STUDIES ON THE EFFECT OF PLANT GROWTH PROMOTING RHIZOBACTERIA AND GA_3 ON PLANT GROWTH, FRUITING AND SOIL HEALTH OF STRAWBERRY (*FRAGARIA X ANANASSA* DUCH.) CULTIVAR CHANDLER

Thesis

by

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(H-2011-18-D)

Submitted to

DR YASHWANT SINGH PARMAR UNIVERSITY OF HORTICULTURE AND FORESTRY SOLAN (NAUNI) HP – 173 230 INDIA

in

Partial fulfilment of the requirements for the degree

of

DOCTOR OF PHILOSOPHY
(FRUIT SCIENCE)

(DEPARTMENT OF FRUIT SCIENCE)
(HORTICULTURAL SCIENCES)
2015

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CERTIFICATE - I

This is to certify that the thesis titled **"Studies on effect of plant growth promoting rhizobacteria and GA_3 on plant growth, fruiting and soil health of strawberry (*Fragaria x ananassa* Duch.) cultivar Chandler",** submitted in partial fulfilment of the requirements for the award of degree of **DOCTOR OF PHILOSOPHY FRUIT SCIENCE** to Dr Yashwant Singh Parmar University of Horticulture and Forestry, (Nauni) Solan (HP) - 173 230 is a bonafide research work carried out by **Ms. Kumari Seema (H-2011-18-D)** son/daughter of Shri Tek Chand Thakur under my supervision and that no part of this thesis has been submitted for any other degree or diploma.

The assistance and help received during the course of investigations have been fully acknowledged.

Place : Nauni, Solan
Dated: ,2015

(Dr Kuldeep Mehta)
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CERTIFICATE-II

This is to certify that the thesis titled, **"Studies on the effect of plant growth promoting rhizobacteria and GA_3 on plant growth, fruiting and soil health of strawberry (*Fragaria x ananassa* Duch.) cultivar Chandler"**, submitted by **Ms. Kumari Seema (H-11-18-D)** ~~son~~/daughter of Shri Tek Chand Thakur to Dr. Yashwant Singh Parmar University of Horticulture & Forestry, (Nauni), Solan (H.P.) - 173230 India in partial fulfilment of the requirements for the degree of **DOCTOR OF PHILOSOPHY FRUIT SCIENCE** in the discipline of **HORTICULTURE** has been approved by the Student's Advisory Committee after an oral examination of the same in collaboration with the External Examiner.

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ACKNOWLEDGEMENT

"Pride, Praise and Perfection Belongs to "Lord Vishnu & Maa Durga". Every effort is motivated by ambition and all ambitions have an inspiration behind. I owe this place to my parents Mr. Tek Chand and Mrs. Savitri Devi who encouraged me to undergo higher studies. The perpetual support and tenacity of my nanaji and naniji has always been a perennial source of inspiration for the attainment of my success. I thank to Almighty for giving me everything.

I emphatically express my deep sense of gratitude towards my esteemed teacher and chairman of my advisory committee, ***Dr. Kuldeep Mehta, Prof. & Head, Department of Seed Science & Technology*** *for his inspiring and freehearted guidance, discreet approach, illative and appraise critique and perpetual encouragement during the entire course of investigation.*

I express my sincere gratitude to ***Dr. P. S. Chauhan (Dean, COH), Dr. N. Sharma (Prof. & Head, Dept. of Fruit Science)*** *and members of my advisory committee* ***Dr. P. K. Mahajan (Prof. & Head, Dept. of Basic Science)*** *and* ***Dr. S. S. Sharma (Prof., Dept of Basic Science)*** *for their help, cooperation and valuable suggestions during entire degree programme.*

I extend my cordial and affectionate thanks to ***Dr C. S. Shrikot, Dr. Rajesh Kaushal, Dr. Anjali, Dr. Narender Verma, Dr S. K. Bhardwaj, Dr. Tripathi*** *and* ***Dr D.D. Sharma*** *for providing the facilities required during my research work.*

'Thanks' is too small a word to express my deep sense of gratitude to ***Dr. S. D. Sharma, Dr. D. P. Sharma, Dr. Vishal Rana, Dr. Anju Thakur, Dr. J. S. Chandel, Dr. Girish Sharma, Dr. K Kumar, Dr. Naveen Chand Sharma and Dr. H. S. Bhatia*** *(Department of Fruit Science) for their sincere, selfless and invaluable help during the course of my study.*

Friendship is a golden chain made stronger with each minute. Each link is forged of memories that make you still dearer. The thoughtful things you say and do become the links of gold that I will treasure through the years and in my heart will hold sweet memories of R. Swamishekhar, Kapil Kalsi, Shikha, Kiran, Chaitanya, Babita Kachi, Usha, Manish sir, Usha, Kishor, Rocky, Shruti, Shalini, Bharti, Komal, Kalpna, Shilpa, Pama, Ankita and Yash for being with me and making my stay in this campus memorable.

Satyanand Stokes Library will always remain a luscious remembrance for furnishing my studies with endless and invaluable information.

The co-operation and assistance extended by the faculty, office, laboratory and field staff, Department of Fruit Science and Directorate of Research, specially Ajmer ji is duly acknowledged.

Last but not the least, I wish to thank DPT computers for their promptness and care while making this manuscript in its present form.

My words cannot substitute my feelings towards my sister for her love.

Needless to say Errors and Omissions are mine.

Place: Nauni, Solan
Dated: , 2015 (**Kumari Seema)**

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LIST OF ABBREVIATIONS

GA_3	:	Gibberellic acid
IAA	:	Indole-3-acetic acid
NAA	:	α-Naphthalene acetic acid
cv.	:	Cultivar
ppm	:	Parts Per Million
TSS	:	Total Soluble Solids
et al.	:	Co –workers
mm	:	Millimeter
cm	:	Centi meter
cm^2	:	Square centi meter
m^3	:	Cubic metre
ηm	:	Nano meter
kg/tree	:	Kilogram per tree
m mol s^{-1}	:	Milli mol per second
μ mol $m^{-2}s^{-1}$	:	Micro mol per meter square per second
mM	:	Milli molar
dm^{-1}	:	Per deci meter
dSm^{-1}	:	Deci Siemen per meter
mg/g	:	Milli gram per gram
EC	:	Electrical conductivity
%	:	Per cent
CD	:	Critical Difference
Ha	:	Hectare (10000 m^2)
^0C	:	Degree Celsius
OD	:	Optical density
@	:	At
PGR	:	Plant growth regulators
PGPR	:	Plant Growth Promoting Rhizobacteria
PGPB		Plant Growth Promoting Bacteria
PSB	:	Phosphate solubilizing bacteria
SPB	:	Siderophore producing bacteria
CFU	:	Colony forming unit
FYM	:	Farmyard manure
VAM	:	Vascular arbuscular mycorhhiza
AMF	:	Arbuscular mycorrhizal fungi

Chapter-1

INTRODUCTION

Strawberry (*Fragaria* × *ananassa* Duch.) is known as one of the most attractive, delicious and refreshing fruit of the world and occupies a significant place in fruit growing. It belongs to family Rosaceae and the most of cultivated varieties are octaploid (2n= 56). The fruits are rich in bioactive phyto-chemicals especially phenolic compounds with high antioxidant capacity and also contain vitamins and minerals and, as a part of daily diet could be beneficial to human health.

Strawberry can be successfully grown in plains as well as in hills up to an elevation of 3000 meters above mean sea level in humid or dry regions. In India, it is cultivated on commercial scale in Maharashtra, Punjab, Haryana, Delhi, hills of Himachal Pradesh, Jammu & Kashmir, Uttrakhand, Uttar Pradesh, Rajasthan and West Bengal (Rana and Chandel, 2003). In Himachal Pradesh, it is being grown on limited scale in Kullu, Kangra, Sirmour, Solan and Shimla districts and occupies an area of 55 ha with annual production of 354 MT (Anonymous, 2014). The area under strawberry in Himachal Pradesh is fast expanding as it has drawn attention of growers for its quick considerable income and nutritional values. Moreover, the climatic conditions of the state provide unique opportunities to grow strawberry for its production in lower areas and at higher elevation, it can be grown both for fruit and runner production.

Strawberry is a shallow rooted, herbaceous plant of which 50-90 % of the root system is confined to upper 15 cm of soil (Galletta and Bringhurst, 1990). Therefore, fertility, moisture, drainage and microbial status of upper layer of soil have a great impact on growth, development, fruit yield, quality and production of runners. The modern strawberry cultivation that warrants high yield and quality requires extensive use of chemical fertilizers which not only disrupt balance of nature, but also reduce economic efficiency. It also degrades physico-chemical and biological properties of soil as well as plants. It is well known that intensive agricultural production and increased synthetic nitrogen inputs affect environment through the pollution with nitrogen metabolites. The investigations suggest that nitrogenous fertilizers used in agriculture contaminate surface and underground water (Beman *et al.*, 2005 and Wolfe and Patz, 2002), enhance N_2O emissions into the atmosphere

(Galloway *et al.*, 2003) and result in possible nitrate accumulation in plants. Thus, to overcome adverse effects of chemical fertilizers, current trends are focused on the improved management practices including use of plant growth promoting rhizobacteria and plant growth regulators which have been becoming a resurgence of interest in sustainable and organic cultural practices (Esitken *et al.*, 2005). A more intensified use of PGPR, supplements to chemical fertilizers, has been evidenced in the production of field, vegetable, forage and cash crops (Cvijanovic *et al.*, 2007). More recently, the use of plant growth promoting rhizobacteria has been exploited in fruit crops and they have proved to be a major tool in fruit production. Plant growth promoting rhizobacteria may improve plant growth and yield by means of producing plant growth regulators (auxin, gibberellins, cytokinins etc.), solublizing of organic phosphate or mineralizing organic phosphate or other nutrients, fixing atmospheric nitrogen, facilitating the uptake of nutrients and preventing deleterious effects on soil as produced by chemical fertilizers. Various research workers found that plant growth promoting rhizobacteria could stimulate growth and increase yield in apple, sweet cherry, citrus, raspberry, high bush blueberry, mulberry and apricot (Pirlak and Kose, 2009). Plant growth promoting rhizobacteria have gained worldwide importance and acceptance for horticultural benefits. These are probably potential tools to a sustainable horticulture and trend for the future.

Beside these, Plant growth regulators are also known to improve growth, fruiting and quality of fruit crops through various physiological and metabolic processes. Thus, the plant growth regulators have been much used for improving growth, fruiting and yield as well as runner production in strawberry. Among PGRs, Gibberellic acid (GA_3) is a growth regulator which stimulate the effect of long day lengths in short day plants by improving vegetative development and increasing runner production. Gibberellic acid progressively increased the plant height, canopy spread, leaf area, number of leaves, petiole length and induces stem elongation when applied exogenously to strawberry plants. Gibberellic acid initiate early flowering and thus early fruit development and harvesting occur. It also increase number of flowers per crown, fruit set percentage, total number of fruits per plant (Kasim *et al.*, 2007; Paroussi *et al.*, 2002 and Sharma & Singh, 2009). It also enhanced the number of runners in all strawberry varieties by specifically stimulating the stolon forming systems during long days. It is also responsible for increasing the number of runners per crown at higher rates of application. Gibberellic acid also improve the fruit quality by affecting various physico-chemical characteristics of the fruit such as high ascorbic acid and total soluble sugars,

whereas, inducing no significant effect on titratable acidity (Usenik *et al.,* 2005 and Sharma & Singh, 2009). Strawberries are ideal model for nutrient interaction studies in perennial fruit crops. Since, they are relatively precocious in producing their first crop within months of planting and also, they can easily be excavated and divided into vegetative and reproductive components, allowing for detailed evaluation of observed growth or other responses (May and Pritts, 1993). Balanced nutrient at proper time is one of the mean to reach a commercial fruit production, improved yield and fruit quality. The use of plant growth promoting rhizobacteria (PGPR) and plant growth regulators could be exploited to improve the plant growth and to increase the commercial value of the plant. Thus the present study was carried out to investigate the following objectives:

i) To study the effect of plant growth promoting rhizobacteria (PGPR) on plant growth, yield, quality, leaf nutrient status and soil health

ii) To study the effect of GA_3 and its combinations with plant growth promoting rhizobacteria (PGPR) on plant growth, yield, quality and leaf nutrient status

Chapter-2

REVIEW OF LITERATURE

The findings of various research workers on the effect of plant growth promoting rhizobacteria (PGPR) and GA_3 on growth, yield, fruit quality, leaf nutrient status and soil health of strawberry are reviewed as under:

2.1 EFFECT OF PLANT GROWTH PROMOTING RHIZOBACTERIA (PGPR)

Plant growth promoting rhizobacteria (PGPR) are bioresources which may be viewed as a novel and potential tool for providing substantial benefits to the agriculture. Plant growth-promoting rhizobacteria (PGPR) was first defined by Kloepper and Schroth (1978) to describe soil bacteria that colonize the roots of plants following inoculation and enhance plant growth. These are also defined as free-living soil, rhizosphere, rhizoplane and phylosphere bacteria that under some conditions enhance emergence, colonize roots, stimulate growth, enhance yield and soil health by increasing nutrient absorption, producing plant hormones, solubilization of inorganic phosphates or mineralizing organic phosphate or other nutrients, fixing atmospheric nitrogen, and preventing deleterious effects etc. This may help to sustain environmental health and soil productivity. Scientific researches involve multidisciplinary approaches to understand adaptation of PGPR, their effects on plant physiology and growth, yield, quality, nutrient status and soil health. By virtue of their rapid rhizosphere colonization and stimulation of plant growth, there is currently considerable interest in exploiting these rhizosphere bacteria to improve crop production. They affect plant growth directly (N_2 fixation, production of siderophores, phytohormones, antibiotics, P solubilization etc.) or indirectly (resistance against soil born pathogen by producing siderophore, enzymes, antibiotic etc.). During the past couple of decades, the use of plant growth promoting rhizobacteria (PGPR) for sustainable agriculture has increased tremendously in various parts of the world. Significant increases in growth and yield of horticulturally important crops such as apple, sweet cherry, citrus, raspberry, high bush blueberry, mulberry and apricot in response to inoculation with PGPR have been repeatedly reported (Figueiredo *et al.*, 2011 and Pirlak and Kose, 2009).

2.1.1 Effect on plant growth parameters

Godara (1993) inoculated peach seedlings with two *Azotobactor* stains viz. A 41 and MAC 27 and observed that A 41 was more effective in increasing plant height, leaf area and dry weight of shoots and roots over MAC 27 and un-inoculated control. Kukkonen and Vesalo (2000) reported 33 per cent more production of strawberry runners with *Azotobactor* inoculation.

De Silva *et al.* (2000) reported that applying *Pseudomonas fluorescens* Pf 5 increased the leaf area and stem diameter of high bush blueberry. Rana and Chandel (2003) determined the effect of nitrogen (0, 60, 80 and 100 kg N/ha) and biofertilizers (*Azotobacter, Azospirillum* and *Azotobacter* + *Azospirillum*) on strawberry cultivar Chandler and found that *Azotobacter* inoculated plants produced maximum plant height (24.92 cm), number of leaves per plant (26.29) and the number of runners per plant (18.70) whereas the maximum leaf area (102.50 cm^2) was recorded with *Azotobacter* inoculation combined with 60 kg N/ha.

Highest leaf area (35.18 cm^2) was obtained in raspberry cultivar Heritage, when treated with different strains of phosphate solubilizing bacteria (Orhan *et al.,* 2006). Aseri *et al.* (2005) recorded the maximum leaf area (419.1, 131.6 and 292.9 cm^2 per plant of ber, aonla and pomegranate, respectively) when plants were dual inoculated with *Azotobacter chroococcum* + *Glomus mosseae.*

Karlidag *et al.* (2007) observed an increase in shoot length (16-29 %) and diameter (16-18 %) in apple with the inoculation of nitrogen fixing and phosphate solubilizing bacteria (*Bacillus* M-3, *Bacillus* OSU-142 and *Microbacterium* FS01). Aslantas *et al.* (2007) reported that the number of shoots in young apple trees was significantly increased with the inoculation of BA-8 followed by OSU-7 and M-3. Bacterial inoculation also increased shoot length from 7.0 to 59.2 % and shoot diameter from 7.0 to 16.3 % when compared to control.

Malusa *et al.* (2007) observed an increase in total plant biomass in strawberry plants inoculated with a substrate containing arbuscular mycorrhizal fungi *Trichoderma viride* and plant growth promoting rhizobacteria (PGPR) without any fertilization treatment in all three cultivars 'Senga Sengana', 'Elsanta' and 'Kent'. Citrus seedlings inoculated with localized inoculum of AM fungi and *Azotobacte*r showed significantly improved growth responses over uninoculated control (Sharma *et al.,* 2009). Treatments of *Glomus fasciculatum (Gf1)*

and *Azotobacter isolates-1(AZ$_1$)* significantly increased height and leaf area of citrus seedling as compared to control.

Dias *et al.* (2009) observed that seven *Bacillus spp.* strains promoted root development and one strain of *Sphingopyxis sp*. promoted the development of shoots in strawberry. The plant growth promotion showed to be correlated to IAA production and phosphate solubilization. Seo *et al.* (2009) reported that the leaf area of strawberry in plots treated with micro-organisms EXTN (*Bacillus vallismortis*) and Ofarmgaurd (*Pseudomonas spp*.) were larger (121.0-122.5 cm^2) than control (110.6 cm^2) while crown volume was larger (15.8 mm) in the plot treated with O-sis (*Pseudomonas chlororaphis*). An increased plant height (16.65 cm) was recorded with the application of rhizospheric bacteria culture (4 kg/ha) in strawberry by Kirad *et al.* (2009) as compared to control (recommended fertilizers rate i.e. 100: 80: 60 kg/ ha).

Esitken *et al.* (2010) reported that the root inoculation of M-3 and, foliar application of OSU-142 and BA-8 bacteria stimulated plant growth in strawberry. On the other hand, Pedraza *et al.* (2010) obtained increased plant growth in terms of dry weight of root and shoot in strawberry plants of the cultivars 'Milsei', 'Selva' and 'Camarosa' with root inoculation of *Azospirillum brasilense* (strains REC3, RLC1, PEC5).

A study conducted by Yadav *et al.* (2010) on integrated nutrient management of strawberry cultivation recorded that the maximum plant growth in terms of number of crowns (4.33/ plant), number of runners (11.33/plant), length of runners (45.67 cm) and number of plantlets (12.53 lakh/ha) with *Azotobactor* inoculated treatment in which 50 per cent nitrogen was substituted by vermicompost and remaining 50 per cent was added by top dressing in two equal split doses each at establishment and before flowering stages over inorganic fertilizer treatments

Pirlak and Kose (2010) found that foliar + root application of PGPR strains significantly increased the number of runner per plant, leaf area and the ratio of usable runner in strawberry cultivar Selva. The results indicated that *Pseudomonas* BA-8, *Bacillus* OSU-142 and *Bacillus* M-3 have the potential to increase runner yield and quality in strawberry cultivar Selva and also reported that foliar + root application method was more effective than the other methods.

The highest values of leaf area (95.28 cm^2) was recorded with dual inoculation of phosphorus solubilizing bacteria (PSB) and arbuscular mycorrhizae of guava trees cultivated in sandy calcareous soil (Ibrahim *et al*., 2010). Fawzi *et al*. (2010) reported that leaf area (25.33 cm^2 during 2008 and 26.30 cm^2 during 2009) was significantly increased with the application of phosphorus solubilizing bacteria in 'Le-conte' pear trees as compared to control.

Tripathi and Gupta (2012) studied the effect of *Azotobacter* and vermicompost alone and in combination on vegetative growth of strawberry cv. Chandler during 2009-10 and 2010-11, and observed maximum plant height (19.45 and 17.65 cm, respectively), number of leaves (63.60 and 59.60, respectively), number of crowns (7.28 and 6.27, respectively), number of runners (5.34 and 4.32, respectively) per plant with the application of 7 kg/ ha *Azotobacter* + 30 tonnes/ ha vermicompost.

Erturk *et al.* (2012) evaluated the effect of plant growth promoting rhizobacteria RC 01 (*Bacillus megaterium*), RC 03 (*Bacillus spp*), RC 05 (*Paenibacillus polymyxa*), RC 19 (*Bacillus simplex*) and RC 23 (*Bacillus spp*) on growth and yield of strawberry cultivar Fern and noted highest leaf area (31.54 cm^2) with RC 03 (*Bacillus spp*) application followed by RC 01 (*Bacillus megaterium*) (31.47 cm^2).

Pandit *et al.* (2013) investigated the effect of biofertilizers on vegetative growth of strawberry under subtropical conditions of Uttar Pradesh and reported increased plant height, number of leaves and petiole length with the application of *Azotobacter*, phophobacte*r* and *Azospirillum* as compared to control.

Ipek *et al.* (2014) studied the plant growth promoting effects of *Alcaligenes* 637 C, *Staphylococcus* MFD Ca-1, MFD Ca-2, *Agrobacterium* A 18, *Pantoea* FF 1 and *Bacillus* M-3 in strawberry cultivar Aromas and recorded maximum leaf area (465.9 cm^2) with *Alcaligenes* 637 Ca application.

Tripathi *et al.* (2014) recorded that the combined application of *Azotobacter* and PSB (each 6 kg/ ha) significantly increased the plant height (19.66 and 18.92 cm respectively), number of leaves (65.75 and 62.88, respectively), number of crowns (7.21 and 7.13, respectively) and number of runners (5.22 and 5.30 respectively) in strawberry during 2009 and 2010.

2.1.2 Effect on yield parameters

Wange (1996) reported that the application of *Azospirillum* with 150 kg N/ha increased yields by 54% compared with applying 150 kg N alone in strawberry, and the number of fruits per plant and crown weight were also highest in this treatment. Wange *et al.* (1998) revealed that the microbial treatments, Microphos [phosphate-solubilizing bacteria], *Azotobacter*, *Azospirillum*, *Azotobacter* + *Azospirillum* and *Azotobacter* + *Azospirillum* + P-solubilizing bacteria + Microphos were most effective and significantly increased the number of leaves/plant, number of fruits/plant, total weight of fruits and average fruit weight compared to the control treatment in strawberry.

Burelle (2003) obtained earlier and higher yields in strawberry cultivars 'Sweet Charlie' and 'Camarosa' when propagated with plugs amended in plant growth promoting rhizobacteria LS 213 than bare root transplants. Rana and Chandel (2003) also recorded significantly higher fruit yield (79.12 q/ha) in strawberry plants treated with *Azotobacter* + 60 kg N/ha. The inoculation of strawberry cultivar Siqiouao with *Azospirillum brasilense* resulted in early and higher fruit yield (46.9%) than the uninoculated control (El Rewainy and Abd Alla, 2005). An increase in cumulative yield per plant by 26 to 88 per cent was observed in apple cultivar Granny Smith with multi-inoculation of *Bacillus* M-3, *Bacillus* OSU-142 and *Microbacterium* FS01.

Umar *et al*. (2008) reported an increase in fruit yield with inoculation of *Azotobactor chrococcum* in strawberry seedlings and maximum strawberry yield of 372.89 quintals per hectare was obtained with the application of full nitrogen as urea along with *Azotobacter*. The higher number of fruits (11.1-11.5) was recorded from strawberry plants inoculated with EXTN (*Bacillus vallismortis*) and Ofarmgaurd (*Pseudomonas spp*.) over contol (10.8) as reported by Seo *et al.* (2009).

Pirlak and Kose (2009) observed significant increase in fruit yield (158.5 g) per plant with foliar + root application of plant growth promoting rhizobacteria (PGPR) strains in strawberry cultivar Selva.

Balode (2009) also recorded a significant increase in yield with BioMikss-treated strawberry plants as compared to control where BioMikss is a mixture of microorganisms, containing cells of seven various bacteria (*Azotobacter chroococcum* 23, *Polyangium*

cellulosum 5-t, *Polyangium* 56, *Pseudomonas putida* 48-t, *Rhizobium meliloti* 15, *Streptomyces griseoviridis* P-t and *Streptomyces cellulosae* D) and cells of two fungus (*Trihoderma harzianum* 7-t and *Trihoderma viride* A-L).

According to Yadav *et al.* (2010), highest values for fruiting characters like number of berries (22.27/plant), duration of flowering (142.33 days), duration of harvesting (71.67 days) and fruit yield (101.99 q/ha) were recorded in the integrated nutrient (*Azotobactor* inoculation) management treatments having 50 per cent nitrogen replacement by vermicompost and remaining inorganic nitrogen in two split doses.

Esitken *et al.* (2010) reported that M-3+BA-8, BA-8+OSU-142, M-3, M-3 +OSU-142 and BA-8 applications increased cumulative yield of strawberry by 33.2%, 18.4%, 18.2%, 15.3% and 10.5%, respectively and the number of fruits per plant significantly increased by the applications of M-3+BA-8 (91.73) and M-3 (81.58) compared with the control (68.66). Erturk *et al*. (2012) observed increased number of fruits and yield per plant (33.2–54.7%) in all plant growth promoting rhizobacteria treatments [RC 01 (*Bacillus megaterium*), RC 03 (*Bacillus* spp), RC 05 (*Paenibacillus polymyxa*), RC 19 (*Bacillus simplex*) and RC 23 (*Bacillus* spp)] as compared to control (without PGPR) and recorded highest number of fruits (74) and yield per plant (561 g) with RC19 (*Bacillus simplex*) application.

Plant growth promoting effects of *Bacillus subtilis* EY 2, *Bacillus atrophaeus* EY 6, *Bacillus spharicus* GC subgroup B EY 30, *Staphylococcus kloosii* EY 37 and *Kocuria erythromyxa* EY 43 were tested on strawberry cv. Fern and found that the EY 30, EY 37 and EY 43 treatments significantly increased fruit yield (54.4 %, 51.7 % and 94.9 %) as compared to the plants without plant growth promoting bacteria (PGPB) (Karlidag *et al.*, 2011). In another study, Karlidag *et al.* (2013) have shown the similar results as the highest yield (228 g/plant) with EY 43 followed by EY 37 (225 g/plant) as compared to control (154 g/plant) in strawberry.

Tripathi and Gupta (2012) recorded maximum number of flowers (67.48 and 64.51, respectively), fruit set (39.21 and 36.19 %, respectively) per plant, increased duration of harvesting (71.04 and 69.02 days, respectively) and minimum number of days taken to first flower with significantly higher yield (324.38 and 320.39 g/plant, respectively) with the combined application of *Azaotobacter* (6 kg/ha) and vermicompost (30 tonnes/ha) in strawberry cultivar Chandler during 2009-10 and 2010-11. Pandit *et al.* (2013) obtained

higher yield per plant and yield per hectare in strawberry plants treated with *Azotobacter*, phosphobacter and *Azospirillum* as compared to untreated plants.

Ipek *et al.* (2014) recorded the maximum number of fruits (46.33) and yield (806.2 g) per plant with the application of *Alcaligenes* 637 Ca in strawberry cultivar Aromas as compared to others (*Staphylococcus* MFD Ca-1, MFD Ca-2, *Agrobacterium* A 18, *Bacillus* M-3 and control). Tripathi *et al.* (2014) studied the effect of *Azotobacter* and PSB on flowering and yield of strawberry cv. Chandler during 2008-09 and 2009-10 and observed significantly increased number of flowers (69.05 and 65.05, respectively), fruit set (38.80 and 36.97 %, respectively) per plant, minimum days taken to produce first flower (57.69 and 56.63 days, respectively), maximum duration of harvesting (70.91 and 70.90 days, respectively) and yield per plant (346.56 g and 297.78 g, respectively) with combined application of *Azotobacter* and PSB (each 6 kg/ ha).

2.1.3 Effect on fruit quality parameters

Rana and Chandel (2003) reported maximum fruit length (37.32 mm), fruit breadth (23.65 mm) and fruit weight (10.02 g) with *Azotobacter* inoculation combined with 60 kg N/ha while the maximum TSS (8.78 ^{0}Brix) content was recorded with *Azotobacter* combined with 80 kg N/ha in strawberry cultivar Chandler.

Sahoo and Singh (2005) observed that total soluble solids (8.6 ^{0}Brix) of strawberry cultivar Sweet Charlie were enhanced by the application of 6 kg *Azotobacter*/ha whereas the application of 6 kg *Azospirillum*/ ha increased the total sugar (8.1 %).

The fruit quality viz. total soluble solids, total sugars, ascorbic acid and anthocyanin content was highest in fruits obtained from plants supplied with 25 per cent nitrogen through FYM + 75 per cent nitrogen in the form of urea + *Azotobacter* recording 6.81 ^{0}Brix, 4.73 per cent, 73.71 mg/100 g fresh berries and 0.191 OD respectively (Umar *et al*., 2009). Pirlak and Kose (2009) reported that the root application of plant growth promoting rhizobacteria (PGPR) strains significantly increased total soluble solids (8.15 %), total sugar (5.90 %) and reducing sugar (4.69 %) but decreased titratable acidity (0.82 %) in strawberry cultivar Selva while foliar application resulted in increased fruit weight (9.53 g) and fruit pH (3.33). The foliar + root application produced highest ascorbic acid content (53.1 mg/100 g) as compared to other treatments.

Kirad *et al.* (2009) obtained increased TSS (7.13 %), total sugars (6.02 %), ascorbic acid content (48.31 mg/100 g) and decreased acidity (0.72 %) with the application of rhizospheric bacteria culture (4 kg/ha) as compared to recommended fertilizer rate of NPK (100: 80: 60 kg/ ha).

Yadav *et al.* (2010) recorded maximum berry weight (10.08 g) in *Azotobactor* inoculated integrated nutrient management with farmyard manure and inorganic nitrogen than other treatments. Singh *et al.* (2010) recorded the maximum TSS (8.81 ^{0}Brix), TSS/acidity ratio (12.77), total sugars (7.40 %) and ascorbic acid (50.69 mg/100 g) under co-inoculation of strawberry plants with *Azotobacter* + *Azospirillum* + *Pseudomonus striata* being at par with *Azotobacter* + *Azospirillum* + AMF.

Erturk *et al.* (2012) reported that plant growth promoting rhizobacteria (PGPR) [RC 01 (*Bacillus megaterium*), RC 03 (*Bacillus* spp), RC 05 (*Paenibacillus polymyxa*), RC 19 (*Bacillus simplex*) and RC 23 (*Bacillus* spp)] significantly increased average fruit weight, soluble solid content and vitamin C content in strawberry cultivar Fern and obtained maximum fruit weight (8.31 g), soluble solid content (12.83 %) with RC 01 (*Bacillus megaterium*) treatment while vitamin C content (53.88 mg/100 g) with RC 05 (*Paenibacillus polymyxa*) application.

Tripathi and Gupta (2012) studied the effect of *Azotobacter* and vermicompost on fruit quality of strawberry cultivar Chandler during 2009-10 and 2010-11 and recorded maximum length (5.01 and 4.51 cm, respectively), width (2.64 and 2.34 cm, respectively), weight (9.02 and 8.49 g, respectively), TSS (10.31 and 9.29 ^{0}Brix, respectively), total sugars (9.73 and 8.74 %, respectively) and ascorbic acid (56.52 and 54.53 mg/100 g, respectively) with minimum acidity (0.52 and 0.47 %, respectively) with the application of 7 kg *Azotobacter* in combination with 30 tonnes per hectare vermicompost. In another study, Tripathi *et al.* (2014) observed maximum berry length (4.72 and 4.55 cm, respectively), width (2.66 and 2.62 cm, respectively), weight (8.91 and 8.05 g, respectively), TSS (10.34 and 10.26 ^{0}Brix, respectively), total sugars (9.65 and 9.43 %, respectively), ascorbic acid content (57.96 and 57.15 mg/ 100 g, respectively) and minimum acidity (0.560 and 0.537 %, respectively) in strawberry cv. Chandler plants treated with *Azotobacter* and phosphate solubilizing bacteria (each at 6 kg/ ha) during 2008-09 and 2009-10.

Ipek *et al.* (2014) obtained highest ascorbic acid content (67.36 mg/100 g) and acidity (0.87 %) in strawberry cultivar Aromas plants treated with *Agrobacterium* A 18 while fruit weight (15.32 g) was maximum with *Alcaligenes* 637 Ca application.

2.1.4 Effect on physiological parameters

Godara (1993) reported increased chlorophyll contents in peach seedlings inoculated with the A 41 *Azotobactor* strain as compared to MAC 27 strain and un-inoculated (control). PGPR inoculation increased the physiological properties of the banana specially photosynthetic rate and stomatal conductance as reported by Mia *et al*. (2000). Increased chlorophyll content was observed in all the treatments inoculated with plant growth promoting rhizobacteria (*Azotobactor* and *Azospirillum*) in strawberry cultivar Chandler as compared to control (un-inoculated) and highest cholorophyll content (2.71 mg/100 g) was recorded with the application of *Azotobactor* as reported by Rana (2001). *Azospirillum* and rhizobacterial inoculation increased the photosynthetic rate of oil palm seedlings (Amir *et al.*, 2001).

Vasane and Kothari (2008) recorded higher chlorophyll content (5.6 mg g^{-1}), when banana plants were dual inoculated with AM fungi + phosphate solubilizing bacteria. Osman and El-rhman (2010) also reported that total chlorophyll content was significantly increased, when fig tree was inoculated with *Azotobacter*. Karlidag *et al*. (2013) studied the effect of five plant growth promoting rhizobacteria (*Bacillus subtilis* EY 2, *Bacillus atrophaeus* EY 6, *Bacillus spharicus* GC subgroup B EY 30, *Staphylococcus kloosii* EY 37 and *Kocuria erythromyxa* EY 43) and a control (no PGPR) and observed the highest amount of chlorophyll (39.95 mg/g) with EY 6 application.

Singh *et al*. (2012) recorded the maximum photosynthetic potential as CO_2 reference (438 ppm) in strawberry cultivar Sescape followed by ‘Gorella’ and ‘Chandler’ when treated with *Azotobactor* + phosphate solubilizing bacteria along with recommended dose of NPK (340:150:340 kg/ha). In contrast, maximum stomatal conductance was observed with minimum CO_2 concentration as reported by Morison (2001).

According to Stefan *et al.* (2013), the photosynthetic and transpiration rates were significantly influenced by the utilization of plant growth promoting rhizobacterial strains S4 and S7 and the values of net photosynthesis in runner bean leaves ranged from 2.12 to 8.19 μ

mol m^{-2} s^{-1} while S7 strain was more effective in promoting plant transpiration (upto 24.24 %) than S4 and S4+S7 strains.

2.1.5 Effect on leaf nutrient status

Inoculation of peach seedlings with *Azotobacter* strain A-41 enhanced N uptake in seedlings while dual inoculation with VAM and *Azotobacter* resulted in increased uptake of N, P, K and Mg (Awasthi *et al.*, 1996). El-Monien and Radwan (2003) investigated the effect of biofertilizers (PSB, *Azotobactor* sp., *Azospirillum* sp. and *Pseudomonas* sp.) in the presence of reduced doses of chemical fertilizers and reported that application of 75 per cent NPK plus biofertilizers significantly increased the leaf macronutrient content in 'William' banana plants.

Gryndler *et al.* (2002) reported that the potassium uptake was increased to a larger extent when strawberry plants were inoculated with *Pseudomonas* sp. + *Glomus* sp. than by *Bacillus* sp. + *Glomus* sp. Ahmed *et al*. (2004) studied the effect of nitrogenous fertilizer with or without biofertilizer *Azotobactor chroococcum* strain (M-4 and CBD-15) on nutrient uptake of ten years old 'Amrapali' mango plants. The treatments were (T_0) control, (T_1) full dose of nitrogen + M-4, (T_2) full dose of nitrogen + CBD- 15, (T_3) 2/3 dose of nitrogen + M-4, (T_4) 2/3 dose of nitrogen + CBD-15, (T_5) 1/3 dose of nitrogen + M-4, (T_6) 1/3 dose of nitrogen + CBD-15, (T_7) M-4 only and (T_8) CBD-15 only. They observed the increased leaf nitrogen, phosphorus, Cu and Zn content in all treatments and treatment T_2 showed the highest uptake of nitrogen at flowering and after harvest, followed by T_7 and T_8 while the highest P observed in treatments T_1, T_2 and T_6. Leaf nitrogen and phosphorus content were relatively higher with the application of CBD-15 as compared to M-4. Leaf potassium content was generally higher after harvest than at the flowering, with the highest values being observed in T_4 and T_2.

Malusa *et al.* (2007) observed significantly higher potassium content (2.93, 2.75 and 2.18 %) in strawberry cultivars 'Senga Sengana', 'Elsanta' and 'Kent' respectively with the inoculation of *Bacillus subtilis, Pseudomonas fluorescens, Streptomyces* spp. and mycorrhizal fungi as compared to control (foliar fertilization of N, P and K). Aseri *et al*. (2008) reported that dual inoculation with *Azotobacter chroococcum* and *Glomus mosseae* recorded maximum leaf N, P, K, Ca, Mg and micronutrients in pomegranate seedlings. Ibrahim *et al.* (2010) also noticed that highest leaf N (1.80 %), P (0.159 %), K (1.48%), Ca (1.53%) and Mg

(0.42%) respectively were recorded when guava trees were dual inoculated with AM fungi and *Bacillus megaterium*.

Esitken *et al.* (2006) reported that bacterial inoculation of *Pseudomonas* BA-8 significantly increased leaf N, P and K contents in sweet cherry. In another study, they reported that bacterial treatments significantly increased plant nutrient contents of strawberry leaves were significantly increased with bacterial inoculation under organic growing conditions. In particular, root inoculation of M-3 and foliar BA-8 or OSU-142 spraying promoted P, Fe and Zn uptake of strawberry cv. Fern. The highest P (1.27%), Fe (23.99 ppm) and Zn (37.95 ppm) contents were obtained from M-3 + BA-8 + OSU-142, BA-8 + OSU-142 applications, which increased P, Fe and Zn content of leaves by 53.0 %, 20.1 % and 77.9 % compared to control (Esitken *et al.* 2010).

Singh and Singh (2009) recorded the maximum leaf N (2.94 %) and Mg (0.31 %), when strawberry plants were inoculation with *Azotobacter chroococcum.* Osman and El-rhman (2010) also reported the significant increase in leaf N (1.56 %), P (0.17 %), K (1.50 %), Ca (1.98 %) and Mg (0.45 %), when fig trees were inoculated with *Azotobacter chroococcum.* Micro-organisms inoculation increased fruit and leaf nutrient concentrations (N, P, K, Ca, and Fe) of strawberry with the largest increases upon addition of *Bacillus* FS-3 as reported by Gunes *et al.* (2009).

Root inoculation with *Pseudomonas*, *Bacillus* M-3, *Bacillus* OSU-142 and *Microbacterium* FS01 bacterial strains significantly affected plant nutrient contents of leaves in apple cv. Granny smith (Karlidag *et al.*, 2007). Results showed that the multi-inoculation with M-3 + OSU-142 + FS01 recorded maximum N (3.37 %), P (0.35 %), K (0.33 %), Ca (0.67 %), Mg (0.15 %), Fe (125.3 %), Cu (34.2 %), Mn (42.5 %) and Zn (62.5 %) contents respectively. Mia *et al.* (2010) reported an increase in uptake of NO_3^-, NH_4^+, HPO_4^2, K^+ and Fe^{++} in banana leaves with PSB inoculation and observed increased foliar dry matter and accumulation of minerals in stem and leaves. Karakurt and Aslantas (2010) reported that the applications of *Agrobacterium rubi* A-18 bacteria decreased the concentration of N, K and Cu and increased the concentration of P and Zn in the leaves. *Bacillus subtilis* OSU-142 application resulted in the highest Mg (0.13 %) and Fe (32.7 ppm) contents and *Burkholderia gladioli* OSU-7 in the highest Mn content (40.3 ppm).

Erturk *et al.* (2011) observed that the root inoculation with *Arthrobacter agilis* 2/3, *Acinetobacter calcoaceticus* 47/6, *Rhizobium radiobacter* 42/1 and *Lysobacter enzymogenes* 9/8 strains enhanced N, P and K uptake of hazelnut seedlings cultivar Tombul. The highest Fe, Na and Al contents were obtained from *Rhizobium radiobacter* 42/1 and *Lysobacter enzymogenes* 9/8 applications compared to control. Root inoculation of *Stenotrophomonas maltophilia* 21/1, *Rhizobium radiobacter* 42/1 and *Paenibacillus macquariensis* 59/8 applications enhanced N, P and K uptake of hazelnut seedling cultivar Sivri. The highest Mg, Mn, Fe content of leaves were obtained from the *Pantoea agglomerans* 5/8 application compared the control.

Karlidag *et al.* (2013) recorded significant increase in nutrient element contents of leaves and roots with PGPR inoculations in strawberry and the highest nitrogen (N), potassium (K), phosphorus (P), calcium (Ca), magnesium (Mg), sulfur (S), manganese (Mn), copper (Cu), and iron (Fe) concentrations were obtained from EY 43 and followed by E 6, E 37, and E 30, and increasing ratio of leaves and root N, P, K, Ca, Mg, S, Mn, Cu, and Fe contents were 22 % to 33 %, 34 % to 8.8 %, 89 % to 11 %, 11.0 % to 7.2 %, 5.1 % to 6.2 %, 97 % to 65 %, 120 % to 140 %, 300 % to 15 %, and 111 % to 9.0 %, respectively.

Ipek *et al.* (2014) reported that all bacterial applications (*Alcaligenes* 637 Ca, *Staphylococcus* MFD Ca-1, MFD Ca-2, *Agrobacterium* A 18 and *Bacillus* M-3) significantly increased leaf nutrient content in strawberry cultivar Aromas, and the highest nitrogen (2.50 %), phosphorus (0.41 %) and calcium content (1.69 %) content were determined from *Bacillus* M-3 treatment. Potassium content of leaves significantly increased by *Alcaligenes* 637 Ca (2.54%) followed by *Staphylococcus* MFD Ca-1 (2.45%) treatment. The highest Fe, Cu, Mn, and B content of leaves were obtained from *Staphylococcus* MFD Ca-1 (85.7 ppm), MFD Ca-2 (6.17 ppm), MFD Ca-1 (120.8 ppm) and A 18 (99.9 ppm), respectively.

2.1.6 Effect on soil nutrient status

Sharma *et al*. (2005) reported that *Azotobacter* population in soil had shown a positive correlation with organic carbon content of soil in apple. Decrease in soil pH and increase in organic carbon content in banana orchards were recorded with dual inoculation of *Azotobacter* and PSB (Gogoi *et al.*, 2004). Kumari *et al.* (2004) observed that decrease in soil pH and electrical conductivity, when troyer citrange plants were inoculated with AM fungi and *Azotobacter chroococcum*.

Yadav (2006) found significant increase in organic carbon and cation exchange capacity (CEC), whereas decreased electrical conductivity was recorded when strawberry plants were inoculated with *Azotobactor chrococcum.* Orhan *et al*. (2006) reported that bacterial inoculations with OSU-142 and M-3 decreased pH level of experimental soil from 6.7 to 6.0 ± 0.4 and decreased soil pH stimulated the availability of plant nutrient element (PNE) such as P, Ca, Fe and Mn.

Cakmacki *et al.* (2007) reported that bacterial inoculation in barley field significantly increased total mineral N and P in soil. The maximum NO_3-N was measured in soil treated with N_2 fixing *Bacillus* OSU-142, followed by *Paenibacillus polymyxa* RC 05 and *Rhodobacter capsulatus* RC 04 whereas *Bacillus* M-13, RC 01 and RC 02 isolates were capable of dissolving insoluble P at the rate of 38.3, 42.3 and 20.4 µg solubilized P per ml of culture per day, respectively. The increased level of available P content was seen in soil treated with *Bacillus* M-13 and *Bacillus megaterium* RC 01 by 27.9 % and 10.3 %, respectively, compared to control. The soil pH values decreased in all treatments with no statistical difference however, *Bacillus megaterium* RC 01 and *Bacillus* M-13 inoculation produced the lowest soil pH in comparison to other treatments.

Umar *et al.* (2008) recorded highest organic carbon content (0.63 %) and available soil potassium (141.5 kg/ha) in the treatment where full nitrogen as FYM+ *Azotobacter* was applied. However, highest available nitrogen and phosphorus of 256.4 and 19.7 kg respectively per hectare were observed when 25 % nitrogen was applied as FYM+ 75 % nitrogen through urea+ *Azotobacter*. Calcium and magnesium built up was highest (7.88 and 2.95 m eq 100 g^{-1} soil) in treatment where full N was applied as urea+ *Azotobacter*.

Gunes *et al.* (2009) observed that inoculation of *Bacillus* FS-3 and *Aspergillus* FS-9 resulted in P-fertilizer savings of 149 kg P ha^{-1} and 102 kg P ha^{-1}, respectively and it was concluded that both the inoculation were most effective as yield-enhancing soil amendments in P-deficient calcareous soils in Turkey. Mahendra *et al.* (2009) reported that ber orchard soil inoculated with *Azotobacter* and phosphorus solubilizing bacteria (PSB) along with FYM+ 100 per cent NPK resulted in higher soil organic carbon (0.47 %), N (275.90 kg/ha), P (22 kg/ha), K (258.85 kg/ha), Ca (4.20 %), Mg (5.98 %) and minimum soil pH (8.31) and EC (3.28 dSm^{-1}).

Umar *et al.* (2010) recorded maximum organic carbon content (0.62 %) in plots treated with *Azotobacter* in combination with FYM: Urea (75: 25 and 50: 50) under strawberry cv. Chandler. Maximum soil available nitrogen (255.40 kg/ha) and phosphorus (21.05 kg/ha) were observed in plots applied with *Azotobacter* + FYM: Urea (25:75), whereas maximum soil potassium (143.12 kg/ha) was recorded with the application of *Azotobacter* + 100 per cent FYM and, calcium (7.98 meq/100 g soil) and magnesium (2.95 meq/100 g soil) with the application of *Azotobacter* + 100 per cent Urea.

Singh *et al.* (2010) reported that the multi-inoculation of *Azotobacter* + *Azospirillum* + PSB (phosphorus solublizing bacteria) and *Azotobacter* + *Azospirillum* + AMF increased available soil N by 1.81 and 16.9 % and, P by 1.60 and 15.1 % over their initial levels, respectively. As reported by Esitken *et al.* (2010), available phosphorus content of soil were increased from 0.35 kg P_2O_5/ha to 2.00, 1.97 and 1.82 kg P_2O_5/ha by M-3+OSU-142, M-3-+BA-8 and M-3+BA-8+OSU-142 applications, respectively. Soil Mn also increased from 2.20 ppm to 3.34 ppm by M-3 + BA-8 + OSU-142, to 3.30 ppm by M-3 + BA-8 and to 3.17 ppm by BA-8 applications.

2.1.7 Effect on soil biological properties

The number of *Azotobactor chroococcum* in Indian soils rarely exceeds 10^4- 10^5/g soil (Subba Rao, 1993). *Azotobacter* population significantly increased when peach plants were inoculated with *Azotobacter* at lower doses of nitrogen fertilizers (Godara, 1993). However, maximum root colonization (35.25 %) was recorded with AM fungi + *Azotobacter* treatment in pecan seedlings (Joolka *et al.*, 2004). Grape vines when inoculated with *Azotobacter* resulted in highest number of *Azotobacter* population (Sonawane and Konde, 1997).

Gogoi *et al.* (2004) reported that dual inoculation with *Azotobacter* and PSB increased the microbial biomass and dehydrogenase activity. Vestberg *et al.* (2004) also detected sufficient densities of inoculated micro-organisms at four weeks after inoculation in strawberry rhizosphere. Orhan *et al.* (2006) reported that inoculation with phosphate solubilizing bacteria (PSB) significantly increased root colonization of raspberry (*Rubus spp*) cultivar Heritage.

Cakmacki *et al.* (2007) reported that total bacteria density varied between 2.9 and 14.8 × 10^6 cfu/g soil, depending on the particular treatment. The highest density was observed with P solubilising *Bacillus* M-13. The density of N_2 fixing organisms ranged

between 1.4×10^5 and 4.1×10^6 cfu/g. The degree of root colonization and sporulation in rhizosphere soils of pomegranate was higher in dual inoculation with *Azotobacter chroococcum* + *Glomus mosseae* as compared to single inoculation treatment (Aseri *et al.*, 2008).

Archina (2008) also noticed that dual inoculation with same treatment significantly increased soil microbial population and root colonization in plum rhizosphere. Raj and Sharma (2009) reported that treatment combination comprising of *Azotobacter chroococcum* and *Glomus vesiculatum* of arbuscular mycorrhizae recorded 46.4 and 50.3 per cent higher spore count per 100 g of soil in comparison with untreated plots of apple seedlings.

Seo *et al.* (2009) reported increased density of rhizobacteria in EXTN (*Bacillus valismortis*) treated plot as compared to other treatments. Higher spore count of 35 and 36.4 percent were recorded in higher root colonization during both the years of study as reported by Singh *et al.* (2010). Multi-inoculation of *Azotobacter*+ *Azospirillum* + PSB, being at par with *Azotobacter* + *Azospirillum* + AMF recorded significantly higher viable count of *Azotobacter chroococcum, Azospirillum brasilense* and *Pseudomonas striata* over rest of the treatments. They also recorded highest population of *Azotobacter* (4.0 cfu/g soil), *Pseudomonas* (3.47 cfu/g soil) and AM spore (271.6 cfu/g soil) under multi-inoculation of *Azotobacter* + *pseudomonas* + AMF.

Pesakovic *et al.* (2013) studied the effect of PGPR-1which is consists of pure culture of Gram-negative diazotrophic nitrogen-fixing bacteria *Klebsiella planticola,* PGPR-2 which is a combination of nitrogen fixing and phospho-mineralizing bacteria (*Azotobacter chroococcum, A. vinelandi, Derxia* sp., *Bacillus megatherium, B. lichenformis* and *B. subtilis*) and KMg on strawberry 'Sena Sengana'. Compared to different fertilizers, PGPR-1 gave the highest number of microorganisms in soil except *Azotobacter* which was highest in PGPR-2 treatment whereas the lowest population of all the microbes was recorded in control. It was also observed that irrespective of treatments microbial population buildup was higher in second growing year.

