistically analyzed and results are presented separately under the following headings in this chapter.

4.1 Experiment I: To study the effect of shoot bending and application of growth regulators on maximizing the yield and quality of Dutch rose

4.1.1 Growth parameters

4.1.1.1 Plant Height (cm)

Observations recorded for plant height at different stages *viz.,* peak vegetative stage, bud appearance and peak flowering stage (25, 35 and 45 days after bending) respectively. The plant height differed significantly due to bending and interaction effect of growth regulators (**Table.1**).

Among the bending practices, bending at shoot junction bud (B_1) recorded the highest mean plant height of 112.91cm, 142.51 cm and 153.17 cm at all the three stages (Peak vegetative, bud appearance and peak flowering respectively). Similarly among the growth regulator treatments, BA 200ppm (G_4) registered increased plant height (108.37 cm, 135.88 cm and 146.61 cm) in all the three stages respectively.

Among the interactions, B_1G_4 (bending at shoot junction bud (B_1) + BA 200ppm (G_4) recorded the highest plant height at all the stages (Peak vegetative, bud appearance and peak flowering) of the crop growth (126.29 cm, 154.81 cm and 165.33 cm respectively) followed by B_1G_3 (bending at shoot junction bud (B_1) + BA 100ppm (G_3)

Table 1. Effect of bending and growth regulators on plant height at different stages (Days after bending)

Treatment	Plant height (cm)																	
	Vegetative stage						Bud appearance stage						Flowering stage					
	G_1	G_2	G_3	G_4	G_0	Mean	G_1	G_2	G_3	G_4	G_0	Mean	G_1	G_2	G_3	G_4	G_0	Mean
B_1	104.73	107.61	121.96	126.29	103.95	**112.91**	141.71	145.41	148.26	154.81	122.36	**142.51**	152.70	156.03	159.22	165.33	132.55	**153.17**
B_2	108.36	107.08	111.77	108.03	96.48	**106.34**	139.26	139.07	142.42	139.64	118.89	**135.86**	149.93	150.05	153.67	150.62	128.99	**146.65**
B_3	103.46	100.57	105.39	109.29	92.60	**102.26**	136.77	134.17	129.28	136.47	117.69	**130.88**	148.13	145.63	141.21	148.30	127.22	**142.10**
B_4	100.77	107.85	104.83	97.54	90.55	**100.31**	126.70	126.91	122.27	125.22	114.35	**123.09**	138.36	137.59	132.03	135.49	123.80	**133.45**
B_0	84.78	91.63	93.17	100.72	83.53	**90.77**	116.15	113.91	119.21	123.26	112.81	**117.07**	125.61	124.79	130.83	133.32	121.33	**127.18**
Mean	**100.42**	**102.95**	**107.42**	**108.37**	**93.42**	**102.52**	**132.12**	**131.89**	**132.29**	**135.88**	**117.22**	**129.88**	**142.95**	**142.82**	**143.39**	**146.61**	**126.78**	**140.51**
	B		**G**		**B x G**		**B**		**G**		**B x G**		**B**		**G**		**B x G**	
SEd	0.46935		0.46935		1.04949		0.34342		0.34342		0.76791		0.29569		0.29569		0.66118	
CD at 5%	0.94373		0.94373		2.11026		0.69052		0.69052		1.54406		0.59456		0.59456		1.32947	

Treatments details

Symbols	Factor -1 (Bending)	Symbols	Factor -2 (GRs)
B_1 -	Bending at shoot junction bud	G_1 -	GA_3 (100 ppm)
B_2 -	Bending above second leaf bud	G_2 -	GA_3 (200 ppm)
B_3 -	Bending above third leaf bud	G_3 -	BA (100 ppm)
B_4 -	Bending above fourth leaf bud	G_4 -	BA (200 ppm)
B_0 -	Bending above first leaf bud	G_0 -	Without GR

(GA_3- Gibberellic Acid ; BA- Benzyl Adenine) ; B_0 G_0 - Control (Farmer's practice)

which recorded a plant height of 121.96 cm, 148.26 cm and 159.22 cm respectively in three stages. The lowest plant height of 83.53 cm, 112.81 cm and 121.33 cm respectively recoded in B_0G_0 (control - bending above first leaf bud (B_0) + without GR (G_0).

4.1.1.2 Number of compound leaves per plant

Significant differences were observed for number of compound leaves at different stages *viz.*, peak vegetative stage, bud appearance and peak flowering stage (25, 35 and 45 days after bending) respectively. The number of compound leaves differed significantly due to bending and interaction effect of growth regulators (**Table. 2**).

Among the bending practices, bending above second leaf bud (B_2) recorded maximum mean number of compound leaves 74.30, 89.10 and 94.65 at (Peak vegetative, bud appearance and peak flowering respectively). Similarly among the growth regulator treatments, BA 100ppm (G_3) registered increased number of compound leaves (69.16, 83.53 and 88.85) in all the three stages respectively. Among the interactions, B_1G_4 (bending at shoot junction bud (B_1) + BA 200ppm (G_4) recorded the highest number of compound leaves (83.23, 98.07 and 104.13 respectively) at all three stages (Peak vegetative, bud appearance and peak flowering) of the crop development followed by B_1G_3 (bending at shoot junction bud + BA 100ppm) recorded (82.33, 97.47 and 103.20 respectively). Whereas, B_0G_4 recorded the lowest number of compound leaves (52.93, 66.03 and 69.93 respectively).

4.1.1.3 Number of basal shoots per plant

Significant variations were observed in the various interactions with regard to the number of basal shoots (**Table.3**).

The maximum mean number of basal shoots (3.21) was found in bending practice at shoot junction bud (B_1) and application of BA 100ppm (G_3) recorded maximum mean number of basal shoots (3.15). Among the interactions, bending at shoot junction bud (B_1) + BA 200ppm (G_4) recorded more number of basal shoots (3.33) followed by bending at shoot junction bud + BA 100ppm (3.27). These two treatments were statistically on par with each other. Interaction effect (B_4G_0) produced lowest number of basal shoots (2.87) followed by B_2G_0, B_3G_0, B_0G_1 and B_0G_4 (2.93) which were significantly lower than other interactions.

Table 2. Effect of bending and growth regulators on number of compound leaves /plant at different stages (Days after bending)

Treatment	Number of compound leaves /plant																	
	Vegetative stage						Bud appearance stage						Flowering stage					
	G_1	G_2	G_3	G_4	G_0	Mean	G_1	G_2	G_3	G_4	G_0	Mean	G_1	G_2	G_3	G_4	G_0	Mean
B_1	58.13	66.53	82.33	83.23	61.33	**70.31**	71.13	80.90	97.47	98.07	75.50	**84.61**	74.47	83.87	103.20	104.13	81.33	**89.40**
B_2	75.93	81.80	82.13	73.73	57.93	**74.30**	90.07	97.00	97.60	89.80	71.03	**89.10**	94.93	102.60	103.07	95.73	76.93	**94.65**
B_3	66.67	60.80	55.27	60.67	56.20	**59.92**	82.73	76.20	69.40	74.80	69.20	**74.47**	88.67	82.13	75.27	80.67	74.20	**80.19**
B_4	54.07	61.73	63.80	68.33	63.40	**62.27**	68.23	75.77	77.93	82.47	76.67	**76.21**	74.07	81.73	83.80	88.33	81.40	**81.87**
B_0	61.13	65.53	62.27	52.93	54.53	**59.28**	74.33	78.67	75.27	66.03	67.63	**72.39**	79.13	81.53	78.93	69.93	72.53	**76.41**
Mean	**63.19**	**67.28**	**69.16**	**67.78**	**58.68**	**65.22**	**77.30**	**81.71**	**83.53**	**82.23**	**72.01**	**79.36**	**82.25**	**86.37**	**88.85**	**87.76**	**77.28**	**84.50**
	B		**G**		**B x G**		**B**		**G**		**B x G**		**B**		**G**		**B x G**	
SEd	0.74022		0.74022		1.65519		0.70609		0.70609		1.57888		0.69338		0.69338		1.55045	
CD at 5%	1.48840		1.48840		3.32816		1.41977		1.41977		3.17471		1.39421		1.39421		3.11756	

Treatments details

Symbols	Factor -1 (Bending)	Symbols	Factor -2 (GRs)
B_1 -	Bending at shoot junction bud	G_1 -	GA_3 (100 ppm)
B_2 -	Bending above second leaf bud	G_2 -	GA_3 (200 ppm)
B_3 -	Bending above third leaf bud	G_3 -	BA (100 ppm)
B_4 -	Bending above fourth leaf bud	G_4 -	BA (200 ppm)
B_0 -	Bending above first leaf bud	G_0 -	Without GR

(GA_3- Gibberellic Acid ; BA- Benzyl Adenine) ; B_0 G_0 - Control (Farmer's practice)

Table 3. Effect of bending and growth regulators on various growth parameters

Treatment	Number of basal shoots /plant						Plant spread (cm^2)					
	G_1	**G_2**	**G_3**	**G_4**	**G_0**	**Mean**	**G_1**	**G_2**	**G_3**	**G_4**	**G_0**	**Mean**
B_1	3.20	3.13	3.27	3.33	3.13	**3.21**	40.33	41.44	43.35	45.19	38.81	**41.82**
B_2	3.13	3.00	3.13	3.07	2.93	**3.05**	39.74	38.98	40.70	42.71	38.99	**40.22**
B_3	3.13	3.13	3.20	3.07	2.93	**3.09**	39.01	36.26	41.97	42.26	39.44	**39.79**
B_4	3.07	3.13	3.07	3.07	2.87	**3.04**	39.52	37.97	41.62	43.30	38.51	**40.18**
B_0	2.93	3.00	3.07	2.93	3.00	**2.99**	35.10	36.05	37.94	39.77	39.13	**37.60**
Mean	**3.09**	**3.08**	**3.15**	**3.09**	**2.97**	**3.08**	**38.74**	**38.14**	**41.12**	**42.65**	**38.98**	**39.92**
	B		**G**		**B x G**		**B**		**G**		**B x G**	
SEd	0.05572		0.05572		0.12460		0.32738		0.32738		0.73204	
CD at 5%	0.11205		0.11205		0.25054		0.65827		0.65827		1.47194	

Treatments details

Symbols	Factor -1 (Bending)	Symbols	Factor -2 (GRs)
B_1 -	Bending at shoot junction bud	G_1 -	GA_3 (100 ppm)
B_2 -	Bending above second leaf bud	G_2 -	GA_3 (200 ppm)
B_3 -	Bending above third leaf bud	G_3 -	BA (100 ppm)
B_4 -	Bending above fourth leaf bud	G_4 -	BA (200 ppm)
B_0 -	Bending above first leaf bud	G_0 -	Without GR

(GA_3- Gibberellic Acid ; BA- Benzyl Adenine) ; B_0 G_0 - Control (Farmer's practice)

4.1.1.4 Plant spread (cm^2)

Analysis of variance pertaining to the plant spread revealed significant differences among the interactions under study (**Table. 3**).

In the present study, bending at shoot junction bud (B_1) recorded highest mean plant spread (41.82 cm^2) and BA 200ppm (G_4) sprayed plants produced maximum mean plant spread (42.65 cm^2). Among the interactions, maximum plant spread (45.19 cm^2) was achieved by bending at shoot junction bud (B_1) + BA 200 ppm (G_4) followed by bending at shoot junction bud (B_1) + BA 100ppm (G_3) (43.35cm^2). While, minimum plant spread (35.10 cm^2) was recorded in B_0G_1.

4.1.1.5 Inter nodal length (cm)

The inter nodal length differed significantly in different interactions (**Table. 4**). The maximum mean intermodal length (5.70 cm) was found in level of bending at shoot junction bud (B_1) and BA 200ppm sprayed plants produced longest internode (5.43 cm).

Among the treatments, B_1G_4 (bending at shoot junction bud (B_1) + BA 200 ppm (G_4) registered significantly the highest value of 6.13 cm followed by 6.02 cm in B_1G_3 (bending at shoot junction bud + BA 100 ppm). The lowest inter nodal length (4.54 cm) was recorded in control (B_0G_0) followed by B_3G_0 (4.80 cm).

4.1.1.6 Total number of shoots per plant after bending

Data pertaining to total number of shoots produced after bending by different interactions under naturally ventilated polyhouse is presented in **Table.4**. Significant variations were observed among the interactions with regard to the number of shoots produced. Among the bending practices, bending at shoot junction bud (B_1) produced highest mean number of shoots (4.39) and growth regulator GA_3 100ppm sprayed plants produced maximum mean number of shoots (3.99). Among the interactions, B_1G_4 (bending at shoot junction bud (B_1) + BA 200 ppm (G_4) produced maximum number of shoots (5.47) closely followed by bending at shoot junction bud (B_1) + BA 100 ppm (G_3) (5.00) which were found to be statistically on par with each other. Whereas (B_0G_0) control produced lowest number of shoots (2.67) followed by B_2G_0 and B_3G_0 (2.80) which were significantly lower than other treatments.

Table 4. Effect of bending and growth regulators on various growth parameters

Treatment	Inter nodal length (cm)						Shoots per plant after bending					
	G_1	**G_2**	**G_3**	**G_4**	**G_0**	**Mean**	**G_1**	**G_2**	**G_3**	**G_4**	**G_0**	**Mean**
B_1	5.60	5.84	6.02	6.13	4.90	**5.70**	4.53	4.07	5.00	5.47	2.87	**4.39**
B_2	5.58	5.89	5.23	5.18	4.94	**5.36**	4.47	3.93	3.60	3.27	2.80	**3.61**
B_3	5.14	5.05	5.07	5.15	4.80	**5.04**	3.20	3.13	3.47	3.40	2.80	**3.20**
B_4	4.97	4.81	4.99	5.07	4.87	**4.94**	4.00	3.07	2.93	3.20	3.13	**3.27**
B_0	5.13	5.45	5.72	5.63	4.54	**5.29**	3.73	2.87	3.13	3.47	2.67	**3.17**
Mean	**5.28**	**5.41**	**5.41**	**5.43**	**4.81**	**5.27**	**3.99**	**3.41**	**3.63**	**3.76**	**2.85**	**3.53**
	B		**G**		**B x G**		**B**		**G**		**B x G**	
SEd	0.02360		0.02360		0.05276		0.11683		0.11683		0.26125	
CD at 5%	0.04745		0.04745		0.10609		0.23492		0.23492		0.52531	

Treatments details

Symbols	Factor -1 (Bending)	Symbols	Factor -2 (GRs)
B_1 -	Bending at shoot junction bud	G_1 -	GA_3 (100 ppm)
B_2 -	Bending above second leaf bud	G_2 -	GA_3 (200 ppm)
B_3 -	Bending above third leaf bud	G_3 -	BA (100 ppm)
B_4 -	Bending above fourth leaf bud	G_4 -	BA (200 ppm)
B_0 -	Bending above first leaf bud	G_0 -	Without GR

(GA_3- Gibberellic Acid ; BA- Benzyl Adenine) ; B_0 G_0 - Control (Farmer's practice)

4.1.2 Flowering parameters

4.1.2.1 Number of days taken for shoot emergence on bent shoots

The data in **Table. 5** indicated that there was significant variation for days taken to shoot emergence on bent shoots. The level of bending at shoot junction bud (B_1) took minimum days (11.51) for first shoot emergence and BA 100 ppm (G_3) sprayed plants were produced first shoot emergence in 11.80 days than other treatments. The interaction effect of bending with growth regulator showed that B_1G_4 (bending at shoot junction bud (B_1) + BA 200 ppm (G_4) required minimum duration (10.87 days) for first shoot emergence followed by B_1G_3 (bending at shoot junction bud (B_1) + BA 100 ppm (G_3) which took 10.93 days. Whereas, maximum days required for shoot emergence (13.70 days) observed in B_4G_0 followed by B_3G_0 (13.57 days).

4.1.2.2 Number of days taken for flower bud appearance after bending

Observations on days taken for first flower bud appearance after bending differed significantly for interaction effects of bending with growth regulators (**Table. 5**).

Minimum number of days (28.00) required for flower bud appearance was found in bending level at shoot junction bud and BA 100 ppm treated plants took (28.85 days). Among the interactions, B_1G_4 (bending at shoot junction bud (B_1) + BA 200 ppm (G_4) registered earlier flower bud appearance (26.40 days) followed by 26.93 days in B_1G_3 (bending at shoot junction bud (B_1) + BA 100 ppm (G_3).Whereas, maximum days taken for flower bud appearance (31.30 days) observed in B_0G_0 (control) followed by B_4G_0 (31.20 days) and B_0G_4 (31.13 days).

4.1.2.3 Number of days taken for harvest from flower bud appearance

Significant differences were observed among the interaction effects for days to harvest from flower bud appearance (**Table. 6**).

Among the bending practices, bending at shoot junction bud (B_1) taken minimum (12.37 days) and growth regulator BA 200ppm sprayed plants required (12.57 days) taken for harvest from flower bud appearance. Among the interactions, the minimum duration (11.53 days) required for harvesting of flowers observed in B_1G_4 (bending at shoot junction bud (B_1) + BA 200 ppm (G_4) followed by 12.03 days in B_1G_3. They were

Table 5. Effect of bending and growth regulators on various flowering parameters

Treatment	Number of days taken for											
	Shoot emergence on bent shoots						Flower bud appearance					
	G_1	G_2	G_3	G_4	G_0	Mean	G_1	G_2	G_3	G_4	G_0	Mean
B_1	12.00	11.80	10.93	10.87	11.97	**11.51**	28.47	27.60	26.93	26.40	30.60	**28.00**
B_2	12.17	12.37	11.40	11.30	12.77	**12.00**	29.97	29.47	27.47	27.70	30.73	**29.07**
B_3	12.87	12.90	12.00	11.97	13.57	**12.66**	28.53	29.83	29.27	30.43	30.80	**29.77**
B_4	12.70	12.73	12.37	12.73	13.70	**12.85**	31.00	30.70	30.07	30.57	31.20	**30.71**
B_0	12.90	13.00	12.30	12.17	12.23	**12.52**	30.70	30.73	30.50	31.13	31.30	**30.87**
Mean	**12.53**	**12.56**	**11.80**	**11.81**	**12.85**	**12.31**	**29.73**	**29.67**	**28.85**	**29.25**	**30.93**	**29.68**
	B		**G**		**B x G**		**B**		**G**		**B x G**	
SEd	0.10707		0.10707		0.23941		0.13843		0.13843		0.30953	
CD at 5%	0.21529		0.21529		0.48140		0.27834		0.27834		0.62238	

Treatments details

Symbols	Factor -1 (Bending)	Symbols	Factor -2 (GRs)
B_1 -	Bending at shoot junction bud	G_1 -	GA_3 (100 ppm)
B_2 -	Bending above second leaf bud	G_2 -	GA_3 (200 ppm)
B_3 -	Bending above third leaf bud	G_3 -	BA (100 ppm)
B_4 -	Bending above fourth leaf bud	G_4 -	BA (200 ppm)
B_0 -	Bending above first leaf bud	G_0 -	Without GR

(GA_3- Gibberellic Acid ; BA- Benzyl Adenine) ; B_0 G_0 - Control (Farmer's practice)

statistically at par with each other. The plants of B_0G_1 (Bending above first leaf bud (B_0) + GA_3 100 ppm (G_1) took maximum duration (13.80 days) for harvesting of flowers followed by B_0 G_2 (13.63 days) and control (13.60 days).

4.1.2.4 Number of days taken for harvesting of flowering shoot after bending

Minimum number of days (51.89) required for harvesting of flowering shoot was found in bending level at shoot junction bud and BA 100 ppm treated plants took (53.40 days). Among the interactions, minimum (48.80 days) in B_1G_4 (bending at shoot junction bud (B_1) + BA 200 ppm (G_4) followed by 49.93 days in B_1G_3. B_4G_0 recorded the maximum days (57.90days) for harvest followed by B_0G_1 required (57.40 days) for harvesting of flowering shoot (**Table. 6**).

4.1.2.5 Number of compound leaves per flowering shoot

Significant differences were observed for number of leaves among the interaction effects (**Table.7**).

The level of bending at shoot junction bud produced (13.85) and BA200 ppm treated plants recorded higher number of compound leaves (13.77) per flowering shoot. Among the interactions, bending at shoot junction bud (B_1) + BA 200ppm (G_4) produced more number of compound leaves (16.13) followed by bending above third leaf bud (B_3) + BA 100ppm (G_3) which recorded 14.87 leaves followed by B_1G_3 (14.67). These two treatments were statistically on par with each other. The lowest number of compound leaves (11.20) observed in B_4G_0 followed by 11.27 numbers in both B_2G_0 and B_0G_0 (control).

4.1.2.6 Length of flowering shoot (cm)

The length of flowering shoot is an important character for deciding the quality and vase life of flowers. Different levels of bending and growth regulator interactions had significant influence on the variation for shoot length of flower. A perusal of data given in (**Table.7**) showed that the maximum length of flowering shoot (74.58 cm) by bending at shoot junction bud and growth regulator BA 200 ppm sprayed plants recorded longer flowering shoot (68.54 cm). Among the interactions, maximum length of flowering shoot (86.79 cm) was produced by B_1G_4 (bending at shoot junction bud (B_1) + BA 200 ppm

Table 6. Effect of bending and growth regulators on various flowering parameters

Treatment	Number of days taken for											
	Harvest from flower bud appearance						Harvest after bending					
	G_1	G_2	G_3	G_4	G_0	Mean	G_1	G_2	G_3	G_4	G_0	Mean
B_1	12.90	12.70	12.03	11.53	12.67	**12.37**	53.37	52.10	49.93	48.80	55.23	**51.89**
B_2	12.77	12.93	12.77	12.97	12.73	**12.83**	54.90	54.77	51.63	51.97	56.23	**53.90**
B_3	12.67	12.93	12.70	12.73	12.90	**12.79**	54.07	55.67	53.97	55.13	57.27	**55.22**
B_4	12.90	12.27	12.87	12.87	13.00	**12.78**	56.60	55.70	55.30	56.17	57.90	**56.33**
B_0	13.80	13.63	13.37	12.77	13.60	**13.43**	57.40	57.37	56.17	56.07	57.13	**56.83**
Mean	**13.01**	**12.89**	**12.75**	**12.57**	**12.98**	**12.84**	**55.27**	**55.12**	**53.40**	**53.63**	**56.75**	**54.83**
	B		**G**		**B x G**		**B**		**G**		**B x G**	
SEd	0.08301		0.08301		0.18561		0.18252		0.18252		0.40813	
CD at 5%	0.16691		0.16691		0.37322		0.36700		0.36700		0.82064	

Treatments details

Symbols	Factor -1 (Bending)	Symbols	Factor -2 (GRs)
B_1 -	Bending at shoot junction bud	G_1 -	GA_3 (100 ppm)
B_2 -	Bending above second leaf bud	G_2 -	GA_3 (200 ppm)
B_3 -	Bending above third leaf bud	G_3 -	BA (100 ppm)
B_4 -	Bending above fourth leaf bud	G_4 -	BA (200 ppm)
B_0 -	Bending above first leaf bud	G_0 -	Without GR

(GA_3- Gibberellic Acid ; BA- Benzyl Adenine) ; B_0 G_0 - Control (Farmer's practice)

Table 7. Effect of bending and growth regulators on various flowering parameters

Treatment	Number of compound leaves /flowering shoot						Length of flowering stem (cm)					
	G_1	G_2	G_3	G_4	G_0	Mean	G_1	G_2	G_3	G_4	G_0	Mean
B_1	13.13	12.40	14.67	16.13	12.93	**13.85**	70.43	68.83	76.43	86.79	70.41	**74.58**
B_2	13.93	13.73	14.27	13.40	11.27	**13.32**	62.21	65.17	71.46	67.53	57.71	**64.82**
B_3	13.13	13.07	14.87	13.20	12.07	**13.27**	66.31	65.64	70.41	69.63	57.62	**65.92**
B_4	13.07	13.33	12.73	13.60	11.20	**12.79**	64.53	60.69	64.30	61.51	53.82	**60.97**
B_0	12.67	12.93	12.33	12.53	11.27	**12.35**	61.88	55.07	53.12	57.25	59.98	**57.46**
Mean	**13.19**	**13.09**	**13.77**	**13.77**	**11.75**	**13.11**	**65.07**	**63.08**	**67.14**	**68.54**	**59.91**	**64.75**
	B		**G**		**B x G**		**B**		**G**		**B x G**	
SEd	0.11335		0.11335		0.25345		0.33802		0.33802		0.75585	
CD at 5%	0.22791		0.22791		0.50962		0.67968		0.67968		1.51981	

Treatments details

Symbols	Factor -1 (Bending)	Symbols	Factor -2 (GRs)
B_1 -	Bending at shoot junction bud	G_1 -	GA_3 (100 ppm)
B_2 -	Bending above second leaf bud	G_2 -	GA_3 (200 ppm)
B_3 -	Bending above third leaf bud	G_3 -	BA (100 ppm)
B_4 -	Bending above fourth leaf bud	G_4 -	BA (200 ppm)
B_0 -	Bending above first leaf bud	G_0 -	Without GR

(GA_3- Gibberellic Acid ; BA- Benzyl Adenine) ; B_0 G_0 - Control (Farmer's practice)

(G_4) followed by 76.43 cm in B_1G_3. Whereas, B_0G_3 (bending above first leaf bud (B_0) + BA 100 ppm (G_3) produced shortest flowering shoot (53.12 cm) followed by B_4G_0 which recorded 53.82 cm. In all other treatment interactions, the length of flowering shoot ranged from 57.00 cm to 72.00 cm.

4.1.2.7 Length of flower bud at harvest (cm)

The length of flower bud at harvest differed significantly by interaction effects (**Table.8**). In the present study, bending at shoot junction bud (B_1) recorded a flower bud length of 5.52 cm and in BA 100ppm (G_3) sprayed plants, flower bud was 5.60. Among the interactions, B_1G_4 (bending at shoot junction bud (B_1) + BA 200 ppm (G_4) registered the longest flower bud (6.26 cm) followed by B_1G_3 (bending at shoot junction bud (B_1) + BA 100 ppm (G_3) which recorded a bud length of 6.02 cm. The shortest length of flower bud (4.67cm) was produced by control (B_0G_0) followed by B_0G_3 (4.70 cm).

4.1.2.8 Pedicel length (cm)

Significant differences were observed among the levels of bending and growth regulators interactions for pedicel length (**Table.8**). Maximum length (7.54 cm) of pedicel was registered in (B_1) bending at shoot junction bud and growth regulator GA_3 at 200ppm treated plants were produced 8.02 cm of pedicel length. The highest pedicel length (9.67 cm) observed in B_1G_2 (bending at shoot junction bud (B_1) + GA_3 200 ppm (G_2) followed by 8.81 cm in B_1G_1. The treatment B_4G_4 (bending above fourth leaf bud (B_4) + BA 200 ppm (G_4) recorded the lowest pedicel length (5.54 cm) followed by B_3G_3 (5.76 cm) and B_3G_4 (5.79 cm). The pedicel length produced by other interaction effects ranged from 6.00 to 8.50 cm.

4.1.2.9 Circumference of flower bud at harvest (cm)

The circumference of flower bud is very important character for deciding the quality of flowers. Different interaction effects varied significantly from each other with respect to circumference of flower bud. The data presented in **Table. 9** indicated that level of bending at shoot junction bud produced bigger size of flower bud (11.49 cm) and that of BA 100 ppm sprayed plants recorded 12.03 cm. Among the interactions, larger circumference of flower bud (13.13 cm) was observed in B_1G_4 [bending at shoot junction

Table 8. Effect of bending and growth regulators on various flowering parameters

Treatment	Length of flower bud (cm) at harvest						Pedicel length (cm)					
	G_1	**G_2**	**G_3**	**G_4**	**G_0**	**Mean**	**G_1**	**G_2**	**G_3**	**G_4**	**G_0**	**Mean**
B_1	5.15	5.03	6.02	6.26	5.13	**5.52**	8.81	9.67	6.41	6.59	6.20	**7.54**
B_2	5.32	5.11	5.95	5.84	5.15	**5.47**	8.25	9.55	6.49	6.44	6.68	**7.48**
B_3	5.20	5.15	5.83	5.57	5.23	**5.40**	6.92	7.02	5.76	5.79	6.70	**6.44**
B_4	5.29	5.17	5.50	5.37	5.15	**5.30**	6.61	7.28	6.03	5.54	6.88	**6.47**
B_0	4.73	4.71	4.70	4.73	4.67	**4.71**	6.53	6.58	6.57	6.71	6.73	**6.62**
Mean	**5.14**	**5.03**	**5.60**	**5.55**	**5.07**	**5.28**	**7.42**	**8.02**	**6.25**	**6.21**	**6.64**	**6.91**
	B		**G**		**B x G**		**B**		**G**		**B x G**	
SEd	0.03841		0.03841		0.08589		0.06060		0.06060		0.13551	
CD at 5%	0.07724		0.07724		0.17271		0.12186		0.12186		0.27248	

Treatments details

Symbols	Factor -1 (Bending)	Symbols	Factor -2 (GRs)
B_1 -	Bending at shoot junction bud	G_1 -	GA_3 (100 ppm)
B_2 -	Bending above second leaf bud	G_2 -	GA_3 (200 ppm)
B_3 -	Bending above third leaf bud	G_3 -	BA (100 ppm)
B_4 -	Bending above fourth leaf bud	G_4 -	BA (200 ppm)
B_0 -	Bending above first leaf bud	G_0 -	Without GR

(GA_3- Gibberellic Acid ; BA- Benzyl Adenine) ; B_0 G_0 - Control (Farmer's practice)

bud (B_1) + BA 200 ppm (G_4)] followed by 13.09 cm in B_1G_3. Both were statistically at par with each other. Whereas, the least circumference of flower bud was observed in B_1G_2 (9.75 cm) followed by B_2G_2 (10.32 cm).

4.1.2.10 Stem girth (cm)

A perusal of data presented in **Table .9** revealed that the level of bending at shoot junction bud (B_1) recorded a stem girth 0.70 cm and that of BA 200ppm (G_4) sprayed plants registered a of stem girth of 0.73 cm. Among the interaction treatments, maximum girth of flower stem (0.87 cm) was found in B_1G_4 (bending at shoot junction bud (B_1) + BA 200 ppm (G_4) followed by 0.84 cm in B_1G_3. These interaction effects were statistically on par with each other for stem girth. Minimum stem girth was found in B_0G_1 (0.50 cm) followed by B_4 G_0, B_0 G_2 (0.53 cm).

4.1.2.11 Weight of flowering shoot at harvest (g)

Significant differences were observed among the levels of bending and growth regulator interactions for flowering shoot weight (**Table. 9**). Maximum weight of flowering shoot (74.63 g) was registered in level of bending at shoot junction bud while a shoot of weight 70.96 g recorded in BA 200 ppm treated plants. Among the interactions, B_1G_4 (bending at shoot junction bud (B_1) + BA 200 ppm (G_4) recorded the highest flowering shoot weight (91.84 g) followed by B_1G_3 (bending at shoot junction bud (B_1) + BA 100 ppm (G_3) which recorded 89.02g. The lowest flowering shoot weight (49.80 g) observed in B_0G_1.

4.1.2.12 Number of quality grade flowers/m^2

The perusal of data of **Table.10** indicated that more number of 'A' grade flowers (170.40) was recorded in bending practice at shoot junction bud while BA 200 ppm treated plants produced 144.89 flowers. Among the treatment interactions, B_1G_4 (bending at shoot junction bud (B_1) + BA 200 ppm (G_4) produced maximum number of "A" grade flowers (214.40/m^2) followed by B_1G_3 (bending at shoot junction bud (B_1) + BA 100 ppm (G_3) produced 200.80 flowers/ m^2. Minimum number of "A" grade flowers was recorded in B_3G_0 and B_4 G_0 (20.00/m^2). B_3G_0 produced increased number of "B" grade flowers (177.60) followed by B_2G_0(174.40). Maximum number of "C" grade flowers (46.40) was produced by B_0G_2 while minimum number of "C" grade flowers (7.20) was recorded in B_4G_4.

Table 9. Effect of bending and growth regulators on various flowering parameters

Treatment	Circumference of flower bud (cm) at harvest						Stem girth (cm)						Weight of flowering shoot at harvest (g)					
	G_1	G_2	G_3	G_4	G_0	Mean	G_1	G_2	G_3	G_4	G_0	Mean	G_1	G_2	G_3	G_4	G_0	Mean
B_1	10.81	9.75	13.09	13.13	10.67	**11.49**	0.57	0.55	0.84	0.87	0.65	**0.70**	61.92	67.00	89.02	91.84	63.39	**74.63**
B_2	10.56	10.32	12.21	11.25	11.13	**11.09**	0.58	0.62	0.70	0.72	0.56	**0.64**	55.03	60.52	71.75	70.98	56.56	**62.97**
B_3	11.07	10.46	12.17	11.64	11.23	**11.31**	0.64	0.57	0.77	0.75	0.55	**0.66**	60.94	56.73	66.85	70.77	54.36	**61.93**
B_4	10.74	10.55	12.18	12.29	10.72	**11.30**	0.66	0.57	0.66	0.69	0.53	**0.62**	60.69	57.04	67.00	65.59	52.16	**60.50**
B_0	10.54	10.62	10.50	10.46	10.60	**10.54**	0.50	0.53	0.61	0.63	0.58	**0.57**	49.80	52.95	57.12	55.63	51.65	**53.43**
Mean	**10.74**	**10.34**	**12.03**	**11.75**	**10.87**	**11.15**	**0.59**	**0.57**	**0.72**	**0.73**	**0.57**	**0.64**	**57.68**	**58.85**	**70.35**	**70.96**	**55.62**	**62.69**
	B		**G**		**B x G**		**B**		**G**		**B x G**		**B**		**G**		**B x G**	
SEd	0.09082		0.09082		0.20307		0.00756		0.00756		0.01691		0.26514		0.26514		0.59286	
CD at 5%	0.18261		0.18261		0.40832		0.01521		0.01521		0.03401		0.53312		0.53312		1.19209	

Treatments details

Symbols	Factor -1 (Bending)	Symbols	Factor -2 (GRs)
B_1 -	Bending at shoot junction bud	G_1 -	GA_3 (100 ppm)
B_2 -	Bending above second leaf bud	G_2 -	GA_3 (200 ppm)
B_3 -	Bending above third leaf bud	G_3 -	BA (100 ppm)
B_4 -	Bending above fourth leaf bud	G_4 -	BA (200 ppm)
B_0 -	Bending above first leaf bud	G_0 -	Without GR

(GA_3- Gibberellic Acid ; BA- Benzyl Adenine) ; B_0 G_0 - Control (Farmer's practice)

Table 10. Effect of bending and growth regulators on various flower grades

Treatment	Grade flowers / m^2/ year																	
	A						B						C					
	G_1	G_2	G_3	G_4	G_0	Mean	G_1	G_2	G_3	G_4	G_0	Mean	G_1	G_2	G_3	G_4	G_0	Mean
B_1	164.00	168.00	200.80	214.40	104.80	**170.40**	71.20	70.40	72.00	76.80	125.60	**83.20**	41.60	32.00	18.40	26.40	20.80	**27.84**
B_2	169.60	105.60	163.20	162.40	32.80	**126.72**	55.20	114.40	91.20	97.60	174.40	**106.56**	30.40	23.20	12.00	18.40	35.20	**23.84**
B_3	50.40	50.40	166.40	168.00	20.00	**91.04**	160.00	172.00	87.20	75.20	177.60	**134.40**	37.60	30.40	15.20	11.20	36.80	**26.24**
B_4	78.40	54.40	134.40	132.00	20.00	**83.84**	152.80	171.20	116.00	121.60	169.60	**146.24**	15.20	32.00	14.40	7.20	31.20	**20.00**
B_0	31.20	24.80	32.00	47.64	28.00	**32.73**	147.20	128.80	141.60	116.62	160.00	**138.84**	25.60	46.40	32.00	30.16	20.00	**30.83**
Mean	**98.72**	**80.64**	**139.36**	**144.89**	**41.12**	**100.95**	**117.28**	**131.36**	**101.60**	**97.56**	**161.44**	**121.85**	**30.08**	**32.80**	**18.40**	**18.67**	**28.80**	**25.75**
	B		**G**		**B x G**		**B**		**G**		**B x G**		**B**		**G**		**B x G**	
SEd	3.12851		3.12851		6.99556		2.80872		2.80872		6.28049		2.21698		2.21698		4.95732	
CD at 5%	6.29062		6.29062		14.06626		5.64761		5.64761		12.62844		4.45778		4.45778		9.96790	

Treatments details

Symbols	Factor -1 (Bending)	Symbols	Factor -2 (GRs)
B_1 -	Bending at shoot junction bud	G_1 -	GA_3 (100 ppm)
B_2 -	Bending above second leaf bud	G_2 -	GA_3 (200 ppm)
B_3 -	Bending above third leaf bud	G_3 -	BA (100 ppm)
B_4 -	Bending above fourth leaf bud	G_4 -	BA (200 ppm)
B_0 -	Bending above first leaf bud	G_0 -	Without GR

(GA_3- Gibberellic Acid ; BA- Benzyl Adenine) ; B_0 G_0 - Control (Farmer's practice)

4.1.2.13 Yield of cut stems / plant /year

It is apparent from the data presented in **Table.11** which showed that various interactions had significant variation on the mean of cut stems per plant per year. The data indicates that the level of bending at shoot junction bud was produced higher number of flowers (23.45) and BA 200 ppm treated plants were produced maximum number of flowers (21.80) per plant. In the interaction studies, maximum number of cut stems (26.47) produced by B_1G_4 (bending at shoot junction bud + BA 200 ppm) followed by B_1G_3 (bending at shoot junction bud + BA 100 ppm) which produced 24.27 flowers. Whereas, minimum number of cut stems per plant (16.40) were recorded in B_0 G_4 followed by B_0 G_2 which produced 16.67 stems.

4.1.2.14 Yield of flowers / m^2 /year

Data on the mean yield of flowers /m^2 on the levels of bending and growth regulators interactions are significantly different (**Table.11 & Fig.12**). The maximum mean yield of flowers (281.44) was produced by bending at shoot junction bud (B_1) and BA 200ppm sprayed plants recorded 261.12 flowers/m^2. Among the different interactions, highest mean yield of flowers /m^2 was recorded in the treatment B_1G_4 (317.60) followed by B_1G_3 (bending at shoot junction bud + BA 100 ppm) which produced 291.20 flowers/m^2. The treatment B_0G_4 recorded lowest yield of 194.42 /m^2/year followed by B_0G_2 produced 200.00 of flowers / m^2.

4.1.2.15 Vase life (days)

Significant differences were observed among the interactions for vase life (**Table. 11**). Among the bending practices, bending at shoot junction bud (B_1) registered extended (10.33) days for vase life and growth regulator BA 200ppm sprayed plants recorded maximum mean number of vase life days (8.87). Among the interactions, the maximum number of 12.37 days for vase life was recorded in B_1G_4 (bending at shoot junction bud + BA 200 ppm) followed by B_1G_3 (bending at shoot junction bud + BA 100 ppm) which recorded 11.37 days for vase life. Minimum number of days (6.72) was recorded in B_4G_3 followed by B_4G_4 (6.77 days) for vase life.

Table 11. Effect of bending and growth regulators on various cut flower yield and vase life parameters

Treatment	Yield of flowers /																	
	plant / year						m^2 / year						Vase life (days)					
	G_1	G_2	G_3	G_4	G_0	Mean	G_1	G_2	G_3	G_4	G_0	Mean	G_1	G_2	G_3	G_4	G_0	Mean
B_1	23.07	22.53	24.27	26.47	20.93	**23.45**	276.80	270.40	291.20	317.60	251.20	**281.44**	8.73	10.78	11.37	12.37	8.41	**10.33**
B_2	21.27	20.27	22.20	23.20	20.20	**21.43**	255.20	243.20	266.40	278.40	242.40	**257.12**	10.43	10.32	10.94	10.60	7.11	**9.88**
B_3	20.67	21.07	22.40	21.20	19.53	**20.97**	248.00	252.80	268.80	254.40	234.40	**251.68**	8.38	8.59	7.39	6.81	7.93	**7.82**
B_4	20.53	21.47	22.07	21.73	18.40	**20.84**	246.40	257.60	264.80	260.80	220.80	**250.08**	6.81	7.60	6.72	6.77	7.17	**7.01**
B_0	17.00	16.67	17.13	16.40	17.33	**16.91**	204.00	200.00	205.60	194.42	208.00	**202.40**	7.13	7.02	6.96	7.71	7.13	**7.19**
Mean	**20.51**	**20.40**	**21.61**	**21.80**	**19.28**	**20.72**	**246.08**	**244.80**	**259.36**	**261.12**	**231.36**	**248.54**	**8.30**	**8.84**	**8.68**	**8.87**	**7.55**	**8.45**
	B		**G**		**B x G**		**B**		**G**		**B x G**		**B**		**G**		**B x G**	
SEd	0.14040		0.14040		0.31395		2.85916		2.85916		6.39327		0.04167		0.04167		0.09317	
CD at 5%	0.28231		0.28231		0.63127		5.74903		5.74903		12.85523		0.08378		0.08378		0.18735	

Treatments details

Symbols	Factor -1 (Bending)	Symbols	Factor -2 (GRs)
B_1 -	Bending at shoot junction bud	G_1 -	GA_3 (100 ppm)
B_2 -	Bending above second leaf bud	G_2 -	GA_3 (200 ppm)
B_3 -	Bending above third leaf bud	G_3 -	BA (100 ppm)
B_4 -	Bending above fourth leaf bud	G_4 -	BA (200 ppm)
B_0 -	Bending above first leaf bud	G_0 -	Without GR

(GA_3- Gibberellic Acid ; BA- Benzyl Adenine) ; B_0 G_0 - Control (Farmer's practice)

4.1.3 Histological studies

Significant differences were observed for stomata aperture and vascular tissue organization of cross sectioned stem **(Table. 12).**

The size of the stomata aperture differed between control and treatment of rose leaves. **(Plate.14)** The leaf stomata aperture width was ranged from 6.84 to 8.32 µm and length ranged between 21.49 to 26.08 µm in (**Plate.14a)** B_0G_0 (bending above first leaf bud + without GR). But the stomatal aperture in treatment combination (**Plate.14b)** B_1G_4 (bending at shoot junction bud + BA 200 ppm) recorded increased width from 8.186 to 12.130 µm and length from 21.08 to 25.26 µm compared to control. A transverse section of control and treated stem vascular tissue organization was also differed**. (Plate.15)** The sclerenchyma tissues (beneath the epidermis) apparently shows the cell size was ranged from 31.96 to 36.43 µm and middle portion of stem cells size was 119.80 to 144.30 µm in (**Plate.15c)** B_0G_0 (bending above first leaf bud + without GR). But the vascular tissue organization in treatment combination (**Plate.15d)** B_1G_4 (bending at shoot junction bud + BA 200 ppm) was observed that size of the sclerenchyma tissues (beneath the epidermis) increased from 21.01 to 52.78 µm and middle portion of stem cells size increased from 133.10 to 169.40 µm compared to control.

4.1.4 Physiological attributes

4.1.4.1 Chlorophyll 'a' content (mg g^{-1})

The interaction effect on different levels of bending and growth regulators on chlorophyll 'a' content at flowering stage recorded significant differences. **Table.13** shows that maximum chlorophyll 'a'content (1.21 mg g^{-1}) was recorded in bending above fourth leaf bud (B_4) and BA 100 ppm sprayed plants recorded 1.24 mg g^{-1} of chlorophyll 'a' content. Among the interactions, maximum chlorophyll 'a' content (1.58 mg g^{-1}) was recorded in the interaction B_4G_4 (bending above fourth leaf bud + BA 200 ppm) which is followed by B_3G_3 (bending above third leaf bud + BA 100 ppm) by recording 1.41 mg g^{-1} of leaf tissue. B_2G_0 recorded the lowest chlorophyll 'a' content of 0.71 mg g^{-1}.

Table 12. Effect of bending and growth regulators on abaxial leaves of stomata and stem

Treatments	Stomata aperture		Stem	
			Vascular tissue organization (µm)	
	Width (µm)	Length (µm)	Outer portion	Middle portion
Control	6.844 to 8.322	21.49 to 26.08	31.96 to 36.43	119.8 to 144.30
Best treatment	8.186 to 12.13	21.08 to 25.26	21.01 to 52.78	133.10 to 169.40

Treatments details

Control - B_0G_0 - Bending above first leaf bud (B_0) + Without GR (G_0)

Best treatment - B_1G_4 - Bending at shoot junction bud (B_1) + BA (200 ppm) (G_4)

4.1.4.2 Chlorophyll 'b'content (mg g^{-1})

The mean data regarding chlorophyll 'b' content influenced significant differences upon the interactions (**Table.13**). Maximum chlorophyll 'b' content (0.29 mg g^{-1}) was recorded in bending above first leaf bud (B_0) and among the growth regulators BA 100 ppm and 200ppm sprayed plants recorded (0.31 mg g^{-1}) of chlorophyll 'b' content. Among the interactions, B_1G_4 (bending at shoot junction bud + BA 200 ppm) recorded the highest chlorophyll 'b' content of 0.38 mg g^{-1} followed by B_1G_3 (bending at shoot junction bud + BA 100 ppm) by recording 0.36 mg g^{-1} of fresh tissue. The lowest chlorophyll 'b' content (0.18 mg g^{-1}) was recorded) in B_1G_0 and B_2G_0.

4.1.4.3 Total chlorophyll contents (mg g^{-1})

The perusal of data indicates that the level of bending above second leaf bud recorded higher content of total chlorophyll 1.83 mg g^{-1} and plants treated with BA200 ppm produced maximum content (2.13 mg g^{-1}) of total chlorophyll. Among the interactions, the highest total chlorophyll content of 2.55 mg g^{-1} was recorded at flowering stage in the shoot bended at junction bud + BA 200 ppm (B_1G_4) and it was followed by B_2G_1 (bending above second leaf bud + GA_3 100 ppm) recording 2.32 mg g^{-1}. B_2G_0 recorded the lowest total chlorophyll content (1.08 mg g^{-1}) followed by B_0 G_0 (control) recorded (1.16 mg g^{-1}) at flowering stage (**Table.13**).

4.1.4.4 IAA oxidase (µg of unoxidised auxin g^{-1} h^{-1})

During the flowering stage different levels of bending and growth regulators are influenced with significant differences (**Table.14**). In the present study, bending at shoot junction bud (B_1) recorded 20.83 µg of unoxidised auxin g^{-1} h^{-1} and BA 100ppm (G_3) recorded maximum acitivity (21.86 µg of unoxidised auxin g^{-1} h^{-1}) of IAA oxidase. Among the interaction studies, highest IAA oxidase activity (22.48 µg of unoxidised auxin g^{-1} h^{-1}) was recorded in the treatment combination B_1G_4 (bending at shoot junction bud + BA 200 ppm) followed by B_1G_3 (bending at shoot junction bud + BA 100 ppm) by recording (22.33 µg of unoxidised auxin g^{-1} h^{-1}) and lowest IAA oxidase activity of 16.03 µg of unoxidised auxin g^{-1} h^{-1} was recorded in the treatment combination (B_0G_0).