2.2 EFFECT OF GA_3 AND ITS COMBINATION WITH PLANT GROWTH PROMOTING RHIZOBACTERIA

GA_3 is a natural growth hormone and is a part of a type of plant hormones called gibberellins. GA_3 promotes cell division, number of plant development mechanisms and

encourages numerous desirable effects such as plant height, uniform flowering, reduced time to flowering, increased flower number and size (Srivastava and Srivastava, 2007). Gibberellic acid (GA_3) has been reported to increase fruit set, growth, colour development, ripening and helps in increasing production of healthy fruit in many fruit crops like Clementine orange, strawberry, sweet cherry etc. (Van Rensburg *et al.*, 1996; Hossain, 2012 and Choi *et al.*, 2002). Beside this, GA_3 in combination with plant growth promoting rhizobacteria (PGPR) have also shown significant effect on plant and soil health. Some of the reviews are as under:

2.2.1 Effect on plant growth:

Singh and Phogat (1983) obtained maximum leaf number and runner production in Majestic cultivar of strawberry treated with 50 ppm gibberellic acid. Highest plant height (31.0 cm), number of leaves per 20 plants (395.7) and number of suckers per 20 plants (98.7) were found with 100 ppm GA_3 application in strawberry cultivar Murree as reported by Mohammad *et al.* (1990). Anwar *et al*. (1990) also recorded maximum plant height, number of leaves per plant with 100 ppm GA_3 treatment.

Sharma and Singh (1990) observed the maximum plant height and spread in strawberry cultivar Pusa Early Dwarf when sprayed with GA_3 at 75 ppm + cloches (a plastic cover over a bamboo framework) than other treatments. Thakur *et al.* (1991) reported that the Activol (GA_3, BA and GA_{4+7} mixture) at 50, 100 or 200 ppm resulted in increased vegetative growth of strawberry cultivar Teoga compared with the control and the highest crown height (7.2 cm) was obtained with 100 ppm Activol. Pankov (1992) studied the effect of GA_3 (0.002, 0.004, 0.006, 0.008, 0.01, 0.02 or 0.03 %) and CCC (0.3, 0.6, 1.2, 2.4 or 4.8 %) on ‘Yasna’ and ‘Senga Sengana’ cultivars of strawberry and found the increased number of usable runner plants by 22 per cent upon pre-harvest application of GA_3 at 0.008 per cent.

Pipattanawong *et al.* (1996) reported that the application of GA_3 or GA_3 + BA at 50 ppm resulted in a 2- to 3- fold increase in the number of runners in strawberry cultivar Miyoshi whereas up to about 8 and 4 times increase in cultivars ‘Enrai’ and ‘Summer Berry’, respectively. GA_3 significantly increased petiole length in ‘Miyoshi’ and ‘Enrai’, and increased the number of leaves in ‘Miyoshi’ only. Sangwook *et al.* (1996) found that runner development was promoted by GA_3 treatment and GA_3 + cold storage for 600 hour in strawberry cv. Samahberi. Turemis and Kaska (1997) applied the GA_3 at 50 or 100 ppm concentration to June bearing strawberry cultivars ‘Cruz’, ‘Vista’, ‘Tufts’, ‘Pocahontas’ and

‘Aliso’, 30 or 60 days after planting which resulted in increased number of runners per square meter and stem diameter.

Dwivedi *et al.* (1999) evaluated the effect of Gibberellic acid (25, 50 and 100 ppm), Alar (250, 500 and 1000 ppm), Ethrel (250, 500 and 1000 ppm), Morphactin (25, 50 and 100 ppm) and Cycocel (500, 1000 and 2000 ppm) on strawberry cultivars ‘Senga Sengana’ and ‘Missionary’ and showed that the application of GA_3 (50 ppm) resulted in the maximum leaf number, petiole length and number of runners in both the cultivars while increased the leaf area only in ‘Senga Sengana’.

Paroussi *et al.* (2002a) studied the effect of gibberellic acid (GA_3) (0, 50, 200 mg per litre) on vegetative growth in three strawberry cultivars ‘Camarosa’, ‘Laguna’ and ‘Seascape’ grown under different photoperiod regimes and observed that GA_3 application @ 200 mg/ liter increased the leaf area and petiole length to a greater extent than at 50 mg/ liter. Asrey *et al.* (2003) reported that the application of gibberellic acid (GA_3 @ 25, 50 and 75 ppm) on strawberry (*Fragaria ananassa*) cultivar Chandler caused highly significant reduction in plant (runners) survival during summer (May and June) compared to untreated plant while the growth and population of runners were significantly higher during mild summer (March-April).

Mir *et al.* (2004) used GA_3 at 20, 40 and 60 ppm and NAA at 12, 15 and 20 ppm in strawberry cultivar Sweet Charlie and observed that application of GA_3 significantly increased the number of runners as compared to NAA and control. Tripathi and Shukla (2006) obtained the maximum plant height (20-39 cm) and number of leaves (18.09) with GA_3 application at 100 ppm when studied the effect of NAA, GA_3, CCC and BA on growth, yield and quality of strawberry cultivar Chandler. Kumar *et al.* (2008) reported that the GA_3 at 90 ppm gave maximum vegetative growth and runner production in strawberry cultivar Sweet Charlie as compared to other treatments.

Perez *et al*. (2009) observed the highest leaf number, crown number and the number of flowers in plants of the strawberry cultivar Chandler treated with 20 mg per litre of gibberellic acid. Hytonen *et al.* (2009) concluded that GA_3 is needed for runner initiation in strawberry and the inhibition of GA biosynthesis leads to the formation of crown branches. GA_3 applied at a concentration of 1.0- 2.0 mg dm^{-1} significantly increased the number of

axillary shoots (mainly crown shoots), whereas under higher (5.0- 10.0 mg dm^{-3}) doses it stimulated the development of runners as reported by Litwinczuk *et al*. (2009).

Sharma and Singh (2009) reported that spray of GA_3 (75 ppm) during mid November and mid February increased the vegetative growth in terms of petiole length (7.2 cm), leaf area (31.6 cm2), leaf number (17.8) crown height (18.5 cm) and crown spread (21.4 cm), significantly. Singh and Singh (2009) observed maximum plant height (27.63 cm) and total biomass (42.02 mg/ 100g) in the strawberry plants cultivar Sweet Charlie when treated with 100 ppm GA_3 in combination with *Azotobacter*+ *Azospirillium*+ 60 kg N per hectare as compared to other treatments.

Singh and Tripathi (2010) investigated the efficacy of GA_3, boric acid and zinc sulphate on growth, flowering, yield and quality of strawberry cultivar 'Chandler'. GA_3 at 100 ppm concentration sprayed on the plants before bud initiation (65 days after transplanting) increased plant height, number of leaves and runners per plant. Al Madhagi *et al*. (2011) reported the significant effect of GA_3 on the dry matter of strawberry by its own action where, 17.06 % dry matter content was produced under application of 50 ppm GA_3 as compared to control.

Kumar *et al*. (2011) observed that plants treated with 75 ppm gibberellic acid showed an increase in all the vegetative characteristics of plants viz., plant height (46.10 cm), petiole length (15.53 cm), number of leaves (15.54) plant spread (29.40 cm)and leaf area index (0.816). Jamal *et al.* (2012) also found that GA_3 treated strawberry at 75 ppm resulted in tallest plant (31.4 cm), maximum number of leaves (11.1) and leaf area (64.5 cm). Momenpour *et al.* (2011) reported that the highest number of plantlets with a standard diameter of 6.15 mm was produced by applying mixture of GA_3 300 ppm and BA 1200 ppm (sprayed in May) as the best treatment as compared to control.

The application of 100 ppm GA_3 resulted in maximum number of runners and leaf area in the strawberry cultivar Merak (Saied *et al.,* 2012). Hossain (2012) recorded highest plant height (31.4 cm), leaf number (11.1), leaf area (64.5 cm^2) and number of runners (4.0/ plant) from GA_3@75ppm treated plants as compared to control at 73 DAT (day after transplanting) in strawberry. Eshghi *et al.* (2012) observed the increased dry weight and number of runners of strawberry plants with GA_3 application at 50 and 100 ppm respectively.

Kumar *et al*. (2012b) studied the effect of GA_3 (30, 60 and 90 ppm), NAA (20, 30 and 40 ppm) and cycocel (250, 500 and 750 ppm) and observed that GA_3 at 90 ppm was most effective for enhancing the plant growth of strawberry as observed from highest plant height (23.12 cm), plant spread (32.96 cm), petiole length (11.28 cm) and number of runners (4.77).

Qureshi *et al.* (2013) found increased vegetative growth in terms of leaf area (63.63 ± 0.27 cm^2), number of leaves (4.877 ± 0.27) and number of runners (2.033 ± 0.09) with GA_3 application at 50 ppm while the plant height (18.47 ± 0.81 cm), spread (29.61 ± 0.58 cm), fresh weight (23.31± 0.73 g) and dry weight (8.63 ± 0.09 g) with the application of GA_3 (50 ppm) and $CaCl_2$ (0.4%) in strawberry cultivar Chandler as compared to other treatments. Asadi *et al*. (2013) also reported maximum number of runners (4.5) with GA_3 (50 ppm) as compared to other treatments (0 and 25 ppm) in 'Gaviota' strawberry.

2.2.2 Effect on yield parameters:

Stalder *et al.* (1990) reported that GA_3 has a tendency to increase the number of fruits in strawberry. The highest increase in fruit number and yield in strawberry cultivar 'Pusa Early Dwarf' was observed in plants treated with 75 ppm GA_3 + cloches (Sharma and Singh, 1990). Pankov (1992) noted that average yield increased in 'Yaasna' and 'Sena Sengana' cultivars of strawberry with increasing GA_3 concentration from 0.006 per cent to 0.10 per cent.

Ozguven and Kaska (1992) applied GA_3 (12.5, 25 and 50 ppm) on three dates starting from November to April and observed well advanced flowering in strawberry cultivars 'Aliso', 'Pocahontas' and 'Tioga' when applied in November. Similarily, the effectiveness of GA_3 @ 0, 5, 10 and 20 ppm, applied during 2nd and 4th week of January was assessed on 'Camarosa' strawberry plants and the earlier flowering was recorded with increased GA_3 dose (20 ppm) applied during 2nd week of January (Ozguven and Yilmaz, 2002).

Camargo *et al.* (1995) noted the increased number of fruits in the 4th and 5th harvests in strawberry plants when sprayed with GA_3 at 50 mg per liter. Tehranifar and Battey (1997) also found significantly higher number of strawberry fruits and highest yield from 50 ppm GA_3 treatment as compared to other treatments. Application of gibberellins at concentration of 1 g/ liter to citrus trees, guava, strawberry and pawpaw resulted in an increased fruit yield (Delgado *et al.*, 1998).

Rana (2001) recorded maximum number of berries per plant and yield with the application of GA_3 at 100 ppm in strawberry cultivar Chandler. Paroussi *et al.* (2002a) noted that the GA_3 at 50 ppm resulted in earlier inflorescence emergence, accelerated flowering, earlier fruit setting and maturation over control in strawberry cultivar Seascape. Singh and Singh (2005) carried out a study to investigate the effects of growth regulators viz., GA_3 at 50 and 100 ppm, NAA at 50 and 100 ppm and Benzyladenin (BA) at 50 and 100 ppm on strawberry cultivar Sweet Charlie. Plants treated with GA_3 at 100 ppm showed the earliest flowering produced the maximum number of flowers per trusses, fruit set, better yield and yield attributing characters.

Tripathi and Shukla (2006) studied the effect of plant bioregulators on growth, yield and quality of strawberry cultivar Chandler and found that the GA_3 at 100 ppm concentration produced maximum number of flowers (16.23), extended duration of flowering (72.66 days) and higher yield (112.95 gram per plant).

Sharma and Singh (2009) studied the effect of foliar application of GA_3 on flowering, fruiting and other processes in 'Chandler' strawberry and observed that GA_3 application in mid November resulted in earlier flowering and harvesting but increased flowering and harvesting period (65.7 and 54.2 days, respectively) over control. They also observed that the GA_3 (75 ppm) spray increased number of flowers per plant (64.6), fruit set (81.4 %) and yield (526 g/ plant) significantly over control. A significant increase in number of flowers and total yield of strawberry cultivar Sweet Charlie was observed with GA_3 application at 10 ppm (El Shabasi *et al.*, 2009). Perez *et al.* (2009) reported that the exogenous application of GA_3 at 20 ppm resulted maximum number of inflorescences and flowers in strawberry cultivar 'Chandler'.

Singh and Singh (2009) observed the effect of biofertilizers and bioregulators on growth, yield and nutrient status of strawberry cultivar Sweet Charlie and the maximum fruit set (84.28 %) and yield (94.26 q/ha) were recorded in plants treated with *Azotobacter* and *Azospirillum* along with 60 kg N per ha and 100 ppm GA_3.

Al Madhagi *et al*. (2012) reported increased number of fruits per plant with the application of GA_3 at 50 ppm in strawberry cultivar Camarosa. Hossain (2012) recorded the maximum number of flowers (28.7/plant), fruits (25.9/plant) and yield (336.6 g/plant) in

strawberry plant treated with GA_3 75 ppm which was closely followed GA_3 100 ppm and minimum (21.1, 19.6 and 248.9 g/plant, respectively) in control.

Kumar *et al.* (2012a) noted highest fruit yield (130.77 g/plant and 7.96 t/ha) in strawberry with application GA_3 at 30 ppm as compared to GA_3 at 60 and 90 ppm. Jamal *et al.* (2012) reported that among GA_3 treatments at 50, 75 and 100 ppm on strawberry, maximum number of flowers (28.7), number of fruits (25.9/plant), fruit weight (13.2 g) and yield (336.6 g/plant) was obtained with 75 ppm GA_3 application, whereas the minimum was recorded in control.

Lolaei *et al.* (2013) recorded the maximum yield per plant (189.12 g) in 'Selva' and (265.6 g) in 'Queen Eliza' from GA_3 treatment at 150 ppm and minimum in control (148.23 and 190.9 g, respectively) as compared to other treatments (GA_3 @ 50 and 100 ppm). Qureshi *et al.* (2013) observed earliest flowering, increased fruit set (92.17 %) and number of fruits (14.77 ± 0.23) with the application of 50 ppm GA_3 in strawberry cultivar Chandler.

Kazemi (2014a) reported that the leaf area, number of runners, mean dry weight and length of the roots were increased significantly with foliar application of 100 mg/L gibberellic acid in strawberry cultivar Camarosa.

2.2.3 Effect on fruit quality:

Anwar *et al.* (1990) recorded maximum fruit weight with the application of 100 ppm GA_3 as compared to its lower concentration in strawberry cultivar Murree. Sharma and Singh (1990) observed an increase in individual weight, TSS and acidity in strawberry fruits of cultivar Pusa Early Dwarf sprayed with 75 ppm GA_3 + cloches. Increased fruit anthocyanin content in strawberry was found in all treatments of Activol except 200 ppm treatment (Thakur *et al.*, 1991).

Camargo *et al*. (1995) also reported increased fruit weight in 5th harvest when the plants were sprayed with GA_3 at 50 mg/liter. Similarly Tehranifar and Battey (1997) obtained significantly higher fruit weight with 75 ppm GA_3 application.

Martinez *et al.* (1994) found that GA_3 had an inhibitory effect on fruit ripening, evidenced by a decrease in the respiratory activity and a delay in anthocyanin synthesis and chlorophyll degradation, when slices of strawberry cv. Selva fruits at different ripening stages

were incubated with 0.05-0.5 mM GA_3. In another study, Martinez *et al.* (1996) again reported a significant delay in red colour development in GA_3 treated fruits of strawberry. In contrast, Montero *et al.* (1999) noticed the increased fruit weight, size and colour of strawberry and found that the anthocyanin content and PAL (phenylalanine ammonia lyase) activity are enhanced by the exogenous treatment of GA_3 in the range of 30 µg per litre. However, with the higher GA_3 treatment, the anthocyanin content is affected and they had suggested that gibberellic acid effect on PAL, TAL and ultimately anthocyanin enhancement is dosage related and saturation of the response occurs at 30 µg per liter.

Ozguven *et al.* (2000) reported that application of GA_3 at 200 ppm before flowering in strawberry cultivar Camarosa resulted in higher TSS and acidity. Pre-harvest application of GA_3 at 100 ppm resulted in higher TSS and total sugars contents in fruits of strawberry cultivar Chandler as reported by Rana (2001). Choi *et al.* (2002) found that spraying GA_3 increased the fruit size and firmness in cherry fruits.

Gibberellic acid treatment has been found to enhance colour formation of strawberry fruits by affecting phenylalanine ammonia lyase and tyrosine ammonia lyase activitys which results in higher anthocyanin content as reported by Schwab and Raab (2004). Singh and Singh (2005) observed that GA_3 applied at 100 ppm markedly increased fruit quality attributes like size and weight in strawberry cultivar Sweet Charlie. Tripathi and Shukla (2006) recorded the maximum length (3.09 cm) and weight of berries (8.28 g) in strawberry cultivar Chandler when treated with GA_3 at 100 ppm concentration.

Kumar *et al.* (2008) conducted an experiment with GA_3, NAA and CCC to study their effect on growth, yield and quality of strawberry cultivar Sweet Charlie. The treatment of GA_3 at 90 ppm resulted in maximum acidity as compared to other treatments. Singh and Singh (2006) reported that the application of biofertilizers in combination with bioregulators resulted in better fruit quality of strawberry cultivar Sweet Charlie and they obtained highest berry length (45.36 mm), weight (16.75 g), TSS (8.96 ^{0}Brix), total sugars (8.55 %) and ascorbic acid content (59.22 g/100 g) with *Azotobacter* and *Azospirillum* application in combination with 60 kg nitrogen per hectare and 100 ppm GA_3.

Sharma and Singh (2009) obtained highest juice content (74.8 %) and ascorbic acid content (50.4 mg/100 g) in strawberry cultivar Chandler when plants were twice sprayed with GA_3 (75 ppm) during mid November and mid February. Roussos *et al.* (2009) observed that

anthocyanin content in strawberry fruit increased significantly when the plants were treated with GA_3. Gholami *et al.* (2009) reported the reduced TSS in sweet cherry with the application of GA_3.

Singh and Tripathi (2010) reported that the GA_3 treatments (50, 75 and 100 ppm) significantly increased berry length, breadth, total soluble solids and total sugars as compared to control. Moneruzzaman *et al.* (2011) reported that the fruit colour was greatly enhanced by 50 and 100 ppm GA_3 treatment in wax apple (S*yzygium samarangense* var. Red Jambu air madu). The highest amount of anthocyanin was observed in 50 mg/L treated fruits followed by 100 and 20 mg/L treatment, whereas untreated control fruits showed the lowest anthocyanin. Al Madhagi *et al*. (2012) reported that the application of GA_3 at 50 ppm increased the fruit weight in strawberry cultivar Camarosa.

Kumar *et al.* (2012a) recorded the maximum fruit length diameter ratio (1.28 cm), juice content (87.35 %) and TSS (9.07 %) with GA_3 application at 30 ppm while maximum ascorbic acid (63.03 mg/100 g) and acidity (0.75 %) with GA_3 at 90 ppm. Hossain (2012) recorded the maximum fruit length (32.7 mm), diameter (25.0 mm), fruit weight (13.2 g) and TSS (4.7 %) in strawberry plants treated with GA_3 75 ppm as compared to control (no GA_3). GA_3 applied at 50, 75 and 100 ppm on strawberry increased the sweetness of the berries in comparison to control (Jamal *et al.*, 2012).

Dadashpour and Jouki (2012) reported that the treatment N_2 (manure + *Azotobacter* + woodash + phosphorus solubilizing bacteria + oil cake) improved fruit quality of strawberry cultivar Kurdistan with respect to diameter (3.11cm), length (3.95 cm), volume (20.397 cm^3), weight (11.11g), total sugars (7.95%), total soluble solids (9.01 °Brix), acidity (0.857), TSS: acidity ratio(11.12) and yields (238.95 g/plant) as compared to recommended dose of NPK (340:150:340 kg/ha).

As reported by Lolaei *et al.* (2013), the highest value of fruit TSS and TSS: acidity ratio in 'Selva' (7.1 ^{0}Brix and 7.71) and 'Queen Elisa' (7.9 ^{0}Brix and 8.77) were found with GA_3 application @ 50 ppm while fruit weight and acidity were maximum with GA_3 application at 150 ppm in both the cultivars (9.60 g, 11.40 g, 0.98 and 0.95 % respectively). Qureshi *et al.* (2013) found maximum fruit size (2.22 ± 0.09 mm) in T_2 treatment (GA_3 50 ppm alone), while TSS (8.37 ± 0.19 ^{0}Brix) and ascorbic acid (69.41 ± 1.08 mg/100 g) were

maximum in T_5 treatment (GA_3 50 ppm + $CaCl_2$ 0.4%) when compared with other treatments.

Kazemi (2014a) observed an increase in number of flowers, length of flowering period and number of achenes with foliar application of GA_3 @100 ppm. Kazemi (2014b) reported that TSS, vitamin C and fruit lycopene content in tomato increased significantly with foliar application of GA_3 and K either alone or in combination. The TSS, vitamin C and fruit lycopene content increased from 4 °Brix, 14.8 mg/100 g and 1 mg/100 g respectively in the control to a maximum of 6.8 °Brix, 35.12 mg/100 g and 2.34 mg/100 g with 10^{-8} mM GA_3+8 mM potassium nitrate application, followed by 5.58 °Brix, 33.14 mg/100 g and 2.17 mg/100 g with 10^{-8} mM GA_3, respectively.

Khunte *et al.* (2014) studied the effect of plant growth regulators (NAA, GA, Tricontanol and Cycocel) and organic manure on physico-chemical properties of strawberry **(***Fragaria x ananassa* Duch.) cultivar Chandler and recorded highest acidity (0.87 %) with application of GA_3 (150 ppm) + poultry manure (5.50 tonnes per hectare).

Nor *et al.* (2014) reported that dragon fruit (*Hylocereus polyrhizus*) plants treated with 50 ppm of GA_3 gave the best quality of fruits with respect to fruit weight, length, width and volume (561.4 g, 11 cm, 9.3 cm and 547.40 cm^3, respectively) as compared to control.

2.2.4 Effect on physiological parameters:

Khan *et al*. (1998) have shown that GA_3 application on mustard plants increased the leaf area and photosynthesis by 29.6% and 31.1% respectively as compared to untreated plants. Shun (2000) investigated the effect of CO_2 enrichment and fruit application of NAA, GA and CPPU on photosynthesis in strawberry and found significantly effective in increasing net photosynthetic rate, with close correlations between net photosynthetic rate and intracellular CO_2, stomatal conductance and transpiration rate, respectively.

Singh and Singh (2009) reported that the application *Azotobacter*+*Azospirillium*+60 kg N ha^{-1}+100 ppm GA_3 resulted in highest leaf chlorophyll content (2.63 mg/g) in strawberry cultivar Sweet Charlie. Lim *et al.* (2003) also reported increased leaf chlorophyll content in apple with the application of GA_3. Significantly higher chlorophyll content (250.76 mg/g) was observed in carnation cv. Red Sim plants treated with 50 and 100 ppm GA_3 in combination with 100 ppm P_2O_5 (El Naggar *et al.*, 2009).

Shahin *et al.* (2010) recorded significantly highest leaf chlorophyll a and b content in apple cultivar Anna with the application of 20 ppm GA_3 + 2.5 mg/ l Fertifol Misr (N, P, K, Mg, Zn, Fe, Mn, Cu, Mo and B) than other treatments and control. Moneruzzaman *et al.* (2011) reported increased level of chlorophyll content in the leaves of wax apple treated with 20 ppm GA_3 followed by 50 ppm GA_3 and control, and decreased level in 100 ppm GA_3. This suggests that chlorophyll synthesis was enhanced by lower GA_3 concentrations and higher concentration of showed a negative effect on chlorophyll synthesis.

Turkyilmaz (2012) observed increased leaf chlorophyll content (1.138 ± 0.030 mg/ 100g) in wheat when sprayed with 200 mM NaCl + 10 ppm GA_3 as compared to control (0.854 ± 0.062 mg/100 g). Kazemi (2014b) recorded increased chlorophyll content in tomato leaves with the application of 10^{-4} and 10^{-8} mM GA_3 (34.7 and 39.8 SPAD, respectively) as compared to control (30.12 SPAD).

Swamishekhar (2013) reported that the rate of photosynthesis was significantly affected by different concentrations of growth regulator treatments in which maximum photosynthetic rate (8.31 µ mole/m^2/sec.) was registered in plants treated with CPPU 6 ppm + GA_3 50 ppm treatment followed by CPPU 4 ppm + GA_3 50 ppm, GA_3 75 ppm and CPPU 2 ppm + GA_3 50 ppm treatments, while the minimum photosynthesis (3.39 µ mole/m^2/sec.) was recorded in control**.**

Misratia *et al.* (2013) reported that the application of GA_3 at 150 ppm resulted in significantly higher rate of photosynthesis, stomatal conductance, transpiration rate in rice cultivars ‘MR 219’ and ‘Pokkali’ compared to no GA_3 application.

2.2.5 Effect on leaf nutrient status

Monge *et al.* (1994) recorded higher leaf potassium, copper, zinc and Fe/ Mn ratio in peach cultivar Red haven plants treated with GA_3 @ 1000 mg/l as compared to control. Agegnehu and Taye (2004) obtained increased phosphorus content (0.18 %) in maize leaves when plants treated with 52 mg phosphorus + 1 mg GA as compared to control. Verma *et al.* (2005) conducted correlation studies on N and GA_3 with vegetative growth, flowering, fruiting and leaf nutrient status in low chill plum cultivar Titron and reported that the two split doses of nitrogen (200 g each) per tree along with 100 ppm GA_3 was most beneficial treatment for leaf nutrient status in plum. They also observed that the leaf nitrogen was

positively and significantly correlated with magnesium and zinc content but negatively correlated with P, K, Ca and boron.

Khan *et al.* (2006) recorded maximum leaf nitrogen in tomato with the application of 10^{-6} M GA_3 followed by 10^{-8} M GA_3 treatment. However, treatment 10^{-8} M GA_3 proved superior for P content. Treatments 10^{-8} and 10^{-4} M GA_3 being at par, gave higher value for leaf potassium than the other treatments.

Singh and Singh (2009) observed that the dual inoculation with *Azotobactor* and *Azospirillum* along with 60 kg N ha^{-1} and 100 ppm GA_3 application resulted in maximum N and Mg content in strawberry plants cultivar Sweet Charlie while the maximum Zn content was obtained in dual inoculation along with 90 kg N ha^{-1} and 100 ppm GA_3. El Shabasi *et al.* (2009) reported that GA_3 application resulted in increased total carbohydrate percentage in the foliage of strawberry plants. El Naggar *et al.* (2009) recorded significantly highest leaf phosphorus content (0.52 %) in carnation cv. Red Sim plants treated with 100 ppm GA_3 in combination with 200 ppm P_2O_5.

Garner *et al.* (2009) recorded significantly highest leaf nitrogen (2.55 %) content in 'Hass' avocado trees treated with GA_3 at 25 mg/l in mid September compared to the trees treated with GA_3 in mid-January (2.38 % N), at the end of June - beginning of July (2.35 % N) and the untreated control (2.30 % N).

Shahin *et al.* (2010) reported increased level of leaf nitrogen, potassium, magnesium, iron, zinc, manganese and copper contents in apple cultivar Anna with the application of 20 ppm GA_3 + 2.5 g/ l Fertifol Misr (2.43 %, 1.56 %, 0.50 %, 138.01 ppm, 43.18 ppm, 32.33 ppm and 38.03 ppm, respectively) followed by 20 ppm GA_3 alone (2.06 %, 1.37 %, 0.35 %, 103.11 ppm, 36.10 ppm 23.16 ppm and 29 ppm respectively) as compared to control. A similar study was reported by Soest (2012).

Significantly higher leaf nitrogen (1.71 %), phosphorus (0.87 %), potassium (1.66 %), calcium (0.32 %) and magnesium (0.93 %) contents were recorded by Stino *et al.* (2011) in Le- conte pear cultivar with the application of Berelex (GA_3 10 %) as compared to control (1.61, 0.55, 1.49, 0.23 and 0.51 %, respectively).

Kazemi (2014b) observed increased leaf nitrogen, phosphorus and potassium contents (2.41, 0.34 and 1.8 %, respectively) in tomato plants sprayed with 10^{-8} mM GA_3 + 8 mM

potassium nitrate followed by 10^{-8} mM GA_3 (2.5, 0.31 and 1.71 % respectively). Mazid and Roychowdhury (2014) noted maximum leaf nitrogen, phosphorus and potassium in chick pea plants treated with 10^{-6} M GA_3 as compared to control.

Leaf-N, P and K contents in fenugreek were significantly enhanced by foliar application of GA_3, with optimum combination treatment (P-40 + 10^{-6} M GA_3) proving the best (Dar *et al.*, 2015). The application of 10^{-6} M GA_3 in combination with soil-applied P increased the content of leaf N by 17.47 and 19.20 %, leaf P by 17.80 and 22.22 % and leaf K by 13.78 and 17.24 % at 60 and 90 days after sowing (DAS), respectively.

Chapter-3

MATERIALS AND METHODS

The present investigation entitled "Studies on effect of plant growth promoting rhizobacteria and GA_3 on plant growth, fruiting and soil health of strawberry (*Fragaria x ananassa* Duch.) cultivar Chandler" was carried out during 2013 and 2014.

The details of material used and methodologies employed have been described as under:

3.1 GENERAL

3.1.1 Location

The experimental plot was laid out in Model Farm of Directorate of Research, Dr Y S Parmar University of Horticulture & Forestry, Nauni, Solan, Himachal Pradesh at an elevation of 1320 m above mean sea level on the Northern aspect and lies at 30° 50' 45" N latitude and 77° 88' 33" E longitude.

3.1.2 Climate

The experimental area lies under the sub- temperate, sub-humid mid hill agro-climatic zone of Himachal Pradesh where summer is moderately hot during May- June while winter is severe during December- January. The average annual rainfall in this area ranges from 100-300 cm, most of which was received during monsoon months of July and August. Meteorological data pertaining to experimental site for the year 2013 and 2014 are presented in Appendix- I.

3.1.3 Soil

Before the commencement of the experiment, the soil of the experimental area was analyzed for physico-chemical and biological properties with following methods:

Sr. No.	Particulars	Contents	Method used
1.	**Soil nutrient status**		
	Soil pH	6.80	1:2 soil water suspension (Jackson, 1973) Digital pH meter.
	Electrical conductivity (dSm^{-1})	0.260	1:2 soil water suspension (Jackson, 1973) Systronic's Conductivity meter
	Organic carbon (%)	1.51	Walkeley and Black rapid titration method (Piper, 1966)
	Available N (kg ha^{-1})	235.00	Alkaline potassium permanganate method (Subbiah and Asija, 1956)
	Available P (kg ha^{-1})	44.50	Olsen's method using $NaHCO_3$ extractant at (pH 8.5) and colour development with stannous chloride reduce ammonium molybedate method (Olsen *et al.*, 1954)
	Available K (Kg ha^{-1})	164.25	Ammonium acetate (1N) extraction and determination using Flame Photometer (Mervin and Peech, 1951)
	Zinc (ppm)	2.02	DTPA extraction at pH 7.3 (Lindsay and Norvell, 1978) and determination using Atomic absorption spectrophotometer
	Manganese (ppm)	18.98	DTPA extraction at pH 7.3 (Lindsay and Norvell, 1978) and determination using Atomic absorption spectrophotometer
	Copper (ppm)	3.08	DTPA extraction at pH 7.3 (Lindsay and Norvell, 1978) and determination using Atomic absorption spectrophotometer
	Iron (ppm)	45.98	DTPA extraction at pH 7.3 (Lindsay and Norvell, 1978) and determination using Atomic absorption spectrophotometer
2.	**Biological properties**		
	Total bacterial count on nutrient agar (x 10^5 cfu/g of soil)	64	Serial dilution technique
	Total bacterial count on Pikovskaya's medium (x 10^5 cfu/g of soil)	32	Serial dilution technique
	Total bacterial count on chromoazeurol-S medium (x 10^5 cfu/g of soil)	19	Serial dilution technique
	Total bacterial count on Jensen's medium (x 10^5 cfu/g of soil)	28	Serial dilution technique
	Per cent Phosphate solublizing bacteria (10^5 cfu/ g of soil) (%)	47	Serial dilution technique
	Per cent Siderophore producing bacteria (x 10^5 cfu/ g of soil) (%)	51	Serial dilution technique
	Per cent Nitrogen producing bacteria (x 10^5 cfu/ g of soil) (%)	43	Serial dilution technique

3.2 EXPERIMENTAL DETAIL

The experiment was laid out as randomized block design with 35 treatments consisting 105 beds (2 X 2 m) in which strawberry runners were planted at a distance of 50 x 25 cm having 32 plants per bed. Each treatment was replicated thrice having three bed per treatment. The details of treatments are given as under:

Experiment 1: To study the effect of plant growth promoting rhizobacteria (PGPR) on growth yield, quality, leaf nutrient status and soil health

A. PGPR Treatments:

i. S_1 : *Bacillus licheniformis* CKA 1 (10^9 cfu/ ml)

ii. S_2 : *Bacillus subtilis* CB 8 A (10^9 cfu/ ml)

iii. S_3 : *Bacillus sp.* RG1 (10^9 cfu/ ml)

iv. S_4 : *Bacillus sp.* S_1 (10^9 cfu/ ml)

v. S_5 : *Bacillus sp* S_2 (10^9 cfu/ ml)

B. Method of application

i. M_1 : Root dip method

ii. M_2 : Foliar application method

iii. M_3 : Root dip + Foliar application method

C. Treatments : 16

T_1 : S_1 + Root dip method

T_2 : S_1+ Foliar application

T_3 : S_1 + Root dip method + Foliar application

T_4 : S_2+ Root dip method

T_5 : S_2+ Foliar application

T_6 : S_2 + Root dip method + Foliar application

T_7 : S_3 + Root dip method

T_8 : S_3+ Foliar application

T_9 : S_3 + Root dip method + Foliar application

T_{10} : S_4+ Root dip method

T_{11} : S_4+ Foliar application

T_{12} : S_4 + Root dip method + Foliar application

T_{13} : S_5 + Root dip method

T_{14} : S_5+ Foliar application

T_{15} : S_5 + Root dip method + Foliar application

T_{16} : Control (Sterile water application)

Experiment 2: To study effect of GA_3 and its combinations with plant growth promoting bacteria on growth, yield, quality and leaf nutrient status

A. GA_3 treatments

i. G_1 : GA_3 @ 25 ppm

ii. G_2 : GA_3 @ 50 ppm

iii. G_3 : GA_3 @ 75 ppm

B. PGPR treatments

i. S_1 : *Bacillus licheniformis* CKA 1 (10^9 cfu/ ml)

ii. S_2 : *Bacillus subtilis* CB 8 A (10^9 cfu/ ml)

iii. S_3 : *Bacillus sp.* RG1 (10^9 cfu/ ml)

iv. S_4 : *Bacillus sp.* S_1 (10^9 cfu/ ml)

v. S_5 : *Bacillus sp.* S_2 (10^9 cfu/ ml)

C. Method of application : Foliar application method

D. Treatments : 19

T_1 : GA_3 @ 25 ppm

T_2 : GA_3 @ 50 ppm

T_3 : GA_3 @ 75 ppm

T_4 : S_1 + GA_3 @ 25 ppm

T_5 : S_1 + GA_3 @ 50 ppm

T_6 : S_1 + GA_3 @ 75 ppm

T_7 : S_2+ GA_3 @ 25 ppm

T_8 : S2+ GA_3 @ 50 ppm

T_9 : S_2 + GA_3 @ 75 ppm

T_{10} : S_3 + GA_3 @ 25 ppm

T_{11} : S_3+ GA_3 @ 50 ppm

T_{12} : $S_3 + GA_3$ @ 75 ppm

T_{13} : $S_4 + GA_3$ @ 25 ppm

T_{14} : $S_4 + GA_3$ @ 50 ppm

T_{15} : $S_4 + GA_3$ @ 75 ppm

T_{16} : $S_5 + GA_3$ @ 25 ppm

T_{17} : $S_5 + GA_3$ @ 50 ppm

T_{18} : $S_5 + GA_3$ @ 75 ppm

T_{19} : Control (Sterile water application)

3.3 SOURCE OF BACTERIAL STRAINS:

Bacterial strains (S_1, S_2, S_3, S_4 and S_5) were procured from Department of Basic Science (Microbiology), College of Forestry, Dr Y S Parmar University of Horticulture and Forestry, Nauni, Solan (HP).

3.4 TIME OF APPLICATION:

GA_3 was applied as foliar spray 20 days before flowering while isolates of plant growth promoting rhizobacteria (PGPR) were applied as root dip at the time of planting and as foliar application 20 days before flowering.

3.5 OBSERVATIONS RECORDED

The observations were recorded from each replication of each treatment during the entire course of investigations and are given as under:

3.5.1 Plant growth parameters

3.5.1.1 Plant height

The plant height was measured from the ground level to the top with the help of a graduated scale and mean was worked out and expressed in centimeters (cm).

3.5.1.2 Plant spread

The plant spread was recorded by measuring the width in East-West and North-South directions with the help of a graduated scale and average of both the measurements were worked out to express mean value in centimeters (cm).

3.5.1.3 Leaf area

Twenty fully expanded mature leaves were taken randomly from five plants from each replication of each treatment. The leaf area was measured with the help of leaf area meter (Licor-Model 3100) and average leaf area of each treatment was calculated and expressed as square centimeter (cm^2).

3.5.1.4 Number of crowns

Number of crown were recorded by counting their number form randomly selected five plants in each replication for each treatment and their average was expressed in number of crowns per plant.

3.5.1.5 Number of runners

Number of runner were recorded by counting their number from randomly selected five plants in each replication for each treatment their average was expressed in number of runners per plant.

3.5.1.6 Plant biomass

After the completion of harvesting, the total biomass of the mother plants was recorded by uprooting the complete plant without damaging root system. The roots and shoots were washed with distilled water, air dried and weighed for fresh weight measurement. After that, these samples were kept separately in brown paper bags and exposed to 65±2 ^{0}C temperature in the hot air oven till the sample attained constant weight. The dry weight was recorded by using electronic weighing balance and expressed in grams (g).

3.5.2 Yield parameters

3.5.2.1 Dates of first flower opening

The dates related to first flower opening were timely recorded from selected plants of each replication of each treatments and the mean of all replications was taken as date of first flower open of each treatment.

3.5.2.2 Duration of flowering

The duration of flowering is the period between the emergence of flowers in 10 per cent plants and ceasing of flowering in 80 per cent plants. The duration is recorded for each replication of each treatment and expressed as number of days.

3.5.2.3 Dates of first harvesting

The dates related to first harvesting were timely recorded from selected plants for each replication of each treatments and average of all replications was taken as date of first harvesting.

3.5.2.4 Duration of fruit harvest

The duration of harvesting is the period between first harvesting in 20 per cent plant and ceasing of harvesting in 80 per cent plants in each beds and the data was expressed in number of days.

3.5.2.5 Number of fruits per plant

Number of fruits from randomly selected five plants were counted at the time of harvesting periodically and their average was expressed in number of fruits per plant

3.5.2.6 Yield per plant

The total number of fruits from five randomly selected plants were weighed periodically at the time of harvesting and their average were worked out and expressed as grams/ plant.

3.5.2.7 Yield per hectare

The yield per hectare was calculated on the basis of yield recorded in kg per plot and expressed in t/ ha.

3.5.3 Fruit quality parameters

3.5.3.1 Fruit weight

Weight of the ten fruits from each beds of each treatment was measured by weighing them on a top pan electronic balance and the average weight per fruit was calculated and expressed in gram (g).

3.5.3.2 Fruit length

The fruit length was measured with the help of Digital Vernier Calliper's and mean of the observations worked out and expressed in millimeter (mm).

3.5.3.1 Fruit diameter

Fruit diameter was measured for the same fruits which were used for measuring length, with the help of Digital Vernier Calliper's and mean was expressed in millimeter (mm).

3.5.3.2 Total soluble solids (TSS)

Total soluble solids (TSS) of the fruit juice were determined by Erma hand refractrometer (0-32^{0}Brix). The refractrometer was calibrated with distilled water before use. The total soluble solids were expressed as degree Brix of juice.

3.5.3.3 Titratable acidity

Ten grams of fruit pulp was crushed in a Warring blender, adding distilled water and the final volume was made up to 100 ml. The contents were filtered through Whatman No. I filter paper. Ten ml of extract was titrated against 0.1 N NaOH solution using phenolphthalene as an indicator. The appearance of pink colour indicated the end point. The total titratable acidity was calculated on the basis of 1 ml of 0.1 N NaOH equivalents to 0.0067 gram of anhydrous malic acid. The results were expressed as percentage of total titratable acidity on fresh fruit weight basis.

$$\text{Percent acidity} = \frac{\text{Titre value x normality of NaOH x volume made x equivalent weight of acid}}{\text{Weight of sample x Aliquot taken x 1000}} \text{ x } 100$$

3.5.3.4 TSS: acid ratio

The ratio was worked out by finding out the TSS and acidity of the fruits separately and dividing the TSS by acidity.

$$\text{TSS:Acid ratio} = \frac{\text{TSS}}{\text{Titratable Acidity}} \text{ x } 100$$

3.5.3.5 Total sugars

Twenty five grams of fruit pulp was taken in a 250 ml volumetric flask and thoroughly homogenized in distilled water. To this 10 ml of 45 per cent saturated lead acetate was added and the contents were shaken and filtered and kept for ten minutes. Thereafter, ten ml of 22 per cent potassium oxalate was added to precipitate the excess of lead and make the

final volume 250 ml with distilled water. Then the contents were again filtered and 100 ml of the filtrate was taken in another 250 ml volumetric flask and 5 ml of concentrated hydrochloric acid was added to it. The hydrolysis was carried out by keeping it overnight. The excess of acid was then neutralized by adding saturated sodium hydroxide and the final volume was made to 250 ml with distilled water. The hydrolyzed aliquot was then taken in a burette and titrated against a boiling mixture of 5 ml solution each of Fehling A and Fehling B using methylene blue as an indicator (A.O.A.C., 1980). The end point was indicated by the appearance of brick red colour. Total sugars were expressed in per cent on fresh fruit weight basis.

$$\text{Total sugar (\%)} = \frac{\text{Fehling Factor x Dilution x Dilution}}{\text{Titre value x volume of the aliquate taken for measurement x weight of sample taken}} \text{ x } 100$$

3.5.3.6 Reducing sugars

The remaining filtered stock solution was used for determination of reducing sugars. Boiling solution mixture containing 5 ml each of Fehling A and Fehling B reagents was titrated against remaining unhydrolyzed, de-leaded and clarified pulp solution obtained from above total sugars solution using methylene blue as an indicator. The end point was indicated by the appearance of brick red colour. The results were expressed as per cent on fresh fruit weight basis as given in A.O. A.C. (1980).

$$\text{Reducing sugar (\%)} = \frac{\text{Fehling Factor x Dilution}}{\text{Titre value x weight of sample taken}} \text{ x } 100$$

3.5.3.7 Non reducing sugars

The amount of non-reducing sugars was worked out by subtracting reducing sugars from total sugars and multiplying the difference by standard factor 0.95.

Non-reducing sugars = (Total sugars - reducing sugars) x 0.95

3.5.3.8 Ascorbic acid

The quantitative determination of ascorbic acid was done according to the method given in A.O.A.C. (1980).

Reagents

i) Extraction solution

Thirty grams of metaphosphoric acid pallets were dissolved in 80 ml glacial acetic acid and 400 ml of distilled water. The volume was made one liter with distilled water. The solution was filtered rapidly through Whatman No.1 filter paper and stored in coloured bottles in a refrigerator.

ii) Standard ascorbic acid

One hundred milligrams of analytical grade ascorbic acid (reference standard) was accurately weighed on electronic balance and dissolved in 10 ml of metaphosphoric acid extraction solution. The content was transferred to a 100 ml volumetric flask and volume was made to 100 ml by addition of metaphosphoric acid solution. Now this solution was diluted upto twenty times before use with metaphosphoric acid solution so as to reduce the consumption of dye.

iii) Indophenol standard solution

Fifty mg of 2, 6-dichlorophnol indophenols sodium salt was dissolved in 50 ml hot distilled water. Forty-two mg of sodium bicarbonate was added to it. The contents were shaken vigorously and when 2,6-dichlorophenol indophenols was dissolved, it was diluted to 200 ml with distilled water, filtered and stored in dark coloured bottle in a refrigerator.

iv) Standardization of dye

Take five ml of standard ascorbic acid solution and add five ml of 3 per cent metaphosphoric acid. Titrate it with dye taken in the buerette till the appearance of light pink colour (end point) which should persist for atleast 15 seconds. Determine the dye factor by using following formula:

$$\text{Dye factor} = 0.5/\ \text{titre value}$$

Procedure

Stock solution was prepared by dissolving ten ml of fruit juice in 3 per cent metaphosphoric acid solution to make final volume of 100 ml. Then ten ml sample of this freshly prepared and filtered stock solution was taken and ten ml of extracting solution was added to it. This solution was titrated against 2, 6-dichlorophenol indophenols dye.

Appearance of light pink colour indicated the end point. The amount of ascorbic acid in milligrams per hundred grams of juice was calculated using formula:

$$\text{Ascorbic acid (mg/100 g)} = \frac{\text{Dye factor x Titre value x volume made}}{\text{Weight of fruit Taken x volume taken for estimation}} \text{x } 100$$

3.5.3.9 Anthocyanin content

Total anthocyanin present in the samples were determined by the method given by Rangana (2007). The procedure involved extraction of the anthocyanins with methanolic-HCl and measurement of colour at the wavelength of 535 ηm against blank of methanolic-HCl using a UV-Vis spectrophotometer (Model Shimadzu, Japan). The anthocyanins were calculated and expressed as mg per 100 ml using the formula given below:

$$\text{Total OD/100 mL} = \frac{\text{Optical Density (OD)} \times \text{Volume made up of the extract used for the colour} \times \text{Total volume}}{\text{volume of the extract used x volume of the sample taken}} \text{x } 100$$

$$\text{Total anthocyanins content (mg/100 mL)} = \frac{X}{E}$$

where, X = Total OD/100 mL

E = Extinction coefficient (98.2)

3.5.4 Physiological parameters

3.5.4.1 Chlorophyll content

For the estimation of chlorophyll, five well expanded leaves per replication were collected in ice box and brought to the laboratory. Then, leaf samples were washed and chopped into fine pieces.

Extraction

For the extraction of chlorophyll, 100 milligram of chopped sample was placed in vial containing 7 ml of dimethyle sulphoxide (DMSO). The contents of vials were incubated at 65 ^{0}C for half an hour and then extract was transferred to graduated test tube and final volume was made ten ml with dimethyl sulphoxide as suggested by Hiscox and Israelstam (1979).

Estimation

Optical density (OD) of the above extract was recorded on Spectronic- 20 at 645 and 663 ηm wavelength against a DMSO blank and total chlorophyll contenet was calculated by using following formula:

$$\text{Total chlorophyll (mg/ g)} = \frac{20.2\,A645 + 8.02\,A663 \times V}{A \times 1000 \times W}$$

Where,

V	=	Volume of the extract used
A	=	Length of light path in cell (usually 1 cm)
W	=	Weight of the sample (g)
A_{645}	=	Absorbance at 645 ηm wavelength
A_{663}	=	Absorbance at 663 ηm wavelength

The results were expressed as chlorophyll content in mg/g in fresh weight.

3.5.4.2 Photosynthesis, stomatal conductance, resistance and transpiration

Photosynthesis, stomatal resistance, conductance and transpiration were recorded during fruit development stage. The observations were recorded between 9:00 to 12:00 am with the help of LICOR- 6200 portable photosynthesis meter. The results were expressed in µ mol/m^2/s, S cm^{-1}, m mol/s and m mol/m^2/s for photosynthesis, stomatal conductance, resistance and transpiration respectively.

3.5.5 Leaf nutrient status

3.5.4.1 Collection of samples

For estimation of macro and micronutrients status of plant, twenty-five fully mature and expanded leaves were collected all around the plants for each replication of each treatment. The collected leaf samples were first washed under tap water followed by 0.1 N HCl, distilled water and finally with double distilled water. The drying, grinding and storing of samples were carried out in accordance with the procedure described by Kenworthy (1964).

3.5.5.1 Digestion of leaf samples for nitrogen estimation

One gram well dried and grounded leaf samples were used for estimation of leaf nitrogen. The samples were digested on automatic digestion system using one gram of

digestion mixture and 20 ml of concentrated sulphuric acid. The digestion mixture was prepared by mixing 400 parts potassium sulphate, 20 parts copper sulphate, 3 parts of mercuric chloride and one part of selenium powder as suggested by Jackson (1967). The boiling of samples was continued till the appearance of light blue color. The samples were cooled and diluted to100 ml with distilled water.

3.5.5.2 Digestion of leaf samples for other nutrients

For other nutrients elements, one gram well dried and grinded leaf samples were used for digestion in di-acid (HNO_3 and $HClO_4$ in 4:1 v/v) and all relevant precautions as suggested by Piper (1966) were observed. The samples were digested on electric hot plate. The digestion was continued till 2-3 ml of clear digested material was left in the conical flasks. After complete digestion the samples were diluted to 100 ml with the help of distilled water.

3.5.5.3 Estimation of leaf nitrogen

The leaf samples digested for nitrogen estimation were fed to Auto analyzer Kjeltec FOSS Tecator Model 2300 for auto distillation and titration of the samples. The end point was the appearance of slight red colour.

3.5.5.4 Estimation of other nutrients

The phosphorous was estimated by Vanado-molybdo-phosphoric acid method (Jackson, 1973). Five ml of extract (di- acid digested sample) was taken in 25 ml of volumetric flask. To this flask 20 ml of working solution was added and final volume was made to 25 ml with distilled water. The contents were mixed and used for estimation of phosphorous on Spectronic-20 D at 470 ηm wavelength using red filter. The colour intensity (yellow) was recorded and the phosphorous content was measured with the help of standard curve.

The potassium in plant tissue was estimated on flame photometer (Jackson, 1973). The digested samples were diluted to 100 ml with distilled water. 5 ml of this prepared sample was diluted to 50 ml with distilled water. The samples vis-à-vis to standards are fed one by one to the Flame photometer and readings were recorded in ppm.

The determination of other elements of Ca, Mg, Zn, Cu, Mn and Fe were carried out on Atomic absorption spectrophotometer model 4141 by using 10 ml of 100 ml prepared

sample, which was further diluted to 50 ml with distilled water. The macro and micronutrients of leaf were computed on dry weight basis and expressed as per cent and ppm, respectively.

3.5.6 Soil Analysis

Collection and preparation of soil samples

Soil samples from 0-15 cm layer of experimental plot were collected for different treatments at the time of removal of runners during both the years. Four samples from four direction of each plot/ bed were taken and mixed to form one composite sample. Then, the soil was air dried, grounded, passed through 2 mm plastic sieve and stored in cloth bags for further analysis.

3.5.6.1 Soil pH

The soil pH was determined by soil: water ratio as 1:2:5 by pH meter, as described by Jackson (1973).

3.5.6.2 Electrical conductivity

The electrical conductivity in 1:2:5 soil suspensions was measured by Systronic's conductivity meter and expressed as dSm^{-1} (Jackson, 1973).

3.5.6.3 Organic carbon

Organic carbon was determined by Chromic acid titration method of Walkley and Black (1934).

3.5.6.4 Available N

Twenty gram of soil was weighed and moistened with distilled water. Then, it is added to Kjeldahl distillation flask and 100 ml of 0.32 per cent KMnO4 and 100 ml of 2.5 per cent NaOH were added to the assembly and cork was fitted immediately (Subbiah and Asija, 1956). 25 ml of 0.02 N H_2SO_4 was taken in conical flask and 2-3 drops of methyl red indicator was added into conical flask. Hot plate was switched on to distill ammonia gas and 25- 30 ml of distillate in 0.02 N H_2SO_4 containing conical flask was collected. The excess of H_2SO_4 in conical flask was titrated against 0.02 N NaOH and change in colour from pink to yellow was note as end point.

Where,

$$\text{Available Nitrogen (\%)} = \frac{(25 - A) \times 0.00028}{\text{Weight of soil}} \times 100$$

A = Volume of 0.02 N NaOH used

ppm of available nitrogen in soil = Available nitrogen (%) x 10,000

Available Nitrogen kg/ ha = ppm x 2.24

3.5.6.5 Available Phosphorus

One gram of soil was taken in a 100 ml conical flask followed by the addition of pinch of Darco- G 60 and 20 ml of 0.5 N sodium bicarbonate (Olsen's *et al.*, 1954). The contents were shaken for thirty minutes and filtered to obtain clear filtrate. To five ml of the filtrate, five ml of ammonium molybdate was added. The mixture was thoroughly shaken to remove the CO_2 evolved and the contents of the flask were diluted to about 20 ml. Thereafter, one ml of working solution of stannous chloride was added and final volume of 25 ml was made. The content was mixed thoroughly and the blue colour intensity was measured after five minutes at 660 nm keeping blank appropriately.

ppm of available phosphorus in soil = A x total dilution

where,

A = Concentration of P read from the standard curve

Available Phosphorus kg/ha = ppm x 2.24

3.5.6.6 Available Potassium

Five gram of soil was transferred to a 150 ml of conical flask. Twenty five ml of neutral ammonium acetate solution was added and the contents were vigorously shaken on electric shaker for five minutes. The contents of the conical flask were filtered and the filtrate was fed to the automizer of the flame photometer. The reading was noted and expressed in ppm (Mervin and Peech, 1951).

ppm of available potassium in soil = Y x Total dilution

where,

Y = ppm as read from the standard curve

Available potassium kg/ ha = ppm x 2.24

3.5.6.7 DTPA Extractable Micronutrients (Zn, Fe, Cu and Mn)

The analysis of soil micronutrients was carried out as per method suggested by Lindsey and Novell (1978). The method consists shaking of 10 g soil with a buffered solution of DTPA (diethylene triamine penta- acetic acid). This chemical acts as a mild chelating agent, which extracts the easily soluble Zn, Fe, Cu and Mn. The extracting solution was buffered at 7.3 pH by TEA (tri-ethanolamine) and in addition includes calcium chloride to prevent the dissolution of calcium carbonate. These conditions permit the light amount of Zn, Fe, Cu and Mn to be dissolved and $CaCl_2$ is to stabilize the pH of the extractant. The samples with extracting solution were shaken for two hours and filtered through Whatman No. 42 filter paper. The dissolved elements in extracts are then measured by the Atomic Absorption Spectophotometer (AAS).

3.5.7 Soil Biological properties

3.5.7.1 Isolation and enumeration of rhizobacteria

Plants collected from different sites were shaken vigorously to remove the soil i.e. tightly adhere to the roots. One gram of this rhizosphere soil was placed in 9 ml of sterilized distilled water under aseptic conditions. The soil suspension was diluted to 10 folds series as 10^{-4}, 10^{-5}, 10^{-6} and 10^{-7} by serial dilution method. One ml of this serially diluted suspension of soil was spread on the Petri-plate containing pre-poured solidified Nutrient Agar (NA) medium and incubated at 37(±2) ^{0}C, in inverted position for 24- 48 hours. After incubation, the isolated colonies that developed on enriched medium (master plate) were counted and the dilution factor was calculated to get the Colony Forming Unit (CFU) in each ml of diluted inoculums. Take the mean CFU and the viable cell/ g dry soil was calculated as follows:

$$\text{Viable cells/g of soil} = \frac{\text{Mean plate count x Dilution factor}}{\text{Dry weight of soil}}$$

(Dilution factor = Reciprocal of the dilution (eg. $10^{-7} = 10^{7}$))

3.5.7.2 Isolation and enumeration endorhizobacteria

The root samples were surface sterilized by 0.2 per cent mercuric chloride ($HgCl_2$) for two minutes followed by repeated washing in sterilized distilled water. The surface sterility of roots was cross checked by incubating the surface sterilized roots in sterilized Nutrient Agar medium for 24 hours at 37(±2) ^{0}C. One gram of surface sterilized root sample wa

Plate 1(a). Rhizobacteria on nutrient agar

Plate 1(b). Phosphate solubilizing bacteria on PVK medium

Plate 1(c). Siderophore producing bacteria on CAS medium

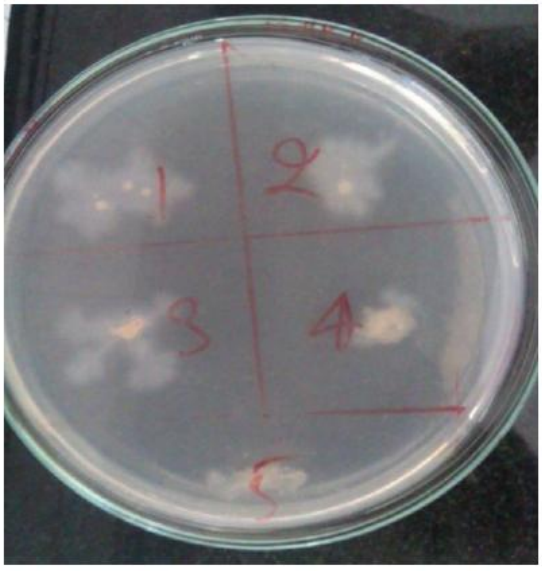


Plate 1(d). Nitrogen fixing bacteria on Jensen's medium

crushed in 9 ml of sterilized distilled water and was crushed to produce slurry using pestle mortar under aseptic conditions. One ml of serially diluted suspension of roots was spread on Petri-plate containing pre poured solidified Nutrient Agar medium and incubated at 37(±2) ^{0}C in inverted position. After incubation, same procedure was followed as in case of rhizobacterial count.

3.5.7.3 Estimation of per cent phosphate solubilizing bacteria

Twenty four hour old culture from different test bacteria formed on nutrient agar was spotted on pre-poured solid violet coloured PVK agar plate and incubated for 48- 72 hours at 37 ^{0}C in inverted position. Formation of colonies with yellow zone and yellowish fluorescence on dark violet/ pinkish medium indicated the production of phosphate solubilizing bacteria (Pikovskaya, 1948). The phosphate solubilizing bacteria were counted and percentage was calculated as:

$$\text{Per cent phosphate solubilizing bacteria} = \frac{\text{Number of phoaphate solubilizing bacteria}}{\text{Total number of bacteria}} \times 100$$

3.5.7.4 Estimation of per cent siderophore producing bacteria

Siderophore production was detected by plate assay method using ternary complex chromeazurol- S/ Fe^{3+}/ hexadecyltrimethylammonium bromide as an indicator (Schwyn and Neilands, 1987). Twenty four hour old culture of different test bacteria formed on nutrient agar was spotted on pre- poured blue coloured chromeazurol- S agar plate. Plates were incubated for 48- 72 hours at 37 ^{0}C in inverted position. Formation of a bright zone with a yellowish fluorescence in dark blue medium indicated the production of siderophore. Then siderophore producing bacteria was calculated and expressed in per cent.

$$\text{Per cent phosphate solubilizing bacteria} = \frac{\text{Number of siderophore producing bacteria}}{\text{Total number of bacteria}} \times 100$$

3.5.7.5 Estimation of per cent nitrogen fixing bacteria

Twenty four hour old culture from different test bacteria formed on nutrient agar was spotted on pre-poured white coloured Jensen's agar plate and incubated for 48- 72 hours at 37 ^{0}C in inverted position (Jensen, 1987). Formation of bigger white colonies on medium indicated the production of nitrogen fixing bacteria. The phosphate solubilizing bacteria were counted and percentage was calculated as:

$$\text{Per cent phosphate solubilizing bacteria} = \frac{\text{Number of nitrogen fixing bacteria}}{\text{Total number of bacteria}} \times 100$$

3.6 STATISTICAL ANALYSIS

The statistical analysis was carried out for each observed character under the study using MS-Excel, SPSS 16.0 and OPSTAT packages. The mean values of data were subjected to analysis of variance as described by Gomez and Gomez (1984) for Randomized Block Design.

Chapter-4

EXPERIMENTAL RESULTS

The present investigation entitled "Studies on the effect of plant growth promoting rhizobacteria and GA_3 on plant growth, fruiting and soil health of strawberry (*Fragaria x ananassa* Duch.) cultivar Chandler" was conducted at Model Farm, Directorate of Research, Dr Y S Parmar university of Horticulture and Forestry, Nauni, Solan, Himachal Pradesh during 2012-2013 and 2013-2014. The experimental results obtained are presented under the appropriate heads:

4.1 Effect of plant growth promoting rhizobacteria

4.2 Effect of GA_3 and plant growth promoting rhizobacteria

4.1 EFFECT OF PLANT GROWTH PROMOTING RHIZOBACTERIA

4.1.1 Growth parameters

4.1.1.1 Plant height

The data pertaining to the effect of plant growth promoting rhizobacteria on plant height are given in Table 1(a) to 1(b).

The inoculation of strawberry plants with plant growth promoting rhizobacteria through different application methods have shown significant effect on plant height during both the years of study which varied from 23.42 to 29.54 cm. The pooled data given in Table 1(a) showed that the maximum plant height (29.54 cm) was recorded in T_3 followed by T_{15} (28.49 cm) which was statistically higher than other treatments while minimum plant height (23.42 cm) was in control (T_{16}). A similar trend was observed during 2013. However, during 2014, maximum plant height (29.93 cm) was obtained from T_9 which was statistically at par with T_3, T_{15}, T_{12}, T_6 and T_5 (29.58, 29.50, 28.83, 28.83 and 28.50 cm respectively). The minimum plant height was recorded in T_{16} for both the years (22.20 and 24.63 cm respectively).

Table 1(a). Effect of plant growth promoting rhizobacteria on plant height of strawberry cultivar Chandler

Treatments		Plant height (cm)		
		2013	2014	Pooled
T_1	S_1 + Root dip method	24.03	25.50	24.77
T_2	S_1+ Foliar application	25.52	25.87	25.69
T_3	S_1 + Root dip method + Foliar application	29.50	29.58	29.54
T_4	S_2+ Root dip method	23.33	26.87	25.10
T_5	S_2+ Foliar application	25.57	28.50	27.04
T_6	S_2 + Root dip method + Foliar application	25.96	28.83	27.40
T_7	S_3 + Root dip method	22.87	25.67	24.27
T_8	S_3+ Foliar application	23.42	27.60	25.51
T_9	S_3 + Root dip method + Foliar application	25.70	29.93	27.82
T_{10}	S_4+ Root dip method	23.17	27.50	25.33
T_{11}	S_4+ Foliar application	26.15	27.80	26.98
T_{12}	S_4 + Root dip method + Foliar application	26.63	28.83	27.73
T_{13}	S_5 + Root dip method	22.92	26.67	24.79
T_{14}	S_5+ Foliar application	23.85	27.20	25.53
T_{15}	S_5 + Root dip method + Foliar application	27.48	29.50	28.49
T_{16}	Control	22.20	24.63	23.42
$CD_{0.05}$		2.19	1.59	1.41

Table 1(b). Interaction effect of plant growth promoting rhizobacteria and their application methods on plant height of strawberry cultivar Chandler

Treatment	Plant height (cm)											
	2013				2014				Pooled			
	M_1	M_2	M_3	MEAN	M_1	M_2	M_3	MEAN	M_1	M_2	M_3	MEAN
S_1	24.03	25.52	29.50	26.35	25.50	25.87	29.58	26.98	24.77	25.69	29.54	26.67
S_2	23.33	25.57	25.96	24.96	26.87	28.50	28.83	28.07	25.10	27.03	27.40	26.51
S_3	22.87	23.42	25.70	24.00	25.67	27.60	29.93	27.73	24.27	25.51	27.82	25.87
S_4	23.17	26.15	26.63	25.32	27.50	27.80	28.83	28.04	25.33	26.97	27.73	26.68
S_5	22.92	23.85	27.48	24.75	26.67	27.20	29.50	27.79	24.79	25.53	28.49	26.27
MEAN	23.26	24.90	27.06		26.44	27.39	29.33		24.85	26.15	28.19	
$CD_{0.05}$ for S : 1.30					$CD_{0.05}$ for S : NS				$CD_{0.05}$ for S : NS			
$CD_{0.05}$ for M : 1.01					$CD_{0.05}$ for M : 0.73				$CD_{0.05}$ for M : 0.65			
$CD_{0.05}$ for SxM : NS					$CD_{0.05}$ for SxM : NS				$CD_{0.05}$ for SxM : NS			

The interaction values between different plant growth promoting rhizobacterial strains and their application methods for plant height are given in Table 1(b). The pooled value for S x M was found non-significant, however maximum plant height (29.54 cm) was recorded in S_1M_3 and minimum (24.27 cm) in S_3M_1. The results further showed that all the rhizobacterial strains were non-significant in their effect on plant height whereas, during 2013, significant impact of strains was observed and S_1 was found promising for plant height. Among different application methods, M_3 was the best method.

4.1.1.2 Plant spread

The mean values pertaining to the effect of plant growth promoting rhizobacteria on plant spread are presented in Table 2(a) to 2(b). Plant growth promoting rhizobacteria significantly increased the plant spread in strawberry cultivar 'Chandler' during both the years of study which varied from 25.92 to 34.52 cm. The pooled data showed that maximum plant spread (34.52 cm) was recorded in T_3 which was statistically at par with T_6 (33.92 cm) and significantly higher than other treatments, while minimum (25.92 cm) was in T_{16} [Table 2(a)]. Similar trend was observed during 2013 and 2014.

Table 2(a). Effect of plant growth promoting rhizobacteria on plant spread of strawberry cultivar Chandler

Treatments		Plant spread (cm)		
		2013	2014	Pooled
T_1	S_1 + Root dip method	26.78	34.33	30.56
T_2	S_1+ Foliar application	25.97	31.33	28.65
T_3	S_1 + Root dip method + Foliar application	31.03	38.00	34.52
T_4	S_2+ Root dip method	27.90	36.67	32.28
T_5	S_2+ Foliar application	26.93	34.50	30.72
T_6	S_2 + Root dip method + Foliar application	29.92	37.92	33.92
T_7	S_3 + Root dip method	25.06	34.63	29.85
T_8	S_3+ Foliar application	24.34	33.95	29.15
T_9	S_3 + Root dip method + Foliar application	28.18	37.00	32.59
T_{10}	S_4+ Root dip method	26.34	34.08	30.21
T_{11}	S_4+ Foliar application	25.95	33.17	29.56
T_{12}	S_4 + Root dip method + Foliar application	27.40	36.08	31.74
T_{13}	S_5 + Root dip method	24.13	32.17	28.15
T_{14}	S_5+ Foliar application	23.37	29.67	26.52
T_{15}	S_5 + Root dip method + Foliar application	28.45	37.33	32.89
T_{16}	Control	23.05	28.78	25.92
$CD_{0.05}$		1.92	1.76	1.43

Table 2(b). Interaction effect of plant growth promoting rhizobacteria and their application methods on plant spread of strawberry cultivar Chandler

Treatment	Plant spread (cm)											
	2013				2014				Pooled			
	M_1	M_2	M_3	MEAN	M_1	M_2	M_3	MEAN	M_1	M_2	M_3	MEAN
S_1	26.78	25.97	31.03	27.93	34.33	31.33	38.00	34.56	30.56	28.65	34.52	31.24
S_2	27.90	26.93	29.92	28.25	36.67	34.50	37.92	36.36	32.28	30.71	33.92	32.31
S_3	25.06	24.34	28.18	25.86	34.63	33.95	37.00	35.19	29.84	29.14	32.59	30.53
S_4	26.34	25.95	27.40	26.56	34.08	33.17	36.08	34.44	30.21	29.56	31.74	30.50
S_5	24.13	23.37	28.45	25.32	32.17	29.67	37.33	33.06	28.15	26.52	32.89	29.19
MEAN	26.04	25.31	29.00		34.38	32.52	37.27		30.21	28.92	33.13	
$CD_{0.05}$ for S : 1.08					$CD_{0.05}$ for S : 1.04				$CD_{0.05}$ for S : 0.84			
$CD_{0.05}$ for M : 0.83					$CD_{0.05}$ for M : .81				$CD_{0.05}$ for M : 0.65			
$CD_{0.05}$ for SxM : NS					$CD_{0.05}$ for SxM : 1.81				$CD_{0.05}$ for SxM : 1.46			

The interactive effect of different plant growth promoting rhizobacterial strains and their application methods with respect to plant spread was found significant as pooled data depicted in Table 2(b). The pooled data reveals that the maximum plant spread (34.52 cm) was observed in S_1M_3 followed by S_2M_3 (33.92 cm) which were statistically at par with each other while minimum (26.52 cm) was in S_5M_2. However, it was non-significant during 2013 and significant during 2014 following the similar trend as pooled data. Furthermore, among different PGPR strains, S_2 was found most effective for plant spread which was statistically higher than other strains and M_3 was proved best as application method.

4.1.1.3 Leaf area

The perusal of data presented in Table 3(a) and 3(b) reveals the significant influence of different plant growth promoting rhizobacteria and application methods on the leaf area of strawberry during both the years of investigation. The pooled data showed that maximum leaf area (134.00 cm^2) was recorded in T_{15} followed by T_3 (133.07 cm^2) which were statistically at par with each other and the minimum was recorded in control (107.87 cm^2) [Table 3(a)]. A similar trend was observed during both the years of study (2013 and 2014).

The interaction between plant growth promoting rhizobacteria and their application methods have significantly increased the leaf area of strawberry during both years of study. Maximum leaf area (134.00 cm^2) was observed in S_5M_3 which was statistically at par with S_1M_3 (33.07 cm^2) and minimum in S_4M_2 (110.74 cm^2) as pooled value presented in Table 3(b). A similar pattern was observed during both the years of study. During the study,

$T_{15} = S_5 + M_3$

$T_3 = S_1 + M_3$

$T_{11} = S_4 + M_2$

T_{16} = Control

Plate 2. Effect of plant growth promoting rhizobacteria and their application methods on leaf area of strawberry cv. Chandler

S_5 was proved most efficient strain and M_3 was recorded as most effective application method.

Table 3(a). Effect of plant growth promoting rhizobacteria on leaf area of strawberry cultivar Chandler

Treatments		Leaf area (cm^2)		
		2013	2014	Pooled
T_1	S_1 + Root dip method	125.07	130.40	127.90
T_2	S_1+ Foliar application	115.52	118.85	117.19
T_3	S_1 + Root dip method + Foliar application	129.90	136.23	133.07
T_4	S_2+ Root dip method	109.83	115.32	112.58
T_5	S_2+ Foliar application	108.97	114.97	111.97
T_6	S_2 + Root dip method + Foliar application	110.27	116.60	113.44
T_7	S_3 + Root dip method	110.12	115.76	112.94
T_8	S_3+ Foliar application	107.85	113.85	110.85
T_9	S_3 + Root dip method + Foliar application	125.05	131.60	128.33
T_{10}	S_4+ Root dip method	111.18	116.85	114.01
T_{11}	S_4+ Foliar application	107.78	113.78	110.78
T_{12}	S_4 + Root dip method + Foliar application	116.55	122.88	119.71
T_{13}	S_5 + Root dip method	121.89	127.56	124.72
T_{14}	S_5+ Foliar application	120.48	126.48	123.48
T_{15}	S_5 + Root dip method + Foliar application	130.67	137.34	134.00
T_{16}	Control	104.70	111.04	107.87
$CD_{0.05}$		2.96	1.51	1.70

Table 3(b). Interaction effect of plant growth promoting rhizobacteria and their application methods on leaf area of strawberry cultivar Chandler

Treatment	Leaf area (cm^2)											
	2013				2014				Pooled			
	M_1	M_2	M_3	MEAN	M_1	M_2	M_3	MEAN	M_1	M_2	M_3	MEAN
S_1	125.07	115.52	129.90	123.50	130.74	118.85	136.23	128.61	127.90	117.19	133.07	126.05
S_2	109.83	108.97	110.27	109.69	115.32	114.97	116.60	115.63	112.58	111.97	113.44	112.66
S_3	110.12	107.85	125.05	114.34	115.76	113.85	131.60	120.40	112.94	110.85	128.33	117.37
S_4	111.18	107.78	116.55	111.84	116.85	113.78	122.88	117.84	114.01	110.78	119.71	114.84
S_5	121.89	120.48	130.67	124.35	127.56	126.48	137.34	130.46	124.72	123.48	134.00	127.40
MEAN	115.62	112.12	122.49		121.24	117.59	128.93		118.43	114.85	125.71	
$CD_{0.05}$ for S : 1.75					$CD_{0.05}$ for S : 0.61				$CD_{0.05}$ for S : 0.89			
$CD_{0.05}$ for M : 1.35					$CD_{0.05}$ for M : 0.47				$CD_{0.05}$ for M : 0.69			
$CD_{0.05}$ for SxM : 3.02					$CD_{0.05}$ for SxM : 1.06				$CD_{0.05}$ for SxM : 1.55			

4.1.1.4 Number of crowns per plant

It is evident from the Table 4(a) and 4(b) that plant growth promoting rhizobacteria resulted in significantly higher number of crowns per plant as compared to control which varies from 3.50 to 4.78. Pooled data in Table 4(a) indicated that the highest number of crowns per plant were produced in T_9 (4.78) which was statistically at par with T_{15} (4.61) and T_7 (4.48) while lowest number was observed in T_{16} (3.50). Other treatments are statistically at par with each other. A similar trend was observed during both the years of study.

The interaction values between plant growth promoting rhizobacterial strains and their application methods given in Table 4(b) registered non-significant effect on number of crowns during both the years of study. However, maximum number of crowns (4.78) was found in S_3M_3 and minimum (3.61) in S_1M_2 and S_2M_2 as pooled values. Results further showed that among different bacterial strains, S_3 produced maximum number of crowns statistically higher that other strains while M_3 was recorded as best method of PGPR application.

Table 4(a). Effect of plant growth promoting rhizobacteria on number of crowns per plant of strawberry cultivar Chandler

Treatments		Number of crowns/ plant		
		2013	2014	Pooled
T_1	S_1 + Root dip method	3.78	4.00	3.89
T_2	S_1+ Foliar application	3.50	3.71	3.61
T_3	S_1 + Root dip method + Foliar application	4.18	4.39	4.29
T_4	S_2+ Root dip method	3.73	3.95	3.84
T_5	S_2+ Foliar application	3.44	3.78	3.61
T_6	S_2 + Root dip method + Foliar application	4.00	4.32	4.16
T_7	S_3 + Root dip method	4.38	4.58	4.48
T_8	S_3+ Foliar application	4.08	4.39	4.24
T_9	S_3 + Root dip method + Foliar application	4.62	4.93	4.78
T_{10}	S_4+ Root dip method	3.87	4.17	4.02
T_{11}	S_4+ Foliar application	3.82	4.02	3.92
T_{12}	S_4 + Root dip method + Foliar application	4.08	4.41	4.24
T_{13}	S_5 + Root dip method	4.07	4.27	4.17
T_{14}	S_5+ Foliar application	3.85	4.12	3.98
T_{15}	S_5 + Root dip method + Foliar application	4.44	4.78	4.61
T_{16}	Control	3.33	3.67	3.50
$CD_{0.05}$		0.51	0.47	0.33

Table 4(b). Interaction effect of plant growth promoting rhizobacteria and their application methods on number of crowns per plant of strawberry cultivar Chandler

Treatment	Number of crowns/ plant											
	2013				2014				Pooled			
	M_1	M_2	M_3	MEAN	M_1	M_2	M_3	MEAN	M_1	M_2	M_3	MEAN
S_1	3.78	3.50	4.18	3.82	4.00	3.71	4.39	4.03	3.89	3.61	4.29	3.93
S_2	3.73	3.44	4.00	3.73	3.95	3.78	4.32	4.02	3.84	3.61	4.16	3.87
S_3	4.38	4.08	4.62	4.36	4.58	4.39	4.93	4.64	4.48	4.24	4.78	4.50
S_4	3.87	3.82	4.08	3.92	4.17	4.02	4.41	4.20	4.02	3.92	4.24	4.06
S_5	4.07	3.85	4.44	4.12	4.27	4.12	4.78	4.39	4.17	3.98	4.61	4.25
MEAN	3.96	3.74	4.26		4.19	4.00	4.57		4.08	3.87	4.42	
$CD_{0.05}$ for S : 0.30					$CD_{0.05}$ for S : 0.25				$CD_{0.05}$ for S : 0.19			
$CD_{0.05}$ for M : 0.23					$CD_{0.05}$ for M : 0.19				$CD_{0.05}$ for M : 0.15			
$CD_{0.05}$ for SxM : NS					$CD_{0.05}$ for SxM : NS				$CD_{0.05}$ for SxM : NS			

4.1.1.5 Number of runners per plant

The data pertaining to the plant growth promoting effect of rhizobacteria on production of runners per plant are presented in Table 5(a) to 5(b). The data showed significant increase in number of runners per plant which varied from 21.08 to 43.59. In pooled values, maximum number of runners per plant (43.59) was recorded in T_{12} which was statistically higher than other treatments while minimum number (21.08) was observed in T_{16}. Furthermore, a similar trend was observed during both the years of study [Table 5(a)].

The interactive effect of plant growth promoting rhizobacterial strains and their application methods recorded significant increase in number of runners per plant during both the years of study. The pooled data given in Table 5(b) showed statistically higher number of runners per plant (43.59) in S_4M_3 as compared to other treatments and minimum in S_5M_2 (24.83) which was statistically at par with S_2M_2 (24.92), S_3M_2 (25.00) and S_4M_2 (25.33). A similar trend was observed during 2014. However, in 2013, maximum number of runners per plant (48.43) was recorded in S_4M_3, whereas minimum number (28.09) found in S_2M_2 which was statistically at par with S_3M_2, S_4M_2 and S_5M_2 (28.17, 28.83 and 28.67). The study further showed that S_4 was most effective in producing maximum number of runners per plant (34.56) as compared to other strains and M_3 as application method during both the years of study.

T_{16} = Control

$T_{14} = S_5 + M_2$

$T_{12} = S_4 + M_3$

Plate 3. Effect of plant growth promoting rhizobacteria and their application methods on number of runners of strawberry cv. Chandler

Table 5(a). Effect of plant growth promoting rhizobacteria on number of runners per plant of strawberry cultivar Chandler

Treatments		Number of runners/ plant		
		2013	2014	Pooled
T_1	S_1 + Root dip method	35.58	28.92	32.25
T_2	S_1+ Foliar application	31.75	25.42	28.58
T_3	S_1 + Root dip method + Foliar application	40.00	33.00	36.50
T_4	S_2+ Root dip method	30.92	23.92	27.42
T_5	S_2+ Foliar application	28.09	21.76	24.92
T_6	S_2 + Root dip method + Foliar application	32.54	25.54	29.04
T_7	S_3 + Root dip method	36.43	29.76	33.09
T_8	S_3+ Foliar application	28.17	21.83	25.00
T_9	S_3 + Root dip method + Foliar application	38.79	32.10	35.45
T_{10}	S_4+ Root dip method	38.09	31.39	34.74
T_{11}	S_4+ Foliar application	28.83	21.83	25.33
T_{12}	S_4 + Root dip method + Foliar application	48.43	38.76	43.59
T_{13}	S_5 + Root dip method	31.58	24.92	28.25
T_{14}	S_5+ Foliar application	28.67	21.00	24.83
T_{15}	S_5 + Root dip method + Foliar application	36.40	29.40	32.90
T_{16}	Control	22.25	19.92	21.08
$CD_{0.05}$		2.84	2.31	2.23

Table 5(b). Interaction effect of plant growth promoting rhizobacteria and their application methods on number of runners per plant of strawberry cultivar Chandler

Treatment	Number of runners/ plant											
	2013				2014				Pooled			
	M_1	M_2	M_3	MEAN	M_1	M_2	M_3	MEAN	M_1	M_2	M_3	MEAN
S_1	35.58	31.75	40.00	35.78	28.92	25.42	33.00	29.11	32.25	28.58	36.50	32.44
S_2	30.92	28.09	32.54	30.52	23.92	21.76	25.54	23.74	27.42	24.92	29.04	27.13
S_3	36.43	28.17	38.79	34.46	29.76	21.83	32.10	27.90	33.09	25.00	35.45	31.18
S_4	38.09	28.83	48.43	38.45	31.39	21.83	38.76	30.66	34.74	25.33	43.59	34.56
S_5	31.58	28.67	36.40	32.22	24.92	21.00	29.40	25.11	28.25	24.83	32.90	28.66
MEAN	34.52	29.10	39.23		27.78	22.37	31.76		31.15	25.73	35.50	
$CD_{0.05}$ for S : 1.62					$CD_{0.05}$ for S : 1.25				CD $CD_{0.05}$ for S : 1.21			
$CD_{0.05}$ for M : 1.26					$CD_{0.05}$ for M : 0.97				CD $CD_{0.05}$ for M : 0.94			
$CD_{0.05}$ for SxM : 2.81					$CD_{0.05}$ for SxM : 2.17				CD $CD_{0.05}$ for SxM : 2.10			

4.1.1.6 Plant biomass on fresh weight basis

The data on the effect of plant growth promoting rhizobacteria on plant biomass on fresh weight basis are presented in Table 6(a) and 6(b). The pooled data depicted in Table 6(a) showed significant increase in plant biomass on fresh weight basis which varied from

32.52 to 45.37 g per plant. Highest plant biomass (45.37 g/plant) was recorded in T_{15} which was statistically at par with T_3 (44.87 g/plant), whereas minimum (32.52 g/plant) in T_{16}. The results further showed the similar trend during 2013 and 2014 under investigations.

The interaction study between plant growth promoting rhizobacteria and their application methods revealed non-significant effect on plant biomass on fresh weight [Table 6(b)].

Table 6(a). Effect of plant growth promoting rhizobacteria plant biomass on fresh weight basis of strawberry cultivar Chandler

Treatments		Plant biomass on fresh weight basis (g/plant)		
		2013	**2014**	**Pooled**
T_1	S_1 + Root dip method	38.11	42.03	40.07
T_2	S_1+ Foliar application	35.12	40.12	37.62
T_3	S_1 + Root dip method + Foliar application	42.31	47.43	44.87
T_4	S_2+ Root dip method	37.50	39.51	38.50
T_5	S_2+ Foliar application	36.31	38.65	37.48
T_6	S_2 + Root dip method + Foliar application	41.13	44.56	42.85
T_7	S_3 + Root dip method	36.63	38.14	37.39
T_8	S_3+ Foliar application	35.00	37.31	36.16
T_9	S_3 + Root dip method + Foliar application	39.86	42.40	41.13
T_{10}	S_4+ Root dip method	37.73	39.39	38.56
T_{11}	S_4+ Foliar application	36.91	38.91	37.91
T_{12}	S_4 + Root dip method + Foliar application	42.29	44.21	43.25
T_{13}	S_5 + Root dip method	37.02	43.29	40.16
T_{14}	S_5+ Foliar application	35.75	42.19	38.97
T_{15}	S_5 + Root dip method + Foliar application	42.92	47.81	45.37
T_{16}	Control	30.25	34.78	32.52
$CD_{0.05}$		2.43	2.08	1.08

Table 6(b). Interaction effect of plant growth promoting rhizobacteria and their application methods on plant biomass on fresh weight basis of strawberry cultivar Chandler

Treatment	Plant biomass on fresh weight basis (g/plant)											
	2013				**2014**				**Pooled**			
	M_1	**M_2**	**M_3**	**MEAN**	**M_1**	**M_2**	**M_3**	**MEAN**	**M_1**	**M_2**	**M_3**	**MEAN**
S_1	38.11	35.12	42.31	38.51	42.03	40.12	47.43	43.19	40.07	37.62	44.87	40.85
S_2	37.50	36.31	41.13	38.31	39.51	38.65	44.56	40.91	38.50	37.48	42.85	39.61
S_3	36.63	35.00	39.86	37.16	38.14	37.31	42.40	39.28	37.39	36.16	41.13	38.22
S_4	37.73	36.91	42.29	38.98	39.39	38.91	44.21	40.84	38.56	37.91	43.25	39.91
S_5	37.02	35.75	42.92	38.56	43.29	42.19	47.81	44.43	40.16	38.97	45.37	41.50
MEAN	37.40	35.82	41.70		40.47	39.44	45.28		38.94	37.63	43.49	
$CD_{0.05}$ for S : NS					$CD_{0.05}$ for S : 1.23				$CD_{0.05}$ for S : 0.64			
$CD_{0.05}$ for M : 1.12					$CD_{0.05}$ for M : 0.95				$CD_{0.05}$ for M : 0.50			
$CD_{0.05}$ for SxM : NS					$CD_{0.05}$ for SxM : NS				$CD_{0.05}$ for SxM : NS			

However, highest plant biomass on fresh weight basis (45.37 g/plant) was recorded in S_5M_3 followed by S_1M_3 (44.87 g/plant), whereas minimum (36.16 g/plant) in S_3M_2. Similar trend was observed during both the years of study. The comparison among different strains showed that S_4 was proved most effective whereas M_3 (root dip+ foliar application method) was most effective as application method.

4.1.1.7 Plant biomass on dry weight basis

The data pertaining to plant biomass on dry weight basis are given in Table 7(a) and 7(b) which revealed significant increase in plant biomass in all treatments as compared to control. The pooled data in Table 7(a) showed maximum plant biomass on dry weight basis (14.29 g/plant) in T_{15} which was statistically at par with T_3, T_6, T_9, T_{12} and T_{13} (13.57, 13.37, 13.95, 13.74 and 13.53 g/plant, respectively), while minimum plant biomass (9.96 g/plant) was observed in T_{16}. Furthermore, a similar trend was recorded for both the years under study.

Table 7(a). Effect of plant growth promoting rhizobacteria on plant biomass on dry weight basis of strawberry cultivar Chandler

Treatments		Plant biomass on dry weight basis (g/plant)		
		2013	2014	Pooled
T_1	S_1 + Root dip method	12.14	13.49	12.82
T_2	S_1+ Foliar application	12.18	12.52	12.35
T_3	S_1 + Root dip method + Foliar application	13.24	13.91	13.57
T_4	S_2+ Root dip method	12.17	13.35	12.76
T_5	S_2+ Foliar application	11.50	12.63	12.07
T_6	S_2 + Root dip method + Foliar application	13.02	13.72	13.37
T_7	S_3 + Root dip method	12.40	13.29	12.85
T_8	S_3+ Foliar application	12.00	13.03	12.52
T_9	S_3 + Root dip method + Foliar application	13.39	14.51	13.95
T_{10}	S_4+ Root dip method	12.63	13.99	13.31
T_{11}	S_4+ Foliar application	11.40	13.63	12.52
T_{12}	S_4 + Root dip method + Foliar application	13.28	14.20	13.74
T_{13}	S_5 + Root dip method	13.20	13.86	13.53
T_{14}	S_5+ Foliar application	12.90	12.95	12.93
T_{15}	S_5 + Root dip method + Foliar application	13.62	14.97	14.29
T_{16}	Control	9.21	10.71	9.96
$CD_{0.05}$		1.29	1.06	0.92

Table 7(b). Interaction effect of plant growth promoting rhizobacteria and their application methods on plant biomass on dry weight basis of strawberry cultivar Chandler

Treatment	Plant biomass on dry weight basis (g/plant)											
	2013				2014				Pooled			
	M_1	M_2	M_3	MEAN	M_1	M_2	M_3	MEAN	M_1	M_2	M_3	MEAN
S_1	12.14	12.18	13.24	12.52	13.49	12.52	13.91	13.31	12.82	12.35	13.57	12.91
S_2	12.17	11.50	13.02	12.23	13.35	12.63	13.72	13.23	12.76	12.07	13.37	12.73
S_3	12.40	12.00	13.39	12.60	13.29	13.03	14.51	13.61	12.85	12.52	13.95	13.10
S_4	12.63	11.40	13.28	12.44	13.99	13.63	14.20	13.94	13.31	12.52	13.74	13.19
S_5	13.20	12.90	13.62	13.24	13.86	12.95	14.97	13.93	13.53	12.93	14.29	13.58
MEAN	12.51	12.00	13.31		13.60	12.95	14.26		13.05	12.47	13.79	
$CD_{0.05}$ for S : 0.60					$CD_{0.05}$ for S : 0.53				$CD_{0.05}$ for S : 0.38			
$CD_{0.05}$ for M : 0.47					$CD_{0.05}$ for M : 0.41				$CD_{0.05}$ for M : 0.30			
$CD_{0.05}$ for SxM : NS					$CD_{0.05}$ for SxM : NS				$CD_{0.05}$ for SxM : NS			

The data on interaction study between plant growth promoting rhizobacteria and their application methods are presented in Table 7(b) which showed non-significant effect on plant biomass on dry weight basis. However, highest plant biomass was observed in S_5M_3 (14.29 g/plant) and minimum in S_2M_2 (12.07 g/plant) as pooled value. Furthermore, S_5 was showed significantly increased plant biomass on dry weight basis and M_3 (root dip + foliar application method) was proved to be most effective application method.

4.1.2 Yield parameters

4.1.2.1 Dates of first flower opening

Dates of first flower opening are presented in Table 8(a). The effect of plant growth promoting rhizobacteria on first flower opening dates had shown greater variation ranging from 16th February to 14th March during 2013 and 20th February to 10th March during 2014. The flowering was earliest in T_{15} (16th February) followed by T_3 (22nd February) and last flowering in T_5 (14th March) followed by T_2 (9th March) during 2013 whereas it was earliest (20th February) in T_3 and T_{16} followed by T_{15} (22nd February) and plant flowered at last in T_{11} (10th March) during 2014. Results further showed that the earliest flowering was recorded in treatments in which plant growth promoting rhizobacteria were applied through root dip + foliar methods while delayed flowering resulted in treatments where plant growth promoting rhizobacteria were applied through foliar method during both the years of study.

Table 8(a). Effect of plant growth promoting rhizobacteria on dates of first flower opening of strawberry cultivar Chandler

Treatments		Date of first flower opening	
		2013	2014
T_1	S_1 + Root dip method	FEB. 25	FEB. 23
T_2	S_1+ Foliar application	MAR. 9	FEB. 26
T_3	S_1 + Root dip method + Foliar application	FEB. 22	FEB. 20
T_4	S_2+ Root dip method	MAR. 8	MAR.1
T_5	S_2+ Foliar application	MAR.14	MAR. 6
T_6	S_2 + Root dip method + Foliar application	FEB. 26	FEB. 25
T_7	S_3 + Root dip method	MAR. 1	FEB. 27
T_8	S_3+ Foliar application	MAR. 4	MAR. 1
T_9	S_3 + Root dip method + Foliar application	FEB. 27	FEB. 25
T_{10}	S_4+ Root dip method	MAR.6	MAR. 3
T_{11}	S_4+ Foliar application	MAR. 7	MAR.10
T_{12}	S_4 + Root dip method + Foliar application	MAR. 2	MAR. 1
T_{13}	S_5 + Root dip method	FEB. 24	FEB. 24
T_{14}	S_5+ Foliar application	MAR. 5	FEB. 25
T_{15}	S_5 + Root dip method + Foliar application	FEB. 16	FEB. 22
T_{16}	Control	Mar. 6	FEB. 20

4.1.2.2 Duration of flowering

The data related to duration of flowering as affected by plant growth promoting rhizobacteria are presented in Appendix- II [Table 9(a) and 9(b)] ranging from 80.33 to 93.67 days. Pooled data given in Table 9(a) revealed that maximum flowering duration (93.67 days) was observed in T_{15} followed by T_3 (92.60 days) which were statistically at par with each other and minimum duration of flowering (80.33 days) in T_5 followed by T_{11} (80.67 days). During 2013, maximum flowering duration (78.33 days) was recorded in T_{15} followed by T_3 (72.33 days) and minimum in T_2 (56.67 days) followed by T_5 (57 days), whereas flowering duration was maximum (112.87 days) in T_3 followed by T_1 (110. 67 days) and minimum in T_{11} (100.67 days) followed by T_{14} (103.00 days) during 2014. Thus the results showed that flowering duration was longest in plants inoculated with plant growth promoting rhizobacteria through root dip + foliar application method followed by root dip method, and shortest in plants inoculated through foliar application method (Fig. 1).

Fig. 1. Effect of plant growth promoting rhizobacteria and their application methods on duration of flowering of strawberry cv. Chandler

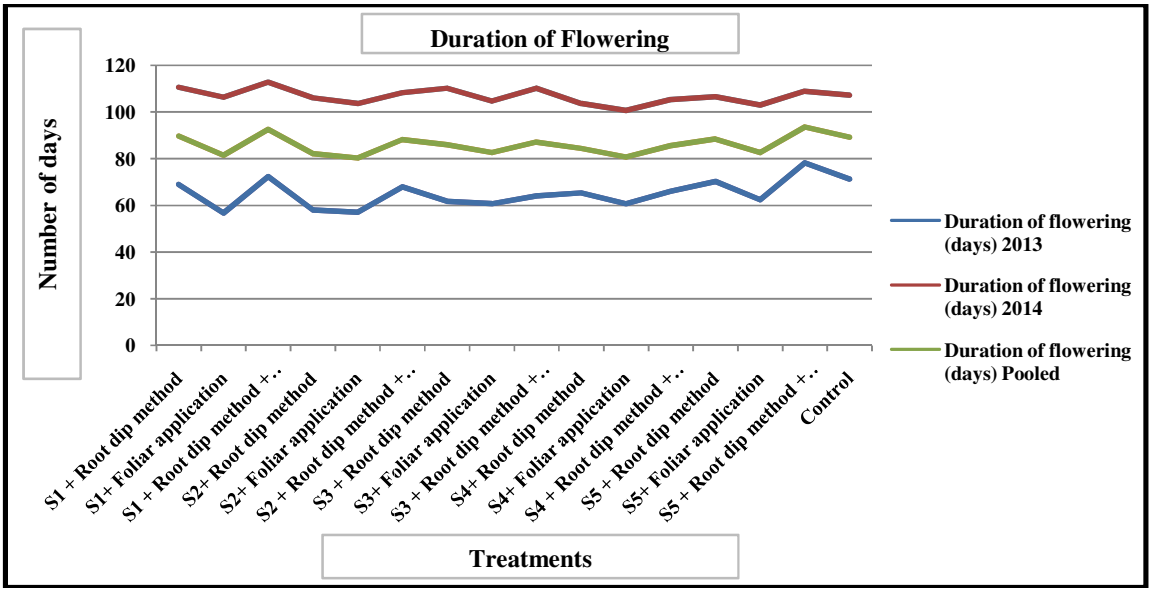
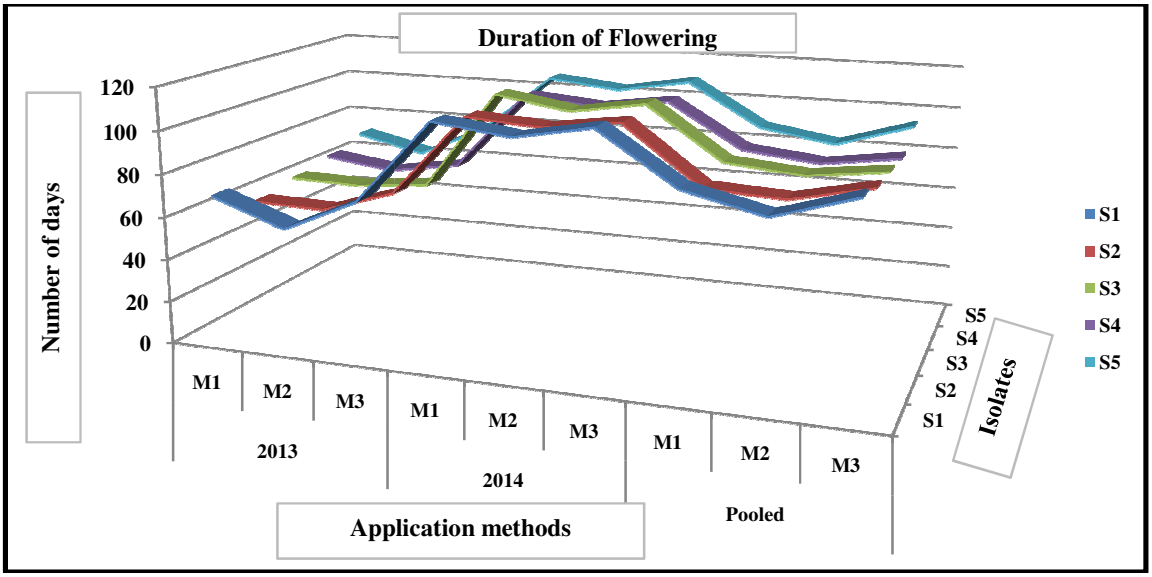


Fig. 2. Interaction effect of plant growth promoting rhizobacteria and their application methods on duration of flowering of strawberry cv. Chandler



The cummulative effect of SxM given in Table 9 (b) revealed that that plant growth promoting rhizobacteria and their application methods had overall significant effect on flowering duration showing maximum duration (93.67 days) in S_5M_3 followed by S_1M_3 and minimum in S_2M_2 (80.33 days). Among different plant growth promoting strains, S_1 was most effective and among their application methods, M_3 was proved to be the best method (Fig.2).

4.1.2.3 Date of first harvesting

The dates related to first harvesting presented in Table 10(a) varied from 3rd to 9th April during 2013 and 31st March to 8th April during 2014. The earliest harvesting (3rd April) was recorded in T_{15} followed by T_6 (4th April) whereas harvesting was late in T_5 (9th April) followed by T_2, T_8, T_{10}, T_{11} and T_{16} (8th April) during 2013. In 2014, the harvesting was earliest in T_{12} (31st March) followed by T_6 and T_{10} (1st April) while late harvesting was recorded in T_8 and T_{14} (8th April). This study showed that the harvesting was recorded earliest from the treatments in which plant growth promoting rhizobacteria were applied through root dip + foliar application method followed by root dip method whereas late in treatments in which plants inoculated through foliar application methods.

Table 10(a). Effect of plant growth promoting rhizobacteria on date of first harvesting of strawberry cultivar Chandler

Treatments		Date of first harvesting	
		2013	2014
T_1	S_1 + Root dip method	APR. 5	APR. 2
T_2	S_1+ Foliar application	APR. 8	APR. 5
T_3	S_1 + Root dip method + Foliar application	APR. 5	APR.3
T_4	S_2+ Root dip method	APR. 7	APR. 4
T_5	S_2+ Foliar application	APR. 9	APR. 7
T_6	S_2 + Root dip method + Foliar application	APR. 4	APR.1
T_7	S_3 + Root dip method	APR. 7	APR. 4
T_8	S_3+ Foliar application	APR. 8	APR. 8
T_9	S_3 + Root dip method + Foliar application	APR. 6	APR. 3
T_{10}	S_4+ Root dip method	APR. 8	APR. 1
T_{11}	S_4+ Foliar application	APR. 8	APR.2
T_{12}	S_4 + Root dip method + Foliar application	APR. 5	MAR.31
T_{13}	S_5 + Root dip method	APR. 5	APR.7
T_{14}	S_5+ Foliar application	APR. 7	APR.8
T_{15}	S_5 + Root dip method + Foliar application	APR. 3	APR.4
T_{16}	Control	APR. 8	APR.7

4.1.2.4 Duration of fruit harvest

It is evident from the Table 11(a) and (b) that duration of flowering was significantly affected by plant growth promoting rhizobacteria. The duration of fruit harvest given in Table 11(a) varied from 34.00 to 45.50 days. The maximum duration of fruit harvest was recorded in T_6 (45.50 days) followed by T_3 (44.83 days) and minimum in T_{16} (34.00 days) followed by T_7 (35.50 days) as pooled value which were statistically at par with each other.