Table 13. Effect of bending and growth regulators on various chlorophyll parameters

Treatment	Chlorophyll 'a'(mg/g)						Chlorophyll 'b' (mg/g)						Total chlorophyll (mg/g)					
	G_0	G_2	G_3	G_4	G_0	Mean	G_1	G_2	G_3	G_4	G_0	Mean	G_1	G_2	G_3	G_4	G_0	Mean
B_1	0.75	0.88	1.22	1.27	0.74	**0.97**	0.22	0.26	0.36	0.38	0.18	**0.28**	1.21	1.41	1.96	2.55	1.19	**1.66**
B_2	0.83	0.92	1.15	1.17	0.71	**0.95**	0.25	0.27	0.28	0.35	0.18	**0.27**	2.32	1.48	2.07	2.18	1.08	**1.83**
B_3	0.79	0.94	1.41	1.08	0.77	**1.00**	0.25	0.28	0.35	0.32	0.19	**0.28**	1.42	1.52	2.14	2.05	1.17	**1.66**
B_4	1.02	1.12	1.41	1.58	0.92	**1.21**	0.31	0.33	0.21	0.19	0.23	**0.25**	1.65	1.82	1.98	1.98	1.38	**1.76**
B_0	0.81	0.97	1.00	1.04	0.76	**0.92**	0.27	0.32	0.34	0.34	0.19	**0.29**	1.22	1.37	1.72	1.87	1.16	**1.47**
Mean	**0.84**	**0.96**	**1.24**	**1.23**	**0.78**	**1.01**	**0.26**	**0.29**	**0.31**	**0.31**	**0.19**	**0.27**	**1.56**	**1.52**	**1.97**	**2.13**	**1.20**	**1.68**
	B		**G**		**B x G**		**B**		**G**		**B x G**		**B**		**G**		**B x G**	
SEd	0.02386		0.02386		0.05335		0.00974		0.00974		0.02178		0.03061		0.03061		0.06845	
CD at 5%	0.04797		0.04797		0.10727		0.01959		0.01959		0.04380		0.06155		0.06155		0.13764	

Treatments details

Symbols	Factor -1 (Bending)	Symbols	Factor -2 (GRs)
B_1 -	Bending at shoot junction bud	G_1 -	GA_3 (100 ppm)
B_2 -	Bending above second leaf bud	G_2 -	GA_3 (200 ppm)
B_3 -	Bending above third leaf bud	G_3 -	BA (100 ppm)
B_4 -	Bending above fourth leaf bud	G_4 -	BA (200 ppm)
B_0 -	Bending above first leaf bud	G_0 -	Without GR

(GA_3- Gibberellic Acid ; BA- Benzyl Adenine) ; B_0 G_0 - Control (Farmer's practice)

Table 14. Effect of bending and growth regulators on various physiological parameters

Treatment	IAA Oxidase (µg/g/hr)						Soluble protein (mg/g)						Nitrate Reductase (µg of NO_2 g^{-1} h^{-1})					
	G_1	G_2	G_3	G_4	G_0	Mean	G_1	G_2	G_3	G_4	G_0	Mean	G_1	G_2	G_3	G_4	G_0	Mean
B_1	20.79	21.87	22.33	22.48	16.66	**20.83**	27.24	29.84	34.61	39.81	25.68	**31.44**	1.96	2.07	2.10	2.04	2.01	**2.04**
B_2	21.00	20.79	21.80	21.77	16.72	**20.42**	30.31	31.93	32.07	31.97	22.01	**29.66**	2.14	2.19	2.01	1.84	2.10	**2.06**
B_3	20.75	20.89	21.62	21.71	17.00	**20.39**	30.26	31.14	31.01	33.86	23.90	**30.03**	2.04	2.10	2.22	2.04	2.02	**2.08**
B_4	19.42	19.61	22.02	21.61	16.77	**19.89**	27.45	27.52	29.97	27.38	20.67	**26.60**	1.99	2.08	2.00	2.12	2.23	**2.08**
B_0	21.18	21.90	21.55	21.30	16.03	**20.39**	27.08	28.32	29.65	29.80	23.02	**27.57**	2.00	2.07	2.10	1.99	2.14	**2.06**
Mean	**20.63**	**21.01**	**21.86**	**21.78**	**16.64**	20.38	**28.47**	**29.75**	**31.46**	**32.56**	**23.06**	29.06	**2.03**	**2.10**	**2.09**	**2.00**	**2.10**	2.06
	B		**G**		**B x G**		**B**		**G**		**B x G**		**B**		**G**		**B x G**	
SEd	0.30362		0.30362		0.67892		0.37039		0.37039		0.82822		0.00294		0.00294		0.00657	
CD at 5%	0.61050		0.61050		1.36512		0.74476		0.74476		1.66534		0.00591		0.00591		0.01321	

Treatments details

Symbols	Factor -1 (Bending)	Symbols	Factor -2 (GRs)
B_1 -	Bending at shoot junction bud	G_1 -	GA_3 (100 ppm)
B_2 -	Bending above second leaf bud	G_2 -	GA_3 (200 ppm)
B_3 -	Bending above third leaf bud	G_3 -	BA (100 ppm)
B_4 -	Bending above fourth leaf bud	G_4 -	BA (200 ppm)
B_0 -	Bending above first leaf bud	G_0 -	Without GR

(GA_3- Gibberellic Acid ; BA- Benzyl Adenine) ; B_0 G_0 - Control (Farmer's practice)

4.1.4.5 Soluble protein (mg g^{-1})

Soluble protein content of cut rose leaves are significantly influenced by interactions at the flowering stage (**Table.14**). Maximum soluble protein content (31.44 mg g^{-1}) was registered in level of bending at shoot junction bud (B_1) and higher content of soluble protein (32.56 mg g^{-1}) was registered in BA 200 ppm treated plants. Among the interactions, B_1G_4 (bending at shoot junction bud + BA 200 ppm) recorded the highest soluble protein content (39.81 mg g^{-1}) followed by B_1G_3 (bending at shoot junction bud + BA 100 ppm) by recording 34.61 mg g^{-1}. B_4G_0 (bending above fourth leaf bud + without GR) recorded the lowest soluble protein content (20.67 mg g^{-1}) at flowering stage.

4.1.4.6 Nitrate reductase activity (µ moles NO_2 g^{-1} h^{-1})

Significant differences were observed among interactions at flowering stage. **Table.14** shows that maximum nitrate reductase activity (2.08 µmoles NO_2 g^{-1} h^{-1}) was recorded in B_3 & B_4 and while G_1 & G_0 recorded (2.10 µmoles NO_2 g^{-1} h^{-1}) of nitrate reductase activity. Among the interactions, bending above fourth leaf bud + without GR (B_4G_0) recorded the maximum nitrate reductase activity (2.23 µmoles NO_2 g^{-1} h^{-1}) followed by B_3G_3 by producing 2.22 µ moles NO_2 g^{-1} h^{-1}. The lowest nitrate reductase activity of 1.84 µ moles NO_2 g^{-1} h^{-1} was recorded in B_2G_4 at flowering stage.

4.1.4.7 Total phenolics (µg g^{-1})

The mean data regarding total phenolics content influenced significant differences upon the interactions (**Table.15**). Maximum phenol content of 313.30 µg g^{-1} was recorded in bending at shoot junction bud (B_1) while BA 100ppm recorded 322.16 µg g^{-1} of total phenol. Among the interactions, maximum phenol content of 375.57 µg g^{-1} was recorded in the treatment combination B_1G_3 (bending at shoot junction bud + BA 100 ppm) followed by B_1G_4 (bending at shoot junction bud + BA 200 ppm) by recording 362.54 µg g^{-1} and lowest phenols content (172.03 µg g^{-1}) was registered in the treatment (B_1G_0).

4.1.4.8 Peroxidase activity (OD at 430nm $min^{-1}g^{-1}$)

The interaction effect on different levels of bending and growth regulators on peroxidase activity at flowering stage of plant growth recorded significant differences.

Table 15. Effect of bending and growth regulators on various physiological parameters

Treatment	Total phenolics (µg/g)						Peroxidase (OD at 430nm /min/g)						Anthocyanin content					
	G_1	G_2	G_3	G_4	G_0	Mean	G_1	G_2	G_3	G_4	G_0	Mean	G_1	G_2	G_3	G_4	G_0	Mean
B_1	330.51	325.86	375.57	362.54	172.03	**313.30**	0.82	0.84	1.17	1.21	0.78	**0.97**	0.52	0.74	0.78	0.49	0.16	**0.54**
B_2	235.02	339.99	327.52	302.95	328.33	**306.76**	0.78	0.84	1.03	1.06	0.80	**0.90**	0.50	0.71	0.69	0.50	0.12	**0.51**
B_3	324.26	354.38	315.89	252.82	242.19	**297.91**	0.97	0.77	1.07	1.09	0.83	**0.95**	0.49	0.65	0.73	0.41	0.12	**0.48**
B_4	303.37	274.54	292.02	303.12	294.08	**293.43**	0.94	0.80	1.09	1.11	0.70	**0.93**	0.39	0.63	0.67	0.17	0.11	**0.39**
B_0	322.01	301.33	299.77	253.35	276.01	**290.49**	0.92	0.99	1.08	1.06	0.79	**0.97**	0.10	0.54	0.52	0.56	0.11	**0.47**
Mean	**303.03**	**319.22**	**322.16**	**294.96**	**262.53**	**300.38**	**0.89**	**0.85**	**1.09**	**1.10**	**0.78**	**0.94**	**0.40**	**0.65**	**0.68**	**0.53**	**0.12**	**0.48**
	B		**G**		**B x G**		**B**		**G**		**B x G**		**B**		**G**		**B x G**	
SEd	0.77452		0.77452		1.73189		0.13107		0.13107		0.29308		0.00152		0.00152		0.00340	
CD at 5%	1.55737		1.55737		3.48238		0.26355		0.26355		0.58931		0.00305		0.00305		0.00683	

Treatments details

Symbols	Factor -1 (Bending)	Symbols	Factor -2 (GRs)
B_1 -	Bending at shoot junction bud	G_1 -	GA_3 (100 ppm)
B_2 -	Bending above second leaf bud	G_2 -	GA_3 (200 ppm)
B_3 -	Bending above third leaf bud	G_3 -	BA (100 ppm)
B_4 -	Bending above fourth leaf bud	G_4 -	BA (200 ppm)
B_0 -	Bending above first leaf bud	G_0 -	Without GR

(GA_3- Gibberellic Acid ; BA- Benzyl Adenine) ; B_0 G_0 - Control (Farmer's practice)

Table.15 shows that bending above first leaf bud (B_0) recorded 0.97 abs $min^{-1}g^{-1}$ and also BA 200ppm (G_4) sprayed plants recorded maximum acitivity (1.10 abs min^{-1} g^{-1}) of peroxidase. Among the interactions, maximum peroxidase activity (1.21 abs min^{-1} g^{-1}) was recorded in the interaction B_1G_4 [bending at shoot junction bud (B_1) + BA 200 ppm (G_4)] followed by B_1G_3 (bending at shoot junction bud + BA 100 ppm recorded 1.17 abs min^{-1} g^{-1}. Minimum peroxidase activity (0.70 abs min^{-1} g^{-1}) recorded in B_4G_0.

4.1.4.9 Anthocyanin content

The intensity of anthocyanin content in cut rose petals are significantly influenced by different interactions (**Table.15**). The perusal of data indicates that the level of bending at shoot junction bud was registered higher content of anthocyanin 0.54 and BA 100 ppm treated plants were produced maximum content (0.68) of anthocyanin. Among the interactions, B_1G_3 (bending at shoot junction bud + BA 100 ppm recorded the maximum anthocyanin content (0.78) followed by B_1G_2 - bending at shoot junction bud (B_1) + GA_3 200 ppm (G_2) recorded (0.74). B_0G_1 - bending above first leaf bud (B_0) + GA_3 (100 ppm) (G_1) recorded the lowest anthocyanin content (0.10).

4.2 Experiment II: Optimization of fertigation schedule along with the application of micronutrients and bio-agents for improved growth, yield, quality and disease management in Dutch rose

4.2.1 Growth parameters

4.2.1.1 Plant Height (cm)

Observations recorded for plant height at different stages *viz.,* peak vegetative stage, bud appearance and peak flowering stage respectively. The plant height differed significantly by effect of fertigation, micronutrients and *Bacillus spp* (**Table. 16**).

Among the treatments, T_{19} (T_3 + 0.5 %EDTA micronutrient mixture + *B. megaterium* + *B. amyloliquefaciens* each @ 10 ml/m^2) recorded the maximum plant height (128.96 cm, 153.63 cm and 167.26 cm) at all the stage of the crop development which followed by T_{20} (T_4 + 0.5 % EDTA micronutrient mixture + *B. megaterium* + *B. amyloliquefaciens* each @ 10 ml/m^2) by recording 126.05 cm, 151.48 cm and 164.23 cm

Table 16. Effect of fertigation, micronutrients and *Bacillus spp* on plant height at different stages

Treatments	Vegetative stage	Bud appearance stage	Flowering stage
T_1	89.38	114.59	125.77
T_2	94.48	120.55	131.39
T_3	91.36	116.58	127.69
T_4	98.09	124.03	135.30
T_5	102.79	128.78	140.54
T_6	108.12	134.25	144.96
T_7	106.17	131.77	143.03
T_8	110.93	136.43	148.65
T_9	112.29	138.43	150.50
T_{10}	106.78	132.49	144.61
T_{11}	112.33	137.60	150.25
T_{12}	114.49	139.14	152.04
T_{13}	114.10	139.53	152.00
T_{14}	116.05	141.64	154.69
T_{15}	119.09	144.31	157.96
T_{16}	124.11	149.97	161.92
T_{17}	119.24	144.57	157.03
T_{18}	123.28	148.95	161.47
T_{19}	128.96	153.63	167.26
T_{20}	126.05	151.48	164.23
T_{21}	100.84	126.15	137.71
T_{22}	75.97	101.95	113.69
SED	**0.8439**	**1.3004**	**0.6671**
CD at 5%	**1.7035**	**2.6249**	**1.3465**

Treatments details

T_1 - 75% of RDF @ 125:62.4:62.4 g NPK /m^2 /yr
T_2 - 100% of RDF @ 166.4: 83.2:83.2 g NPK /m^2 / yr
T_3 - 125% of RDF @ 208:104:104 g NPK /m^2 / yr
T_4 - 150% of RDF @ 250:125:125 g NPK /m^2 /yr
T_5 - T_1 + 0.5 %EDTA - MN+ *B. megaterium* each @ 10 ml/m^2
T_6 - T_2 + 0.5 %EDTA - MN+ *B. megaterium* each @ 10 ml/m^2
T_7 - T_3 + 0.5 %EDTA - MN+ *B. megaterium* each @ 10 ml/m^2
T_8 - T_4 + 0.5 %EDTA- MN + *B. megaterium* each @ 10 ml/m^2
T_9 - T_1 + 0.5 %EDTA - MN+ *B. amyloliquefaciens* each @ 10 ml/m^2
T_{10} - T_2 + 0.5 %EDTA -MN+ *B. amyloliquefaciens* each @ 10 ml/m^2
T_{11} - T_3 + 0.5 %EDTA-MN +*B. amyloliquefaciens* each @ 10 ml/m^2
T_{12} - T_4 + 0.5 %EDTA- MN +*B. amyloliquefaciens* each @ 10 ml/m^2
T_{13} - T_1 + 0.5 %EDTA-MN + *B. megaterium* + *B. amyloliquefaciens* each @ 5 ml/m^2
T_{14} - T_2 + 0.5 %EDTA-MN + *B. megaterium* + *B. amyloliquefaciens* each @ 5 ml/m^2
T_{15} - T_3 + 0.5 %EDTA -MN+ *B. megaterium* + *B. amyloliquefaciens* each @ 5 ml/m^2
T_{16} - T_4 + 0.5 %EDTA -MN+ *B. megaterium* + *B. amyloliquefaciens* each @ 5 ml/m^2
T_{17} - T_1 + 0.5 %EDTA-MN + *B. megaterium* + *B. amyloliquefaciens* each @ 10 ml/m^2
T_{18} T_2 + 0.5 %EDTA -MN+ *B. megaterium* + *B. amyloliquefaciens* each @10 ml/m^2
T_{19} - T_3 + 0.5 %EDTA -MN+ *B. megaterium* + *B. amyloliquefaciens* each @ 10 ml/m^2
T_{20} - T_4 + 0.5 % EDTA -MN+ *B. megaterium* + *B. amyloliquefaciens* each @ 10 ml/m^2
T_{21} - Farmers practice's (119: 140: 98 g NPK/ m^2 /yr)
T_{22} - Control (without fertilizers)

(75% P as SSP through soil application, EDTA -MN– 0.5% foliar spray, foliar and soil application of *Bacillus spp.*) Spray interval for (EDTA – 0.5 % in 10 days and *Bacillus sp* once in 7 days)

at different stages **(Plate.22&23)**. The lowest plant height of 75.97 cm, 101.95 cm and 113.69 cm was recorded in (T_{22}) control.

4.2.1.2 Number of compound leaves per plant

Significant differences were observed for number of compound leaves at different stages *viz.*, peak vegetative stage, bud appearance and peak flowering stage (25, 35 and 45 days after pruning) respectively (**Table.17**).

Among the treatments, T_{19} (T_3 + 0.5 % EDTA micronutrient mixture + *B. megaterium* + *B. amyloliquefaciens* each @ 10 ml/m^2) produced higher number of compound leaves(69.20, 95.57 and 100.33) at different stages of the crop which followed by T_{20} (T_4 + 0.5 % EDTA micronutrient mixture + *B. megaterium* + *B. amyloliquefaciens* each @ 10 ml/m^2) produced 68.90, 95.37 and 99.60 compound leaves. T_{22} (control) recorded the lowest number of compound leaves (33.00, 59.00 and 63.47) in all the growth stages respectively.

4.2.1.3 Number of basal shoots per plant

Significant variations were observed in the treatments with regard to the number of basal shoots (**Table.18**). Among the treatments, more number of basal shoots (3.47) was recorded in T_{20} (T_4 + 0.5 % EDTA micronutrient mixture + *B. megaterium* + *B. amyloliquefaciens* each @ 10 ml/m^2) followed by T_{19} (T_3 + 0.5 % EDTA micronutrient mixture + *B. megaterium* + *B. amyloliquefaciens* each @ 10 ml/m^2) produced 3.45 basal shoots. Treatment (T_1 &T_2) recorded lowest number of basal shoots (2.87).

4.2.1.4 Plant spread (cm^2)

Analysis of variance pertaining to the plant spread revealed significant differences among the treatments (**Table.18**). Maximum plant spread of 47.82 cm^2 was observed in T_{19} (T_3 + 0.5 % EDTA micronutrient mixture + *B. megaterium* + *B. amyloliquefaciens* each @ 10 ml/m^2) followed by T_{20} (T_4 + 0.5 % EDTA micronutrient mixture + *B. megaterium* + *B. amyloliquefaciens* each @ 10 ml/m^2) by registering 46.59 cm^2. While, minimum plant spread (32.53 cm^2) was recorded in T_{22} (control).

Table 17. Effect of fertigation, micronutrients and *Bacillus spp* on number of compound leaves /plant at different stages

Treatments	Vegetative stage	Bud appearance stage	Flowering stage
T_1	40.93	66.80	71.07
T_2	46.20	72.43	75.97
T_3	46.27	72.60	76.40
T_4	51.67	77.63	81.60
T_5	46.87	72.27	76.77
T_6	45.20	71.73	75.27
T_7	41.83	67.53	72.07
T_8	42.30	67.70	72.30
T_9	43.00	68.53	72.30
T_{10}	46.20	72.50	76.27
T_{11}	51.77	77.40	81.60
T_{12}	50.90	75.77	80.40
T_{13}	54.80	80.63	84.40
T_{14}	51.20	77.13	81.30
T_{15}	46.93	73.37	76.53
T_{16}	52.83	78.60	82.87
T_{17}	53.93	80.20	84.43
T_{18}	62.77	88.63	92.70
T_{19}	69.20	95.57	100.33
T_{20}	68.90	95.37	99.60
T_{21}	49.27	74.80	78.73
T_{22}	33.00	59.00	63.47
SED	**1.0356**	**1.1334**	**1.0928**
CD at 5%	**2.0904**	**2.2878**	**2.2058**

4.2.1.5 Inter nodal length (cm)

The inter nodal length differed significantly by different treatments (**Table.18**). Among the treatments, T_{19} (T_3 + 0.5 % EDTA micronutrient mixture + *B. megaterium* + *B. amyloliquefaciens* each @ 10 ml/m^2) recorded highest inter nodal length (6.25 cm) which followed by T_{20} (T_4 + 0.5 % EDTA micronutrient mixture + *B. megaterium* + *B. amyloliquefaciens* each @ 10 ml/m^2) by recording 6.21 cm. The lowest inter nodal length of 4.55 cm was recorded in control (T_{22}).

4.2.1.6 Total number of shoots per plant after pruning

Data pertaining to total number of shoots produced after pruning by different treatments under naturally ventilated polyhouse is presented in (**Table.18**). Significant variations were observed among the treatments with regard to the number of shoots produced. T_{20} (T_4 + 0.5 % EDTA micronutrient mixture + *B. megaterium* + *B. amyloliquefaciens* each @ 10 ml/m^2) registered maximum number of shoots (5.23) followed by T_{19} (T_3 + 0.5 % EDTA micronutrient mixture + *B. megaterium* + *B. amyloliquefaciens* each @ 10 ml/m^2) which recorded 5.20 shoots. (T_{22}) control produced lowest number of shoots (2.80).

4.2.2 Flowering parameters

4.2.2.1 Number of days taken for shoot emergence after pruning

The data in **Table 19** indicated that there was significant variation for days taken to shoot emergence on bent shoots. The treatment T_{19} (T_3 + 0.5 % EDTA micronutrient mixture + *B. megaterium* + *B. amyloliquefaciens* each @ 10 ml/m^2) taken minimum duration of 11.20 days for first shoot emergence followed by T_{20} (T_4 + 0.5 % EDTA micronutrient mixture + *B. megaterium* + *B. amyloliquefaciens* each @ 10 ml/m^2) by registering 11.23 days. Whereas, maximum days required for shoot emergence (13.26 days) was recorded in T_{22} (control).

4.2.2.2 Number of days taken for flower bud appearance after pruning

Observations on days taken for first flower bud appearance after pruning differed significantly by different treatments (**Table.19**). Among the treatments, T_{19} (T_3 + 0.5 % EDTA micronutrient mixture + *B. megaterium* + *B. amyloliquefaciens* each @ 10 ml/m^2)

Table 18. Effect of fertigation, micronutrients and *Bacillus spp* on various growth parameters

Treatments	Number of basal shoots /plant	Plant spread (cm^2)	Inter nodal length (cm)	Total number of shoots per plant after pruning
T_1	2.87	34.14	5.44	2.87
T_2	2.86	32.79	5.61	2.87
T_3	2.93	34.58	5.56	3.60
T_4	3.40	36.56	5.33	3.80
T_5	3.20	37.81	5.43	4.13
T_6	3.20	37.80	5.50	3.73
T_7	3.20	38.84	5.21	4.00
T_8	3.20	40.58	5.18	4.13
T_9	3.33	38.28	5.14	3.73
T_{10}	3.33	37.38	5.20	3.13
T_{11}	3.27	39.52	5.52	3.47
T_{12}	3.00	42.17	5.54	3.40
T_{13}	3.27	37.66	5.45	3.20
T_{14}	3.40	39.11	5.23	3.33
T_{15}	3.13	41.33	5.50	3.60
T_{16}	3.13	42.91	5.60	3.80
T_{17}	3.33	40.38	5.98	4.56
T_{18}	3.07	43.09	6.19	4.95
T_{19}	3.45	47.82	6.25	5.20
T_{20}	3.47	46.59	6.21	5.23
T_{21}	3.13	34.55	5.05	3.27
T_{22}	3.13	32.53	4.55	2.80
SED	**0.1559**	**0.3713**	**0.1217**	**0.2128**
CD at 5%	**0.3146**	**0.7495**	**0.2456**	**0.4296**

Table 19. Effect of fertigation, micronutrients and *Bacillus spp* on various flowering parameters

Treatments	Number of days taken for			
	Shoot emergence after pruning	**Flower bud appearance**	**Harvest from flower bud appearance**	**Harvest after pruning**
T_1	12.63	30.21	12.80	55.64
T_2	12.30	30.64	12.90	55.84
T_3	12.21	30.98	12.94	56.13
T_4	11.87	30.73	12.31	54.91
T_5	12.37	31.23	12.96	56.56
T_6	12.94	31.58	13.01	57.53
T_7	12.87	31.71	12.82	57.40
T_8	12.93	30.12	12.34	55.39
T_9	12.39	29.58	12.48	54.45
T_{10}	12.87	29.12	12.73	54.72
T_{11}	12.33	29.47	12.94	54.74
T_{12}	12.13	28.36	12.58	53.07
T_{13}	12.59	28.71	12.39	53.69
T_{14}	12.73	28.94	12.03	53.70
T_{15}	12.98	27.21	11.54	51.73
T_{16}	12.39	27.94	11.98	52.31
T_{17}	12.13	27.38	11.32	50.83
T_{18}	11.26	27.39	11.90	50.55
T_{19}	11.20	26.93	11.13	49.08
T_{20}	11.23	27.01	11.33	49.57
T_{21}	12.10	28.72	12.30	53.12
T_{22}	13.26	32.60	13.29	59.15
SED	**0.2206**	**0.2146**	**0.1631**	**0.2560**
CD at 5%	**0.4452**	**0.4331**	**0.3293**	**0.5167**

took minimum duration of 26.93 days for first flower bud appearance followed by T_{20} (T_4 + 0.5 % EDTA micronutrient mixture + *B. megaterium* + *B. amyloliquefaciens* each @ 10 ml/m^2) recorded 27.01 days.Whereas, maximum days taken for flower bud appearance (32.60 days) was recorded in (T_{22}) control.

4.2.2.3 Number of days taken for harvest from flower bud appearance

Significant differences were observed among the treatments for fertigation, micronutrients and *Bacillus spp* on days to harvest from flower bud appearance (**Table. 19**). The minimum duration of 11.13 days for harvesting of flowers from flower bud appearance was recorded in T_{19} (T_3 + 0.5 % EDTA micronutrient mixture + *B. megaterium* + *B. amyloliquefaciens* each @ 10 ml/m^2) which is followed by T_{17} (T_1 + 0.5 % EDTA + *B. megaterium* + *B. amyloliquefaciens* each @ 10 ml/m^2) recorded 11.32 days. T_{22} (control) taken maximum number of 13.29 days for harvesting of flowers from flower bud appearance.

4.2.2.4 Number of days taken for harvesting of flowering shoots after pruning

A minimum time of 49.08 days for harvesting of flowering shoot was recorded in T_{19} (T_3 + 0.5 % EDTA micronutrient mixture + *B. megaterium* + *B. amyloliquefaciens* each @ 10 ml/m^2) followed by T_{20} - (T_4 + 0.5 % EDTA micronutrient mixture + *B. megaterium* + *B. amyloliquefaciens* each @ 10 ml/m^2) required 49.57 days for harvest. (T_{22}) recorded the maximum days of 59.15 for harvesting of flowering shoot (**Table. 19**).

4.2.2.5 Number of compound leaves per flowering shoot

Significant differences were observed for number of compound leaves (**Table.20**). Among the treatments, T_{19} (T_3 + 0.5 % EDTA micronutrient mixture + *B. megaterium* + *B. amyloliquefaciens* each @ 10 ml/m^2) produced more number of compound leaves (16.67) which is followed by T_{20} - (T_4 + 0.5 % EDTA micronutrient mixture + *B. megaterium* + *B. amyloliquefaciens* each @ 10 ml/m^2) by recording (16.20). Treatment T_{22} (control) recorded lowest number of compound leaves (10.47).

4.2.2.6 Length of flowering shoot (cm)

Different fertigation levels are registered significant variation for shoot length of flower. A perusal of data given in **Table.20** showed that the maximum length of

Table 20. Effect of fertigation, micronutrients and *Bacillus spp* on various flowering parameters

Treatments	Number of compound leaves /flowering shoot	Length of flowering shoot (cm)	Length of flower bud (cm) at harvest
T_1	11.13	52.81	5.15
T_2	12.20	58.30	5.03
T_3	12.40	62.09	5.61
T_4	11.27	63.30	5.73
T_5	11.47	62.21	5.32
T_6	12.20	65.41	5.11
T_7	11.07	64.15	5.22
T_8	11.40	67.53	5.37
T_9	12.20	66.31	5.20
T_{10}	12.33	65.64	5.15
T_{11}	12.67	62.57	5.53
T_{12}	13.80	65.81	5.16
T_{13}	12.47	64.53	5.29
T_{14}	12.33	61.24	5.17
T_{15}	12.53	67.30	4.97
T_{16}	14.73	66.32	5.37
T_{17}	15.00	64.29	5.13
T_{18}	15.53	68.26	5.79
T_{19}	16.67	83.77	5.85
T_{20}	16.20	79.54	5.82
T_{21}	12.13	58.75	4.67
T_{22}	10.47	50.50	4.73
SED	**0.2007**	**0.9752**	**0.0811**
CD at 5%	**0.4051**	**1.9685**	**0.1636**

flowering shoot (83.77 cm) was produced by T_{19} (T_3 + 0.5 % EDTA micronutrient mixture + *B. megaterium* + *B. amyloliquefaciens* each @ 10 ml/m^2) followed by T_{20} (T_4 + 0.5 % EDTA micronutrient mixture + *B. megaterium* + *B. amyloliquefaciens* each @ 10 ml/m^2) which produced 79.54 cm. Shortest length of flowering shoot (50.50 cm) was recorded in T_{22} control (without fertilizers).

4.2.2.7 Length of flower bud at harvest (cm)

The length of flower bud at harvest differed significantly by different treatments (**Table.20**). Longest flower bud (5.85 cm) was recorded in T_{19} (T_3 + 0.5 % EDTA micronutrient mixture + *B. megaterium* + *B. amyloliquefaciens* each @ 10 ml/m^2) which is followed by T_{20} (T_4 + 0.5 % EDTA micronutrient mixture + *B. megaterium* + *B. amyloliquefaciens* each @ 10 ml/m^2) produced 5.82 cm. The shortest flower bud of 4.73cm was registered in control (T_{22}).

4.2.2.8 Pedicel length (cm)

Significant differences were observed among the levels of fertigation for pedicel length (**Table.21**). Treatment T_{20} (T_4 + 0.5 % EDTA micronutrient mixture + *B. megaterium* + *B. amyloliquefaciens* each @ 10 ml/m^2) recorded longest pedicel length (6.93 cm) which is followed by T_{19} (T_3 + 0.5 % EDTA micronutrient mixture + *B. megaterium* + *B. amyloliquefaciens* each @ 10 ml/m^2) recorded 6.91 cm. T_{22} (Control) recorded shortest pedicel length of 4.58 cm followed by T_2 (5.01 cm).

4.2.2.9 Circumference of flower bud at harvest (cm)

The circumference of flower bud is very important character for deciding the quality of flowers. Different treatment effects varied significantly from each other with respect to circumference of flower bud. The data presented in **Table.21** indicates that larger circumference of flower (12.81 cm) was observed in T_{19} (T_3 + 0.5 % EDTA micronutrient mixture + *B. megaterium* + *B. amyloliquefaciens* each @ 10 ml/m^2) followed by T_{20} (T_4 + 0.5 % EDTA micronutrient mixture + *B. megaterium* + *B. amyloliquefaciens* each @ 10 ml/m^2) by recording 12.52 cm. Which were statistically in par other. Whereas, least circumference of flower bud (10.58 cm) was observed in (T_{22} - control).

Table 21. Effect of fertigation, micronutrients and *Bacillus spp* on various flowering parameters

Treatments	Pedicel length (cm)	Circumference of flower bud (cm) at harvest	Stem girth (cm)	Weight of flowering shoot at harvest (g)
T_1	5.63	10.81	0.57	44.50
T_2	5.01	10.59	0.55	44.66
T_3	5.14	11.09	0.52	48.57
T_4	5.08	10.96	0.54	52.77
T_5	5.35	11.19	0.53	55.03
T_6	5.32	11.27	0.57	60.52
T_7	5.31	11.29	0.57	66.06
T_8	5.22	11.15	0.59	70.98
T_9	5.21	11.03	0.60	60.94
T_{10}	5.11	11.01	0.58	57.64
T_{11}	6.16	11.32	0.67	66.85
T_{12}	5.11	10.83	0.65	70.77
T_{13}	5.12	11.36	0.63	60.69
T_{14}	6.11	11.21	0.70	57.04
T_{15}	6.26	11.29	0.69	67.00
T_{16}	6.83	11.56	0.69	70.57
T_{17}	6.15	12.05	0.71	73.83
T_{18}	6.32	11.95	0.75	82.61
T_{19}	6.91	12.81	0.83	90.55
T_{20}	6.93	12.52	0.80	84.58
T_{21}	5.75	11.34	0.53	48.50
T_{22}	4.58	10.58	0.48	42.63
SED	**0.1520**	**0.2476**	**0.0154**	**0.6173**
CD at 5%	**0.3067**	**0.4997**	**0.0312**	**1.2462**

4.2.2.10 Stem girth (cm)

A perusal of data presented in **Table.21** revealed that the maximum girth of flower stem (0.83 cm) was observed in T_{19} (T_3 + 0.5 % EDTA micronutrient mixture + *B. megaterium* + *B. amyloliquefaciens* each @ 10 ml/m^2) followed by T_{20} - (T_4 + 0.5 % EDTA micronutrient mixture + *B. megaterium* + *B. amyloliquefaciens* each @ 10 ml/m^2) which recorded 0.80 cm. These treatments were statistically on par with each other for stem girth. Minimum stem girth of 0.48 cm was observed in (T_{22} - control).

4.2.2.11 Weight of flowering shoot at harvest (g)

Significant differences were observed among the levels of fertigation for flowering shoot weight (**Table.21**). Among the treatments, T_{19} (T_3 + 0.5 % EDTA micronutrient mixture + *B. megaterium* + *B. amyloliquefaciens* each @ 10 ml/m^2) recorded the highest flowering stem weight of 90.55 g followed by T_{20} (T_4 + 0.5 % EDTA micronutrient mixture + *B. megaterium* + *B. amyloliquefaciens* each @ 10 ml/m^2) recorded the highest flowering shoot weight 84.58 g. T_{22} (control) recorded the lowest flowering shoot weight of 42.63 g.

4.2.2.12 Number of quality grade flowers / m^2

Treatment T_{19} (T_3 + 0.5 % EDTA micronutrient mixture + *B. megaterium* + *B. amyloliquefaciens* each @ 10 ml/m^2) produced maximum number of "A" grade flowers (218.47) followed by T_{20} (T_4 + 0.5 % EDTA micronutrient mixture + *B. megaterium* + *B. amyloliquefaciens* each @ 10 ml/m^2 produced 205.83 flowers. Minimum number of "A" grade flowers was produced by T_2 (10.37). T_{14} (T_2 + 0.5 % EDTA micronutrient mixture + *B. megaterium* + *B. amyloliquefaciens* each @ 5 ml/m^2) produced by maximum number of "B" grade flowers (171.49) followed by T_5 which recorded 161.05 flowers and T_{22} produced minimum number of "B" grade flowers (32.62). Maximum number of "C" grade flowers (105.10) was observed in T_1 (**Table.22**).

4.2.2.13 Cut flower stems / plant /year

It is apparent from the data presented in **Table.23** shows that treatments had significant variation regarding the mean of cut flower stems per plant per year. The perusal of data indicates that the maximum number of cut stems 27.07 was recorded in

Table 22. Effect of fertigation, micronutrients and *Bacillus spp* on various flower grades

Treatments	Grade flowers / m^2/year			
	A	**B**	**C**	**Total**
T_1	13.26	64.40	105.10	182.76
T_2	10.37	79.81	101.93	192.12
T_3	23.04	104.51	66.03	193.56
T_4	24.85	129.62	62.36	216.84
T_5	46.45	161.05	47.75	255.24
T_6	91.60	129.57	22.09	243.24
T_7	163.45	91.11	11.84	266.40
T_8	157.00	88.64	15.12	260.76
T_9	86.59	149.66	11.79	248.04
T_{10}	76.67	148.95	19.17	244.80
T_{11}	163.48	92.71	12.62	268.80
T_{12}	165.83	99.02	3.11	267.96
T_{13}	89.63	151.22	5.51	246.36
T_{14}	61.51	171.49	24.62	257.64
T_{15}	137.49	116.17	11.19	264.84
T_{16}	149.66	127.96	3.19	280.80
T_{17}	152.08	114.40	3.88	270.36
T_{18}	181.09	111.54	11.22	303.84
T_{19}	218.47	101.53	4.84	324.84
T_{20}	205.83	105.23	8.97	320.04
T_{21}	44.30	146.12	51.02	241.44
T_{22}	0.00	32.62	95.06	127.68
SED	**4.9837**	**6.5626**	**5.2735**	**3.1184**
CD at 5%	**10.0599**	**13.2469**	**10.6447**	**6.2946**

T_{19} (T_3 + 0.5 % EDTA micronutrient mixture + *B. megaterium* + *B. amyloliquefaciens* each @ 10 ml/m^2) followed by T_{20} (T_4 + 0.5 % EDTA micronutrient mixture + *B. megaterium* + *B. amyloliquefaciens* each @ 10 ml/m^2) which produced 26.67 flowers. Whereas, minimum number of cut flower stems per plant (10.64) were counted in T_{22} (Control) followed by T_1 produced 15.23cut stems.

4.2.2.14 Cut flowers stem / m^2 /year

Data on the mean yield of flowers /m^2 on the levels of fertigation treatments are significantly varied (**Table.23**). Among the different treatments, highest yield /m^2 (324.84) was recorded in the treatment T_{19} (T_3 + 0.5 % EDTA micronutrient mixture + *B. megaterium* + *B. amyloliquefaciens* each @ 10 ml/m^2) followed by T_{20} (T_4 + 0.5 % EDTA micronutrient mixture + *B. megaterium* + *B. amyloliquefaciens* each @ 10 ml/m^2) produced 320.04 flowers/m^2. The treatment (T_{22}) recorded lowest yield /m^2 (127.68) followed by T_1 which produced 182.76 of flowers / m^2.

4.2.2.15 Vase life (days)

Significant differences were observed among the interactions for vase life of cut rose var. Tajmahal (**Table.23**). Maximum vase life (11.50 days) was recorded in T_{19} (T_3 + 0.5 % EDTA micronutrient mixture + *B. megaterium* + *B. amyloliquefaciens* each @ 10 ml/m^2) followed by T_{10}, T_{13}, T_{18} and T_{20} recorded (11.27 days) for vase life. Minimum number of 6.23 days was recorded in T_4 for vase life.

4.2.3 Physiological attributes

4.2.3.1 Chlorophyll 'a' content (mg g^{-1})

The effect on different levels of fertgation on chlorophyll 'a' content at flowering stage of plant growth recorded significant differences. **Table.24** shows that maximum chlorophyll 'a' content of 1.36 mg g^{-1} was recorded in the treatment T_{19} (T_3 + 0.5 % EDTA micronutrient mixture + *B. megaterium* + *B. amyloliquefaciens* each @ 10 ml/m^2) which is followed by T_{20} (T_4 + 0.5 % EDTA micronutrient mixture + *B. megaterium* + *B. amyloliquefaciens* each @ 10 ml/m^2) by recording 1.32 mg g^{-1}. T_{22} recorded the lowest content (0.63 mg g^{-1}) followed by T_1 (0.75 mg g^{-1}).

Table 23. Effect of fertigation, micronutrients and *Bacillus spp* on various cut flower yield and vase life parameters

Treatments	Flowers /		Vase life (days)
	plant / year	m^2 / year	
T_1	15.23	182.76	8.28
T_2	16.01	192.12	7.37
T_3	16.13	193.56	8.33
T_4	18.07	216.84	6.23
T_5	21.27	255.24	9.23
T_6	20.27	243.24	8.27
T_7	22.20	266.40	9.20
T_8	21.73	260.76	7.33
T_9	20.67	248.04	10.33
T_{10}	20.40	244.80	11.27
T_{11}	22.40	268.80	10.33
T_{12}	22.33	267.96	9.30
T_{13}	20.53	246.36	11.27
T_{14}	21.47	257.64	10.37
T_{15}	22.07	264.84	9.30
T_{16}	23.40	280.80	9.20
T_{17}	22.53	270.36	10.23
T_{18}	25.32	303.84	11.27
T_{19}	27.07	324.84	11.50
T_{20}	26.67	320.04	11.27
T_{21}	20.12	241.44	10.43
T_{22}	10.64	127.68	8.37
SED	**0.2599**	**3.1184**	**0.1619**
CD at 5%	**0.5246**	**6.2946**	**0.3268**

Table 24. Effect of fertigation, micronutrients and *Bacillus spp* on various chlorophyll parameters

Treatments	Chlorophyll 'a' (mg/g)	Chlorophyll 'b' (mg/g)	Total chlorophyll (mg/g)
T_1	0.75	0.24	1.13
T_2	0.87	0.29	1.21
T_3	0.81	0.22	1.17
T_4	0.85	0.25	1.23
T_5	0.83	0.25	1.32
T_6	0.92	0.31	1.50
T_7	0.95	0.28	1.53
T_8	1.04	0.31	1.63
T_9	0.82	0.27	1.54
T_{10}	0.95	0.26	1.65
T_{11}	1.06	0.31	1.69
T_{12}	1.23	0.35	1.73
T_{13}	1.16	0.34	1.71
T_{14}	1.17	0.31	1.75
T_{15}	1.18	0.33	1.87
T_{16}	1.28	0.32	1.91
T_{17}	1.22	0.33	2.07
T_{18}	1.27	0.34	2.73
T_{19}	1.36	0.39	2.99
T_{20}	1.32	0.37	2.87
T_{21}	1.02	0.34	1.79
T_{22}	0.63	0.16	1.10
SED	**0.0080**	**0.0020**	**0.0206**
CD at 5%	**0.0162**	**0.0041**	**0.0415**

4.2.3.2 Chlorophyll 'b'content (mg g^{-1})

The mean data regarding chlorophyll 'b' content recorded significant differences by the treatments (**Table.24**). T_{19} (T_3 + 0.5 % EDTA micronutrient mixture + *B. megaterium* + *B. amyloliquefaciens* each @ 10 ml/m^2) recorded the highest chlorophyll 'b' content (0.39 mg g^{-1}) followed by T_{20} (T_4 + 0.5 % EDTA micronutrient mixture + *B. megaterium* + *B. amyloliquefaciens* each @ 10 ml/m^2) which recorded 0.37 mg g^{-1}. The lowest chlorophyll 'b' content of 0.16 mg g^{-1} was recorded in T_{22} (Control).

4.2.3.3 Total chlorophyll contents (mg g^{-1})

Among the treatments, highest total chlorophyll content (2.99 mg g^{-1}) was recorded at flowering stage in T_{19} (T_3 + 0.5 % EDTA micronutrient mixture + *B. megaterium* + *B. amyloliquefaciens* each @ 10 ml/m^2) and it was followed by T_{20} (T_4 + 0.5 % EDTA micronutrient mixture + *B. megaterium* + *B. amyloliquefaciens* each @ 10 ml/m^2) which recorded 2.87 mg g^{-1}. T_{22} (control) recorded the lowest total chlorophyll content 1.10 mgg^{-1} which is followed by T_1 (1.13 mg g^{-1}) at flowering stage (**Table.24**).

4.2.3.4 IAA oxidase (µg of unoxidised auxin g^{-1} h^{-1})

During the flowering stage different levels of fertigations are influenced significant differences (**Table.25**). Maximum IAA oxidase activity of 26.53 µg of unoxidised auxin g^{-1} h^{-1} was recorded in the treatment T_{19} (T_3 + 0.5 % EDTA micronutrient mixture + *B. megaterium* + *B. amyloliquefaciens* each @ 10 ml/m^2) and it was followed by T_{20} (T_4 + 0.5 % EDTA micronutrient mixture + *B. megaterium* + *B. amyloliquefaciens* each @ 10 ml/m^2) which recorded 25.93 µg of unoxidised auxin g^{-1} $h^{-1}$and lowest IAA oxidase activity (13.66 µg of unoxidised auxin g^{-1} h^{-1}) was recorded in the control (T_{22}).

4.2.3.5 Soluble protein (mg g^{-1})

Soluble protein content of cut rose leaves are significantly influenced by different treatments at the flowering stage (**Table.25**). Among the treatments, T_{19} (T_3 + 0.5 % EDTA micronutrient mixture + *B. megaterium* + *B. amyloliquefaciens* each @ 10 ml/m^2) recorded the highest soluble protein content (39.08 mg g^{-1}) which is followed by T_{18} (T_2 + 0.5 % EDTA micronutrient mixture + *B. megaterium* + *B. amyloliquefaciens* each

Table 25. Effect of fertigation, micronutrients and *Bacillus spp* on various physiological parameters

Treatments	IAA Oxidase (µg/g/hr)	Soluble protein (mg/g)	Nitrate Reductase (µg of NO_2 g^{-1} h^{-1})
T_1	16.83	23.63	1.99
T_2	17.16	22.95	1.71
T_3	16.60	24.27	2.12
T_4	16.49	23.34	1.74
T_5	22.38	30.85	1.74
T_6	21.44	32.02	1.92
T_7	22.24	34.00	1.83
T_8	21.63	34.64	1.90
T_9	22.01	32.09	1.92
T_{10}	22.52	31.82	1.72
T_{11}	21.87	30.73	2.09
T_{12}	22.14	28.42	2.00
T_{13}	21.97	29.32	2.09
T_{14}	23.12	33.17	2.10
T_{15}	22.22	34.08	2.14
T_{16}	21.98	36.02	2.19
T_{17}	24.23	34.18	2.32
T_{18}	25.23	38.55	2.14
T_{19}	26.53	39.08	2.04
T_{20}	25.93	35.12	1.83
T_{21}	16.03	25.31	2.00
T_{22}	13.66	21.24	1.35
SED	**0.1333**	**0.2014**	**0.0083**
CD at 5%	**0.2691**	**0.4065**	**0.0167**

@ 10 ml/m^2) by recording 38.55 mg g^{-1}. T_{22} recorded the lowest soluble protein content (21.24 mg g^{-1}) at flowering stage.

4.2.3.6 Nitrate reductase activity (µ moles NO_2 g^{-1} h^{-1})

Significant differences were observed among treatments at flowering stage (**Table.25**). Among the treatments, T_{17} (T_1 + 0.5 % EDTA micronutrient mixture + *B. megaterium* + *B. amyloliquefaciens* each @ 10 ml/m^2) recorded the maximum nitrate reductase activity (2.32 µmoles NO_2 g^{-1} h^{-1}) followed by T_{16} recorded 2.19 µ moles NO_2 g^{-1} h^{-1}. The lowest nitrate reductase activity of 1.35 µ moles NO_2 g^{-1} h^{-1} was recorded in T_{22} at flowering stage.

4.2.3.7 Total phenolics (µg g^{-1})

The mean data regarding total phenolics content influenced significant differences by treatments (**Table.26**). Among the treatments, maximum phenol content (365.51 µg g^{-1}) was recorded in the treatment T_{17} (T_1 + 0.5 % EDTA micronutrient mixture + *B. megaterium* + *B. amyloliquefaciens* each @ 10 ml/m^2) followed by T_{20} which recorded 354.96 µg g^{-1} and lowest phenols content of 201.40 µg g^{-1} was recorded in the control (T_{22}).

4.2.3.8 Peroxidase activity (OD at 430nm $min^{-1}g^{-1}$)

The effect of fertigation at different levels on peroxidase activity at flowering stage of plant growth recorded significant differences. **Table.26** shows that maximum peroxidase activity (1.53 abs min^{-1} g^{-1}) was recorded in the T_{18} (T_2 + 0.5 % EDTA micronutrient mixture + *B. megaterium* + *B. amyloliquefaciens* each @ 10 ml/m^2) which is followed by T_{19} (T_3 + 0.5 % EDTA micronutrient mixture + *B. megaterium* + *B. amyloliquefaciens* each @ 10 ml/m^2) recorded (1.50 abs min^{-1} g^{-1}). Minimum peroxidase activity of 0.64 abs min^{-1} g^{-1} was recorded in control (T_{22}).

4.2.3.9 Anthocyanin content

The intensity of anthocyanin content in cut rose petals are significantly influenced by different fertigation treatments (**Table.26**). Among the treatments, T_{18} (T_2 + 0.5 % EDTA micronutrient mixture + *B. megaterium* + *B. amyloliquefaciens* each @ 10 ml/m^2)

Table 26. Effect of fertigation, micronutrients and *Bacillus spp* on various physiological parameters

Treatments	Total phenolics (µg/g)	Peroxidase (OD at 430nm /min/g)	Anthocyanin content
T_1	215.80	0.66	0.53
T_2	212.95	0.84	0.47
T_3	219.39	0.82	0.44
T_4	226.40	0.79	0.47
T_5	346.40	0.98	0.59
T_6	308.34	1.04	0.60
T_7	296.94	1.01	0.64
T_8	266.95	1.00	0.76
T_9	283.36	1.04	0.65
T_{10}	295.81	1.04	0.63
T_{11}	315.88	1.22	0.78
T_{12}	354.96	1.29	0.89
T_{13}	322.90	1.29	0.72
T_{14}	286.37	1.27	0.74
T_{15}	346.49	1.26	0.82
T_{16}	332.41	1.34	0.87
T_{17}	365.51	1.35	0.83
T_{18}	331.89	1.53	0.98
T_{19}	348.80	1.50	0.91
T_{20}	354.96	1.43	0.94
T_{21}	324.76	0.73	0.79
T_{22}	201.40	0.64	0.41
SED	**2.0342**	**0.0105**	**0.0023**
CD at 5%	**4.1062**	**0.0213**	**0.0047**

recorded the maximum anthocyanin content (0.98) followed by T_{20} which recorded 0.94. T_{22} recorded the lowest anthocyanin content (0.41).

4.2.4. Effect of fertigation, micronutrients and *Bacillus spp* on available soil nutrients at different growth stages

4.2.4.1 Available Nitrogen (kg ha^{-1})

The available soil nitrogen at different stages of the crop growth exhibited significant differences among the fertigation levels (**Table.27**). Among the fertigation levels, the minimum amount of available soil nitrogen was recorded in T_{19} (T_3 + 0.5 % EDTA micronutrient mixture + *B. megaterium* + *B. amyloliquefaciens* each @ 10 ml/m^2) at vegetative (207.38 kg ha^{-1}), bud appearance stage (193.04 kg ha^{-1}) and flowering stage (172.63 kg ha^{-1}). The lowest available soil nitrogen was recorded in control (T_{22}) at all the stages of the crop growth.

4.2.4.2 Available Phosphorus (kg ha^{-1})

The available phosphorus followed the trend of steady increase up to bud appearance stage and decreased slightly during flowering stage of crop growth in cut rose (**Table.28**). Among the different levels of fertigation, T_{19} (T_3 + 0.5 % EDTA micronutrient mixture + *B. megaterium* + *B. amyloliquefaciens* each @ 10 ml/m^2) recorded the minimum quantity available soil phosphorus at vegetative stage (17.34 kg ha^{-1}), bud appearance (15.54 kg ha^{-1}) and flowering stage (14.93 kg ha^{-1}) and this is followed by T_{18} (T_2 + 0.5 % EDTA micronutrient mixture + *B. megaterium* + *B. amyloliquefaciens* each @ 10 ml/m^2) recorded the minimum quantity available soil phosphorus at vegetative stage (17.46 kg ha^{-1}), T_{17} at bud appearance (15.92 kg ha^{-1}) andT_{17} flowering stage (15.93 kg ha^{-1}). The available soil phosphorus was recorded in control (T_{22}) at vegetative stage (23.59 kg ha^{-1}), bud appearance (19.06 kg ha^{-1}) and flowering stage (17.45 kg ha^{-1}) of the crop growth.