Table 11(a). Effect of plant growth promoting rhizobacteria on duration of harvesting of strawberry cultivar Chandler

Treatments		Duration of fruit harvest (days)		
		2013	2014	Pooled
T_1	S_1 + Root dip method	34.00	38.67	36.33
T_2	S_1+ Foliar application	37.33	40.67	39.00
T_3	S_1 + Root dip method + Foliar application	42.00	47.67	44.83
T_4	S_2+ Root dip method	35.67	38.67	37.17
T_5	S_2+ Foliar application	38.33	39.00	38.67
T_6	S_2 + Root dip method + Foliar application	44.67	46.33	45.50
T_7	S_3 + Root dip method	34.33	36.67	35.50
T_8	S_3+ Foliar application	38.00	38.83	38.42
T_9	S_3 + Root dip method + Foliar application	43.00	44.67	43.83
T_{10}	S_4+ Root dip method	32.83	40.67	36.75
T_{11}	S_4+ Foliar application	34.00	42.33	38.17
T_{12}	S_4 + Root dip method + Foliar application	43.87	44.67	44.27
T_{13}	S_5 + Root dip method	37.00	38.33	37.67
T_{14}	S_5+ Foliar application	40.00	41.00	40.50
T_{15}	S_5 + Root dip method + Foliar application	42.33	44.00	43.17
T_{16}	Control	32.00	35.67	34.00
$CD_{0.05}$		1.72	1.08	1.04

Table 11(b). Interaction effect of plant growth promoting rhizobacteria and their application methods on duration of harvesting of strawberry cultivar Chandler

Treatment	Duration of fruit harvest (days)											
	2013				2014				Pooled			
	M_1	M_2	M_3	MEAN	M_1	M_2	M_3	MEAN	M_1	M_2	M_3	MEAN
S_1	34.00	37.33	42.00	37.78	38.67	40.67	47.67	42.33	36.33	39.00	44.83	40.06
S_2	35.67	38.33	44.67	39.56	38.67	39.00	46.33	41.33	37.17	38.67	45.50	40.44
S_3	34.33	38.00	43.00	38.44	36.67	38.33	44.67	40.06	35.50	38.42	43.83	39.25
S_4	32.83	34.00	43.87	36.90	40.67	42.33	44.67	42.56	36.75	38.17	44.27	39.73
S_5	37.00	40.00	42.33	39.78	38.33	41.00	44.00	41.11	37.67	40.50	43.17	40.44
MEAN	34.77	37.53	43.17		38.60	40.37	45.47		36.68	38.95	44.32	
$CD_{0.05}$ for S : 1.00					$CD_{0.05}$ for S : 0.63				$CD_{0.05}$ for S : 0.62			
$CD_{0.05}$ for M : 0.75					$CD_{0.05}$ for M : 0.49				$CD_{0.05}$ for M : 0.48			
$CD_{0.05}$ for SxM : 1.73					$CD_{0.05}$ for SxM : 1.09				$CD_{0.05}$ for SxM : 1.07			

During 2013, maximum duration (44.67 days) was observed in T_6 followed by T_{12} (43.87 days) and T_9 (43.00 days) while minimum duration (32.00 days) was recorded in T_{16} followed by T_{10} (32.83 days). However, during 2014, significantly longest duration of fruit harvest (47.67 days) was recorded in T_3 and shortest in T_{16} (35.57 days) followed by T_7 (36.67 days).

The interaction effect of plant growth promoting rhizobacteria and their application methods were found to be significant with respect to duration of fruit harvest as depicted in Table 11(b). The pooled data showed that the maximum duration of fruit harvest (45.50 days) was observed in S_2M_3 and minimum in S_3M_1 (35.50 days). The harvest duration was longest in S_2M_3 (44.67 days) but shortest in S_4M_1 (32.83 days) during 2013. However, during 2014, the duration was maximum in S_1M_3 (47.67 days) and minimum in S_3M_1 (36.67 days).

The pooled data also showed that S_2 and S_5 were most effective in extended duration of fruit harvest in comparison to other strains. A similar trend was recorded during 2013. However, during 2014, S_4 proved best among other plant growth promoting strains while M_3 reported as best method for application of plant growth rhizobacteria during both the years of study.

4.1.2.5 Number of fruits per plant

It is apparent from perusal of data depicted in Table 12(a) that plant growth promoting rhizobacteria had significantly increased the number of fruits per plant ranging from 15.14 to 21.42. The pooled data showed that highest number of fruits (21.42) was obtained from T_3 which was statistically at par with T_{15} (20.82), T_9 (20.56) and T_2 (20.27) whereas lowest number of fruits per plant were recorded in T_{16} (15.14). In 2013, the maximum number of fruits was recorded in T_{15} (18.07) while the number was significantly higher in T_3 (26.10) during 2014. The minimum number was recorded in T_{16} during both the years of study.

The interactions between plant growth promoting rhizobacteria and their application methods had overall non-significant effect on number of fruits per plant as depicted in Table 12(b) but the interaction effect was significant during 2014. From data given in this table, it is also revealed that S_1 was most effective in increasing number of fruits per plant among all other rhizobacterial strains under study while S_5 was most effective during 2013. Among their application methods, M_3 was most efficient method.

Table 12(a). Effect of plant growth promoting rhizobacteria on number of fruits per plant of strawberry cultivar Chandler

Treatments		Number of fruits/ plant		
		2013	2014	Pooled
T_1	S_1 + Root dip method	14.82	23.54	19.18
T_2	S_1+ Foliar application	16.10	24.44	20.27
T_3	S_1 + Root dip method + Foliar application	16.73	26.10	21.42
T_4	S_2+ Root dip method	14.53	18.11	16.32
T_5	S_2+ Foliar application	16.40	19.12	17.76
T_6	S_2 + Root dip method + Foliar application	16.60	19.72	18.16
T_7	S_3 + Root dip method	15.27	21.67	18.47
T_8	S_3+ Foliar application	16.93	22.68	19.81
T_9	S_3 + Root dip method + Foliar application	17.27	23.85	20.56
T_{10}	S_4+ Root dip method	14.53	19.00	16.77
T_{11}	S_4+ Foliar application	15.47	21.83	18.65
T_{12}	S_4 + Root dip method + Foliar application	15.80	23.94	19.87
T_{13}	S_5 + Root dip method	16.53	19.62	18.08
T_{14}	S_5+ Foliar application	17.33	21.28	19.30
T_{15}	S_5 + Root dip method + Foliar application	18.07	23.57	20.82
T_{16}	Control	13.20	17.08	15.14
$CD_{0.05}$		2.08	1.12	1.18

Table 12(b). Interaction effect of plant growth promoting rhizobacteria and their application methods on number of fruits per plant of strawberry cultivar Chandler

Treatment	Number of fruits/ plant											
	2013				2014				Pooled			
	M_1	M_2	M_3	MEAN	M_1	M_2	M_3	MEAN	M_1	M_2	M_3	MEAN
S_1	14.82	16.10	16.73	15.88	23.54	24.44	26.10	24.70	19.18	20.27	21.42	20.29
S_2	14.53	16.40	16.60	15.84	18.11	19.12	19.72	18.98	16.32	17.76	18.16	17.41
S_3	15.27	16.93	17.27	16.49	21.67	22.68	23.85	22.73	18.47	19.81	20.56	19.61
S_4	14.53	15.47	15.80	15.27	19.00	21.83	23.94	21.59	16.77	18.65	19.87	18.43
S_5	16.53	17.33	18.07	17.31	19.62	21.28	23.57	21.49	18.08	19.30	20.82	19.40
MEAN	15.14	16.45	16.89		20.39	21.87	23.44		17.76	19.16	20.17	
$CD_{0.05}$ for S : 1.15					$CD_{0.05}$ for S : 0.67				$CD_{0.05}$ for S : 0.62			
$CD_{0.05}$ for M : 0.89					$CD_{0.05}$ for M : 0.52				$CD_{0.05}$ for M : 0.48			
$CD_{0.05}$ for SxM : NS					$CD_{0.05}$ for SxM : 1.16				$CD_{0.05}$ for SxM : NS			

4.1.2.6 Fruit yield per plant

The plant growth promoting rhizobacteria and their application methods had a significant effect on fruit yield per plant as presented in Table 14(a) and (b). The pooled value for fruit yield per plant (366.21 g) was significantly higher in T_{12} as compared to other treatments followed by T_9 (352.17 g) whereas lowest fruit yield was recorded from T_{16}

(200.19 g) as shown in Table 14(a). A similar trend was recorded during 2014. However, in 2013, fruit yield was highest in T_{15} (253.64 g) followed by T_{14} (251.89 g) which were statistically at par with each other. The minimum fruit yield was recorded in T_{16} during both the years of study (161.43 and 238.95 g, respectively).

Table 13(a). Effect of plant growth promoting rhizobacteria yield per plant of strawberry cultivar Chandler

Treatments		Yield/ plant (g)		
		2013	2014	Pooled
T_1	S_1 + Root dip method	192.15	376.93	284.54
T_2	S_1+ Foliar application	229.50	393.57	311.54
T_3	S_1 + Root dip method + Foliar application	234.21	456.76	345.49
T_4	S_2+ Root dip method	186.73	322.91	254.82
T_5	S_2+ Foliar application	214.72	357.04	285.88
T_6	S_2 + Root dip method + Foliar application	223.48	433.96	328.72
T_7	S_3 + Root dip method	185.07	422.97	304.02
T_8	S_3+ Foliar application	211.94	447.21	329.57
T_9	S_3 + Root dip method + Foliar application	214.09	490.25	352.17
T_{10}	S_4+ Root dip method	182.31	356.98	269.65
T_{11}	S_4+ Foliar application	208.94	428.45	318.70
T_{12}	S_4 + Root dip method + Foliar application	210.38	522.03	366.21
T_{13}	S_5 + Root dip method	222.03	333.66	277.85
T_{14}	S_5+ Foliar application	251.89	367.71	309.80
T_{15}	S_5 + Root dip method + Foliar application	253.64	422.57	338.11
T_{16}	Control	161.43	238.95	200.19
$CD_{0.05}$		1.93	2.01	1.33

Table 13(b). Interaction effect of plant growth promoting rhizobacteria and their application methods on yield per plant of strawberry cultivar Chandler

Treatment	Yield/ plant (g)											
	2013				2014				Pooled			
	M_1	M_2	M_3	MEAN	M_1	M_2	M_3	MEAN	M_1	M_2	M_3	MEAN
S_1	192.15	229.50	234.21	218.62	376.93	393.57	456.76	409.09	284.54	311.54	345.49	313.85
S_2	186.73	214.72	223.48	208.31	322.91	357.04	433.96	371.30	254.82	285.88	328.72	289.81
S_3	185.07	211.94	214.09	203.70	422.97	447.21	490.25	453.48	304.02	329.57	352.17	328.59
S_4	182.31	208.94	210.38	200.54	356.98	428.45	522.03	435.82	269.65	318.70	366.21	318.18
S_5	222.03	251.89	253.64	242.52	333.66	367.71	422.57	374.65	277.85	309.80	338.11	308.59
MEAN	193.66	223.40	227.16		362.69	398.79	465.12		278.17	311.10	346.14	
$CD_{0.05}$ for S : 1.14					$CD_{0.05}$ for S : 1.20				$CD_{0.05}$ for S : 0.78			
$CD_{0.05}$ for M : 0.88					$CD_{0.05}$ for M : 0.93				$CD_{0.05}$ for M : 0.61			
$CD_{0.05}$ for SxM : 1.97					$CD_{0.05}$ for SxM : 2.08				$CD_{0.05}$ for SxM : 1.35			

Plant growth promoting rhizobacteria and their interaction with application methods significantly influenced the fruit yield per plant as depicted in Table 14(b). Pooled data showed that the maximum yield was obtained from S_4M_3 (366.21 g) and minimum from S_2M_1 (254.82 g). A similar trend was observed in 2014, however, the fruit yield was highest in S_5M_3 (253.64 g) and lowest in S_4M_1 (182.31 g) during 2013. Results further showed that S_3 was overall most effective strain however, during 2013, S_1 was found most effective. Among their application methods, M_3 (root dip + foliar application method) proved as best method.

4.1.2.7 Fruit yield per hectare

The data pertaining to yield per hectare are presented in Appendix- II [Table 14(a) and (b)] as affected by plant growth promoting rhizobacteria and their application methods. The pooled data depicted in Table 14(a) revealed that highest fruit yield per hectare was recorded in T_{12} (29.30 t/ha) which was statistically at par with T_9 (28.17 t/ha) whereas lowest fruit yield was recorded from T_{16} (16.02 t/ha). A similar trend was recorded during 2014. However, in 2013, fruit yield was highest in T_{15} (20.29 t/ha) followed by T_{14} and T_3 (20.15 and 18.74 t/ha respectively) which were statistically at par with each other. The minimum fruit yield per hectare was recorded in T_{16} during both the years of study (Fig. 3).

The interaction between plant growth promoting rhizobacteria and their application methods significantly influenced the fruit yield per hectare as depicted in Fig. 4. Pooled data expressed that the maximum yield was obtained from S_4M_3 (29.30 t/ha) and minimum from S_2M_1 (20.39 t/ ha). A similar trend was observed in 2014. However, the yield was highest in S_5M_3 (20.29 t/ha) and lowest in S_4M_1 (14.58 t/ ha) during 2013 (Fig.4). Results further showed that S_3 was overall most effective strain, however, during 2013, S_1 was found most effective. Among their application methods, root dip + foliar application method (M_3) was proved as best method Appendix-II [Table 14(b)].

4.1.3 Fruit quality

4.1.3.1 Fruit weight

It is evident from the Table 15(a) and 15(b) that plant growth promoting rhizobacteria had a significant effect on fruit weight. Pooled data given in Table 15(a) revealed that maximum fruit weight was recorded from T_{12} (18.22 g) which was statistically at par with T_6 (17.95 g), and minimum fruit weight was recorded from T_{16} (13.08 g). A similar trend was

Fig. 3. Effect of plant growth promoting rhizobacteria and their application methods on fruit yield per hectare of strawberry cv. Chandler

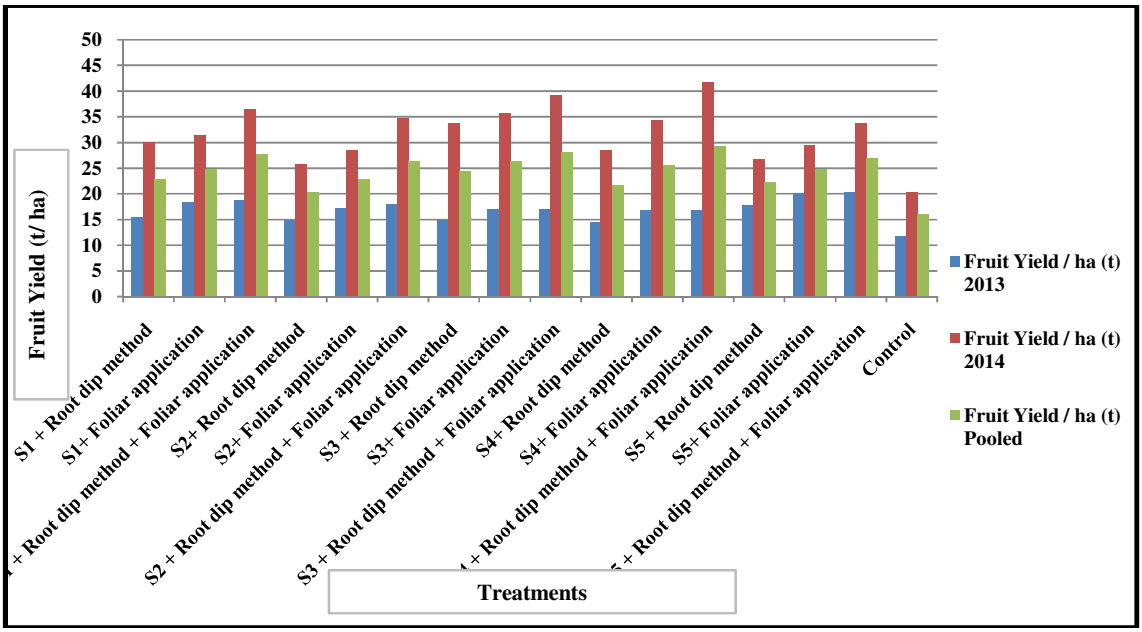


Fig. 4. Interaction effect of plant growth promoting rhizobacteria and their application methods on fruit yield per hectare of strawberry cv. Chandler

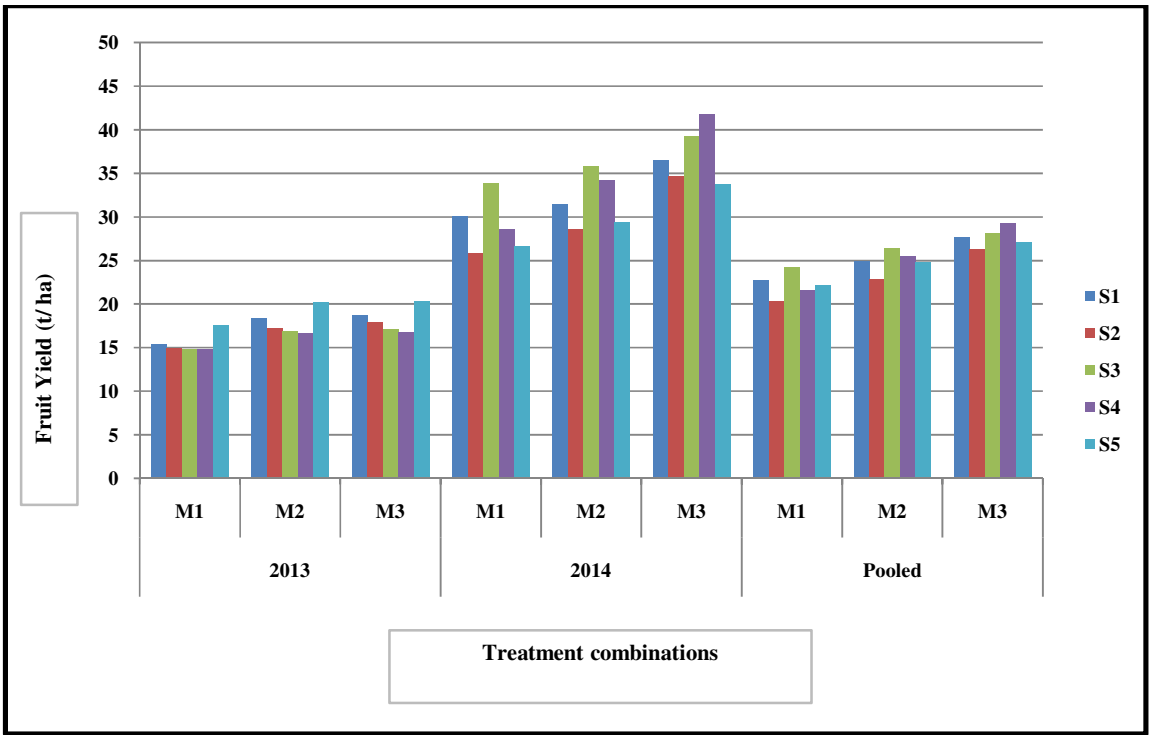


Table 15(a). Effect of plant growth promoting rhizobacteria on fruit weight of strawberry cultivar Chandler

Treatments		Fruit weight (g)		
		2013	2014	Pooled
T_1	S_1 + Root dip method	12.66	16.31	14.48
T_2	S_1+ Foliar application	13.76	16.37	15.06
T_3	S_1 + Root dip method + Foliar application	14.43	17.72	16.08
T_4	S_2+ Root dip method	12.82	18.07	15.44
T_5	S_2+ Foliar application	12.94	18.85	15.89
T_6	S_2 + Root dip method + Foliar application	13.63	22.27	17.95
T_7	S_3 + Root dip method	12.16	19.77	15.97
T_8	S_3+ Foliar application	12.41	20.17	16.29
T_9	S_3 + Root dip method + Foliar application	12.63	20.85	16.74
T_{10}	S_4+ Root dip method	12.56	19.22	15.89
T_{11}	S_4+ Foliar application	13.28	19.96	16.62
T_{12}	S_4 + Root dip method + Foliar application	13.60	22.83	18.22
T_{13}	S_5 + Root dip method	13.46	17.27	15.36
T_{14}	S_5+ Foliar application	13.98	17.49	15.73
T_{15}	S_5 + Root dip method + Foliar application	14.62	18.11	16.37
T_{16}	Control	11.17	14.98	13.08
$CD_{0.05}$		0.90	0.74	0.63

Table 15(b). Interaction effect of plant growth promoting rhizobacteria and their application methods on fruit weight of strawberry cultivar Chandler

Treatment	Fruit weight (g)											
	2013				2014				Pooled			
	M_1	M_2	M_3	MEAN	M_1	M_2	M_3	MEAN	M_1	M_2	M_3	MEAN
S_1	12.66	13.76	14.43	13.62	16.31	16.37	17.72	16.80	14.48	15.06	16.08	15.21
S_2	12.82	12.94	13.63	13.13	18.07	18.85	22.27	19.73	15.44	15.89	17.95	16.43
S_3	12.16	12.41	12.63	12.40	19.77	20.17	20.85	20.26	15.97	16.29	16.74	16.33
S_4	12.56	13.28	13.60	13.15	19.22	19.96	22.83	20.67	15.89	16.62	18.22	16.91
S_5	13.46	13.98	14.62	14.02	17.27	17.49	18.11	17.62	15.36	15.73	16.37	15.82
MEAN	12.73	13.27	13.78		18.12	18.57	20.36		15.43	15.92	17.07	
$CD_{0.05}$ for S : 0.50					$CD_{0.05}$ for S : 0.41				$CD_{0.05}$ for S : 0.34			
$CD_{0.05}$ for M : 0.39					$CD_{0.05}$ for M : 0.32				$CD_{0.05}$ for M : 0.27			
$CD_{0.05}$ for SxM : NS					$CD_{0.05}$ for SxM : 0.72				$CD_{0.05}$ for SxM : 0.60			

observed during 2014. However, in 2013, fruit weight was maximum in T_{15} (14.62 g) followed by T_3 (14.43 g) and minimum in T_{16} (11.17 g).

The data on cumulative effect of plant growth promoting rhizobacteria and their application methods are presented in Table 15(b) in which fruit weight varied from 14.48 to 18.22 g. Maximum fruit weight (18.22 g) was obtained from S_4M_3 followed by S_2M_3 (17.95

g) and minimum fruit weight was recorded from S_1M_1 (14.48 g) as pooled value. A similar trend was recorded during 2014 whereas the interaction effect was non-significant during 2013. Furthermore, S_4 was resulted as most effective strain as compared to other strains, and M_3 was found to be most effective application method under study.

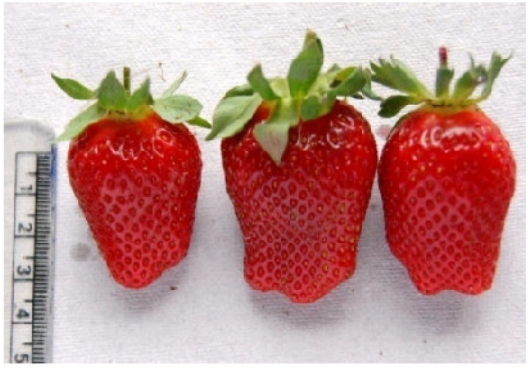
4.1.3.2 Fruit length

The inquisition of data presented in Table 16(a) and (b) reveals that plant growth promoting rhizobacteria treatments had significant effect on fruit length. On the basis of pooled mean value given in Table 16(a), maximum fruit length (41.81 mm) was recorded in T_9 which was statistically at par with T_{12} (41.71 mm), T_{11} (41.27 mm) and T_6 (41.16 mm) whereas minimum fruit length (35.75 mm) was recorded from T_{16}. During 2013, fruit length was maximum in T_{15} (39.14 mm) followed by T_{14}, T_9 and T_3 (38.53, 38.15 and 38.04 mm respectively), while, it was maximum in T_{12} (45.90 mm) followed by T_9 (45.48 mm) and T_{11} (45.42 mm) during 2014. The minimum fruit length was recorded in T_{16} during both the years of study.

The results related to interaction effect given in Table 16(b) reveals that plant growth promoting rhizobacteria and their application methods had non-significant effect on fruit length. However, maximum fruit length was obtained from S_3M_3 (41.81 mm) and minimum from S_5M_1 (38.23 mm) as pooled value. But the interaction effect was significant during 2013 as presented in Table 16(b) where maximum fruit length

Table 16(a). Effect of plant growth promoting rhizobacteria on fruit length of strawberry cultivar Chandler

Treatments		Fruit length (mm)		
		2013	**2014**	**Pooled**
T_1	S_1 + Root dip method	37.27	40.59	38.93
T_2	S_1+ Foliar application	37.45	42.50	39.98
T_3	S_1 + Root dip method + Foliar application	38.04	43.27	40.65
T_4	S_2+ Root dip method	36.98	43.57	40.27
T_5	S_2+ Foliar application	37.44	44.25	40.84
T_6	S_2 + Root dip method + Foliar application	37.70	44.63	41.16
T_7	S_3 + Root dip method	36.17	42.82	39.50
T_8	S_3+ Foliar application	36.52	43.94	40.23
T_9	S_3 + Root dip method + Foliar application	38.15	45.48	41.81
T_{10}	S_4+ Root dip method	34.09	44.45	39.27
T_{11}	S_4+ Foliar application	37.12	45.42	41.27
T_{12}	S_4 + Root dip method + Foliar application	37.52	45.90	41.71
T_{13}	S_5 + Root dip method	36.32	40.14	38.23
T_{14}	S_5+ Foliar application	38.53	41.43	39.98
T_{15}	S_5 + Root dip method + Foliar application	39.14	42.06	40.60
T_{16}	Control	32.62	38.87	35.75
$CD_{0.05}$		1.29	1.14	0.96



T_{16} = Control

$T_{12} = S_3 + M_3$

$T_9 = S_3 + M_3$

Plate 4. Effect of plant growth promoting rhizobacteria and their application methods on fruit size of strawberry cv. Chandler

Table 16(b). Interaction effect of plant growth promoting rhizobacteria and their application methods on fruit length of strawberry cultivar Chandler

Treatment	Fruit length (mm)											
	2013				2014				Pooled			
	M_1	M_2	M_3	MEAN	M_1	M_2	M_3	MEAN	M_1	M_2	M_3	MEAN
S_1	37.27	37.45	38.04	37.59	40.59	42.50	43.27	42.12	38.93	39.98	40.65	39.85
S_2	36.98	37.44	37.70	37.37	43.57	44.25	44.63	44.15	40.27	40.84	41.16	40.76
S_3	36.17	36.52	38.15	36.95	42.82	43.94	45.48	44.08	39.50	40.23	41.81	40.51
S_4	34.09	37.12	37.52	36.24	44.45	45.42	45.90	45.25	39.27	41.27	41.71	40.74
S5	36.32	38.53	39.14	38.00	40.14	41.43	42.06	41.21	38.23	39.98	40.60	39.60
MEAN	36.17	37.41	38.11		42.31	43.51	44.27		39.24	40.46	41.19	
$CD_{0.05}$ for S : 0.76					$CD_{0.05}$ for S : 0.68				$CD_{0.05}$ for S : 0.57			
$CD_{0.05}$ for M : 0.59					$CD_{0.05}$ for M : 0.53				$CD_{0.05}$ for M : 0.41			
$CD_{0.05}$ for SxM : 1.31					$CD_{0.05}$ for SxM : NS				$CD_{0.05}$ for SxM : NS			

was recorded from S_5M_3 (39.14 mm) and minimum in S_4M_1 (34.09 mm). Pooled data further showed that S_2 was most effective strain as compared to other strains under study while S_5 was observed most effective during 2013 and S_4 during 2014. Among different application methods, M_3 was observed as best method of rhizobacterial application during both the years of investigations.

4.1.3.3 Fruit diameter

It is apparent from the Table 17(a) that plant growth promoting rhizobacteria had significantly influenced the fruit diameter. The pooled data analysis showed that fruit diameter was maximum in T_6 (30.87 mm) statistically at par with T_{12} (30.50 mm), while minimum fruit diameter was observed in T_{16} (25.82 mm). A similar trend was observed during 2014. However, in 2013, maximum fruit diameter was recorded in T_3 (28.33 mm) which was statistically at par with T_{15}, T_{14}, T_2, T_{13}, T_6, T_1 and T_9 (28.12, 28.05, 27.83, 27.74, 27.73, 27.47 and 27.45 mm, respectively).

The plant growth promoting rhizobacteria and their interactions with application methods had significant effect on fruit diameter as shown in Table 17(b). The pooled value revealed that S_2M_3 had maximum fruit diameter (30.87 mm) followed by S_4M_3 (30.50 mm), whereas minimum was recorded in S_4M_1 (27.39 mm) followed by S_1M_1 and S_2M_1 (27.82 and 27.99 mm, respectively). During 2014, similar trend was observed for maximum value, but minimum was observed in S_1M_1 (28.17 mm) followed by S_1M_2 (28.50 mm) and S_2M_1 (29.02 mm). But, in 2013, the interaction effect was found to be non-significant. The complete study of interaction effect on fruit diameter further showed that S_2 was significantly effective strain

for increasing fruit diameter followed by S_5 whereas M_3 emerged as most effective method for plant growth promoting rhizobacteria application.

Table 17(a). Effect of plant growth promoting rhizobacteria on fruit diameter of strawberry cultivar Chandler

Treatments		Fruit diameter (mm)		
		2013	2014	Pooled
T_1	S_1 + Root dip method	27.47	28.17	27.82
T_2	S_1+ Foliar application	27.83	28.50	28.17
T_3	S_1 + Root dip method + Foliar application	28.33	29.17	28.75
T_4	S_2+ Root dip method	26.96	29.02	27.99
T_5	S_2+ Foliar application	27.00	29.84	28.42
T_6	S_2 + Root dip method + Foliar application	27.73	34.01	30.87
T_7	S_3 + Root dip method	26.64	30.18	28.41
T_8	S_3+ Foliar application	26.94	30.47	28.71
T_9	S_3 + Root dip method + Foliar application	27.45	31.09	29.27
T_{10}	S_4+ Root dip method	25.48	29.30	27.39
T_{11}	S_4+ Foliar application	26.97	29.94	28.46
T_{12}	S_4 + Root dip method + Foliar application	27.16	33.85	30.50
T_{13}	S_5 + Root dip method	27.74	29.21	28.47
T_{14}	S_5+ Foliar application	28.05	29.49	28.77
T_{15}	S_5 + Root dip method + Foliar application	28.12	31.18	29.65
T_{16}	Control	25.16	26.47	25.82
$CD_{0.05}$		0.96	0.90	0.61

Table 17(b). Interaction effect of plant growth promoting rhizobacteria and application methods on fruit diameter of strawberry cultivar Chandler

Treatment	Fruit diameter (mm)											
	2013				2014				Pooled			
	M_1	M_2	M_3	MEAN	M_1	M_2	M_3	MEAN	M_1	M_2	M_3	MEAN
S_1	27.47	27.83	28.33	27.88	28.17	28.50	29.17	28.62	27.82	28.17	28.75	28.25
S_2	26.96	27.00	27.73	27.23	29.02	29.84	34.01	30.96	27.99	28.42	30.87	29.09
S_3	26.64	26.94	27.45	27.01	30.18	30.47	31.09	30.58	28.41	28.71	29.27	28.79
S_4	25.48	26.97	27.16	26.54	29.30	29.94	33.85	31.03	27.39	28.46	30.50	28.78
S_5	27.74	28.05	28.12	27.97	29.21	29.49	31.18	29.96	28.47	28.77	29.65	28.97
MEAN	26.86	27.36	27.76		29.17	29.65	31.86		28.02	28.50	29.81	
$CD_{0.05}$ for S : 0.57					$CD_{0.05}$ for S : 0.52				$CD_{0.05}$ for S : 0.37			
$CD_{0.05}$ for M : 0.44					$CD_{0.05}$ for M : 0.41				$CD_{0.05}$ for M : 0.28			
$CD_{0.05}$ for SxM : NS					$CD_{0.05}$ for SxM : 0.91				$CD_{0.05}$ for SxM : 0.63			

4.1.3.4 Total soluble solids

The data pertaining to total soluble solids is presented in Table 18(a) and (b) which showed that plant growth promoting rhizobacteria has improved total soluble solids in strawberry. The pooled data given in Table 18(a) reveals that highest total soluble solids were recorded with T_{13} (10.74 ^{0}Brix) followed by T_1 (10.45 ^{0}Brix) and T_4 (10.23 ^{0}Brix) whereas minimum were in T_{16} (8.17 ^{0}Brix). A similar trend was observed during 2013 and 2014.

The interaction study as presented in Table 18(b) showed non-significant effect on total soluble solid content, but during 2014, the interaction effect was significant. However, maximum total soluble solids were found in S_5M_1 (10.74 ^{0}Brix) followed by S_1M_1 (10.45 ^{0}Brix) and minimum in S_4M_2 (8.82 ^{0}Brix) in pooled values. The similar trend was observed during both the years of study, but minimum total soluble solids were recorded with S_3M_2 (9.43 ^{0}Brix) during 2013. Among different plant growth promoting strains, S_5 was found effective in enhancing total soluble solids followed by S_1 and M_3 as most effective method among their application methods.

Table 18(a). Effect of plant growth promoting rhizobacteria on total soluble solids of strawberry cultivar Chandler

Treatments		TSS (^{0}Brix)		
		2013	**2014**	**Pooled**
T_1	S_1 + Root dip method	10.85	10.05	10.45
T_2	S_1+ Foliar application	9.60	9.51	9.56
T_3	S_1 + Root dip method + Foliar application	9.64	9.69	9.67
T_4	S_2+ Root dip method	10.73	9.73	10.23
T_5	S_2+ Foliar application	9.66	9.00	9.33
T_6	S_2 + Root dip method + Foliar application	9.86	9.30	9.58
T_7	S_3 + Root dip method	10.64	8.90	9.77
T_8	S_3+ Foliar application	9.43	8.68	9.05
T_9	S_3 + Root dip method + Foliar application	9.56	9.30	9.43
T_{10}	S_4+ Root dip method	9.99	9.58	9.79
T_{11}	S_4+ Foliar application	9.63	8.00	8.82
T_{12}	S_4 + Root dip method + Foliar application	9.80	9.20	9.50
T_{13}	S_5 + Root dip method	10.91	10.56	10.74
T_{14}	S_5+ Foliar application	9.84	8.35	9.10
T_{15}	S_5 + Root dip method + Foliar application	10.36	9.40	9.88
T_{16}	Control	9.01	7.33	8.17
$CD_{0.05}$		0.67	0.74	0.51

Table 18(b). Interaction effect of plant growth promoting rhizobacteria and their application methods on total soluble solids of strawberry cultivar Chandler

Treatment	TSS (^{0}Brix)											
	2013				**2014**				**Pooled**			
	M_1	**M_2**	**M_3**	**MEAN**	**M_1**	**M_2**	**M_3**	**MEAN**	**M_1**	**M_2**	**M_3**	**MEAN**
S_1	10.85	9.60	9.64	10.03	10.05	9.51	9.69	9.75	10.45	9.56	9.67	9.89
S_2	10.73	9.66	9.86	10.08	9.73	9.00	9.30	9.34	10.23	9.33	9.58	9.71
S_3	10.64	9.43	9.56	9.88	8.90	8.68	9.30	8.96	9.77	9.05	9.43	9.42
S_4	9.99	9.63	9.80	9.81	9.58	8.00	9.20	8.93	9.79	8.82	9.50	9.37
S_5	10.91	9.84	10.36	10.37	10.56	8.35	9.40	9.44	10.74	9.10	9.88	9.90
MEAN	10.63	9.63	9.85		9.77	8.71	9.38		10.20	9.17	9.61	
$CD_{0.05}$ for S : NS					$CD_{0.05}$ for S : 0.40				$CD_{0.05}$ for S : 0.30			
$CD_{0.05}$ for M : 0.30					$CD_{0.05}$ for M : 0.31				$CD_{0.05}$ for M : 0.23			
$CD_{0.05}$ for SxM : NS					$CD_{0.05}$ for SxM : 0.70				$CD_{0.05}$ for SxM : NS			

4.1.3.5 Acidity

It is evident from the Table 19(a) and (b) that plant growth promoting rhizobacteria had significantly decreased fruit acidity varied from 1.10 to 2.04 per cent. The pooled values presented in Table 19(a) expressed that fruits with lowest acidity were obtained from T_7 (1.10 %) followed by T_{13}, T_9 and T_4 (1.15, 1.21 and 1.21 %, respectively), whereas highest acidity (2.04 %) was found in fruits from control (T_{16}).

Table 19(a). Effect of plant growth promoting rhizobacteria on fruit acidity of strawberry cultivar Chandler

Treatments		Acidity (%)		
		2013	2014	Pooled
T_1	S_1 + Root dip method	1.41	1.61	1.51
T_2	S_1+ Foliar application	1.56	1.75	1.65
T_3	S_1 + Root dip method + Foliar application	1.47	1.09	1.28
T_4	S_2+ Root dip method	1.21	1.21	1.21
T_5	S_2+ Foliar application	1.70	1.64	1.67
T_6	S_2 + Root dip method + Foliar application	1.52	1.02	1.27
T_7	S_3 + Root dip method	1.25	0.94	1.10
T_8	S_3+ Foliar application	1.55	1.68	1.61
T_9	S_3 + Root dip method + Foliar application	1.34	1.07	1.21
T_{10}	S_4+ Root dip method	1.36	1.21	1.29
T_{11}	S_4+ Foliar application	1.47	1.67	1.57
T_{12}	S_4 + Root dip method + Foliar application	1.41	1.40	1.41
T_{13}	S_5 + Root dip method	1.42	0.88	1.15
T_{14}	S_5+ Foliar application	1.70	1.21	1.46
T_{15}	S_5 + Root dip method + Foliar application	1.66	1.04	1.35
T_{16}	Control	1.91	2.17	2.04
$CD_{0.05}$		0.20	0.25	0.16

Table 19(b). Interaction effect of plant growth promoting rhizobacteria and their application methods on fruit acidity of strawberry cultivar Chandler

Treatment	Acidity (%)											
	2013				2014				Pooled			
	M_1	M_2	M_3	MEAN	M_1	M_2	M_3	MEAN	M_1	M_2	M_3	MEAN
S_1	1.41	1.56	1.47	1.48	1.61	1.75	1.09	1.48	1.51	1.65	1.28	1.48
S_2	1.21	1.70	1.52	1.48	1.21	1.64	1.02	1.29	1.21	1.67	1.27	1.38
S_3	1.25	1.55	1.34	1.38	0.94	1.68	1.07	1.23	1.10	1.61	1.21	1.31
S_4	1.36	1.47	1.41	1.41	1.21	1.67	1.40	1.43	1.29	1.57	1.41	1.42
S_5	1.42	1.70	1.66	1.59	0.88	1.21	1.04	1.04	1.15	1.46	1.35	1.32
MEAN	1.33	1.59	1.48		1.17	1.59	1.12		1.25	1.59	1.30	
$CD_{0.05}$ for S : 0.12					$CD_{0.05}$ for S : 0.15				$CD_{0.05}$ for S : 0.09			
$CD_{0.05}$ for M : 0.09					$CD_{0.05}$ for M : 0.11				$CD_{0.05}$ for M : 0.07			
$CD_{0.05}$ for SxM : NS					$CD_{0.05}$ for SxM : 0.25				$CD_{0.05}$ for SxM : 0.16			

Plant growth promoting rhizobacteria and their application methods interaction had significant effect on fruit acidity, but the effect was non-significant during 2013 as presented

in Table 19(b). The pooled data revealed that the maximum fruit acidity was recorded from S_2M_2 (1.67 %) followed by S_1M_2 (1.65 %) and S_3M_2 (1.61 %) and minimum acidity was recorded in S_3M_1 (1.10 %) which was statistically at par with S_2M_1, S_3M_3 and S_5M_1 (1.21, 1.21 and 1.15 % respectively). During 2014, the acidity was maximum in S_1M_2 (1.75 %) followed by S_3M_2 (1.68 %) and S_4M_2 (1.67 %), whereas minimum acidity was recorded with S_5M_1 (0.88%), which was statistically at par with S_3M_1, S_1M_3, S_2M_3, S_3M_3 and S_5M_3 (0.94, 1.09. 1.02, 1.07 and 1.04 % respectively). Among different isolates, S_1 was found to be most effective in increasing acid content while S_3 was recorded with least acid content. Among their application methods, M_3 (root dip + foliar application) was recorded with decreased acid content and M_2 (foliar application method) was noted with increased acid content in strawberry fruits.

4.1.3.6 TSS: acid ratio

The observations related to TSS: acid ratio are given in Table 20(a) and (b). The pooled data depicted in Table 20(a) revealed that T_{13} had significantly higher TSS: acid ratio (9.89), while significantly lowest ratio was recorded from T_{16} (4.08). A similar trend was recorded during 2014. However, the TSS: acid ratio was maximum in T_4 (8.87) followed by T_7 (8.56), and minimum in T_{16} (4.80).

Table 20(a). Effect of plant growth promoting rhizobacteria on TSS: acid ratio of strawberry cultivar Chandler

Treatments		TSS: acid ratio		
		2013	2014	Pooled
T_1	S_1 + Root dip method	7.72	6.25	6.99
T_2	S_1+ Foliar application	6.20	5.89	6.04
T_3	S_1 + Root dip method + Foliar application	6.63	9.17	7.90
T_4	S_2+ Root dip method	8.87	8.05	8.46
T_5	S_2+ Foliar application	5.69	5.52	5.60
T_6	S_2 + Root dip method + Foliar application	6.61	9.14	7.88
T_7	S_3 + Root dip method	8.56	9.41	8.98
T_8	S_3+ Foliar application	6.23	5.23	5.73
T_9	S_3 + Root dip method + Foliar application	7.56	8.71	8.14
T_{10}	S_4+ Root dip method	7.43	7.98	7.71
T_{11}	S_4+ Foliar application	6.57	4.81	5.69
T_{12}	S_4 + Root dip method + Foliar application	7.01	6.55	6.78
T_{13}	S_5 + Root dip method	7.76	12.02	9.89
T_{14}	S_5+ Foliar application	5.94	6.92	6.43
T_{15}	S_5 + Root dip method + Foliar application	6.25	9.04	7.65
T_{16}	Control	4.80	3.36	4.08
$CD_{0.05}$		1.00	1.41	0.84

Table 20(b). Interaction effect of plant growth promoting rhizobacteria and their application methods on TSS: acid ratio of strawberry cultivar Chandler

Treatment	TSS: acid ratio											
	2013				2014				Pooled			
	M_1	M_2	M_3	MEAN	M_1	M_2	M_3	MEAN	M_1	M_2	M_3	MEAN
S_1	7.72	6.20	6.63	6.85	6.26	5.89	9.17	7.10	6.99	6.05	7.90	6.98
S_2	8.87	5.69	6.61	7.06	8.05	5.52	9.14	7.57	8.46	5.60	7.88	7.31
S_3	8.55	6.23	7.56	7.45	9.41	5.23	8.71	7.78	8.98	5.73	8.13	7.62
S_4	7.43	6.57	7.01	7.00	7.98	4.81	6.55	6.45	7.71	5.69	6.78	6.72
S_5	7.76	5.94	6.25	6.65	12.02	6.91	9.04	9.33	9.89	6.43	7.65	7.99
MEAN	8.07	6.13	6.81		8.75	5.67	8.52		8.41	5.90	7.67	
$CD_{0.05}$ for S : NS					$CD_{0.05}$ for S : 0.83				$CD_{0.05}$ for S : 0.50			
$CD_{0.05}$ for M : 0.46					$CD_{0.05}$ for M : 0.65				$CD_{0.05}$ for M : 0.39			
$CD_{0.05}$ for SxM : NS					$CD_{0.05}$ for SxM : 1.44				$CD_{0.05}$ for SxM : 0.87			

The interaction study between plant growth promoting rhizobacteria and their application methods showed significant effect on TSS: acid ratio but the effect was non-significant during 2013. The pooled values given in Table 20(b) revealed that the highest TSS: acid ratio was obtained from S_5M_1 (9.89) and minimum from S_2M_2 (5.60). During 2013, maximum ratio was recorded from S_2M_1 (8.87) and minimum from S_2M_2 (5.69), whereas in 2014, it was significantly higher in S_5M_1 (12.02) and minimum in S_4M_1 (4.81). The interaction study further showed that S_5 was significantly effective in increasing TSS: acid ratio.

4.1.3.7 Total sugars

The data on total sugars recorded under different plant growth promoting rhizobacteria and their application methods are given in Table 21(a) and (b). It reveals significant differences in total sugars content among the treatments. In pooled data given in Table 21(a), highest total sugars were noted with T_{13} (6.72 %) followed by T_1 (6.48 %), whereas T_{16} had significantly lowest total sugars (4.45 %) content. A similar trend was observed during 2014, whereas total sugars were highest in T_{10} (6.70 %) followed by T_7 (6.54 %) and lowest in T_{16} (4.68 %) during 2013.

The overall cumulative effect of plant growth promoting rhizobacteria and their application methods on total sugars was found to be non-significant. However, maximum total sugars were recorded from S_5M_1 (6.72 %) followed by S_1M_1 (6.48 %) and minimum from S_3M_2 (4.90 %) as pooled value. The effect was significant during 2014 and registered similar trend. Furthermore, S_1 was found to be most effective bacterial strain for increasing total sugars followed by S_5. However, S_4 was observed best during 2013 and S_5 during 2014

as compared to other strains under study. Among application methods, M_1 was observed as best method for increasing total sugars followed by M_3 during both the years of study.

Table 21(a). Effect of plant growth promoting rhizobacteria on total sugars of strawberry cultivar Chandler

Treatments		Total sugars (%)		
		2013	2014	Pooled
T_1	S_1 + Root dip method	6.44	6.52	6.48
T_2	S_1+ Foliar application	5.78	5.28	5.53
T_3	S_1 + Root dip method + Foliar application	5.97	5.73	5.85
T_4	S_2+ Root dip method	5.85	6.25	6.05
T_5	S_2+ Foliar application	5.46	5.03	5.25
T_6	S_2 + Root dip method + Foliar application	5.60	5.79	5.70
T_7	S_3 + Root dip method	6.54	5.59	6.06
T_8	S_3+ Foliar application	5.06	4.74	4.90
T_9	S_3 + Root dip method + Foliar application	6.18	5.51	5.85
T_{10}	S_4+ Root dip method	6.70	5.31	6.00
T_{11}	S_4+ Foliar application	6.02	4.64	5.33
T_{12}	S_4 + Root dip method + Foliar application	6.24	5.05	5.64
T_{13}	S_5 + Root dip method	6.14	7.30	6.72
T_{14}	S_5+ Foliar application	5.11	5.19	5.15
T_{15}	S_5 + Root dip method + Foliar application	5.92	5.88	5.90
T_{16}	Control	4.68	4.22	4.45
$CD_{0.05}$		0.67	0.35	0.41

Table 21(b). Interaction effect of plant growth promoting rhizobacteria and application methods on total sugars of strawberry cultivar Chandler

Treatment	Total sugars (%)											
	2013				2014				Pooled			
	M_1	M_2	M_3	MEAN	M_1	M_2	M_3	MEAN	M_1	M_2	M_3	MEAN
S_1	6.44	5.78	5.97	6.06	6.52	5.28	5.73	5.84	6.48	5.53	5.85	5.95
S_2	5.85	5.46	5.60	5.64	6.25	5.03	5.79	5.69	6.05	5.25	5.70	5.67
S_3	6.54	5.06	6.18	5.93	5.59	4.74	5.51	5.28	6.06	4.90	5.85	5.60
S_4	6.70	6.02	6.24	6.32	5.31	4.64	5.05	5.00	6.00	5.33	5.64	5.66
S_5	6.14	5.11	5.92	5.73	7.30	5.19	5.88	6.12	6.72	5.15	5.90	5.92
MEAN	6.33	5.49	5.98		6.19	4.98	5.59		6.26	5.23	5.79	
$CD_{0.05}$ for S : 0.41					$CD_{0.05}$ for S : 0.56				$CD_{0.05}$ for S : 0.24			
$CD_{0.05}$ for M : 0.31					$CD_{0.05}$ for M : 0.43				$CD_{0.05}$ for M : 0.19			
$CD_{0.05}$ for SxM : NS					$CD_{0.05}$ for SxM : 0.97				$CD_{0.05}$ for SxM : NS			

4.1.3.8 Reducing sugars

The data pertaining to reducing sugars as affected by plant growth promoting rhizobacteria are presented in Table 22(a) and (b). The pooled data depicted in Table 22(a) reveals that maximum reducing sugars were obtained from T_{13} (4.95 %) which was statistically at par with T_7 (4.81 %), T_4 (4.75 %), T_1 (4.66 %) and T_6 (4.54 %), whereas,

Table 22(a). Effect of plant growth promoting rhizobacteria on reducing sugars of strawberry cultivar Chandler

Treatments		Reducing sugars (%)		
		2013	2014	Pooled
T_1	S_1 + Root dip method	4.08	5.23	4.66
T_2	S_1+ Foliar application	3.30	4.13	3.72
T_3	S_1 + Root dip method + Foliar application	3.65	4.48	4.06
T_4	S_2+ Root dip method	4.77	4.73	4.75
T_5	S_2+ Foliar application	3.95	3.76	3.86
T_6	S_2 + Root dip method + Foliar application	4.53	4.55	4.54
T_7	S_3 + Root dip method	5.20	4.42	4.81
T_8	S_3+ Foliar application	3.76	3.29	3.53
T_9	S_3 + Root dip method + Foliar application	4.37	4.08	4.23
T_{10}	S_4+ Root dip method	4.64	4.17	4.41
T_{11}	S_4+ Foliar application	3.72	3.56	3.64
T_{12}	S_4 + Root dip method + Foliar application	4.04	3.93	3.99
T_{13}	S_5 + Root dip method	4.89	5.00	4.95
T_{14}	S_5+ Foliar application	3.79	4.02	3.90
T_{15}	S_5 + Root dip method + Foliar application	4.07	4.67	4.37
T_{16}	Control	3.25	3.15	3.20
$CD_{0.05}$		0.69	0.25	0.41

Table 22(b). Interaction effect of plant growth promoting rhizobacteria and their application methods on reducing sugars of strawberry cultivar Chandler

Treatment	Reducing sugars (%)											
	2013				2014				Pooled			
	M_1	M_2	M_3	MEAN	M_1	M_2	M_3	MEAN	M_1	M_2	M_3	MEAN
S_1	4.08	3.30	3.65	3.68	5.23	4.13	4.48	4.62	4.66	3.72	4.06	4.15
S_2	4.77	3.95	4.53	4.42	4.73	3.76	4.55	4.34	4.75	3.86	4.54	4.38
S_3	5.20	3.76	4.37	4.45	4.42	3.29	4.08	3.93	4.81	3.53	4.23	4.19
S_4	4.64	3.72	4.04	4.13	4.17	3.56	3.93	3.89	4.41	3.64	3.99	4.01
S_5	4.89	3.79	4.07	4.25	5.00	4.02	4.67	4.56	4.95	3.90	4.37	4.41
MEAN	4.72	3.70	4.13		4.71	3.75	4.34		4.71	3.73	4.24	
$CD_{0.05}$ for S : 0.40					$CD_{0.05}$ for S : 0.15				$CD_{0.05}$ for S : 0.23			
$CD_{0.05}$ for M : 0.31					$CD_{0.05}$ for M : 0.11				$CD_{0.05}$ for M : 0.18			
$CD_{0.05}$ for SxM : NS					$CD_{0.05}$ for SxM : 0.26				$CD_{0.05}$ for SxM : NS			

minimum reducing sugars were recorded from T_{16} (3.20 %). During 2013, reducing sugars were maximum in T_7 (5.20 %) which were statistically at par with T_{13} (4.89 %), T_4 (4.77 %), T_{10} (4.64 %) and T_6 (4.53 %). However, during 2014, reducing sugars were maximum in T_1 (5.23 %), which were statistically at par with T_{13} (5.00 %). The sugars were lowest in T_{16} during both the years of study.

The combined effect of plant growth promoting rhizobacteria and their application methods presented in Table 22(b) found to be non-significant with respect to reducing sugars.

However, the interaction effect was significant during 2014, in which maximum reducing sugars were obtained from S_1M_1 (5.23 %) statistically at par with S_5M_1 (5.00 %) and minimum from S_3M_2 (3.29 %). Further study also showed that, among different strains of plant growth promoting rhizobacteria under study, S_5 was most effective which was statistically at par with S_1, whereas, M_1 was proved as best application method.

4.1.3.9 Non-reducing sugars

The pooled data given in Table 23(a) showed non-significant effect of plant growth promoting rhizobacteria and their application methods on non-reducing sugars, but the effect was significant during both the years of study. During 2013, highest non-reducing sugars were obtained from T_2 (2.36 %) followed by T_1 (2.24 %) and minimum from T_6 (1.02 %). The non-reducing sugars were significantly higher in T_{13} (2.19 %) and minimum in T_{16} (1.01) followed by T_{11} (1.02 %) during 2014.

The interaction values between plant growth promoting rhizobacteria and their application methods are presented in Table 23(b) which showed non-significant effect on non-reducing sugars, but the effect was significant during 2014, in which significantly higher non-reducing sugars were obtained from S_5M_1 (2.19 %) and lowest from S_4M_2 (1.02 %). Among different isolates of plant growth promoting rhizobacteria, S_1 was most effective, however, during 2014, S_5 was recorded to be most efficient isolate.

Table 23(a). Effect of plant growth promoting rhizobacteria on non-reducing sugars of strawberry cultivar Chandler

Treatments		Non-reducing sugars (%)		
		2013	2014	Pooled
T_1	S_1 + Root dip method	2.24	1.22	1.73
T_2	S_1+ Foliar application	2.36	1.09	1.72
T_3	S_1 + Root dip method + Foliar application	2.21	1.19	1.70
T_4	S_2+ Root dip method	1.03	1.45	1.24
T_5	S_2+ Foliar application	1.44	1.21	1.32
T_6	S_2 + Root dip method + Foliar application	1.02	1.18	1.10
T_7	S_3 + Root dip method	1.27	1.11	1.19
T_8	S_3+ Foliar application	1.23	1.38	1.31
T_9	S_3 + Root dip method + Foliar application	1.72	1.35	1.54
T_{10}	S_4+ Root dip method	1.95	1.08	1.52
T_{11}	S_4+ Foliar application	2.19	1.02	1.61
T_{12}	S_4 + Root dip method + Foliar application	2.09	1.06	1.58
T_{13}	S_5 + Root dip method	1.18	2.19	1.68
T_{14}	S_5+ Foliar application	1.26	1.12	1.19
T_{15}	S_5 + Root dip method + Foliar application	1.76	1.15	1.45
T_{16}	Control	1.36	1.01	1.18
$CD_{0.05}$		0.90	0.43	NS

Table 23(b). Interaction effect of plant growth promoting rhizobacteria and their application methods on non-reducing sugars of strawberry cultivar Chandler

Treatment	Non- reducing sugars (%)											
	2013				2014				Pooled			
	M_1	M_2	M_3	MEAN	M_1	M_2	M_3	MEAN	M_1	M_2	M_3	MEAN
S_1	2.24	2.36	2.21	2.27	1.22	1.10	1.19	1.17	1.73	1.72	1.70	1.72
S_2	1.03	1.44	1.02	1.16	1.45	1.21	1.18	1.28	1.24	1.33	1.10	1.22
S_3	1.27	1.23	1.72	1.41	1.11	1.39	1.35	1.28	1.19	1.31	1.54	1.34
S_4	1.95	2.19	2.09	2.08	1.08	1.02	1.06	1.06	1.52	1.61	1.58	1.57
S_5	1.18	1.26	1.76	1.40	2.19	1.12	1.15	1.49	1.69	1.19	1.46	1.44
MEAN	1.53	1.69	1.76		1.41	1.17	1.19		1.47	1.43	1.47	
$CD_{0.05}$ for S : 0.54					$CD_{0.05}$ for S : 0.25				$CD_{0.05}$ for S : 0.32			
$CD_{0.05}$ for M : NS					$CD_{0.05}$ for M : 0.20				$CD_{0.05}$ for M : NS			
$CD_{0.05}$ for SxM : NS					$CD_{0.05}$ for SxM : 0.44				$CD_{0.05}$ for SxM : NS			

4.1.3.10 Ascorbic acid content

The perusal of data given Table 24(a) and (b) reveals that plant growth promoting rhizobacteria and their application methods had significant effect on ascorbic acid content of the fruit. The pooled data given in Table 24(a) showed that ascorbic acid was significantly highest in T_{16} (60.17 mg/100g) and lowest in T_1 (38.75 mg/100 g). A similar trend was observed during both the years of with a difference, that minimum ascorbic acid content was recorded in T_{13} (41.40 mg/100 g) in 2014.

Table 24(a). Effect of plant growth promoting rhizobacteria on ascorbic acid content of strawberry cultivar Chandler

Treatments		Ascorbic acid (mg/100 g)		
		2013	2014	Pooled
T_1	S_1 + Root dip method	31.30	46.20	38.75
T_2	S_1+ Foliar application	38.33	50.40	44.37
T_3	S_1 + Root dip method + Foliar application	35.34	49.03	42.19
T_4	S_2+ Root dip method	37.50	47.15	42.33
T_5	S_2+ Foliar application	52.50	57.73	55.12
T_6	S_2 + Root dip method + Foliar application	41.00	49.55	45.28
T_7	S_3 + Root dip method	39.17	56.60	47.88
T_8	S_3+ Foliar application	47.08	64.44	55.76
T_9	S_3 + Root dip method + Foliar application	43.83	58.07	50.95
T_{10}	S_4+ Root dip method	41.17	52.90	47.03
T_{11}	S_4+ Foliar application	52.08	60.50	56.29
T_{12}	S_4 + Root dip method + Foliar application	43.78	58.27	51.02
T_{13}	S_5 + Root dip method	45.42	41.40	43.41
T_{14}	S_5+ Foliar application	49.58	46.00	47.79
T_{15}	S_5 + Root dip method + Foliar application	48.57	43.70	46.13
T_{16}	Control	55.33	65.00	60.17
$CD_{0.05}$		1.06	0.94	0.80

Table 24(b). Interaction effect of plant growth promoting rhizobacteria and their application methods on ascorbic acid of strawberry cultivar Chandler

Treatment	Ascorbic acid (mg/100g)											
	2013				2014				Pooled			
	M_1	M_2	M_3	MEAN	M_1	M_2	M_3	MEAN	M_1	M_2	M_3	MEAN
S_1	31.30	38.33	35.34	34.99	46.20	50.40	49.03	48.54	38.75	44.37	42.19	41.77
S_2	37.50	52.50	41.00	43.67	47.15	57.73	49.55	51.48	42.33	55.12	45.28	47.57
S_3	39.17	47.08	43.83	43.36	56.60	64.44	58.07	59.70	47.88	55.76	50.95	51.53
S_4	41.17	52.08	43.78	45.68	52.90	60.50	58.27	57.22	47.03	56.29	51.02	51.45
S_5	45.42	49.58	48.57	47.86	41.40	46.00	43.70	43.70	43.41	47.79	46.13	45.78
MEAN	38.91	47.92	42.50		48.85	55.81	51.72		43.88	51.87	47.11	
$CD_{0.05}$ for S : 0.61					$CD_{0.05}$ for S : 0.56				$CD_{0.05}$ for S : 0.46			
$CD_{0.05}$ for M : 0.47					$CD_{0.05}$ for M : 0.43				$CD_{0.05}$ for M : 0.35			
$CD_{0.05}$ for SxM : 1.06					$CD_{0.05}$ for SxM : 0.97				$CD_{0.05}$ for SxM : 0.79			

The data on cumulative effect between S x M are given in Table 24(b) which reveals that maximum pooled value for ascorbic acid content was obtained from S_4M_2 (56.29 mg/100 g) statistically at par with S_3M_2 (55.76 mg/100 g), while minimum ascorbic acid was obtained from S_1M_1 (38.75 mg/100 g). During 2013, the ascorbic acid content was maximum in S_2M_2 (52.50 mg/100 g) followed by S_4M_2 (52.08 mg/100 g) and minimum in S_1M_1 (31.30 mg/100 g). However during 2014, ascorbic acid content was significantly highest in S_3M_2 (64.44 mg/100 g) and lowest in S_5M_1 (41.40 mg/100 g). Interaction study further showed that the S_3 was most effective strain followed by S_4 for increasing ascorbic acid content. But during 2013, S_4 was proved most effective, whereas, S_1 decreased the ascorbic acid content. However, during 2014, S_5 was effective in decreasing ascorbic acid among all plant growth promoting rhizobacteria strain. Furthermore, M_1 (root dip) method of PGPR was found most effective in decreasing the ascorbic acid content of strawberry fruits.

4.1.3.11 Anthocyanin content

The anthocyanin content of strawberry fruits was significantly enhanced by different plant growth promoting rhizobacteria treatments as compared to the control as presented in Table 25(a). The pooled values revealed that the anthocyanin content was significantly higher in T_1 (41.33 mg/100 ml) followed by T_{13} (40.17 mg/100 ml) and lower in T_{16} (28.18 mg/100 ml). A similar trend was observed during 2013 and 2014.

The interaction study between plant growth promoting rhizobacteria and their application methods revealed a significant effect on anthocyanin content of strawberry cultivar Chandler as shown in Table 25(b). The maximum pooled anthocyanin content was

obtained from S_1M_1 (41.33 mg/100 ml), which was statistically higher than other treatments, while minimum anthocyanin content was recorded from S_2M_2 (29.37 mg/ 100 ml), which was statistically at par with S_5M_2 (30.04 mg/100 ml). A similar trend was observed during both the years of study. Results further showed that S_4 was most promising rhizobacterial strain for increasing anthocyanin content among all other strains under study, whereas M_1 was found to be most effective method of application.

Table 25(a). Effect of plant growth promoting rhizobacteria on anthocyanin content of strawberry cultivar Chandler

Treatments		Anthocyanin (mg/100 ml)		
		2013	2014	Pooled
T_1	S_1 + Root dip method	40.83	41.83	41.33
T_2	S_1+ Foliar application	30.50	31.07	30.78
T_3	S_1 + Root dip method + Foliar application	32.12	33.79	32.96
T_4	S_2+ Root dip method	38.83	39.33	39.08
T_5	S_2+ Foliar application	29.06	29.68	29.37
T_6	S_2 + Root dip method + Foliar application	30.31	31.15	30.73
T_7	S_3 + Root dip method	38.17	39.83	39.00
T_8	S_3+ Foliar application	30.49	32.49	31.49
T_9	S_3 + Root dip method + Foliar application	34.90	35.70	35.30
T_{10}	S_4+ Root dip method	38.58	39.37	38.98
T_{11}	S_4+ Foliar application	32.92	34.31	33.62
T_{12}	S_4 + Root dip method + Foliar application	37.64	38.31	37.98
T_{13}	S_5 + Root dip method	39.17	41.17	40.17
T_{14}	S_5+ Foliar application	29.61	30.46	30.04
T_{15}	S_5 + Root dip method + Foliar application	36.14	37.14	36.64
T_{16}	Control	27.85	28.52	28.18
$CD_{0.05}$		1.43	1.51	1.06

Table 25(b). Interaction effect of plant growth promoting rhizobacteria and their application methods on anthocyanin content of strawberry cultivar Chandler

Treatment	Anthocyanin content (mg/100 ml)											
	2013				2014				Pooled			
	M_1	M_2	M_3	MEAN	M_1	M_2	M_3	MEAN	M_1	M_2	M_3	MEAN
S_1	40.83	30.50	32.12	34.49	41.83	31.07	33.79	35.56	41.33	30.78	32.96	35.02
S_2	38.83	29.06	30.31	32.73	39.33	29.68	31.15	33.38	39.08	29.37	30.73	33.06
S_3	38.17	30.49	34.90	34.52	39.83	32.49	35.70	36.01	39.00	31.49	35.30	35.26
S_4	38.58	32.92	37.64	36.38	39.37	34.31	38.31	37.33	38.98	33.62	37.98	36.86
S_5	39.17	29.61	36.14	34.97	41.17	30.46	37.14	36.25	40.17	30.04	36.64	35.61
MEAN	39.11	30.51	34.22		40.30	31.60	35.22		39.71	31.06	34.72	
$CD_{0.05}$ for S : 0.85					$CD_{0.05}$ for S : 0.73				$CD_{0.05}$ for S : 0.56			
$CD_{0.05}$ for M : 0.66					$CD_{0.05}$ for M : 0.57				$CD_{0.05}$ for M : 0.44			
$CD_{0.05}$ for SxM : 1.47					$CD_{0.05}$ for SxM : 1.28				$CD_{0.05}$ for SxM : 0.98			

4.1.4 Physiological parameters

4.1.4.1 Chlorophyll content

The data on the effect of plant growth promoting rhizobacteria and their application methods on chlorophyll content are presented in Table 26(a) and (b). The inquisition of data reveals that plant growth promoting rhizobacteria increased the chlorophyll content in all treatments as compared to control. It is evident from the pooled data given in Table 26(a) that chlorophyll content was highest in T_{15} (3.07 mg/g) which was statistically at par with T_3 and T_9 (3.02 and 2.98 mg/g, respectively), whereas minimum content was obtained from T_{16} (2.54 mg/g). A similar trend was observed during both the years of investigation.

The plant growth promoting rhizobacteria and their application methods interaction also exerted a significant effect on chlorophyll content as presented in Table 26(b). However, the effect was non-significant during 2014. The maximum chlorophyll content (3.07 mg/g) was obtained from S_5M_3 which was statistically at par with S_1M_3 and S_3M_3 (3.02 and 2.98 mg/g, respectively) and minimum from S_3M_1 (2.60 mg/g) closely followed by S_4M_1 (2.62 mg/g) as pooled value. A similar trend was observed for maximum chlorophyll content during both the years of study, whereas minimum chlorophyll content was recorded from S_3M_1 (2.53 mg/g) during 2013 and S_4M_1 (2.65 mg/g) during 2014. Considering the individual effect of isolates, the maximum chlorophyll content was obtained from plants treated with S_5, however among application methods, M_3 was found to be most effective in producing maximum chlorophyll content during both the years of study.

Table 26(a). Effect of plant growth promoting rhizobacteria on leaf chlorophyll content of strawberry cultivar Chandler

Treatments		Chlorophyll (mg/g)		
		2013	2014	Pooled
T_1	S_1 + Root dip method	2.70	2.68	2.69
T_2	S_1+ Foliar application	2.76	2.78	2.77
T_3	S_1 + Root dip method + Foliar application	2.93	3.10	3.02
T_4	S_2+ Root dip method	2.71	2.74	2.73
T_5	S_2+ Foliar application	2.78	2.85	2.82
T_6	S_2 + Root dip method + Foliar application	2.90	2.92	2.91
T_7	S_3 + Root dip method	2.53	2.66	2.60
T_8	S_3+ Foliar application	2.61	2.72	2.66
T_9	S_3 + Root dip method + Foliar application	2.95	3.02	2.98
T_{10}	S_4+ Root dip method	2.59	2.65	2.62
T_{11}	S_4+ Foliar application	2.67	2.68	2.68
T_{12}	S_4 + Root dip method + Foliar application	2.72	2.89	2.81
T_{13}	S_5 + Root dip method	2.69	2.71	2.70
T_{14}	S_5+ Foliar application	2.71	2.91	2.81
T_{15}	S_5 + Root dip method + Foliar application	3.01	3.12	3.07
T_{16}	Control	2.51	2.56	2.54
$CD_{0.05}$		0.10	0.14	0.10

Table 26(b). Interaction effect of plant growth promoting rhizobacteria and their application methods on leaf chlorophyll content of strawberry cultivar Chandler

Treatment	Chlorophyll content (mg/g)											
	2013				2014				Pooled			
	M_1	M_2	M_3	MEAN	M_1	M_2	M_3	MEAN	M_1	M_2	M_3	MEAN
S_1	2.70	2.76	2.93	2.79	2.68	2.78	3.10	2.86	2.69	2.77	3.02	2.82
S_2	2.71	2.78	2.90	2.80	2.74	2.85	2.92	2.84	2.73	2.82	2.91	2.82
S_3	2.53	2.61	2.95	2.70	2.66	2.72	3.02	2.80	2.60	2.66	2.98	2.75
S_4	2.59	2.67	2.72	2.66	2.65	2.68	2.89	2.74	2.62	2.68	2.81	2.70
S_5	2.69	2.71	3.01	2.80	2.71	2.91	3.12	2.91	2.70	2.81	3.07	2.86
MEAN	2.64	2.71	2.90		2.69	2.79	3.01		2.67	2.75	2.96	
$CD_{0.05}$ for S : 0.05					$CD_{0.05}$ for S : 0.08				$CD_{0.05}$ for S : 0.06			
$CD_{0.05}$ for M : 0.04					$CD_{0.05}$ for M : 0.06				$CD_{0.05}$ for M : 0.04			
$CD_{0.05}$ for SxM : 0.09					$CD_{0.05}$ for SxM : NS				$CD_{0.05}$ for SxM : 0.10			

4.1.4.2 Photosynthesis

The data presented in Table 26(a) and (b) reveals that rate of photosynthesis was significantly influenced by plant growth promoting rhizobacteria and their application methods. The pooled data given in Table 26(a) showed that significantly higher rate of photosynthesis was noted in T_{15} (10.02 µ mol/m^2/s) followed by T_9 (9.29 µ mol/m^2/s) and lowest in T_{16} (5.68 µ mol/m^2/s), which was statistically at par with T_1 (5.93 µ mol/m^2/s). A similar trend was observed during both the years of study.

Table 27(a). Effect of plant growth promoting rhizobacteria on rate of photosynthesis of strawberry cultivar Chandler

Treatments		Photosynthesis (µ mol/m^2/s)		
		2013	2014	Pooled
T_1	S_1 + Root dip method	5.68	6.19	5.93
T_2	S_1+ Foliar application	7.93	8.43	8.18
T_3	S_1 + Root dip method + Foliar application	8.22	8.72	8.47
T_4	S_2+ Root dip method	6.02	6.52	6.27
T_5	S_2+ Foliar application	6.23	6.73	6.48
T_6	S_2 + Root dip method + Foliar application	6.83	7.33	7.08
T_7	S_3 + Root dip method	6.55	7.05	6.80
T_8	S_3+ Foliar application	7.16	7.66	7.41
T_9	S_3 + Root dip method + Foliar application	9.04	9.54	9.29
T_{10}	S_4+ Root dip method	6.71	7.21	6.96
T_{11}	S_4+ Foliar application	6.75	7.25	7.00
T_{12}	S_4 + Root dip method + Foliar application	6.94	7.44	7.19
T_{13}	S_5 + Root dip method	6.56	7.06	6.81
T_{14}	S_5+ Foliar application	7.68	8.18	7.93
T_{15}	S_5 + Root dip method + Foliar application	9.77	10.27	10.02
T_{16}	Control	5.43	5.93	5.68
$CD_{0.05}$		0.57	0.43	0.47

Table 27(b). Interaction effect of plant growth promoting rhizobacteria and their application methods on rate of photosynthesis of strawberry cultivar Chandler

Treatment	Photosynthesis (µ mol/m^2/s)											
	2013				2014				Pooled			
	M_1	M_2	M_3	MEAN	M_1	M_2	M_3	MEAN	M_1	M_2	M_3	MEAN
S_1	5.68	7.93	8.22	7.28	6.19	8.43	8.72	7.78	5.93	8.18	8.47	7.53
S_2	6.02	6.23	6.83	6.36	6.52	6.73	7.33	6.86	6.27	6.48	7.08	6.61
S_3	6.55	7.16	9.04	7.58	7.05	7.66	9.54	8.08	6.80	7.41	9.29	7.83
S_4	6.71	6.75	6.94	6.80	7.21	7.25	7.44	7.30	6.96	7.00	7.19	7.05
S_5	6.56	7.68	9.77	8.00	7.06	8.18	10.27	8.50	6.81	7.93	10.02	8.25
MEAN	6.30	7.15	8.16		6.80	7.65	8.66		6.55	7.40	8.41	
$CD_{0.05}$ for S : 0.34					$CD_{0.05}$ for S : 0.25				$CD_{0.05}$ for S : 0.27			
$CD_{0.05}$ for M : 0.26					$CD_{0.05}$ for M : 0.19				$CD_{0.05}$ for M : 0.21			
$CD_{0.05}$ for SxM : 0.59					$CD_{0.05}$ for SxM : 0.43				$CD_{0.05}$ for SxM : 0.47			

Interactions between plant growth promoting rhizobacteria and their application methods were significant with respect to the rate of photosynthesis as presented in Table 26(b). The maximum rate of photosynthesis (10.02 µ mol/m^2/s) was noted from S_5M_3 followed by S_3M_3 (9.29 µ mol/m^2/s) and minimum from S_1M_1 (5.93 µ mol/m^2/s) statistically at par with S_2M_1 (6.27 µ mol/m^2/s). A similar trend was also observed for interactions study during 2013 and 2014. Among different plant growth promoting isolates under study, S_5 was found to be most effective for increasing photosynthetic rate followed by S_3, and M_3 as best application method followed by M_2.

4.1.4.3 Stomatal conductance

The data pertaining to stomatal conductance as affected by plant growth promoting rhizobacteria are presented in Table 28(a) and (b). The pooled data given in Table 28(a) reveals that significantly higher stomatal conductance (0.634 m mol/s) was recorded from T_{15} followed by T_9 (0.603 m mol/s) and lowest in T_{16} (0.414 m mol/s). All other treatments had also increased the stomatal conductance as compared to the control. A similar trend was observed during both the years of investigations.

The values on cumulative effect of plant growth promoting rhizobacteria and their application methods are presented in Table 28(b) showing significant effect on stomatal conductance. The highest stomatal conductance was recorded from S_5M_3 (0.634 m mol/s) followed by S_3M_3 (0.603 m mol/s) and lowest from S_1M_1 (0.459 m mol/s), which was statistically at par with S_2M_1, S_2M_2, S_3M_1 and S_4M_1 (0.462, 0.467, 0.481 and 0.479 m mol/s, respectively). A similar trend for highest stomatal conductance was observed during both the

years of study, but minimum stomatal conductance was observed in S_2M_1 (0.421 m mol/s) closely followed by S_1M_1 (0.422 m mol/s) during 2013 and S_1M_1 (0.496 m mol/s) followed by S_2M_1 (0.502 m mol/s) during 2014. Among different isolates of plant growth promoting rhizobacteria, S_5 showed significantly higher individual effect on stomatal conductance followed by S_3, while M_3 was observed as most effective application methods as compared to other methods.

Table 28(a). Effect of plant growth promoting rhizobacteria on stomatal conductance of strawberry cultivar Chandler

Treatments		Stomatal conductance (m mol/s)		
		2013	2014	Pooled
T_1	S_1 + Root dip method	0.422	0.496	0.459
T_2	S_1+ Foliar application	0.461	0.537	0.499
T_3	S_1 + Root dip method + Foliar application	0.510	0.587	0.549
T_4	S_2+ Root dip method	0.421	0.502	0.462
T_5	S_2+ Foliar application	0.423	0.511	0.467
T_6	S_2 + Root dip method + Foliar application	0.458	0.530	0.494
T_7	S_3 + Root dip method	0.425	0.536	0.481
T_8	S_3+ Foliar application	0.444	0.611	0.528
T_9	S_3 + Root dip method + Foliar application	0.570	0.637	0.603
T_{10}	S_4+ Root dip method	0.438	0.520	0.479
T_{11}	S_4+ Foliar application	0.441	0.527	0.484
T_{12}	S_4 + Root dip method + Foliar application	0.449	0.548	0.499
T_{13}	S_5 + Root dip method	0.455	0.543	0.499
T_{14}	S_5+ Foliar application	0.503	0.590	0.547
T_{15}	S_5 + Root dip method + Foliar application	0.606	0.661	0.634
T_{16}	Control	0.372	0.456	0.414
$CD_{0.05}$		0.041	0.020	0.020

Table 28(b). Interaction effect of plant growth promoting rhizobacteria and their application methods on rate of photosynthesis of strawberry cultivar Chandler

Treatment	Stomatal conductance (m mol/s)											
	2013				2014				Pooled			
	M_1	M_2	M_3	MEAN	M_1	M_2	M_3	MEAN	M_1	M_2	M_3	MEAN
S_1	0.422	0.461	0.510	0.464	0.496	0.537	0.587	0.540	0.459	0.499	0.549	0.502
S_2	0.421	0.423	0.458	0.434	0.502	0.511	0.530	0.515	0.462	0.467	0.494	0.474
S_3	0.425	0.444	0.570	0.480	0.536	0.611	0.637	0.595	0.481	0.528	0.603	0.537
S_4	0.438	0.441	0.449	0.443	0.520	0.527	0.548	0.532	0.479	0.484	0.499	0.487
S_5	0.455	0.503	0.606	0.521	0.540	0.590	0.661	0.597	0.497	0.547	0.634	0.559
MEAN	0.432	0.454	0.519		0.518	0.555	0.593		0.475	0.505	0.556	
$CD_{0.05}$ for S : 0.021					$CD_{0.05}$ for S : 0.017				$CD_{0.05}$ for S : 0.014			
$CD_{0.05}$ for M : 0.016					$CD_{0.05}$ for M : 0.013				$CD_{0.05}$ for M : 0.011			
$CD_{0.05}$ for SxM : 0.037					$CD_{0.05}$ for SxM : 0.029				$CD_{0.05}$ for SxM : 0.024			

4.1.4.4 Stomatal resistance

It is evident from the Table 29(a) and (b) that plant growth promoting rhizobacteria and their application methods had significantly influenced the stomatal resistance. The significantly lowest stomatal resistance was recorded in T_{15} (0.602 S cm^{-1}) and highest in T_{16} (1.229 S cm^{-1}) as pooled value. A similar trend was observed during both the years of study.

Data depicted in Table 29(b) showed that values of stomatal resistance differed significantly with respect to interaction effect between plant growth promoting rhizobacteria and their application methods. The pooled data reveals that highest stomatal resistance was recorded from S_1M_1 (1.187 S cm^{-1}) which was statistically at par with S_1M_2, S_2M_1 and S_3M_1 (1.147, 1.156 and 1.168 S cm^{-1}, respectively) and significantly lower stomatal resistance was recorded from S_5M_3 (0.602 S cm^{-1}). Again, similar trend was observed during both the years of investigation.

Furthermore, results showed that the dual application of plant growth promoting rhizobacteria as root dip + foliar method (M_3) decreased the stomatal resistance as compared to single application as root (M_1) or foliar (M_2) application methods. Among different plant growth promoting rhizobacterial isolates, S_1 was found to significantly increase the stomatal resistance followed by S_2 whereas S_5 was reported to decrease the stomatal resistance in strawberry cultivar Chandler.

Table 29(a). Effect of plant growth promoting rhizobacteria on stomatal resistance of strawberry cultivar Chandler

Treatments		Stomatal resistance (S cm^{-1})		
		2013	**2014**	**Pooled**
T_1	S_1 + Root dip method	1.162	1.212	1.187
T_2	S_1+ Foliar application	1.110	1.185	1.147
T_3	S_1 + Root dip method + Foliar application	0.997	1.091	1.044
T_4	S_2+ Root dip method	1.103	1.208	1.156
T_5	S_2+ Foliar application	0.890	1.124	1.007
T_6	S_2 + Root dip method + Foliar application	0.840	0.936	0.888
T_7	S_3 + Root dip method	1.135	1.201	1.168
T_8	S_3+ Foliar application	0.955	1.004	0.979
T_9	S_3 + Root dip method + Foliar application	0.739	0.930	0.835
T_{10}	S_4+ Root dip method	0.822	0.946	0.884
T_{11}	S_4+ Foliar application	0.733	0.781	0.757
T_{12}	S_4 + Root dip method + Foliar application	0.636	0.767	0.702
T_{13}	S_5 + Root dip method	0.838	0.866	0.852
T_{14}	S_5+ Foliar application	0.682	0.764	0.723
T_{15}	S_5 + Root dip method + Foliar application	0.597	0.606	0.602
T_{16}	Control	1.242	1.217	1.229
$CD_{0.05}$		0.082	0.061	0.041

Table 29(b). Interaction effect of plant growth promoting rhizobacteria and their application methods on stomatal resistance of strawberry cultivar Chandler

Treatment	Stomatal resistance (S cm^{-1})											
	2013				2014				Pooled			
	M_1	M_2	M_3	MEAN	M_1	M_2	M_3	MEAN	M_1	M_2	M_3	MEAN
S_1	1.162	1.110	0.997	1.089	1.212	1.185	1.091	1.163	1.187	1.147	1.044	1.126
S_2	1.103	0.890	0.840	0.944	1.208	1.124	0.936	1.089	1.156	1.007	0.888	1.017
S_3	1.135	0.955	0.739	0.943	1.201	1.004	0.930	1.045	1.168	0.979	0.835	0.994
S_4	0.822	0.733	0.636	0.731	0.946	0.781	0.767	0.831	0.884	0.757	0.702	0.781
S_5	0.838	0.682	0.597	0.706	0.866	0.764	0.606	0.745	0.852	0.723	0.602	0.726
MEAN	1.012	0.874	0.762		1.087	0.972	0.866		1.049	0.923	0.814	
$CD_{0.05}$ for S : 0.044					$CD_{0.05}$ for S : 0.035				$CD_{0.05}$ for S : 0.026			
$CD_{0.05}$ for M : 0.034					$CD_{0.05}$ for M : 0.027				$CD_{0.05}$ for M : 0.020			
$CD_{0.05}$ for SxM : 0.076					$CD_{0.05}$ for SxM : 0.061				$CD_{0.05}$ for SxM : 0.045			

4.1.4.5 Transpiration rate

Plant growth promoting rhizobacteria and their application methods had significant impact on transpiration rate as depicted in Table 30 (a). The pooled data showed that T_{15} had significantly higher transpiration rate (39.14 m mol/ m^2/s) as compared to other treatments whereas significantly lower transpiration rate was observed in T_{16} (23.09 m mol/ m^2/s).

Table 30(a). Effect of plant growth promoting rhizobacteria on transpiration rate of strawberry cultivar Chandler

Treatments		Transpiration rate (m mol/ m^2/s)		
		2013	2014	Pooled
T_1	S_1 + Root dip method	24.02	24.73	24.40
T_2	S_1+ Foliar application	24.39	25.24	24.81
T_3	S_1 + Root dip method + Foliar application	26.79	27.31	27.05
T_4	S_2+ Root dip method	25.41	25.16	25.28
T_5	S_2+ Foliar application	27.83	26.68	27.26
T_6	S_2 + Root dip method + Foliar application	29.67	28.45	29.06
T_7	S_3 + Root dip method	24.07	25.22	24.59
T_8	S_3+ Foliar application	26.98	27.65	27.32
T_9	S_3 + Root dip method + Foliar application	30.10	28.75	29.43
T_{10}	S_4+ Root dip method	29.78	27.70	28.74
T_{11}	S_4+ Foliar application	33.82	30.48	32.15
T_{12}	S_4 + Root dip method + Foliar application	34.86	33.76	34.31
T_{13}	S_5 + Root dip method	28.11	29.48	28.79
T_{14}	S_5+ Foliar application	34.42	34.09	34.25
T_{15}	S_5 + Root dip method + Foliar application	38.80	39.47	39.14
T_{16}	Control	22.76	23.43	23.09
$CD_{0.05}$		0.57	0.69	0.47

Table 30(b). Interaction effect of plant growth promoting rhizobacteria and their application methods on transpiration rate of strawberry cultivar Chandler

Treatment	Transpiration rate (m mol/ m^2/s)											
	2013				2014				Pooled			
	M_1	M_2	M_3	MEAN	M_1	M_2	M_3	MEAN	M_1	M_2	M_3	MEAN
S_1	24.02	24.39	26.79	25.07	24.73	25.24	27.31	25.76	24.38	24.81	27.05	25.41
S_2	25.41	27.83	29.67	27.64	25.16	26.68	28.45	26.76	25.28	27.26	29.06	27.20
S_3	24.07	26.98	30.10	27.05	25.22	27.65	28.75	27.21	24.65	27.32	29.43	27.13
S_4	29.78	33.82	34.86	32.82	27.70	30.48	33.76	30.65	28.74	32.15	34.31	31.74
S_5	28.11	34.42	38.80	33.78	29.48	34.09	39.47	34.34	28.79	34.25	39.14	34.06
MEAN	26.28	29.49	32.04		26.46	28.83	31.55		26.37	29.16	31.80	
$CD_{0.05}$ for S : 0.25					$CD_{0.05}$ for S : 0.41				$CD_{0.05}$ for S : 0.25			
$CD_{0.05}$ for M : 0.20					$CD_{0.05}$ for M : 0.32				$CD_{0.05}$ for M : 0.19			
$CD_{0.05}$ for SxM : 0.44					$CD_{0.05}$ for SxM : 0.71				$CD_{0.05}$ for SxM : 0.43			

The data on interaction effect between plant growth promoting rhizobacteria and their application methods are presented in Table 30(b). The pooled values given in Table 30(b) revealed that the maximum transpiration rate was recorded from S_5M_3 (39.14 m mol/ m^2/s) which was significantly higher than other treatments whereas the rate was lowest in S_1M_1 (24.38 m mol/ m^2/s) statistically at par with S_1M_2 and S_3M_1 (24.81 and 24.65 m mol/ m^2/s respectively). A similar trend was observed during 2013 and 2014 under study. The results further reveals that the transpiration rate was increased in plants inoculated with S_5 followed by S_4 as compared to other plant growth promoting rhizobacterial isolates and also showed increased transpiration rate when plant growth promoting rhizobacteria were applied through root dip + foliar (M_3) application methods.

4.1.5 Leaf nutrients

4.1.5.1 Nitrogen

Leaf nutrient status was significantly influenced by different plant growth promoting rhizobacteria and their application methods. Pooled data as presented in Table 31(a) reveals that significantly highest leaf nitrogen content 2.81 per cent was recorded in strawberry leaves treated with *Bacillus subtilis* CB 8 A isolate of plant growth promoting rhizobacteria applied as root dip + foliar method (T_6) followed by T_3 whereas, minimum leaf nitrogen content (2.09 %) was recorded in control (T_{16}) which was statistically at par with T_7 (2.19 %) and T_8 (2.15 %). A similar trend was observed during both the years of study except that, during 2014, minimum leaf nitrogen content (2.10 %) was also at par with T_{14}.

Table 31(a). Effect of plant growth promoting rhizobacteria on leaf nitrogen content of strawberry cultivar Chandler

Treatments		Nitrogen (%)		
		2013	2014	Pooled
T_1	S_1 + Root dip method	2.27	2.47	2.37
T_2	S_1+ Foliar application	2.22	2.28	2.25
T_3	S_1 + Root dip method + Foliar application	2.55	2.76	2.65
T_4	S_2+ Root dip method	2.42	2.63	2.53
T_5	S_2+ Foliar application	2.31	2.34	2.33
T_6	S_2 + Root dip method + Foliar application	2.80	2.83	2.81
T_7	S_3 + Root dip method	2.16	2.22	2.19
T_8	S_3+ Foliar application	2.12	2.19	2.15
T_9	S_3 + Root dip method + Foliar application	2.23	2.32	2.28
T_{10}	S_4+ Root dip method	2.41	2.48	2.45
T_{11}	S_4+ Foliar application	2.26	2.33	2.30
T_{12}	S_4 + Root dip method + Foliar application	2.54	2.62	2.58
T_{13}	S_5 + Root dip method	2.25	2.30	2.28
T_{14}	S_5+ Foliar application	2.19	2.21	2.20
T_{15}	S_5 + Root dip method + Foliar application	2.55	2.63	2.59
T_{16}	Control	2.07	2.10	2.09
$CD_{0.05}$		0.10	0.14	0.10

Table 31(b). Interaction effect of plant growth promoting rhizobacteria and their application methods on leaf nitrogen content of strawberry cultivar Chandler

Treatment	Nitrogen (%)											
	2013				2014				Pooled			
	M_1	M_2	M_3	MEAN	M_1	M_2	M_3	MEAN	M_1	M_2	M_3	MEAN
S_1	2.27	2.22	2.55	2.35	2.47	2.28	2.76	2.50	2.37	2.25	2.65	2.42
S_2	2.42	2.31	2.80	2.51	2.63	2.34	2.83	2.60	2.53	2.33	2.81	2.56
S_3	2.16	2.12	2.23	2.17	2.22	2.19	2.32	2.24	2.19	2.15	2.28	2.21
S_4	2.41	2.26	2.54	2.40	2.48	2.33	2.62	2.48	2.45	2.30	2.58	2.44
S_5	2.25	2.19	2.55	2.33	2.30	2.21	2.63	2.38	2.28	2.20	2.59	2.35
MEAN	2.30	2.22	2.53		2.42	2.27	2.63		2.36	2.25	2.58	
$CD_{0.05}$ for S : 0.06					$CD_{0.05}$ for S : 0.08				$CD_{0.05}$ for S : 0.05			
$CD_{0.05}$ for M : 0.04					$CD_{0.05}$ for M : 0.06				$CD_{0.05}$ for M : 0.04			
$CD_{0.05}$ for SxM : 0.10					$CD_{0.05}$ for SxM : 0.14				$CD_{0.05}$ for SxM : 0.09			

The cummulative effect of plant growth promoting rhizobacteria and their application methods presented in Table 31(b) revealed that leaf nitrogen content (2.81 %) was significantly highest in S_2M_3 followed by S_1M_3 (2.65 %), whereas minimum was recorded from S_3M_2 (2.15 %) which was statistically at par with S_3M_1 (2.19 %) and S_5M_2 (2.20 %) as pooled values. The significantly highest leaf nitrogen content (2.56 %) was obtained from S_2 which was observed most effective isolate among all the plant growth promoting rhizobacterial isolates under study, while M_3 (2.58 %) was found to best method of their application. A similar trend was followed during both the years of study.

4.1.5.2 Phosphorus

The data presented in Table 32(a) and (b) revealed that all the plant growth promoting rhizobacteria treatments resulted in an increase in leaf phosphorus content. It is apparent from the pooled data given in Table 32(a) that maximum 0.298 per cent leaf phosphorus content was found in T_3 which was statistically at par with T_{15} recording 0.282 per cent phosphorus

Table 32(a). Effect of plant growth promoting rhizobacteria on leaf phosphorus content of strawberry cultivar Chandler

Treatments		Phosphorus (%)		
		2013	2014	Pooled
T_1	S_1 + Root dip method	0.261	0.268	0.264
T_2	S_1+ Foliar application	0.253	0.262	0.258
T_3	S_1 + Root dip method + Foliar application	0.292	0.304	0.298
T_4	S_2+ Root dip method	0.237	0.243	0.240
T_5	S_2+ Foliar application	0.230	0.238	0.234
T_6	S_2 + Root dip method + Foliar application	0.262	0.280	0.271
T_7	S_3 + Root dip method	0.234	0.252	0.243
T_8	S_3+ Foliar application	0.219	0.227	0.223
T_9	S_3 + Root dip method + Foliar application	0.256	0.263	0.259
T_{10}	S_4+ Root dip method	0.251	0.256	0.253
T_{11}	S_4+ Foliar application	0.245	0.252	0.248
T_{12}	S_4 + Root dip method + Foliar application	0.266	0.274	0.270
T_{13}	S_5 + Root dip method	0.257	0.261	0.259
T_{14}	S_5+ Foliar application	0.248	0.252	0.250
T_{15}	S_5 + Root dip method + Foliar application	0.279	0.286	0.282
T_{16}	Control	0.202	0.211	0.207
$CD_{0.05}$		0.020	0.041	0.020

Table 32(b). Interaction effect of plant growth promoting rhizobacteria and their application methods on leaf phosphorus content of strawberry cultivar Chandler

Treatment	Phosphorus (%)											
	2013				2014				Pooled			
	M_1	M_2	M_3	MEAN	M_1	M_2	M_3	MEAN	M_1	M_2	M_3	MEAN
S_1	0.261	0.253	0.292	0.269	0.268	0.262	0.304	0.278	0.264	0.258	0.298	0.273
S_2	0.237	0.230	0.262	0.243	0.243	0.238	0.280	0.254	0.240	0.234	0.271	0.248
S_3	0.234	0.219	0.256	0.236	0.252	0.227	0.263	0.247	0.243	0.223	0.259	0.242
S_4	0.251	0.245	0.266	0.254	0.256	0.252	0.274	0.260	0.253	0.248	0.270	0.257
S_5	0.257	0.248	0.279	0.262	0.261	0.252	0.286	0.266	0.259	0.250	0.282	0.264
MEAN	0.248	0.239	0.271		0.256	0.246	0.281		0.252	0.243	0.276	
$CD_{0.05}$ for S : 0.012					$CD_{0.05}$ for S : 0.019				$CD_{0.05}$ for S : 0.013			
$CD_{0.05}$ for M : 0.010					$CD_{0.05}$ for M : 0.015				$CD_{0.05}$ for M : 0.010			
$CD_{0.05}$ for SxM : NS					$CD_{0.05}$ for SxM : NS				$CD_{0.05}$ for SxM : NS			

whereas, minimum 0.207 per cent leaf phosphorus content was recorded in control. A similar trend was observed during both the years of study in addition, the maximum leaf phosphorus content was also statistically at par with T_1, T_6, T_9 and T_{12} (0.268, 0.280, 0.263 and 0.274 %, respectively) during 2014.

The interaction values between plant growth promoting rhizobacteria and their application methods given in Table 32(b) revealed non-significant effect on leaf phosphorus content of strawberry cultivar Chandler. However, maximum leaf phosphorus content was recorded from S_1M_3 (0.298 %) and minimum from S_3M_2 (0.223 %) as pooled value. Among different rhizobacterial isolates under study, S_1 was found most effective in increasing leaf phosphorus content (0.273 %) followed by S_5 (0.264 %), while M_3 (0.276 %) was best among their application methods. A similar trend was observed during both the years of study.

4.1.5.3 Potassium

Leaf potassium content was significantly influenced by different treatments as presented in Table 33(a) during both the years of study. The pooled value given in this table revealed that T_3 was found to be most effective which increased leaf potassium content to 1.73 per cent which was statistically at par with T_1, T_6, $T_{10,}$ T_{12}, T_{13} and T_{15} recording 1.59, 1.60, 1.65, 1.70, 1.60 and 1.64 per cent, respectively whereas, minimum 1.38 per cent leaf potassium content was recorded in T_{16} statistically at par with T_5, T_7, T_8, T_{11} and T_{14} (1.43, 1.47, 1.42, 1.52 and 1.51 %, respectively). A similar trend was recorded during both the years of study except that T_1 was not statistically at par with maximum leaf potassium content during 2013 whereas during 2014, the maximum leaf potassium content (1.70 %) was also statistically at par with T_2 and T_9 (1.60 and 1.58 %, respectively).

The interaction study between plant growth promoting rhizobacteria and their application methods did not exert significant effect on per cent leaf potassium content of strawberry cultivar Chandler as presented in Table 33(b). However, maximum leaf potassium content was recorded from S_1M_3 (1.73 %) and minimum from S_3M_2 (1.42 %). A similar trend was observed during both the years of study, but minimum potassium content was in $S_2M_{2.}$ The S_1 and S_4 isolates were recorded to be most effective for increasing leaf potassium (1.62 %) among different plant growth promoting rhizobacteria under study and was statistically at par with S_5 (1.58 %) whereas M_3 (1.64 %) was best among their application methods. A similar trend was recorded during both the years of investigations.

Table 33(a). Effect of plant growth promoting rhizobacteria on leaf potassium content of strawberry cultivar Chandler

Treatments		Potassium (%)		
		2013	2014	Pooled
T_1	S_1 + Root dip method	1.52	1.66	1.59
T_2	S_1+ Foliar application	1.48	1.60	1.54
T_3	S_1 + Root dip method + Foliar application	1.70	1.75	1.73
T_4	S_2+ Root dip method	1.52	1.54	1.53
T_5	S_2+ Foliar application	1.34	1.51	1.43
T_6	S_2 + Root dip method + Foliar application	1.58	1.62	1.60
T_7	S_3 + Root dip method	1.42	1.52	1.47
T_8	S_3+ Foliar application	1.38	1.47	1.42
T_9	S_3 + Root dip method + Foliar application	1.50	1.58	1.54
T_{10}	S_4+ Root dip method	1.62	1.68	1.65
T_{11}	S_4+ Foliar application	1.51	1.53	1.52
T_{12}	S_4 + Root dip method + Foliar application	1.69	1.72	1.70
T_{13}	S_5 + Root dip method	1.55	1.64	1.60
T_{14}	S_5+ Foliar application	1.46	1.56	1.51
T_{15}	S_5 + Root dip method + Foliar application	1.60	1.67	1.64
T_{16}	Control	1.32	1.43	1.38
$CD_{0.05}$		0.16	0.18	0.14

Table 33(b). Interaction effect of plant growth promoting rhizobacteria and their application methods on leaf potassium content of strawberry cultivar Chandler

Treatment	Potassium (%)											
	2013				2014				Pooled			
	M_1	M_2	M_3	MEAN	M_1	M_2	M_3	MEAN	M_1	M_2	M_3	MEAN
S_1	1.52	1.48	1.70	1.57	1.66	1.60	1.75	1.67	1.59	1.54	1.73	1.62
S_2	1.52	1.34	1.58	1.48	1.54	1.51	1.62	1.56	1.53	1.43	1.60	1.52
S_3	1.42	1.38	1.50	1.43	1.52	1.47	1.58	1.53	1.47	1.42	1.54	1.48
S_4	1.62	1.51	1.69	1.60	1.68	1.53	1.72	1.64	1.65	1.52	1.70	1.62
S_5	1.55	1.46	1.60	1.54	1.64	1.56	1.67	1.62	1.60	1.51	1.64	1.58
MEAN	1.53	1.43	1.61		1.61	1.54	1.67		1.57	1.48	1.64	
$CD_{0.05}$ for S : 0.10					$CD_{0.05}$ for S : 0.09				$CD_{0.05}$ for S : 0.08			
$CD_{0.05}$ for M : 0.08					$CD_{0.05}$ for M : 0.07				$CD_{0.05}$ for M : 0.06			
$CD_{0.05}$ for SxM : NS					$CD_{0.05}$ for SxM : NS				$CD_{0.05}$ for SxM : NS			

4.1.5.4 Calcium

The inquisition of data given in Table 34(a) revealed that the leaf calcium content was significantly affected by plant growth promoting rhizobacteria and their application methods. The pooled values given in this table showed that the maximum leaf calcium content (1.44 %) was recorded in T_{15} which was statistically at par with T_1, T_2, T_3, T_6, T_9, T_{12} and T_{13} recording 1.38, 1.37, 1.42, 1.40, 1.39, 1.40 and 1.37 per cent, respectively while, significantly minimum content of leaf calcium (1.08 %) was noted from T_{16}. A similar trend was observed during both the years of study.

The pooled values for interaction between plant growth promoting rhizobacteria and their application methods had shown non-significant effect on leaf calcium content. However, the maximum leaf calcium content (1.44 %) was recorded from S_5M_3 and minimum from S_4M_2 (1.28%). The different isolates of plant growth promoting rhizobacteria under study had also non- significant effect on leaf calcium content, but the effect was significant during 2013. On overall basis, S_1 was proved to be most effective in increasing leaf calcium content (1.39 %) but S_5 was best during 2014. The application methods had significant effect on leaf calcium content and M_3 was found to be best among their application methods followed by root dip method (M_1).

Table 34(a). Effect of plant growth promoting rhizobacteria on leaf calcium content of strawberry cultivar Chandler

Treatments		Calcium (%)		
		2013	2014	Pooled
T_1	S_1 + Root dip method	1.37	1.39	1.38
T_2	S_1+ Foliar application	1.36	1.37	1.37
T_3	S_1 + Root dip method + Foliar application	1.41	1.43	1.42
T_4	S_2+ Root dip method	1.33	1.35	1.34
T_5	S_2+ Foliar application	1.30	1.33	1.32
T_6	S_2 + Root dip method + Foliar application	1.38	1.41	1.40
T_7	S_3 + Root dip method	1.32	1.36	1.34
T_8	S_3+ Foliar application	1.28	1.32	1.30
T_9	S_3 + Root dip method + Foliar application	1.37	1.40	1.39
T_{10}	S_4+ Root dip method	1.32	1.33	1.32
T_{11}	S_4+ Foliar application	1.26	1.31	1.28
T_{12}	S_4 + Root dip method + Foliar application	1.39	1.41	1.40
T_{13}	S_5 + Root dip method	1.36	1.38	1.37
T_{14}	S_5+ Foliar application	1.31	1.37	1.34
T_{15}	S_5 + Root dip method + Foliar application	1.42	1.46	1.44
T_{16}	Control	1.00	1.15	1.08
$CD_{0.05}$		0.08	0.12	0.08

Table 34(b). Interaction effect of plant growth promoting rhizobacteria and their application methods on leaf calcium content of strawberry cultivar Chandler

Treatment	Calcium (%)											
	2013				2014				Pooled			
	M_1	M_2	M_3	MEAN	M_1	M_2	M_3	MEAN	M_1	M_2	M_3	MEAN
S_1	1.37	1.36	1.41	1.38	1.39	1.37	1.43	1.39	1.38	1.37	1.42	1.39
S_2	1.33	1.30	1.38	1.34	1.35	1.33	1.41	1.36	1.34	1.32	1.40	1.35
S_3	1.32	1.28	1.37	1.32	1.36	1.32	1.40	1.36	1.34	1.30	1.39	1.34
S_4	1.32	1.26	1.39	1.32	1.33	1.31	1.41	1.35	1.32	1.28	1.40	1.34
S_5	1.36	1.31	1.42	1.36	1.38	1.37	1.46	1.40	1.37	1.34	1.44	1.38
MEAN	1.34	1.30	1.40		1.36	1.34	1.42		1.35	1.32	1.41	
$CD_{0.05}$ for S : 0.04					$CD_{0.05}$ for S : NS				$CD_{0.05}$ for S : NS			
$CD_{0.05}$ for M : 0.03					$CD_{0.05}$ for M : 0.05				$CD_{0.05}$ for M : 0.04			
$CD_{0.05}$ for SxM : NS					$CD_{0.05}$ for SxM : NS				$CD_{0.05}$ for SxM : NS			

4.1.5.5 Magnesium

It is evident from the data given in Table 35(a) that plant growth promoting rhizobacteria and their application methods had significantly influenced the leaf magnesium content of strawberry cultivar Chandler. The pooled values given in Table 35(a) showed that the leaf magnesium content (0.332 %) was maximum in T_3 which was statistically at par with T_1, T_4, T_6, T_{13} and T_{15} (0.319, 0.312, 0.324, 0.316 and 0.327 %, respectively) whereas minimum (0.249 %) was recorded in T_{16}. A similar trend was observed during both the years of study. All the treatments were significantly at par with each other.