4.2.4.3 Available Potassium (kg ha^{-1})

Significant differences were observed among the fertigation levels for available potassium in cut rose (**Table.29**). Among the treatment levels, T_{19} (T_3 + 0.5 % EDTA micronutrient mixture + *B. megaterium* + *B. amyloliquefaciens* each @ 10 ml/m^2)

Table 27. Effect of fertigation on available soil nitrogen (kg ha^{-1}) at different stages

Treatments	Available soil nitrogen (kg ha^{-1}) at different stages		
	Vegetative stage	**Bud appearance stage**	**Flowering stage**
T_1	220.55	214.06	202.25
T_2	228.59	215.56	204.95
T_3	231.23	213.40	201.56
T_4	232.55	220.23	205.86
T_5	229.92	216.11	210.65
T_6	221.12	212.13	209.60
T_7	220.16	213.72	215.53
T_8	223.36	216.52	210.64
T_9	227.18	219.89	215.74
T_{10}	239.85	228.61	216.94
T_{11}	246.86	234.61	211.57
T_{12}	243.95	230.30	218.36
T_{13}	240.21	221.66	209.04
T_{14}	239.06	218.62	196.44
T_{15}	237.38	217.82	207.78
T_{16}	242.22	212.69	201.16
T_{17}	238.75	211.97	197.63
T_{18}	234.83	206.06	181.36
T_{19}	207.38	193.04	172.63
T_{20}	227.94	202.12	177.08
T_{21}	210.35	194.66	173.49
T_{22}	182.13	154.00	135.13
SED	**8.9233**	**7.7357**	**6.3476**
CD at 5%	**18.0121**	**15.6150**	**12.8129**

Table 28. Effect of fertigation on available soil phosphorus (kg ha^{-1}) at different stages

Treatments	Available soil phosphorus (kg ha^{-1}) at different stages		
	Vegetative stage	**Bud appearance stage**	**Flowering stage**
T_1	25.73	23.41	22.24
T_2	23.50	21.39	21.81
T_3	24.01	21.85	20.76
T_4	24.23	22.05	20.95
T_5	21.01	19.12	18.16
T_6	20.37	18.54	17.61
T_7	19.97	18.17	17.52
T_8	21.18	19.27	17.61
T_9	24.22	22.04	21.69
T_{10}	22.51	20.49	19.47
T_{11}	24.31	21.37	20.70
T_{12}	26.21	22.82	21.08
T_{13}	21.53	19.60	18.08
T_{14}	18.96	17.25	16.12
T_{15}	18.23	17.18	16.55
T_{16}	18.06	17.77	17.12
T_{17}	17.50	15.92	15.93
T_{18}	17.46	16.35	16. 06
T_{19}	17.34	15.54	14.93
T_{20}	17.69	16.10	16.34
T_{21}	30.02	27.32	27.86
T_{22}	23.59	19.06	17.45
SED	**0.7455**	**0.7981**	**0.1875**
CD at 5%	**1.5048**	**1.6109**	**0.3784**

Table 29. Effect of fertigation on available soil potassium (kg ha^{-1}) at different stages

Treatments	Available soil potassium (kg ha^{-1}) at different stages		
	Vegetative stage	Bud appearance stage	Flowering stage
T_1	193.64	182.03	171.10
T_2	198.66	186.74	175.54
T_3	206.69	194.29	182.63
T_4	218.73	205.60	193.27
T_5	221.74	208.43	195.93
T_6	236.79	222.58	209.23
T_7	239.80	225.41	211.88
T_8	243.81	229.18	215.43
T_9	235.78	221.64	208.34
T_{10}	246.82	232.01	218.09
T_{11}	264.88	248.99	234.05
T_{12}	268.89	252.76	237.59
T_{13}	259.86	244.27	229.62
T_{14}	264.88	248.99	234.05
T_{15}	295.98	278.22	261.53
T_{16}	289.96	272.57	256.21
T_{17}	292.17	274.64	258.16
T_{18}	287.96	270.68	254.44
T_{19}	302.00	283.88	266.85
T_{20}	291.97	274.45	257.99
T_{21}	293.18	282.20	277.49
T_{22}	173.58	163.16	153.37
SED	**3.2053**	**1.4135**	**1.3290**
CD at 5%	**6.4701**	**2.8533**	**2.6827**

recorded the highest available potassium content at the different stages *viz.*, vegetative (302.00 kg ha^{-1}), bud appearance (283.88 kg ha^{-1}) and except flowering stage (T_{21}- 277.49 kg ha^{-1}). The lowest available soil potassium content at vegetative (173.58 kg ha^{-1}), bud appearance (163.16 kg ha^{-1}) and flowering stage (153.37 kg ha^{-1}) was recorded in T_{22} (control).

4.2.5 Effect of fertigation on leaf nutrient content at different growth stages

4.2.5.1 Nitrogen content (%)

Nitrogen content at bud appearance and flowering stage showed significant difference among the fertigation levels (**Table. 30**). The highest nitrogen content was recorded in T_{19} (T_3 + 0.5 % EDTA micronutrient mixture + *B. megaterium* + *B. amyloliquefaciens* each @ 10 ml/m^2) recorded the highest available nitrogen content at the different stages *viz.*, bud appearance (2.69 %) and flowering stage (3.15 %). Which T_{22} (control) recorded the lowest nitrogen content at bud appearance 0.64 % and flowering 1.05 %.

4.2.5.2 Phosphorus content (%)

The phosphorus content in the plant during the bud appearance and peak flowering stages exhibited significant differences among the treatments (**Table.31**). The highest 'P' content of 0.36 % at bud appearance and flowering stage 0.34 % was recorded in treatment T_{19} respectively. Similarly the lowest phosphorus content of (0.19 and 0.17 %) was recorded by the treatment T_{22} (control) at bud appearance and flowering stage respectively.

4.2.5.3 Potassium content (%)

Significant differences were observed among the fertigation levels for potassium content (**Table.32**) for cut rose. T_{19} (T_3 + 0.5 % EDTA micronutrient mixture + *B. megaterium* + *B. amyloliquefaciens* each @ 10 ml/m^2) recorded the highest available potassium content at the different stages *viz.*, bud appearance (2.62 %) and flowering stage (3.36 %) followed by T_{20} and lowest potassium content was recorded in T_{22} (control) at all the stages.

Table 30. Effect of fertigation on leaf nitrogen content (%) at different stages

Treatments	Nitrogen content (%) at different stages	
	Bud appearance stage	**Flowering stage**
T_1	1.43	1.66
T_2	1.49	1.72
T_3	1.55	1.78
T_4	1.60	1.84
T_5	1.87	2.04
T_6	1.75	2.19
T_7	1.81	2.16
T_8	1.98	2.30
T_9	1.84	2.28
T_{10}	1.93	2.39
T_{11}	2.04	2.51
T_{12}	2.10	2.74
T_{13}	1.98	2.45
T_{14}	1.93	2.28
T_{15}	2.04	2.57
T_{16}	2.39	2.68
T_{17}	2.63	2.92
T_{18}	2.45	2.98
T_{19}	2.69	3.15
T_{20}	2.54	3.09
T_{21}	1.08	1.98
T_{22}	0.64	1.05
SED	**0.2030**	**0.2299**
CD at 5%	**0.4097**	**0.4640**

Table 31. Effect of fertigation on leaf phosphorus content (%) at different stages

Treatments	Phosphorus content (%) at different stages	
	Bud appearance stage	**Flowering stage**
T_1	0.20	0.21
T_2	0.23	0.22
T_3	0.25	0.23
T_4	0.26	0.29
T_5	0.29	0.27
T_6	0.30	0.27
T_7	0.31	0.29
T_8	0.32	0.30
T_9	0.28	0.27
T_{10}	0.28	0.26
T_{11}	0.28	0.25
T_{12}	0.29	0.26
T_{13}	0.30	0.28
T_{14}	0.31	0.30
T_{15}	0.33	0.29
T_{16}	0.30	0.28
T_{17}	0.31	0.27
T_{18}	0.34	0.33
T_{19}	0.36	0.34
T_{20}	0.36	0.32
T_{21}	0.23	0.20
T_{22}	0.19	0.17
SED	**0.0407**	**0.0287**
CD at 5%	**0.0822**	**0.0579**

Table 32. Effect of fertigation on leaf potassium content (%) at different stages

Treatments	Potassium content (%) at different stages	
	Bud appearance stage	**Flowering stage**
T_1	0.91	1.15
T_2	0.82	1.15
T_3	0.98	1.14
T_4	0.99	1.17
T_5	1.34	1.61
T_6	1.43	2.02
T_7	1.33	2.07
T_8	1.51	2.05
T_9	2.06	2.38
T_{10}	2.10	2.24
T_{11}	1.92	2.21
T_{12}	1.98	2.19
T_{13}	2.08	2.31
T_{14}	1.96	2.27
T_{15}	1.85	2.12
T_{16}	2.04	2.37
T_{17}	2.10	2.43
T_{18}	2.15	2.60
T_{19}	2.62	3.36
T_{20}	2.56	3.13
T_{21}	1.03	1.27
T_{22}	0.64	1.09
SED	**0.0668**	**0.1365**
CD at 5%	**0.1349**	**0.2756**

4.2.6 Effect of fertigation on leaf micronutrient uptake at different growth stages

4.2.6.1 Copper content (mg plant^{-1})

Fertigation exerted a significant effect on copper uptake of the plant during the different stages (**Table.33**). Comparison of the performance of treatments expressed that the treatment T_{19} (T_3 + 0.5 % EDTA micronutrient mixture + *B. megaterium* + *B. amyloliquefaciens* each @ 10 ml/m^2) recorded higher values for copper during bud appearance (30.17 mg plant^{-1}) and T_{20} recorded during flowering stage (33.18 mg plant^{-1}) and the lowest uptake value during bud appearance (5.83 mg plant^{-1}) and flowering stage (3.15 mg plant^{-1}) was found in T_{22}.

4.2.6.2 Iron content (mg plant^{-1})

Fertigation exerted a significant effect on iron uptake of the plant during the different stages (**Table.34**). Comparison of the performance of treatments revealed that the treatment T_{19} (T_3 + 0.5 % EDTA micronutrient mixture + *B. megaterium* + *B. amyloliquefaciens* each @ 10 ml/m^2) recorded higher values for iron uptake during bud appearance (149.23 mg plant^{-1}) and flowering stage (167.01 mg plant^{-1}) and the lowest uptake value during bud appearance (35.44 mg plant^{-1}) and flowering stage (40.85 mg plant^{-1}) was found in T_{22}.

4.2.6.3 Zinc content (mg plant^{-1})

Foliar application of EDTA micronutrient mixture shows significant effect on zinc uptake of the plant during the different stages (**Table.35**). Comparison of the performance of treatments indicated that the treatment T_{19} (T_3 + 0.5 % EDTA micronutrient mixture + *B. megaterium* + *B. amyloliquefaciens* each @ 10 ml/m^2) recorded higher values for zinc uptake during bud appearance (121.12 mg plant^{-1}) and flowering stage (147.66 mg plant^{-1}) and the lowest uptake value during bud appearance (11.03 mg plant^{-1}) and flowering stage (14.18 mg plant^{-1}) was found in T_{22}.

4.2.6.4 Manganese content (mg plant^{-1})

Foliar application of EDTA micronutrient mixture shows significant effect on manganese uptake of the plant during the different stages (**Table.36**). Comparison of the performance of treatments revealed that the treatment T_{19} (T_3 + 0.5 % EDTA micronutrient

Table 33. Effect of fertigation on leaf micronutrient copper uptake of Dutch rose at different stages

Treatments	Copper uptake (mg plant^{-1}) at different stages	
	Bud appearance stage	**Flowering stage**
T_1	6.83	5.34
T_2	6.30	4.63
T_3	6.96	4.41
T_4	6.34	4.10
T_5	15.86	20.76
T_6	18.44	18.95
T_7	18.83	20.75
T_8	19.47	22.05
T_9	16.94	19.43
T_{10}	17.61	19.00
T_{11}	18.04	19.29
T_{12}	20.69	22.79
T_{13}	21.27	24.34
T_{14}	24.83	26.93
T_{15}	26.18	23.81
T_{16}	25.95	30.80
T_{17}	26.78	28.35
T_{18}	27.31	28.56
T_{19}	30.17	32.63
T_{20}	29.30	33.18
T_{21}	8.68	5.34
T_{22}	5.83	3.15
SED	**2.5259**	**2.3361**
CD at 5%	**5.0987**	**4.7155**

Table 34. Effect of fertigation on leaf micronutrient iron uptake of Dutch rose at different stages

Treatments	Iron uptake (mg plant^{-1}) at different stages	
	Bud appearance stage	**Flowering stage**
T_1	40.49	54.44
T_2	45.89	56.73
T_3	52.53	58.60
T_4	56.28	63.85
T_5	87.74	94.08
T_6	91.87	105.89
T_7	89.84	101.12
T_8	99.62	114.83
T_9	117.12	138.49
T_{10}	125.90	155.35
T_{11}	126.79	146.14
T_{12}	130.33	150.23
T_{13}	133.76	151.43
T_{14}	132.48	148.87
T_{15}	135.19	149.95
T_{16}	134.66	155.22
T_{17}	138.21	159.31
T_{18}	141.36	158.36
T_{19}	149.23	167.01
T_{20}	145.52	164.60
T_{21}	44.98	51.59
T_{22}	35.44	40.85
SED	**7.9156**	**6.7885**
CD at 5%	**15.9781**	**13.7030**

Table 35. Effect of fertigation on leaf micronutrient zinc uptake of Dutch rose at different stages

Treatments	Zinc uptake (mg plant^{-1}) at different stages	
	Bud appearance stage	**Flowering stage**
T_1	16.28	22.94
T_2	17.91	25.86
T_3	20.83	26.50
T_4	25.52	30.36
T_5	28.77	35.93
T_6	51.94	52.06
T_7	42.53	65.86
T_8	50.61	76.69
T_9	65.94	85.53
T_{10}	73.04	90.21
T_{11}	74.73	97.65
T_{12}	87.31	100.23
T_{13}	91.68	99.45
T_{14}	90.47	99.80
T_{15}	93.23	104.48
T_{16}	95.97	103.65
T_{17}	98.18	119.18
T_{18}	100.22	111.30
T_{19}	121.12	147.66
T_{20}	118.81	138.89
T_{21}	45.93	69.93
T_{22}	11.03	14.18
SED	**8.8938**	**10.3466**
CD at 5%	**17.9526**	**20.8852**

Table 36. Effect of fertigation on leaf micronutrient manganese uptake at different stages

Treatments	Manganese uptake (mg plant^{-1}) at different stages	
	Bud appearance stage	**Flowering stage**
T_1	25.20	31.50
T_2	26.93	38.67
T_3	29.70	39.07
T_4	32.42	42.36
T_5	38.47	49.01
T_6	35.34	53.99
T_7	51.31	67.88
T_8	53.28	68.73
T_9	58.03	72.95
T_{10}	59.62	73.07
T_{11}	61.29	77.06
T_{12}	65.94	82.43
T_{13}	68.63	80.79
T_{14}	67.25	87.40
T_{15}	69.72	88.82
T_{16}	72.09	85.55
T_{17}	73.41	87.18
T_{18}	78.05	90.48
T_{19}	82.27	94.50
T_{20}	81.36	92.32
T_{21}	28.09	30.11
T_{22}	17.64	22.05
SED	**7.3918**	**7.9647**
CD at 5%	**14.9208**	**16.0772**

mixture + *B. megaterium* + *B. amyloliquefaciens* each @ 10 ml/m^2) recorded higher values for manganese uptake during bud appearance (82.27 mg $plant^{-1}$) and flowering stage (94.50 mg $plant^{-1}$) and the lowest uptake value during bud appearance (17.64 mg $plant^{-1}$) and flowering stage (22.05 mg $plant^{-1}$) was found in T_{22} (control).

4.2.7 Effect of fertigation on soil enzyme content at different growth stages

4.2.7.1 Dehydrogenase activity (Δ in OD at 480 nm)

The data on dehydrogenase activity with influence of systems of fertilization for cut rose are presented in the **Table.37** exhibited significant differences.

In the fertigation levels, maximum dehydrogenase activity (0.096, 0.098, 0.099 Δ in OD at 485nm) was recorded in the treatment T_{19} (T_3 + 0.5 % EDTA micronutrient mixture + *B. megaterium* + *B. amyloliquefaciens* each @ 10 ml/m^2) which is followed by T_{20} (T_4 + 0.5 % EDTA micronutrient mixture + *B. megaterium* + *B. amyloliquefaciens* each @ 10 ml/m^2) by recorded (0.095, 0.096 and 0.098 Δ in OD at 485nm) at the different stages *viz.*, vegetative, bud appearance and flowering stage respectively. The least dehydrogenase activity was recorded in control T_{22} (0.038, 0.041 and 0.043 Δ in OD at 485nm) respectively.

4.2.7.2 Acid Phosphatase activity (µ moles PNP released g^{-1} min^{-1})

The data pertaining to the acid phosphatase activity in soil at the different stages of the crop growth exhibited significant influence (**Table.38**).

Among the fertigation levels, maximum acid phosphatase activity (0.194 and 0.195 µ moles PNP released g^{-1} min^{-1}) was recorded in the treatment T_{13} (T_1 + 0.5 % EDTA-MN + *B. megaterium* + *B. amyloliquefaciens* each @ 5 ml/m^2) at vegetative and bud appearance stage, T_6 was recorded (0.199 µ moles PNP released g^{-1} min^{-1} at flowering stage. The least dehydrogenase activity was recorded in T_{22} control (0.093, 0.097 and 0.098 µ moles PNP released g^{-1} min^{-1}) respectively.

4.2.7.3 Urease activity (µg NH_4-N released g^{-1} h^{-1})

Significant differences were observed among the fertigation levels for soil urease activity in cut rose (**Table.39**).

Table 37. Effect of fertigation on dehydrogenase activity (Δ in OD at 480 nm) at different stages

Treatments	Dehydrogenase activity (Δ in OD at 480 nm) at different stages		
	Vegetative stage	Bud appearance stage	Flowering stage
T_1	0.046	0.048	0.049
T_2	0.042	0.046	0.047
T_3	0.045	0.047	0.049
T_4	0.052	0.055	0.064
T_5	0.064	0.067	0.068
T_6	0.072	0.077	0.078
T_7	0.079	0.085	0.086
T_8	0.061	0.063	0.064
T_9	0.057	0.059	0.065
T_{10}	0.063	0.066	0.069
T_{11}	0.071	0.073	0.079
T_{12}	0.083	0.085	0.087
T_{13}	0.075	0.074	0.079
T_{14}	0.082	0.084	0.083
T_{15}	0.087	0.086	0.089
T_{16}	0.088	0.089	0.091
T_{17}	0.078	0.079	0.081
T_{18}	0.083	0.085	0.089
T_{19}	0.096	0.098	0.099
T_{20}	0.095	0.096	0.098
T_{21}	0.043	0.045	0.046
T_{22}	0.038	0.041	0.043
SED	**0.0007**	**0.0007**	**0.0008**
CD at 5%	**0.0015**	**0.0015**	**0.0015**

Table 38. Effect of fertigation on acid phosphatase (µ moles PNP released g^{-1} min^{-1}) at different stages

Treatments	Acid phosphatase (µ moles PNP released g^{-1} min^{-1})		
	Vegetative stage	**Bud appearance stage**	**Flowering stage**
T_1	0.117	0.119	0.120
T_2	0.116	0.117	0.119
T_3	0.165	0.187	0.192
T_4	0.159	0.183	0.185
T_5	0.120	0.156	0.192
T_6	0.190	0.197	0.199
T_7	0.185	0.188	0.192
T_8	0.143	0.178	0.181
T_9	0.171	0.176	0.179
T_{10}	0.163	0.167	0.169
T_{11}	0.171	0.175	0.178
T_{12}	0.181	0.183	0.184
T_{13}	0.194	0.195	0.197
T_{14}	0.186	0.188	0.189
T_{15}	0.179	0.179	0.175
T_{16}	0.184	0.186	0.189
T_{17}	0.186	0.189	0.191
T_{18}	0.183	0.185	0.189
T_{19}	0.123	0.124	0.126
T_{20}	0.125	0.126	0.128
T_{21}	0.121	0.119	0.117
T_{22}	0.093	0.097	0.098
SED	**0.0017**	**0.0011**	**0.0053**
CD at 5%	**0.0034**	**0.0021**	**0.0106**

Table 39. Effect of fertigation on urease activity (µg NH_4-N released g^{-1} h^{-1}) at different stages

Treatments	Urease activity (µg NH_4-N released g^{-1} h^{-1})		
	Vegetative stage	Bud appearance stage	Flowering stage
T_1	101.25	102.57	103.41
T_2	113.41	116.31	118.65
T_3	113.19	114.79	117.34
T_4	107.28	109.33	112.22
T_5	105.33	110.28	115.69
T_6	118.36	121.58	122.34
T_7	116.32	118.36	124.39
T_8	108.75	109.93	111.13
T_9	103.34	107.5	109.83
T_{10}	109.56	109.59	109.62
T_{11}	112.36	113.54	113.98
T_{12}	113.64	114.25	114.69
T_{13}	107.82	109.64	113.54
T_{14}	111.6	113.68	114.21
T_{15}	109.78	109.99	110.32
T_{16}	114.65	115.98	116.32
T_{17}	112.69	113.55	113.98
T_{18}	115.69	116.71	117.36
T_{19}	121.42	123.87	124.52
T_{20}	123.34	125.58	126.67
T_{21}	101.69	101.97	102.39
T_{22}	97.59	98.79	99.28
SED	**0.2415**	**0.2374**	**0.2547**
CD at 5%	**0.4875**	**0.4792**	**0.5141**

Among the treatments, the fertigation levels of T_4 + 0.5 % EDTA micronutrient mixture + *B. megaterium* + *B. amyloliquefaciens* each @ 10 ml/m^2 (T_{20}) registered maximum soil urease activity (123.34, 125.58 and 126.67 µg NH_4-N released g^{-1} h^{-1}) at vegetative, bud appearance stage and flowering stage respectively. The lowest activity (97.59, 98.79 and 99.28 µg NH_4-N released g^{-1} h^{-1}) was recorded in T_{22} (control) at all the stages of crop growth.

4.2.8 Application of fertigation doses and *Bacillus spp* on the population dynamics of micro flora

4.2.8.1. Bacteria, fungi and actinomycetes

The population dynamics of soil micro flora associated in the rhizosphere was quantified by dilution plate technique and expressed in terms of colony forming units per gram (cfu^{-1}) of soil. Bacteria, fungi and actinomycetes were measured at 10^{-6}, 10^{-4} and 10^{-5} dilutions respectively (**Table.40**). Different doses of fertigation and soil application of *Bacillus megaterium* and *Bacillus amyloliquefaciens* are influenced the microbial (bacterial, fungi and actinomycetes) population significantly in all the fertigation levels in rhizosphere soil.

Among the different fertigation doses with *Bacillus spp* combined application of T_{20} (150% of RDF @ 250:125:125 g NPK /m^2 /yr + 0.5 % EDTA micronutrient mixture + *B. megaterium* + *B. amyloliquefaciens* each @ 10 ml/m^2) recorded higher populations of bacteria (63.73 x 10^6 CFU g^{-1}). T_{18} (100% of RDF @ 166.4: 83.2:83.2 g NPK /m^2 /yr + 0.5 % EDTA micronutrient mixture + *B. megaterium* + *B. amyloliquefaciens* each @ 10 ml/m^2) recorded higher populations of fungi (29.67 x 10^4 CFU g^{-1}) and T_{12} (150% of RDF @ 250:125:125 g NPK /m^2 / yr + 0.5 % EDTA micronutrient mixture + *B. amyloliquefaciens* @ 10 ml/m^2) recorded (37.77 x 10^5 CFU g^{-1}) populations of actinomycetes than other treatments at harvesting stage. In contrast, the lowest population of bacteria (19.90 x 10^6 CFU g^{-1}), fungi (12.33 x 10^4 CFU g^{-1}) and actinomycetes (13.33 x 10^5 CFU g^{-1}) were found in control (T_{22}) treatment.

Table 40. Effect of fertigation, micronutrients and *Bacillus spp* on population dynamics of microbes in rhizosphere

Treatments	Bacteria (x 10^6 CFU g^{-1})	Fungi (x 10^4 CFU g^{-1})	Actinomycetes (x 10^5 CFU g^{-1})
T_1	21.43	12.40	17.83
T_2	23.67	19.10	15.33
T_3	28.33	20.20	20.67
T_4	26.87	20.33	19.67
T_5	42.98	20.00	22.33
T_6	49.70	20.73	25.17
T_7	48.73	16.67	32.33
T_8	49.23	21.33	31.53
T_9	47.57	24.60	36.23
T_{10}	45.33	26.00	37.67
T_{11}	44.63	15.97	36.23
T_{12}	48.43	20.33	37.77
T_{13}	50.73	19.83	35.17
T_{14}	48.80	20.40	33.67
T_{15}	50.33	19.93	32.20
T_{16}	48.67	18.67	27.17
T_{17}	55.63	27.00	26.67
T_{18}	57.30	29.67	31.50
T_{19}	62.33	17.00	35.20
T_{20}	63.73	21.23	31.20
T_{21}	23.33	17.53	21.20
T_{22}	19.90	12.33	13.33
SED	**2.0416**	**1.1955**	**2.5840**
CD at 5%	**4.1211**	**2.4132**	**5.2159**

4.2.9 Effect of *Bacillus spp* on powdery mildew (Percent Disease Index)

The experimental results (**Table.41**) revealed that, soil and foliar application of *Bacillus megaterium* and *Bacillus amyloliquefaciens* have effectively reduced the powdery mildew incidence at different growth stages. Minimum percent disease index of 5.40, 5.69 and 6.10 percent was recorded in the plots applied with 150% of RDF @ 250:125:125 g NPK /m^2 /yr + combined with foliar application of 0.5 % EDTA micronutrient mixture along with 10 ml of the liquid formulations of *B. megaterium* + *B. amyloliquefaciens* during the vegetative, bud appearance and except flowering stage i.e. T_{18} (6.05) respectively. However the maximum percent disease index of 21.74, 34.00 and 39.53 percent was recorded in the untreated control.

4.3 Benefit-Cost Ratio (BCR)

4.3.1 Effect of bending and growth regulators on cost economics (Experiment – I)

The economics was worked out for different levels of bending and growth regulator interactions are presented in **Table.42**. Among the different interactions, B_1G_4 (bending at shoot junction bud + BA 200 ppm) recorded the highest benefit cost ratio (3.70) and which is followed by B_1G_3 with benefit cost ratio (3.46). The B_0G_4 control recorded lowest benefit cost ratio (2.26).

4.3.2 Effect of fertigation on cost economics (Experiment – II)

The economics worked out for fertigation levels are presented in the **Table.43**. In this experiment, the treatment T_{19} (T_3 + 0.5 % EDTA micronutrient mixture + *B. megaterium* + *B. amyloliquefaciens* each @ 10 ml/m^2) followed by T_{20} (T_4 + 0.5 % EDTA micronutrient mixture + *B. megaterium* + *B. amyloliquefaciens* each @ 10 ml/m^2) recorded a higher benefit cost ratio of 3.15 and 3.10 respectively. T_{21} Farmers practice's recorded a benefit cost ratio of 2.05 and the control recorded lowest benefit cost ratio (1.08).

Table 41. Effect of *Bacillus spp* on the incidence of powdery mildew (Percent Disease Index) at different stages of crop growth

Treatments	Vegetative stage	Bud appearance stage	Flowering stage
T_1	18.93	29.16	35.51
T_2	16.23	27.42	32.75
T_3	15.18	28.16	34.13
T_4	14.28	26.74	31.58
T_5	10.22	9.12	8.53
T_6	9.18	8.72	8.26
T_7	9.10	7.24	6.84
T_8	9.66	8.42	7.95
T_9	9.28	8.20	7.74
T_{10}	8.54	7.78	7.37
T_{11}	8.12	7.54	7.16
T_{12}	6.42	6.39	6.07
T_{13}	8.22	7.64	7.28
T_{14}	7.57	7.18	6.83
T_{15}	8.11	7.50	7.12
T_{16}	9.54	8.51	8.10
T_{17}	7.35	7.04	6.71
T_{18}	6.27	6.32	6.05
T_{19}	5.77	5.94	6.33
T_{20}	5.40	5.69	6.10
T_{21}	18.24	25.28	32.86
T_{22}	21.74	34.00	39.53
SED	**0.6432**	**0.6824**	**0.5443**
CD at 5%	**1.2983**	**1.3774**	**1.0987**

Table 42. Effect of bending and growth regulators on cost economics of Dutch rose (var. Tajmahal) Experiment - I

Treatments	Flower yield (no of stems/500m^2)	Gross return (Rs.)	Cost of cultivation (Rs.)	Net return (Rs.)	BCR
$B_1 G_1$	138400	249120	83685	165435	2.98
$B_1 G_2$	135200	243360	84815	158545	2.87
$B_1 G_3$	145600	291200	84210	206990	3.46
$B_1 G_4$	158800	317600	85860	231740	3.70
$B_2 G_1$	127600	255200	83685	171515	3.05
$B_2 G_2$	121600	243200	84815	158385	2.87
$B_2 G_3$	133200	266400	84210	182190	3.16
$B_2 G_4$	139200	278400	85860	192540	3.24
$B_3 G_1$	124000	248000	83685	164315	2.96
$B_3 G_2$	126400	252800	84815	167985	2.98
$B_3 G_3$	134400	268800	84210	184590	3.19
$B_3 G_4$	127200	254400	85860	168540	2.96
$B_4 G_1$	123200	246400	83685	162715	2.94
$B_4 G_2$	128800	257600	84815	172785	3.04
$B_4 G_3$	132400	264800	84210	180590	3.14
$B_4 G_4$	130400	260800	85860	174940	3.04
$B_1 G_0$	125600	251200	85940	165260	2.92
$B_2 G_0$	121200	242400	85940	156460	2.82
$B_3 G_0$	117200	234400	85940	148460	2.73
$B_4 G_0$	110400	220800	85940	134860	2.57
$B_0 G_0$	104000	208000	85940	122060	2.42
$B_0 G_1$	102000	204000	83685	120315	2.44
$B_0 G_2$	100000	200000	84815	115185	2.36
$B_0 G_3$	102800	205600	84210	121390	2.44
$B_0 G_4$	97210	194420	85860	108560	2.26

Table 43. Effect of fertigation on cost economics of Dutch rose (var. Tajmahal) Experiment - II

Treatments	Flower yield (no of stems/500m^2)	Gross return (Rs.)	Cost of cultivation (Rs.)	Net return (Rs.)	BCR
T_1	91380	456900	199164	257736	2.29
T_2	96060	480300	235732	244568	2.04
T_3	96785	483925	220401	263524	2.20
T_4	108415	542075	257069	285006	2.11
T_5	127620	574290	197064	377226	2.91
T_6	121620	608100	230732	377368	2.64
T_7	133200	666000	268401	397599	2.48
T_8	130380	651900	304069	347831	2.14
T_9	124020	570492	197064	373428	2.89
T_{10}	122400	612000	232732	379268	2.63
T_{11}	134400	672000	268401	403599	2.50
T_{12}	133980	669900	304069	365831	2.20
T_{13}	123180	554310	197064	357246	2.81
T_{14}	128820	644100	232732	411368	2.77
T_{15}	132420	662100	268401	393699	2.47
T_{16}	140400	702000	304069	397931	2.31
T_{17}	135180	567756	197064	370692	2.88
T_{18}	151920	683640	232732	450908	2.94
T_{19}	162420	944088	268401	640019	3.15
T_{20}	160015	844584	304069	576183	3.10
T_{21}	120720	277656	135710	141946	2.05
T_{22}	63840	111720	83060	6316	1.08

Discussion

CHAPTER V

DISCUSSION

Commercial production of cut flowers and their economic value in the past two decades has been increased significantly and there is also great potential for continuing cultivation in the future for domestic and international markets. Introduction of greenhouse technology for the cultivation of cut flowers in India has changed the scenario of Indian floriculture. Huge capital investments have been made for the production of cut flowers meant for 100 percent export purpose. In order to achieve the quality standards of the international markets, imported production technologies and handling procedures are in practice at present. However, a total dependence on these practices is not advisable due to the changing responses of the crop with changing edaphic and climatic factors.

Among different cut flowers, Rose is a unique and different coloured cut flower grown primarily for export purpose under protected conditions. A tough competition exists in the international market, where Indian roses suffer from low prices due to variation in quality. The causes of inadequate quality can be attributed to non adoption of scientific management practices. The most important one among them is the lack of knowledge regarding the crop regulation practices.

Today with the advancement of scientific technology like using greenhouse for environmental control, rose cultivation is all set to go hi-tech and possible to produce all year round. The successful cultivation of the crop depends on the suitable soil, effective nutrient supply, plant growth regulation by different techniques like bending, foliar spray of PGRs, micronutrients and application of bio-agents for cost effective disease and pest management strategies.

While the requirements for rose as cut flower namely growing media, pruning levels, fertilization, disease management by chemicals and post harvest technology has been standardized by many earlier workers. (Fascella and Zizzo, 2005; Man Bihari *et al*., 2010; Bar-Yosef *et al*., 2009; Ghaffoor *et al*., 2000; Singh, 2005; Qasim *et al*., 2008; Gholami *et al.,* 2011; Shahid Javed Butt. 2005). Studies relating to the standardization of

bending with PGR interactions, fertigation schedule, foliar spray of micronutrients with bio control agents for quality improvement and disease management of cut rose in Hosur region are still lacking. The growing medium encourages root aeration with good physico-chemical properties effect on the availability of nutrients particularly minor elements along with beneficial microbes (Bunt, 1976).

Growing of plants in artificial substrates has many advantages over soil (Dutt *et al*., 2002). Rose is a leading cut flower crop but yet no micronutrients are applied to improve yield and quality. Growth, yield and quality are greatly affected by nutrient management practice (Savvas, 2002). Optimal fertigation scheduling of greenhouse crops is very important since it influences the rhizosphere environment, media water potential and salt accumulation, which in turn affect plant growth and consequently crop production and quality (Raviv and Blom, 2001). Inadequate plant nutrition causes serious disorders in rose cultivation and may eventually lead to decline of plant vigor and ultimately reduction of yield. Flower production can be enhanced by increasing the level of NPK nutrients (Young *et al.*, 1976, Umma and Gowda, 1986).

Plant growth regulators generally modify the physiological processes of plants and ultimately affect the yield and quality of flowers. Yield and quality improvement are important aims of florists. Low yield and low quality are two problems in India compared to other countries such as the Netherlands, Colombia, Kenya and USA. These problems can be rectified by optimizing the production conditions and application of plant growth regulators. Good quality production is usually achieved by manipulating growth factors such as light and temperature. These physical factors are very difficult to control and perhaps expensive. Plant growth and flowering depends on PGRs equilibrium and in general, quickly respond to change of hormonal balance (Khangoli, 2001).

Bio-control agents not only supress the disease but also enhance the root and plant growth by way of encouraging the beneficial soil microflora which helps in the volatilization and sequestration of certain inorganic nutrients (Chandrasekhar and Gopinath, 2001). Hence the present study was undertaken to standardize certain precision production technologies of cut rose and its effect on growth, yield and quality of flowers. The experiments were conducted separately based on their objective and the observations recorded are statistically interpreted and the results discussed are furnished below.

5.1 Experiment I: To study the effect of shoot bending and application of growth regulators on maximizing the yield and quality of Dutch rose

5.1.1 Effect of shoot bending and growth regulators on growth parameters

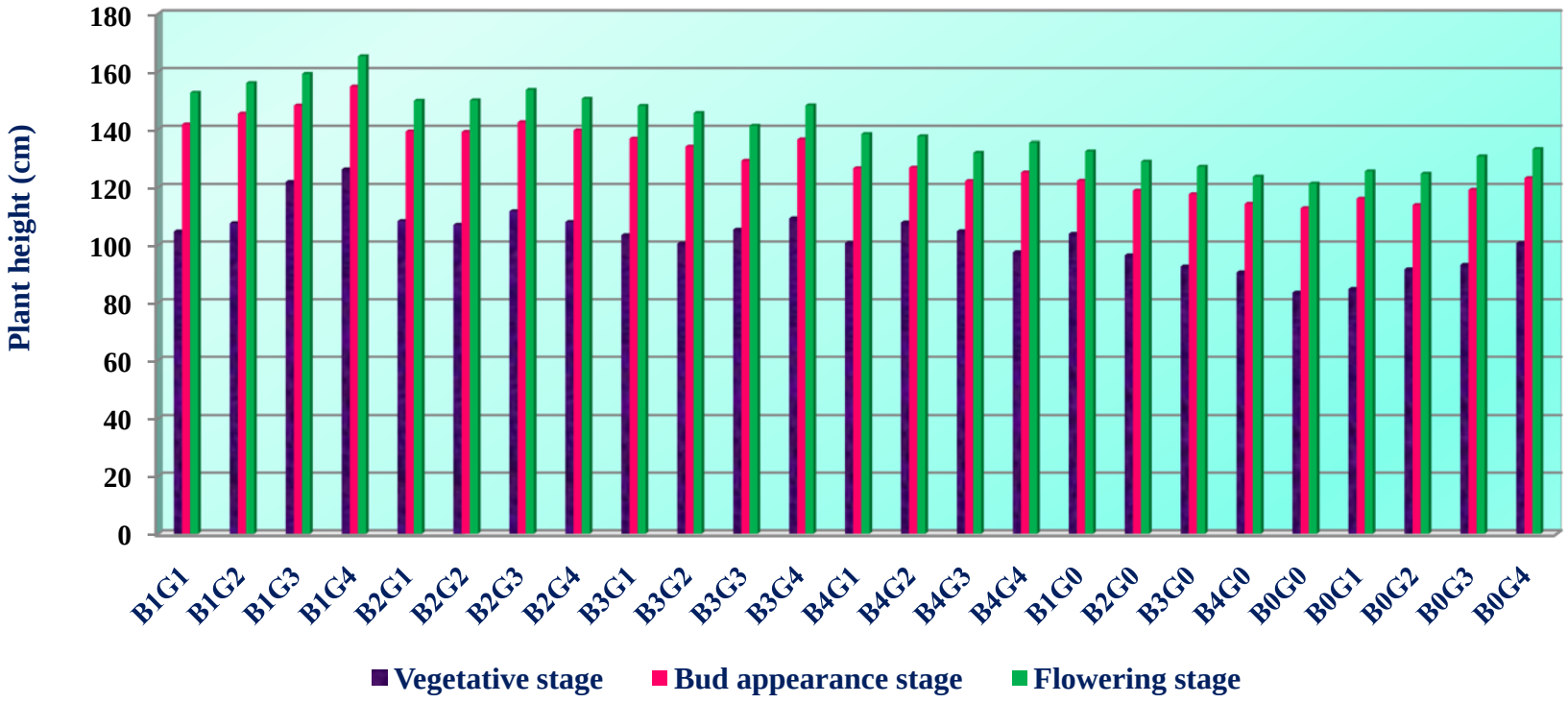
Various growth parameters *viz.,* plant height, number of compound leaves, number of basal shoots, plant spread, inter nodal length, total number of shoots after bending were variably influenced by the bending effect and also by the effect of application of growth regulators.

There are different type of factors that affect the growth and development of rose plants. In intensive greenhouse cultivation production (controlled environment condition), improving yield and quality of flower is necessary. The major growth factor is the management of plant architecture which plays an important role on the year round flower production as it greatly determines plant longevity (Marcelis-Van Acker, 1993; Kool *et al*., 1997) and allows controlling both plant development and the quality of the flowering shoots. The bending technique involves to down the unmarketable shoots after breaking their apical dominance, thus leading to a heterogeneous canopy structure formed by both upright shoots and horizontally bent shoots which fill in the space between the plants and between the rows. It favours a better quality of the flowering shoots (Okhawa and Suematsu, 1999; Sarkka and Rita, 1999; Pien *et al.,* 2001; Kim and Lieth, 2004).

Plant height is an important growth related morphological character and plays an important role in plant duration and productivity of any flower crop. In the present investigation, the height of the plants of B_1G_4 was found superior over other interactions. Bending at shoot junction bud + BA 200 ppm) recorded maximum plant height which is followed by (B_1G_3) at all the growth stages of the crop development *viz.,* vegetative, bud appearance and flowering stage **(Fig. 1& Plate.12).** The increase in plant height might be due to the bending effect of primary shoots which promotes the formation of axillary shoots by breaking apical dominance as reported by Cline (1991). Zieslin and Halevy (1978) found that in roses bending of stems caused growth of a strong shoot close to the bend and another strong shoot close to the distal end.

This fact can be linked with the accessibility and accumulation of more carbohydrates in basal shoots to promote the rate of development of the newly initiated bud growth.

Fig 1. Effect of bending and growth regulators on plant height (cm) at different stages



Rahman *et al*. (2000) stated that more number of leaves manufacture more photosynthates which results in increase of plant height in *Phlox drummondii*.. It has been shown that increased cytokinin concentration in the xylem sap promotes stomatal opening and simultaneously decreases sensitivity to ABA (Wilkinson and Davies, 2002).

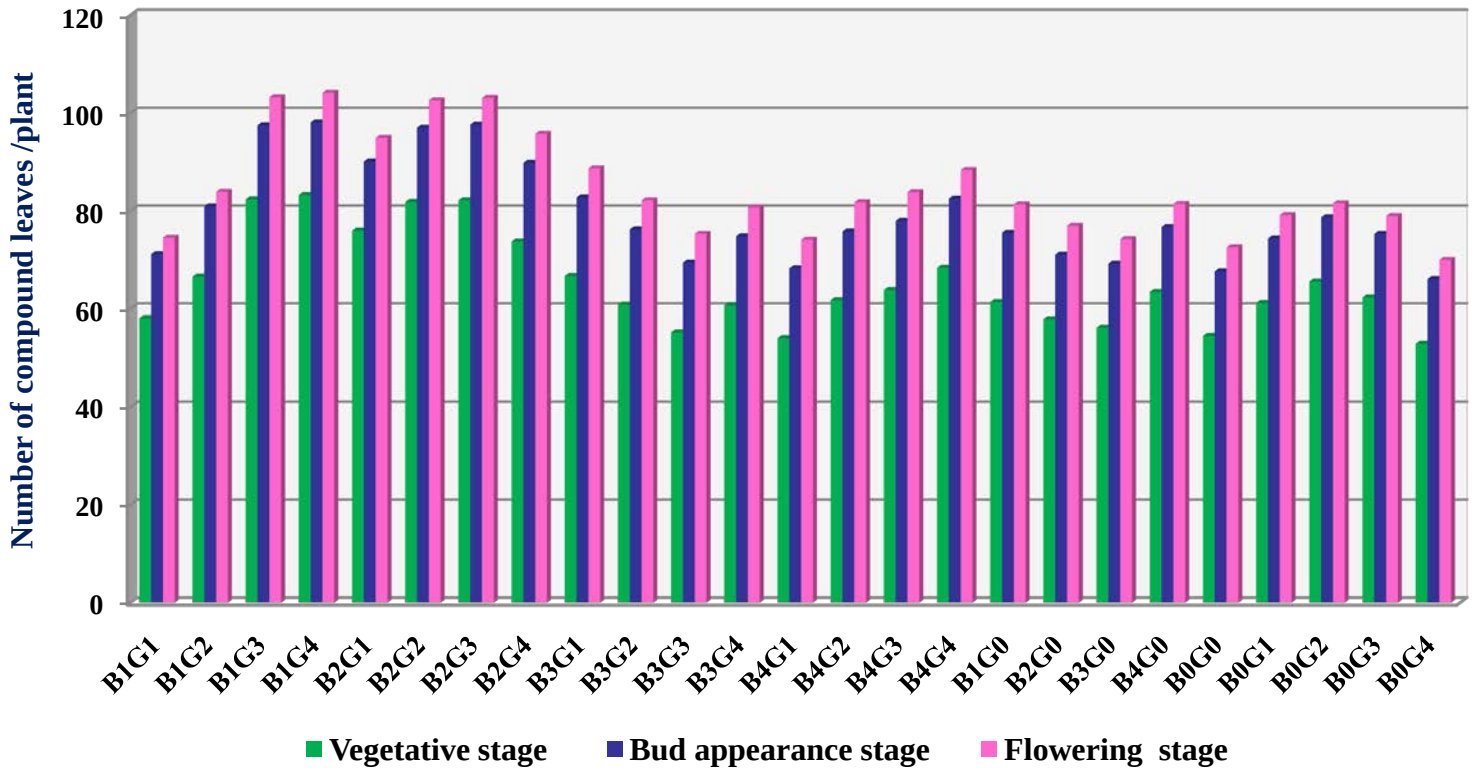
Stomatal response to exogenous application of cytokinin depends on the concentration and cytokinin type. Both synthetic and natural cytokinins can cause stomatal opening in grass *Anthephora pubescens* (Jewer and Incoll, 1980). The results are in close conformity with the findings of Muthu Kumar *et al.* (2012) in cut rose cv. First Red. Hashemabadi and Zarchini (2010) conducted similar studies to find out the effect of growth regulators on yield and quality of rose. Similar variation in plant height was reported by Hussain and Khan (2004) and Chaudhari *et al*. (2010) in rose.

Leaves are the functional units for photosynthesis, which greatly influence the growth and flower yield of many crops. Leaves serve as the index of measurement of vegetative growth and determining the yield potential. Number of leaves produced per plant varied significantly among interactions studied. Maximum number of leaves per plant was produced in B_1G_4 (bending at shoot junction bud + BA 200ppm) at all the growth stages of the crop growth **(Fig.2 & Plate.5).**

This could be attributed to the profound effect on the vegetative growth of rose by increased nutrient uptake, photosynthesis, source-sink relationship and stomatal opening by applied BA. The production of more number of leaves in interaction was due to the increase in plant height. Maximum number of leaves per plant was reported by Ashok and Rengasamy (2000) who studied the effect of N fertigation at different levels and sources on growth of cut rose cv. First Red. The findings of the present study are in agreement with the findings of similar variation in rose as reported by Jadhav *et al.* (2003) and Parbiati and Santoso (2007).

Number of basal shoots is an important parameter for production of more branches and flowering shoots. With respect to number of basal shoots per plant, B_1G_4 showed significant differences among different interactions, which recorded maximum number of basal shoots which might be due to the bottom breaks of apical dominance during bending at young stage of plants which enabled the enhanced production of basal shoots.

Fig 2. Effect of bending and growth regulators on number of compound leaves /plant at different stages



Durkin (1960) indicated that renewal (basal) shoots are more common on young rose plants are prone to produce basal and axillary shoots by application of plant growth regulators. Basal application of 75 ppm or 125 ppm BA produced an average of more than three axillary shoots than 0 ppm or 250 ppm for the rose cv. 'Honor'. BA is a cytokinin that stimulates cell division and interacts with auxin (Wareing and Phillips, 1981).

Environmental and endogenous factors affecting roses may also influence consistent increases in basal and axillary shoot production (Carpenter, 1975; Khayat and Zieslin, 1982; Mor and Zieslin. 1987). Muthu Kumar *et al.* (2012) studied the effect of growth regulators at various concentrations and found that MH at 100 ppm recorded the maximum mean number of branches of 4.47 followed by MH at 50ppm with 4.21 branches. The results of the present study was in conformity with the findings of Ramalingam (2008) who also reported that the highest number of shoots per plant was noticed with the application of 0.2 % humic acid at monthly intervals.

In general B_1G_4 recorded (bending at shoot junction bud + BA 200 ppm) maximum plant spread. Higher plant spread in the interaction was due to production of more number of leaves and presence of longer bent shoots which resulted in maximum plant spread. The major and minor nutrient elements might have helped in initial vigour and better metabolic activities especially with the production of photo assimilates, which would have favoured the production of more number of leaves which would have ultimately increase the leaf area and plant spread.

Similar results have been reported by Chaudhari *et al.*, 2010 who studied bio and nitrogen fertilizers on growth and yield of rose and recorded maximum plant spread (N-S- 95.20 cm) and (E-W- 100 cm) was recorded in rose. The results of present investigation was also supported by Patil *et al*. (2012) who found that spraying of BA 100 ppm in open field conditions registered maximum plant spread (N-S- 81.28 cm) and (E-W- 87.03 cm) in rose cv. Gladiator.

The inter nodal length is an important parameter contributing significantly towards the quality of stem length. In the present study, the plants of B_1G_4 produced the highest intermodal length. Foliar spray of BA 200 ppm promotes stomatal opening and increase more photosynthates simultaneously which would have promoted the internode elongation.

Wachowicz *et al*. (2006) studied the effect of growth regulators on stomatal aperture in senescing cut leaves of *Zantedeschia aethiopica* and Hosta. The stomata aperture was higher (about 21%) in *Zantedeschia* and 44% in *Hosta* cut leaves treated with GA_3 and BA respectively, as compared to water (control). Promotion of stomatal opening induced by application of cytokinin (BA) in *Hosta* 'Undulata Erromena' was in accordance with the results of Rulcova and Pospisilova (2001). Cytokinins are often considered ABA antagonists in many processes including the regulation of stomatal opening, but the effects are species specific and depend on cytokinin type, concentration and method of application (Pospisilova, 2003). The present study can be comparable with the findings in rose by Gul *et al*. (2006) who applied GA_3 on *Araucaria heterophylla* and observed that maximum internodal length (8.6 cm) by application of GA_3 at 300 ppm.

The total number of shoots after bending recorded maximum in B_1G_4 **(Fig. 3).** The higher number of shoots after bending might be due to the phenomenon of basipetal movement of auxin from top to bottom of bent portion (at shoot junction B_1) of shoot **(Plate.10).** Manjula (2005) found significant variations among the different cultivars of rose with regard to the number of shoots produced after bending. Maximum number of shoots were produced in cv. Tineke followed by GrandGala. Bending may increase the number of bud sprouts by altering canopy structure, and hormonal or source–sink relations. The quality of the bottom breaks is also important because healthy shoots increase the number of outgrowing laterals (Kool and Van de Pol, 1993). These findings are in agreement with the report of Faber and White (1977) and Zieslin and Halevy (1978) in rose.

5.1.2 Effect of bending and growth regulators on flowering parameters

In general, the flowering and yield parameters of any crop are determined by various yield components. Flowering and yield parameters *viz*., earliness in shoot emergence, flower bud appearance, harvest from flower bud appearance, number of compound leaves per flowering shoot, length of flowering shoot, pedicel length, circumference of flower bud, stem girth, weight of flowering shoot, number of quality grade flowers, cut stem yield / m^2 and vase life are influenced by the effect of different levels of bending and growth regulator application.

Fig 3.Effect of bending and growth regulators on total number of shoots per plant after bending

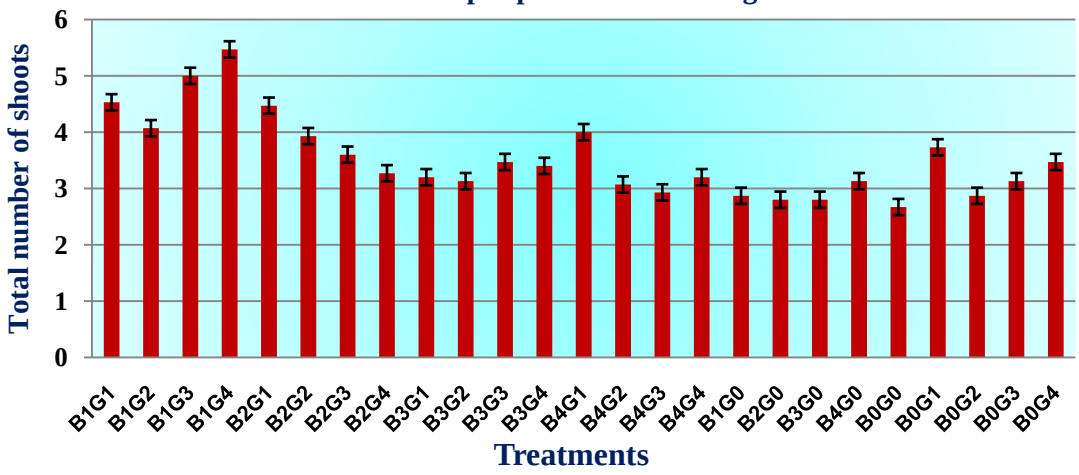


Fig 4.Effect of bending and growth regulators on number of days taken for flower bud appearance

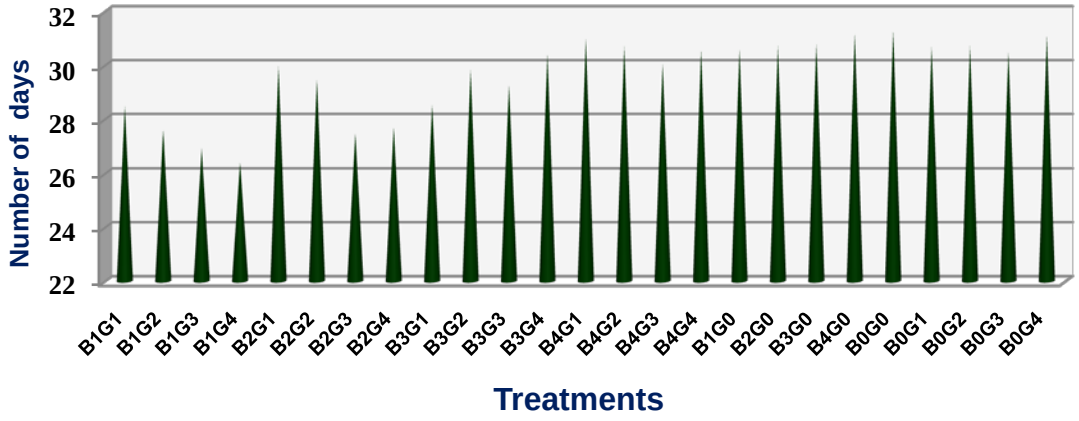
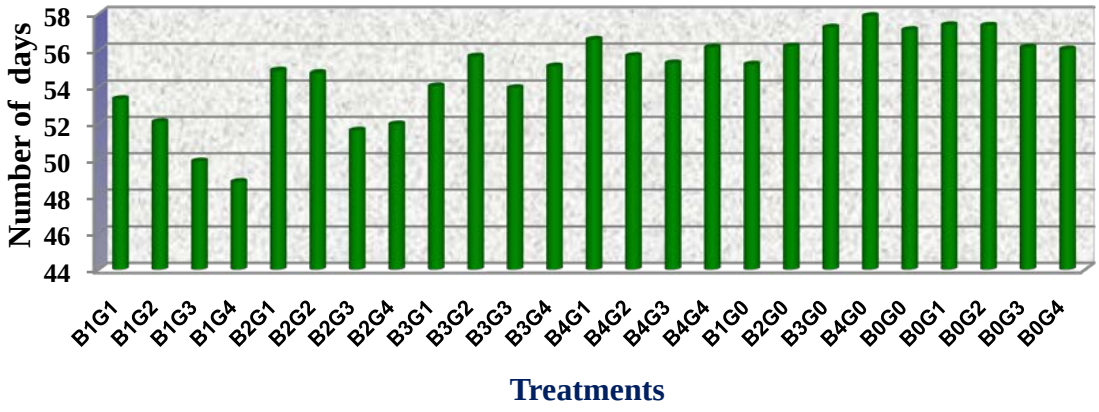


Fig 5.Effect of bending and growth regulators on number of days taken for harvest after bending



Earliness (10.87 days) in shoot emergence on bent shoots was observed in B_1G_4 which was reflected due to the bending and growth regulator interaction **(Plate.6).** The interaction might have an indirect role which aids to favourable source - sink relation with faster and more efficient mobilization of photosynthates. Because of the role of axillary shoots as one of the major factors determining flower production, as well as the effects of cytokinin treatments on bud sprouting, renewal of shoot formation and flower development can be achieved (Mor and Zieslin, 1987) in rose.

Days to flower bud appearance is an important character, which decides the early yield (precocity) of the crop. Early flowering might be due to the combined effect of bending along with growth regulators creating a conducive source sink relationship. **(Fig. 4).** The commencement of flower bud appearance noticed in B_1G_4 might be due to the effect of hormones which are associated with the increased shoot length and leaf area resulted in more photosynthesis and thus increased the transformation of manufactured food material from source (leaf) to sink (flower bud).

Since the work of Kohl and Randle (1974) who showed that the rate of bud break in rose plants increased following exogenous treatments with cytokinins, numerous reports on the effects of cytokinins has been published (Chmelnitsky *et al*., 2001; Mor and Zieslin, 1987). The results of present investigation was in conformity with the findings of Vieanny Jennifer (2010) in cut rose varietes. Similar results were also reported by Manjula (2005) and Prashant Paramagoudar (2010) in rose.

In the present study, minimum number of days taken for harvest from flower bud appearance after bending was noticed in B_1G_4. This might due to the increased photosynthesis and enhanced activity of cytokinin and auxin in the shoots due to the effect of bending and application of BA. This would help in the early transformation from vegetative to reproductive stage. The nutrients movement from source to sink would have taken place in a consistent manner and made the nutrient for uniform distribution to all plant parts for quick development of flower from bud stage for harvest. Ramalingam (2008) recorded lowest number of days (16.70) for flower harvest in cut rose cv. Happy Hour. Similar findings were obtained by Vieanny Jennifer (2010) in rose var. Hollywood.

Among the bending and growth regulator interactions, the plants of B_1G_4 took minimum days for first flower harvest **(Fig .5 & Plate.7).** Stomatal responses to naturally occurring or synthetic cytokinins are variable (Pharmawati *et al*., 1998 and Incoll *et al.*, 1987) although cytokinins can increase stomatal aperture. The apparent insensitivity of stomata to cytokinin application may be because cytokinin concentration is already optimal for stomatal opening (Incoll *et al.*, 1987). Advanced bud formation and onset of flowering in bending at shoot junction bud along with BA treated rose plants is attributable to early flowering.

Increased photosynthesis and respiration along with enhanced photosynthates in BA treated plants also could be responsible for early flowering. Prashant Paramagoudar (2010) recorded least number of days for first harvest (36.36) which was noticed in cv. First Red, may be due to early bud initiation. Similar variation with time taken for harvesting was reported by Chandrashekaraiah (1973) in roses. The results of present study also in line with the finding of Manjula (2005), Ramalingam (2008) and Vieanny Jennifer (2010) in rose.

The plants of treatment interaction B_1G_4 produced more number of compound leaves per flowering shoot.Leaves are the functional units for photosynthesis, which greatly influence the growth and flower yield of many crops. More number of leaves and maximum length of flowering shoot are correlated with each other. A higher number of leaves remaining on the parent shoot resulted in a higher assimilate production for the outgrowth of the buds (Marcelis-Van Acker 1994b). In ‘Mercedes’ variety of cut rose, bending the shoots had a positive effect on shoot growth. Prashant Paramagoudar (2010) recorded more number of leaves (5.80) per 10 cm of shoot length in Gold Strike. The production of higher number of leaves in these cultivars was due to the increased plant height. Similar results were also reported by Jadhav *et al.* (2003) and Parbiati and Santoso (2007).

Stem length is the most important parameter for grading the quality of a rose. Long stalk for cut roses are pre requisite in the international market. The results of the present study indicated that increase in shoot length in treatment B_1G_4 **(Fig.6 & Plate.8)** might be due to the bending effect which might have increased the stem length by

Fig 6.Effect of bending and growth regulators on length of flowering stem (cm)

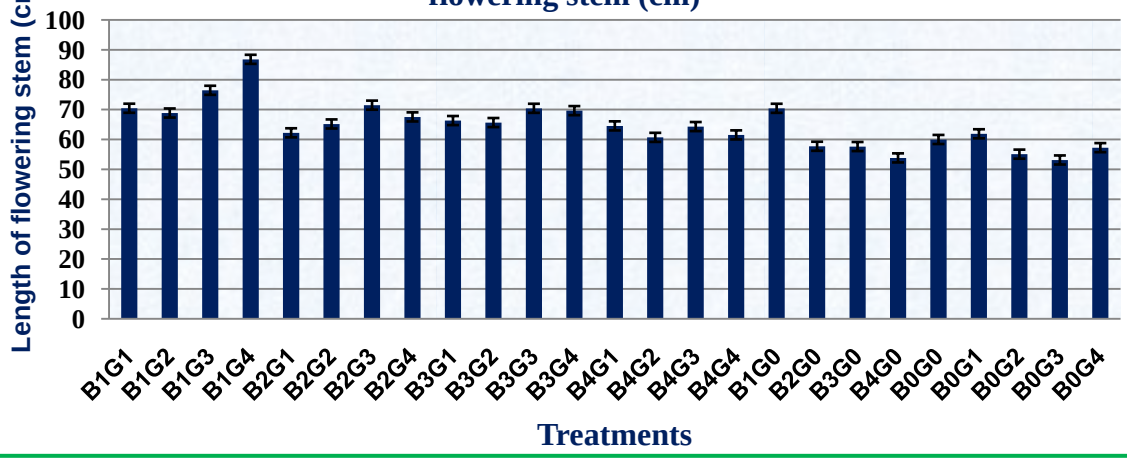


Fig 7.Effect of bending and growth regulators on circumference of flower bud (cm) at harvest

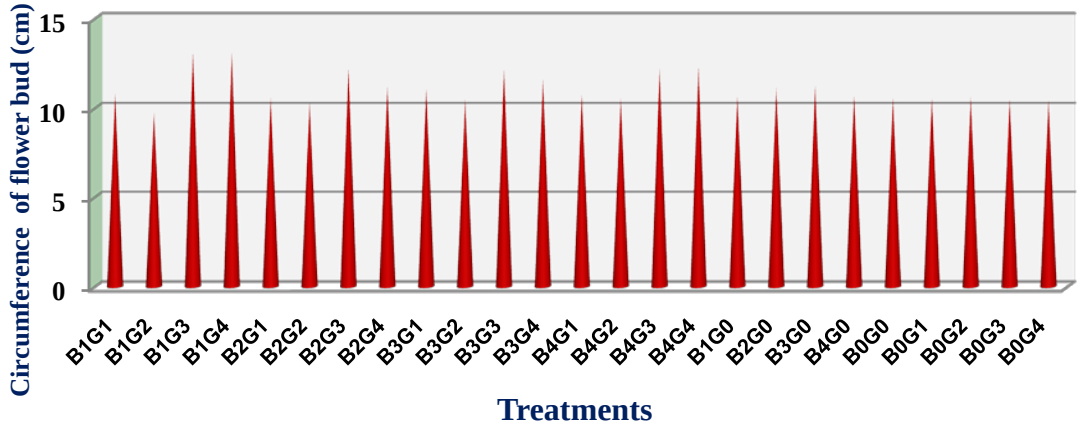
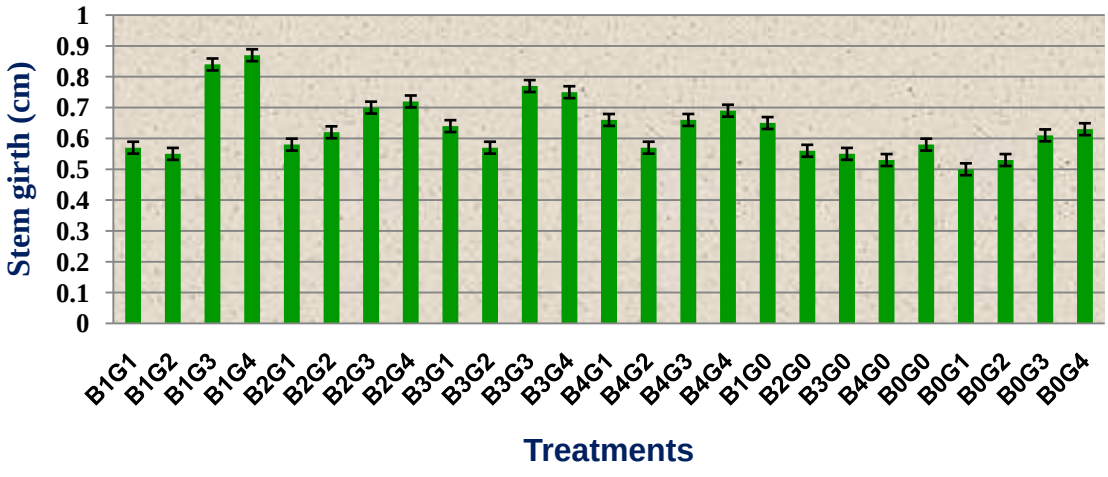


Fig 8.Effect of bending and growth regulators on stem girth (cm)



altering canopy structure, hormonal or source - sink relations, or by selective removal of short shoots from the harvests. BA application accelerates cell division and stomatal opening for more photosynthetic efficiency which would have resulted in increased stem length and plant height simultaneously. The increase in length of flower stalk might be accounted due to an increase in the length of branch. Prashant Paramagoudar (2010) recorded maximum stalk length (63.03 cm) in cut rose var. Grand Gala. Similar results were reported by Mantur *et al.* (2005), Fascella and Zizzo (2007) and Patil *et al*. (2012) in rose. These results of the current study are in line with these findings.

Among the bending and growth regulators interactions, B_1G_4 plants produced longest length of flower bud (cm) at harvest. The possible reasons for the interaction effects on the bud length may be due to disbudding and de-shooting during bud developmental stage. The translocation of photosynthates from source to sink is very important for the development of economic part (Amanullah *et al*., 2010). Mendhe *et al*. (2011) studied the effect of pruning levels and recorded superior length of flower bud in pruning at 60 cm from ground level followed by 50 cm pruning height. Ramalingam (2008) studied the effect of growth regulating substances on cut rose cv. Happy Hour and reported that application of 0.2% humic acid increased the flower bud length (5.40 to 5.60 cm). Prashant Paramagoudar (2010) recorded that the cultivar Grand Gala and Gold Strike recorded maximum bud length. Similar results were reported by Jadhav *et al.* (2003) and Man Bihari *et al.* (2009) in rose.

Pedicel length is a vital character responsible for elegance of the flower, setting apart the flower from the foliage. Varieties possessing a medium pedicel length are preferred in general because a ‘too short’ or ‘too long’ pedicel looks disproportionate in proportion to the size of the flower bud. Significant variations among the interactions were observed with regard to pedicel length. The treatment interaction B_1G_2 plants produced longest pedicel length which may be due to the exogenous application of gibberellic acid which accelerates cell division and longitudinal growth of the plant cell. A significant difference in neck length of flower bud was observed among the cultivars tested by Manjula (2005). The maximum neck length (6.49cm) was recorded in GrandGala followed by Skyline (6.08cm). Mendhe *et al.* (2011) studied the effect of pruning levels and recorded maximum length of pedicel (8.89 cm) in pruning at 60 cm from ground level.

The characters like, shoot length, bud length, bud diameter, number of petals and vase life were considered to be of prime importance (primary characters) and should be more stressed upon as pre-requisites for cut flower purpose. A good variety possessing the desirable primary characters is considered as a good variety for cut flower production. Long stalk for cut roses are pre requisite in the international market. Whereas, flower diameter in the local market as well as international market still occupies an important character for consumer preference.

In the present investigation, B_1G_4 & B_1G_3 interactions produced maximum circumference of flower bud **(Fig.7&Plate.8)**. The possible reasons may be these interactions retain more number of leaves, bending at shoot junction bud and exogenous application of BA alters the endogenous concentration of hormones. Application of BA increased the cytokinin concentration in the xylem sap which promotes stomatal opening and simultaneously decreases sensitivity to ABA (Wilkinson and Davies, 2002).

Exogenous application of cytokinin increases the stomatal opening and accelerates the photosynthetic efficiency for more photosynthesis and thus increased the transformation of manufactured food material from source (leaf) to sink (flower bud). BA seems to affect the flower diameter by forming sink in a position where it accumulates and draws the available photosynthates to this site. The better quality of flower might also be due to the physiological action of cell division and cell enlargement by BA (Pandey and Sinha, 2004). Muthu Kumar *et al.* (2012) recorded the highest mean flower diameter of 6.89cm in treatment of GA_3 at 100ppm. Prashant Paramagoudar (2010) recorded maximum flower diameter (3.10cm) in Grand Gala. Patil *et al*. (2012) studied the effect of BA and growth conditions and found that BA 100 ppm registered maximum flower diameter (13.68cm) in rose cv. Gladiator.

Stem girth is very essential parameter for cut flowers to possess a strong stem of sufficient strength to hold bloom firmly erect (Malik, 1968). Stem girth indicates the sturdiness of the cut flowers. In the present investigation stem girth was maximum in interaction treatment B_1G_4 **(Fig. 8).** The occurrence of variation in stem girth may be due to change in bending levels and hormone concentrations. Bending might have allowed the bent stem to form abundant photosynthesizing leaves enough to supply extra

assimilates and thus results in the increment of thickness of the newly oriented growth. This could be due to better nutrient uptake, higher photosynthesis, source sink relationship, besides excellent physiological activities in statice (Gayithri *et al*., 2004). Getachew *et al.* (2012) recorded maximum stem thickness (1.01 cm) after bending at shoot junction. Prashanth *et al.* (2006) observed maximum stem thickness (1.39 cm) by application of cycocel 3000 ppm. Patil *et al*. (2012) observed maximum stem girth (2.06 cm) in rose cv. Gladiator. Manjula (2005) reported that stalk girth (1.01cm) was maximum in Ravel followed by Skyline (1.00 cm). Muthu Kumar *et al*. (2012) registered maximum stem girth (1.66 cm) in cut rose cv. First Red. The present study findings are line in with the results of Ramalingam (2008) who studied the effect of growth regulating substances on growth, yield and post harvest quality of cut Rose cv. Happy Hour.

In the present investigation, the same interactive treatments (B_1G_4 & B_1G_3) produced maximum weight of flowering shoot **(Fig .9).** This might be due to longer stem length, more stem girth, bigger sized flower and higher petal weight of flower. Variation among the interactive treatments was mainly because of increased flower size with prominent stalk length and also due to presence of fairly more number of well developed petals. The application of BA enhances the physiological action of cell division and cell enlargement (Pandey and Sinha, 2004). Mendhe *et al*. (2011) studied the effect of pruning levels and recorded more weight of flower (18.20 cm) by pruning at 60 cm from ground level. Hashemabadi and Zarchini (2010) conducted similar studies and observed maximum fresh weight of flower in cut rose cv. Poison. Manjula (2005) recorded maximum stalk weight (13.88 g) in cut rose var. Ravel. Similar findings were also observed by Patil *et al*. (2012) in rose.

Flowers are graded based on the stalk length and diameter of flower. Among the interactions, bending at shoot junction bud with BA 200 ppm (B_1G_4) produced maximum number of ‘A’ grade flowers **(Fig .10 & Plate.13)** and the mean yield of flowers per plant **(Fig .11& Plate.11)** also was the highest in this interaction treatment. In the present investigations, higher yield of flowers might be due to morphological parameters like increased plant height, more number of leaves and plant spread which help in production of more photosynthates resulting in greater accumulation of dry matter which inturn leads to production of more number of flowers per plant.

Fig 9.Effect of bending and growth regulators on weight of flowering shoot at harvest (g)

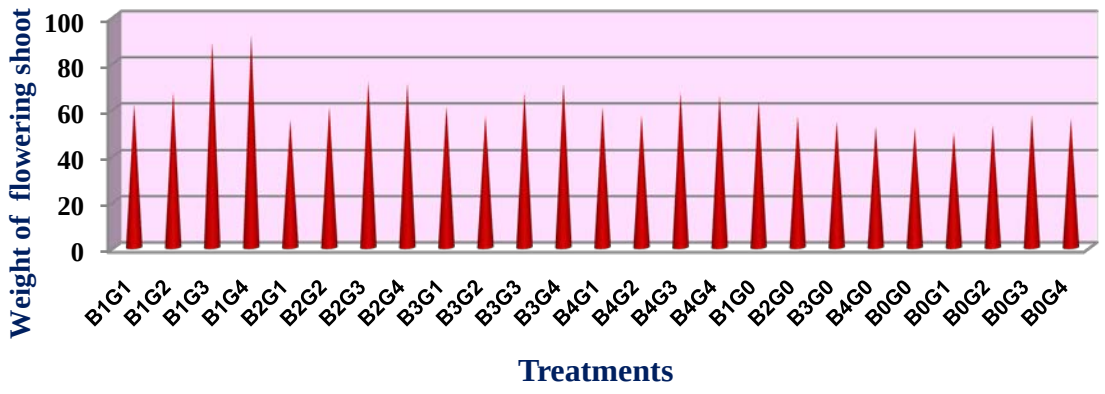


Fig 11. Effect of bending and growth regulators on mean yield of flowers /plant / year

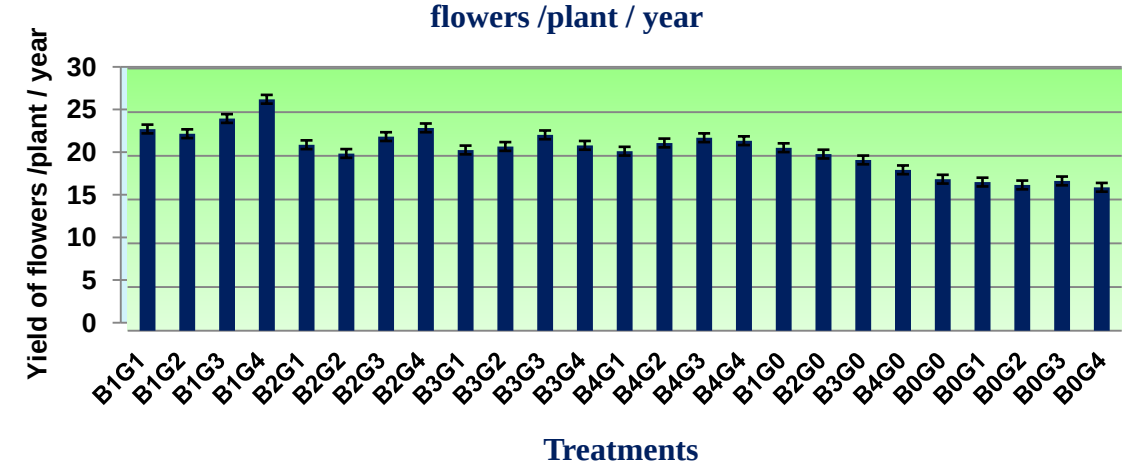


Fig 12. Effect of bending and growth regulators on mean yield of flowers /m^2 / year

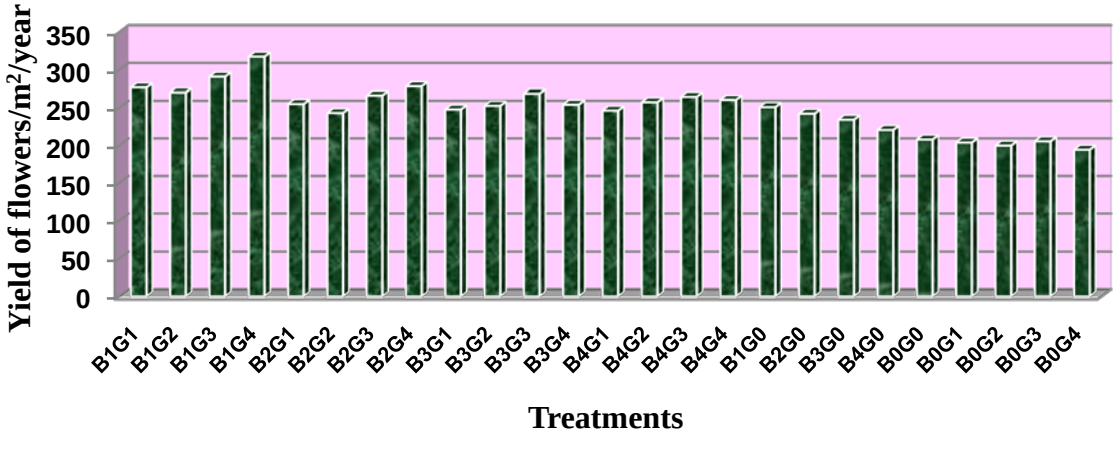
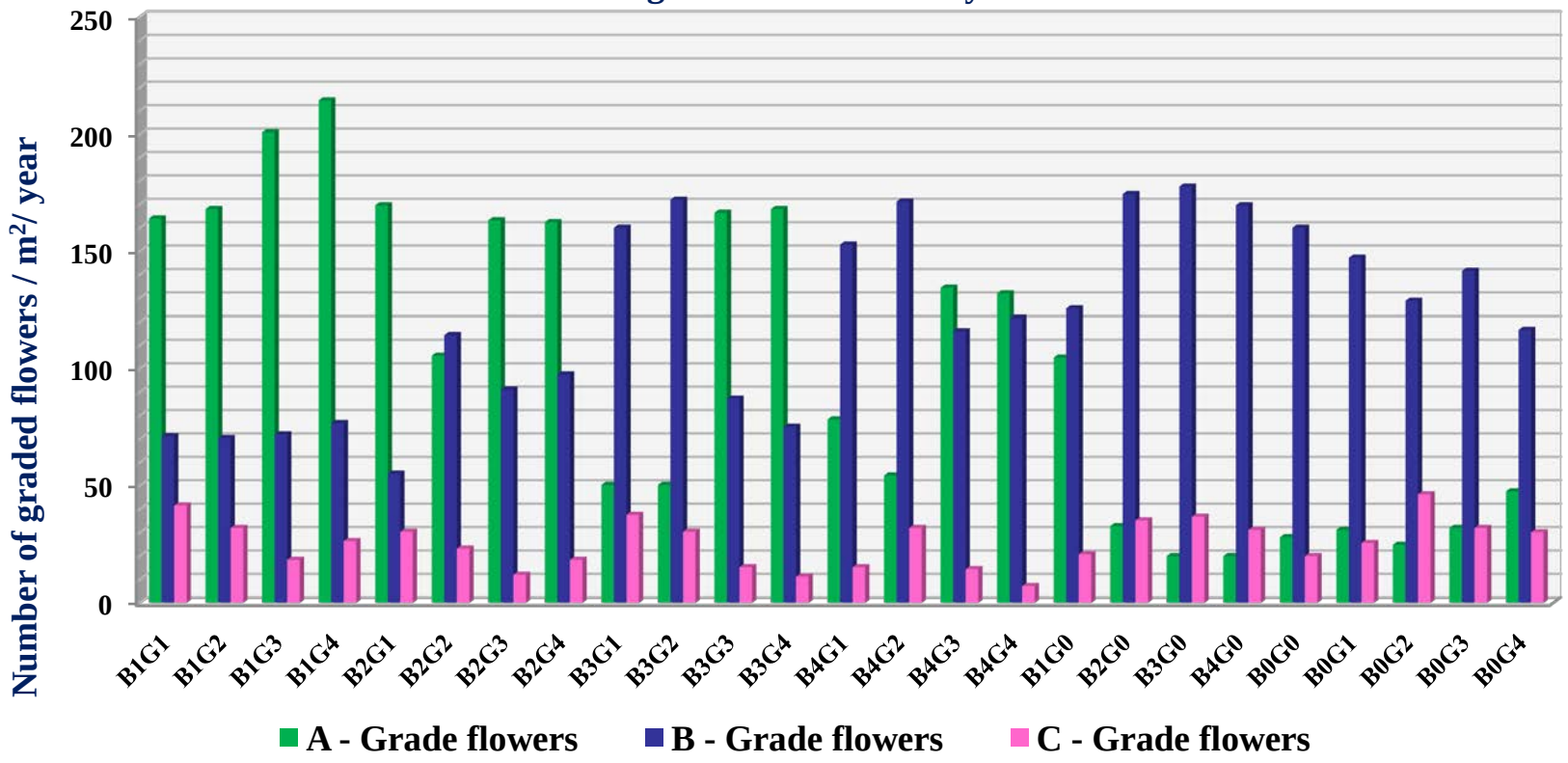


Fig 10.Effect of bending and growth regulators on number of graded flowers / m^2/ year



BA causes increase in photosynthesis through the action of cell division and enhances better vegetative growth of plant. Patil *et al*. (2012) recorded 26.80 flowers by foliar application of BA 100ppm, 28.11 flowers under open field condition and combination of this treatment yielded 35.10 flowers in cv. Gladiator. Variation in flower yield was also observed previously in rose by Nagaraj (1996); Sindhu and Rameshkumar (2004) and Mantur *et al.* (2005).

A strong shoot with long shoot is a pre requisite for ideal rose cut flower as blooms. Which, fetch a better price in the market and accepted in the export market (Mukhopadhyay, 1990). This could be because of the convenience and beauty of such flowers in flower arrangement, strong consumer acceptance and increased vase life (Prince *et al*., 1980; Gothmare, 1993). In the present study, the B_1G_4 & B_1G_3 interactions recorded maximum days of vase life **(Fig .13 & Plate. 9a,b,c).** This might be attributed to the presence of higher amount of assimilates in the bottom portion of the shoots which enables to maintain the dry matter and respirable substates, especially in the flower petals which helps in extending the keeping quality of cut flowers with longer stems Coorts (1973). Halevy (1976) reported that the translocation of sugars from stem to corolla increased the water uptake and helped to maintain turgidity of the stem, thus prolonging the shelf life. The stem was said to possess increased sucrose inversion capacity aiding the increase in shelf life (Chin and Sacalis, 1977).

Cut flowers are living, actively metabolizing, heterogeneous organs composed of floral and foliar parts each of which may be at different physiological and developmental stage. The ageing processes accelerate in harvested flowers from their mother plants. To delay their ageing processes and subsequently increase their vase lives, post harvest treatment is crucial. This is because flowers take up about 80% of their water requirement within the first two hours after harvest. Delaying the rate of deterioration extends the quality and maintains the natural appearances of cut flowers (Tsegaw *et al.*, 2011). The termination of vase life of *Ipomoea tricolor* flowers is characterized by wilting even though they are constantly held in water (Kende and Baumgartner, 1974). The point of termination of vase life varies from the first sign of wilting and fading (Halevy and Kofranek, 1977) to the total death of flower (Salinger, 1975). Halevy and Mayak (1979) opined that the term vase life should represent the potential useful longevity of the flowers to consumer.

Fig 13. Effect of bending and growth regulators on vase life (days)

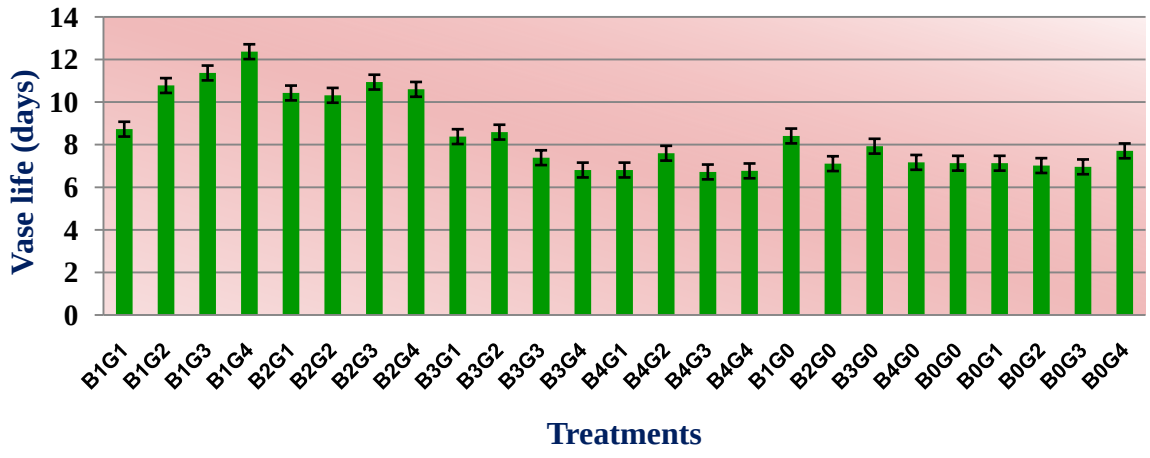


Fig 14.Effect of bending and growth regulators on total chlorophyll (mg/g)

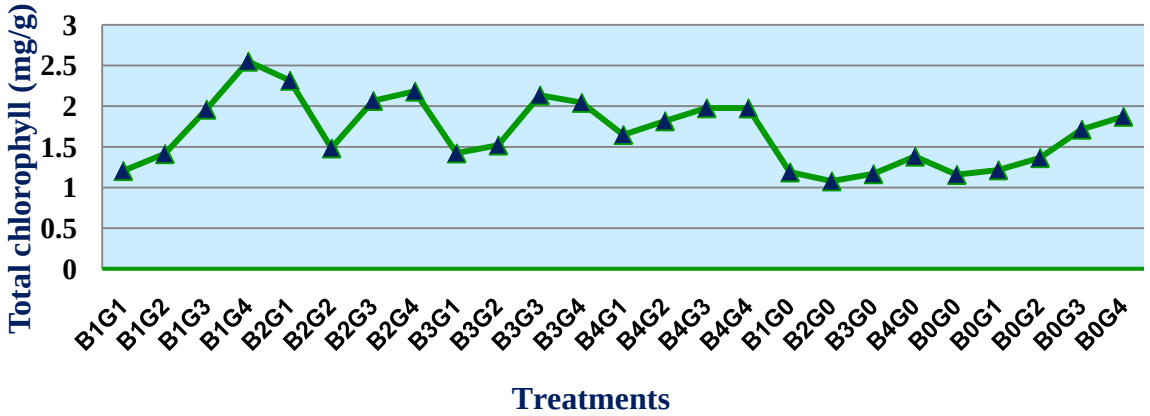
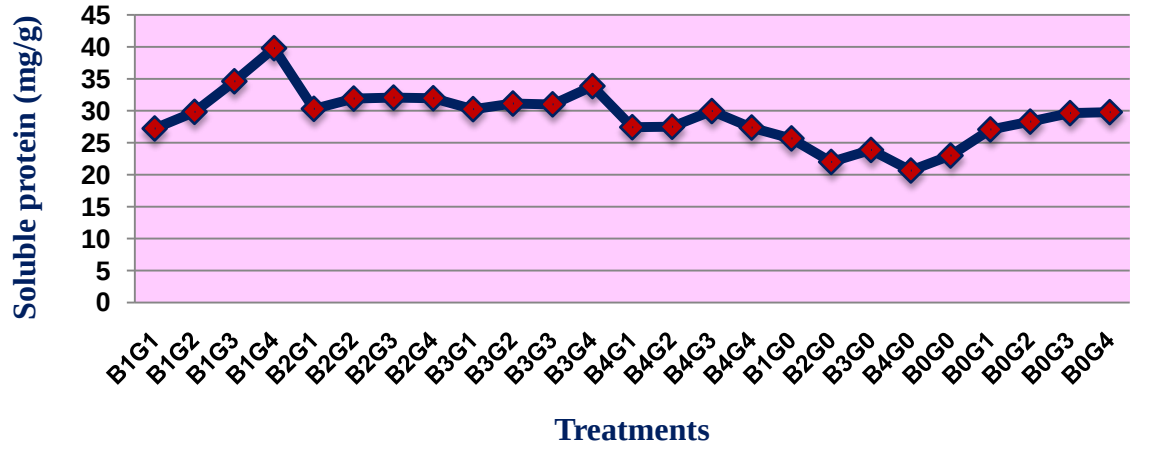


Fig 15.Effect of bending and growth regulators on Soluble protein (mg/g)



Flower longevity can be extended by providing three essential ingredients, namely biocide, sugar and acidifier. Growth regulators or hormones may be incorporated to the fresh flower foods to reduce leaf yellowing. Under normal conditions, cut flowers could last only for a few days maintaining their beauty and attractiveness. However, most of the people like to enjoy cut flowers in their natural beauty and appearances for a longer period of time having the socioeconomic value of flowers intact. Hence the use of preservative solutions to promote the quality and prolong the vase life of cut flowers. A source of repairable substrate is also very important for longevity of flowers (Rogers, 1973). The importance of water, sugar and various other chemical preservatives to promote the keeping quality of cut flowers, has been reported by several workers (Halevy and Mayak, 1979; Shobha and Gowda, 1993).

Prashant Paramagoudar (2010) studied the vase life of rose using different preservatives. But rose stems kept in aluminium sulphate at 300 ppm concentration remained fresh for longer period, recording significantly higher vase life 12.89 days over other treatments. This might be mainly because of increase in fresh weight up to fourth day and improved water balance by maintaining turgidity of the rose petals. Similar results were also reported by Divya *et al.* (2004), Madhubala *et al.* (2008) and Manjula (2005) in rose cultivars.

5.1.3 Effect of bending and growth regulators on histological parameters

Microscopic under (Scanning Electron Microscope) observations on cut stem and leaf stomata of interaction treatment (B_1G_4) showed anatomical changes by bending along with application of PGRs **(Plate.14 & 15).** The changes are due to increased cytokinin concentration in the xylem sap which promotes stomatal opening and simultaneously decreases sensitivity to ABA (Wilkinson and Davies, 2002). Larger protoxylem vessels can improve water and nutrient conduction in *Eriophorum vaginatum* (Cholewa and Griffith, 2004). Large phloem area can enhance the conduction of assimilates (Hose *et al*., 2001). In addition, higher stomatal density along with large stomata are closely linked to water-use efficiency as this influences stomatal conductance (Zhang *et al*., 2007). Stomatal responses to naturally occurring or synthetic cytokinins are variable (Pharmawati *et al*., 1998). Although cytokinins can increase stomatal

aperture, the apparent insensitivity of stomata to cytokinin application may be because cytokinin concentration is already optimal for stomatal opening (Incoll *et al*., 1987).

5.1.4 Effect of bending and growth regulators on physiological parameters

B_1G_4 interaction showed higher chlorophyll content in the leaves than control **(Fig.14).** The phenomenon of increased chlorophyll content due to bigger size stomata and increased photosynthetic efficiency observed in this interaction treatment. Chlorophyll, the pigment controlling photosynthetic system in crop plants was profoundly influenced by growth regulating chemicals. Higher number of leaves with large leaf area was recorded in greenhouse grown roses because of assimilation of more photosynthates in greenhouse. Muthu Kumar *et al.* (2012) recorded the highest total chlorophyll content (1.826mg g^{-1}) in cut rose cv. First Red by pre harvest spray of GA_3 at 100ppm. Similar reports on the influence of GA_3 on chlorophyll content had been reported by Sairam (1994) in wheat, Bhatia and Kaur (1997) in mung beans. The present study results were line with findings of Ramalingam (2008) in rose.

IAA is a prime bioregulator that regulates the apical dominance and initiation of vegetative and flower buds. The amino acid tryptophan and zinc content in leaves influence the IAA level. IAA oxidase is the enzyme responsible for destruction of auxin through the process of oxidation. Therefore, the enzyme activity causes reduction in auxin content and thereby increases the normal growth of the plant. At flowering stage, remarkable differences in IAA oxidase observed in various interactions. Similar results were reported by Vinodh (2012) in lilium.

The soluble protein content, an indicator of carboxylation process was higher in the period of active growth of plants. Results of the present study revealed that soluble protein content of leaf was influenced more by different levels of bending and PGRs concentration. The best treatment (B_1G_4) showed its profound influence on the soluble protein content of leaf **(Fig.15)**. The soluble protein content in leaves indirectly indicates the photosynthetic efficiency of the crop since it constitutes more than 70 per cent of the RuBP carboxylase, the enzyme responsible for CO_2 fixation in photosynthesis in *Gloriosa superba* (Balakumbahan, 2008).

High N level could enhance the protein synthesis throughout the growth by direct participation as an ingredient of protein. Level of soluble protein content is considered as an index for the assessment of photosynthetic efficiency. Mortazavi *et al*. (2007) reported that cytokinin increased the total protein content in rose comparison to control. Cytokinin increased total protein content by inducing the accumulation of amino acids and proteins in treated tissue. The effect of biostimulants on increased soluble protein content in leaves was already reported by Kanimozhi (2004) in brahmi. Similar findings were also reported in chrysanthemum (Ganesh, 2013).

The pathway of 'N assimilation' is considered the major route of conversion of inorganic form into a biologically useful organic form in plants. The primary step in 'N assimilation' involves reduction of nitrate to nitrite catalyzed by the enzyme 'Nitrate reductase'(NRase). Nitrite is sequentially reduced to ammonia by the enzyme Nitrite reductase which, in turn, is incorporated into amino acids. Activity of NRase in plants gives a good estimate of metabolic status of plants and is very often correlated with growth and yields (Srivastava, 1980). The 'Nitrate reductase' activity has been considered as an important factor in improving 'nitrogen use efficiency' of the crop and in turn, yielding ability.

Various interactions have increased the nitrate reductase enzyme activity of crop growth in the current study. The nitrate reductase favourably influenced the protein synthesis leading to improved productivity. Similar results were observed by Swapna (2010) in marigold. Utilization of N depends upon nitrate reductase enzyme and high activity of this enzyme has been related to increase in yield and protein content of *Gloriosa superba* (Balakumbahan, 2008).

The total phenol content in the present study was the highest in B_1G_3 & B_1G_4 treatments, than the control. The accumulation of phenols might be due to the excess production of hydrogen peroxide by increased respiration (Farkas and Kiraly, 1962) or due to the activation of hexose monophosphate (HMP) shunt pathway, acetate pathway and release of bound phenols by hydrolytic enzymes (Goodman *et al.,* 1967). The depletion in sugar level is also responsible for the accumulation of phenols since the sugars are utilized for the synthesis of phenols (Fruton and Simmonds, 1960). Phenols

play an important role in determining resistance or susceptibility of a host to parasite infection (Vidhyasekaran, 1998 a and b). Lignin is the phenolic polymer which is difficult to be breached by pathogen and has been implicated in plant defense against pests and diseases (Nicholson and Hammerschmidt, 1992).

Peroxidase enzyme is ubiquitous in plants and at the site of the cell walls, it participates in lignin biosynthesis. It scavenges excess amount of H_2O_2 formed in plant cells under normal and stress conditions. The present study revealed that peroxidase activity was similar in all interactions. This could be related to decrease in water potential and stomatal closure resulting in an increased production of active oxygen (Syherri *et al*., 1993). Peroxidase is a key enzyme in the biosynthesis of lignin which limits the extent of pathogen spread (Bruce and West, 1989).

Increased peroxidase activity has been shown in a number of resistant interactions involving plant pathogenic fungi, bacteria and viruses (Chen *et al*., 2000; Nandakumar *et al*., 2001 in rice by plant growth promoting rhizobacteria; Kandan *et al*., 2002 in tomato by *Pseudomonas fluorescens*). Peroxidase is an important multifunctional enzyme that reflects environmental and physiological stresses. So, sensitive plants showed the increase of peroxidase activities under stress conditions in sesame (Fazeli *et al*., 2007). The results of the present study were in line with the findings of Thakur *et al.* (2014) in rose cv. Poison.

The stability of anthocyanin pigments is strongly correlated with the value of vacuolar pH, which increases during flower senescence (Mazza and Miniati, 1993). Furthermore, anthocyanins are oxidized by peroxidases whose activity increases under the effect of oxidative stress, which is correlated with flowers senescence in *Brunfelsia calycina* (Vaknin *et al*., 2005). In the present study maximum anthocyanin content observed in B_1G_3 & B_1G_4 treatments. This may be due to the application of BA which enhances the physiological activity. Recently it has been shown that in darkness, cytokinin induces stomatal opening by decreasing H_2O_2 levels and NO levels within guard cells (She and Song, 2006; Song *et al.,* 2006 in *Vicia faba*). Muthu Kumar *et al*. (2012) reported that GA_3 application at 100ppm increased the anthocyanin content in flowers having an optical density value (0.1970). Similar findings were also reported by

Dahab *et al*. (1987) in chrysanthemum, Goyal and Gupta (1994); Arun (1999) and Ramalingam (2008) in rose.

5.2 Experiment II: Optimization of fertigation schedule in Dutch rose along with the application of micronutrients and *Bacillus spp* for improved growth, yield, quality and disease management

Fertigation has gained popularity in developed countries and it could help in long way for efficient and uniform application of both water and fertilizers with minimum labour input. Drip irrigation and fertigation resulted in great success by increasing wide range of yield in horticultural crops. By introducing fertigation, it is possible to increase the yield potential by two times with the same quantity of water, saving around 45 to 50 per cent of irrigation water and increasing the productivity by 40 per cent. It was observed that yield could be increased in addition to saving of fertilizer up to 30 per cent through fertigation. While the requirements for macronutrients namely N, P, K has been standardized by earlier workers. However, the studies relating to the influence of micronutrients on this crop are still lacking. Micronutrients are known to involve in all metabolic and cellular functions like energy metabolism, primary and secondary metabolism, hormonal synthesis and signal transduction etc. (Hansch and Mendel, 2009).

Combined application of bio control agents along with micronutrients has synergistic effect on plant growth development and disease reduction. Bio-control agents not only control the disease but also enhance the root and plant growth by way of encouraging the beneficial soil microflora which helps in the volatilization and sequestration of certain inorganic nutrients. Hence, understanding the influence of fertigation doses along with foliar spray of micronutrients and soil and foliar application of *Bacillus spp.* on Dutch rose var. Tajmahal for growth and production becomes inevitable. Integrated supply of micronutrients along with macronutrients in adequate amounts and suitable proportions is one of the most important factors that control the plant growth in flower crops (Zende, 1996). With the above background, the present investigation was designed to determine whether fertigation doses along with micronutrients and *Bacillus spp* could increase yield and quality of flowers in cut rose.

The effects of different treatment combinations were assessed and the results are discussed below.