Table 35(a). Effect of plant growth promoting rhizobacteria on leaf magnesium content of strawberry cultivar Chandler

Treatments		Magnesium (%)		
		2013	2014	Pooled
T_1	S_1 + Root dip method	0.318	0.320	0.319
T_2	S_1+ Foliar application	0.302	0.307	0.305
T_3	S_1 + Root dip method + Foliar application	0.330	0.335	0.332
T_4	S_2+ Root dip method	0.311	0.314	0.312
T_5	S_2+ Foliar application	0.298	0.305	0.301
T_6	S_2 + Root dip method + Foliar application	0.320	0.327	0.324
T_7	S_3 + Root dip method	0.285	0.291	0.288
T_8	S_3+ Foliar application	0.270	0.281	0.275
T_9	S_3 + Root dip method + Foliar application	0.307	0.311	0.309
T_{10}	S_4+ Root dip method	0.301	0.302	0.301
T_{11}	S_4+ Foliar application	0.277	0.278	0.278
T_{12}	S_4 + Root dip method + Foliar application	0.306	0.314	0.310
T_{13}	S_5 + Root dip method	0.310	0.322	0.316
T_{14}	S_5+ Foliar application	0.280	0.286	0.283
T_{15}	S_5 + Root dip method + Foliar application	0.325	0.328	0.327
T_{16}	Control	0.247	0.251	0.249
$CD_{0.05}$		0.041	0.020	0.020

Table 35(b). Interaction effect of plant growth promoting rhizobacteria and their application methods on leaf magnesium content of strawberry cultivar Chandler

Treatment	Magnesium (%)											
	2013				2014				Pooled			
	M_1	M_2	M_3	MEAN	M_1	M_2	M_3	MEAN	M_1	M_2	M_3	MEAN
S_1	0.318	0.302	0.330	0.317	0.320	0.307	0.335	0.321	0.319	0.305	0.332	0.319
S_2	0.311	0.298	0.320	0.310	0.314	0.305	0.327	0.315	0.312	0.301	0.324	0.312
S_3	0.285	0.270	0.307	0.287	0.291	0.281	0.311	0.294	0.288	0.275	0.309	0.291
S_4	0.301	0.277	0.306	0.295	0.302	0.278	0.314	0.298	0.301	0.278	0.310	0.296
S_5	0.310	0.280	0.325	0.305	0.322	0.286	0.328	0.312	0.316	0.283	0.327	0.309
MEAN	0.305	0.286	0.318		0.310	0.291	0.323		0.307	0.288	0.320	
$CD_{0.05}$ for S : 0.020					$CD_{0.05}$ for S : 0.012				$CD_{0.05}$ for S : 0.014			
$CD_{0.05}$ for M : 0.016					$CD_{0.05}$ for M : 0.009				$CD_{0.05}$ for M : 0.011			
$CD_{0.05}$ for SxM : NS					$CD_{0.05}$ for SxM : NS				$CD_{0.05}$ for SxM : NS			

The data on interaction between plant growth promoting rhizobacteria and their application methods as presented in Table 35(b) had non- significant effect on leaf magnesium content of strawberry cultivar Chandler. However, maximum leaf magnesium content (0.332 %) was recorded from S_1M_3 and minimum (0.275 %) from S_3M_2 as pooled value. A similar trend was recorded during both the years of study except that leaf magnesium content was minimum (2.78 %) in S_4M_2 during 2014. Furthermore, among different rhizobacterial isolates, S_1 recorded to be most effective as it increased leaf magnesium content (0.319 %) and was statistically at par with S_2 and S_5 (0.312 and 0.309 % respectively), whereas M_3 was recorded to be most effective among their application methods. A similar trend was observed during both the years of study.

4.1.5.6 Zinc

The perusal of data presented in Table 36(a) and (b) reveals that plant growth promoting rhizobacteria had significant effect on leaf zinc content. The pooled values given in Table 36(a) reveals that the leaf zinc content ranged from low 17.94 to as high as 28.80 ppm. The highest leaf zinc content 28.80 ppm was recorded from T12 which was statistically at par with T_9 (28.21 ppm), whereas significantly lowest leaf zinc content (17.94 ppm) was recorded in control (T_{16}). During 2013, maximum leaf zinc content (27.85 ppm) was obtained from T_9 which was statistically at par with T_{12} (27.57 ppm), whereas the leaf zinc content was significantly highest in T_{12} (30.03 ppm) during 2014. The leaf zinc content was significantly lowest in T_{16} (17.58 and 18.30 ppm, respectively) during both the years of study. Other treatments had also shown significant increase in leaf zinc content in strawberry cultivar Chandler and were statistically at par with each other.

The data on interaction study between plant growth promoting rhizobacteria and their application methods had also shown significant effect on leaf zinc content as presented in Table 36(b). The pooled values showed that maximum leaf zinc content (28.80 ppm) was obtained from S_4M_3 and was statistically at par with S_3M_3 (28.21 ppm), whereas lowest leaf zinc content (21.95 ppm) was recorded from S_5M_1 which was statistically at par with S_1M_1 and S_4M_1 (22.59 and 22.40 ppm, respectively). During 2013, the maximum leaf zinc content was recorded from S_3M_3 (27.85 ppm) which was statistically at par with S_4M_3 (27.57 ppm), while lowest was recorded from S_4M_1 (21.54 ppm) which was statistically at par with S_1M_1, S_3M_1 and S_5M_1 (22.42, 22.27 and 21.67 ppm respectively). During 2014, highest leaf zinc content (30.03 ppm) was obtained from S_4M_3 which was statistically at par with S_2M_3 (28.95

ppm) whereas lowest (22.23 ppm) was recorded from S_5M_1 statistically at par with S_1M_1, S_3M_1 and S_4M_1 (22.77, 23.05 and 23.26 ppm, respectively).

Table 36(a). Effect of plant growth promoting rhizobacteria on leaf zinc content of strawberry cultivar Chandler

Treatments		Zinc (ppm)		
		2013	2014	Pooled
T_1	S_1 + Root dip method	22.42	22.77	22.59
T_2	S_1+ Foliar application	23.18	25.82	24.50
T_3	S_1 + Root dip method + Foliar application	25.02	26.60	25.81
T_4	S_2+ Root dip method	23.48	24.63	24.06
T_5	S_2+ Foliar application	25.25	27.17	26.21
T_6	S_2 + Root dip method + Foliar application	26.55	28.95	27.75
T_7	S_3 + Root dip method	22.27	23.05	22.66
T_8	S_3+ Foliar application	23.43	23.55	23.49
T_9	S_3 + Root dip method + Foliar application	27.85	28.57	28.21
T_{10}	S_4+ Root dip method	21.54	23.26	22.40
T_{11}	S_4+ Foliar application	22.76	24.84	23.80
T_{12}	S_4 + Root dip method + Foliar application	27.57	30.03	28.80
T_{13}	S_5 + Root dip method	21.67	22.23	21.95
T_{14}	S_5+ Foliar application	23.29	23.80	23.55
T_{15}	S_5 + Root dip method + Foliar application	25.08	25.66	25.37
T_{16}	Control	17.58	18.30	17.94
$CD_{0.05}$		1.08	1.06	0.74

Table 36(b). Interaction effect of plant growth promoting rhizobacteria and their application methods on leaf zinc content of strawberry cultivar Chandler

Treatment	Zinc (ppm)											
	2013				2014				Pooled			
	M_1	M_2	M_3	MEAN	M_1	M_2	M_3	MEAN	M_1	M_2	M_3	MEAN
S_1	22.42	23.18	25.02	23.54	22.77	25.82	26.60	25.06	22.59	24.50	25.81	24.30
S_2	23.48	25.25	26.55	25.09	24.63	27.17	28.95	26.91	24.06	26.21	27.75	26.00
S_3	22.27	23.43	27.85	24.52	23.05	23.55	28.57	25.05	22.66	23.49	28.21	24.79
S_4	21.54	22.76	27.57	23.96	23.26	24.84	30.03	26.04	22.40	23.80	28.80	25.00
S_5	21.67	23.29	25.08	23.35	22.23	23.80	25.66	23.90	21.95	23.55	25.37	23.62
MEAN	22.28	23.58	26.41		23.19	25.03	27.96		22.73	24.31	27.19	
$CD_{0.05}$ for S : 0.62					$CD_{0.05}$ for S : 0.59				$CD_{0.05}$ for S : 0.40			
$CD_{0.05}$ for M : 0.48					$CD_{0.05}$ for M : 0.46				$CD_{0.05}$ for M : 0.31			
$CD_{0.05}$ for SxM : 1.02					$CD_{0.05}$ for SxM : 1.08				$CD_{0.05}$ for SxM : 0.70			

Among different plant growth promoting rhizobacterial isolates under study, S_2 and root dip + foliar application method (M_3) among application methods were reported to be most effective in increasing leaf zinc content in strawberry during both the years of study.

4.1.5.7 Iron

The data pertaining to leaf iron content are presented in Table 37(a) and (b). The pooled data given in Table 37(a) showed the significant effect of plant growth promoting

rhizobacteria and their application methods in which leaf iron content (107.70 ppm) was significantly highest in T_{12} and lowest in T_{16} (75.93 ppm). A similar trend was recorded during both the years of study.

The values related to cummulative effect of plant growth promoting rhizobacteria and their application methods are presented in Table 37(b) which showed that the significantly highest leaf iron content (107.70 ppm) was obtained from S_4M_3 and lowest (82.81 ppm) from S_4M_2 treatment interaction and was statistically at par with S_3M_2 (82.95 ppm) as pooled values.

Table 37(a). Effect of plant growth promoting rhizobacteria on leaf iron content of strawberry cultivar Chandler

Treatments		Iron (ppm)		
		2013	2014	Pooled
T_1	S_1 + Root dip method	90.59	101.44	96.01
T_2	S_1+ Foliar application	83.77	84.78	84.28
T_3	S_1 + Root dip method + Foliar application	98.54	105.59	102.07
T_4	S_2+ Root dip method	84.56	91.46	88.01
T_5	S_2+ Foliar application	81.71	85.77	83.74
T_6	S_2 + Root dip method + Foliar application	90.95	101.12	96.03
T_7	S_3 + Root dip method	94.22	99.17	96.69
T_8	S_3+ Foliar application	82.20	83.69	82.95
T_9	S_3 + Root dip method + Foliar application	97.92	104.89	101.41
T_{10}	S_4+ Root dip method	84.77	96.45	90.61
T_{11}	S_4+ Foliar application	81.57	84.05	82.81
T_{12}	S_4 + Root dip method + Foliar application	100.59	114.80	107.70
T_{13}	S_5 + Root dip method	90.87	97.14	94.01
T_{14}	S_5+ Foliar application	83.19	85.04	84.12
T_{15}	S_5 + Root dip method + Foliar application	100.07	106.88	103.47
T_{16}	Control	74.44	77.41	75.93
$CD_{0.05}$		1.49	1.10	0.65

Table 37(b). Interaction effect of plant growth promoting rhizobacteria and their application methods on leaf iron content of strawberry cultivar Chandler

Treatment	Iron (ppm)											
	2013				2014				Pooled			
	M_1	M_2	M_3	MEAN	M_1	M_2	M_3	MEAN	M_1	M_2	M_3	MEAN
S_1	90.59	83.77	98.54	90.97	101.44	84.78	105.59	97.27	96.01	84.28	102.07	94.12
S_2	84.56	81.71	90.95	85.74	91.46	85.77	101.12	92.78	88.01	83.74	96.03	89.26
S_3	94.22	82.20	97.92	91.44	99.17	83.69	104.89	95.92	96.69	82.95	101.41	93.68
S_4	84.77	81.57	100.59	88.98	96.45	84.05	114.80	98.43	90.61	82.81	107.70	93.71
S_5	90.87	83.19	100.07	91.38	97.14	85.04	106.88	96.35	94.01	84.12	103.47	93.87
MEAN	89.00	82.49	97.61		97.13	84.67	106.66		93.07	83.58	102.14	
$CD_{0.05}$ for S : 0.75					$CD_{0.05}$ for S : 0.50				$CD_{0.05}$ for S : 0.36			
$CD_{0.05}$ for M : 0.58					$CD_{0.05}$ for M : 0.38				$CD_{0.05}$ for M : 0.28			
$CD_{0.05}$ for SxM : 1.30					$CD_{0.05}$ for SxM : 0.86				$CD_{0.05}$ for SxM : 0.62			

A similar trend was observed for maximum leaf iron content during both the years of study, but the minimum leaf iron content (81.57 ppm) was obtained from S_4M_2 statistically at par with S_2M_2 and S_3M_2 (81.71 and 82.20 ppm, respectively) during 2013 and 83.69 ppm leaf iron content was recorded from S_3M_2 during 2014 which was statistically at par with S_4M_2 (84.05 ppm). Among different strains under study, S_1 was recorded to be most effective in increasing leaf iron content (94.12 ppm) which was statistically at par with S_5 (93.87 ppm), but during 2013, S_3 (91.44 ppm) which was statistically at par with S_1 and S_5 (90.97 and 91.38 ppm respectively) and during 2014, S_4 was recorded as most effective isolates. Among their application methods, M_3 (root dip + foliar application method) was recorded as best method for application of plant growth promoting rhizobacteria. The leaf iron content was recorded to be lowest with the foliar application method (M_2).

4.1.5.8 Manganese

The data pertaining to leaf manganese content was given in Table 38(a) and (b). The significantly highest leaf manganese content (85.39 ppm) was recorded in T_3 and lowest in T_{16} (59.14 ppm) as presented in Table 38(a). A similar trend was observed during both the years of study. Other treatments had also increased the leaf manganese content significantly in strawberry as compared to control.

Table 38(a). Effect of plant growth promoting rhizobacteria on leaf manganese content of strawberry cultivar Chandler

Treatments		Manganese (ppm)		
		2013	2014	Pooled
T_1	S_1 + Root dip method	62.51	76.67	69.59
T_2	S_1+ Foliar application	66.97	85.57	76.27
T_3	S_1 + Root dip method + Foliar application	77.15	93.63	85.39
T_4	S_2+ Root dip method	60.22	61.80	61.01
T_5	S_2+ Foliar application	67.92	72.02	69.97
T_6	S_2 + Root dip method + Foliar application	75.63	79.40	77.52
T_7	S_3 + Root dip method	63.25	64.48	63.87
T_8	S_3+ Foliar application	67.02	81.06	74.04
T_9	S_3 + Root dip method + Foliar application	73.14	89.47	81.30
T_{10}	S_4+ Root dip method	65.50	70.42	67.96
T_{11}	S_4+ Foliar application	69.51	76.12	72.82
T_{12}	S_4 + Root dip method + Foliar application	74.36	80.84	77.60
T_{13}	S_5 + Root dip method	65.82	66.26	66.04
T_{14}	S_5+ Foliar application	69.47	74.21	71.84
T_{15}	S_5 + Root dip method + Foliar application	76.44	81.29	78.86
T_{16}	Control	57.27	61.00	59.14
$CD_{0.05}$		1.20	1.37	0.71

Table 38(b). Interaction effect of plant growth promoting rhizobacteria and their application methods on leaf manganese content of strawberry cultivar Chandler

Treatment	Manganese (ppm)											
	2013				2014				Pooled			
	M_1	M_2	M_3	MEAN	M_1	M_2	M_3	MEAN	M_1	M_2	M_3	MEAN
S_1	62.51	66.97	77.15	68.88	76.67	85.57	93.63	85.29	69.59	76.27	85.39	77.08
S_2	60.22	67.92	75.63	67.92	61.80	72.02	79.40	71.07	61.01	69.97	77.52	69.50
S_3	63.25	67.02	73.14	67.80	64.48	81.06	89.47	78.34	63.87	74.04	81.30	73.07
S_4	65.50	69.51	74.36	69.79	70.42	76.12	80.84	75.79	67.96	72.82	77.60	72.79
S_5	65.82	69.47	76.44	70.58	66.26	74.21	81.29	73.92	66.04	71.84	78.86	72.25
MEAN	63.46	68.18	75.34		67.93	77.80	84.93		65.69	72.99	80.13	
$CD_{0.05}$ for S : 0.61					$CD_{0.05}$ for S : 0.47				$CD_{0.05}$ for S : 0.35			
$CD_{0.05}$ for M : 0.47					$CD_{0.05}$ for M : 0.37				$CD_{0.05}$ for M : 0.27			
$CD_{0.05}$ for SxM : 1.06					$CD_{0.05}$ for SxM : 0.82				$CD_{0.05}$ for SxM : 0.61			

The pooled values for the interaction effect between plant growth promoting rhizobacteria and their application methods as presented in Table 38(b) had shown significant effect on leaf manganese content. The pooled value for leaf manganese content (85.39 ppm) was significantly highest in S_1M_3 and lowest in S_2M_1 (61.01 ppm) treatment interactions. A similar trend was recorded for both the years under study. Among different isolates of PGPR, S_1 (77.08 ppm) was observed to be most effective isolate as pooled value and a similar trend was observed during 2014. But during 2013, S_5 (70.58 ppm) was recorded to be most effective isolate. Among their application methods, M_3 (root dip + foliar application method) was observed to be best method.

4.1.5.9 Copper

The inquisition of data given in Table 39(a) and (b) revealed significant effect of plant growth promoting rhizobacteria and their application method on leaf copper content of strawberry cultivar Chandler. The maximum pooled value for leaf copper content (6.75 ppm) was recorded from T_6 which was statistically at par with T_9 and T_{12} (6.69 and 6.73 ppm, respectively), while minimum (5.22 ppm) was obtained from T_{16} as presented in Table 39(a). During 2013, the leaf copper content (6.44 ppm) was significantly highest in T_{12}, while it was highest in T_6 (7.61 ppm) during 2014 which was statistically at par with T_9 (7.45 ppm). The leaf content was lowest in T_{16} during both the years of study.

The interaction study between plant growth promoting rhizobacteria and their application methods had shown significant effect on leaf copper content of strawberry cultivar Chandler as presented in Table 39(b). The pooled values has shown that the

Table 39(a). Effect of plant growth promoting rhizobacteria on leaf copper content of strawberry cultivar Chandler

Treatments		Copper (ppm)		
		2013	2014	Pooled
T_1	S_1 + Root dip method	5.24	5.54	5.39
T_2	S_1+ Foliar application	5.37	5.79	5.58
T_3	S_1 + Root dip method + Foliar application	5.77	6.74	6.26
T_4	S_2+ Root dip method	5.64	6.36	6.00
T_5	S_2+ Foliar application	5.84	6.53	6.18
T_6	S_2 + Root dip method + Foliar application	5.89	7.61	6.75
T_7	S_3 + Root dip method	5.33	5.81	5.57
T_8	S_3+ Foliar application	5.54	6.20	5.87
T_9	S_3 + Root dip method + Foliar application	5.94	7.45	6.69
T_{10}	S_4+ Root dip method	5.42	5.59	5.50
T_{11}	S_4+ Foliar application	6.27	6.36	6.32
T_{12}	S_4 + Root dip method + Foliar application	6.44	7.02	6.73
T_{13}	S_5 + Root dip method	5.85	5.98	5.92
T_{14}	S_5+ Foliar application	5.98	6.42	6.20
T_{15}	S_5 + Root dip method + Foliar application	6.06	6.65	6.36
T_{16}	Control	5.18	5.27	5.22
$CD_{0.05}$		0.14	0.16	0.08

Table 39(b). Interaction effect of plant growth promoting rhizobacteria and their application methods on leaf copper content of strawberry cultivar Chandler

Treatment	Copper (ppm)											
	2013				2014				Pooled			
	M_1	M_2	M_3	MEAN	M_1	M_2	M_3	MEAN	M_1	M_2	M_3	MEAN
S_1	5.24	5.37	5.77	5.46	5.54	5.79	6.74	6.02	5.39	5.58	6.26	5.74
S_2	5.64	5.84	5.89	5.79	6.36	6.53	7.61	6.83	6.00	6.18	6.75	6.31
S_3	5.33	5.54	5.94	5.60	5.81	6.20	7.45	6.49	5.57	5.87	6.69	6.04
S_4	5.42	6.27	6.44	6.04	5.59	6.36	7.02	6.32	5.50	6.32	6.73	6.18
S_5	5.85	5.98	6.06	5.97	5.98	6.42	6.65	6.35	5.92	6.20	6.36	6.16
MEAN	5.49	5.80	6.02		5.86	6.26	7.09		5.68	6.03	6.56	
$CD_{0.05}$ for S : 0.08					$CD_{0.05}$ for S : 0.10				$CD_{0.05}$ for S : 0.05			
$CD_{0.05}$ for M : 0.06					$CD_{0.05}$ for M : 0.08				$CD_{0.05}$ for M : 0.04			
$CD_{0.05}$ for SxM : 0.14					$CD_{0.05}$ for SxM : 0.18				$CD_{0.05}$ for SxM : 0.09			

maximum leaf copper content (6.75 ppm) was recorded in S_2M_3 which was statistically at par with S_3M_3 and S_4M_3 (6.69 and 6.73 ppm, respectively) while minimum was recorded in S_1M_1 (5.39 ppm). A similar trend was observed during 2014, whereas the leaf copper content (6.44 ppm) was significantly highest in S_4M_3 during 2013. The overall effect of S_2 was recorded to be best for increased leaf copper content (6.31 ppm) in strawberry among different plant growth promoting isolates under study and, a similar trend was recorded during 2014 but during 2013, S_4 (6.04 ppm) was found to be most effective. Among application methods, M_3

(root dip + foliar application) was found to be best method followed by M_2 (foliar application method) during both the years of study.

4.1.6 Soil properties

4.1.6.1 Soil pH

The data pertain to soil pH revealed that soil pH was remained in neutral range with all the treatments during both the years of study. Pooled data given in Table 40(a) showed the significant effect of plant growth promoting rhizobacteria on soil pH, whereas the effect was non-significant during both the years of study. Furthermore, pooled data revealed that maximum soil pH (7.61) was recorded in T_{16} which was statistically at par with T_5, T_7, T_8, T_{10}, T_{11} and T_{14} recording soil pH 7.30, 7.30, 7.42, 7.39, 7.52 and 7.31, respectively, while minimum soil pH (7.05) was recorded in T_3 which was statistically at par with all the treatments except T_8, T_{10}, T_{11} and T_{16}.

The interaction study between plant growth promoting rhizobacteria and their application methods also had non-significant effect on soil pH during both the years of study. However, the maximum soil pH (7.52) was recorded from S_4M_2 and minimum from S_1M_3 (7.05) as pooled value presented in Table 40(b). Furthermore, study has shown that the individual effect of plant growth promoting rhizobacteria and their application methods was

Table 40(a). Effect of plant growth promoting rhizobacteria on soil pH

Treatments		Soil pH		
		2013	2014	Pooled
T_1	S_1 + Root dip method	7.09	7.12	7.10
T_2	S_1+ Foliar application	7.26	7.29	7.28
T_3	S_1 + Root dip method + Foliar application	7.02	7.07	7.05
T_4	S_2+ Root dip method	7.15	7.18	7.17
T_5	S_2+ Foliar application	7.28	7.31	7.30
T_6	S_2 + Root dip method + Foliar application	7.08	7.10	7.09
T_7	S_3 + Root dip method	7.25	7.35	7.30
T_8	S_3+ Foliar application	7.41	7.43	7.42
T_9	S_3 + Root dip method + Foliar application	7.18	7.26	7.22
T_{10}	S_4+ Root dip method	7.38	7.41	7.39
T_{11}	S_4+ Foliar application	7.51	7.53	7.52
T_{12}	S_4 + Root dip method + Foliar application	7.17	7.21	7.19
T_{13}	S_5 + Root dip method	7.24	7.26	7.25
T_{14}	S_5+ Foliar application	7.28	7.34	7.31
T_{15}	S_5 + Root dip method + Foliar application	7.03	7.08	7.06
T_{16}	Control	7.60	7.62	7.61
$CD_{0.05}$		NS	NS	0.31

Table 40(b). Interaction effect of plant growth promoting rhizobacteria and their application methods on soil pH

Treatment	Soil pH											
	2013				2014				Pooled			
	M_1	M_2	M_3	MEAN	M_1	M_2	M_3	MEAN	M_1	M_2	M_3	MEAN
S_1	7.09	7.26	7.02	7.12	7.12	7.29	7.07	7.16	7.10	7.28	7.05	7.14
S_2	7.15	7.28	7.08	7.17	7.18	7.31	7.10	7.20	7.17	7.30	7.09	7.19
S_3	7.25	7.41	7.18	7.28	7.35	7.43	7.26	7.35	7.30	7.42	7.22	7.31
S_4	7.38	7.51	7.17	7.35	7.41	7.53	7.21	7.38	7.39	7.52	7.19	7.37
S_5	7.24	7.28	7.03	7.18	7.26	7.34	7.08	7.23	7.25	7.31	7.06	7.21
MEAN	7.22	7.35	7.10		7.26	7.38	7.15		7.24	7.37	7.12	
$CD_{0.05}$ for S : NS					$CD_{0.05}$ for S : 0.11				$CD_{0.05}$ for S : 0.15			
$CD_{0.05}$ for M : NS					$CD_{0.05}$ for M : 0.08				$CD_{0.05}$ for M : 0.12			
$CD_{0.05}$ for SxM : NS					$CD_{0.05}$ for SxM : NS				$CD_{0.05}$ for SxM : NS			

significant during 2014 while the effect was non-significant during 2013. However, the maximum soil pH was recorded from S_4 during both the years of study. The results further expressed that the soil pH was maximum when applied as foliar application method (M_2) while minimum when applied as root dip+ foliar application methods (M_3).

4.1.6.2 Electrical conductivity

The perusal of data presented in Table 41(a) indicates that different plant growth promoting rhizobacteria and their application methods had a significant influence on soil electrical conductivity during both the years of study. The pooled values revealed that maximum electrical conductivity (0.414 dSm^{-1}) was recorded from T_{15} which was statistically at par with T_3, T_6, T_7, T_8, T_9 and T_{12} (0.380, 0.398, 0.382, 0.374, 0.409 and 0.373 dSm^{-1}, respectively), whereas minimum electrical conductivity (0.274 dSm^{-1}) was recorded from T_{16}. The similar trend was observed during both the years of study.

The cummulative effect of plant growth promoting rhizobacteria and their application methods had shown non-significant effect on soil electrical conductivity as presented in Table 41(b). However, maximum soil electrical conductivity (0.414 dSm^{-1}) was recorded from S_5M_3 and minimum (0.337 dSm^{-1}) from S_2M_2. The individual effect of plant growth promoting rhizobacteria also had a non significant effect on soil electrical conductivity where, maximum soil electrical conductivity recorded from S_3 (0.388 dSm^{-1}) and minimum from S_4 (0.356 dSm^{-1}). The individual effect of application methods of plant growth promoting rhizobacteria found to be significant in which maximum soil electrical conductivity (0.395 dSm^{-1}) was recorded from root dip+ foliar application method (M_3)

followed by root dip method(M_1) (0.365 dSm^{-1}) and minimum (0.349 dSm^{-1}) was recorded from foliar application method.

Table 41(a). Effect of plant growth promoting rhizobacteria on soil electrical conductivity

Treatments		Electrical conductivity (dSm^{-1})		
		2013	2014	Pooled
T_1	S_1 + Root dip method	0.350	0.371	0.360
T_2	S_1+ Foliar application	0.349	0.354	0.351
T_3	S_1 + Root dip method + Foliar application	0.383	0.377	0.380
T_4	S_2+ Root dip method	0.357	0.362	0.359
T_5	S_2+ Foliar application	0.334	0.341	0.337
T_6	S_2 + Root dip method + Foliar application	0.387	0.408	0.398
T_7	S_3 + Root dip method	0.372	0.392	0.382
T_8	S_3+ Foliar application	0.371	0.376	0.374
T_9	S_3 + Root dip method + Foliar application	0.393	0.425	0.409
T_{10}	S_4+ Root dip method	0.339	0.374	0.357
T_{11}	S_4+ Foliar application	0.312	0.367	0.339
T_{12}	S_4 + Root dip method + Foliar application	0.368	0.379	0.373
T_{13}	S_5 + Root dip method	0.365	0.370	0.367
T_{14}	S_5+ Foliar application	0.327	0.362	0.345
T_{15}	S_5 + Root dip method + Foliar application	0.397	0.430	0.414
T_{16}	Control	0.263	0.285	0.274
$CD_{0.05}$		0.041	0.061	0.041

Table 41(b). Interaction effect of plant growth promoting rhizobacteria and their application methods on soil electrical conductivity

Treatment	Electrical conductivity (dSm^{-1})											
	2013				2014				Pooled			
	M_1	M_2	M_3	MEAN	M_1	M_2	M_3	MEAN	M_1	M_2	M_3	MEAN
S_1	0.350	0.349	0.383	0.361	0.371	0.354	0.377	0.367	0.360	0.351	0.380	0.364
S_2	0.357	0.334	0.387	0.359	0.362	0.341	0.408	0.370	0.359	0.337	0.398	0.365
S_3	0.372	0.371	0.393	0.379	0.392	0.376	0.425	0.398	0.382	0.374	0.409	0.388
S_4	0.339	0.312	0.368	0.339	0.374	0.367	0.379	0.373	0.357	0.339	0.373	0.356
S_5	0.365	0.327	0.397	0.363	0.370	0.362	0.430	0.387	0.367	0.345	0.414	0.375
MEAN	0.356	0.339	0.386		0.374	0.360	0.404		0.365	0.349	0.395	
$CD_{0.05}$ for S : NS					$CD_{0.05}$ for S : NS				$CD_{0.05}$ for S : NS			
$CD_{0.05}$ for M : 0.022					$CD_{0.05}$ for M : 0.025				$CD_{0.05}$ for M : 0.018			
$CD_{0.05}$ for SxM : NS					$CD_{0.05}$ for SxM : NS				$CD_{0.05}$ for SxM : NS			

4.1.6.3 Organic carbon

It is evident from the data given in Table 42 (a) and (b) that the different plant growth promoting rhizobacteria treatments had significant influence on the organic carbon content of the soil. Pooled data of both the years as presented in Table 42(a) shows that highest organic carbon content (1.47 %) was recorded in T_{16}, whereas minimum (0.72 %) was recorded in T_3 which was statistically at par with T_6 (0.75 %). A similar trend was recorded during both the

years of study except that during 2013, maximum organic carbon content (1.46 %) recorded in T_{16} was statistically at par with T_8, T_{10}, T_{11} and T_{14} (1.37, 1.34, 1.38 and 1.35 %, respectively) and the minimum organic carbon content recorded in T_3 (0.60 %) was statistically at par with T_6, T_9 and T_{15} (0.66, 0.71 and 0.64 %, respectively), while during 2014, maximum organic carbon content recorded in T_{16} (1.48 %) was statistically at par with T_8, T_{11} and T_{14} (1.40, 1.41 and 1.40 %, respectively) and minimum organic carbon content (0.84 %) was recorded from T_6 which was statistically at par with T_3 (0.85%).

Table 42(a). Effect of plant growth promoting rhizobacteria on soil organic carbon content

Treatments		Organic carbon (%)		
		2013	2014	Pooled
T_1	S_1 + Root dip method	0.95	1.17	1.06
T_2	S_1+ Foliar application	0.98	1.31	1.15
T_3	S_1 + Root dip method + Foliar application	0.60	0.85	0.72
T_4	S_2+ Root dip method	1.10	1.31	1.21
T_5	S_2+ Foliar application	1.28	1.37	1.33
T_6	S_2 + Root dip method + Foliar application	0.66	0.84	0.75
T_7	S_3 + Root dip method	1.18	1.15	1.17
T_8	S_3+ Foliar application	1.37	1.40	1.39
T_9	S_3 + Root dip method + Foliar application	0.71	1.06	0.89
T_{10}	S_4+ Root dip method	1.34	1.37	1.35
T_{11}	S_4+ Foliar application	1.38	1.41	1.40
T_{12}	S_4 + Root dip method + Foliar application	1.08	1.29	1.19
T_{13}	S_5 + Root dip method	1.14	1.31	1.22
T_{14}	S_5+ Foliar application	1.35	1.40	1.38
T_{15}	S_5 + Root dip method + Foliar application	0.64	1.05	0.85
T_{16}	Control	1.46	1.48	1.47
$CD_{0.05}$		0.12	0.08	0.06

Table 42(b). Interaction effect of plant growth promoting rhizobacteria and their application methods on soil organic content

Treatment	Organic carbon (%)											
	2013				2014				Pooled			
	M_1	M_2	M_3	MEAN	M_1	M_2	M_3	MEAN	M_1	M_2	M_3	MEAN
S_1	0.95	0.98	0.60	0.84	1.17	1.31	0.85	1.11	1.06	1.15	0.72	0.98
S_2	1.10	1.28	0.66	1.01	1.31	1.37	0.84	1.17	1.21	1.33	0.75	1.09
S_3	1.18	1.37	0.71	1.09	1.15	1.40	1.06	1.20	1.17	1.39	0.89	1.15
S_4	1.34	1.38	1.08	1.27	1.37	1.41	1.29	1.36	1.35	1.40	1.19	1.31
S_5	1.14	1.35	0.64	1.04	1.31	1.40	1.05	1.25	1.22	1.38	0.85	1.15
MEAN	1.14	1.28	0.74		1.26	1.38	1.02		1.20	1.33	0.88	
$CD_{0.05}$ for S : 0.06					$CD_{0.05}$ for S : 0.05				$CD_{0.05}$ for S : 0.04			
$CD_{0.05}$ for M : 0.05					$CD_{0.05}$ for M : 0.04				$CD_{0.05}$ for M : 0.03			
$CD_{0.05}$ for SxM : 0.11					$CD_{0.05}$ for SxM : 0.09				$CD_{0.05}$ for SxM : 0.07			

The pooled data on interaction study between plant growth promoting rhizobacteria and their application methods presented in Table 41(b) showed a significant effect on soil organic carbon content. The maximum organic carbon content (1.40 %) was recorded from S_4M_2 which was statistically at par with S_2M_2, S_3M_2, S_4M_1 and S_5M_2 (1.33, 1.39, 1.35 and 1.38 %, respectively), while minimum organic carbon content (0.72 %) was registered from S_1M_3 which was statistically at par with S_2M_3 (0.75 %). A similar trend was observed during both the years of study except that during 2014, minimum organic carbon content (0.84 %) was recorded from S_2M_3 which was statistically at par with S_1M_3 (0.85 %).

The individual effect of plant growth promoting rhizobacteria and their application methods was also significant as presented in Table 42(b) which revealed that among different plant growth promoting rhizobacterial isolates, significantly highest organic carbon content was recorded in plants inoculated with S_4 and lowest in plants inoculated with S_1 whereas, among application methods, maximum organic carbon content was recorded with M_2 (foliar application method) and minimum with M_3 (root dip + foliar application).

4.1.6.4 Available nitrogen

The data on the effects of different plant growth promoting rhizobacteria and their application methods are presented in Table 43(a) and (b). The pooled data given in Table 43(a) showed that the available nitrogen content (503.21 kg/ha) was significantly highest in T_6 and lowest in T_{16} (319.76 kg/ha). A similar pattern was observed during 2014, but the available nitrogen content (498.59 kg/ha) was highest in T_3 during 2013 which was statistically at par with T_6 (496.99 kg/ha). The available nitrogen content was significantly lowest in T_{16} during both the years of study.

The interaction values between plant growth promoting rhizobacteria and their application methods as presented in table 43(b) revealed that significantly highest available nitrogen content (503.21 kg/ha) was obtained from S_2M_3 and lowest from S_5M_2 (408.22 kg/ha) which was statistically at par with S_1M_2 (409.59 kg/ha). A similar trend was recorded during 2014 but the maximum available nitrogen content (498.59 kg/ha) was observed in S_1M_3 which was statistically at par with S_1M_3 (496.99 kg/ha). Among different plant growth promoting rhizobacteria, maximum available nitrogen content was recorded from S_2 (468.56 kg/ha) followed by S_3 (465.52 kg/ha) and M_3 (root dip+ foliar application method) was reported to be effective among application methods for increased nitrogen content (489.16

kg/ha) followed by M_2 (root dip method; 460.39 kg/ha). A similar trend was observed during both the years of study.

Table 43(a). Effect of plant growth promoting rhizobacteria on available soil nitrogen content

Treatments		Available nitrogen (kg/ha)		
		2013	2014	Pooled
T_1	S_1 + Root dip method	425.56	427.45	426.51
T_2	S_1+ Foliar application	402.13	417.05	409.59
T_3	S_1 + Root dip method + Foliar application	498.59	500.87	499.73
T_4	S_2+ Root dip method	457.57	478.51	468.04
T_5	S_2+ Foliar application	418.27	450.58	434.43
T_6	S_2 + Root dip method + Foliar application	496.99	509.42	503.21
T_7	S_3 + Root dip method	471.88	485.72	478.80
T_8	S_3+ Foliar application	409.29	436.45	422.87
T_9	S_3 + Root dip method + Foliar application	491.61	498.18	494.89
T_{10}	S_4+ Root dip method	451.90	489.17	470.54
T_{11}	S_4+ Foliar application	429.08	446.36	437.72
T_{12}	S_4 + Root dip method + Foliar application	470.98	494.47	482.73
T_{13}	S_5 + Root dip method	427.66	488.49	458.08
T_{14}	S_5+ Foliar application	401.20	415.23	408.22
T_{15}	S_5 + Root dip method + Foliar application	434.85	495.63	465.24
T_{16}	Control	309.46	330.06	319.76
$CD_{0.05}$		2.12	2.02	1.51

Table 43(b). Interaction effect of plant growth promoting rhizobacteria and their application methods on available soil nitrogen content

Treatment	Available nitrogen (kg/ha)											
	2013				2014				Pooled			
	M_1	M_2	M_3	MEAN	M_1	M_2	M_3	MEAN	M_1	M_2	M_3	MEAN
S_1	425.56	402.13	498.59	442.09	427.45	417.05	500.87	448.46	426.51	409.59	499.73	445.28
S_2	457.57	418.27	496.99	457.61	478.51	450.58	509.42	479.50	468.04	434.43	503.21	468.56
S_3	471.88	409.29	491.61	457.59	485.72	436.45	498.18	473.45	478.80	422.87	494.89	465.52
S_4	451.90	429.08	470.98	450.65	489.17	446.36	494.47	476.67	470.54	437.72	482.73	463.66
S_5	427.66	401.20	434.85	421.23	488.49	415.23	495.63	466.45	458.08	408.22	465.24	443.84
MEAN	446.91	411.99	478.60		473.87	433.13	499.72		460.39	422.56	489.16	
$CD_{0.05}$ for S : 1.25					$CD_{0.05}$ for S : 1.19				$CD_{0.05}$ for S : 0.90			
$CD_{0.05}$ for M : 0.97					$CD_{0.05}$ for M : 0.92				$CD_{0.05}$ for M : 0.70			
$CD_{0.05}$ for SxM : 2.16					$CD_{0.05}$ for SxM : 2.06				$CD_{0.05}$ for SxM : 1.56			

4.1.6.5 Available phosphorus

A perusal of data presented in Table 44(a) and (b) revealed that different plant growth promoting rhizobacteria treatments exerted a significant influence on the available phosphorus in soil during both the years of study. The pooled value for available soil phosphorus content (67.14 kg/ha) was significantly highest in T_3 and lowest in T_{16} (45.11 kg/ ha) as presented in Table 44(a). A similar trend was recorded during both the years of study.

Table 44(a). Effect of plant growth promoting rhizobacteria on available soil phosphorus content

Treatments		Available phosphorus (kg/ha)		
		2013	2014	Pooled
T_1	S_1 + Root dip method	57.62	58.48	58.05
T_2	S_1+ Foliar application	54.37	56.53	55.45
T_3	S_1 + Root dip method + Foliar application	66.77	67.51	67.14
T_4	S_2+ Root dip method	60.39	63.12	61.75
T_5	S_2+ Foliar application	56.23	60.03	58.13
T_6	S_2 + Root dip method + Foliar application	65.67	67.39	66.53
T_7	S_3 + Root dip method	62.16	64.02	63.09
T_8	S_3+ Foliar application	55.63	58.91	57.27
T_9	S_3 + Root dip method + Foliar application	65.37	66.63	66.00
T_{10}	S_4+ Root dip method	59.78	63.98	61.88
T_{11}	S_4+ Foliar application	57.23	59.53	58.38
T_{12}	S_4 + Root dip method + Foliar application	62.47	65.39	63.93
T_{13}	S_5 + Root dip method	58.12	64.65	61.39
T_{14}	S_5+ Foliar application	55.07	56.93	56.00
T_{15}	S_5 + Root dip method + Foliar application	60.04	66.61	63.33
T_{16}	Control	44.19	46.04	*45.11*
$CD_{0.05}$		0.57	0.55	*0.37*

Table 44(b). Interaction effect of plant growth promoting rhizobacteria and their application methods on available soil phosphorus content

Treatment	Available phosphorus (kg/ ha)											
	2013				2014				Pooled			
	M_1	M_2	M_3	MEAN	M_1	M_2	M_3	MEAN	M_1	M_2	M_3	MEAN
S_1	57.62	54.37	66.77	59.59	58.48	56.53	67.51	60.84	58.05	55.45	67.14	60.21
S_2	60.39	56.23	65.67	60.76	63.12	60.03	67.39	63.51	61.75	58.13	66.53	62.14
S_3	62.16	55.63	65.37	61.05	64.02	58.91	66.63	63.19	63.09	57.27	66.00	62.12
S_4	59.78	57.23	62.47	59.83	63.98	59.53	65.39	62.97	61.88	58.38	63.93	61.40
S_5	58.12	55.07	60.04	57.74	64.65	56.93	66.61	62.73	61.39	56.00	63.33	60.24
MEAN	59.61	55.71	64.06		62.85	58.38	66.71		61.23	57.05	65.39	
$CD_{0.05}$ for S : 0.33					$CD_{0.05}$ for S : 0.30				$CD_{0.05}$ for S : 0.20			
$CD_{0.05}$ for M : 0.26					$CD_{0.05}$ for M : 0.24				$CD_{0.05}$ for M : 0.15			
$CD_{0.05}$ for SxM : 0.58					$CD_{0.05}$ for SxM : 0.53				$CD_{0.05}$ for SxM : 0.34			

The values related to interaction effect between plant growth promoting rhizobacteria and their application methods presented in Table 44(b) revealed significant effect on available soil phosphorus content. The significantly highest available soil phosphorus content (67.14 kg/ ha) was recorded from S_1M_3 and lowest from S_1M_2 (55.45 kg/ ha). Again a similar trend was followed for interaction study during both the years of study. Among different rhizobacterial isolates, S_2 (62.14 kg/ ha) was observed to be most effective which was statistically at par with S_3 (62.12 kg/ ha), whereas M_3 (65.39 kg/ ha) was best among application methods. A similar trend was observed during both the years of study except that

S_3 (61.05 kg/ ha) was reported be most effective during 2013 statistically at par with S_2 (60.76 kg/ ha).

4.1.6.6 Available potassium

The data on available soil potassium content as influenced by plant growth promoting rhizobacteria and their application methods are presented in Table 45(a) and (b). The pooled data presented in Table 45(a) revealed that the available soil potassium (274.28 kg/ha) was significantly highest in T_9 and lowest available potassium content (159.49 kg/ha) was recorded from T_{16}. A similar trend was observed during both the years of study.

The cummulative study between plant growth promoting rhizobacteria and their application methods as presented in Table 45(b) revealed that maximum pooled value for available potassium content (274.28 kg/ha) was recorded from S_3M_3 and minimum (175.33 kg/ha) from S_4M_2 which was statistically at par with S_5M_2 (176.35 kg/ha). The pooled data have further revealed that S_3 (237.44 kg/ha) was best among different rhizobacterial isolates under study followed by S_1 (212.23 kg/ha). Among different application methods, M_3 (root dip + foliar application method) was recorded to be best in increasing available soil potassium (231.79 kg/ha) content followed by M_1 (root dip method; 211.62 kg/ha). A similar trend was observed during both the years of study.

Table 45(a). Effect of plant growth promoting rhizobacteria on available soil potassium content

Treatments		Available potassium (kg/ha)		
		2013	2014	Pooled
T_1	S_1 + Root dip method	187.07	224.14	205.61
T_2	S_1+ Foliar application	174.35	209.11	191.73
T_3	S_1 + Root dip method + Foliar application	218.17	260.53	239.35
T_4	S_2+ Root dip method	181.24	217.15	199.20
T_5	S_2+ Foliar application	169.84	203.64	186.74
T_6	S_2 + Root dip method + Foliar application	186.10	223.19	204.65
T_7	S_3 + Root dip method	205.35	246.39	225.87
T_8	S_3+ Foliar application	192.99	231.34	212.16
T_9	S_3 + Root dip method + Foliar application	249.55	299.00	274.28
T_{10}	S_4+ Root dip method	195.92	235.08	215.50
T_{11}	S_4+ Foliar application	159.41	191.24	175.33
T_{12}	S_4 + Root dip method + Foliar application	199.55	239.31	219.43
T_{13}	S_5 + Root dip method	192.75	231.12	211.94
T_{14}	S_5+ Foliar application	160.52	192.17	176.35
T_{15}	S_5 + Root dip method + Foliar application	201.45	241.00	221.23
T_{16}	Control	153.14	165.84	159.49
$CD_{0.05}$		2.63	2.37	1.82

Table 45(b). Interaction effect of plant growth promoting rhizobacteria and their application methods on available soil potassium content

Treatment	Available potassium (kg/ha)											
	2013				2014				Pooled			
	M_1	M_2	M_3	MEAN	M_1	M_2	M_3	MEAN	M_1	M_2	M_3	MEAN
S_1	187.07	174.35	218.17	193.20	224.14	209.11	260.53	231.26	205.61	191.73	239.35	212.23
S_2	181.24	169.84	186.10	179.06	217.15	203.64	223.19	214.66	199.20	186.74	204.65	196.86
S_3	205.35	192.99	249.55	215.96	246.39	231.34	299.00	258.91	225.87	212.16	274.28	237.44
S_4	195.92	159.41	199.55	184.96	235.08	191.24	239.31	221.88	215.50	175.33	219.43	203.42
S_5	192.75	160.52	201.45	184.91	231.12	192.17	241.00	221.43	211.94	176.35	221.23	203.17
MEAN	192.47	171.42	210.96		230.78	205.50	252.61		211.62	188.46	231.79	
$CD_{0.05}$ for S : 1.20					$CD_{0.05}$ for S : 1.38				$CD_{0.05}$ for S : 0.88			
$CD_{0.05}$ for M : 0.93					$CD_{0.05}$ for M : 1.07				$CD_{0.05}$ for M : 0.68			
$CD_{0.05}$ for SxM : 2.07					$CD_{0.05}$ for SxM : 2.39				$CD_{0.05}$ for SxM : 1.53			

4.1.6.7 Zinc

The data on the effect of plant growth promoting rhizobacteria and their application methods on DPTA extractable zinc are presented in Table 46(a) and (b). It is evident from the pooled data given in Table 46(a) that the impact of plant growth promoting rhizobacterial treatments was significant for zinc content in the soil. The highest zinc content (3.31 ppm) was observed in T_9 which was statistically at par with T_3, T_6, T_7, T_{13} and T_{15} recording 3.24, 3.22, 3.27, 3.17 and 3.26 ppm, respectively), whereas, the lowest zinc content (2.33 ppm) was recorded in T_{16}. A similar trend was observed during 2013 except that the maximum zinc content (3.30 ppm) recorded in T_9 was not statistically at par with T_6 and T_{13}. However, during 2014, the soil zinc content was highest (3.40 ppm) in T_{15} which was statistically at par with T_1, T_3, T_4, T_6, T_7, T_9 and T_{13} (3.22, 3.33, 3.25, 3.36, 3.29, 3.32 and 3.34 ppm, respectively)

The plant growth promoting rhizobacteria and their application methods interaction did not influence the soil zinc content significantly as presented in Table 46(b). The pooled data with respect to zinc content indicated that maximum soil zinc content (3.31 ppm) was found in S_3M_3 interaction and minimum in S_2M_2 (2.92 ppm). A similar trend was observed during 2013. However, the interaction between plant growth promoting rhizobacteria and their application methods had significant effect on soil zinc content during 2014, where the maximum zinc content (3.40 ppm) was recorded from S_5M_3 which was statistically at par with S_3M_3, S_2M_3 and S_3M_3 (3.33, 3.36 and 3.32 ppm, respectively) and minimum from S_2M_2 (2.97 ppm) which was statistically at par with S_5M_2 (3.05 ppm). Among different plant growth promoting rhizobacteria isolates under study, S_3 (3.20 ppm) was most effective during

2013, whereas S_5 (3.26 ppm) during 2014. M_3 was reported best application method followed by M_1.