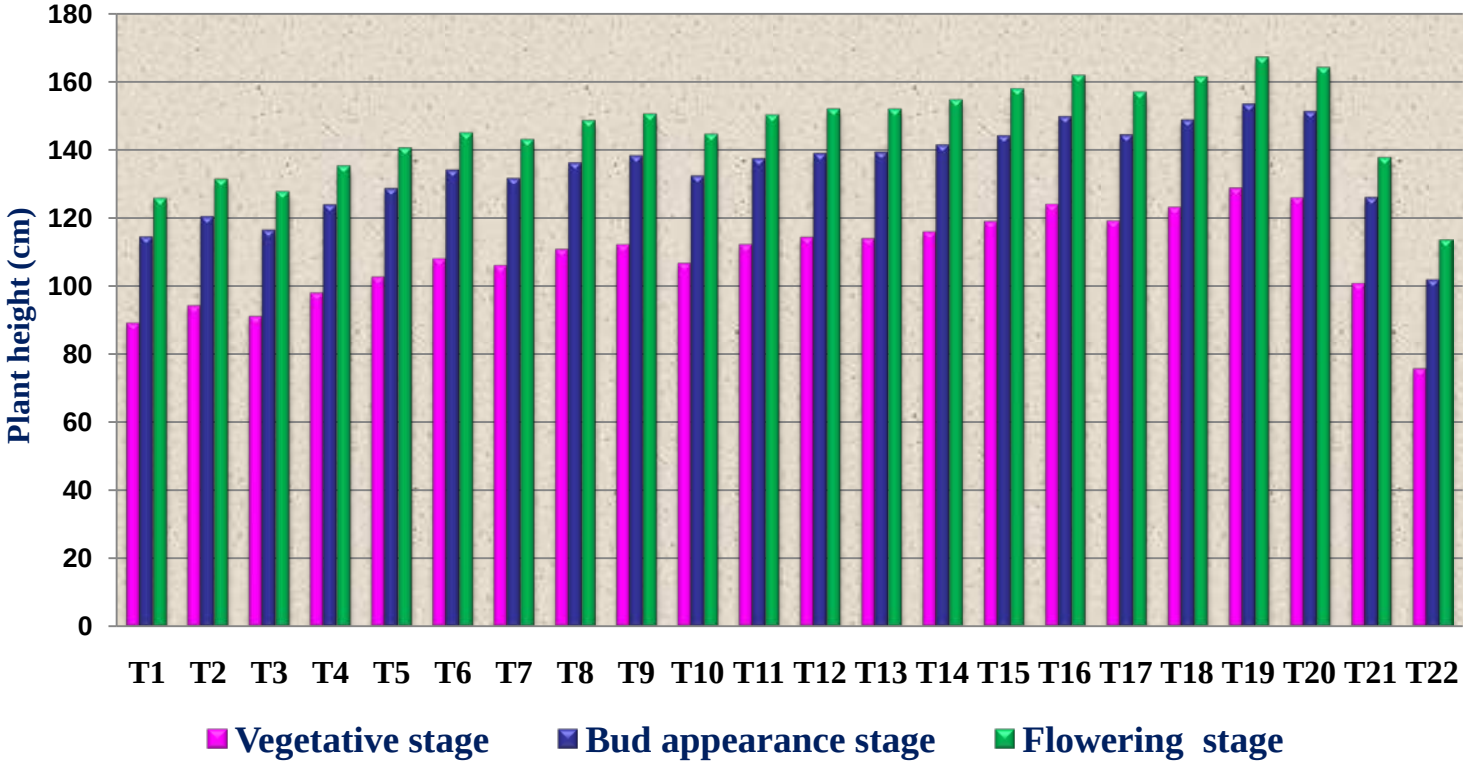
5.2.1 Effect of fertigation, micronutrients and *Bacillus spp* on growth parameters

Various growth parameters *viz.,* plant height, number of compound leaves, number of basal shoots, plant spread, inter nodal length, total number of shoots after pruning were variably influenced by the effect of fertigation, application of micronutrients and *Bacillus spp*.

There are different types of factors that affect the growth and development of rose plants. In intensive greenhouse production (controlled environment condition), improving yield and quality of flower is necessary. Plant height is an important growth related morphological character and plays an important role in plant duration and productivity of any flower crop. In the present investigation, the height of the plant varied significantly among different treatments. The treatment T_{19} (125% of recommended dose of fertilizers @ 208:104:104 g NPK / m^2 / year + 0.5 % EDTA micronutrient mixture + *Bacillus megaterium* + *Bacillus amyloliquefaciens each* @ 10 ml/m^2 foliar application at 10 days interval) were significantly influenced the plant height at all the three stages **(Plate.22 & Fig. 16).** This might be due to frequent application of fertilizers at convenient intervals and soil and foliar application of *Bacillus spp*, which increases the available nutrient status in the root zone thus increasing the uptake of nutrients and further influencing the growth of the plant. The *Bacillus spp* have principal mechanisms of growth promotion include production of growth stimulating phytohormones, solubilization and mobilization of phosphate, siderophore production, antibiosis, i.e., production of antibiotics, inhibition of plant ethylene synthesis and induction of plant systemic resistance to pathogens (Richardson *et al*., 2009; Idris *et al*., 2007; Gutierrez-Manero *et al*., 2001). Qasim *et al*. (2008) applied NPK (500 ml at 2 days interval) and recorded increased plant height (65.16cm) in rose. The findings of present study were confirmed by the studies of Palai *et al.* (2002) who observed desirable plant height in rose cv. Montezuma. Similar results were also reported by Gurav *et al*. (2004b) and Chaudhari *et al*. (2010) in rose.

Leaves are the functional units for photosynthesis, which greatly influence the growth and flower yield of many crops. Leaves serves as the index of measurement of

Fig 16. Effect of fertigation, micronutrients and *Bacillus spp* on plant height (cm)at different stages



vegetative growth and in determining the yield potential. Number of leaves produced per plant varied significantly among the treatments studied. Maximum number of compound leaves per plant was produced in T_{19} (125% of recommended dose of fertilizers @ 208:104:104 g NPK / m^2 / year + 0.5 % EDTA micronutrient mixture + *Bacillus megaterium* + *Bacillus amyloliquefaciens each* @ 10 ml/m^2 foliar application at 10 days interval) at all the stages of the crop growth **(Fig .17& Plate.17).** This could be attributed to the profound effect on the vegetative growth of rose by increased nutrient uptake, photosynthesis, source-sink relationship and stomatal opening by application of BA. Jagtap *et al*. (2012) recorded maximum number of leaves per plant by spray of each 0.3 % of $ZnSo_4$ + $MnSo_4$ + $FeSo_4$ in rose. It was supported by Ashok and Rengasamy (2000) in rose. The findings in the present study are in agreement with the findings of similar variation in rose reported by Jadhav *et al*. (2003) and Singh *et al*. (2006).

Basal shoot is a very important parameter for production of more branches and flowering shoots. With respect to number of basal shoots per plant, it has shown significant differences among the treatments in rose. T_{20} (150% of recommended dose of fertilizers @ 250:125:125 g NPK /m^2 / year + 0.5 % EDTA micronutrient mixture + *B. megaterium* + *B. amyloliquefaciens* each @ 10 ml/m^2) recorded maximum number of basal shoots and these results were at par with T_{19}, which might be due to the bottom breaks with apical dominance during bending at young stage of plants which enhanced the production of basal shoots. Gurav *et al*. (2005) recorded more number of flowering shoots/plant (4.40) by treating 400:200: 200 ppm NPK/plant/week. Maximum branches $plant^{-1}$ were also reported by Katsoulas *et al*. (2006) in *Rosa hybrida* cv. First Red. The results of the present study was in accordance with the study of Ramalingam (2008) who reported the highest number of shoots per plant (3.4, 4.3 and 7.5) in rose.

Among the treatment maximum plant spread was recorded in T_{19} (125% of recommended dose of fertilizers @ 208:104:104 g NPK / m^2 / year + 0.5 % EDTA micronutrient mixture + *Bacillus megaterium* + *Bacillus amyloliquefaciens each* @ 10 ml/m^2 foliar application at 10 days interval. (**Fig.18).** The major and minor elements, frequent supply of sufficient nutrient, micro-organisms and physiological actions of BA (cell division and cell enlargement) might have favoured in initial vigour and better metabolic activities especially with the production of photo assimilates. These assimilates

Fig 17. Effect of fertigation, micronutrients and *Bacillus spp* on number of compound leaves /plant at different stages

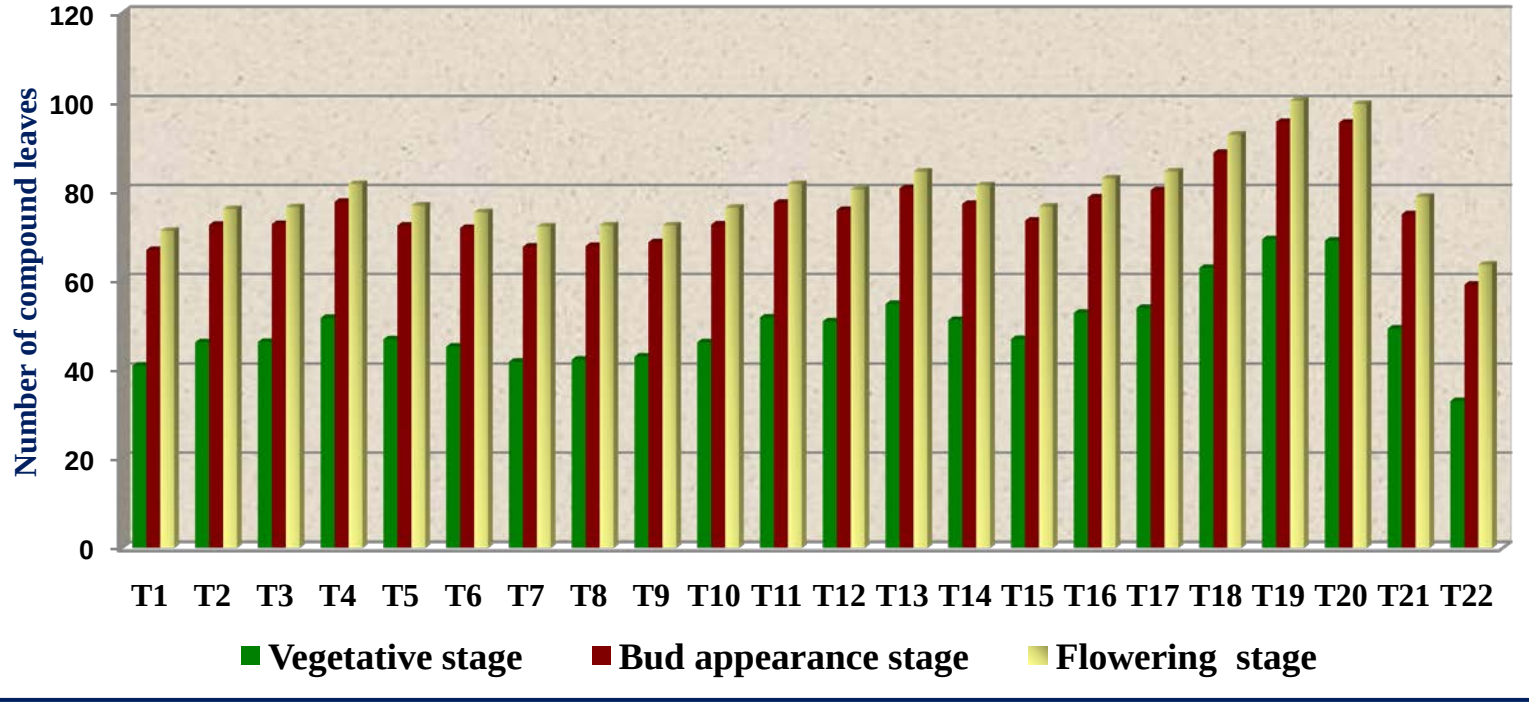


Fig 18. Effect of fertigation, micronutrients and *Bacillus spp* on plant sppread (cm^2)

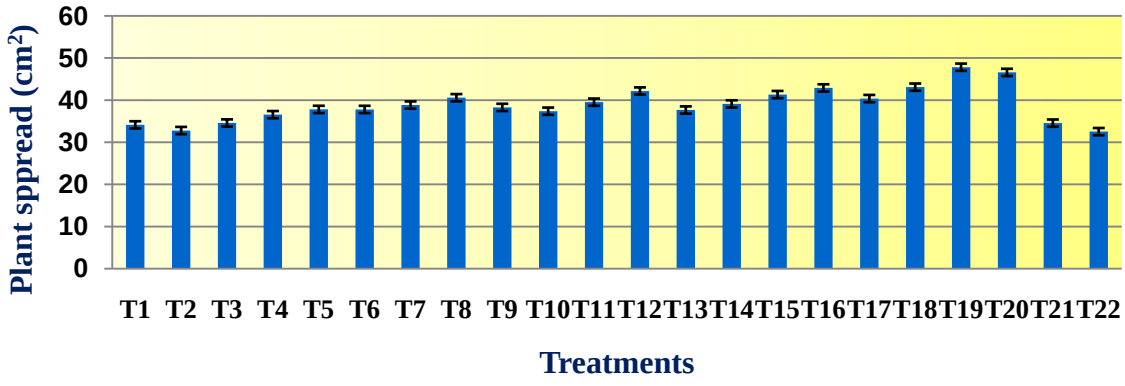


Fig 20. Effect of fertigation, micronutrients and *Bacillus spp* on length of flowering shoot (cm)

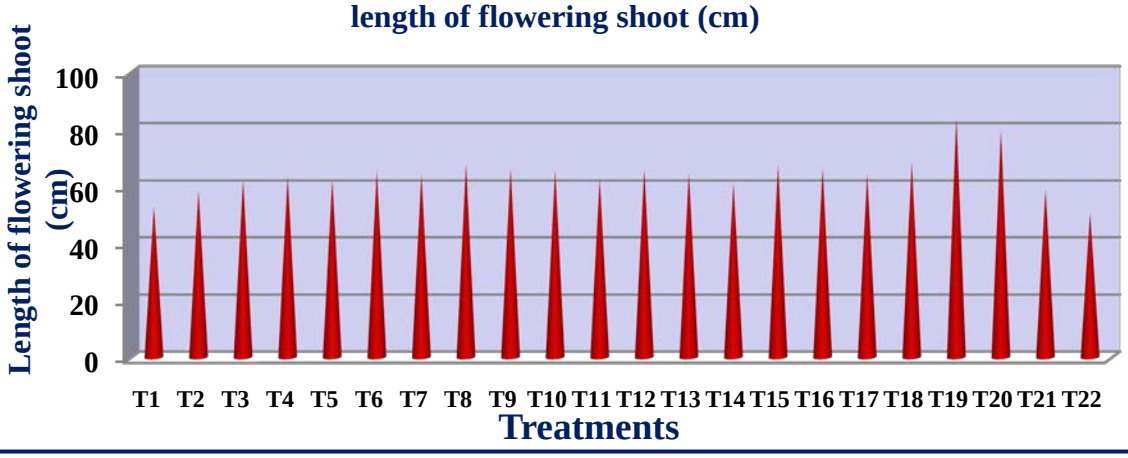
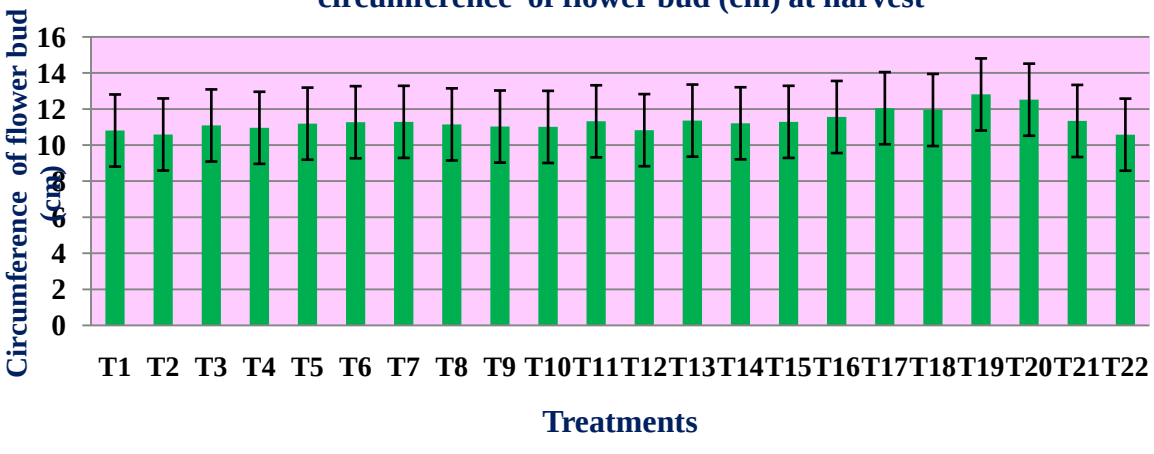


Fig 21. Effect of fertigation, micronutrients and *Bacillus spp* on circumference of flower bud (cm) at harvest



would have favoured production of more leaf numbers, ultimately increasing the leaf area and plant spread. Ahmad *et al*. (2010) applied micronutrients and found that B 0.5 % + Zn 1.5 % combination produced maximum leaf area (62.45 cm^2). Haq *et al*. (1999) recorded more plant spread (99.00 cm) in a fertilizer study in rose. Similar results were obtained by Chaudhari *et al.* (2010) who studied bio and nitrogen fertilizers on growth and yield of rose and recorded maximum plant spread (N-S- 95.20 cm) and (E-W- 100 cm) in rose. The results were supported by Patil *et al*. (2012) who found that BA 100 ppm in open field conditions registered maximum plant spread (N-S- 81.28 cm) and (E-W- 87.03 cm) in rose cv. Gladiator.

The internodal length is also an important parameter contributing significantly towards the quality of stem length. In the present study, T_{19} (125% of recommended dose of fertilizers @ 208:104:104 g NPK / m^2 / year + 0.5 % EDTA micronutrient mixture + *Bacillus megaterium* + *Bacillus amyloliquefaciens each* @ 10 ml/m^2 foliar application at 10 days interval) produced highest intermodal length. T_{19} which produced more number of leaves and more plant spread might have an indirect contribution to the inter node elongation. Foliar spray of BA 200 ppm might have promoted stomatal opening and increased the photosynthates simultaneously which favoured elongation. Wachowicz *et al*. (2006) studied the effect of growth regulators on stomatal aperture in senescing cut leaves of *Zantedeschia aethiopica* and Hosta. The stomata aperture was higher (about 21%) in *Zantedeschia* and 44% in *Hosta* cut leaves treated with GA_3 and BA respectively, as compared to water (control). Cytokinins are often considered ABA antagonists in many processes including the regulation of stomatal opening, but the effects are species specific and depend on cytokinin type, concentration and method of application (Pospisilova, 2003). Maximum inter nodal length (8.6 cm) observed in the present study are comparable with the findings in *Araucaria heterophylla* by Gul *et al*. (2006).

Total number of shoots after pruning was maximum in T_{20}. The higher number of shoots after pruning might be due to absorption of higher N rate, water and nutrients, synthesis of some plant hormones by root system. Further, higher plant spread accumulated more carbohydrates which ultimately used to increase number of shoots per plant (Patil *et al*., 2012). Under drip fertigation, nearly 80 per cent of the roots were concentrated at upper soil profile (0 to 15 cm) with less root length because of the lesser

depth of irrigation and continuous availability of moisture in top layer as confirmed by Swapna (2010) in marigold and Bini Sundhar in jasmine (2011). Qasim *et al*. (2008) applied NPK (500 ml at 2 days interval) and recorded maximum number of shoots (7.16) in rose. The results of the present study are in line with the study made by Ghafoor *et al*. (2000) in rose.

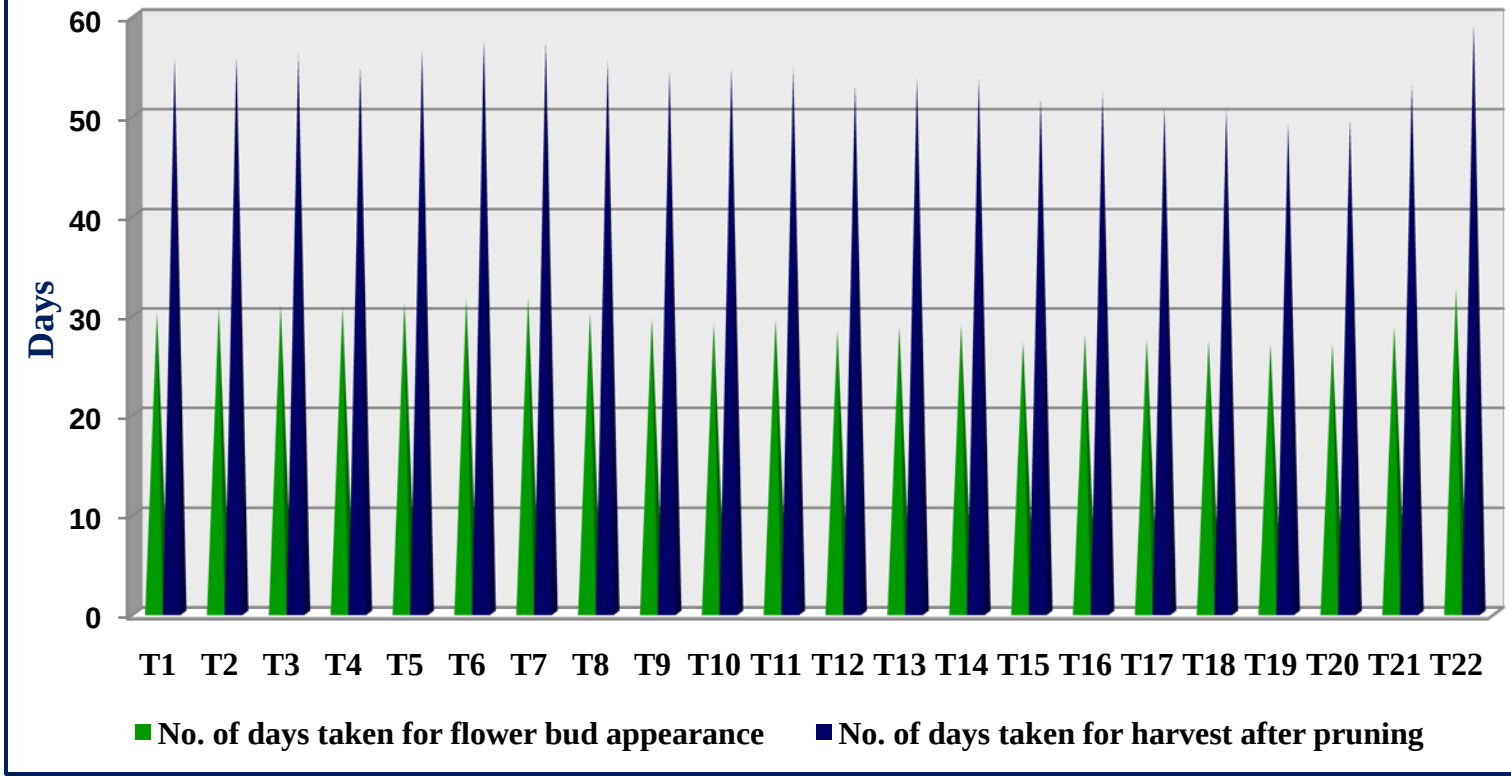
5.2.2 Effect of fertigation, micronutrients and *Bacillus spp* on flowering parameters

In general, the flowering and yield parameters of any crop are determined by various yield components. Flowering and yield parameters *viz*., earliness in shoot emergence, days taken for flower bud appearance, harvest from flower bud appearance, number of compound leaves per flowering shoot, length of flowering shoot, pedicel length, circumference of flower bud, stem girth, weight of flowering shoot, number of quality grade flowers, cut stem yield / m^2 and vase life are influenced by different levels of fertigation and other nutrients.

Earliness of shoot emergence on pruned plants was found in T_{19}. The minimum days might have an indirect role which aids to favourable source - sink relation with faster and more efficient mobilization of photosynthates. The reason may be due to the improved efficiency of the applied macro and micronutrients and their good effects on the sprouting of the vegetative buds. The findings are in agreement to those reported by Ghaffoor *et al*. (2000).

Days to flower bud appearance is an important character, which decides the early yield (precocity) of the crop. Early commencement of flower buds were noticed in T_{19} which might be due to the combined effect of N, P, K through fertigation and spray of micronutrients, *Bacillus spp* creating a conducive source sink relationship **(Fig.19& Plate.18).** Application of nitrogen encourages the formation of new cells, cell division and cell elongation. This results in vigorous growth of root system which ultimately helps in better absorption and utilization of nutrients from soil solution by applied microorganisms, which reflected in terms of better plant growth. Further, higher total leaf area and plant spread observed in the treatment T_{19} might be due to increased photosynthetic activity, which ultimately increased the carbohydrates and thus, increase in C: N ratio, which had induced early flowering (Dutta, 1994). Moreover, another possible reason that could have been attributed to early flowering is the abundant availability

Fig 19. Effect of fertigation, micronutrients and *Bacillus spp* on flowering parameters



of phosphorus in the soil that would have led to the induction of early flowering. This was confirmed by the reports of Beniwal *et al*. (2005) in chrysanthemum. Patil *et al*. (2012) recorded minimum days (31.05) required for first flower bud initiation in rose cv. Gladiator. The findings of the present study are in accordance with the results of Singh *et al*., 2003; Patel *et al*., 2007 and Chaudhari *et al*., 2010 in rose.

In the present study, minimum number of days taken for harvest from flower bud appearance after pruning was noticed in T_{19}. The possible reason for the earliness might be due to the effect of N, P, K and micro nutrients, being a constituent of proteins, amino acids, nucleic acid, various enzymes and coenzymes which are associated with the increased shoot length and leaf area resulted in more photosynthesis and thus increased the transformation of manufactured food material from source (leaf) to sink (flower bud). This would help in the early transformation to bud initiation. The nutrient movement from source to sink would have been done in a consistent manner and made the nutrient flow to all plant parts for quick development of bud to flower for harvest. Singh *et al*. (2006) recorded minimum days for flowering in rose. Ramalingam (2008) recorded lowest number of days for flower harvest in cut rose cv. Happy Hour. Similar findings were reported by Vieanny Jennifer (2010) in rose var. Hollywood.

In the present study, treatment T_{19} (125% of recommended dose of fertilizers @ 208:104:104 g NPK / m^2 / year + 0.5 % EDTA micronutrient mixture + *Bacillus megaterium* + *Bacillus amyloliquefaciens each* @ 10 ml/m^2 foliar application at 10 days interval) taken minimum days for first flower harvest compared to other treatments **(Fig.19 &Plate.19).** This might be due to the interaction effect of zinc and boron which is in conformity with the results of Misra (2001) in chrysanthemum. All micronutrients combination might have also played a positive role for the early flower bud opening as reported in carnation by Naggar (2009). Increased photosynthesis and respiration along with enhanced photosynthates in plants also could be responsible for early flower emergence. Early flower emergence in roses in response to NPK @ 300 ppm was also observed by Palai *et al*. (2002).

The treatment (T_{19}) produced more number of compound leaves per flowering shoot. Leaves also possess very important quality attributes for cut rose for various

purpose. Leaves are the functional units for photosynthesis, which greatly influence the growth and yield of many flower crops. More number of leaves and maximum length of flowering shoot are correlated with each other. Higher number of leaves remaining on the parent shoot resulted in a higher assimilate production for the outgrowth of the buds (Marcelis-Van Acker, 1994b). Micronutrients play a vital role in production of vegetative growth and ultimately encourage the number of primary branches, secondary branches, leaves and shoots of plants by involving in oxidation reduction and photosynthesis process. These findings are in close proximity with the results of Sabale *et al*. (1992) in rose. Ahmad *et al*. (2010) applied micronutrients and found that B 0.5 % + Zn 1.5 % combination produced more number of leaves (28.41) in rose. Jagtap *et al*. (2012) recorded maximum number of leaves per shoot in rose var. First Red with foliar application of 0.3 % of $ZnSo_4$ + $MnSo_4$ + $FeSo_4$ each.

Stem length is the most important quality parameter and primary indicator for production of cut flower rose. Shoots with length lower than 30 cm could be considered unmarketable, shoots with length between 30 and 60 cm could be considered as medium quality and shoots longer than 60 cm could be considered relatively of high quality. Long stalk for cut roses are pre requisite in the international market. The results of the study indicated that increased shoot length in treatment T_{19} (125% of recommended dose of fertilizers @ 208:104:104 g NPK / m^2 / year + 0.5 % EDTA micronutrient mixture + *Bacillus megaterium* + *Bacillus amyloliquefaciens each* @ 10 ml/m^2 foliar application at 10 days interval) **(Fig.20 & Plate.20)** might be due to the effect of micronutrients which plays an important role involving in photosynthesis, break down of IAA, auxin and protein synthesis. Increased physiological activity and productive process through foliar application of micronutrients were also reported by Bhattachajee (1993) and Kewate and Sabale (1997) in rose. Man Bihari *et al*. (2010) recorded maximum length of flowering stem in (pruning at one bud + soil applied bio-fertilizers + vermi-wash foliar spray) rose cv. Rakta Local. The findings of present study were thus in accordance with the results of Jagtap *et al*. (2012) who recorded maximum length of flowering shoot (70.92 cm) in rose var. First Red with foliar application of 0.3 % of $ZnSo_4$ + $MnSo_4$ + $FeSo_4$ each. Ahmad *et al*. (2010) applied micronutrients and found that B 0.5 % + Zn 1.5 % combination produced

maximum stalk length in rose. The present research findings were also supported by Gurav *et al*. (2004b and 2005) in rose.

Among different treatments, T_{19} and T_{20} produced longest length of flower bud and pedicel length at harvest compared to other treatments. The possible reasons for the bud length may be due to disbudding and de-shooting during bud developmental stage.

The combination effects and frequent availability of macro nutrients through fertigation and micronutrients through foliar spray with help of *Bacillus spp* would have helped in solublizing the nutrients. The translocation of photosynthates from source to sink is very important for the development of economic part (Amanullah *et al*., 2010). Pedicel length is a vital character responsible for elegance of the flower, setting apart the flower from the foliage. Jagtap *et al*. (2012) studied the effect of foliar application of micronutrients in rose and obtained similar results as that of present study. Mendhe *et al*. (2011) studied the effect of pruning levels and recorded maximum length of pedicel (pruning at 60 cm from ground level). This clearly indicated the necessity to provide combination of micronutrients to enhance the beneficial effects. Similar effects have also been documented in marigold and gladiolus by Prabhat Kumar and Arora (2002). The findings of present study are in agreement to those reported by Ghaffoor *et al*. (2000) and (Fascella and Zizzo, 2005) in rose.

In the present investigation, treatment T_{19} produced maximum circumference of flower bud **(Fig. 21).** The possible reason might be retention of more number of leaves which accelerates photosynthetic efficiency for more photosynthesis and thus increased the transformation of manufactured food material from source (leaf) to sink (flower bud). The applied N and K also played role in increasing the flower size. Good vegetative growth as measured through plant height, number of leaves and leaf area is indicative of better uptake of nutrients which in turn is used in synthesis and utilization of carbohydrates during vegetative growth. This energy was distributed among other flower parts at reproductive phase (Malhotra and Kumar, 2000). This may be assigned to early breaking of apical dominance followed by easy and better translocation of nutrients to the flowers brought about by inoculation with beneficial microbial inoculants. The positive effect of vermicompost on flower diameter has been reported in marigold (Mashaldi, 2000).

Chinnaswamy and Kulandi (1966) also reported that improved nutritional environment in the rhizosphere as well as its utilization in the plant system enhanced translocation to reproductive structures *viz*., flowers and other plant parts in tomato. Mona *et al*. (2010) studied the response of *Schefflera arboricola* plant to foliar fertilizer spray which increased all growth parameters significantly specially flower diameter. Mostafa (1996) studied the effect of B, Mn and Mg on the growth of carnation & found increased flower diameter. Present research findings are in line with the results of Viradia and Singh, 2004; Ahmad *et al*., 2010; Man Bihari *et al*., 2010 and Patil *et al*., 2012 in rose.

Stem girth is a very essential parameter for cut flowers to possess a strong stem of sufficient strength to hold bloom firmly erect (Malik, 1968). Stem girth indicates the sturdiness of the cut flowers. In the present investigation stem girth was maximum in T_{19} and T_{20} **(Fig .22)**. The occurrence of variation in stem girth might be due to foliar feeding of micronutrients combined with fertigation levels. Foliar feeding of nutrients may actually promote root absorption of the same nutrient or other nutrients through improving root growth and increasing nutrients uptake in wheat (Saqib *et al*., 2006). Ahmad *et al*. (2010) recorded mixture of B 0.5 % + Zn 1.5 %+ Fe 1% micronutrients in rose cv. Rosy Cheeks produced maximum stalk diameter. Present research findings are in accordance with the results of Patil *et al*., 2012 and Jagtap *et al*., 2012 in rose.

Among the fertigation levels, more weight of flowering shoot was observed in T_{19} treatment. This might be due to longer stem length, more stem girth, bigger sized flower, and higher petal weight of flower. Variation among the fertigation levels was mainly because of increased flower size with prominent stalk length and also due to presence of fairly more number of well developed petals. The application of BA enhances the physiological action of cell division and cell enlargement (Pandey and Sinha, 2004). These results could be explained through the role of BA in increasing the width of conductive tissues (xylem and phloem) and consequently increasing the absorption and translocation of the elements necessary for plant growth (Krishnamoorthy, 1981). Van-Steveninck (1976) stated that the influence of BA on the mechanism of ions uptake may be related to its effect on membrane permeability and rate of ion entry through the membrane, or enhance their translocation to the shoot in rose. Katsoulas *et al*. (2006) studied the effect of irrigation frequency on rose flower production and quality and

Fig 22. Effect of fertigation, micronutrients and *Bacillus spp* on stem girth (cm)

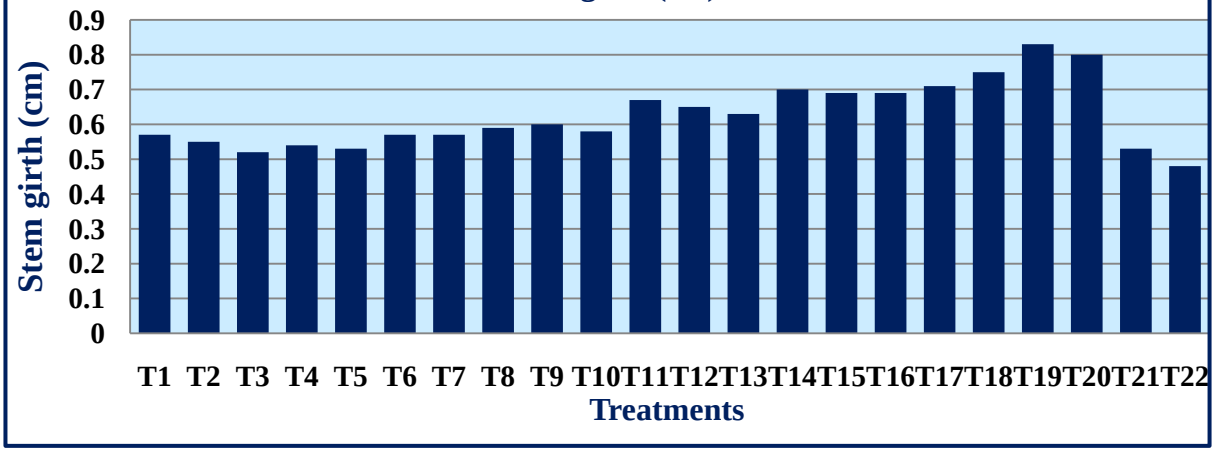


Fig 24.Effect of fertigation, micronutrients and *Bacillus spp* on mean yield of flowers / plant / year

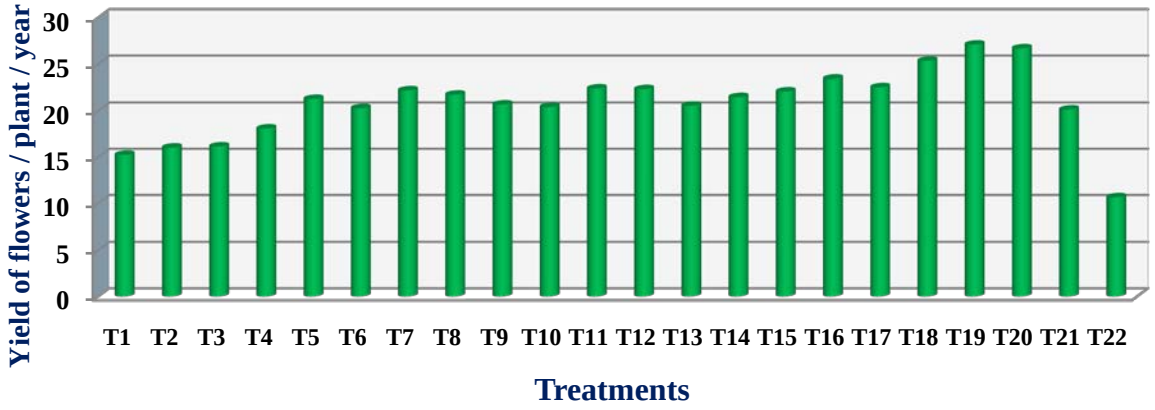
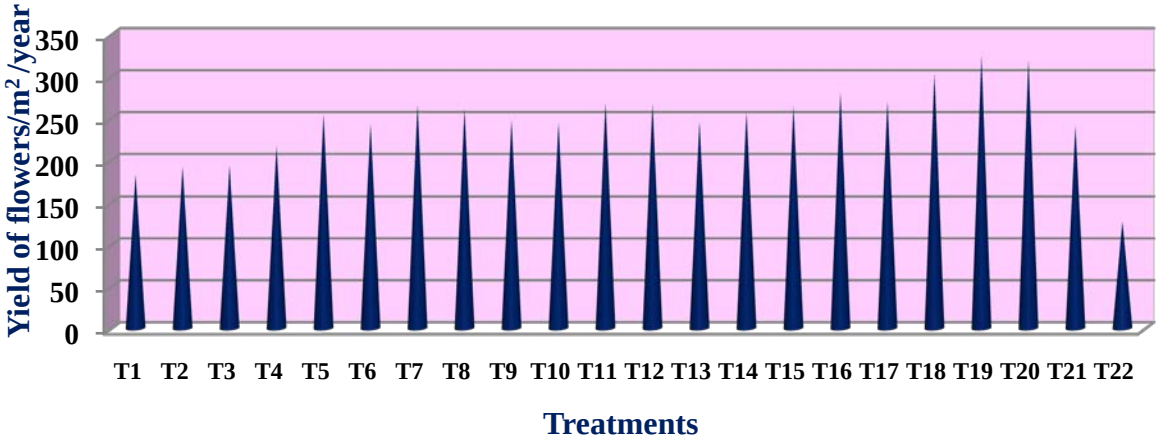


Fig 25. Effect of fertigation, micronutrients and *Bacillus spp* on mean yield of flowers/m^2 /year



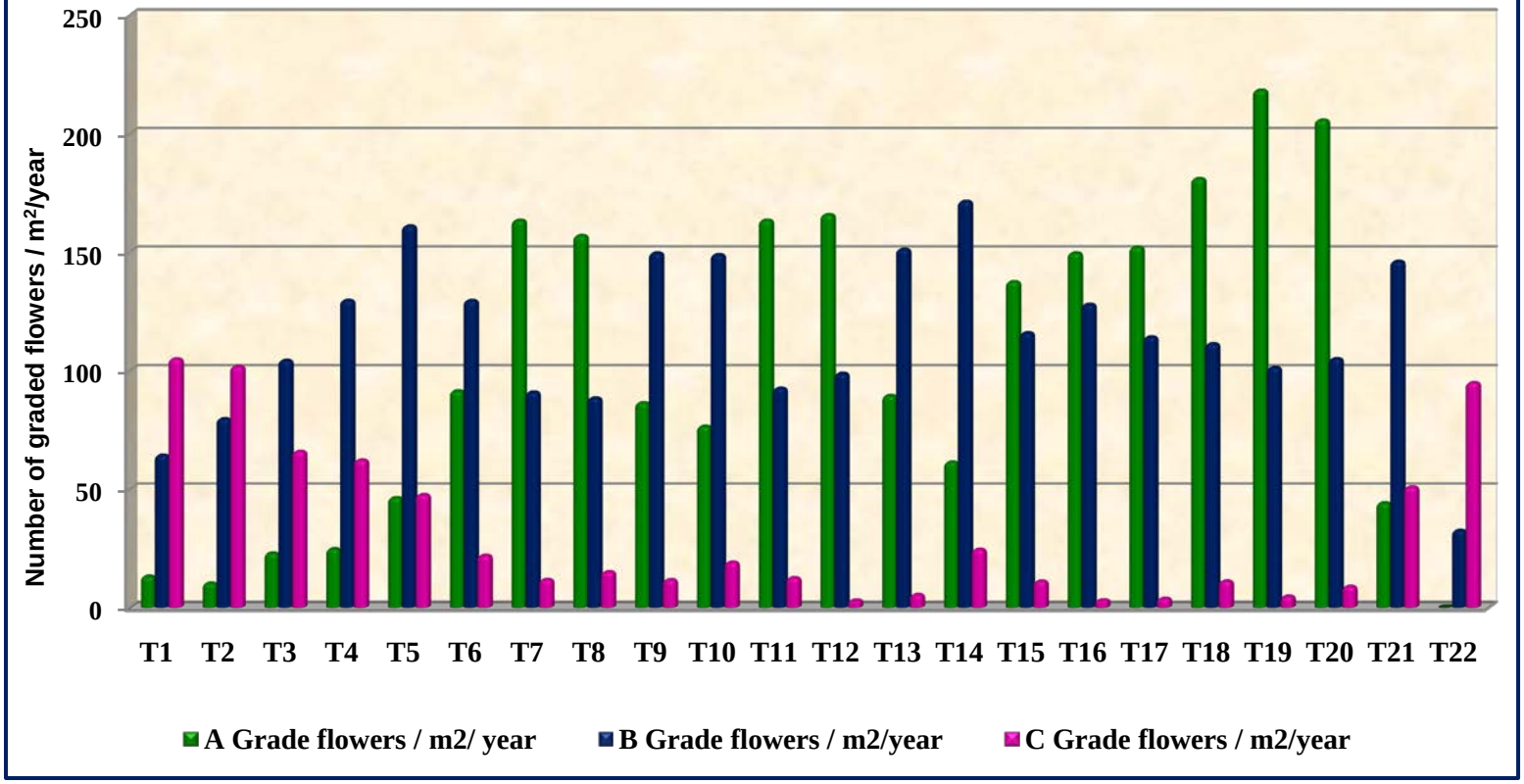
recorded more weight of flowering shoot (> 80 g) in *Rosa hybrida* cv. First Red. Similar findings were also reported by Patil *et al*. (2012) in rose.

Flowers are graded based on the stalk length and diameter of flower. Among the treatments, T_{19} produced maximum number of 'A' grade flowers **(Fig.23& Plate.24)** and the mean yield of flowers per plant **(Fig. 24)** was also maximum in this treatment. In the present investigation, higher yield might be due to the morphological parameters like plant height, more number of leaves and plant spread which help in production of more photosynthates resulting in greater accumulation of dry matter which inturn leads to production of more number of flowers per plant. Further, higher production of auxin and growth substances by micronutrients at early phase of growth would have contributed to more floral bud formation. This might possibly be due to reduced nutrient losses by leaching and efficient use of nutrients through fertigation, which has been well established by several workers (Singh *et al*., 2006 and Qasim *et al.,* 2008) in rose, (Shrikant, 2008) in gerbera, (Swapna, 2010) in marigold and (Bini Sundhar, 2011) in jasmine. Eid *et al*. (2010) reported the beneficial interaction effect of Zn and BA through foliar application at suitable concentrations on the flowering characteristics of tuberose. Patil *et al*. (2012) stated that BA causes increase in photosynthesis through the action of cell division and enhances better vegetative growth of plant. It was observed that combination of 175 ppm of K and N and P at 50 ppm produced the maximum number of flowers and plant height in roses (Gurav *et al*., 2002). Variation in flower yield was also observed previously in rose by Nagaraj (1996); Viradia and Singh (2004); Gurav *et al*. (2004a); Sindhu and Rameshkumar (2004) and Mantur *et al.* (2005). Jagtap *et al*. (2012) recorded similar results for flower yield by foliar application of each 0.3 % of $ZnSo_4$ + $MnSo_4$ + $FeSo_4$ in rose.

The characters like, shoot length, bud length, bud diameter, vase life and number of flowers were considered to be of prime importance (Primary characters) and should be more stressed upon as pre-requisites for cut flower purpose. Which, fetch a better price in the market and accepted in the export market (Hussein, 1955).

The above recorded yield contributing parameters of rose var. Tajmahal are improved by combined effects of macro and micro nutrients along with bio agents.

Fig 23.Effect of fertigation, micronutrients and *Bacillus spp* on number of graded flowers / m^2/year



Micronutrients plays an important role involving in photosynthesis, break down of IAA, auxin and protein synthesis. Increased physiological activity and productive process through foliar application of micronutrient were also reported by Bhattachajee (1993) and Kewate and Sabale (1997) in rose.

In the present study, the treatment T_{19} recorded extented days of vase life (**Plate.21a,b,c)**. This may be attributed due to the presence of higher amount of assimilates in the bottom portion of the shoots. (Malhotra and Kumar, 2000) Further, longer and thick stalk, bigger sized flower containing more carbohydrates decreased the respiration rate and enables to maintain the dry matter and respirable substrates, especially in the flower petals which helps in extending the keeping quality of cut flowers with longer stems (Coorts,1973). The vase solution which contains aluminum sulphate can decrease cut rose petal acidity and cause fixation of anthocyanin pigments and thus increase flower vase life (Tjeerd and Jaap, 2003; Hassanpour Asil *et al*., 2004). Sugars are essential precursors for cut flower respiration. Sucrose is the main transporting form of sugar to flower bud (Sarkka, 2005). In several experiments application of aluminum sulphate alone or in combination with sucrose have kept quality and vase life of cut flowers at post harvest stage (Hassanpour Asil *et al*., 2004; Ichimura *et al*., 2006). Seyf *et al.* (2012) studied the effect of aluminum sulphate (alone or with sucrose) on quality and vase life of cut rose flower at post harvest stage.

Prashant Paramagoudar (2010) studied the vase life of rose using different preservatives. But rose stems kept in aluminium sulphate at 300 ppm concentration remained fresh for longer period and recorded a significantly higher days of vase life over other treatments, this was mainly because of increase in fresh weight up to fourth day and it showed an improved water balance there by maintained turgidity of the rose petals. Similar findings were also reported by Divya *et al.* (2004) and Madhubala *et al.* (2008) in rose. Manjula (2005) also recorded similar results in rose cultivars.

5.2.3 Effect of fertigation, micronutrients and *Bacillus spp* on physiological parameters

The leaf chlorophyll content is an important physiological factor as it directly influence the photosynthesis and it occurs in chloroplast as green pigments in all photosynthetic tissues.

T_{19} (125% of recommended dose of fertilizers @ 208:104:104 g NPK / m^2 / year + 0.5 % EDTA micronutrient mixture + *Bacillus megaterium* + *Bacillus amyloliquefaciens each* @ 10 ml/m^2 foliar application at 10 days interval) registered significantly the highest chlorophyll 'a', 'b' and total chlorophyll contents. The plants of T_{19} enhanced the photosynthetic efficiency and helped to produce more carbohydrates for growth and development of the plants. These results are in conformity with the findings of Torre *et al.* (2001); Pettersen *et al*. (2006) and Qasim *et al.*(2008) in rose. In combination with micronutrients, it might have favoured the synthesis and accumulation of chlorophylls in plant system. Presence of iron would enhance the function of photosystem, ultimately increasing the chlorophyll content of leaves. This may also be ascribed to the indirect role of iron in chlorophyll biosynthesis. This might be due to better availability of N in the treatment, because N is the basic nutrient associated with the formation of chloroplast – protein complex, a necessary condition for chlorophyll biosynthesis (Ahloowalia *et al*., 2004; Theunissen *et al*., 2010). Magnesium, the chlorophyll molecule acts as an activator of photosynthesis and necessary for protein synthesis.

Hebbar *et al*. (2004) also revealed that being a constituent of chlorophyll, increased supply of nitrogen accelerate high synthesis of chlorophyll without altering the composition of chlorophyll a and b in tomato. Nitrogen along with phosphorous and potassium is the most recognized basic element required for most metabolic activities of the plants resulting in the synthesis of chlorophyll cytochrome which are essential for photosynthesis and respiration process of the plant. The phenomenon of increased chlorophyll content with increased nutrients as observed in the present study was also reported by several workers (Damke and Bhattacharjee, 1997; Virghine Tenzia, 2003 and Balasubramaniam, 2008 in tomato). Muthu Kumar *et al.* (2012) recorded the highest total chlorophyll content in cut rose cv. First Red. Present findings are in accordance with the results of Reezi *et al.*, 2009; Ahmad *et al.*, 2011; Rubinowska *et al.*, 2012; Kashefi *et al.*, 2012 and Talebi *et al.*, 2013 in rose.

IAA is a prime bioregulator that regulates the apical dominance and initiation of vegetative and flower buds. In this experiment, the fertigation levels in T_{19} (125% of recommended dose of fertilizers @ 208:104:104 g NPK / m^2 / year + 0.5 % EDTA

micronutrient mixture + *Bacillus megaterium* + *Bacillus amyloliquefaciens each* @ 10 ml/m^2 foliar application at 10 days interval) significantly enhanced the IAA oxidase activity at flowering stage **(Fig.26).** Results of the present study revealed that soluble protein content of leaf was influenced more by different levels of fertigation. The best treatment (T_{19}) through fertigation showed its profound influence on the soluble protein content of leaf **(Fig.27).**

Level of soluble protein content is considered as an index for the assessment of photosynthetic efficiency. This suggests that the carboxylation process is probably regulated by the foliar application of micronutrients and bio control agents. Also zinc present in the micronutrient mixture was involved in protein synthesis. The total phenol content in the present study was high in (T_{20}) than the control. T_{18} recorded maximum peroxidase activity. The results of the present study were in line with the findings of (Gerailoo and Ghasemnezhad, 2011; Mortazavi *et al*., 2007; Kashefi *et al.,* 2012) in rose. The results are supported by findings of (Thakur *et al.,* 2014) in rose cv. Poison. In the present study maximum anthocyanin content observed in T_{18} treatment. This may be due to the application of BA which enhance the physiological activity. Recently it has been shown that in darkness, cytokinin induces stomatal opening by decreasing H_2O_2 levels and NO levels within guard cells (She and Song, 2006; Song *et al.,* 2006). Muthu Kumar *et al*. (2012) reported that GA_3 application at 100ppm increased the anthocyanin content in flowers. The findings are in agreement with the reports of Ramalingam (2008) and Rubinowska *et al*. (2012) in rose. The details of physiological parameters are discussed in Experiment –I.