Table 46(a). Effect of plant growth promoting rhizobacteria on soil zinc content of strawberry cultivar Chandler

Treatments		Zinc (ppm)		
		2013	2014	Pooled
T_1	S_1 + Root dip method	3.05	3.22	3.13
T_2	S_1+ Foliar application	2.96	3.07	3.01
T_3	S_1 + Root dip method + Foliar application	3.15	3.33	3.24
T_4	S_2+ Root dip method	2.91	3.25	3.08
T_5	S_2+ Foliar application	2.86	2.97	2.92
T_6	S_2 + Root dip method + Foliar application	3.08	3.36	3.22
T_7	S_3 + Root dip method	3.25	3.29	3.27
T_8	S_3+ Foliar application	3.05	3.14	3.10
T_9	S_3 + Root dip method + Foliar application	3.30	3.32	3.31
T_{10}	S_4+ Root dip method	3.01	3.08	3.04
T_{11}	S_4+ Foliar application	2.95	3.03	2.99
T_{12}	S_4 + Root dip method + Foliar application	3.05	3.18	3.11
T_{13}	S_5 + Root dip method	3.00	3.34	3.17
T_{14}	S_5+ Foliar application	2.94	3.05	3.00
T_{15}	S_5 + Root dip method + Foliar application	3.12	3.40	3.26
T_{16}	Control	2.23	2.42	2.33
$CD_{0.05}$		0.20	0.18	0.16

Table 46(b). Interaction effect of plant growth promoting rhizobacteria and their application methods on soil zinc content

Treatment	Zinc (ppm)											
	2013				2014				Pooled			
	M_1	M_2	M_3	MEAN	M_1	M_2	M_3	MEAN	M_1	M_2	M_3	MEAN
S_1	3.05	2.96	3.15	3.05	3.22	3.07	3.33	3.20	3.13	3.01	3.24	3.13
S_2	2.91	2.86	3.08	2.95	3.25	2.97	3.36	3.20	3.08	2.92	3.22	3.07
S_3	3.25	3.05	3.30	3.20	3.29	3.14	3.32	3.25	3.27	3.10	3.31	3.22
S_4	3.01	2.95	3.05	3.00	3.08	3.03	3.18	3.10	3.04	2.99	3.11	3.05
S_5	3.00	2.94	3.12	3.02	3.34	3.05	3.40	3.26	3.17	3.00	3.26	3.14
MEAN	3.04	2.95	3.14		3.24	3.05	3.32		3.14	3.00	3.23	
$CD_{0.05}$ for S : 0.10					$CD_{0.05}$ for S : 0.05				$CD_{0.05}$ for S : 0.06			
$CD_{0.05}$ for M : 0.08					$CD_{0.05}$ for M : 0.04				$CD_{0.05}$ for M : 0.04			
$CD_{0.05}$ for SxM : NS					$CD_{0.05}$ for SxM : 0.08				$CD_{0.05}$ for SxM : NS			

4.1.6.8 Iron

The perusal of data given in Table 47(a) and (b) reveals that different plant growth promoting rhizobacteria and their application methods significantly influenced the soil iron content. The pooled data expressed that plant growth promoting rhizobacteria has produced significantly highest soil iron content in T_6 (99.60 ppm) and lowest in T_{16} (43.82 ppm). A

similar trend was recorded during 2014, whereas during 2013, the soil iron content was maximum in T_9 (87.68 ppm) which was statistically at par with T_{12} (86.45 ppm).

Table 47(a). Effect of plant growth promoting rhizobacteria on soil iron content

Treatments		Iron (ppm)		
		2013	2014	Pooled
T_1	S_1 + Root dip method	78.76	91.16	84.96
T_2	S_1+ Foliar application	69.72	80.42	75.07
T_3	S_1 + Root dip method + Foliar application	83.87	105.39	94.63
T_4	S_2+ Root dip method	71.43	106.21	88.82
T_5	S_2+ Foliar application	54.88	102.43	78.65
T_6	S_2 + Root dip method + Foliar application	79.30	119.90	99.60
T_7	S_3 + Root dip method	82.95	96.89	89.92
T_8	S_3+ Foliar application	71.50	87.73	79.62
T_9	S_3 + Root dip method + Foliar application	87.68	99.44	93.56
T_{10}	S_4+ Root dip method	77.52	99.24	88.38
T_{11}	S_4+ Foliar application	75.40	93.92	84.66
T_{12}	S_4 + Root dip method + Foliar application	86.45	106.43	96.44
T_{13}	S_5 + Root dip method	77.32	100.32	88.82
T_{14}	S_5+ Foliar application	70.22	90.56	80.39
T_{15}	S_5 + Root dip method + Foliar application	81.26	115.15	98.21
T_{16}	Control	39.97	47.66	43.82
$CD_{0.05}$		2.10	2.12	1.35

Table 47(b). Interaction effect of plant growth promoting rhizobacteria and their application methods on soil iron content

Treatment	Iron (ppm)											
	2013				2014				Pooled			
	M_1	M_2	M_3	MEAN	M_1	M_2	M_3	MEAN	M_1	M_2	M_3	MEAN
S_1	78.76	69.72	83.87	77.45	91.16	80.42	105.39	92.32	84.96	75.07	94.63	84.89
S_2	71.43	54.88	79.30	68.53	106.21	102.43	119.90	109.51	88.82	78.65	99.60	89.02
S_3	82.95	71.50	87.68	80.71	96.89	87.73	99.44	94.69	89.92	79.62	93.56	87.70
S_4	77.52	75.40	86.45	79.79	99.24	93.92	106.43	99.86	88.38	84.66	96.44	89.83
S_5	77.32	70.22	81.26	76.27	100.32	90.56	115.15	102.01	88.82	80.39	98.21	89.14
MEAN	77.60	68.34	83.71		98.76	91.01	109.26		88.18	79.68	96.49	
$CD_{0.05}$ for S : 1.24					$CD_{0.05}$ for S : 1.26				$CD_{0.05}$ for S : 0.80			
$CD_{0.05}$ for M : 0.96					$CD_{0.05}$ for M : 0.97				$CD_{0.05}$ for M : 0.62			
$CD_{0.05}$ for SxM : 2.16					$CD_{0.05}$ for SxM : 2.18				$CD_{0.05}$ for SxM : 1.38			

The SxM interaction significantly influenced the soil iron content during both the years of study as presented Table 47(b). The pooled data with respect to soil iron content indicate that significantly highest iron content was recorded under S_2M_3 (99.60 ppm) and lowest was recorded under S_1M_2 (75.07 ppm). A similar trend was recorded during 2014 under study, whereas during 2013, highest iron content was recorded from S_3M_3 (87.68 ppm) statistically at par with S_4M_3 (86.45 ppm) and minimum from S_2M_2 (54.88 ppm). Among

different rhizobacterial isolates under study, S_4 (89.83 ppm) was observed to be most effective, however, S_3 (109.51 ppm) was most effective during 2013 and S_2 (80.71 ppm) during 2014. Among application methods under study, M_3 was reported to be best method followed by M_1 during both the years of study.

4.1.6.9 Copper

The data on the effect of plant growth promoting rhizobacteria and their application methods with respect to soil copper content are presented in Table 48(a) and (b). It is evident from the pooled data presented in Table 48(a) that different plant growth promoting rhizobacteria and their application methods had a significant effect on soil copper content. The maximum soil copper content (8.96 ppm) was registered in plants under T_3 which was significantly higher than other treatments, whereas it was minimum in T_{16} (3.92 ppm) as pooled value. A similar trend was observed during both the years of study.

The interaction between plant growth promoting rhizobacteria and their application methods also exerted a significant effect on soil copper content as presented in Table 48(b). The significantly highest copper content was recorded from S_1M_3 (8.96 ppm) and lowest from S_4M_2 (4.83 ppm). The data on interaction study also followed a similar trend during both the years of study. Among different isolates under study, S_1 was reported to be most effective followed by S_3 during both the years of study and M_3 followed by M_2 among application methods.

Table 48(a). Effect of plant growth promoting rhizobacteria on soil copper content

Treatments		Copper (ppm)		
		2013	2014	Pooled
T_1	S_1 + Root dip method	6.36	7.55	6.95
T_2	S_1+ Foliar application	5.63	5.92	5.78
T_3	S_1 + Root dip method + Foliar application	8.79	9.13	8.96
T_4	S_2+ Root dip method	5.62	6.03	5.82
T_5	S_2+ Foliar application	4.95	5.58	5.26
T_6	S_2 + Root dip method + Foliar application	6.11	7.40	6.76
T_7	S_3 + Root dip method	6.26	6.37	6.31
T_8	S_3+ Foliar application	5.57	5.96	5.77
T_9	S_3 + Root dip method + Foliar application	6.60	8.16	7.38
T_{10}	S_4+ Root dip method	4.97	5.51	5.24
T_{11}	S_4+ Foliar application	4.88	4.78	4.83
T_{12}	S_4 + Root dip method + Foliar application	6.80	8.16	7.48
T_{13}	S_5 + Root dip method	5.19	5.58	5.38
T_{14}	S_5+ Foliar application	5.05	5.46	5.26
T_{15}	S_5 + Root dip method + Foliar application	6.05	6.42	6.24
T_{16}	Control	3.96	3.87	3.92
$CD_{0.05}$		0.35	0.41	0.27

Table 48(b). Interaction effect of plant growth promoting rhizobacteria and their application methods on soil copper content

Treatment	Copper (ppm)											
	2013				2014				Pooled			
	M_1	M_2	M_3	MEAN	M_1	M_2	M_3	MEAN	M_1	M_2	M_3	MEAN
S_1	6.36	5.63	8.79	6.92	7.55	5.92	9.13	7.53	6.95	5.78	8.96	7.23
S_2	5.62	4.95	6.11	5.56	6.03	5.58	7.40	6.34	5.82	5.26	6.76	5.95
S_3	6.26	5.57	6.60	6.14	6.37	5.96	8.16	6.83	6.31	5.77	7.38	6.49
S_4	4.97	4.88	6.80	5.55	5.51	4.78	8.16	6.15	5.24	4.83	7.48	5.85
S_5	5.19	5.05	6.05	5.43	5.58	5.46	6.42	5.82	5.38	5.26	6.24	5.63
MEAN	5.68	5.22	6.87		6.21	5.54	7.86		5.94	5.38	7.36	
$CD_{0.05}$ for S : 0.21					$CD_{0.05}$ for S : 0.13				$CD_{0.05}$ for S : 0.11			
$CD_{0.05}$ for M : 0.16					$CD_{0.05}$ for M : 0.10				$CD_{0.05}$ for M : 0.09			
$CD_{0.05}$ for SxM : 0.36					$CD_{0.05}$ for SxM : 0.23				$CD_{0.05}$ for SxM : 0.20			

4.1.6.10 Manganese

The data with respect to soil manganese as influenced by plant growth promoting rhizobacteria and their application methods are presented in Table 49(a) and (b). From the pooled data given in Table 49(a), it is evident that manganese content was significantly highest in T_9 (54.54 ppm) and lowest in T_{16} (21.08 ppm). Other treatments also influenced the soil manganese content significantly as compared to the control. A similar trend was observed during 2013. However, during 2014, soil manganese content was highest in T_3 (58.73 ppm) which was statistically at par with T_{15} (57.35 ppm) and lowest in T_{16} (23.71 ppm).

Table 49(a). Effect of plant growth promoting rhizobacteria on soil manganese content

Treatments		Manganese (ppm)		
		2013	2014	Pooled
T_1	S_1 + Root dip method	32.63	48.35	40.49
T_2	S_1+ Foliar application	27.22	35.71	31.47
T_3	S_1 + Root dip method + Foliar application	35.60	58.73	47.17
T_4	S_2+ Root dip method	26.42	36.58	31.50
T_5	S_2+ Foliar application	23.19	31.44	27.32
T_6	S_2 + Root dip method + Foliar application	28.01	39.45	33.73
T_7	S_3 + Root dip method	37.93	38.16	38.05
T_8	S_3+ Foliar application	26.20	26.92	26.56
T_9	S_3 + Root dip method + Foliar application	53.36	55.72	54.54
T_{10}	S_4+ Root dip method	29.45	39.91	34.68
T_{11}	S_4+ Foliar application	28.16	36.04	32.10
T_{12}	S_4 + Root dip method + Foliar application	34.35	50.33	42.34
T_{13}	S_5 + Root dip method	37.17	36.42	36.80
T_{14}	S_5+ Foliar application	32.11	33.55	32.83
T_{15}	S_5 + Root dip method + Foliar application	39.58	57.35	48.46
T_{16}	Control	18.45	23.71	21.08
$CD_{0.05}$		1.78	1.63	1.39

Table 49(b). Interaction effect of plant growth promoting rhizobacteria and their application methods on soil manganese content

Treatment	Manganese (ppm)											
	2013				2014				Pooled			
	M_1	M_2	M_3	MEAN	M_1	M_2	M_3	MEAN	M_1	M_2	M_3	MEAN
S_1	32.63	27.22	35.60	31.82	48.35	35.71	58.73	47.60	40.49	31.47	47.17	39.71
S_2	26.42	23.19	28.01	25.87	36.58	31.44	39.45	35.82	31.50	27.32	33.73	30.85
S_3	37.93	26.20	53.36	39.16	38.16	26.92	55.72	40.27	38.05	26.56	54.54	39.71
S_4	29.45	28.16	34.35	30.65	39.91	36.04	50.33	42.09	34.68	32.10	42.34	36.37
S_5	37.17	32.11	39.58	36.29	36.42	33.55	57.35	42.44	36.80	32.83	48.46	39.36
MEAN	32.72	27.38	38.18		39.88	32.73	52.32		36.30	30.05	45.25	
$CD_{0.05}$ for S : 0.75					$CD_{0.05}$ for S : 0.71				$CD_{0.05}$ for S : 0.58			
$CD_{0.05}$ for M : 0.58					$CD_{0.05}$ for M : 0.55				$CD_{0.05}$ for M : 0.45			
$CD_{0.05}$ for SxM : 1.30					$CD_{0.05}$ for SxM : 1.22				$CD_{0.05}$ for SxM : 1.01			

It is evident from the Table 49(b) that the interaction between plant growth promoting rhizobacteria and their application methods had significant effect on soil manganese content. The pooled data reveals that the soil manganese content was significantly highest under S_3M_3 (54.54 ppm), whereas lowest was recorded under S_3M_2 (26.56 ppm). A similar trend was observed during 2013 for maximum value but the minimum manganese content was recorded from S_2M_3 (23.19 ppm). Whereas, during 2014, the maximum soil manganese content was recorded from S_1M_3 (58.73 ppm) and minimum from S_3M_2 (26.92 ppm). Furthermore, among different rhizobacterial isolates, S_1 and S_3 were reported to be best, and among application methods, M_3 (root dip + foliar application method) followed by M_1 was best during both the years of study.

4.1.7 Soil biological properties

4.1.7.1 Total rhizobacterial counts on nutrient agar

The rhizobacterial population increased significantly with the application of plant growth promoting rhizobacteria isolates as presented in Table 50(a) and (b). The perusal of data in Table 50(a) reveals that the highest rhizobacterial counts (242.72 x 10^5 cfu/g) were recorded in T_3 followed by T_6 (237.11 x 10^5 cfu/g), whereas minimum count (59.78 x 10^5 cfu/g) was recorded in T_{16}. A similar trend was observed during both the years of investigations.

Furthermore, the data on interaction study between plant growth promoting rhizobacteria and their application methods also reveals significant effect on rhizobacteria counts [Table 50(b)]. The highest rhizobacterial counts (242.72 x 10^5 cfu/g) were recorded under S_1M_3 while lowest counts (169.28 x 10^5 cfu/g) recorded under S_4M_2. The different

Table 50(a). Effect of plant growth promoting rhizobacteria on total rhizobacterial counts on nutrient agar

Treatments		Total rhizobacterial counts (x 10^5 cfu/ g soil)		
		2013	2014	Pooled
T_1	S_1 + Root dip method	203.89	221.89	212.89
T_2	S_1+ Foliar application	182.67	191.67	187.17
T_3	S_1 + Root dip method + Foliar application	232.33	253.11	242.72
T_4	S_2+ Root dip method	180.00	197.67	188.83
T_5	S_2+ Foliar application	167.33	187.22	177.28
T_6	S_2 + Root dip method + Foliar application	225.67	248.56	237.11
T_7	S_3 + Root dip method	175.00	192.56	183.78
T_8	S_3+ Foliar application	171.00	176.56	173.78
T_9	S_3 + Root dip method + Foliar application	196.33	217.11	206.72
T_{10}	S_4+ Root dip method	173.00	185.44	179.22
T_{11}	S_4+ Foliar application	165.00	173.56	169.28
T_{12}	S_4 + Root dip method + Foliar application	192.33	221.11	206.72
T_{13}	S_5 + Root dip method	175.33	198.55	186.94
T_{14}	S_5+ Foliar application	168.00	182.89	175.45
T_{15}	S_5 + Root dip method + Foliar application	211.00	234.22	222.61
T_{16}	Control	59.00	60.56	59.78
$CD_{0.05}$		1.45	2.06	1.43

Table 50(b). Interaction effect of plant growth promoting rhizobacteria and their application methods on total rhizobacterial count on nutrient agar

Treatment	Total rhizobacterial counts (x 10^5 cfu/ g soil)											
	2013				2014				Pooled			
	M_1	M_2	M_3	MEAN	M_1	M_2	M_3	MEAN	M_1	M_2	M_3	MEAN
S_1	203.89	182.67	232.33	206.30	221.89	191.67	253.11	222.22	212.89	187.17	242.72	214.26
S_2	180.00	167.33	225.67	191.00	197.67	187.22	248.56	211.15	188.83	177.28	237.11	201.07
S_3	175.00	171.00	196.33	180.78	192.56	176.56	217.11	195.41	183.78	173.78	206.72	188.09
S_4	173.00	165.00	192.33	176.78	185.44	173.56	221.11	193.37	179.22	169.28	206.72	185.07
S_5	175.33	168.00	211.00	184.78	198.55	182.89	234.22	205.22	186.94	175.45	222.61	195.00
MEAN	181.44	170.80	211.53		199.22	182.38	234.82		190.33	176.59	223.18	
$CD_{0.05}$ for S : 0.68					$CD_{0.05}$ for S : 1.11				$CD_{0.05}$ for S : 0.69			
$CD_{0.05}$ for M : 0.53					$CD_{0.05}$ for M : 0.86				$CD_{0.05}$ for M : 0.53			
$CD_{0.05}$ for SxM : 1.19					$CD_{0.05}$ for SxM : 1.92				$CD_{0.05}$ for SxM : 1.19			

isolates and their application methods under study also had significant effect when compared individually. Among different isolates, S_1 was reported to be most effective followed by S_2, whereas among application methods, M_3 followed by M_1 was reported to be best during both the years of study.

4.1.7.2 Total rhizobacterial counts on PVK medium

The data presented in Table 51(a) and (b) revealed that the plant growth promoting rhizobacteria and their application methods had a significant effect on rhizobacterial counts

on PVK medium. The pooled data presented in Table 51(a) showed that the highest rhizobacterial counts (208.08 x 10^5 cfu/g) were recorded in T_3 followed by T_6 (197.60 x 10^5 cfu/g), whereas the count was minimum in T_{16} (33.40 x 10^5 cfu/g). A similar trend was observed during both the years of study.

The values pertaining to cummulative effects of plant growth promoting rhizobacteria and their application methods presented in Table 51(b) reveals that the maximum pooled rhizobacterial count (208.08 x 10^5 cfu/g) was recorded from S_1M_3 followed by S_2M_3, whereas the minimum was recorded from S_4M_2 (122.24 x 10^5 cfu/g).

Table 51(a). Effect of plant growth promoting rhizobacteria on total rhizobacterial counts on Pikovskaya's (PVK) medium

Treatments		Total rhizobacterial counts (x 10^5 cfu/ g soil)		
		2013	2014	Pooled
T_1	S_1 + Root dip method	159.16	191.48	175.32
T_2	S_1+ Foliar application	134.85	172.79	153.82
T_3	S_1 + Root dip method + Foliar application	184.47	231.68	208.08
T_4	S_2+ Root dip method	150.59	171.05	160.82
T_5	S_2+ Foliar application	124.35	153.90	139.13
T_6	S_2 + Root dip method + Foliar application	177.63	217.58	197.60
T_7	S_3 + Root dip method	123.34	158.24	140.79
T_8	S_3+ Foliar application	110.24	137.37	123.81
T_9	S_3 + Root dip method + Foliar application	160.18	195.02	177.60
T_{10}	S_4+ Root dip method	122.85	162.45	142.65
T_{11}	S_4+ Foliar application	108.14	136.33	122.24
T_{12}	S_4 + Root dip method + Foliar application	161.19	194.02	177.60
T_{13}	S_5 + Root dip method	134.54	169.00	151.77
T_{14}	S_5+ Foliar application	122.69	146.62	134.66
T_{15}	S_5 + Root dip method + Foliar application	176.80	210.49	193.65
T_{16}	Control	32.31	34.49	33.40
$CD_{0.05}$		2.04	1.88	1.33

Table 51(b). Interaction effect of plant growth promoting rhizobacteria and their application methods on total rhizobacterial counts on Pikovskaya's (PVK) medium

Treatment	Total rhizobacterial counts (x 10^5 cfu/ g soil)											
	2013				2014				Pooled			
	M_1	M_2	M_3	MEAN	M_1	M_2	M_3	MEAN	M_1	M_2	M_3	MEAN
S_1	159.16	134.85	184.47	159.50	191.48	172.79	231.68	198.65	175.32	153.82	208.08	179.07
S_2	150.59	124.35	177.63	150.86	171.05	153.90	217.58	180.84	160.82	139.13	197.60	165.85
S_3	123.34	110.24	160.18	131.26	158.24	137.37	195.02	163.54	140.79	123.81	177.60	147.40
S_4	122.85	108.14	161.19	130.73	162.45	136.33	194.02	164.27	142.65	122.24	177.60	147.50
S_5	134.54	122.69	176.80	144.68	169.00	146.62	210.49	175.37	151.77	134.66	193.65	160.02
MEAN	138.10	120.06	172.06		170.44	149.40	209.76		154.27	134.73	190.91	
$CD_{0.05}$ for S : 1.13					$CD_{0.05}$ for S : 1.12				$CD_{0.05}$ for S : 0.76			
$CD_{0.05}$ for M : 0.88					$CD_{0.05}$ for M : 0.87				$CD_{0.05}$ for M : 0.59			
$CD_{0.05}$ for SxM : 1.96					$CD_{0.05}$ for SxM : 1.95				$CD_{0.05}$ for SxM : 1.32			

The data on individual effect of different strains and their application methods presented in Table 51(b) showed a significant increase in rhizobacterial counts on PVK medium as the maximum rhizobacteria was obtained under S_1 (179.07 x 10^5 cfu/g) followed by S_2 (165.85 x 10^5 cfu/g), whereas minimum was noted under S_3 (147.40 x 10^5 cfu/g) which was statistically at par with S_4 (147.50 x 10^5 cfu/g). Among application methods, root dip + foliar application methods (M_3) was found to be best method followed by root dip (M_1).

4.1.7.3 Total rhizobacterial counts on CAS medium

The inoculation of plant growth promoting rhizobacteria by either root dip or foliar spray or conjoint application method had significant effect on the total rhizobacterial counts capable of growing on CAS medium [Table 52(a) and (b)]. It is evident from the data given in Table 52(a) that rhizobacterial count capable of growing on CAS medium was maximum in T_3 (60.82 x 10^4 cfu/g) followed by T_{12} (59.33 x 10^4 cfu/g), while minimum counts was recorded in T_{16} (31.64 x 10^4 cfu/g).

The interaction study of plant growth promoting rhizobacteria and their application methods showed significant effect on rhizobacterial count on CAS medium [Table 52(b)]. The pooled data given in this table reveals that the rhizobacterial count was maximum in S_1M_3 (60.82 x 10^4 cfu/g) followed by S_4M_3 (59.33 x 10^4 cfu/g), whereas minimum was in

Table 52(a). Effect of plant growth promoting rhizobacteria on total rhizobacterial counts on Chromeazurol-S (CAS) medium

Treatments		Total rhizobacterial counts (x 10^4 cfu/g soil)		
		2013	2014	Pooled
T_1	S_1 + Root dip method	51.68	59.68	55.68
T_2	S_1+ Foliar application	34.10	40.94	37.52
T_3	S_1 + Root dip method + Foliar application	59.90	61.73	60.82
T_4	S_2+ Root dip method	40.88	51.09	45.99
T_5	S_2+ Foliar application	32.61	38.06	35.34
T_6	S_2 + Root dip method + Foliar application	54.44	55.49	54.96
T_7	S_3 + Root dip method	35.77	43.42	39.59
T_8	S_3+ Foliar application	32.07	34.71	33.39
T_9	S_3 + Root dip method + Foliar application	52.18	56.85	54.52
T_{10}	S_4+ Root dip method	37.85	47.72	42.79
T_{11}	S_4+ Foliar application	34.23	39.87	37.05
T_{12}	S_4 + Root dip method + Foliar application	59.12	59.55	59.33
T_{13}	S_5 + Root dip method	39.51	49.53	44.52
T_{14}	S_5+ Foliar application	34.83	37.18	36.01
T_{15}	S_5 + Root dip method + Foliar application	57.42	56.78	57.10
T_{16}	Control	30.67	32.61	31.64
$CD_{0.05}$		1.90	1.84	1.18

Table 52(b). Interaction effect of plant growth promoting rhizobacteria and their application methods on total rhizobacterial counts on Chromeazurol-S (CAS) medium

Treatment	Total rhizobacterial counts (x 10^4 cfu/g soil)											
	2013				2014				Pooled			
	M_1	M_2	M_3	MEAN	M_1	M_2	M_3	MEAN	M_1	M_2	M_3	MEAN
S_1	51.68	34.10	59.90	48.56	59.68	40.94	61.73	54.12	55.68	37.52	60.82	51.34
S_2	40.88	32.61	54.44	42.64	51.09	38.06	55.49	48.21	45.99	35.34	54.96	45.43
S_3	35.77	32.07	52.18	40.01	43.42	34.71	56.85	44.99	40.65	34.47	54.52	42.50
S_4	37.85	34.23	59.12	43.74	47.72	39.87	59.55	49.05	41.08	35.97	59.33	46.39
S_5	39.51	34.83	57.42	43.92	49.53	37.18	56.78	47.83	44.52	36.01	57.10	45.88
MEAN	41.14	33.57	56.61		50.29	38.15	58.08		45.71	35.86	57.35	
$CD_{0.05}$ for S : 1.13					$CD_{0.05}$ for S : 1.04				$CD_{0.05}$ for S : 0.67			
$CD_{0.05}$ for M : 0.88					$CD_{0.05}$ for M : 0.81				$CD_{0.05}$ for M : 0.52			
$CD_{0.05}$ for SxM : 1.96					$CD_{0.05}$ for SxM : 1.80				$CD_{0.05}$ for SxM : 1.17			

S_3M_2 (34.47 x 10^4 cfu/g). Among different isolates under study, the isolate S_1 (51.34 x 10^4 cfu/g) was reported to be most effective while S_3 isolate (42.50 x 10^4 cfu/g) was least effective. Among their application methods, M_3 (57.35 x 10^4 cfu/g) was most efficient method. A similar trend was recorded during both the years of study.

4.1.7.4 Total rhizobacterial counts on Jensen's medium

The inquisition of data presented in Table 53(a) and (b) reveals that the plant growth promoting rhizobacteria and their application methods had a significant effect on rhizobacterial count on Jensen's medium. The pooled data presented in Table 53(a) showed that the maximum rhizobacterial count was obtained in T_3 (204.34 x 10^5 cfu/g) followed by T_6 (194.29 x 10^5 cfu/g), whereas the minimum was obtained from T_{16} (30.67 x 10^5 cfu/g). A similar trend was observed during both the years of study except that during 2014, maximum rhizobacterial count (219.72 x 10^5 cfu/g) under T_3 was followed by T_{15} (204.83 x 10^5 cfu/g).

The data related to cummulative effect of plant growth promoting rhizobacteria and their application methods as presented in Table 53(b) expressed that the maximum rhizobacterial count (204.34 x 10^5 cfu/g) on Jensen's medium was recorded for S_1M_3 followed by S_2M_3 (194.29 x 10^5 cfu/g) whereas minimum was noted in S_4M_2 (122.73 x 10^5 cfu/g). A similar trend was observed during both the years of study except that during 2014, the maximum rhizobacterial count (219.72 cfu/g) obtained from S_1M_3 was followed by S_5M_3 (204.83 x 10^5 cfu/g). The results further showed that the S_1 (169.92 x 10^5 cfu/g) was best isolate which had produced maximum rhizobacterial count than other isolates under study followed by S_2 (161.25 x 10^5 cfu/g) and minimum was obtained from S_3 (149.37 x 10^5 cfu/g).

Table 53(a). Effect of plant growth promoting rhizobacteria on total rhizobacterial count on Jensen's medium

Treatments		Total rhizobacterial counts (x 10^5 cfu/ g soil)		
		2013	2014	Pooled
T_1	S_1 + Root dip method	146.70	184.92	165.81
T_2	S_1+ Foliar application	121.68	157.56	139.62
T_3	S_1 + Root dip method + Foliar application	188.96	219.72	204.34
T_4	S_2+ Root dip method	148.91	162.54	155.72
T_5	S_2+ Foliar application	120.16	147.30	133.73
T_6	S_2 + Root dip method + Foliar application	186.92	201.65	194.29
T_7	S_3 + Root dip method	133.20	157.24	145.22
T_8	S_3+ Foliar application	118.30	135.26	126.78
T_9	S_3 + Root dip method + Foliar application	160.58	191.64	176.11
T_{10}	S_4+ Root dip method	133.47	158.33	145.90
T_{11}	S_4+ Foliar application	116.36	129.10	122.73
T_{12}	S_4 + Root dip method + Foliar application	170.98	196.12	183.55
T_{13}	S_5 + Root dip method	139.66	159.85	149.75
T_{14}	S_5+ Foliar application	119.73	140.92	130.32
T_{15}	S_5 + Root dip method + Foliar application	180.81	204.83	192.82
T_{16}	Control	28.09	33.25	30.67
$CD_{0.05}$		1.72	2.04	1.33

Table 53(b). Interaction effect of plant growth promoting rhizobacteria and their application methods on total rhizobacterial count Jensen's medium

Treatment	Total rhizobacterial counts (x 10^5 cfu/ g soil)											
	2013				2014				Pooled			
	M_1	M_2	M_3	MEAN	M_1	M_2	M_3	MEAN	M_1	M_2	M_3	MEAN
S_1	146.70	121.68	188.96	152.45	184.92	157.56	219.72	187.40	165.81	139.62	204.34	169.92
S_2	148.91	120.16	186.92	152.00	162.54	147.30	201.65	170.50	155.72	133.73	194.29	161.25
S_3	133.20	118.30	160.58	137.36	157.24	135.26	191.64	161.38	145.22	126.78	176.11	149.37
S_4	133.47	116.36	170.98	140.27	158.33	129.10	196.12	161.18	145.90	122.73	183.55	150.73
S_5	139.66	119.73	180.81	146.73	159.85	140.92	204.83	168.53	149.75	130.32	192.82	157.63
MEAN	140.39	119.25	177.65		164.58	142.03	202.79		152.48	130.64	190.22	
$CD_{0.05}$ for S : 0.86					$CD_{0.05}$ for S : 1.20				$CD_{0.05}$ for S : 0.72			
$CD_{0.05}$ for M : 0.66					$CD_{0.05}$ for M : 0.93				$CD_{0.05}$ for M : 0.56			
$CD_{0.05}$ for SxM : 1.49					$CD_{0.05}$ for SxM : 2.07				$CD_{0.05}$ for SxM : 1.25			

Among application methods, M_3 (root dip + foliar application method) was recorded to be best followed by M_1 (root dip method) during both the years of study.

4.1.7.5 Per cent phosphate solubilizing bacteria

It is evident from the data depicted in Table 54(a) and (b) that plant growth promoting rhizobacteria and their application methods had a significant effect on per cent phosphate solubilizing bacteria harbouring in rhizosphere of strawberry cultivar Chandler. The pooled data given in Table 54(a) revealed that the maximum phosphate solubilizing bacteria (92.70

%) was recorded in T_3, which was significantly highest among all other treatments under study followed by T_{15} (91.52 %), whereas minimum was recorded under T_{16} (32.49 %).

The data on interaction study of plant growth promoting rhizobacteria and their application methods as presented in Table 54(b) also reveals that the significantly highest

Table 54(a). Effect of plant growth promoting rhizobacteria on phosphate solubilizing bacteria associated with strawberry cultivar Chandler

Treatments		Per cent phosphate solubilizing bacteria (%)		
		2013	2014	Pooled
T_1	S_1 + Root dip method	85.33(67.49)	90.75(72.30)	88.04(69.77)
T_2	S_1+ Foliar application	80.17(63.54)	87.83(69.59)	84.00(66.41)
T_3	S_1 + Root dip method + Foliar application	89.76(71.36)	95.65(78.21)	92.70(74.41)
T_4	S_2+ Root dip method	80.85(64.04)	89.59(71.16)	85.22(67.38)
T_5	S_2+ Foliar application	79.62(63.15)	83.42(65.95)	81.52(64.52)
T_6	S_2 + Root dip method + Foliar application	86.44(68.38)	93.55(75.31)	90.00(71.55)
T_7	S_3 + Root dip method	76.86(61.23)	90.67(72.22)	83.76(66.22)
T_8	S_3+ Foliar application	74.91(59.92)	82.67(65.38)	78.79(62.56)
T_9	S_3 + Root dip method + Foliar application	83.67(66.15)	94.00(75.92)	88.83(70.49)
T_{10}	S_4+ Root dip method	74.67(59.76)	88.22(69.91)	81.45(64.46)
T_{11}	S_4+ Foliar application	73.00(58.67)	76.13(60.74)	74.57(59.69)
T_{12}	S_4 + Root dip method + Foliar application	81.67(64.63)	92.89(74.52)	87.28(69.09)
T_{13}	S_5 + Root dip method	80.20(63.57)	87.54(69.32)	83.87(66.31)
T_{14}	S_5+ Foliar application	79.52(63.08)	85.02(67.22)	82.27(65.08)
T_{15}	S_5 + Root dip method + Foliar application	88.15(69.84)	94.89(76.93)	91.52(73.05)
T_{16}	Control	31.49(34.11)	33.49(35.34)	32.49(34.73)
$CD_{0.05}$		0.74	1.18	0.76

Table 54(b). Interaction effect of plant growth promoting rhizobacteria and their application methods on phosphate solubilizing bacteria associated with strawberry cultivar Chandler

Treatment	Per cent phosphate solubilizing bacteria (%)											
	2013				2014				Pooled			
	M_1	M_2	M_3	MEAN	M_1	M_2	M_3	MEAN	M_1	M_2	M_3	MEAN
S_1	85.33 (9.24)	80.17 (8.95)	89.76 (9.47)	85.09 (9.22)	90.75 (9.53)	87.83 (9.37)	95.65 (9.78)	91.41 (9.56)	88.04 (9.38)	84.00 (9.16)	92.70 (9.63)	88.25 (9.39)
S_2	80.85 (8.99)	79.62 (8.92)	86.44 (9.30)	82.31 (9.07)	89.59 (9.46)	83.42 (9.13)	93.55 (9.67)	88.85 (9.42)	85.22 (9.23)	81.52 (9.03)	90.00 (9.48)	85.58 (9.25)
S_3	76.86 (8.77)	74.91 (8.65)	83.67 (9.15)	78.48 (8.86)	90.67 (9.52)	82.67 (9.09)	94.00 (9.69)	89.11 (9.44)	83.76 (9.14)	78.79 (8.87)	88.83 (9.42)	83.80 (9.15)
S_4	74.67 (8.64)	73.00 (8.54)	81.67 (9.04)	76.44 (8.74)	88.22 (9.39)	76.13 (8.72)	92.89 (9.64)	85.75 (9.25)	81.45 (9.02)	74.57 (8.63)	87.28 (9.34)	81.10 (9.00)
S_5	80.20 (8.96)	79.52 (8.92)	88.15 (9.39)	82.62 (9.09)	87.54 (9.36)	85.02 (9.22)	94.89 (9.74)	89.15 (9.44)	83.87 (9.16)	82.27 (9.07)	91.52 (9.56)	85.89 (9.26)
MEAN	79.58 (8.92)	77.44 (8.80)	85.94 (9.27)		89.35 (9.45)	83.02 (9.11)	94.20 (9.71)		84.47 (9.19)	80.23 (8.95)	90.07 (9.49)	
$CD_{0.05}$ for S : 0.027					$CD_{0.05}$ for S : 0.027				$CD_{0.05}$ for S : 0.021			
$CD_{0.05}$ for M : 0.021					$CD_{0.05}$ for M : 0.021				$CD_{0.05}$ for M : 0.016			
$CD_{0.05}$ for SxM : 0.047					$CD_{0.05}$ for SxM : 0.047				$CD_{0.05}$ for SxM : 0.037			

percentage of phosphate solubilizing rhizobacteria (92.70 %) was recorded in S_1M_3 followed by S_5M_3 (91.52 %), while the lowest under S_4M_2 (74.57 %). Among different isolates of plant growth promoting rhizobacteria, the isolate S_1 (88.25 %) was found to be best followed by S_5 (85.89 %) and S_2 (85.58 %), whereas per cent phosphate solubilizing bacteria (90.07 %) was highest when plant growth promoting rhizobacteria were applied as root dip+ foliar application method (M_3) followed by root dip method (M_1). A similar trend was observed during both the years of study.

4.1.7.6 Per cent siderophore producing bacteria

The pooled data with regard to per cent siderophore producing rhizobacteria presented in Table 55(a) reveals that the percentage of siderophore producing bacteria significantly increased by inoculation and the highest percentage was noted in T_3 (85.42 %), whereas percentage was lowest in T_{16} (32.23 %). A similar trend was observed during both the years of study.

The pooled data related to cummulative effect of plant growth promoting rhizobacteria isolates and their application methods on per cent siderophore producing bacteria is presented in Table 55(b) which revealed that the significantly higher per cent siderophore producing rhizobacteria (85.42 %) were recorded under S_1M_3 while the minimum percentage (65.98 %) was recorded from S_3M_2 treatment interaction.

Table 55(a). Effect of plant growth promoting rhizobacteria on siderophore producing bacteria associated with strawberry cultivar Chandler

Treatments		Per cent siderophore producing bacteria (%)		
		2013	2014	Pooled
T_1	S_1 + Root dip method	82.33 (65.13)	84.00 (66.42)	83.17 (65.77)
T_2	S_1+ Foliar application	81.00 (64.14)	81.83 (64.75)	81.42 (64.44)
T_3	S_1 + Root dip method + Foliar application	84.33 (66.70)	86.50 (68.51)	85.42 (67.59)
T_4	S_2+ Root dip method	79.58 (63.11)	80.74 (64.02)	80.16 (63.55)
T_5	S_2+ Foliar application	74.14 (59.41)	78.89 (62.64)	76.51 (60.99)
T_6	S_2 + Root dip method + Foliar application	80.80 (63.99)	85.46 (67.59)	83.13 (65.74)
T_7	S_3 + Root dip method	69.14 (56.23)	72.00 (58.03)	70.57 (57.13)
T_8	S_3+ Foliar application	64.26 (53.27)	67.70 (55.35)	65.98 (54.30)
T_9	S_3 + Root dip method + Foliar application	79.79 (63.26)	81.89 (64.81)	80.84 (64.03)
T_{10}	S_4+ Root dip method	66.06 (54.35)	70.74 (57.23)	68.40 (55.78)
T_{11}	S_4+ Foliar application	64.37 (53.33)	68.37 (55.76)	66.37 (54.54)
T_{12}	S_4 + Root dip method + Foliar application	77.61 (61.75)	81.61 (64.59)	79.61 (63.14)
T_{13}	S_5 + Root dip method	66.77 (54.78)	70.63 (57.16)	68.70 (55.96)
T_{14}	S_5+ Foliar application	66.30 (54.49)	68.56 (55.87)	67.43 (55.18)
T_{15}	S_5 + Root dip method + Foliar application	81.77 (64.71)	84.67 (66.94)	83.22 (65.80)
T_{16}	Control	30.63 (33.58)	33.83 (35.55)	32.23 (34.58)
$CD_{0.05}$		1.29	1.23	1.00

Table 55(b). Interaction effect of plant growth promoting rhizobacteria and application methods on siderophore producing bacteria associated with strawberry cultivar Chandler

Treatment	Per cent siderophore producing bacteria (%)											
	2013				2014				Pooled			
	M_1	M_2	M_3	MEAN	M_1	M_2	M_3	MEAN	M_1	M_2	M_3	MEAN
S_1	82.33 (9.07)	81.00 (9.00)	84.33 (9.18)	82.56 (9.09)	84.00 (9.16)	81.83 (9.05)	86.50 (9.30)	84.11 (9.17)	83.17 (9.12)	81.42 (9.02)	85.42 (9.24)	83.33 (9.13)
S_2	79.58 (8.92)	74.14 (8.61)	80.80 (8.99)	78.17 (8.84)	80.74 (8.98)	78.89 (8.88)	85.46 (9.24)	81.70 (9.04)	80.16 (8.95)	76.51 (8.75)	83.13 (9.12)	79.93 (8.94)
S_3	69.14 (8.32)	64.26 (8.02)	79.79 (8.93)	71.06 (8.42)	72.00 (8.49)	67.70 (8.23)	81.89 (9.05)	73.86 (8.59)	70.57 (8.40)	65.98 (8.12)	80.84 (8.99)	72.46 (8.50)
S_4	66.06 (8.13)	64.37 (8.02)	77.61 (8.81)	69.34 (8.32)	70.74 (8.41)	68.37 (8.27)	81.61 (9.03)	73.57 (8.57)	68.40 (8.27)	66.37 (8.15)	79.61 (8.92)	71.46 (8.44)
S_5	66.77 (8.17)	66.30 (8.14)	81.77 (9.04)	71.61 (8.45)	70.63 (8.40)	68.56 (8.28)	84.67 (9.20)	74.62 (8.63)	68.70 (8.29)	67.43 (8.21)	83.22 (9.12)	73.12 (8.54)
MEAN	72.78 (8.52)	70.01 (8.36)	80.86 (8.99)		75.62 (8.69)	73.07 (8.54)	84.03 (9.17)		74.20 (8.61)	71.54 (8.45)	82.44 (9.08)	
$CD_{0.05}$ for S : 0.035					$CD_{0.05}$ for S : 0.048				$CD_{0.05}$ for S : 0.031			
$CD_{0.05}$ for M : 0.027					$CD_{0.05}$ for M : 0.037				$CD_{0.05}$ for M : 0.024			
$CD_{0.05}$ for SxM : 0.061					$CD_{0.05}$ for SxM : 0.083				$CD_{0.05}$ for SxM : 0.054			

Pooled data further shows that among different isolates, the isolate S_1 (83.33 %) was recorded to be most effective followed by S_2 (79.93 %) whereas M_3 (82.44 %) was best application method among tried followed by M_1 (74.20 %). A similar trend was observed during both the years of study.

4.1.7.7 Per cent nitrogen fixing bacteria

The data on per cent nitrogen fixing bacteria as influenced by inoculation with plant growth promoting rhizobacterial isolates presented in Table 56(a) had shown significant increase in per cent nitrogen fixing bacteria, which varied from 29.75 to 93.92 per cent. The pooled data revealed that the maximum per cent nitrogen fixing bacteria (93.92 %) was recorded in T_3 followed by T_6 (91.20 %), whereas minimum (29.75 %) was recorded from T_{16} (control). A similar trend was recorded during both the years. The pooled values related to interactions of plant growth promoting rhizobacterial isolates and their application methods as presented in Table 56(b) revealed that maximum per cent nitrogen fixing bacteria (93.92 %) was noted in S_1M_3 followed by S_2M_3 (91.20 %) whereas minimum (73.84 %) was recorded for

Table 56(a). Effect of plant growth promoting rhizobacteria on nitrogen fixing bacteria associated with strawberry cultivar Chandler

Treatments		Per cent nitrogen fixing bacteria (%)		
		2013	2014	Pooled
T_1	S_1 + Root dip method	80.33 (63.67)	86.51 (68.42)	83.42 (65.96)
T_2	S_1+ Foliar application	72.66 (58.45)	83.15 (65.75)	77.90 (61.94)
T_3	S_1 + Root dip method + Foliar application	90.58 (72.13)	97.25 (81.85)	93.92 (75.80)
T_4	S_2+ Root dip method	78.67 (62.48)	85.00 (67.22)	81.83 (64.76)
T_5	S_2+ Foliar application	74.62 (59.73)	79.99 (63.42)	77.30 (61.53)
T_6	S_2 + Root dip method + Foliar application	87.87 (69.60)	94.54 (76.56)	91.20 (72.75)
T_7	S_3 + Root dip method	77.07 (61.38)	89.00 (70.61)	83.04 (65.66)
T_8	S_3+ Foliar application	72.81 (58.55)	85.97 (67.98)	79.39 (62.97)
T_9	S_3 + Root dip method + Foliar application	86.22 (68.20)	92.00 (73.62)	89.11 (70.74)
T_{10}	S_4+ Root dip method	73.69 (59.12)	87.67 (69.48)	80.68 (63.91)
T_{11}	S_4+ Foliar application	70.97 (57.37)	76.71 61.13)	73.84 (59.21)
T_{12}	S_4 + Root dip method + Foliar application	82.22 (65.04)	91.67 (73.23)	86.95 (68.81)
T_{13}	S_5 + Root dip method	74.84 (59.87)	82.07 (64.94)	78.46 (62.33)
T_{14}	S_5+ Foliar application	71.97 (58.01)	75.89 (60.57)	73.93 (59.28)
T_{15}	S_5 + Root dip method + Foliar application	85.47 (67.58)	88.13 (69.88)	86.80 (68.70)
T_{16}	Control	27.92 (31.87)	31.59 (34.18)	29.75 (33.04)
$CD_{0.05}$		1.16	2.61	1.23

Table 56(b). Interaction effect of plant growth promoting rhizobacteria and their application methods on nitrogen fixing bacteria associated with strawberry cultivar Chandler

Treatment	Per cent nitrogen fixing bacteria (%)											
	2013				2014				Pooled			
	M_1	M_2	M_3	MEAN	M_1	M_2	M_3	MEAN	M_1	M_2	M_3	MEAN
S_1	80.33 (8.96)	72.66 (8.52)	90.58 (9.52)	81.19 (9.00)	86.51 (9.30)	83.15 (9.12)	97.25 (9.86)	88.97 (9.43)	83.42 (9.13)	77.90 (8.82)	93.92 (9.69)	85.08 (9.21)
S_2	78.67 (8.87)	74.62 (8.64)	87.87 (9.37)	80.38 (8.96)	85.00 (9.22)	79.99 (8.94)	94.54 (9.72)	86.51 (9.30)	81.83 (9.04)	77.30 (8.79)	91.20 (9.55)	83.45 (9.13)
S_3	77.07 (8.78)	72.81 (8.53)	86.22 (9.29)	78.70 (8.87)	89.00 (9.43)	85.97 (9.27)	92.00 (9.59)	88.99 (9.43)	83.04 (9.11)	79.39 (8.90)	89.11 (9.44)	83.85 (9.15)
S_4	73.69 (8.58)	70.97 (8.42)	82.22 (9.07)	75.63 (8.69)	87.67 (9.36)	76.71 (8.76)	91.67 (9.57)	85.35 (9.23)	80.68 (8.97)	73.84 (8.59)	86.95 (9.32)	80.49 (8.96)
S_5	74.84 (8.65)	71.97 (8.48)	85.47 (9.24)	77.42 (8.79)	82.07 (9.06)	75.89 (8.71)	88.13 (9.39)	82.03 (9.05)	78.46 (8.85)	73.93 (8.60)	86.80 (9.32)	79.73 (8.92)
MEAN	76.92 (8.77)	72.60 (8.52)	86.47 (9.30)		86.05 (9.28)	80.34 (8.96)	92.72 (9.63)		81.49 (9.02)	76.47 (8.74)	89.60 (9.46)	
$CD_{0.05}$ for S : 0.028					$CD_{0.05}$ for S : 0.046				$CD_{0.05}$ for S : 0.026			
$CD_{0.05}$ for M : 0.022					$CD_{0.05}$ for M : 0.036				$CD_{0.05}$ for M : 0.020			
$CD_{0.05}$ for SxM : 0.048					$CD_{0.05}$ for SxM : 0.080				$CD_{0.05}$ for SxM : 0.045			

S_4M_2 treatment interaction. A similar trend was observed during both the years of study except that the minimum per cent nitrogen fixing bacteria (75.89 %) were recorded from S_5M_2 during 2014. Pooled data also reveals that S_1 isolate (85.08 %) was most effective among different isolates under study followed by S_3 isolate (83.85 %). Furthermore, among

methods of application, M_3 (89.60 %) was found to be best among tried followed by M_1 (81.49 %). A similar pattern was recorded during both the years of study.

4.1.7.8 Total endorhizobacterial counts on nutrient agar

It is apparent from the Table 57(a) and (b) that plant growth promoting rhizobacteria and their application methods had significantly influenced the endorhizobacterial population. Pooled data presented in Table 57(a) revealed that the significant highest number of total endorhizobacteria (224.69 x 10^2 cfu/ g root) were recorded from T_3 treatment, while lowest were recorded from T_{16} (56.91 x 10^2 cfu/g root). Other treatments also showed significant increase in number of endorhizobacteria as compared to control.