5.2.4 Effect of fertigation, micronutrients and *Bacillus spp* on available soil nutrients

Plant nutrient availability in the soil is very important for exploiting higher production. The nutrients, applied at any stage, should proportionately reflect in terms of available nutrient in soil so that the plants could absorb these nutrients efficiently without any hindrance. Leaching, volatilization and fixation of nutrients in soil are some of the factors which affect the availability of soil nutrients. The mobility of nutrients was well pronounced under drip fertigation system. Nutrients were carried along with the water movement and concentrated near the periphery of the wetting zone. Fertigation combines

Fig 26. Effect of fertigation, micronutrients and *Bacillus spp* on IAA Oxidase (µg/g/hr)

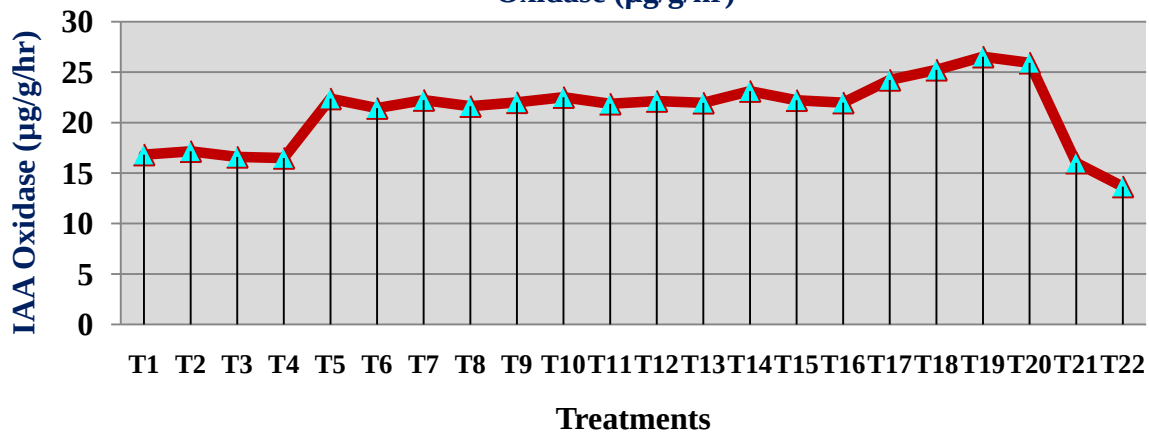


Fig 27. Effect of fertigation, micronutrients and *Bacillus spp* on soluble protein (mg/g)

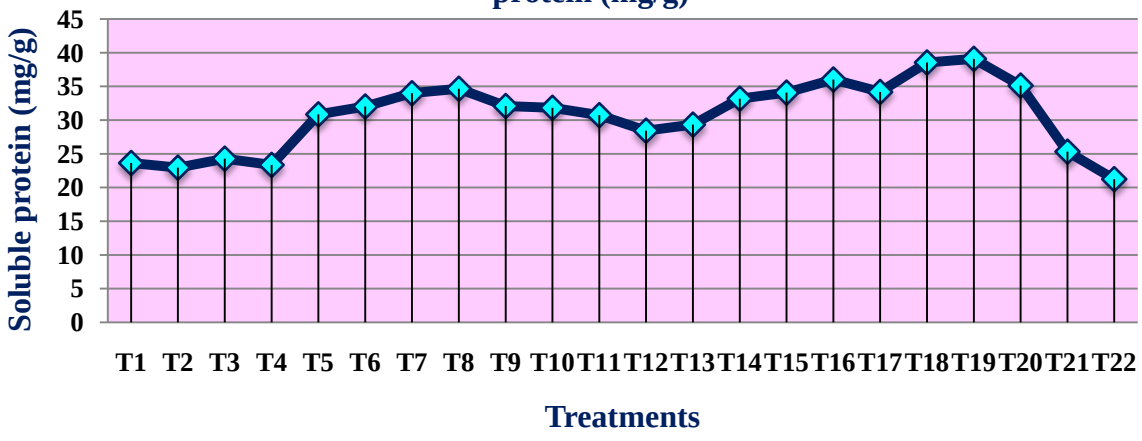
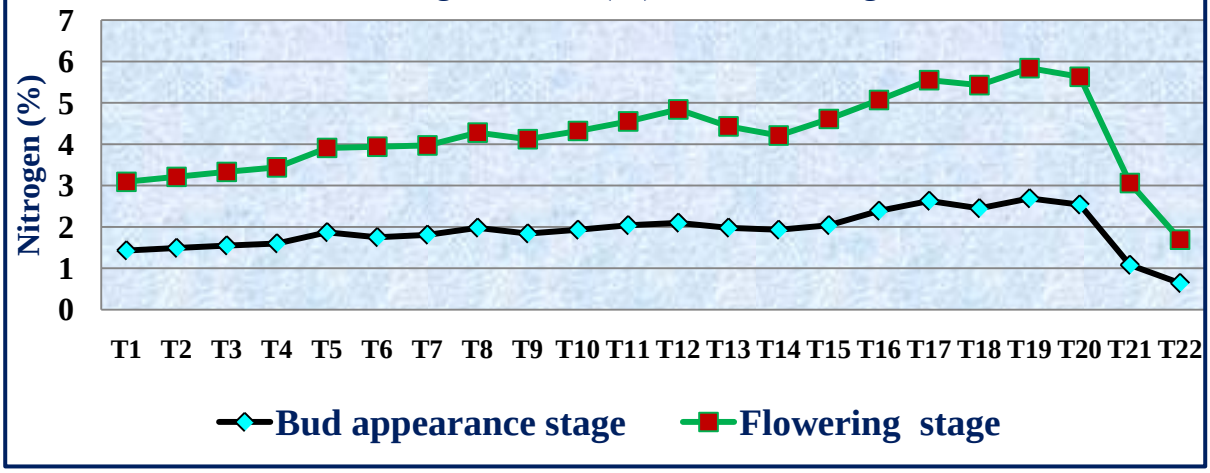


Fig 28. Effect of fertigation, micronutrients and *Bacillus spp* on nitrogen content (%) at different stages



two main inputs required for plant growth and development i.e., water and nutrients. The right combination of water and nutrients is the key for high yield and quality. It has flexibility, cost effectiveness and the potential for improved seasonal fertilizer application efficiency over traditional fertilizer application methods (Jaynes *et al.*, 1992). Moreover, the fact that roses, unlike most other crops, are being constantly harvested and thereby exhibiting large fluctuation of the transpiring area must be taken into consideration when attempting to formulate fertigation schedule.

Available nitrogen

The variations in nutrient availability due to different levels of fertigation were analysed at vegetative, bud appearance and flowering stage. It revealed that application of T_{19} (125% of recommended dose of fertilizers @ 208:104:104 g NPK / m^2 / year + 0.5 % EDTA micronutrient mixture + *Bacillus megaterium* + *Bacillus amyloliquefaciens each* @ 10 ml/m^2 foliar application at 10 days interval) recorded the lowest available N in soil, supporting the concept of lower levels (due to utilization of nutrient by plants) of fertilizers resulting in enhanced growth and yield. But the value of available N status in the control plots was much lower when compared to that of other fertilized plots. The decreased availability of nitrogen in soil recorded may probably be as a result better growth of plants in the treatment. The available N status showed in soil decreasing trend up to flowering stage. This might due to the applied microorganisms which might have enhanced the availability of nutrient uptake to plants during growth stage. *Bacillus spp* are plant growth promoting rhizobacteria (PGPR) which have the ability to colonize the roots and either promote plant growth through direct action or via biological control of plant diseases (Kloepper and Schroth, 1978). These bacteria competitively colonize the roots of plant and can act as biofertilizers and/or antagonists (biopesticides) or simultaneously both. The principal mechanisms of growth promotion include production of growth stimulating phytohormones, solubilization and mobilization of phosphate, siderophore production, antibiosis, i.e., production of antibiotics, inhibition of plant ethylene synthesis, and induction of plant systemic resistance to pathogens (Richardson *et al*., 2009; Idris *et al*., 2007; Gutierrez-Manero *et al*., 2001; Whipps, 2001). Both *Bacillus* and *Paenibacillus* species express antagonistic activities by suppressing the pathogens and numerous reports covering this aspect both under in vitro and in vivo conditions are

available (Chen *et al*., 2009b; Arrebola *et al.*, 2010). Joshi *et al*., (2012) have reported similar results in chrysanthemum cultivars.

Available phosphorus

The fertigation level of 125% of RDF @ 208:104:104 g NPK /m^2 / yr through fertigation at weekly interval + 0.5 % EDTA micronutrient mixture as foliar spray at 10 days interval along with *Bacillus megaterium* and *Bacillus amyloliquefaciens* each @ 10 ml / m^2 at weekly interval significantly influenced the available soil phosphorus. Similarly, earlier reports suggested that long term application of P fertilizer in excess of crop requirement can build up large amounts of P in soil in both the inorganic and organic pools in common bean and cowpea respectively (Singh *et al.,* 2007 and Liu *et al.*, 2010). A significant reduction in available P content of soil observed under NPK due to crop removal. The possible reason for the low availability of P in soil was due to the applied *Bacillus spp* which make the phosphorus soluble and made available to the crop (Idris *et al*., 2007; Kloepper *et al*., 2004). It is also very likely that growth promoting effects of various PGPRs are due to bacterial production of plant growth regulators such as indole-3-acetic acid (IAA), gibberellins and cytokinins (Bottini *et al*., 2004; Bloemberg and Lugtenberg, 2001). A large proportion (80%) of bacteria colonizing the rhizosphere has been reported positive for IAA production in sugar beet (Loper and Schroth, 1986). Idris *et al*., (2004) showed production of substances with auxin (IAA) like bioactivity from strains of *Bacillus subtilis / Bacillus amylolique faciens* including strain FZB42. Further, gibberellin production was confirmed from *Bacillus pumilus* and *Bacillus licheniformis* (Gutierrez-Manero *et al*., 2001). IAA controls a diverse array of functions in plant growth and development and acts as a key component in shaping plant root architecture such as root vascular tissue differentiation, regulation of lateral root initiation, polar root hair positioning, and root gravitropism (Aloni *et al*., 2006). PGPR stimulate the plant growth directly through increase in nutrition acquisition, such as phosphate solubilization, or more generally by rendering the inaccessible nutrients available to the plants (Persello-Cartieaux *et al.,* 2003). After nitrogen, perhaps the essential mineral element that most frequently limits the growth of plants is P, which is taken up from soil solution as phosphate. Although soils generally contain a large amount of total P but only a small proportion is available for uptake by the plants. On an average,

most of mineral nutrients in soil are present in millimolar amounts but P is present in micromolar or even lesser quantities (Khan *et al*., 2006). However, plants are well adapted to uptake of P from low concentration soil solution (Jungk, 2001). Therefore, it is presumed that the supply and availability of P to the root surface is influenced by the root and microbial processes. Phosphate-solubilizing microorganisms (PSM) include a wide range of symbiotic and nonsymbiotic organisms, such as *Pseudomonas, Bacillus* and *Rhizobium species*; actinomycetes; and various fungi-like *Aspergillus* and *Penicillium* species (Richardson *et al*.,2009). Ganesh (2013) and Joshi *et al*. (2012) reported similar results in chrysanthemum cultivars.

Available potassium

In the present experiment, the fertigation levels of 125% of RDF @ 208:104:104 g NPK /m^2 / yr through fertigation at weekly interval + 0.5 % EDTA micronutrient mixture as foliar spray at 10 days interval along with *Bacillus megaterium* and *Bacillus amyloliquefaciens* each @ 10 ml / m^2 at weekly interval significantly increased the available K content in soil. The increase in available K in soil due to more amount of K retained in soil before imposing the experiment. Similar results were recorded by Liu and Yao (2003) and Liu *et al.* (2010). The available K showed significant decline in control as it did not receive fertilizers. Joshi *et al*. (2012) reported similar results in chrysanthemum cultivars.

5.2.5 Effect of fertigation, micronutrients and *Bacillus spp* on availability of macro and micronutrients in plants

Macronutrients (Nitrogen uptake)

Nutrients absorption and the associated increase in their concentration and uptake is a natural phenomenon operating in the growing plants. The uptake is mainly governed by the nutrient concentration and dry matter production. The increased nutrient uptake by crop might be due to the enhanced nutrient availability, root growth and biochemical mechanisms operating within the plant of sunflower (Kastori and Petrovic, 1989). In general, the combined application of inorganic fertilizers, foliar application of micronutrients and *Bacillus spp* resulted in greater dry matter production and enhanced NPK and micronutrients concentration in the plant system.

Nitrogen is the most important plant nutrient and plant contains 1-5 per cent by weight of this nutrient. In the present investigation fertigation level of T_{19} (125% of recommended dose of fertilizers @ 208:104:104 g NPK / m^2 / year + 0.5 % EDTA micronutrient mixture + *Bacillus megaterium* + *Bacillus amyloliquefaciens each* @ 10 ml/m^2 foliar application at 10 days interval) showed higher nitrogen content in whole plant at all the stages over the other levels of fertigation **(Fig .28).** Higher uptake values obtained in these treatments might be due to the increased availability of nitrogen in soil and consequently its uptake by the crop. The nitrogen content was gradually increased in leaves. This might be due to increased nutrient uptake which would have contributed to the higher relative growth rate (RGR) of the plants. Similar findings were reported by (Silberbush and Lieth, 2004; Mattson and Lieth, 2008; Qasim *et al*., 2008; Bar-Yosef *et al*., 2009; Patil *et al*., 2012) in rose, (Eid *et al*., 2010) in tuberose and Joshi *et al*. (2012) in chrysanthemum cultivars.

Phosphorus uptake

Phosphorus is very important for energy transfer system in the plants. The P uptake of rose was significantly influenced by T_{19} (125% of RDF @ 208:104:104 g NPK /m^2 / yr through fertigation at weekly interval + 0.5 % EDTA micronutrient mixture as foliar spray at 10 days interval along with *Bacillus megaterium* and *Bacillus amyloliquefaciens* each @ 10 ml / m^2 at weekly interval) **(Fig.29).** The increase in fertigation doses has resulted in increasing the concentration of phosphorus in all three stages. These results are in accordance with the findings of (Tamimi *et al*., 1999; Silberbush and Lieth, 2004; Mattson and Lieth, 2008; Qasim *et al*., 2008; Bar-Yosef *et al*., 2009) in rose, (Eid *et al*., 2010) in tuberose, Joshi *et al*. (2012) in chrysanthemum cultivars, Swapna (2010) in marigold, Bini Sundar (2011) in jasmine, Palanisamy (2011) in gerbera and Vinodh (2012) in Lilium.

Potassium uptake

Potassium being a protoplasmic factor is an essential plant nutrient. Many enzymes are activated by potassium and are involved in photo and oxidative phosphorylation thus augmenting the energy required for plant growth. In the present study fertigation levels of 125% of RDF @ 208:104:104 g NPK /m^2 / yr through fertigation at weekly interval +

Fig 29. Effect of fertigation, micronutrients and *Bacillus spp* on phosphorus content (%) at different stages

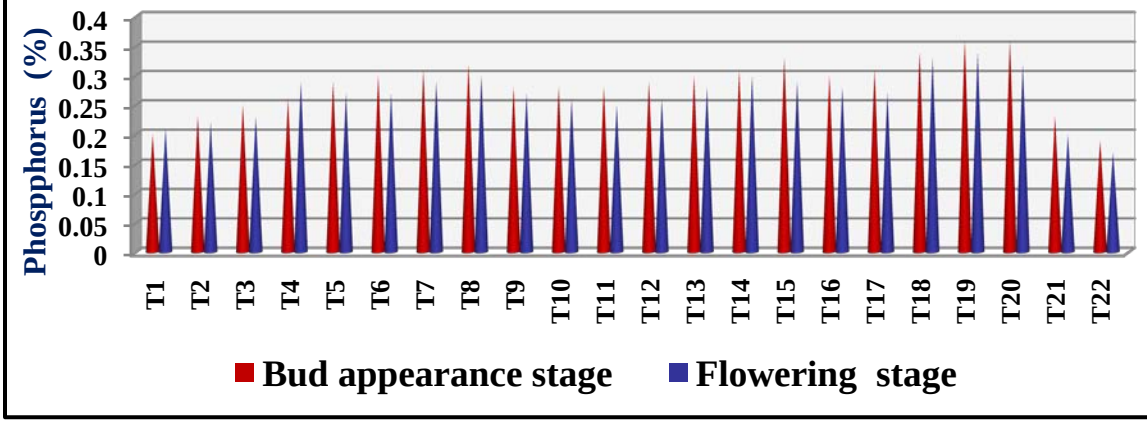


Fig 30. Effect of fertigation, micronutrients and *Bacillus spp* on potassium content (%) at different stages

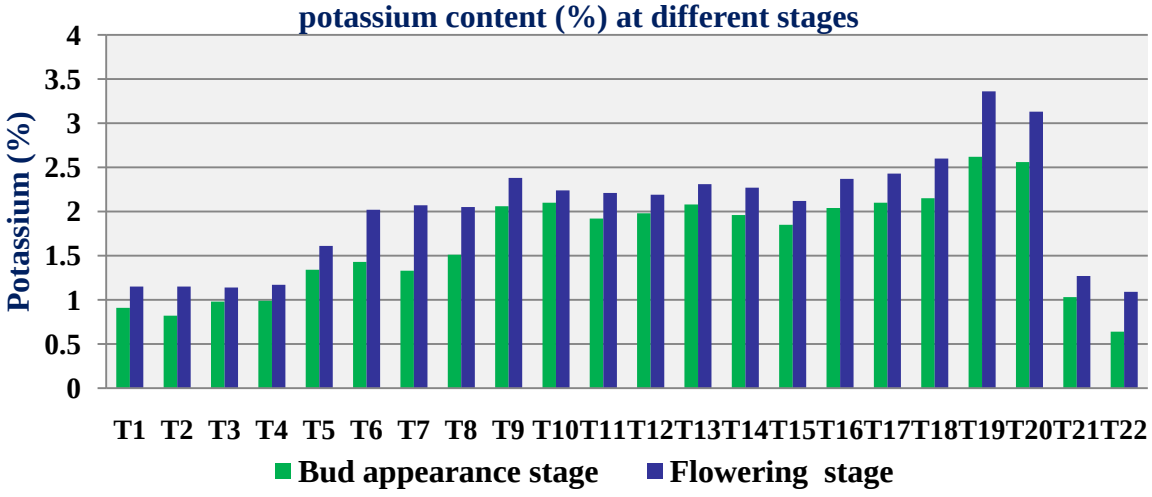
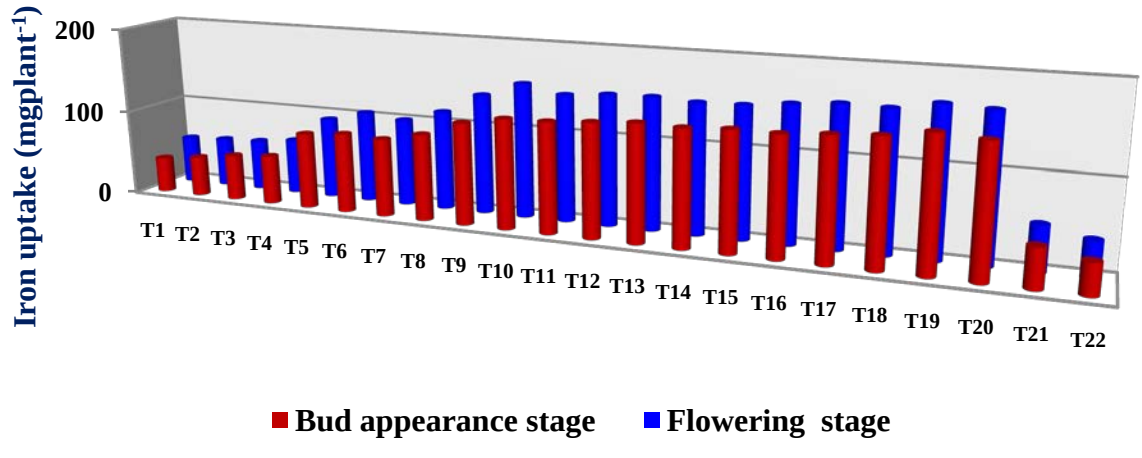


Fig 31. Effect of fertigation, micronutrients and *Bacillus spp* on iron uptake (mg plant^{-1}) at different stages



0.5 % EDTA micronutrient mixture as foliar spray at 10 days interval along with *Bacillus megaterium* and *Bacillus amyloliquefaciens* each @ 10 ml / m^2 at weekly interval exhibited higher potassium content over the other fertigation treatments **(Fig. 30).** These results are in agreement with (Mattson and Lieth, 2008) in rose. The transformation reactions that took place led to greater availability of potassium in the soil and consequently resulted in the better utilization by the plant. Water soluble fertilizer might have activated the physiological processes for the rapid absorption and utilization of the nutrient for primary metabolic processes. Similar findings were reported by (Tamimi *et al*., 1999; Silberbush and Lieth, 2004; Qasim *et al*., 2008; Bar-Yosef *et al*., 2009; Ahmad *et al*., 2012) in rose and Joshi *et al*. (2012) in chrysanthemum.

Micronutrients uptake

Micronutrients, though required in very small quantities by crops, are equally essential as that of major and secondary nutrients for the normal growth and yield of crops. Deficiency of micronutrients found to have a profound effect on the crop productivity because of their strategic function in the physiological activity of the plant. Along with other plant management practices, proper ratio of macro and combination of micronutrients are provides vigorous growth and increase yield by enhancing the number and size of flowers with superior quality in rose. Foliar application is one of the best ways to supply micronutrients to plants (Cabrera *et al.,* 1993). Application of micronutrients on plants has become an established procedure to increase yield and improve the quality of crop products (Romemheld and El-Fouly, 1999). Foliar feeding of nutrients may actually promote root absorption of the same nutrient or other nutrients through improving root growth and increasing nutrients uptake (Saqib *et al*., 2006). Hence, concerted efforts are needed to replenish these nutrients, particularly with a view to maintain sustainability of rose production system.

Copper

Among the fertigation levels, 125% of recommended dose of fertilizers @ 208:104:104 g NPK / m^2 / year + 0.5 % EDTA micronutrient mixture + *Bacillus megaterium* + *Bacillus amyloliquefaciens each* @ 10 ml / m^2 foliar application at 10 days interval recorded relatively higher levels of available copper uptake at bud appearance stage and T_{20} recorded higher levels of available copper uptake at flowering stage. Under

fertigation it is inevitable to apply micronutrients for giving continuous support to rose plants for an improved growth and quality of flowers. Due to continuous fertigation combined with foliar spray, high amount of available copper status has been observed in the plants at all growth stages to develop floral parts and to produce quality flowers. The research findings are line with (Tamimi *et al.,* 1999) in rose. This is in conformity with the results of Ganesh (2013) in chrysanthemum and Dhinesh (2013) in carnation.

Iron

Among the fertigation levels, 125% of recommended dose of fertilizers @ 208:104:104 g NPK / m^2 / year + 0.5 % EDTA micronutrient mixture + *Bacillus megaterium* + *Bacillus amyloliquefaciens each* @ 10 ml/m^2 foliar application at 10 days interval recorded relatively higher levels of iron uptake at all stages **(Fig.31).** Under fertigation it is inevitable to apply micronutrients for giving continuous support to rose for an improved growth and quality of flowers. Due to continuous fertigation combined with foliar spray, high amount of available iron status has been observed in the plant at all growth stages. This is in conformity with the results of Tamimi *et al.* (1999) and Ahmad *et al*. (2010) in rose, Eid *et al.* (2010) in tuberose. The results are supported by Ganesh (2013) in chrysanthemum and Dhinesh (2013) in carnation.

Zinc

Results shown zinc content in leaf was relatively higher in fertigation of 125% of RDF @ 208:104:104 g NPK / m^2 / yr through fertigation at weekly interval + 0.5 % EDTA micronutrient mixture as foliar spray at 10 days interval along with *Bacillus megaterium* and *Bacillus amyloliquefaciens* each @ 10 ml / m^2 at weekly interval **(Fig. 32)**. The available zinc was lower at the bud appearance stage and then the amount of the zinc was found higher in the later stages of crop growth. This might be due to more utilization of zinc by the plant in the final stage. These results are in agreement with Tamimi *et al.* (1999) and Ahmad *et al*. (2010) in rose, Eid *et al.*(2010) in tuberose, Dhinesh (2013) in carnation and Ganesh (2013) in chrysanthemum.

Manganese

The fertigation level of 125% of RDF @ 208:104:104 g NPK /m^2 / yr through fertigation at weekly interval + 0.5 % EDTA micronutrient mixture as foliar spray at

Fig 32. Effect of fertigation, micronutrients and *Bacillus spp* on zinc uptake (mg plant^{-1}) at different stages

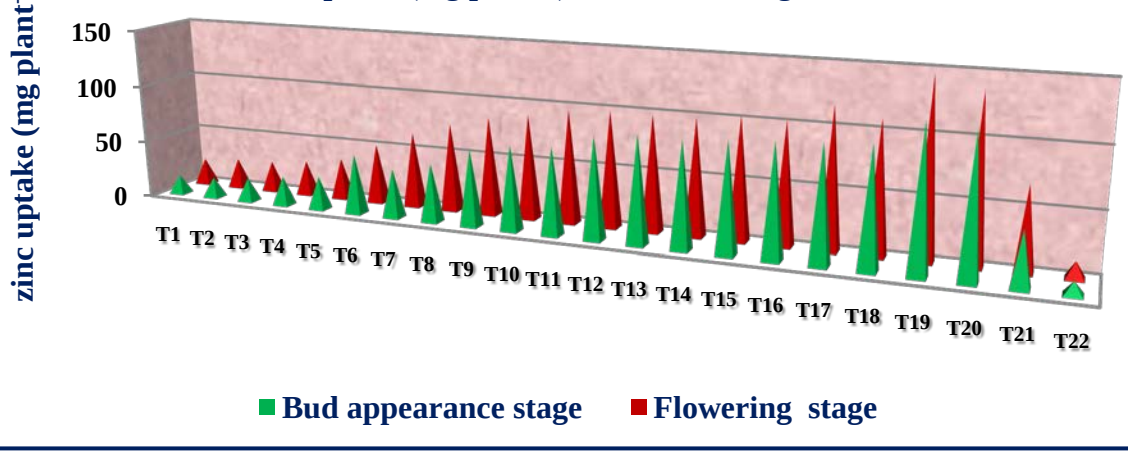


Fig33. Effect of fertigation and *Bacillus spp* on microbial population in rhizospphere soil

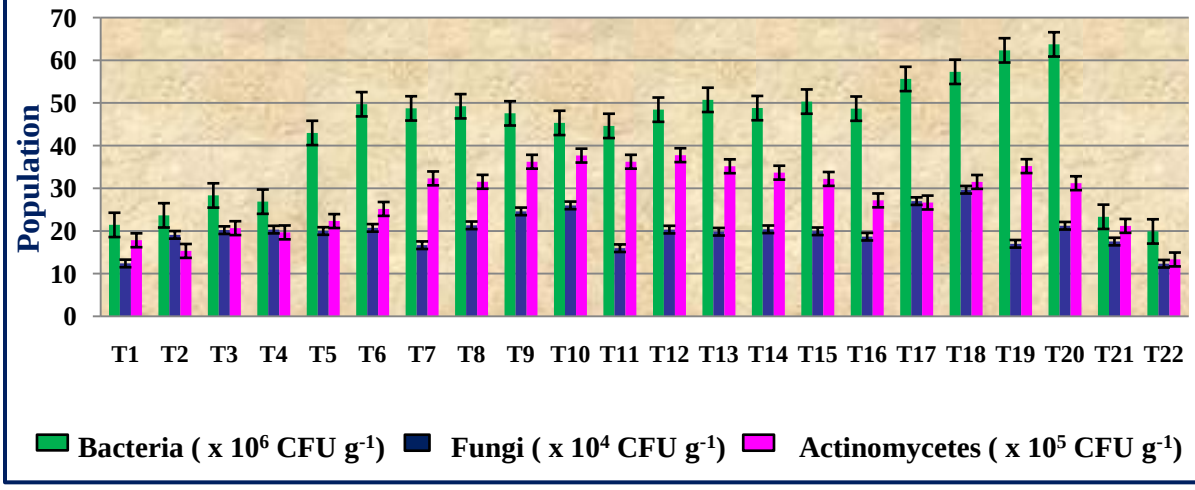
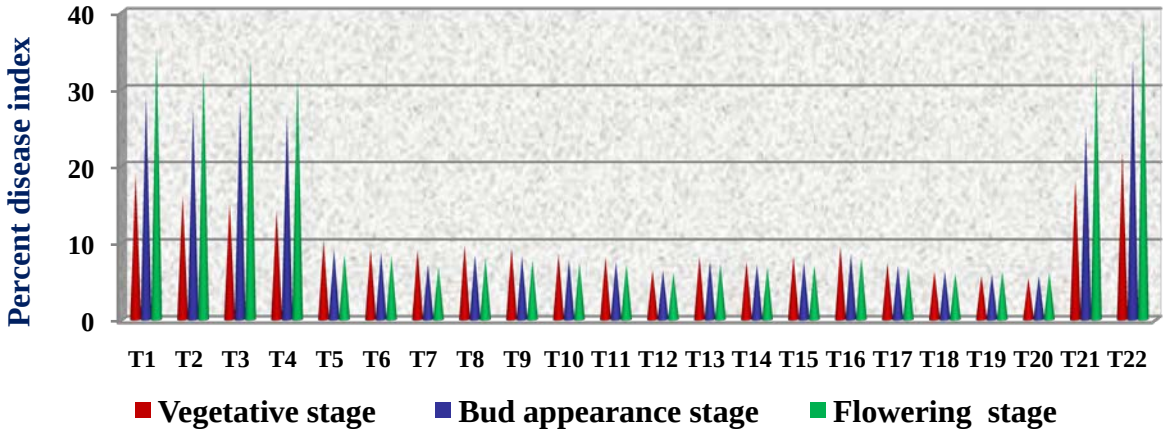


Fig 34. Effect of *Bacillus spp* on powdery mildew incidence (Percent Disease Index) at different stages



10 days interval along with *Bacillus megaterium* and *Bacillus amyloliquefaciens* each @ 10 ml / m^2 at weekly interval also recorded maximum available Mn in the plants and all the treatments had shown a decreasing trend from bud appearance to peak flowering stage. Increased plant uptake has been observed which might be due to higher demand for available Mn during bud appearance and flowering stage since these represent the primary carbohydrate sink. These results are in line with Tamimi *et al.* (1999) and Ahmad *et al.* (2010) in rose, Eid *et al.* (2010) in tuberose. The findings are supported by Karthikeyan (2012) and Dhinesh (2013) in carnation and Ganesh (2013) in chrysanthemum.

5.2.6 Effect of fertigation, micronutrients and *Bacillus spp* on soil enzyme activity in rhizosphere

Dehydrogenase (Δ in OD at 480 nm)

Dehydrogenase was considered to exist in soil as integral part of the intact cells of microorganisms and this was thought to reflect the total range of oxidative activities of the soil microflora (Cassida *et al.,* 1964). The mean values of dehydrogenase activity in soil samples differed significantly not only with stages, but also among the treatments within a stage. During all the three stages, the fertigation obviously was associated with increased activity (125% of RDF @ 208:104:104 g NPK / m^2 / yr through fertigation at weekly interval + 0.5 % EDTA micronutrient mixture as foliar spray at 10 days interval along with *Bacillus megaterium* and *Bacillus amyloliquefaciens* each @ 10 ml / m^2 at weekly interval). It implied the beneficial effect of different fertigation doses and cultivation on soil dehydrogenase activity.

The result in the present study corroborated with these findings was supported by Dkhar and Mishra (1983) who highlighted the positive role of nutrient levels and moisture towards the enzyme activities in maize. From this investigation, it could be seen that the nutrient rich environment is essential for favouring the activity of dehydrogenase. The elimination or low availability of any one of the nutrient resulted in lower activity. Maximum dehydrogenase activity at flowering stage was also earlier reported by Baruah and Mishra (1984) in rice and Damodaran (1987). The findings are line with Dhinesh (2013) in carnation and Ganesh (2013) in chrysanthemum.

Acid Phosphatase (µ moles PNP released g^{-1} min^{-1})

The phosphatase hydrolyses organic phosphorus compounds into inorganic phosphates which are taken up by the plants from soil (Pallab De *et al.,* 1991). In the present study, the fertigation treatment (T_{20}) significantly increased the acid phosphatase activity for all growth stages. This might be due to the fact that N fertilization through fertigation increased plant growth with concomitant increase. The enzyme level in general increased under these conditions. This is supported by the finding of Kudzin *et al.* (1970) who observed that addition of N fertilizers over a period of 35 years increased phosphatase activity. This is also in conformity with the results of Ganesh (2013) in chrysanthemum and Dhinesh (2013) in carnation.

Urease (µg NH_4-N released g^{-1} h^{-1})

Urease catalyses the hydrolysis of urea to ammonia and carbon dioxide (Bremner and Mulvaney (1978). The data indicated that the urease activity varied markedly in all the stages and also in different treatments**.** Obviously, the least activity in control was observed over the drip fertigation indicating the poor hydrolyzing nature of soil in the absence of organic and inorganic nutrients. The urease activity increased significantly with increase in N levels. This was evident to higher availability of substrate nitrogen which promoted urease activity. Increased urease activity with advancement of crop growth period could also be observed in this investigation. Similar trend was reported by Pancholy and Rice (1973). Dkhar and Mishra (1983) also manifested the increased soil urease activity during the growing period of maize. This may be attributed to the continuous activation of the enzyme released from the plant roots and also due to associated microorganisms. This is also in conformity with the results of Ganesh (2013) in chrysanthemum and Dhinesh (2013) in carnation.

5.2.7 Effect of fertigation, micronutrients and *Bacillus spp* on the influence of microbial population in rhizosphere

Bacteria, fungi and actinomycetes

The fertility of soil depends not only on its chemical composition but also on the qualitative and quantitative nature of microorganisms inhabiting it. Soil microorganisms

in the rhizosphere influence the plant growth in many ways. Most of them play a role in the carbon, nitrogen, phosphorus and sulphur cycles and availability of certain trace elements like manganese, copper and iron in the soil. Some soil microbes act as antagonists for soil borne pathogens, thus aiding normal growth of plants. Besides, the soil microbes influence the permeability, water holding capacity and tilth of the soil (Subba Rao, 1977).

In case of different levels of fertigation, an increased microbial population with the increase in the soil fertility was recorded in the treatment T_{20} (150% of RDF @ 250:125:125 g NPK /m^2 /yr + 0.5 % EDTA micronutrient mixture + *B. megaterium* + *B. amyloliquefaciens* each @ 10 ml/m^2) at harvesting stage **(Fig.33)**. It indirectly denoted the post harvest status of soil nutrient. This is supported by Dkhar and Mishra (1983) who recorded the maximum microbial populations in the soils of permanent agriculture which is probably a function of N, P, K, organic carbon.

Nguyen (2003) reported that high aboveground biomass yield is obviously accompanied by an active root system, which releases an array of organic compounds into the rhizosphere. Plant roots release about 17% of the photosynthate. Most of the released photosynthates are utilized by soil organisms. These compounds support the growth of the microbial community and result in the increase of population density of bacteria, fungi and actinomycetes in drip fertigation plot over the control plot at harvesting stage.

5.2.8 Effect of fertigation, micronutrients and *Bacillus spp* on disease management

Management of plant diseases aims in the rational use of fungicides, bactericides, biocontrol agents and the application of non-chemical methods that cause less impact to the environment. Powdery mildew of rose caused by *Sphaerotheca pannosa var. rosae* is one of the important diseases which causes enormous losses both in terms of quality and quantity of rose under protected condition. One of the main task in greenhouse cultivation of rose is management of powdery mildew. Because this disease occurs more or less throughout the year under protected condition and assumes serious form from October to February. In this context, biological control through the use of natural antagonistic micro-organisms has emerged as a promising alternative. In the present investigation foliar application of *B. megaterium* and *B. amyloliquefaciens* along with different

combinations of fertilizers were found effective in reducing the severity of powdery mildew in rose. **(Fig .34).**

This might be due to three main mechanisms: competition for ecological niche/ substrate, production of antibiotics and induction of systemic resistance. Members of multiple *Bacillus* species such as *B. amyloliquefaciens, B. subtilis, B. cereus, B. licheniformis, B. megaterium, B. mycoides,* and *B. pumilus* are known as very efficient producers of antibiotic molecules. Among the vast array of biologically active molecules are synthesized by *Bacillus,* some have been reported for their inhibitory activity against plant pathogens and this antagonistic activity or antibiosis is probably the best known and the most important mechanism used to limit pathogen invasion in host plant tissues. In the present study, *B. megaterium* and *B. amyloliquefaciens* are known to possess several antimicrobial peptide genes such as, surfactin, iturin, fengycin, bacillomycin and bocilysin. These AMP genes might play a crucial role in suppression of fusarium wilt in carnation (Rajeshkumar *et al*., 2014).

Volatile compounds such as 2,3-butanediol (Ryu *et al*., 2004) and lipopeptides are the sole compounds formed by *Bacillus spp*. that were identified as elicitors of ISR. Similarly, characterisation of biomolecules of *B. amyloliquefaciens* and *B.subtilis* indicated the extracellular production of lipopeptides and butanediol based compounds are responsible for triggering ISR mechanism (Nakkeeren *et al*., 2014). The potential of *Bacillus* cLPs as plant resistance inducers was demonstrated by testing pure surfactins and fengycins that provided a significant induced protective effect similar to the one induced by living cells of the producing strain (*B. amyloliquefaciens* S499). Further, the preventive application of *Bacillus spp* are able to minimize the infection and reduce the severity of the disease.

In conclusion, the bio-fungicide products when applied prior to disease infection reduced powdery mildew significantly compared to the control. As a consequence, these products can be used as part of an integrated disease management program as an alternative to reduce the use of fungicides for the control of powdery mildew in rose.

5.2.9 Benefit-Cost ratio (BCR)

5.2.9.1 Effect of bending and growth regulators on cost economics (Experiment – I)

Higher net return of rose could be assured by increasing the production and productivity by adopting judicious management practices. The economics of bending and growth regulator interactions of rose was computed for 500m^2 for a period of year and it was inferred that the bending with application of growth regulators resulted in additional net income compared to control (Farmers practices).

Economics indicated that the plants are treated by bending at shoot junction bud (B_1) + application of BA 200 ppm (G_4) was found to be the best in respect of growth, quality and yield parameter. It was found most remunerative in the experiment and gave maximum benefit cost ratio of 3.70 with a net return of Rs. 2, 31,740 per 500m^2 (Table 39). This was because the more number and superior quality of flowers were produced under this interaction. Again, the better quality flowers fetched higher price in the market. This might be due to higher demand during marriage and Valentine's Day celebration. Similar effect of increased benefit cost ratio in treatments over control was observed by several workers *viz.,* Man Bihari *et al*. (2010), Chaudhari *et al*. (2010) and Patil *et al*. (2012) in rose, Swapna (2010) in marigold, Bini sundhar in jasmine (2011) and Palanisamy in gerbera (2011).

5.2.9.2 Effect of fertigation on cost economics (Experiment – II)

Higher net return of rose could be assured by increasing the production and productivity by adopting judicious management practices. The economics of drip fertigation doses along with micronutrients and *Bacillus spp* was computed for 500m^2 for a period of year and it was inferred that the drip fertigation resulted in additional net income compared to control.

Though the application of 125% of RDF @ 208:104:104 g NPK /m^2 / yr through fertigation at weekly interval + 0.5 % EDTA micronutrient mixture as foliar spray at 10 days interval along with *Bacillus megaterium* and *Bacillus amyloliquefaciens* each @ 10 ml / m^2 at weekly interval was found to be the best in respect of growth, quality and yield parameter. It secured the highest benefit cost ratio of 3.15 with a net return of

Rs. 6, 40,019 per 500m^2 (**Table. 43**). This was because the more number and superior quality of flowers were produced by the rose plants subjected to the above treatment. It was due to the disease suppression by bio-agents and the reduced investment on the fungicide cost. Again, the better quality flowers fetched higher price in the market. Similar effect of increased benefit cost ratio in treatments over control was observed by several workers *viz.,* Vijayselvaraj (2007) in *J.grandiflorum*, Man Bihari *et al*. (2010), Chaudhari *et al*. (2010) and Patil *et al*. (2012) in rose, Swapna (2010) in marigold, Bini sundhar in jasmine (2011) and Palanisamy in gerbera (2011) and (Vinodh, 2012) in lilium.

Conclusion

From the above results, it can be concluded that the plant growth, yield and quality parameters of flowers were found to be superior by the adoption of bending practice at shoot junction bud (B_1) along with the application of BA at 200 ppm (G_4) for the successful production of greenhouse rose. var. Tajmahal. Hence, this treatment interaction can be recommended to obtain increased growth and production of quality flowers in rose. Regarding the cost economics, the highest benefit cost ratio of 3.70 was achieved in the interaction, treatment B_1G_4.

Drip fertigation done with 125% of RDF @ 208:104:104 g NPK /m^2 / yr at weekly interval + 0.5 % EDTA micronutrient mixture as foliar spray at 10 days interval along with *B. megaterium* and *B. amyloliquefaciens* each @ 10 ml / m^2 at weekly intervals (75% P as basal soil application) recorded the highest benefit cost ratio (3.15). Not only B: C ratio was increased, improved plant growth, physiological, nutritional and quality parameters over other treatments. Hence, this treatment can be recommended to obtain increased growth and production of flowers in greenhouse rose var. Tajmahal. Besides powdery mildew can be effectively managed through preventive soil and foliar application of *Bacillus megaterium* + *Bacillus amyloliquefaciens* combination @ 10 ml/m^2 at weekly interval was found to promote better plant growth and the powdery mildew disease can be effectively kept in check.

Summary

CHAPTER VI

SUMMARY

The salient findings of the present study on "Standardization of precision production techniques to maximize the yield and quality of Dutch rose (*Rosa hybrida* var.Tajmahal) conducted during August 2012 to May 2014 in a private farm of M/s Shiva Sakthi Floritech Pvt Ltd at Bagalur, Hosur, Krishnagiri District, Tamil Nadu, are summarized hereunder.

6.1 Experiment I: To study the effect of shoot bending and application of growth regulators for maximizing the yield and quality of Dutch rose

1. In the present study, interaction treatment B_1G_4 [bending at shoot junction bud (B_1) + BA 200ppm (G_4)] recorded the highest plant height (126.29 cm, 154.81 cm and 165.33 cm), number of compound leaves (83.23, 98.07 and 104.13) at all the three stages viz., Peak vegetative, bud appearance and flowering stage of the crop development respectively.

2. Maximum plant spread (45.19 cm^2), highest inter nodal length (6.13 cm), maximum number of shoots (5.47), minimum duration (10.87 days) for first shoot emergence, earlier days for flower bud appearance (26.40 days), earlier days taken for harvesting of flowering shoot (48.80 days), maximum length of flowering shoot (86.79 cm), circumference of flower (13.13 cm), girth of flower stem (0.87 cm), weight of flowering stem (91.84 g) was also recorded in the interaction B_1G_4 [bending at shoot junction bud (B_1) + BA 200ppm (G_4)].

3. B_1G_4 produced maximum number of "A" grade flowers (214.40 / m^2), cut stems / plant (26.47) and highest yield of flowers / m^2 (317.60), vase life (12.37 days), maximum chlorophyll 'b' content (0.380 mg g^{-1}), total chlorophyll content (2.55 mg g^{-1}), maximum IAA oxidase activity (22.48 µg of unoxidised auxin g^{-1} h^{-1}), highest soluble protein content (39.81 mg g^{-1}), maximum peroxidase activity (1.21 abs min^{-1} g^{-1}) and highest benefit cost ratio (3.70).

4. The highest pedicel length (9.67 cm) was produced by the plants of B_1G_2 [bending at shoot junction bud (B_1) + GA_3 200 ppm (G_2)] followed by B_1G_1 (8.81 cm).

5. The stomatal aperture width in treatment interaction B_1G_4 [bending at shoot junction bud (B_1) + BA 200 ppm (G_4)] was ranged from 8.18 to 12.13 µm and that of length from 21.08 to 25.26 µm as compared to that of control. The leaf stomata aperture width was ranged from 6.84 to 8.32 µm and that of length from 21.49 to 26.08 µm B_0G_0 [Bending above first leaf bud (B_0) + Without GR (G_0) – control].
6. The size of cell in sclerenchyma tissue (beneath the epidermis) was ranged from 31.96 to 36.43 µm and that of middle portion of stem cell size from 119.80 to 144.30 µm in B_0G_0 treatment [Bending above first leaf bud (B_0) + Without GR (G_0) – control]. But the vascular tissue organization in treatment B_1G_4 [bending at shoot junction bud (B_1) + BA 200 ppm (G_4)] indicated that increase in cell size of sclerenchyma tissue ranged from 21.01 to 52.78 µm and that of middle portion of stem cell size from 133.10 to 169.40 µm as compared to control.
7. Among the interactions, maximum chlorophyll 'a' content (1.58 mg g^{-1}) was recorded in the interaction B_4G_4 (bending above fourth leaf bud + BA 200 ppm) and B_1G_3 (bending at shoot junction bud + BA 100 ppm recorded the maximum anthocyanin content (0.78).
8. Among the interactions, bending above fourth leaf bud (B_4) + without GR (G_0) recorded the maximum nitrate reductase activity (2.23 µmoles NO_2 g^{-1} h^{-1}) followed by B_3G_3 produced (2.22 µ moles NO_2 g^{-1} h^{-1}).
9. The interaction treatment B_1G_3 [bending at shoot junction bud (B_1) + BA 100 ppm (G_3)] recorded maximum phenol content (375.57 µg g^{-1}) followed by B_1G_4.

6.2 Experiment II: Optimization of fertigation schedule along with the application of micronutrients and *Bacillus spp* for improved growth, yield, quality and disease management in Dutch rose

10. The fertigation levels of T_{19} (125% of recommended dose of fertilizers @ 208:104:104 g NPK / m^2 / year + 0.5 % EDTA micronutrient mixture + *Bacillus megaterium* + *Bacillus amyloliquefaciens each* @ 10 ml/m^2 foliar application at 10 days interval) recorded the maximum plant height (128.96 cm, 153.63 cm and 167.26 cm) and number of compound leaves (69.20, 95.57 and 100.33) at peak vegetative, bud appearance and flowering stage of the crop development respectively.

11. T_{19} produced maximum plant spread (47.82 cm^2), highest inter nodal length (6.25 cm), minimum number of days (11.20) for first shoot emergence, minimum duration (26.93 days) for first flower bud appearance, minimum duration (11.13 days) for harvesting of flowers from flower bud appearance, more number of compound leaves per flowering shoot (16.67), maximum length of flowering shoot (83.77 cm), larger circumference of flower bud (12.81 cm), maximum girth of flower stem (0.83 cm), highest flowering stem weight (90.55 g).

12. Maximum number of "A" grade flowers /m^2 (218.47), maximum number of cut stems/ plant (27.07), highest yield of flowers /m^2 (324.84), maximum vase life (11.50 days), maximum chlorophyll 'a' content (1.36 mg g^{-1}), maximum chlorophyll 'b' content (0.39 mg g^{-1}), total chlorophyll content (2.99 mg g^{-1}), maximum IAA oxidase activity (26.53), highest soluble protein content (39.08 mg g^{-1}) was recorded in treatment T_{19}.

13. The fertigation levels of T_{19} recorded minimum amount of available soil nitrogen (207.38 kg ha^{-1},193.04 kg ha^{-1} and 172.63 kg ha^{-1}), minimum quantity of available soil phosphorus (17.34 kg ha^{-1}, 15.54 kg ha^{-1} and 14.93 kg ha^{-1}) at vegetative, bud appearance and flowering stage respectively and highest available potassium content at the critical stages *viz.*, vegetative (302.00 kg ha^{-1}), bud appearance (283.88 kg ha^{-1}) except flowering stage (T_{21}- 277.49 kg ha^{-1}), highest available nitrogen content in leaf (2.69 % and 3.15 %), available potassium content (2.62% and 3.36 %) at the critical stages *viz.*, bud appearance and flowering stage respectively.

14. Higher values for uptake of micronutrients [iron (149.23 mg $plant^{-1}$ and 167.01 mg $plant^{-1}$), zinc (121.12 mg $plant^{-1}$ and 147.66 mg $plant^{-1}$), manganese (82.27 mg $plant^{-1}$ and 94.50 mg $plant^{-1}$)] during bud appearance and flowering stage respectively and higher benefit cost ratio of 3.15 in T_{19}.

15. More number of basal shoots (3.47) recorded in T_{20} (T_4 + 0.5 % EDTA micronutrient mixture + *B. megaterium* + *B. amyloliquefaciens* each @ 10 ml/m^2).

16. Significant variations were observed among the treatments with regard to the number of shoots produced. T_{20} (T_4 + 0.5 % EDTA micronutrient mixture + *B. megaterium* + *B. amyloliquefaciens* each @ 10 ml/m^2) produced maximum number of shoots (5.23) followed by T_{19} (5.20).

17. Among the treatments, T_{17} - (T_1 + 0.5 % EDTA micronutrient mixture + *B. megaterium* + *B. amyloliquefaciens* each @ 10 ml/m^2) recorded the maximum nitrate reductase activity (2.32 µmoles NO_2 g^{-1} h^{-1}) and phenol content (365.51 µg g^{-1}).

18. Maximum peroxidase activity (1.532 abs min^{-1} g^{-1}), anthocyanin content (0.98) was recorded in T_{18}- (T_2 + 0.5 % EDTA micronutrient mixture + *B. megaterium* + *B. amyloliquefaciens* each @ 10 ml/m^2).

19. The highest 'P' content (0.36 %) was recorded at bud appearance in both treatments T_{19} and T_{20}, (0.34 %) in T_{19} at flowering stage. The lowest phosphorus content (0.19 & 0.17 %) was recorded by the treatment T_{22} (control) at bud appearance and flowering stage respectively.

20. The treatment T_{19} - (T_3 + 0.5 % EDTA micronutrient mixture + *B. megaterium* + *B. amyloliquefaciens* each @ 10 ml/m^2) recorded higher values for uptake of micronutrients viz., copper (30.17 mg $plant^{-1}$) during bud appearance and T_{20} recorded during flowering stage (33.18 mg $plant^{-1}$),

21. In the fertigation levels, maximum dehydrogenase activity (0.096, 0.098, 0.099 Δ in OD at 485nm)was recorded in the treatment T_{19} - (T_3 + 0.5 % EDTA micronutrient mixture + *B. megaterium* + *B. amyloliquefaciens* each @ 10 ml/m^2) at vegetative, bud appearance stage and flowering stage respectively.

22. However maximum acid phosphatase activity (0.194 and 0.195 µ moles PNP released g^{-1} min^{-1}) was recorded in T_{13} at vegetative and bud appearance stage, T_6 was recorded (0.199 µ moles PNP released g^{-1} min^{-1} at flowering stage and maximum soil urease activity (123.34, 125.58 and 126.67 µg NH_4-N released g^{-1} h^{-1}) at vegetative, bud appearance stage and flowering stage was recorded in the treatment T_{20} respectively.

23. Among the different fertigation doses with *Bacillus spp* application higher populations of bacteria were recorded in T_{20}, fungi in T_{18} and actinomycetes in T_{12} at harvesting stage.

24. Minimum percent disease index (5.40, 5.69 and 6.10) was recorded in T_{20} except T_{18} (6.05) at flowering stage and maximum percent disease index (21.74, 34.00 and 39.53) was registered in treatment T_{22} (control) during the vegetative, bud appearance and flowering stage respectively.

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*** Original not seen**

Plates

Plate 1. A view of experimental polyhouse

Plate 2. Overview of pruned plants at 50 cm from ground level (Exp- I)

Plate 3. View of different levels of bending

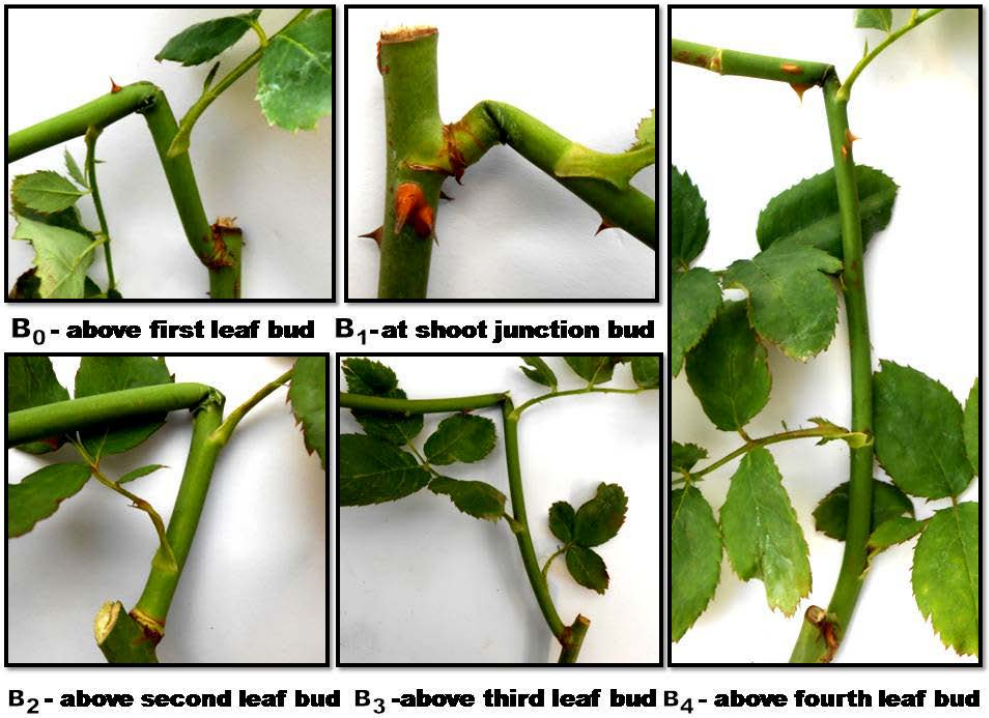


Plate 4. Overview of bent shoots

Plate 5. View of peak vegetative stage (25 days after bending)

Plate 6. View of peak flower bud appearance stage (35 days after bending)

Plate 7. View of peak flowering stage (45 days after bending)

Plate 8. Effect of bending and growth regulators on the length of flowering stem and bud size of Dutch rose (var.Tajmahal)

Plate 9a. Effect of vase solution on vase life studies of Dutch rose var. Tajmahal

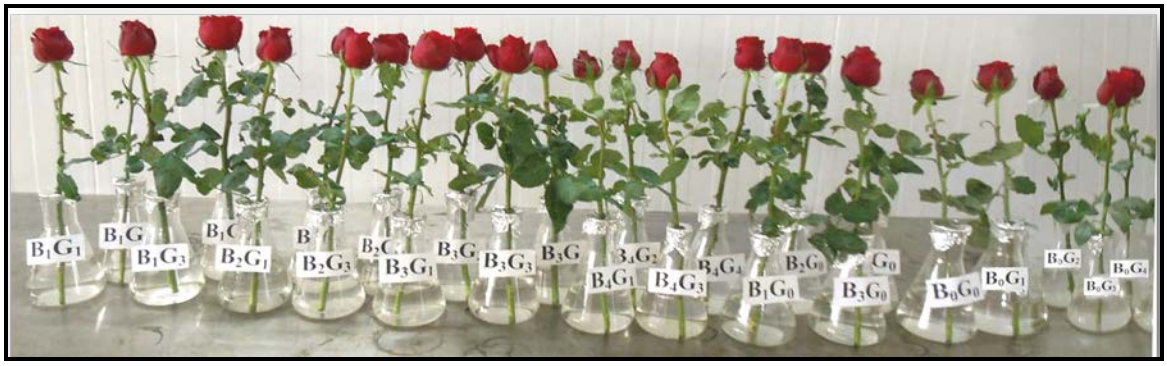
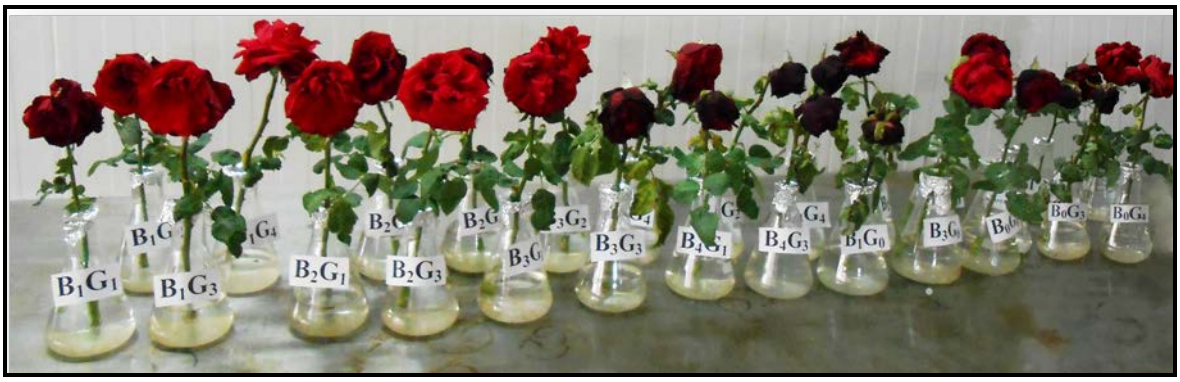


Plate 9b. Blooming stage

Plate 9c. Flowers in vase solution on 12th day



Vase solution: 100 ppm of Aluminum sulphate + 1% of sucrose

Uniform stems of 35 cm length from all treatments kept in vase solution

Plate 10. Best treatment (B_1G_4) showing growth and flower parameters

Plate 11.View of best treatment (B_1G_4) for superior quality flower

Plate 12. Comparison between best treatment (B_1G_4) and control (B_0G_0) at flowering stage

Plate 13. Comparison between best treatment (B_1G_4) and control (B_0G_0) on quality parameters

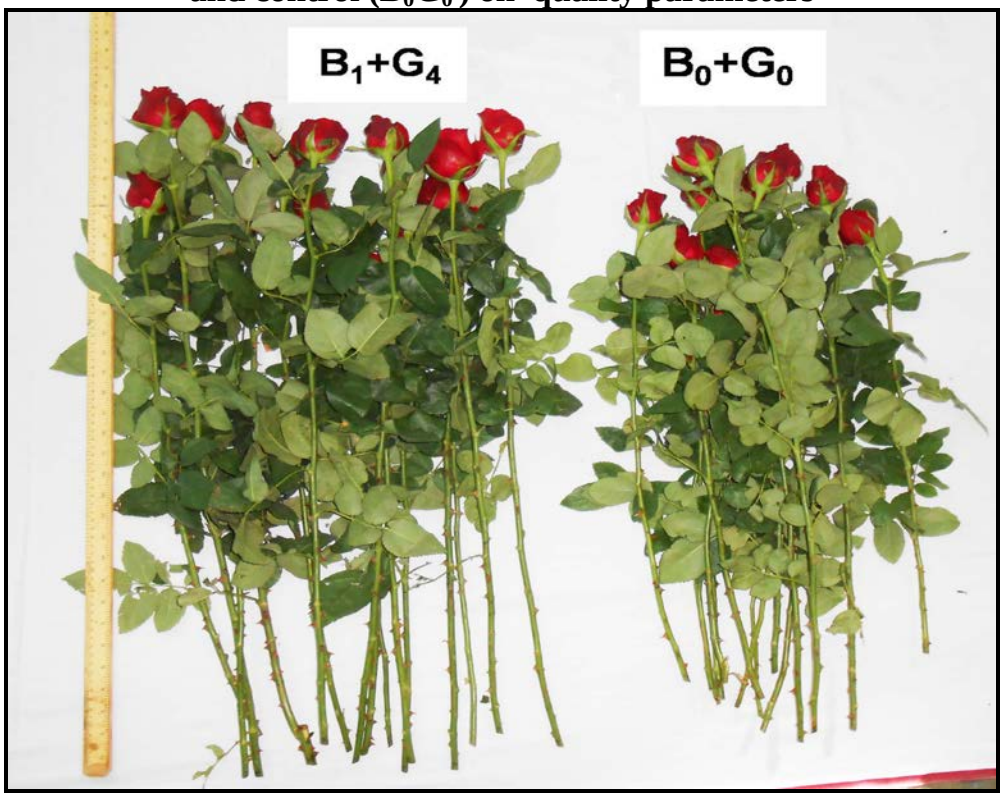
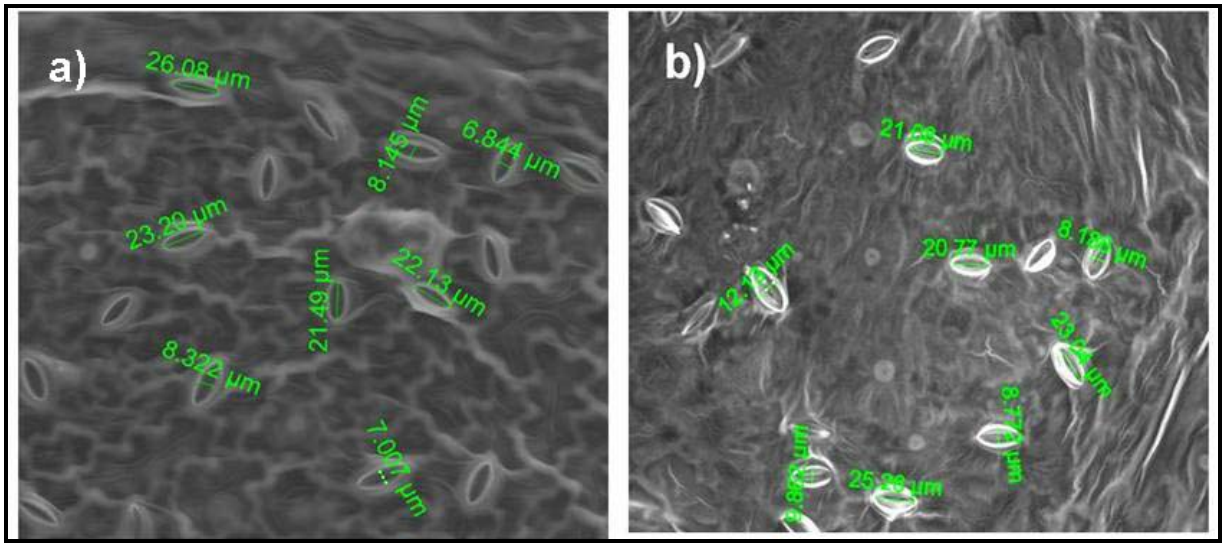
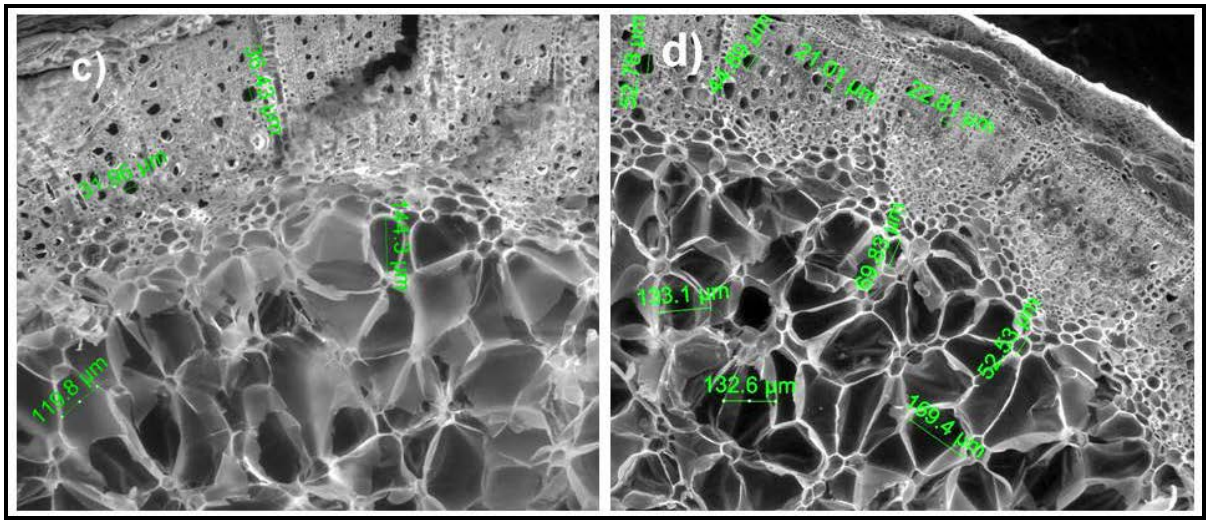


Plate 14. Variation in stomata size between control (B_0G_0) and best treatment (B_1G_4)



a) B_0G_0 – control **b) B_1G_4 -best treatment**

Plate 15. Variation in size of sclerenchyma stem cell between control (B_0G_0) and best treatment (B_1G_4)



c) B_0G_0 – control **d) B_1G_4 -best treatment**

Plate 16. Overview of pruned plants at 50 cm from ground level and bending(B_1) (Exp -II)

Plate 17. View of peak vegetative stage (25 days after pruning)

Plate 18. View of peak flower bud appearance stage (35 days after pruning)

Plate 19. View of peak flowering stage (45 days after pruning)

Plate 20. Effect of fertigation, micronutrients and *Bacillus spp* on the length of flowering shoot and bud size of Dutch rose (var. Tajmahal)

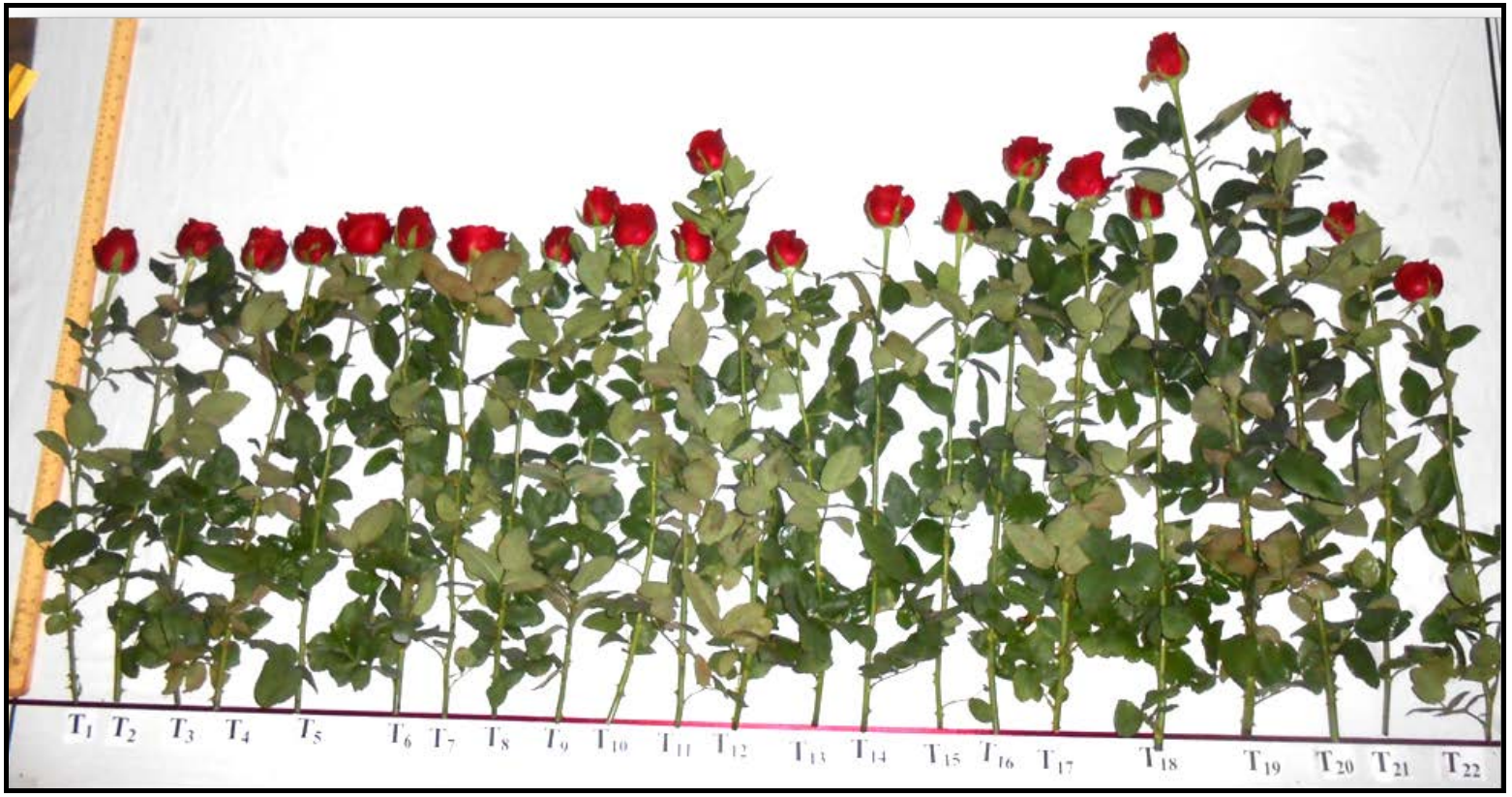


Plate 21a. Effect of vase solution on vase life studies of Dutch rose var. Tajmahal

Plate 21b. Blooming stage

Plate 21c. Flowers in vase solution on 12th day

Vase solution: 100 ppm of Aluminum sulphate + 1% of sucrose

Uniform stems of 35 cm length from all treatments kept in vase solution

Plate 22. Comparison between best treatment (T_{19}) and control (T_{22}) at vegetative stage

Plate 23. Comparison between best treatment (T_{19}) and control (T_{22}) at flowering stage

Plate 24. Comparison of best treatment (T_{19}), farmer practice (T_{21}) and control (T_{22}) of quality parameters

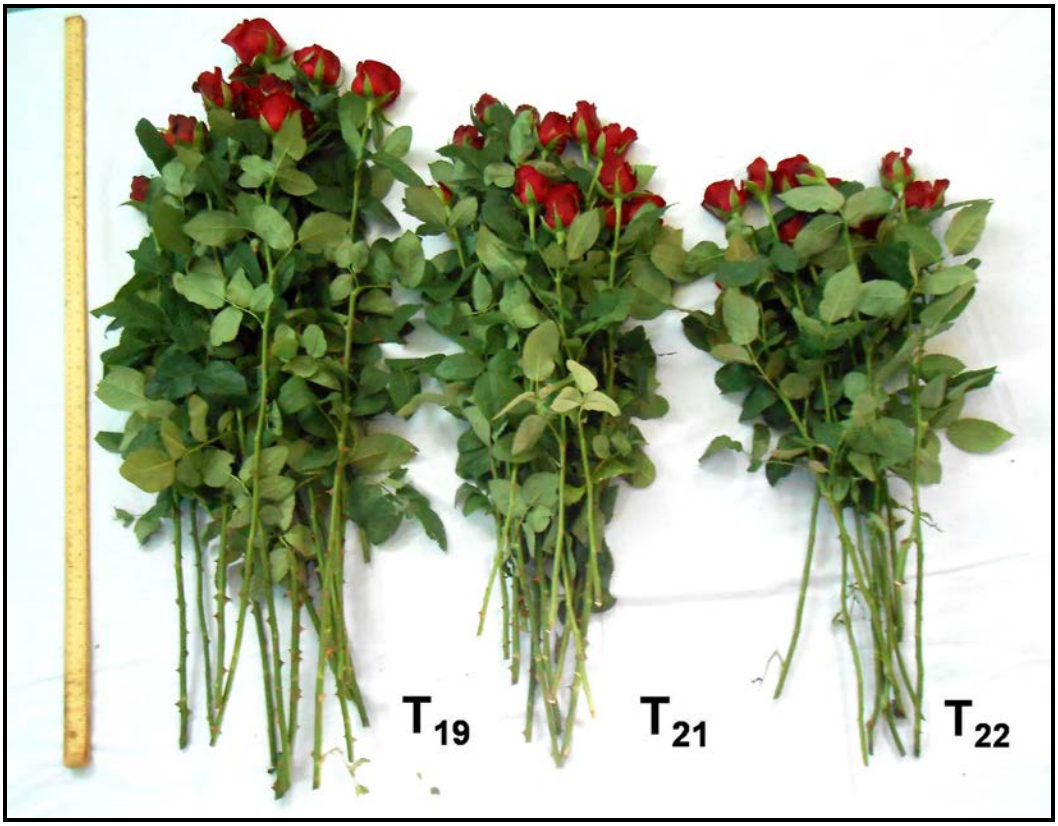
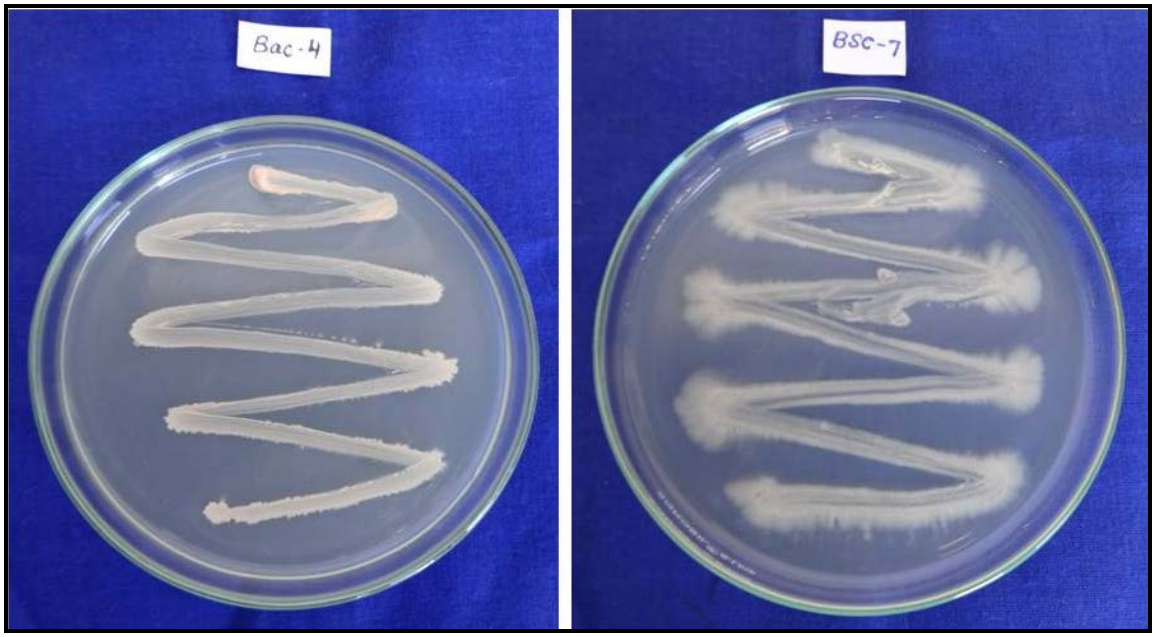


Plate 25. View of bio-agents (*Bacillus megaterium* – (BAC- 4) and (*Bacillus amyloliquefaciens* (BSC-7)



Annexures

ANNEXURE I

Physical, chemical and physiochemical properties of the soil for experiment -II

S. No.	Soil properties	Values of sample
I.	**Physical properties**	
1.	Soil texture	Sandy clay loam
II.	**Chemical properties**	
1.	Available Nitrogen	190 kg ha^{-1}
2.	Available Phosphorus	30 kg ha^{-1}
3.	Available Potassium	339 kg ha^{-1}
4.	Organic matter	0.25 %
5.	Available Zn	1.82 ppm
6.	Available Cu	1.18 ppm
7.	Available Fe	7.14 ppm
8.	Available Mn	5.16 ppm
III.	**Physio –Chemical properties**	
1.	EC	1.72 dSm^{-1}
2.	pH	6.97

ANNEXURE II

FERTIGATION SCHEDULE FOR CUT ROSE (VARIETY: TAJMAHAL)

100% Recommended dose: 1664:832:832 Kg NPK/ha/yr or 16.64:8.32:8.32 Kg NPK/100 m^2 /yr

Sl.No.	Crop stage	Duration in weeks	Fertilizer grade	Total fertilizer (g/15 m^2/ week)	Nutrient supplied			% requirement		
					N	P	K	N	P	K
1.	Pruning to peak vegetative stage (2^{nd} – 5^{th} week) (April -May)	4	19:19:19	9.08	0.6	0.6	0.6	30	30	30
			CN (15-0-0)	84.51	4.4	0	0			
			SOP (0-0-50)	10.96	0	0	1.9			
Sub-total					**5**		**2.5**			
2.	Peak vegetative stage to flower bud emergence (6^{th} -7^{th} week) (May)	2	19:19:19	9.08	0.6	0.6	0.6	30	30	30
			CN (15-0-0)	84.51	4.4	0	0			
			SOP (0-0-50)	10.96	0	0	1.9			
Sub-total					**5**		**2.5**			
3.	Flower bud emergence to Harvesting stage (8^{th} – 9^{th} week) (May- June)	2	19:19:19	12.14	0.84	0.84	0.84	40	40	40
			CN (15-0-0)	113.36	5.8	0	0			
			SOP (0-0-50)	14.42	0	0	2.5			
Sub-total					**6.64**	**0.84**	**3.34**			
Total					**16.64**	**2.04**	**8.34**	**100**	**100**	**100**
4.	Continuation of vegetative to harvesting stage (10^{th} – 52^{nd} week) (June-Feb)	44	19:19:19							
			CN (15-0-0)							
			SOP (0-0-50)							
Sub-total										
Total		**52**	--	--						

75% recommended ‘P’ applied as single super phosphate = 39 Kg/100 m^2 (Basal dose)

ANNEXURE III

ECONOMICS OF ROSE CULTIVATION UNDER NATURALLY VENTILATED POLYHOUSE FOR (500 Sq. m) AREA

S. No	Estimated cost components	Rate/ sq.m (Rs.)	Expenditure (Rs.)
I	**Non-recurring contingency (NRC) (for a life span of 10 years)**		
1.	Construction of polyhouse @ Rs. 500/m^2 Top : UV stabilized polyfilm Side : 70% Agro shade net	550	275000
2.	Irrigation system and others		
a.	Irrigation system including foggers and 2 HP Motor	200	100000
b.	Installation of drip irrigation, Irrigation equipments and fertilizers storage	50	25000
	Total of NRC		**400000**
II	**Recurring contingency (ORC) (For a life span of five years)**		
a.	Planting materials (6000 plants/500 m^2 @12 plants/ m2 @Rs. 10/plant	120	60000
b.	**Field preparation**		
	Tilling (6 hrs) – 350/hr	4.2	2100
	Bed preparation (FYM @25 kg/ sq.m @ Rs.2.0/kg Neem cake, red soil, sand excavation, labour and fertilizers	50 200	25000 100000
	Soil sterilization *Dazomet @ 30 g/sq.m (15 kg/ 500 sq.m)	19.5	9750
	Vermicompost @ 2.5 kg/ sq.m @ Rs. 5/kg	12.5	6250
c.	**Management cost**		
	Supervision, maintenance and harvesting (2 labour per unit for 1 year @ Rs. 2000/month)	96	48000
	Fertilizer and plant protection	40	20000
	a. Crop protection equipment		61000.00
	b. Grading and Packing yard		70000.00
	Total of ORC		**358900**
	Total of NRC + ORC		**758900**

ANNEXURE IV

Weather parameters during cropping period (August, 2012 – July, 2014)

Months	Temperature (^{o} C)		Relative Humidity (%)	Rainfall (mm)
	Max.	Min.		
August 2012	28	19.9	90	147.5
September 2012	28.5	19.6	85	44
October 2012	27.9	18.8	90	139.5
November 2012	27.6	16.1	80	87
December 2012	27.8	15.9	73	16
January 2013	29.5	14.8	68	0
February 2013	30.5	16.3	70	10
March 2013	32.9	18.8	58	0
April 2013	34.2	21.9	68	35.5
May 2013	32.9	21.7	79	79
June 2013	27.4	20.3	88	81.5
July 2013	27	19.9	83	42.5
August 2013	27.2	19.7	88	98.5
September 2013	26.8	19.5	86	131.5
October 2013	27	19.5	86	112.5
November 2013	27.2	20	87	36
December 2013	26.9	21.6	75	5
January 2014	27.4	21	71	0
February 2014	29.5	19.9	60	0
March 2014	33.8	20.4	64	0
April 2014	35.2	23.6	61	0
May 2014	36.5	25.7	57	0
June 2014	34.7	24.3	56	0
July 2014	28.4	20.3	17.7	2.2

ANNEXURE V

AVOVA TABLE FOR VARIOUS PARAMETERS FOR EXPERIMENT -I

Sl No.	Parameters			SS	MS	F	SEd	CD (0.05)	CD (0.01)
	Characters	Stages							
1	Plant height	At vegetative stage	B	4917.645	1229.411	744.129**	0.469	0.943	1.259
			G	143.111	35.777	21.655**	0.469	0.943	1.259
			BG	2228.314	139.269	84.296**	1.049	2.110	2.815
2	Plant height	At bud appearance stage	B	8996.748	2249.187	2542.839**	0.343	0.690	0.921
			G	288.475	72.118	81.534**	0.343	0.690	0.921
			BG	1024.456	64.006	72.363**	0.767	1.544	2.060
3	Plant height	At flowering stage	B	9611.836	2402.959	3664.478**	0.295	0.594	0.793
			G	330.059	82.514	125.834**	0.295	0.594	0.793
			BG	1159.374	72.460	110.501**	0.661	1.329	1.773
4	Number of compound leaves per plant	At vegetative stage	B	3181.335	795.333	193.536**	0.740	1.488	1.985
			G	152.332	38.083	9.267**	0.740	1.488	1.985
			BG	3118.605	194.912	47.430**	1.645	3.328	4.440
5	Number of compound leaves per plant	At bud appearance stage	B	3881.946	970.486	259.538**	0.706	1.419	1.894
			G	186.376	46.594	12.460**	0.706	1.419	1.894
			BG	3303.955	206.497	55.223**	1.578	3.174	4.235
6	Number of compound leaves per plant	At flowering stage	B	4017.506	1004.376	278.541**	0.693	1.394	1.860
			G	198.396	49.599	13.755**	0.693	1.394	2.860
			BG	3599.592	224.974	62.391**	1.550	3.117	4.159

S.No	Parameters			SS	MS	F	SEd	CD (0.05)	CD (0.01)
	Characters	Stages							
7	Number of basal shoots	At vegetative stage	B	0.434	0.108	4.660**	0.055	0.112	0.149
			G	0.295	0.073	3.171*	0.055	0.112	0.149
			BG	0.168	0.010	0.452NS	0.124	0.250	0.334
8	Plant spread	At vegetative stage	B	137.852	34.463	42.874**	0.327	0.658	0.878
			G	163.841	40.960	50.957**	0.327	0.658	0.878
			BG	120.114	7.507	9.339**	0.732	1.471	1.963
9	Inter nodal length	At flowering stage	B	5.299	1.324	317.283**	0.023	0.474	0.063
			G	1.702	0.425	101.908**	0.023	0.474	0.063
			BG	5.944	0.371	88.978**	0.052	0.106	0.141
10	Shoots per plant after bending	At vegetative stage	B	15.693	3.923	38.323**	0.116	0.234	0.313
			G	5.368	1.342	13.109**	0.116	0.234	0.313
			BG	16.615	1.038	10.143**	0.261	0.525	0.700
11	Number of days taken for shoot emergence	At bud appearance stage	B	17.780	4.445	51.701**	0.107	0.215	0.287
			G	10.467	2.616	30.435**	0.107	0.215	0.287
			BG	8.594	0.537	6.247**	0.239	0.481	0.642
12	Number of days taken for flower bud appearance	At bud appearance stage	B	85.279	21.319	148.352**	0.138	0.278	0.371
			G	36.524	9.131	63.538**	0.138	0.278	0.371
			BG	33.963	2.122	14.770**	0.309	0.622	0.830
13	Number of days taken for harvest from flower bud appearance	At flowering stage	B	8.738	2.184	42.274**	0.083	0.166	0.222
			G	0.710	0.177	3.438*	0.083	0.166	0.222
			BG	6.457	0.403	7.809**	0.185	0.373	0.497

Sl No.	Parameters			SS	MS	F	SEd	CD (0.05)	CD (0.01)
	Characters	Stages							
14	Number of days taken for harvest after bending	At flowering stage	B	267.060	66.765	267.214**	0.182	0.367	0.489
			G	29.908	7.477	29.925**	0.182	0.367	0.489
			BG	110.607	6.912	27.667**	0.408	0.820	1.094
15	Number of compound leaves /flowering shoot	At harvesting stage	B	19.624	4.906	50.917**	0.113	0.227	0.304
			G	34.205	8.551	88.749**	0.113	0.227	0.304
			BG	38.610	2.413	25.044**	0.253	0.509	0.679
16	Length of flowering stem	At harvesting stage	B	2481.320	620.330	723.879**	0.338	0.679	0.906
			G	685.269	171.317	199.914**	0.338	0.679	0.906
			BG	988.252	61.765	72.076**	0.755	1.519	2.027
17	Length of flower bud (cm) at harvest	At harvesting stage	B	6.542	1.635	147.792**	0.038	0.077	0.103
			G	4.489	1.122	101.416**	0.038	0.077	0.103
			BG	2.637	0.164	14.893**	0.085	0.172	0.230
18	Pedicel length (cm)	At harvesting stage	B	18.267	4.566	165.797**	0.060	0.121	0.162
			G	38.169	9.542	346.431**	0.060	0.121	0.162
			BG	25.209	1.575	57.200**	0.135	0.272	0.363
19	Circumference of flower bud	At harvesting stage	B	7.036	1.759	28.439**	0.090	0.182	0.243
			G	31.551	7.887	127.519**	0.090	0.182	0.243
			BG	16.896	1.056	17.072**	0.203	0.408	0.544
20	Stem girth (cm)	At harvesting stage	B	0.136	0.034	79.630**	0.007	0.015	0.020
			G	0.324	0.081	188.818**	0.007	0.015	0.020
			BG	0.207	0.012	30.150**	0.169	0.034	0.045

Sl No.	Parameters			SS	MS	F	SEd	CD (0.05)	CD (0.01)
	Characters	Stages							
21	Weight of flowering shoot at harvest (g)	At harvesting stage	B	3508.468	877.117	1663.644**	0.265	0.533	0.711
			G	3013.889	753.472	1429.124**	0.265	0.533	0.711
			BG	1405.947	87.871	166.668**	0.592	1.192	1.590
22	'A' Grade flowers / m^2/ year	At harvesting stage	B	200608.343	50152.085	683.208**	3.128	6.290	8.392
			G	30030.667	7507.666	102.274**	3.128	6.290	8.392
			BG	80438.956	5027.434	68.487**	6.995	14.066	18.766
23	'B' Grade flowers / m^2/ year	At harvesting stage	B	61744.650	15436.162	260.892**	2.808	5.647	7.534
			G	16514.999	4128.749	69.781**	2.808	5.647	7.534
			BG	33504.188	2094.011	35.391**	6.280	12.628	16.848
24	'C' Grade flowers / m^2/ year	At harvesting stage	B	1659.214	414.803	11.252**	2.216	4.457	5.947
			G	1551.387	387.846	10.521**	2.216	4.457	5.947
			BG	4313.121	269.570	7.312**	4.957	9.967	13.298
25	Yield of flowers / plant / year	At harvesting stage	B	338.858	84.714	572.998**	0.140	0.282	0.376
			G	73.146	18.286	123.688**	0.140	0.282	0.376
			BG	38.661	2.416	16.343**	0.313	0.631	0.842
26	Yield of flowers / m^2 / year	At harvesting stage	B	43156.821	10789.205	175.975**	2.859	5.749	7.670
			G	8253.013	2063.253	33.652**	2.859	5.749	7.670
			BG	8161.365	510.085	8.319**	6.393	12.855	17.150
27	Vase life (days)	At harvesting stage	B	144.454	36.113	2773.271**	0.041	0.083	0.111
			G	14.234	3.558	273.285**	0.041	0.083	0.111
			BG	59.323	3.707	284.727**	0.093	0.187	0.249

Sl No.	Parameters			SS	MS	F	SEd	CD (0.05)	CD (0.01)
	Characters	Stages							
28	Chlorophyll 'a'	At flowering stage	B	0.799	0.199	46.788**	0.023	0.047	0.064
			G	0.182	0.045	10.689**	0.023	0.047	0.064
			BG	2.987	0.186	43.738**	0.053	0.107	0.143
29	Chlorophyll 'b'	At flowering stage	B	0.455	0.113	160.003**	0.009	0.019	0.026
			G	0.204	0.051	71.961**	0.009	0.019	0.026
			BG	1.102	0.068	96.799**	0.021	0.043	0.058
30	Total chlorophyll	At flowering stage	B	1.927	0.481	68.577**	0.030	0.061	0.082
			G	0.258	0.064	9.185**	0.030	0.061	0.082
			BG	3.267	0.204	29.052**	0.068	0.137	0.183
31	IAA Oxidase	At flowering stage	B	143.223	35.805	51.788**	0.303	0.610	0.814
			G	1.908	0.477	0.690NS	0.303	0.610	0.814
			BG	155.848	9.740	14.088**	0.678	1.365	1.821
32	Soluble protein	At flowering stage	B	691.479	172.869	168.010**	0.370	0.744	0.993
			G	47.592	11.898	11.563**	0.370	0.744	0.993
			BG	517.705	32.356	31.447**	0.828	1.665	2.221
33	Nitrate Reductase	At flowering stage	B	0.030	0.007	119.443**	0.002	0.005	0.007
			G	0.125	0.031	484.826**	0.002	0.005	0.007
			BG	0.398	0.024	384.519**	0.006	0.013	0.017
34	Total phenolics	At flowering stage	B	42695.686	10673.921	2372.428**	0.774	1.557	2.077
			G	19173.142	4793.285	1065.374**	0.774	1.557	2.077
			BG	84168.381	5260.523	1169.224**	1.731	3.482	4.645
35	Peroxidase	At flowering stage	B	0.204	0.051	0.396 NS	0.131	0.263	0.351
			G	0.114	0.028	0.222 NS	0.131	0.263	0.351
			BG	1.237	0.077	0.600 NS	0.293	0.583	0.786
36	Anthocyanin content	At harvesting stage	B	1.898	0.474	27446.513**	0.001	0.003	0.004
			G	0.038	0.009	550.143**	0.001	0.003	0.004
			BG	1.950	0.121	7046.661**	0.003	0.006	0.009

AVOVA TABLE FOR VARIOUS PARAMETERS FOR EXPERIMENT -II

Sl No.	Parameters			SS	MS	F	SEd	CD (0.05)	CD (0.01)
	Characters	Stages							
1	Plant height	At vegetative stage	Tot Rep Trt	11140.752 9.978 11085.905	171.396 4.989 527.900	494.148**	0.8439	1.7035	2.2771
2	Plant height	At bud appearance stage	Tot Rep Trt	10992.038 20.216 10865.292	169.108 10.108 517.394	203.985**	1.300	2.624	3.508
3	Plant height	At flowering stage	Tot Rep Trt	11903.876 4.573 11871.269	183.136 2.286 565.298	846.947**	0.667	1.346	1.799
4	Number of compound leaves	At vegetative stage	Tot Rep Trt	4795.251 3.905 4723.778	73.773 1.952 224.941	139.823**	1.035	2.090	2.794
5	Number of compound leaves	At bud appearance stage	Tot Rep Trt	4927.992 2.539 4844.526	75.815 1.269 230.691	119.725**	1.133	2.287	3.058
6	Number of compound leaves	At flowering stage	Tot Rep Trt	4987.869 2.191 4910.449	76.736 1.095 233.830	130.547**	1.092	2.205	2.948
7	Number of basal shoots	At vegetative stage	Tot Rep Trt	3.636 0.161 1.944	0.055 0.080 0.092	2.540**	0.155	0.314	0.420

Sl No.	Parameters			SS	MS	F	SEd	CD (0.05)	CD (0.01)
	Characters	Stages							
8	**Plant spread**	**At vegetative stage**	Tot Rep Trt	1043.401 0.391 1034.323	16.052 0.195 49.253	238.146**	0.371	0.749	1.001
9	**Inter nodal length**	**At harvesting stage**	Tot Rep Trt	11.240 0.009 10.298	0.172 0.004 0.490	22.088**	0.121	0.245	0.328
10	**Shoots per plant after pruning**	**At vegetative stage**	Tot Rep Trt	34.854 0.283 31.716	0.536 0.141 1.510	22.227**	0.212	0.429	0.574
11	**Number of days taken for shoot emergence**	**At bud appearance stage**	Tot Rep Trt	21.660 0.253 18.341	0.333 0.126 0.873	11.967**	0.220	0.445	0.595
12	**Number of days taken for flower bud appearance**	**At bud appearance stage**	Tot Rep Trt	155.599 0.123 152.576	2.393 0.061 7.265	105.225**	0.214	0.433	0.578
13	**Number of days taken for harvest from flower bud appearance**	**At harvesting stage**	Tot Rep Trt	24.056 0.038 22.341	0.370 0.019 1.063	26.656**	0.163	0.329	0.440

Sl No.	Parameters			SS	MS	F	SEd	CD (0.05)	CD (0.01)
	Characters	Stages							
14	**Number of days taken for harvest after pruning**	**At harvesting stage**	Tot Rep Trt	379.179 0.265 374.786	5.833 0.132 17.846	181.587**	0.256	0.516	0.690
15	**Number of compound leaves**	**At harvesting stage**	Tot Rep Trt	180.850 0.076 178.237	2.782 0.038 8.487	140.512**	0.200	0.405	0.541
16	**Length of flowering stem**	**At harvesting stage**	Tot Rep Trt	3271.863 0.588 3211.359	50.336 0.294 152.921	107.197**	0.975	1.968	2.631
17	**Length of flower bud (cm) at harvest**	**At harvesting stage**	Tot Rep Trt	6.921 0.023 6.484	0.106 0.011 0.308	31.334**	0.081	0.163	0.218
18	**Pedicel length**	**At harvesting stage**	Tot Rep Trt	31.073 0.060 29.558	0.478 0.030 1.407	40.633**	0.152	0.306	0.306
19	**Circumference of flower bud**	**At harvesting stage**	Tot Rep Trt	24.305 0.362 20.081	0.373 0.181 0.956	10.400**	0.247	0.499	0.668

Sl No.	Parameters			SS	MS	F	SEd	CD (0.05)	CD (0.01)
	Characters	Stages							
20	**Stem girth (cm)**	**At harvesting stage**	Tot Rep Trt	0.566 0.000 0.550	0.008 0.000 0.026	73.330**	0.015	0.031	0.041
21	**Weight of flowering shoot at harvest (g)**	**At harvesting stage**	Tot Rep Trt	11138.849 1.480 11113.358	171.366 0.740 529.207	925.708**	0.617	1.246	1.665
22	**A Grade flowers / m^2/ year**	**At harvesting stage**	Tot Rep Trt	299596.347 58.757 297972.821	4609.174 29.378 14189.181	380.852**	4.983	10.059	13.447
23	**B Grade flowers / m^2/ year**	**At harvesting stage**	Tot Rep Trt	73503.841 54.678 70735.909	1130.828 27.339 3368.376	52.141**	6.562	13.246	17.707
24	**C Grade flowers / m^2/ year**	**At harvesting stage**	Tot Rep Trt	73806.430 11.533 72042.912	1135.483 5.766 3430.614	82.241**	5.273	10.644	14.229
25	**Total flowers/ m^2/year**	**At harvesting stage**	Tot Rep Trt	108240.294 10.817 107616.841	1665.235 5.408 5124.611	351.324**	3.118	6.294	8.414
26	**Yield of flowers / plant / year**	**At harvesting stage**	Tot Rep Trt	751.668709 0.075118 747.339176	11.564 0.037 35.587	351.324**	0.259	0.524	0.701
27	**Yield of flowers / m^2 / year**	**At harvesting stage**	Tot Rep Trt	108240.294 10.817 107616.841	1665.235 5.408 5124.611	351.324**	3.118	6.294	8.414

Sl No.	Parameters			SS	MS	F	SEd	CD (0.05)	CD (0.01)
	Characters	Stages							
28	**Vase life (days)**	**At harvesting stage**	Tot Rep Trt	139.595 0.009 137.934	2.147 0.004 6.568	167.059**	0.161	0.326	0.436
29	**Chlorophyll 'a'**	**At flowering stage**	Tot Rep Trt	2.836 0.104 2.727	0.043 0.052 0.129	1340.328**	0.008	0.016	0.021
30	**Chlorophyll 'b'**	**At flowering stage**	Tot Rep Trt	0.187 0.187 0.178	0.002 0.004 0.008	1364.280**	0.002	0.004	0.005
31	**Total chlorophyll**	**At flowering stage**	Tot Rep Trt	18.338 0.294 0.294	0.282 0.147 0.857	1350.169**	0.020	0.041	0.055
32	**IAA Oxidase**	**At flowering stage**	Tot Rep Trt	802.060 43.744 757.196	12.339 21.872 36.056	1352.269**	0.133	0.269	0.359
33	**Soluble protein**	**At flowering stage**	Tot Rep Trt	1822.526 92.454 1727.517	28.038 46.227 82.262	1352.289**	0.201	0.406	0.543
34	**Nitrate Reductase**	**At flowering stage**	Tot Rep Trt	3.251 0.373 2.873	0.050 0.186 0.136	1337.613**	0.008	0.016	0.022
35	**Total phenolics**	**At flowering stage**	Tot Rep Trt	185256.961 8733.566 176262.695	2850.107 4366.783 8393.461	1352.226**	2.034	4.106	5.488

Sl No.	Parameters			SS	MS	F	SEd	CD (0.05)	CD (0.01)
	Characters	Stages							
36	**Peroxidase**	**At flowering stage**	Tot Rep Trt	4.788 0.117 4.663	0.073 0.058 0.222	1335.578**	0.010	0.021	0.028
37	**Anthocyanin content**	**At harvesting stage**	Tot Rep Trt	1.765 0.005 1.759	0.027 0.002 0.002	10468.266**	0.002	0.004	0.006
38	**Available soil nitrogen**	**At vegetative stage**	Tot Rep Trt	20572.859 2045.087 13511.417	316.505 1022.544 643.400	5.386**	8.923	18.012	24.077
39	**Available soil nitrogen**	**At bud appearance stage**	Tot Rep Trt	21327.236 967.146 16590.085	328.111 483.573 790.004	8.801**	7.735	15.615	20.872
40	**Available soil nitrogen**	**At flowering stage**	Tot Rep Trt	27593.277 0.181 25054.725	424.511 0.090 1193.082	19.740**	6.347	12.812	17.127
41	**Available soil phosphorus**	**At vegetative stage**	Tot Rep Trt	799.864 23.002 741.850	12.305 11.501 35.326	42.377**	0.745	1.504	2.011
42	**Available soil phosphorus**	**At bud appearance stage**	Tot Rep Trt	590.357 10.836 539.395	9.082 5.418 25.685	26.885**	0.798	1.610	2.153
43	**Available soil phosphorus**	**At flowering stage**	Tot Rep Trt	598.007 32.158 563.634	9.200 16.079 26.839	509.082**	0.187	0.378	0.505

Sl No.	Parameters			SS	MS	F	SEd	CD (0.05)	CD (0.01)
	Characters	Stages							
44	**Available soil potassium**	**At vegetative stage**	Tot Rep Trt	95849.677 5330.129 89872.293	1474.610 2665.064 4279.633	277.703**	3.205	6.470	8.648
45	**Available soil potassium**	**At bud appearance stage**	Tot Rep Trt	90760.456 5487.339 85147.240	1396.314 2743.669 4054.630	1352.875**	1.413	2.853	3.814
46	**Available soil potassium**	**At flowering stage**	Tot Rep Trt	80198.353 4848.052 75239.028	1233.820 2424.026 3582.810	1352.333**	1.329	2.682	3.586
47	**Nitrogen content**	**At bud appearance stage**	Tot Rep Trt	17.618 0.152 14.870	0.271 0.076 0.708	11.458**	0.203	0.409	0.547
48	**Nitrogen content**	**At flowering stage**	Tot Rep Trt	20.358 0.027 17.002	0.313 0.013 0.809	10.213**	0.229	0.464	0.620
49	**Phosphorus content**	**At bud appearance stage**	Tot Rep Trt	0.230 0.016 0.109	0.003 0.008 0.005	2.106*	0.040	0.082	0.109
50	**Phosphorus content**	**At flowering stage**	Tot Rep Trt	0.185 0.026 0.107	0.002 0.013 0.005	4.135**	0.028	0.057	0.077
51	**Potassium content**	**At bud appearance stage**	Tot Rep Trt	22.060 0.752 21.026	0.339 0.376 1.001	149.382**	0.066	0.134	0.180

Sl No.	Parameters			SS	MS	F	SEd	CD (0.05)	CD (0.01)
	Characters	Stages							
52	**Potassium content**	**At flowering stage**	Tot Rep Trt	27.690 0.509 26.007	0.426013 0.254702 1.238431	44.2900**	0.1365	0.2756	0.3684
53	**Copper uptake**	**At bud appearance stage**	Tot Rep Trt	4849.954 172.041 4275.954	74.614 86.020 203.616	21.275**	2.525	5.098	6.815
54	**Copper uptake**	**At flowering stage**	Tot Rep Trt	6885.423 152.224 6389.384	105.929 76.112 304.256	37.167**	2.336	4.715	6.303
55	**Iron uptake**	**At bud appearance stage**	Tot Rep Trt	103594.635 188.261 99459.005	1593.763 94.130 4736.143	50.392**	7.915	15.978	21.358
56	**Iron uptake**	**At flowering stage**	Tot Rep Trt	129402.676 737.061 125762.333	1990.810 368.530 5988.682	86.634**	6.788	13.703	18.317
57	**Zinc uptake**	**At bud appearance stage**	Tot Rep Trt	83820.931 132.217 78705.466	1289.552 66.108 3747.879	31.588**	8.893	17.952	23.997
58	**Zinc uptake**	**At flowering stage**	Tot Rep Trt	103817.570 494.323 96578.978	1597.193 247.161 4598.998	28.640**	10.346	20.885	27.917
59	**Manganese uptake**	**At bud appearance stage**	Tot Rep Trt	29918.293 350.316 26125.705	460.281 175.158 1244.081	15.179**	7.391	14.920	19.945

Sl No.	Parameters			SS	MS	F	SEd	CD (0.05)	CD (0.01)
	Characters	Stages							
60	**Manganese uptake**	**At flowering stage**	Tot Rep Trt	38695.644 9.993 34689.131	595.317 4.996 1651.863	17.359**	7.964	16.077	21.490
61	**Dehydrogenase activity**	**At vegetative stage**	Tot Rep Trt	0.0212 0.000 0.020	0.000 0.000 0.000	1264.221**	0.000	0.001	0.001
62	**Dehydrogenase activity**	**At bud appearance stage**	Tot Rep Trt	0.020 0.000 0.0198	0.000 0.000 0.000	1218.200**	0.000	0.001	0.001
63	**Dehydrogenase activity**	**At flowering stage**	Tot Rep Trt	0.020 0.000 0.019	0.000 0.000 0.000	1075.663**	0.000	0.001	0.002
64	**Acid phosphatase**	**At vegetative stage**	Tot Rep Trt	0.123 0.002 0.121	0.001 0.001 0.005	1363.711**	0.001	0.003	0.004
65	**Acid phosphatase**	**At bud appearance stage**	Tot Rep Trt	0.0496 0.002 0.046	0.000 0.001 0.002	1333.671**	0.001	0.002	0.002
66	**Acid phosphatase**	**At flowering stage**	Tot Rep Trt	1.189 0.004 1.183	0.018 0.002 0.056	1354.385**	0.005	0.01	0.014
67	**Urease activity**	**At vegetative stage**	Tot Rep Trt	3681.516 1200.759 2477.082	56.638 600.379 117.956	1348.134**	0.241	0.487	0.651

Sl No.	Parameters			SS	MS	F	SEd	CD (0.05)	CD (0.01)
	Characters	Stages							
68	**Urease activity**	**At bud appearance stage**	Tot Rep Trt	364.262 1237.455 2403.257	56.065 618.727 114.440	1353.982**	0.237	0.479	0.640
69	**Urease activity**	**At flowering stage**	Tot Rep Trt	4047.445 1274.878 2768.480	62.268 637.439 131.832	1354.889**	0.254	0.514	0.687
70	**Bacteria**		Tot Rep Trt	11532.120 17.544 11251.985	177.417 8.772 535.808	85.700**	2.0416	4.121	5.508
71	**Fungi**		Tot Rep Trt	1211.561 25.283 1096.234	18.639 12.641 52.201	24.349**	1.195	2.413	3.225
72	**Actinomycetes**		Tot Rep Trt	4097.744 13.051 3664.051	63.042 6.525 174.478	17.421**	2.584	5.215	6.972
73	**Percent Disease Index**	**At vegetative stage**	Tot Rep Trt	1399.491 8.901 1364.529	21.530 4.450 64.977	104.719**	0.643	1.298	1.7354
74	**Percent Disease Index**	**At bud appearance stage**	Tot Rep Trt	5992.321 2.838 5960.150	92.189 1.419 283.816	406.379**	0.682	1.377	1.841
75	**Percent Disease Index**	**At flowering stage**	Tot Rep Trt	9893.167 8.278 9866.226	152.202 4.139 469.820	1057.302**	0.544	1.098	1.468

*** - Significant at 5%**

**** - Significant at 1%**

NS – Non Significant

ANNEXURE VI

Precision package practices for cut rose production

Selection of budded plants

The age of budded plants should be 2 months old with height of 30 cm, vigorous shoots and free from dieback disease.

Soil and field preparation

Well drained red sandy loam soil with organic matter content is highly preferred for rose cultivation. The soil pH 5.5- 6.5 and Ec - <1 is ideal for successful cultivation. Land should be thoroughly ploughed with disc plough at 60 cm depth for 2 to 3 times. Generally, the soil amendments like coirpith-3 kg, well decomposed farm yard manure - 15 to 20 kg, vermicompost-1 to 2 kg, phorate – 2 g, neem cake – 1 kg per m^2 are applied at last time of plough to improve the texture and nutrient status of the growing medium.

The organic manures should be mixed thoroughly with soil followed by pre-planting sterilization of soil with chemical fumigants so as to eradicate pathogens and pests. Chemical fumigants like dazomet (30 - 40 g/m^2) or formaldehyde (2 $litre/m^2$ of a solution prepared with 1 litre/7 litres of water) is commonly used for soil sterilization. The soil is moistened first and then drenched with the fumigant and immediately soil covered with good quality plastic sheets. After 48 hrs the plastic cover should be removed and the soil should be thoroughly turned for proper aeration. The fumigant should be removed by leaching with plain water 3-4 times with turning of soil each time.

Bed preparation and planting

Generally, the basal fertilizer dose of single super phosphate @ 390 g/m^2 should be evenly spread and thoroughly mixed with the media before bed preparation. Apart from the above fertilizer, bio-fertilizers and bio-control agents for the control of pest and diseases can be incorporated to soil at the time of bed preparation. *Azospirillum, Phosphobcteria, Trichoderma viridi, Pseudomonas fluorescens*, VAM each 1 kg can be added for $500m^2$ area for enriching the soil. Between the two beds a spacing of 45 cm

was left for walking space. The plant spacing of 30 x 15 cm and 12 plants / m^2 were maintained.

Details of polyhouse (Naturally Ventilated Polyhouse)

The naturally ventilated polyhouse (NVP) was oriented in East - West direction with central height of 5.7 m. The frame was constructed with galvanized iron pipe. A rollable low density polyethylene (LDPE) flap was provided on all the sides of the polyhouse to control the ventilation area and to cover the side vents during rainy season to avoid the entry of rainwater and cooling effects inside the polyhouse. Glazing was provided with 200µ (800 gauge) thick ultra violet stabilized low density polyethylene film. The temperature (25 -30^{0}C) and relative humidity (70- 85%) inside the polyhouse were maintained by watering and over head sprinkling.

Layout of drip system

Water was pumped through motor and it was conveyed to the main line after filtering through screen filter. From the source line, water was taken to the field through main line of 2'' PVC pipes. Fertigation tank was installed for fertigation. From the main pipes, 1.5" PVC pipes were fixed as sub-main. From which two laterals of 12mm OD were taken for three replications. There were two sub-mains with tap control for imposing drip irrigation and fertigation treatments. Along the laterals, emitters with a discharge rate of 4litres per hour were fixed at a spacing of 30cm.

Design data

1. Length of each lateral from sub main (12mm OD LDPE) - 15m
2. Emitter spacing - 30 cm
3. Lateral spacing - 30 cm
4. Emitter type - Inline dripper
5. Emitter discharge rate - 4lph
6. Filter size (screen filter) - 100µ

Special horticultural practices

Building of young plants

Bending

Bending is necessary for keeping enough leaves on the plants and the leaves are important for the production of sugars. This mass of leaves is often called the lungs of the plant. From each plant, a minimum of four stems, either flowers or blind shoots, must be bent. For the blind shoots, take out the growing tips, to avoid the new growth on the top after bending. The place where to bend is as close to the original bush as possible (maximum 5 cm), without breaking the branches. To avoid breaking, it is advisable to do the bending in the afternoon and to create two 45 degree bends rather than one 90 degree bend. The bending should be such that the tops of the stems are below the horizontal. This is important for the apical dominance of the plant.

Bottom Breaks

Soon after bending, the first bottom breaks will be coming from the base of the plants. These bottom breaks are most important for the life of the plant, because they will carry the production. Let these bottom breaks come to flower and harvest them.

Second and Third Crop

After cutting the bottom breaks in the proper way, the sprouting will start again very soon with two to three sprouts (generally). These sprouts will become flowers again approximately six to seven weeks after cutting the bottom break and will give the first real quality production.

Wild Shoots

With the development of the shoots, there will also come some wild shoots. These shoots have to be removed when minimal 5 cm long, every week. Most wild shoots are pale green whereas a normal shoot is purple in the beginning and dark green later on. The wild shoots have to be removed completely.

Pinching

The rose bush is regulated to flower in peak seasons. This can be achieved by adopting cultural practices. ‘Pinching’ is one such practice followed first during the third or fourth week of October to produce rose flowers for the Christmas season. The same operation produces the second flush of flowers in February for Valentine’s Day. Most of

the commercial cultivars take about five-and-a-half to six weeks from pinching to produce flowers during summer and about eight weeks during winter.

Pruning

The selected plants were pruned for standard height at 50 cm from ground level.

Fertilizer application through drip irrigation

Drip irrigation system was installed for the complete cropped area. The fertilizer sources for supplying NPK through drip irrigation were Calcium nitrate (15:0:0), All 19 (19:19:19) and Sulphate of potash (0:0:50) respectively. Fertigation was given as per the fertigation schedule.

Fertigation schedule for 60 days (8weeks / 1 cycle) 6 cycle /yr Variety: Tajmahal

125% Recommended dose: 2080:1040:1040 Kg NPK/ha/yr **or** 20.8:10.4:10.4 Kg NPK/100 m^2 /yr

Sl. No.	Crop stage	Duration in weeks	Fertilizer grade	Total fertilizer (Kg/100m^2/yr)	Total fertilizer (g/100m^2/week)
1.	Pruning to peak vegetative stage	4	19:19:19	3.94	75.77
			CN (15-0-0)	36.63	704.42
			SOP (0-0-50)	4.75	91.35
Sub-total					
2.	Peak vegetative stage to flower bud emergence	2	19:19:19	3.94	75.77
			CN (15-0-0)	36.63	704.42
			SOP (0-0-50)	4.75	91.35
Sub-total					
3.	Flower bud emergence to Harvesting stage	2	19:19:19	5.2625	101.20
			CN (15-0-0)	49.125	944.71
			SO**P** (0-0-50)	6.25	120.19
8			**Sub-total**		
4.	Continuation of vegetative to harvesting stage	44	19:19:19		
			CN (15-0-0)		
			SOP (0-0-50)		
Total		**52**	**--**	**--**	

Basal dose of (75% P as SSP through soil @ 48.75 kg / 100 m^2) was applied.

Fertigation techniques

For rose, based on different treatment doses and stages, the fertilizer was given through fertigation throughout the cropping period through split application. The split doses were given once in a week through fertigation. Basal dose of (75% P as SSP through soil @ 48.75 kg / 100 m^2) was applied.

Bending and application of growth regulators

New vegetative shoots were produced from pruned plants after 30 days. The well grown shoots were selected after attaining pencil thickness size for bending **.** The shoots were twisted and gently bent at bending at shoot junction bud. The foliar application of plant growth regulators BA 200 ppm was done immediately after bending. Plant growth regulator was sprayed at fifteen days interval till flowering (2 months).

Application of micronutrients and *Bacillus spp*

The chelated micronutrient mixture contains (Fe- 4.0%, Zn – 4.0 %, Mn-1.5 %, Cu-1.5 %, B- 0.5%, Mg-9.0%, and Mo-0.1%). Foliar application of BA 200 ppm, micronutrient mixture, soil and foliar application of *Bacillus megaterium* and *Bacillus amyloliquefaciens* were done at fifteen days, ten days and seven days interval respectively.

Inter cultivation

The entire rose beds were kept weed free by hand weeding at regular intervals. The scraping of bed was done once in a month.

Irrigation

Application of water through hosepipe was done for plants at two days interval in summer months, to reduce the field heat and to maintain temperature and humidity inside the polyhouse.

Drip irrigation

It was done once in three days @ 4 lph.

Temperature management

To create a favourable environment for plant growth, side ventilation opening was altered depending upon the season, whenever the temperature went high, the rollable polyethylene flap was used to roll up, and sufficient irrigation through hose was given to bring down the temperature. While, under low temperature condition, the rollable polyethylene flap was rolled down in order to conserve the heat inside the polyhouse.

Plant protection

Periodical plant protection measures were carried out to control pests and diseases during crop growth as per the schedule.

Disbudding and de-shooting

Removal of undesirable axillary buds and shoots was done after development of main bud in the growing shoot. Keeping only the central bud to promote the growth of terminal bud, which led to the production and improve the quality of flower

Bud capping /netting

The nylon made small net like caps were covered to the developing bud to regulate the shape and increase the size of the bud and improve the quality of the flower.

Harvesting

The flowering stem was harvested when calyx was reflexed and first petal started opening out (Tight bud stage) leaving two nodes from the base of the shoot.

Pre cooling & grading

After harvesting cut stems were kept in clean bucket with water containing 100 ppm Aluminum sulphate solution were pre-cooled for 5- 10 hrs at < 5^0C in cold room and graded based on the length of stem and size of the bud.

Cold room storage

After grading and proper packing of flowers were kept in clean bucket with water containing 100 ppm Aluminum sulphate solution were stored for 5 -7 days at 2- 5°C for export purpose.

Packing for export purpose

Box size

Length : 100 cm

Width : 30 cm

Height : 45 cm

Number of flowers/ bunch : 20

Number of bunches/ box : 16 - 20

Weight of flower/ box : 12- 15 (Kg)

Quality requirement for export

- Pre cooling of flowers
- Free from pest and disease
- Big size with healthy shining leaf
- Long and straight stem (50 – 80 cm)
- Medium to big size flower bud
- Uniform of particular variety and stage of (tight bud or half open) flower in a bunch

The basic requirements of a quality cut rose are:

- The straight strong stem capable of holding the flower upright.
- Uniform stem length: Flowers with different stem lengths are not be mixed.
- Size of the flower should be the representative of the cultivar (true to type).
- Uniform stage of development.
- Flower should be free from bruising, injuries, diseases and pests or petal discoloration.
- Good, healthy and normal foliage.

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Effect of Fertigation, Micronutrients and *Bacillus* sp for Maximizing the Yield, Quality and Disease Management of Rose (*Rosa hybrida* var., *Tajmahal*) under Greenhouse Conditions

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ABSTRACT

An experiment was conducted to study the effect of fertigation, micronutrients and *bacillus sp* to maximize the yield and quality of rose variety *Tajmahal* under naturally ventilated polyhouse. It consists of 22 treatments for the study, highly significant results were observed with respect to various plant parameters. Among the treatments, the plants of T_{19} significantly recorded highest plant height (167.26 cm), plant spread (47.82 cm^2), early flower bud appearance (26.93 days), minimum duration for harvest (49.08 days), increased stem length (83.77 cm), increased flower bud circumference (12.81 cm), flower stem girth (0.83 cm), increased number of cut flowers per plant (27.07) and extended vase life of 11.50 days in the vase solution containing 100ppm Al_2SO_4 +1% sucrose. It is clear from the study that plant growth parameters, yield and quality of flowers were found to be superior in T_{19} (125% of RDF @ 208:104:104 g NPK /m^2 / year + foliar application of 0.5% EDTA+ soil and foliar application of *B. megaterium and B. amyloliqufaciens* each@ 10 ml/m^2) for the var. Tajmahal.

Key words *Bacilus sp, fertigation, micronutrients, polyhouse, rose, vase life*

Roses (*Rosa hybrida* L.) are one of the most important commercial crops grown for a variety of purposes such as pot plant, garden plant and cut flower production. Among all other cut flowers, Roses being cultivated from ancient times and maintained its position as the Queen of flowers. Introduction of green house technology for cultivation of cut flowers in India in the recent years has changed the scenario of Indian floriculture (Ramalingam, 2008). Among the cut flowers grown in India primarily for export, rose is emerging as a new potential cut flower crop in protected cultivation. In India, it is grown for both domestic and international trade purpose.

Among the various package of practices, fertigation, disease and pest management is directly playing major role for quality of cut rose flower production. Fertigation is the precise application of water soluble fertilizer through sprinkler and drip irrigation (Billsegars, 2003). It permits optimal, improved water and nutrient use efficiency for better plant growth and result in reduces application costs.

Foliar application is one of the best ways to supply micronutrients to plants, which are necessary for the proper growth and yield (Cabrera, *et al.*, 1993). Plant diseases cause considerable losses in crop production. It is one of the main task in greenhouse cultivation of rose is management of powdery mildew, caused by *Sphaerotheca pannosa var. rosae*, because this disease occurs more or less throughout the year under protected condition and causes enormous losses in respect of both quality and quantity. *Bacillus* spp. is involved in the control of plant diseases through a variety of mechanisms of action, such as competition, systemic resistance induction and antibiotic production. Besides the anti-fungal effects, some compounds produced by *Bacillus* spp. may also act as plant growth promoters (Compant, *et al.*, 2005).

The flower stem should be harvested at the appropriate harvesting stage, that is, at the mature and tight bud stage. Aluminium sulphate has been recommended for maintaining the vase life of several cut flowers (Liao, *et al.*, 2001). The viable technology for production needs to be standardized for Indian climate. More over the commercial floriculture venture is very much cultivar specific. Therefore, the present investigation were undertaken to study the effects and optimization of the fertigation, micronutrients and management of powdery mildew for maximizing the yield and export quality of cut rose flowers under protected condition.

MATERIALS AND METHODS

A field experiment was laid out in a randomized block design (RBD) with three replications under greenhouse conditions during the year 2013 – 2014 in a private farm of M/s Shiva Sakthi Floritech Pvt Ltd at Hosur, Tamil Nadu to find out the effect of fertigation, micronutrients and *Bacillus spp*. to maximize the yield and quality of cut rose var.Tajmahal. The budded rose plants were planted in raised beds with a spacing of 30 cm x 15 cm accommodating 12 plants per sq.m. All other agronomic and plant protection measures were carried out as and when required and as per the schedule. Five plants were randomly tagged in each of the plot (replication and treatment wise) and observed for growth and yield attributes.

Fig.1.Pruning and bending

Table 1. Effect of fertigation, miconutrients and *Bacillus spp* on various vegetative & floral parameters

Treatments	Plant height (cm)	No. of compound leaves /flowering shoot	Plant spread (cm^2)	Inter nodal length (cm)	No. of days taken for			Length of flowering stem (cm)
					Flower bud appearance	Harvest from flower bud appearance	Harvest after bending	
T_1	125.77	11.13	34.14	5.44	30.21	12.80	55.64	52.81
T_2	131.39	12.20	32.53	5.61	30.64	12.90	55.84	58.30
T_3	127.69	12.40	34.58	5.56	30.98	12.94	56.13	62.09
T_4	135.30	11.27	36.56	5.33	30.73	12.31	54.91	63.30
T_5	140.54	11.47	37.81	5.43	31.23	12.96	56.56	62.21
T_6	144.96	12.20	37.80	5.50	31.58	13.01	57.53	65.41
T_7	143.03	11.07	38.84	5.21	31.71	12.82	57.40	64.15
T_8	148.65	11.40	40.58	5.18	30.12	12.34	55.39	67.53
T_9	150.50	12.20	38.28	5.14	29.58	12.48	54.45	66.31
T_{10}	144.61	12.33	37.38	5.20	29.12	12.73	54.72	65.64
T_{11}	150.25	12.67	39.52	5.52	29.47	12.94	54.74	62.57
T_{12}	152.04	13.80	42.17	5.54	28.36	12.58	53.07	65.81
T_{13}	152.00	12.47	37.66	5.45	28.71	12.39	53.69	64.53
T_{14}	154.69	12.33	39.11	5.23	28.94	12.03	53.70	61.24
T_{15}	157.96	12.53	41.33	5.50	27.21	11.54	51.73	67.30
T_{16}	161.92	14.73	42.91	5.60	27.94	11.98	52.31	66.32
T_{17}	157.03	15.00	40.38	5.98	27.38	11.32	50.83	64.29
T_{18}	161.47	15.53	43.09	6.19	27.39	11.90	50.55	68.26
T_{19}	167.26	16.67	47.82	6.25	26.93	11.13	49.08	83.77
T_{20}	164.23	16.20	46.59	6.21	27.01	11.33	49.57	79.54
T_{21}	137.71	12.13	34.55	5.05	28.72	12.30	53.12	58.75
T_{22}	113.69	11.47	32.79	4.55	30.60	12.90	56.10	50.50
SED	**0.6671**	**0.2007**	**0.3713**	**0.1217**	**0.2146**	**0.1631**	**0.2560**	**0.9752**
CD at 5%	**1.3465**	**0.4051**	**0.7495**	**0.2456**	**0.4331**	**0.3293**	**0.5167**	**1.9685**

Table 2. Effect of fertigation, miconutrients and *Bacillus spp* on various floral parameters

Treatments	Length of flower bud (cm) at harvest	Pedicel length (cm)	Circumference of flower bud (cm) at harvest	Stem girth (cm)	Mean yield of flowers / plant / year	Mean yield of flowers / m^2 / year	Weight of flowering shoot at harvest (g)	Vase life (days)
T_1	5.15	5.63	10.81	0.57	15.23	182.76	44.50	8.28
T_2	5.03	5.01	10.57	0.55	16.01	192.12	44.66	7.37
T_3	5.61	5.14	11.09	0.52	16.13	193.56	48.57	8.33
T_4	5.73	5.08	10.96	0.54	18.07	216.84	52.77	6.23
T_5	5.32	5.35	11.19	0.53	21.27	255.24	55.03	9.23
T_6	5.11	5.32	11.27	0.57	20.27	243.24	60.52	8.27
T_7	5.22	5.31	11.29	0.57	22.20	266.40	66.06	9.20
T_8	5.37	5.22	11.15	0.59	21.73	260.76	70.98	7.33
T_9	5.20	5.21	11.03	0.60	20.67	248.04	60.94	10.33
T_{10}	5.15	5.11	11.01	0.58	20.40	244.80	57.64	11.27
T_{11}	5.53	6.16	11.32	0.67	22.40	268.80	66.85	10.33
T_{12}	5.16	5.11	10.83	0.65	22.33	267.96	70.77	9.30
T_{13}	5.29	5.12	11.36	0.63	20.53	246.36	60.69	11.27
T_{14}	5.17	6.11	11.21	0.70	21.47	257.64	57.04	10.37
T_{15}	4.97	6.26	11.29	0.69	22.07	264.84	67.00	9.30
T_{16}	5.37	6.83	11.56	0.69	23.40	280.80	70.57	9.20
T_{17}	5.13	6.15	12.05	0.71	22.53	270.36	73.83	10.23
T_{18}	5.79	6.32	11.95	0.75	25.32	303.84	82.61	11.27
T_{19}	5.80	6.91	12.81	0.83	27.07	324.84	90.55	11.50
T_{20}	5.82	6.93	12.52	0.80	26.67	320.04	84.58	11.27
T_{21}	4.67	5.75	11.34	0.53	20.12	241.44	48.50	10.43
T_{22}	4.73	4.58	10.58	0.48	10.64	127.68	42.63	8.37
SED	**0.0811**	**0.1520**	**0.2476**	**0.0154**	**0.2599**	**3.1184**	**0.6173**	**0.2599**
CD at 5%	**0.1636**	**0.3067**	**0.4997**	**0.0312**	**0.5246**	**6.2946**	**1.2462**	**0.5246**

One year old existing rose plants were selected and pruned for standard height at 50 cm from ground level. New vegetative shoots were produced from pruned plants after 30 days. The weak shoots were gently bent at shoot junction bud (Fig.1).

The foliar application of plant growth regulator (BA 200 ppm) was done at fifteen days interval till flowering (2 months). Foliar application of chelated micronutrient (contains Fe, Zn, Mn, Cu, Bo, Mo and Mg) at various percentages were sprayed at 0.5% micronutrients at ten days interval, soil and foliar application of *B. megaterium and B. amyloliqufaciens* at seven days interval for (T_5 - T_{20}). The treatments consist of viz., T_1 - 75% of RDF @ 125:62.4:62.4 g NPK /m^2 /yr, T_2-100% of RDF @ 166.4: 83.2:83.2 g NPK /m^2 / yr, T_3- 125% of RDF @ 208:104:104 g NPK /m^2 / yr, T_4-150% of RDF @ 250:125:125 g NPK / m^2 /yr, (T_5 -T_1, T_6 - T_2, T_7 - T_3, T_8 -T_4) + *B. megaterium* @ 10 ml/m^2, (T_9 -T_1, T_{10}-T_2, T_{11} - T_3, T_{12} - T_4) + *B. amyloliqufaciens* @ 10 ml/m^2, (T_{13} - T_1, T_{14}-T_2, T_{15}-T_3, T_{16} - T_4) + B. *megaterium* +*B. amyloliqufaciens* each@ 5 ml/m^2, (T_{17}- T_1,T_{18} - T_2,T_{19} - T_3, T_{20}- T_4) + B. *megaterium* +*B. amyloliqufaciens* each@ 10 ml/m^2, T_{21} - Farmers practice's (119: 140: 98 g NPK/ m^2 /yr), T_{22} - Control

(without fertilizers). After harvest, the flower stems at equal length of 35cm were kept in aluminum sulfate 100ppm +1% sucrose for vase life study.

RESULTS AND DISCUSSION

Among the different treatments, T_{19} - (T_3 + 0.5 % chelated EDTA + foliar spray & soil application of B. *megaterium* + *B. amyloliqufaciens* each@ 10 ml/m^2) was found to be superior. The plants of T_{19} significantly recorded the highest plant height (167.26 cm), number of leaves (16.67), plant spread (47.82cm^2) and inter nodal length (6.25 cm) (Table.1). Rahman, *et al.*, 2000 stated that availability of more number of leaves in a plant help in manufacture of more photosynthates which might have resulted in increasing plant height and production of more number of branches per plant. Further, minimum days taken for flower bud appearance (26.93 days), minimum duration for harvest from flower bud appearance (11.13 days) and minimum days for harvest after bending (49.08 days) and the highest stem length (83.77 cm) were also observed in the treatment T_{19} (Table.1).

Plants treated with micronutrients exhibited better results with respect to growth, flowering and yield compared to control (Mukesh, *et al.*, 2001). In the same treatment, increased flower bud circumference (12.81 cm), maximum flower stem girth (0.83 cm), maximum number of cut stems per square meter (324.84) and vase life (11.50 days) were observed followed by T_{20} which was on par with T_{19} (Table.2). Spraying with $ZnSO_4$, $FeSO_4$ and $MnSO_4$ or $CuSO_4$ to three-year old hybrid tea rose cv. Raktagandha one month after pruning was the most effective treatment to stimulate secondary shoot production and increasing bud length, flower diameter, number of petals per flower and flower production (Cabrera, *et al.*, 1993).

Biocontrol activity of *Bacillus* strains against multiple plant pathogens have been widely reported and well documented (Kloepper, *et al*., 2004). The combination of micro-organisms gives better results probably due to the different mechanisms used. Pyoung, and Chung, 2004 described the production of antifungal protein by *B.amyloliquefaciens* against *C. lagenarium*, causing watermelon anthracnose. The better quality flowers were obtained from T_{19} and other treatments are due to, regular and prior soil and foliar applications of *Bacilus sp* were significantly decrease the infection of powdery mildew and free plants and flowers over control. The growth and floral parameters are superior due to the interaction effect of fertigation, bending, foliar application of micronutrients and PGRs, soil and foliar application of *Bacillus* sp. The above package of various agro-techniques are significantly increased the yield and export quality of cut rose flowers.

It is clear from the above study that the plant growth, yield and quality parameters of flowers were found to be superior by application of 125% of RDF @ 208:104:104 g NPK /m^2 / yr + foliar application of 0.5% EDTA+ soil and foliar application of *B. megaterium and B. amyloliqufaciens* each@ 10 ml/m^2 for the successful production of greenhouse rose. var. *Tajmahal*

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Effect of Bending and Plant Growth Regulators on Maximizing the Yield and Quality of Rose (*Rosa hybrida* Var., *Tajmahal*) under Greenhouse Conditions

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ABSTRACT

An experiment was conducted to study the effect of bending and plant growth regulators to maximize the yield and quality of rose variety "Tajmahal" under naturally ventilated polyhouse. From the results of the study, a highly significant interaction effect was observed with respect to various plant parameters. Among the interactions, bending at shoot junction bud (B_1) + BA 200 ppm (G_4) significantly recorded highest plant height (165.33 cm), plant spread (45.19 cm^2), early flower bud appearance (26.40 days), minimum duration for harvest (48.80 days), increased stem length (86.79 cm), increased circumference of flower bud (13.13 cm), flower stem girth (0.87 cm), maximum number of cut flowers per plant (26.47) and extended vase life of 12.37 days. The stomata aperture value ranges between (length 25 to 28 µm, width 8.0 µm, length 21 to 25 µm, width 8.0 to12 µm) for control and treatment respectively. Differences between normal and treatment stems are also apparent in the vascular tissue organization and parenchyma cells. It is clear from the study that plant growth parameters, yield and quality of flowers were found to be superior by doing bending practice at shoot junction bud along with the application of BA at 200 ppm for the var. Tajmahal.

Key words *Bending, PGRs , polyhouse, rose, vase life*

Roses (*Rosa hybrid*a L.) are one of the most important commercial crops grown for a variety of purposes such as pot plant, garden plant and cut flower production. Among all other cut flowers, Roses being cultivated from ancient times and maintained its position as the Queen of flowers. Introduction of green house technology for cultivation of cut flowers in India in the recent years has changed the scenario of Indian floriculture (Ramalingam, 2008). Among the cut flowers grown in India primarily for export, rose is emerging as a new potential cut flower crop in protected cultivation. In India, it is grown for both domestic and international trade purpose.

Shoot bending technique is progressively replacing the traditional upright growing technique in greenhouse production. This new technique posed new challenges to both cultivation and research. Bending became a standard method in cut rose production and is generally done repetitively over the entire growing season. The fundamental idea behind shoot-bending is that instead of removing unwanted or marginal stems by pinching or pruning, these are retained in the canopy so as to maintain foliage area and consequently produce assimilates.

It has been reported that bending of the primary shoot promotes the formation of axillary shoots by breaking apical dominance (Cline, 1991). The basal shoots are usually vigorous and act as an important source of flower production (Zieslin, and Mor, 1981). Plant growth regulators also play a key role in increasing the yield and quality of cut flowers by manipulating the hormonal regulation in plant system growth. (Arun, *et al*., 2000) studied the effects of different levels of GA_3 on growth and flowering of rose "First red" and found that GA_3 could improve plant and flower neck height, as well as flowering shoot length.

The flower stem should be harvested at the appropriate harvesting stage, that is, at the mature and tight bud stage. Aluminium sulphate has been recommended for maintaining the vase life of several cut flowers (Liao, *et al*., 2001). The cut flowers are kept in preservative solutions immediately after harvest to extend the vase life. The production technology for viable production needs to be standardized for Indian climate. More over the commercial floriculture venture is very much cultivar specific.

The best results will be useful to all the concerned for developing strategies to increase area, productivity of crop, profit and export earnings for cut flower growers. Therefore, the present investigation were undertaken to study the effects of various growth regulators and different levels of bending on maximizing the yield and export quality of cut rose flowers.

MATERIALS AND METHODS

A field experiment was laid out in a factorial randomized block design (FRBD) with three replications under greenhouse conditions during the year 2012 – 2013 in a private farm of M/s Shiva Sakthi Floritech Pvt Ltd at Hosur, Tamil Nadu to find out the effect of different levels of bending with growth regulators (GA_3 and BA) to maximize the yield and quality of cut rose var.Tajmahal. The plants were planted in raised beds with a spacing of 30 cm x 15 cm accommodating 12 plants per sq.m. All

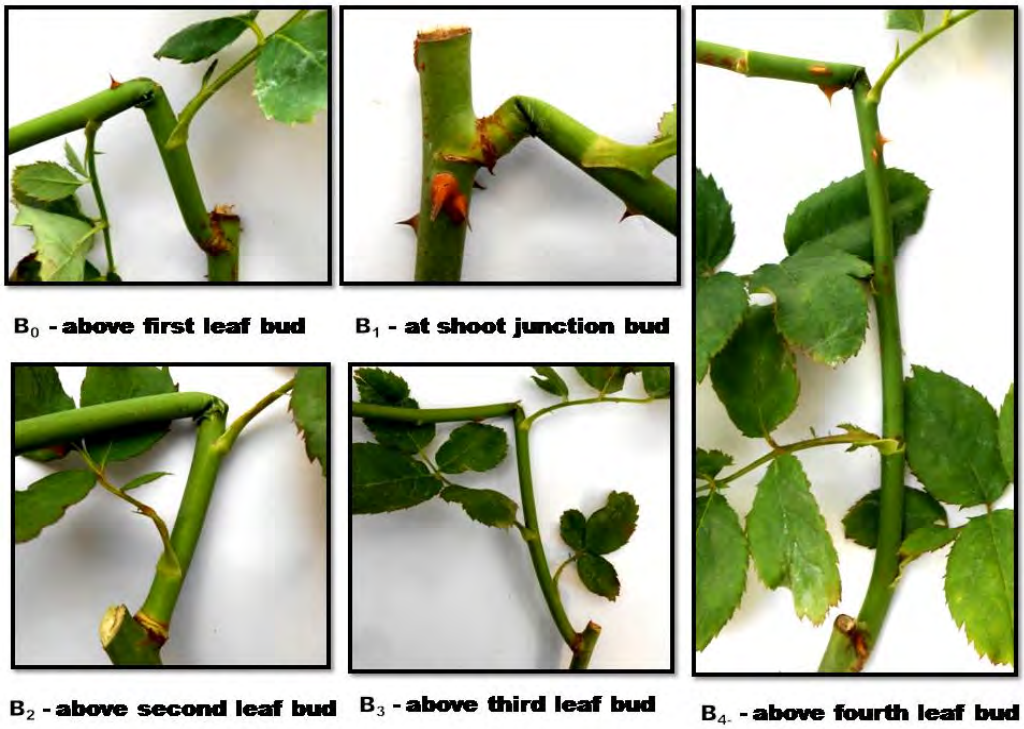

Fig.1.Different levels of bending

other agronomic and plant protection measures were carried out as and when required and as per the schedule. Five plants were randomly tagged in each of the plot (replication and treatment wise) and observed for growth and yield attributes.

One year old existing rose plants were selected and pruned for standard height at 50 cm from ground level. New vegetative shoots were produced from pruned plants after 30 days. The well grown shoots were selected after attaining pencil thickness size for bending. The shoots were gently bent at different levels (Fig.1).

The foliar application of plant growth regulators (GA_3 100, 200 ppm and BA 100, 200 ppm) were done immediately after bending, and continued at fifteen days interval till flowering (2 months). The treatments consist of two factors viz., (Factor-1 - B_0-Bending above first leaf bud (Control), B_1 -

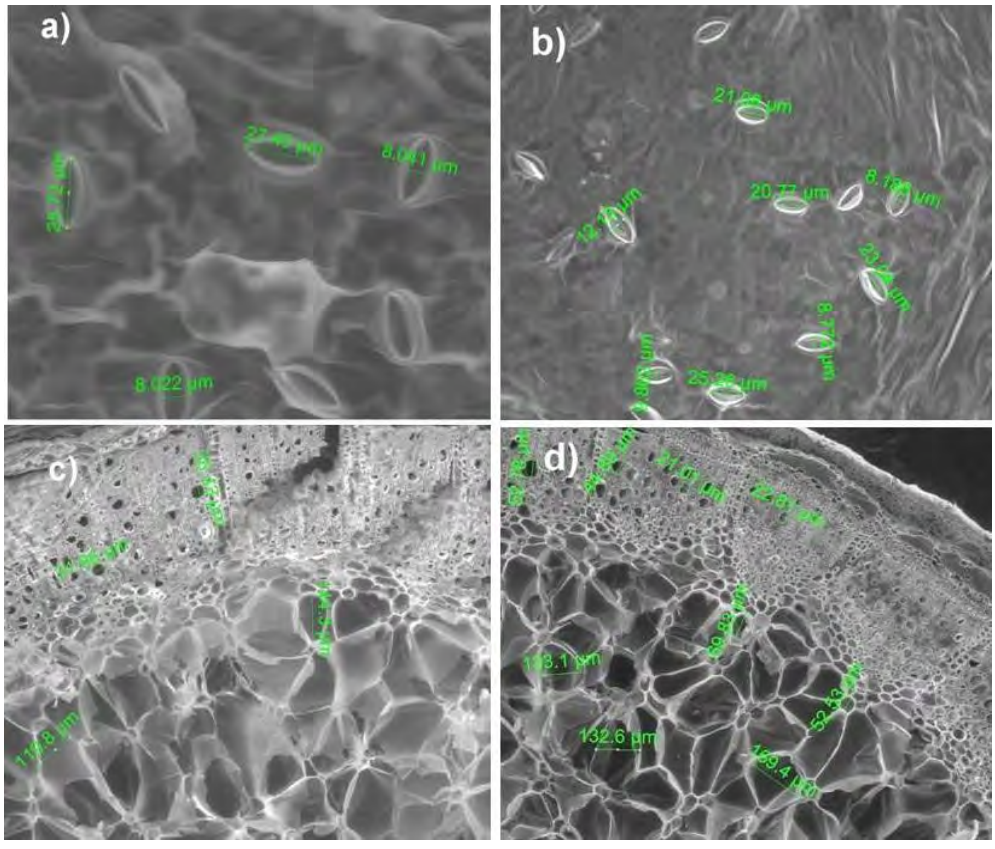

Fig. 2. Replicas of leaf and stem were imaged in SEM .a, c - control (without bending + GR); b, d- treatment (Bending at shoot junction bud +BA 200 ppm).

Table 1. Effect of bending and PGRs on various vegetative & floral parameters

Treatments	Plant height (cm)	No. of compound leaves /flowering shoot	Plant spread (cm^2)	Inter nodal length (cm)	No. of days taken for			Length of flowering stem (cm)
					Flower bud appearance	Harvest from flower bud appearance	Harvest after bending	
$B_1 G_1$	152.70	13.13	40.33	5.60	28.47	12.90	53.37	70.43
$B_1 G_2$	156.03	12.40	41.44	5.84	27.60	12.70	52.10	68.83
$B_1 G_3$	159.22	14.67	43.35	6.02	26.93	12.03	49.93	76.43
$B_1 G_4$	165.33	16.13	45.19	6.13	26.40	11.53	48.80	86.79
$B_2 G_1$	149.93	13.93	39.74	5.58	29.97	12.77	54.90	62.21
$B_2 G_2$	150.05	13.73	38.98	5.89	29.47	12.93	54.77	65.17
$B_2 G_3$	153.67	14.27	40.70	5.23	27.47	12.77	51.63	71.46
$B_2 G_4$	150.62	13.40	42.71	5.18	27.70	12.97	51.97	67.53
$B_3 G_1$	148.13	13.13	39.01	5.14	28.53	12.67	54.07	66.31
$B_3 G_2$	145.63	13.07	36.26	5.05	29.83	12.93	55.67	65.64
$B_3 G_3$	141.21	14.87	41.97	5.07	29.27	12.70	53.97	70.41
$B_3 G_4$	148.30	13.20	42.26	5.15	30.43	12.73	55.13	69.63
$B_4 G_1$	138.36	13.07	39.52	4.97	31.00	12.90	56.60	64.53
$B_4 G_2$	137.59	13.33	37.97	4.81	30.70	12.27	55.70	60.69
$B_4 G_3$	132.03	12.73	41.62	4.99	30.07	12.87	55.30	64.30
$B_4 G_4$	135.49	13.60	43.30	5.07	30.57	12.87	56.17	61.51
$B_1 G_0$	132.55	12.93	38.81	4.90	30.60	12.67	55.23	70.41
$B_2 G_0$	128.99	11.27	38.99	4.94	30.73	12.73	56.23	57.71
$B_3 G_0$	127.22	12.07	39.44	4.80	30.80	12.90	57.27	57.62
$B_4 G_0$	123.80	11.20	38.51	4.87	31.20	13.00	57.90	53.82
$B_0 G_0$	121.33	11.27	39.13	4.54	31.30	13.60	57.13	59.98
$B_0 G_1$	125.61	12.67	35.10	5.13	30.70	13.80	57.40	61.88
$B_0 G_2$	124.79	12.93	36.05	5.45	30.73	13.63	57.37	55.07
$B_0 G_3$	130.83	12.33	37.94	5.72	30.50	13.37	56.17	53.12
$B_0 G_4$	133.32	12.53	39.77	5.63	31.13	12.77	56.07	57.25
SED	0.661	0.253	0.732	0.052	0.309	0.185	0.408	0.755
CD at 5%	1.329	0.509	1.142	0.106	0.622	0.373	0.820	1.519

Bending at shoot junction bud, B_2 -Bending above second leaf bud, B_3 -Bending above third leaf bud, B_4 - Bending above fourth leaf bud and Factor-2- G_0- without GR, G_1- GA_3 100 ppm, G_2 - GA_3 200 ppm, G_3 - BA 100 ppm, G_4 - BA 200 ppm) with 25 combinations. After harvest, the flower stems at equal length of 35cm were kept in aluminum sulfate 100ppm +1% sucrose for vase life study. The stomata from the lower surfaces of leaves and transverse section of stem were imaged and analysed by Scanning Electron Microscopy (SEM). The leaf and stem samples were used for SEM - control (without bending + GR) and treatment (Bending at shoot junction bud +BA 200 ppm).

RESULTS AND DISCUSSION

Among the different combinations, B_1G_4 viz., bending at shoot junction bud (B_1) + application of BA 200 ppm (G_4) was found to be superior. B_1G_4 combination significantly recorded the highest plant height (165.33 cm), number of leaves (16.13), plant spread (45.19cm^2) and inter nodal length (6.13 cm) (Table.1). (Rahman, *et al.*, 2000) stated that availability of more number of leaves in a plant help in manufacture of more photosynthates which results in increasing plant height and produce more number of branches per plant. It has been reported that bending of the primary shoot promotes the formation of axillary shoots by breaking apical dominance (Cline, 1991).

Minimum days taken for flower bud appearance (26.40 days), minimum duration for harvest from flower bud appearance (11.53 days) and minimum days for harvest

Table 2. Effect of bending and PGRs on various floral parameters

Treatments	Length of flower bud (cm) at harvest	Pedicel length (cm)	Circumference of flower bud (cm) at harvest	Stem girth (cm)	Mean yield of flowers /		Weight of flowering shoot at harvest (g)	Vase life (days)
					plant / year	m^2 / year		
$B_1 G_1$	5.15	8.81	10.81	0.57	23.07	276.80	61.92	8.73
$B_1 G_2$	5.03	9.67	9.75	0.55	22.53	270.40	67.00	10.78
$B_1 G_3$	6.02	6.41	13.09	0.84	24.27	291.20	89.02	11.37
$B_1 G_4$	6.26	6.59	13.13	0.87	26.47	317.60	91.84	12.37
$B_2 G_1$	5.32	8.25	10.56	0.58	21.27	255.20	55.03	10.43
$B_2 G_2$	5.11	9.55	10.32	0.62	20.27	243.20	60.52	10.32
$B_2 G_3$	5.95	6.49	12.21	0.70	22.20	266.40	71.75	10.94
$B_2 G_4$	5.84	6.44	11.25	0.72	23.20	278.40	70.98	10.60
$B_3 G_1$	5.20	6.92	11.07	0.64	20.67	248.00	60.94	8.38
$B_3 G_2$	5.15	7.02	10.46	0.57	21.07	252.80	56.73	8.59
$B_3 G_3$	5.83	5.76	12.17	0.77	22.40	268.80	66.85	7.39
$B_3 G_4$	5.57	5.79	11.64	0.75	21.20	254.40	70.77	6.81
$B_4 G_1$	5.29	6.61	10.74	0.66	20.53	246.40	60.69	6.81
$B_4 G_2$	5.17	7.28	10.55	0.57	21.47	257.60	57.04	7.60
$B_4 G_3$	5.50	6.03	12.18	0.66	22.07	264.80	67.00	6.72
$B_4 G_4$	5.37	5.54	12.29	0.69	21.73	260.80	65.59	6.77
$B_1 G_0$	5.13	6.20	10.67	0.65	20.93	251.20	63.39	8.41
$B_2 G_0$	5.15	6.68	11.13	0.56	20.20	242.40	56.56	7.11
$B_3 G_0$	5.23	6.70	11.23	0.55	19.53	234.40	54.36	7.93
$B_4 G_0$	5.15	6.88	10.72	0.53	18.40	220.80	52.16	7.17
$B_0 G_0$	4.67	6.73	10.60	0.58	17.33	208.00	51.65	7.13
$B_0 G_1$	4.73	6.53	10.54	0.50	17.00	204.00	49.80	7.13
$B_0 G_2$	4.71	6.58	10.62	0.53	16.67	200.00	52.95	7.02
$B_0 G_3$	4.70	6.57	10.50	0.61	17.13	205.60	57.12	6.96
$B_0 G_4$	4.73	6.71	10.46	0.63	16.40	195.20	55.63	7.71
SED	0.085	0.135	0.203	0.016	0.313	6.393	0.592	0.093
CD at 5%	0.172	0.272	0.408	0.034	0.631	12.855	1.192	0.187

after bending (48.80 days) and the highest stem length (86.79 cm) was observed in the treatment B_1G_4 (Table.1). Ohkawa, and Suematsu, (1999) accredited following additional benefits of bending in the rose. In the bent system, harvested flowering shoots include basal shoots that are usually strong and long. In the same treatment, highest length of flower bud at harvest (6.26 cm), pedicel length (6.59 cm) and increased circumference of flower bud (13.13 cm) were observed (Table.2).

The treatment that $B_1 G_4$ combination also recorded maximum flower stem girth (0.87 cm), maximum number of cut stems per square meter (317.60) and vase life (12.37 days) followed by $B_1 G_3$ which is on par with each other (Table.2). (Fig.2) shows the variation in stomatal aperture and transverse section of stem in control and treatment. (Fig. 2a, b) shows the stomata aperture value ranges between (length 25 to 28 µm, width 8.0 µm, length 21 to 25 µm, width 8.0 to12 µm) for control and treatment respectively. Differences between normal and treatment stems are also apparent in the vascular tissue organization and parenchyma cells (Fig. 2c, d). Cytokinins are often considered ABA antagonists in many processes including the regulation of stomatal opening, but the effects are species specific and depend on cytokinin type, concentration and method of application (Pospisilova, 2003). It has been shown that increased cytokinin concentration in the xylem sap promotes stomatal opening and simultaneously decreases sensitivity to ABA (Wilkinson, and Davies, 2002).

The growth and floral parameters are superior due to

the interaction effect of bending along with PGRs. The bent stem formed abundant photosynthesizing leaves enough to supply extra assimilates and translocation of carbohydrates to the growing shoots (Amanullah, *et al.*, 2010). Kim, and Lieth, 2004 reported that due to the bending process, the plants showed increase in plant height and produced more number of healthy shoots in cut rose.

It is clear from the above study that the plant growth, yield and quality parameters of flowers were found to be superior by doing bending practice at shoot junction bud along with the application of BA at 200 ppm for the successful production of greenhouse rose. var. Tajmahal.

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