Table 57(a). Effect of plant growth promoting rhizobacteria on total endorhizobacterial counts on nutrient agar

Treatments		Total endorhizobacterial counts (x 10^2 cfu/g root)		
		2013	2014	Pooled
T_1	S_1 + Root dip method	187.56	205.00	196.28
T_2	S_1+ Foliar application	169.96	187.33	178.65
T_3	S_1 + Root dip method + Foliar application	207.26	242.12	224.69
T_4	S_2+ Root dip method	176.67	186.33	181.50
T_5	S_2+ Foliar application	162.70	171.67	167.19
T_6	S_2 + Root dip method + Foliar application	202.00	232.54	217.27
T_7	S_3 + Root dip method	156.67	177.33	167.00
T_8	S_3+ Foliar application	141.11	160.33	150.72
T_9	S_3 + Root dip method + Foliar application	188.74	205.33	197.04
T_{10}	S_4+ Root dip method	166.74	182.33	174.54
T_{11}	S_4+ Foliar application	150.96	165.33	158.15
T_{12}	S_4 + Root dip method + Foliar application	197.70	211.00	204.35
T_{13}	S_5 + Root dip method	170.59	184.00	177.30
T_{14}	S_5+ Foliar application	153.26	169.00	161.13
T_{15}	S_5 + Root dip method + Foliar application	200.30	222.26	211.28
T_{16}	Control	51.48	62.33	56.91
$CD_{0.05}$		1.76	2.04	1.80

Table 57(b). Interaction effect of plant growth promoting rhizobacteria and their application methods on total endorhizobacterial counts on nutrient agar

Treatment	Total endorhizobacterial counts (x 10^2 cfu/ g root)											
	2013				2014				Pooled			
	M_1	M_2	M_3	MEAN	M_1	M_2	M_3	MEAN	M_1	M_2	M_3	MEAN
S_1	187.56	169.96	207.26	188.26	205.00	187.33	242.12	211.48	196.28	178.65	224.69	199.87
S_2	176.67	162.70	202.00	180.46	186.33	171.67	232.54	196.85	181.50	167.19	217.27	188.65
S_3	156.67	141.11	188.74	162.17	177.33	160.33	205.33	181.00	167.00	150.72	197.04	171.59
S_4	166.74	150.96	197.70	171.80	182.33	165.33	211.00	186.22	174.54	158.15	204.35	179.01
S_5	170.59	153.26	200.30	174.71	184.00	169.00	222.26	191.75	177.30	161.13	211.28	183.23
MEAN	171.64	155.60	199.20		187.00	170.73	222.65		179.32	163.17	210.92	
$CD_{0.05}$ for S : 0.41					$CD_{0.05}$ for S : 0.66				$CD_{0.05}$ for S : 0.42			
$CD_{0.05}$ for M : 0.32					$CD_{0.05}$ for M : 0.51				$CD_{0.05}$ for M : 0.32			
$CD_{0.05}$ for SxM : 0.71					$CD_{0.05}$ for SxM : 1.15				$CD_{0.05}$ for SxM : 0.73			

The pooled data depicted in Table 57(b) reveals that the maximum endorhizobacteria (224.69 x 10^2 cfu/g root) were recorded from S_1M_3 and minimum (150.72 x 10^2 cfu/g) from S_3M_2. A similar pattern was followed during both the years of study. Among different isolates of plant growth promoting rhizobacteria under study, S_1 was most efficient as compared to other isolates and among their application methods, M_3 (root dip+ foliar application method) was approved best during both the years of investigations.

4.1.7.9 Total endorhizobacterial counts on PVK medium

A significant effect of plant growth promoting rhizobacteria on total endorhizobacterial counts on Pikovskaya's (PVK) medium was recorded [Table 58(a)]. The maximum endorhizobacterial counts (207.42 x 10^2 cfu/g root) were recorded in T_3 and minimum was noted in T_{16} (34.25 x 10^2 cfu/g root). Almost similar trend was observed during both the years of investigations.

The data on cummulative effect of plant growth promoting rhizobacteria and their application methods presented in Table 58(b) revealed that the maximum endorhizobacterial counts were noted in S_1M_3 (207.42 x 10^2 cfu/g), whereas minimum from S_4M_2 (118.05 x 10^2 cfu/g root). The isolate S_1 (177.74 x 10^2 cfu/g root) was reported to be most effective in increasing endorhizobacteria on PVK medium followed by S_2 (161.16 x 10^2 cfu/g root) as

Table 58(a). Effect of plant growth promoting rhizobacteria on total endorhizobacterial counts on Pikovskaya's (PVK) medium

Treatments		Total endorhizobacterial counts (x 10^2 cfu/g root)		
		2013	2014	Pooled
T_1	S_1 + Root dip method	153.61	201.41	177.51
T_2	S_1+ Foliar application	128.19	168.37	148.28
T_3	S_1 + Root dip method + Foliar application	185.32	229.52	207.42
T_4	S_2+ Root dip method	128.74	177.11	152.93
T_5	S_2+ Foliar application	116.53	156.19	136.36
T_6	S_2 + Root dip method + Foliar application	172.52	215.87	194.19
T_7	S_3 + Root dip method	115.27	174.60	144.93
T_8	S_3+ Foliar application	109.58	145.96	127.77
T_9	S_3 + Root dip method + Foliar application	144.65	202.93	173.79
T_{10}	S_4+ Root dip method	111.88	163.61	137.75
T_{11}	S_4+ Foliar application	103.96	132.15	118.05
T_{12}	S_4 + Root dip method + Foliar application	137.86	205.06	171.46
T_{13}	S_5 + Root dip method	123.11	174.15	148.63
T_{14}	S_5+ Foliar application	116.81	155.49	136.15
T_{15}	S_5 + Root dip method + Foliar application	164.89	215.59	190.24
T_{16}	Control	32.67	35.82	34.25
$CD_{0.05}$		1.61	1.51	1.04

Table 58(b). Interaction effect of plant growth promoting rhizobacteria and their application methods on total endorhizobacterial counts on Pikovskaya's (PVK) medium

Treatment	Total endorhizobacterial counts (x 10^2 cfu/g root)											
	2013				2014				Pooled			
	M_1	M_2	M_3	MEAN	M_1	M_2	M_3	MEAN	M_1	M_2	M_3	MEAN
S_1	153.61	128.19	185.32	155.71	201.41	168.37	229.52	199.76	177.51	148.28	207.42	177.74
S_2	128.74	116.53	172.52	139.26	177.11	156.19	215.87	183.06	152.93	136.36	194.19	161.16
S_3	115.27	109.58	144.65	123.16	174.60	145.96	202.93	174.50	144.93	127.77	173.79	148.83
S_4	111.88	103.96	137.86	117.90	163.61	132.15	205.06	166.94	137.75	118.05	171.46	142.42
S_5	123.11	116.81	164.89	134.94	174.15	155.49	215.59	181.74	148.63	136.15	190.24	158.34
MEAN	126.52	115.01	161.05		178.17	151.63	213.79		152.35	133.32	187.42	
$CD_{0.05}$ for S : 0.93					$CD_{0.05}$ for S : 0.79				$CD_{0.05}$ for S : 0.51			
$CD_{0.05}$ for M : 0.72					$CD_{0.05}$ for M : 0.62				$CD_{0.05}$ for M : 0.40			
$CD_{0.05}$ for SxM : 1.61					$CD_{0.05}$ for SxM : 1.38				$CD_{0.05}$ for SxM : 0.89			

compared to other isolates of plant growth promoting rhizobacteria under investigations, while M_3 (187.42 x 10^2 cfu/g) was noted to be most effective application method. A similar trend was observed during both the years of investigations.

4.1.7.10 Total endorhizobacterial counts on CAS medium

The data on total endorhizobacteria on Chromeazurol-S (CAS) medium as affected by plant growth promoting rhizobacteria and their application methods is presented in Table 59(a) and (b) showing significant effect. The pooled data given in Table 58(a) revealed that the endorhizobacteria were significantly highest in T_3 (55.55 x 10^2 cfu/g root) followed by T_6 (52.27 x 10^2 cfu/g root), whereas lowest in T_{16} (25.66 x 10^2 cfu/g root). Other treatments have also produced significantly highest endorhizobacteria as compared to control. A similar trend was recorded during both the years of study.

The interaction effect of plant growth promoting rhizobacteria and their application methods on endorhizobacteria is presented in Table 59(b). The maximum endorhizobacterial counts were recorded in S_1M_3 (55.55 x 10^2 cfu/g root) and minimum counts were noted in S_4M_2 (32.57 x 10^2 cfu/g root) which was statistically at par with S_3M_2 (33.62 x 10^2 cfu/g root). The results further showed that the isolate S_1 (47.67 x 10^2 cfu/g root) was most effective as compared to other isolates, while M_3 (49.98 x 10^2 cfu/g root) was best application method among tried. A similar pattern was observed during both the years of investigations.

Table 59(a). Effect of plant growth promoting rhizobacteria on total endorhizobacterial count on Chromeazurol-S (CAS) medium

Treatments		Total endorhizobacterial counts (x 10^2 cfu/g root)		
		2013	2014	Pooled
T_1	S_1 + Root dip method	47.89	48.34	48.11
T_2	S_1+ Foliar application	36.44	42.28	39.36
T_3	S_1 + Root dip method + Foliar application	53.20	57.89	55.55
T_4	S_2+ Root dip method	40.43	47.94	44.18
T_5	S_2+ Foliar application	34.39	41.59	37.99
T_6	S_2 + Root dip method + Foliar application	51.26	53.29	52.27
T_7	S_3 + Root dip method	37.23	41.01	39.12
T_8	S_3+ Foliar application	32.37	34.87	33.62
T_9	S_3 + Root dip method + Foliar application	46.52	50.24	48.38
T_{10}	S_4+ Root dip method	37.39	38.92	38.16
T_{11}	S_4+ Foliar application	31.32	33.82	32.57
T_{12}	S_4 + Root dip method + Foliar application	44.88	46.73	45.81
T_{13}	S_5 + Root dip method	37.19	42.30	39.74
T_{14}	S_5+ Foliar application	32.52	36.48	34.50
T_{15}	S_5 + Root dip method + Foliar application	45.49	50.30	47.89
T_{16}	Control	23.38	27.94	25.66
$CD_{0.05}$		1.86	1.94	1.49

Table 59(b). Interaction effect of plant growth promoting rhizobacteria and their application methods on total endorhizobacterial count on Chromeazurol-S (CAS) medium

Treatment	Total endorhizobacterial counts (x 10^2 cfu/g root)											
	2013				2014				Pooled			
	M_1	M_2	M_3	MEAN	M_1	M_2	M_3	MEAN	M_1	M_2	M_3	MEAN
S_1	47.89	36.44	53.20	45.84	48.34	42.28	57.89	49.50	48.11	39.36	55.55	47.67
S_2	40.43	34.39	51.26	42.02	47.94	41.59	53.29	47.61	44.18	37.99	52.27	44.82
S_3	37.23	32.37	46.52	38.71	41.01	34.87	50.24	42.04	39.12	33.62	48.38	40.37
S_4	37.39	31.32	44.88	37.86	38.92	33.82	46.73	39.83	38.16	32.57	45.81	38.84
S_5	37.19	32.52	45.49	38.40	42.30	36.48	50.30	43.03	39.74	34.50	47.89	40.71
MEAN	40.02	33.41	48.27		43.70	37.81	51.69		41.86	35.61	49.98	
$CD_{0.05}$ for S : 1.10					$CD_{0.05}$ for S : 1.16				$CD_{0.05}$ for S : 0.89			
$CD_{0.05}$ for M : 0.86					$CD_{0.05}$ for M : 0.90				$CD_{0.05}$ for M : 0.69			
$CD_{0.05}$ for SxM : 1.91					$CD_{0.05}$ for SxM : 2.01				$CD_{0.05}$ for SxM : 1.55			

4.1.7.11 Total endorhizobacterial counts on Jensen's medium

The total endorhizobacteria capable of growing on Jensen's medium were significantly influenced by plant growth promoting rhizobacterial isolates. The pooled data presented in Table 60(a) revealed that the highest endorhizobacteria were recorded in T_3 (209.18 x 10^2 cfu/g root), while the counts were lowest in T_{16} (27.61 x 10^2 cfu/g root).

The data on interaction between plant growth promoting rhizobacteria and their application methods presented in Table 60(b) also showed significant effect on endorhizobacterial counts. The pooled data showed that the maximum endorhizobacteria

(209.18 x 10^2 cfu/g root) were recorded in S_1M_3 and minimum counts (115.90 x 10^2 cfu/g root) were recorded from S_4M_2. The results further showed that among different isolates under study, the isolate S_1 (174.49 x 10^2 cfu/g root) was found to be most effective, whereas M_3 (191.00 x 10^2 cfu/g root) was found to be best application method among tried. A similar trend was observed during both the years of study.

Table 60(a). Effect of plant growth promoting rhizobacteria on total endorhizobacterial counts on Jensen's medium

Treatments		Total endorhizobacterial counts (x 10^2 cfu/g root)		
		2013	2014	Pooled
T_1	S_1 + Root dip method	153.61	191.96	172.79
T_2	S_1+ Foliar application	123.60	159.38	141.49
T_3	S_1 + Root dip method + Foliar application	196.52	221.84	209.18
T_4	S_2+ Root dip method	132.62	168.06	150.34
T_5	S_2+ Foliar application	109.59	149.77	129.68
T_6	S_2 + Root dip method + Foliar application	188.38	214.99	201.68
T_7	S_3 + Root dip method	126.14	165.72	145.93
T_8	S_3+ Foliar application	107.55	149.78	128.67
T_9	S_3 + Root dip method + Foliar application	162.97	197.42	180.19
T_{10}	S_4+ Root dip method	118.80	161.93	140.37
T_{11}	S_4+ Foliar application	98.99	132.81	115.90
T_{12}	S_4 + Root dip method + Foliar application	146.84	202.70	174.77
T_{13}	S_5 + Root dip method	123.05	162.97	143.01
T_{14}	S_5+ Foliar application	111.39	138.79	125.09
T_{15}	S_5 + Root dip method + Foliar application	171.90	206.44	189.17
T_{16}	Control	26.50	28.71	27.61
$CD_{0.05}$		1.98	2.08	1.70

Table 60(b). Interaction effect of plant growth promoting rhizobacteria and their application methods on total endorhizobacterial counts on Jensen's medium

Treatment	Total endorhizobacterial counts (x 10^2 cfu/g root)											
	2013				2014				Pooled			
	M_1	M_2	M_3	MEAN	M_1	M_2	M_3	MEAN	M_1	M_2	M_3	MEAN
S_1	153.61	123.60	196.52	157.91	191.96	159.38	221.84	191.06	172.79	141.49	209.18	174.49
S_2	132.62	109.59	188.38	143.53	168.06	149.77	214.99	177.61	150.34	129.68	201.68	160.57
S_3	126.14	107.55	162.97	132.22	165.72	149.78	197.42	170.97	145.93	128.67	180.19	151.60
S_4	118.80	98.99	146.84	121.54	161.93	132.81	202.70	165.81	140.37	115.90	174.77	143.68
S_5	123.05	111.39	171.90	135.45	162.97	138.79	206.44	169.40	143.01	125.09	189.17	152.42
MEAN	130.85	110.22	173.32		170.13	146.11	208.68		150.49	128.17	191.00	
$CD_{0.05}$ for S : 0.91					$CD_{0.05}$ for S : 0.99				$CD_{0.05}$ for S : 0.70			
$CD_{0.05}$ for M : 0.71					$CD_{0.05}$ for M : 0.77				$CD_{0.05}$ for M : 0.55			
$CD_{0.05}$ for SxM : 1.58					$CD_{0.05}$ for SxM : 1.72				$CD_{0.05}$ for SxM : 1.22			

4.1.7.12 Per cent phosphate solubilizing endorhizobacteria

The perusal of data given in Table 61(a) and (b) revealed significant effect by inoculation of plant growth promoting rhizobacterial isolates and their application methods

on per cent phosphate solubilizing endorhizobacteria associated with strawberry. The pooled data given in Table 61(a) represents that the per cent phosphate solubilizing endorhizobacteria were significantly highest in T_3 (93.82 %) and lowest in T_{16} (44.53 %). A similar trend was observed during both the years of study.

Table 61(a). Effect of plant growth promoting rhizobacteria on phosphate solubilizing endorhizobacteria associated with strawberry cultivar Chandler

Treatments		Per cent phosphate solubilizing endorhizobacteria (%)		
		2013	2014	Pooled
T_1	S_1 + Root dip method	84.85 (67.09)	92.75 (74.36)	88.80 (70.44)
T_2	S_1+ Foliar application	73.45 (58.97)	90.45 (71.99)	81.95 (64.84)
T_3	S_1 + Root dip method + Foliar application	89.00 (70.61)	98.65 (84.21)	93.82 (75.62)
T_4	S_2+ Root dip method	79.57 (63.11)	91.25 (72.81)	85.41 (67.53)
T_5	S_2+ Foliar application	70.94 (57.36)	88.09 (69.80)	79.52 (63.07)
T_6	S_2 + Root dip method + Foliar application	83.31 (65.87)	96.22 (78.79)	89.77 (71.32)
T_7	S_3 + Root dip method	75.33 (60.21)	89.22 (70.82)	82.28 (65.09)
T_8	S_3+ Foliar application	72.43 (58.30)	85.67 (67.74)	79.05 (62.74)
T_9	S_3 + Root dip method + Foliar application	79.56 (63.10)	93.67 (75.53)	86.62 (68.54)
T_{10}	S_4+ Root dip method	74.56 (59.69)	87.45 (69.23)	81.00 (64.14)
T_{11}	S_4+ Foliar application	71.67 (57.82)	80.22 (63.58)	75.95 (60.61)
T_{12}	S_4 + Root dip method + Foliar application	77.13 (61.41)	91.00 (72.53)	84.07 (66.45)
T_{13}	S_5 + Root dip method	78.86 (62.61)	90.20 (71.77)	84.53 (66.83)
T_{14}	S_5+ Foliar application	75.85 (60.55)	86.36 (68.30)	81.11 (64.21)
T_{15}	S_5 + Root dip method + Foliar application	83.27 (65.84)	96.81 (79.82)	90.04 (71.59)
T_{16}	Control	43.91 (41.48)	45.15 (42.20)	44.53 (41.84)
$CD_{0.05}$		0.76	1.84	0.76

*Figures in parenthesis are arc sine transformed

Table 61(b). Interaction effect of plant growth promoting rhizobacteria and their application methods on phosphate solubilizing endorhizobacteria associated with strawberry cultivar Chandler

Treatment	Per cent phosphate solubilizing endorhizobacteria (%)*											
	2013				2014				Pooled			
	M_1	M_2	M_3	MEAN	M_1	M_2	M_3	MEAN	M_1	M_2	M_3	MEAN
S_1	84.85 (9.21)	73.45 (8.57)	89.00 (9.43)	82.43 (9.07)	92.75 (9.63)	90.45 (9.51)	98.65 (9.93)	93.95 (9.69)	88.80 (9.42)	81.95 (9.04)	93.82 (9.68)	88.19 (9.38)
S_2	79.57 (8.92)	70.94 (8.42)	83.31 (9.13)	77.94 (8.82)	91.25 (9.55)	88.09 (9.39)	96.22 (9.81)	91.85 (9.58)	85.41 (9.24)	79.52 (8.90)	89.77 (9.47)	84.90 (9.20)
S_3	75.33 (8.68)	72.43 (8.51)	79.56 (8.92)	75.78 (8.70)	89.22 (9.45)	85.67 (9.26)	93.67 (9.68)	89.52 (9.46)	82.28 (9.06)	79.05 (8.88)	86.62 (9.30)	82.65 (9.08)
S_4	74.56 (8.63)	71.67 (8.47)	77.13 (8.78)	74.45 (8.63)	87.45 (9.35)	80.22 (8.96)	91.00 (9.54)	86.22 (9.28)	81.00 (8.99)	75.95 (8.71)	84.07 (9.16)	80.34 (8.95)
S_5	78.86 (8.88)	75.85 (8.71)	83.27 (9.13)	79.33 (8.90)	90.20 (9.50)	86.36 (9.29)	96.81 (9.84)	91.12 (9.54)	84.53 (9.19)	81.11 (9.00)	90.04 (9.48)	85.23 (9.22)
MEAN	78.64 (8.86)	72.87 (8.54)	82.46 (9.08)		90.18 (9.50)	86.16 (9.28)	95.27 (9.76)		84.41 (9.18)	79.51 (8.91)	88.86 (9.42)	
$CD_{0.05}$ for S : 0.038					$CD_{0.05}$ for S : 0.025				$CD_{0.05}$ for S : 0.024			
$CD_{0.05}$ for M : 0.029					$CD_{0.05}$ for M : 0.019				$CD_{0.05}$ for M : 0.019			
$CD_{0.05}$ for SxM : 0.065					$CD_{0.05}$ for SxM : 0.043				$CD_{0.05}$ for SxM : 0.042			

*Figures in parenthesis are square root transformed

The cummulative effect of plant growth promoting rhizobacteria and their application methods as presented in Table 61(b) indicated that the significantly higher percentage of phosphate solubilizing bacteria (93.82 %) was recorded in S_1M_3 and the lowest percentage was recorded in S_4M_2 (75.95 %). Pooled data further showed that S_1 (88.19 %) was most effective as compared to other isolates of plant growth promoting rhizobacteria and M_3 (88.86 %) was found to be best application method. A similar trend was observed during both the years of study.

4.1.7.13 Per cent siderophore producing endorhizobacteria

The data pertaining to per cent siderophore producing endorhizobacteria as influenced by plant growth promoting rhizobacteria and their application methods are presented Table 62(a) and (b). The pooled data given in Table 62(a) revealed that percentage of siderophore producing endorhizobacteria was significantly higher in T_3 (88.03 %) and was minimum in T_{16} (34.95 %). A similar trend was observed during both the years of investigation.

The data on interaction effect of plant growth promoting rhizobacterial isolates and their application methods as presented in Table 62(b) expressed that the maximum percentage of siderophore producing endorhizobacteria was recorded in S_1M_3 (88.08 %) and minimum percentage was recorded in S_3M_2 (71.61 %). Results further revealed that among

Table 62(a). Effect of plant growth promoting rhizobacteria on siderophore producing endorhizobacteria associated with strawberry cultivar Chandler

Treatments		Per cent siderophore producing endorhizobacteria (%)*		
		2013	2014	Pooled
T_1	S_1 + Root dip method	82.75(65.47)	84.47(66.77)	83.61(66.11)
T_2	S_1+ Foliar application	77.66(61.78)	80.00(63.41)	78.83(62.59)
T_3	S_1 + Root dip method + Foliar application	87.56(69.34)	88.59(70.24)	88.08(69.78)
T_4	S_2+ Root dip method	79.30(62.93)	81.10(64.21)	80.20(63.56)
T_5	S_2+ Foliar application	76.71(61.13)	77.79(61.87)	77.25(61.50)
T_6	S_2 + Root dip method + Foliar application	84.56(66.87)	87.30(69.10)	85.93(67.95)
T_7	S_3 + Root dip method	75.15(60.08)	78.38(62.28)	76.77(61.16)
T_8	S_3+ Foliar application	70.24(56.92)	72.97(58.65)	71.61(57.78)
T_9	S_3 + Root dip method + Foliar application	80.16(63.53)	82.94(65.58)	81.55(64.54)
T_{10}	S_4+ Root dip method	79.88(63.33)	81.07(64.19)	80.47(63.75)
T_{11}	S_4+ Foliar application	76.17(60.76)	77.61(61.74)	76.89(61.25)
T_{12}	S_4 + Root dip method + Foliar application	84.81(67.05)	86.15(68.13)	85.48(67.58)
T_{13}	S_5 + Root dip method	82.72(65.42)	83.57(66.08)	83.15(65.74)
T_{14}	S_5+ Foliar application	75.10(60.09)	77.31(61.54)	76.21(60.81)
T_{15}	S_5 + Root dip method + Foliar application	85.39(67.51)	86.95(68.80)	86.17(68.43)
T_{16}	Control	33.59(35.39)	36.31(37.03)	34.95(36.22)
$CD_{0.05}$		1.00	0.67	0.65

*Figures in parenthesis are arc sine transformed

Table 62(b). Interaction effect of plant growth promoting rhizobacteria and their application methods on siderophore producing endorhizobacteria associated with strawberry cultivar Chandler

Treatment	Per cent siderophore producing endorhizobacteria (%)*											
	2013				2014				Pooled			
	M_1	M_2	M_3	MEAN	M_1	M_2	M_3	MEAN	M_1	M_2	M_3	MEAN
S_1	82.75 (9.10)	77.66 (8.81)	87.56 (9.36)	82.66 (9.09)	84.47 (9.19)	80.00 (8.94)	88.59 (9.41)	84.36 (9.18)	83.61 (9.14)	78.83 (8.88)	88.08 (9.38)	83.51 (9.14)
S_2	79.30 (8.90)	76.71 (8.76)	84.56 (9.19)	80.19 (8.95)	81.10 (9.01)	77.79 (8.82)	87.30 (9.34)	82.06 (9.06)	80.20 (8.96)	77.25 (8.79)	85.93 (9.27)	81.13 (9.00)
S_3	75.15 (8.67)	70.24 (8.38)	80.16 (8.95)	75.18 (8.67)	78.38 (8.85)	72.97 (8.54)	82.94 (9.11)	78.10 (8.83)	76.77 (8.76)	71.61 (8.46)	81.55 (9.03)	76.64 (8.75)
S_4	79.88(8.94)	76.17 (8.73)	84.81 (9.21)	80.28 (8.96)	81.07 (9.00)	77.61 (8.81)	86.15 (9.28)	81.61 (9.03)	80.47 (8.97)	76.89 (8.77)	85.48 (9.25)	80.95 (8.99)
S_5	82.72 (9.09)	75.10 (8.66)	85.39 (9.24)	81.07 (9.00)	83.57 (9.14)	77.31 (8.79)	86.95 (9.32)	82.61 (9.09)	83.15 (9.12)	76.21 (8.73)	86.17 (9.28)	81.84 (9.04)
MEAN	79.96 (8.94)	75.18 (8.67)	84.49 (9.19)		81.72 (9.04)	77.14 (8.78)	86.39 (9.29)		80.84 (8.99)	76.16 (8.73)	85.44 (9.24)	
$CD_{0.05}$ for S : 0.047					$CD_{0.05}$ for S : 0.031				$CD_{0.05}$ for S : 0.031			
$CD_{0.05}$ for M : 0.036					$CD_{0.05}$ for M : 0.024				$CD_{0.05}$ for M : 0.024			
$CD_{0.05}$ for SxM : 0.081					$CD_{0.05}$ for SxM : 0.054				$CD_{0.05}$ for SxM : 0.054			

*Figures in parenthesis are square root transformed

different isolates under study, the isolate S_1 (83.51 %) was most effective in increasing the per cent siderophore producing endorhizobacteria while, M_3 (85.44 %) was found to be best application method as compare to other methods. A similar trend was observed during both the years of study.

4.1.7.14 Per cent nitrogen fixing endorhizobacteria

The data on the effect of plant growth promoting rhizobacteria and their application methods with respect to per cent nitrogen fixing endorhizobacteria are presented in Table 63(a) and (b). It is evident from the pooled data that the maximum percentage of nitrogen fixing endorhizobacteria was noted in T_6 (90.97 %), although it was statistically at par with T_3 (90.83 %) and T_{15} (90.54 %). However, minimum percentage of nitrogen fixing endorhizobacteria was noted in T_{16} (39.75 %). During 2013, the maximum percentage of nitrogen fixing endorhizobacteria was recorded in T_6 (88.74 %) followed by T_{15} (86.27 %), whereas during 2014, percentage of nitrogen fixing endorhizobacteria was recorded maximum in T_3 (95.80 %) which was statistically at par with T_{15} (94.80 %). A similar trend was followed for the minimum percentage of nitrogen fixing endorhizobacteria during both the years of study.

Table 63(a). Effect of plant growth promoting rhizobacteria on nitrogen fixing endorhizobacteria associated with strawberry cultivar Chandler

Treatments		Per cent nitrogen fixing endorhizobacteria (%)		
		2013	2014	Pooled
T_1	S_1 + Root dip method	75.10 (60.05)	86.46 (68.39)	80.78 (63.98)
T_2	S_1+ Foliar application	72.11 (58.10)	81.43 (64.45)	76.77 (61.16)
T_3	S_1 + Root dip method + Foliar application	85.85 (67.91)	95.80 (78.39)	90.83 (72.41)
T_4	S_2+ Root dip method	78.62 (62.44)	84.54 (66.83)	81.58 (64.57)
T_5	S_2+ Foliar application	74.03 (59.34)	79.98 (63.40)	77.00 (61.33)
T_6	S_2 + Root dip method + Foliar application	88.74 (70.39)	93.20 (74.96)	90.97 (72.53)
T_7	S_3 + Root dip method	78.63 (62.45)	85.65 (67.73)	82.14 (64.98)
T_8	S_3+ Foliar application	76.74 (61.15)	81.24 (64.31)	78.99 (62.70)
T_9	S_3 + Root dip method + Foliar application	85.07 (67.25)	92.02 (73.69)	88.55 (70.23)
T_{10}	S_4+ Root dip method	74.04 (59.35)	83.90 (66.34)	78.97 (62.69)
T_{11}	S_4+ Foliar application	70.44 (57.05)	75.05 (60.01)	72.75 (58.51)
T_{12}	S_4 + Root dip method + Foliar application	81.42 (64.44)	90.89 (72.41)	86.16 (68.13)
T_{13}	S_5 + Root dip method	78.93 (62.66)	84.33 (66.66)	81.63 (64.60)
T_{14}	S_5+ Foliar application	71.59 (57.77)	80.42 (63.72)	76.01 (60.65)
T_{15}	S_5 + Root dip method + Foliar application	86.27 (68.23)	94.80 (76.86)	90.54 (72.07)
T_{16}	Control	38.97 (38.61)	40.52 (39.52)	39.75 (39.06)
$CD_{0.05}$		1.06	1.72	1.14

*Figures in parenthesis are arc sine transformed

Table 63(b). Interaction effect of plant growth promoting rhizobacteria and application methods on nitrogen fixing endorhizobacteria associated with strawberry cultivar Chandler

Treatment	Per cent nitrogen fixing endorhizobacteria (%)*											
	2013				2014				Pooled			
	M_1	M_2	M_3	MEAN	M_1	M_2	M_3	MEAN	M_1	M_2	M_3	MEAN
S_1	75.10 (8.67)	72.11 (8.49)	85.85 (9.27)	77.69 (8.81)	86.46 (9.30)	81.43 (9.02)	95.80 (9.79)	87.90 (9.37)	80.78 (8.98)	76.77 (8.76)	90.83 (9.53)	82.79 (9.09)
S_2	78.62 (8.87)	74.03 (8.60)	88.74 (9.42)	80.46 (8.96)	84.54 (9.19)	79.98 (8.94)	93.20 (9.65)	85.91 (9.26)	81.58 (9.03)	77.00 (8.77)	90.97 (9.54)	83.18 (9.11)
S_3	78.63 (8.87)	76.74 (8.76)	85.07 (9.22)	80.15 (8.95)	85.65 (9.25)	81.24 (9.01)	92.02 (9.59)	86.30 (9.29)	82.14 (9.06)	78.99 (8.89)	88.55 (9.41)	83.23 (9.12)
S_4	74.04 (8.60)	70.44 (8.39)	81.42 (9.02)	75.30 (8.67)	83.90 (9.16)	75.05 (8.66)	90.89 (9.53)	83.28 (9.12)	78.97 (8.88)	72.75 (8.53)	86.16 (9.28)	79.29 (8.90)
S_5	78.93 (8.88)	71.59 (8.46)	86.27 (9.29)	78.93 (8.88)	84.33 (9.18)	80.42 (8.97)	94.80 (9.74)	86.52 (9.30)	81.63 (9.03)	76.01 (8.71)	90.54 (9.51)	82.73 (9.09)
MEAN	77.06 (8.78)	72.98 (8.54)	85.47 (9.24)		84.98 (9.22)	79.62 (8.92)	93.34 (9.66)		81.02 (9.00)	76.30 (8.73)	89.41 (9.45)	
$CD_{0.05}$ for S : 0.027					$CD_{0.05}$ for S : 0.035				$CD_{0.05}$ for S : 0.022			
$CD_{0.05}$ for M : 0.021					$CD_{0.05}$ for M : 0.027				$CD_{0.05}$ for M : 0.017			
$CD_{0.05}$ for SxM : 0.046					$CD_{0.05}$ for SxM : 0.061				$CD_{0.05}$ for SxM : 0.038			

*Figures in parenthesis are square root transformed

The data on interaction study between plant growth promoting rhizobacteria and their application methods are presented in Table 63(b) which clearly showed that the maximum per cent nitrogen fixing endorhizobacteria were recorded with S_2M_3 (90.97 %) which was statistically at par with S_1M_3 (90.83 %) and S_5M_3 (90.54 %), whereas minimum percentage

was recorded in S_4M_2 (72.75 %). The pooled data further reveals that among different isolates, the isolate S_3 (83.23 %) was best, however during 2013, S_2 (80.46 %) was found to be most effective and during 2014, S_1 (87.90 %) was most effective isolates. Furthermore, M_3 (root dip+ foliar application method) was found to be best application method among tried followed by M_1 (root dip method).

4.2 Effect of GA_3 and plant growth promoting rhizobacteria

4.2.1 Growth parameters

4.2.1.1 Plant height

The data pertaining to the effect of GA_3 and plant growth promoting rhizobacteria on plant height are given in Table 64 (a) to (b). The pooled data given in Table 64(a) revealed that the plant height (30.82 cm) was recorded significantly maximum from T_{15} and minimum from T_{19} (22.97 cm) when compared with individual application of all concentration of GA_3. A similar pattern was observed for maximum (30.63 and 31.00 cm) and minimum plant height (21.05 and 24.88 cm) respectively during 2013 and 2014.

Table 64(a). Effect of GA_3 and plant growth promoting rhizobacteria on plant height of strawberry cultivar Chandler

Treatments		Plant height (cm)		
		2013	2014	Pooled
T_1	GA_3 @ 25 ppm	22.18	26.60	24.39
T_2	GA_3 @ 50 ppm	23.08	27.43	25.26
T_3	GA_3 @ 75 ppm	24.29	29.17	26.73
T_4	$S_1 + GA_3$ @ 25 ppm	23.27	27.00	25.14
T_5	$S_1 + GA_3$ @ 50 ppm	25.01	28.67	26.84
T_6	$S_1 + GA_3$ @ 75 ppm	28.43	29.58	29.01
T_7	$S_2 + GA_3$ @ 25 ppm	25.08	28.20	26.64
T_8	S2+ GA_3 @ 50 ppm	25.23	29.00	27.12
T_9	$S_2 + GA_3$ @ 75 ppm	26.05	30.70	28.38
T_{10}	$S_3 + GA_3$ @ 25 ppm	22.94	27.33	25.14
T_{11}	$S_3 + GA_3$ @ 50 ppm	25.37	29.00	27.18
T_{12}	$S_3 + GA_3$ @ 75 ppm	26.48	30.67	28.58
T_{13}	$S_4 + GA_3$ @ 25 ppm	24.64	27.83	26.24
T_{14}	$S_4 + GA_3$ @ 50 ppm	29.28	28.17	28.73
T_{15}	$S_4 + GA_3$ @ 75 ppm	30.63	31.00	30.82
T_{16}	$S_5 + GA_3$ @ 25 ppm	24.47	26.67	25.57
T_{17}	$S_5 + GA_3$ @ 50 ppm	26.04	28.33	27.19
T_{18}	$S_5 + GA_3$ @ 75 ppm	28.48	29.42	28.95
T_{19}	Control	21.05	24.88	22.97
$CD_{0.05}$		1.58	1.78	1.22

Table 64(b). Interaction effect of GA_3 and plant growth promoting rhizobacteria on plant height of strawberry cultivar Chandler

Treatment	Plant height (cm)											
	2013				2014				Pooled			
	G_1	G_2	G_3	MEAN	G_1	G_2	G_3	MEAN	G_1	G_2	G_3	MEAN
S_1	23.27	25.01	28.43	25.57	27.00	28.67	29.58	28.42	25.14	26.84	29.01	26.99
S_2	25.08	25.23	26.05	25.46	28.20	29.00	30.70	29.30	26.64	27.12	28.38	27.38
S_3	22.94	25.37	26.48	24.93	27.33	29.00	30.67	29.00	25.14	27.18	28.58	26.97
S_4	24.64	29.28	30.63	28.19	27.83	28.17	31.00	29.00	26.24	28.73	30.82	28.59
S_5	24.47	26.04	28.48	26.33	26.67	28.33	29.42	28.14	25.57	27.19	28.95	27.24
MEAN	24.08	26.19	28.02		27.41	28.63	30.27		25.74	27.41	29.14	
$CD_{0.05}$ for S : 0.70					$CD_{0.05}$ for S : 1.11				$CD_{0.05}$ for S : 0.70			
$CD_{0.05}$ for G : 0.54					$CD_{0.05}$ for G : 0.86				$CD_{0.05}$ for G : 0.54			
$CD_{0.05}$ for SxG : 1.21					$CD_{0.05}$ for SxG : NS				$CD_{0.05}$ for SxG : NS			

The data on interaction study between GA_3 and plant growth promoting rhizobacteria as presented in Table 64(b) showed non- significant effect on plant height of strawberry cultivar Chandler during 2014 whereas the effect was significant during 2013. However, pooled data revealed that the maximum plant height (30.82 cm) was recorded from S_4G_3 and minimum from S_1G_1 and S_3G_1 (25.14 cm, respectively).

During 2013, maximum significant plant height (30.63 cm) was recorded from S_4G_3 and minimum from S_3G_1 (22.94 cm), whereas during 2014, maximum plant height (31.00 cm) was recorded from S_4G_3 and minimum from S_5G_1 (26.67 cm). Among different rhizobacterial isolates under study, S_4 (28.59 cm) was reported to be most effective in increasing plant height as pooled value and, among different concentrations of GA_3 application, G_3 (GA_3 @ 75 ppm) was found to be most effective followed by its lower concentrations. A similar trend was observed during both the years of study.

4.2.1.2 Plant spread

The data on the influence of GA_3 and plant growth promoting rhizobacteria on plant spread are given in Table 65(a) and (b). The pooled data given in Table 65(a) revealed that maximum plant spread was recorded in T_{12} (37.53 cm) which was statistically at par with T_{15} (37.49 cm) and T_{18} (36.61 cm), whereas minimum plant spread was noted in T_{19} (27.67 cm) and was significantly at par with T_1 (28.03 cm). A related trend was followed during 2014. However during 2013, maximum plant spread was recorded from T_{15} (31.23 cm) and was statistically at par with T_6 (29.45 cm), T_{14} (30.20 cm) and T_{18} (30.22 cm), whereas minimum plant spread was observed in T_{19} (23.70 cm) which was statistically at par with T_1, T_2, T_4,

T_{10}, T_{11}, T_{13} and T_{16} (24.06, 24.65, 25.54, 24.45, 25.20, 24.36 and 25.10 cm, respectively). Thus the results expressed that plant spread was significantly increased with the application of plant growth promoting rhizobacteria in combination with GA_3 as compared to individual application of GA_3 and control.

Table 65(a). Effect of GA_3 and plant growth promoting rhizobacteria on plant spread of strawberry cultivar Chandler

Treatments		Plant spread (cm)		
		2013	2014	Pooled
T_1	GA_3 @ 25 ppm	24.06	32.00	28.03
T_2	GA_3 @ 50 ppm	24.65	33.42	29.04
T_3	GA_3 @ 75 ppm	26.14	39.92	33.03
T_4	$S_1 + GA_3$ @ 25 ppm	25.54	36.92	31.23
T_5	$S_1 + GA_3$ @ 50 ppm	28.81	38.67	33.74
T_6	$S_1 + GA_3$ @ 75 ppm	29.45	41.50	35.48
T_7	$S_2 + GA_3$ @ 25 ppm	26.27	38.83	32.55
T_8	S2+ GA_3 @ 50 ppm	26.95	40.17	33.56
T_9	$S_2 + GA_3$ @ 75 ppm	28.36	40.92	34.64
T_{10}	$S_3 + GA_3$ @ 25 ppm	24.45	41.67	33.06
T_{11}	$S_3 + GA_3$ @ 50 ppm	25.20	46.25	35.72
T_{12}	$S_3 + GA_3$ @ 75 ppm	27.88	47.17	37.53
T_{13}	$S_4 + GA_3$ @ 25 ppm	24.36	39.92	32.14
T_{14}	$S_4 + GA_3$ @ 50 ppm	30.20	41.67	35.93
T_{15}	$S_4 + GA_3$ @ 75 ppm	31.23	43.75	37.49
T_{16}	$S_5 + GA_3$ @ 25 ppm	25.10	40.42	32.76
T_{17}	$S_5 + GA_3$ @ 50 ppm	27.20	41.50	34.35
T_{18}	$S_5 + GA_3$ @ 75 ppm	30.22	43.00	36.61
T_{19}	Control	23.70	31.63	27.67
$CD_{0.05}$		1.95	1.50	1.03

Table 65(b). Interaction effect of GA_3 and plant growth promoting rhizobacteria on plant spread of strawberry cultivar Chandler

Treatment	Plant spread (cm)											
	2013				2014				Pooled			
	G_1	G_2	G_3	MEAN	G_1	G_2	G_3	MEAN	G_1	G_2	G_3	MEAN
S_1	25.54	28.81	29.45	27.93	36.92	38.67	41.50	39.03	31.23	33.74	35.48	33.48
S_2	26.27	26.95	28.36	27.19	38.83	40.17	40.92	39.97	32.55	33.56	34.64	33.58
S_3	24.45	25.20	27.88	25.84	41.67	46.25	47.17	45.03	33.06	35.72	37.53	35.44
S_4	24.36	30.20	31.23	28.60	39.92	41.67	43.75	41.78	32.14	35.93	37.49	35.19
S_5	25.10	27.20	30.22	27.51	40.42	41.50	43.00	41.64	32.76	34.35	36.61	34.57
MEAN	25.14	27.67	29.43		39.55	41.65	43.27		32.35	34.66	36.35	
$CD_{0.05}$ for S : 1.09					$CD_{0.05}$ for S : 0.51				$CD_{0.05}$ for S : 0.60			
$CD_{0.05}$ for G : 0.85					$CD_{0.05}$ for G : 0.39				$CD_{0.05}$ for G : 0.46			
$CD_{0.05}$ for SxG : 1.89					$CD_{0.05}$ for SxG : 0.88				$CD_{0.05}$ for SxG : 1.03			

The interaction study between GA_3 and plant growth promoting rhizobacteria exhibited significant effect on plant spread of strawberry as presented in Table 65(b). The

maximum plant spread from pooled data was recorded from S_3G_3 (37.53 cm) and was statistically at par with S_4G_3 (37.49 cm) and S_5G_3 (36.61 cm), while minimum plant spread was recorded from S_1G_1 (31.23 cm). During 2013, maximum plant spread was recorded from S_4G_3 (31.23 cm) and was statistically at par S_1G_3 (29.45 cm), S_4G_2 (30.20 cm) and S_5G_3 (30.22 cm), whereas minimum plant spread was recorded from S_4G_1 (24.36 cm) which was statistically at par with S_1G_1 (25.54 cm), S_3G_1 (24.45 cm), S_3G_2 (25.20 cm) and S_5G_1 (25.10 cm). However during 2014, significantly maximum plant spread was recorded from S_3G_3 (47.17 cm) and minimum from S_1G_1 (36.92 cm). The pooled data further revealed that among different isolates under study, the isolates S_3 (35.44 cm) was found to be most effective which was statistically at par with S_4 (35.19 cm). A similar trend was observed during 2014 while during 2013, S_4 (28.60 cm) was reported to be best which was statistically at par with S_1 and S_5 (27.93 and 27.51 cm). Among different concentration of GA_3, G_3 was reported to be most effective followed by G_2 during both the years of study.

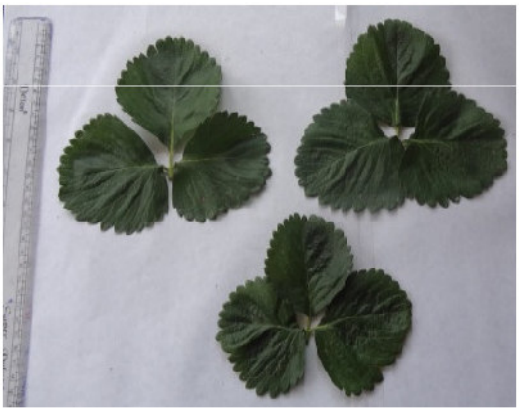
4.2.1.3 Leaf area

It is apparent from the data given in Table 66(a) and (b) that GA_3 and plant growth promoting rhizobacteria had a significant effect on leaf area of strawberry cultivar Chandler during both the years of study. The pooled data given in Table 66(a) revealed that the leaf area was maximum under T_{18} (137.71 cm^2) followed by T_{15} (133.64 cm^2), while leaf area was minimum (106.90 cm^2) in T_{19} which was statistically at par with T_1 (108.72 cm^2). A related trend was observed during 2013. However during 2014, leaf area was recorded maximum in T_{15} (137.95 cm^2), which was statistically at par with T_{18} (137.74 cm^2). The same trend was observed for minimum leaf area for both the years of investigations.

The cummulative effect of GA_3 and plant growth promoting rhizobacteria on leaf area was observed to be significant during both the years of study in strawberry cultivar Chandler. The pooled data in Table 66(b) revealed that the maximum leaf area was recorded from S_5G_3 (137.71 cm^2) followed by S_4G_3 (133.64 cm^2), whereas minimum leaf area was noted from S_3G_1 (109.24 cm^2) which was statistically at par with S_2G_1 (110.58 cm^2) and S_3G_2 (111.39 cm^2). A similar trend was observed during 2013 whereas during 2014, maximum leaf area was obtained from S_4G_3 (137.95 cm^2) statistically at par with S_5G_3 (137.74 cm^2) and minimum leaf area was recorded from S_3G_1 (112.53 cm^2) which was statistically at par with S_2G_1 (113.88 cm^2). Among different isolates under study, S_4 was proved to be most effective in improving leaf area while G_3 (GA_3 @ 75 ppm) was recorded to be best for leaf area

T_{19}= Control

T_1 = GA_3 @ 25 ppm



$T_{15} = S_4 + G_3$

T_{18}= $S_5 + G_3$

Plate 5. Effect of GA_3 and plant growth promoting rhizobacteria on leaf area of strawberry cv. Chandler

increment followed by its lower concentrations when compared with each other during both the years of study.

Table 66(a). Effect of GA_3 and plant growth promoting rhizobacteria on leaf area of strawberry cultivar Chandler

Treatments		Leaf area (cm^2)		
		2013	2014	Pooled
T_1	GA_3 @ 25 ppm	105.37	112.07	108.72
T_2	GA_3 @ 50 ppm	107.07	113.67	110.37
T_3	GA_3 @ 75 ppm	109.88	116.56	113.22
T_4	$S_1 + GA_3$ @ 25 ppm	108.68	114.94	111.81
T_5	$S_1 + GA_3$ @ 50 ppm	111.40	118.00	114.70
T_6	$S_1 + GA_3$ @ 75 ppm	116.09	122.68	119.39
T_7	$S_2 + GA_3$ @ 25 ppm	107.28	113.88	110.58
T_8	S2+ GA_3 @ 50 ppm	112.07	118.67	115.37
T_9	$S_2 + GA_3$ @ 75 ppm	120.00	126.93	123.46
T_{10}	$S_3 + GA_3$ @ 25 ppm	105.95	112.53	109.24
T_{11}	$S_3 + GA_3$ @ 50 ppm	108.10	114.67	111.39
T_{12}	$S_3 + GA_3$ @ 75 ppm	112.04	118.63	115.33
T_{13}	$S_4 + GA_3$ @ 25 ppm	121.62	128.20	124.91
T_{14}	$S_4 + GA_3$ @ 50 ppm	126.72	133.31	130.02
T_{15}	$S_4 + GA_3$ @ 75 ppm	129.34	137.95	133.64
T_{16}	$S_5 + GA_3$ @ 25 ppm	114.92	121.20	118.06
T_{17}	$S_5 + GA_3$ @ 50 ppm	118.13	124.73	121.43
T_{18}	$S_5 + GA_3$ @ 75 ppm	137.68	137.74	137.71
T_{19}	Control	103.61	110.20	106.90
$CD_{0.05}$		2.39	2.58	2.29

Table 66(b). Interaction effect of GA_3 and plant growth promoting rhizobacteria on leaf area of strawberry cultivar Chandler

Treatment	Leaf area (cm^2)											
	2013				2014				Pooled			
	G_1	G_2	G_3	MEAN	G_1	G_2	G_3	MEAN	G_1	G_2	G_3	MEAN
S_1	108.68	111.40	116.09	112.06	114.94	118.00	122.68	118.54	111.81	114.70	119.39	115.30
S_2	107.28	112.07	120.00	113.12	113.88	118.67	126.93	119.83	110.58	115.37	123.46	116.47
S_3	105.95	108.10	112.04	108.70	112.53	114.67	118.63	115.28	109.24	111.39	115.33	111.99
S_4	121.62	126.72	129.34	125.89	128.20	133.31	137.95	133.15	124.91	130.02	133.64	129.52
S_5	114.92	118.13	137.68	123.57	121.20	124.73	137.74	127.89	118.06	121.43	137.71	125.73
MEAN	111.69	115.28	123.03		118.15	121.88	128.79		114.92	118.58	125.91	
$CD_{0.05}$ for S : 1.51					$CD_{0.05}$ for S : 1.20				$CD_{0.05}$ for S : 1.27			
$CD_{0.05}$ for M : 1.17					$CD_{0.05}$ for M : 0.93				$CD_{0.05}$ for M : 0.99			
$CD_{0.05}$ for SxM : 2.62					$CD_{0.05}$ for SxM : 2.08				$CD_{0.05}$ for SxM : 2.21			

4.2.1.4 Number of crowns per plant

The values related to the effect of GA_3 and plant growth promoting rhizobacteria on number of crowns per plant are given in Table 67 (a) to (b). The pooled data given in Table 67(a) revealed that the number of crowns per plant (4.85) were significantly maximum under

T_9 which was statistically at par with T_6, T_{12}, T_{15}, T_{17} and T_{18} (4.52, 4.36, 4.75, 4.42 and 4.50, respectively), whereas minimum number of crowns were recorded under T_{19} (3.38) which was statistically at par with T_1, T_7, T_{10} and T_{13} (3.50, 3.81, 3.71 and 3.69, respectively). A similar trend was observed during 2013 but maximum number of crowns per plant (4.95) recorded in T_9 were statistically at par with T_6 (4.24) and T_{15} (4.33) and minimum number of crowns per plant (3.15) recorded in T_{19} were statistically at par with T_1, T_2, T_4, T_7, T_{10}, T_{11}, T_{13}, T_{14} and T_{16} (3.22, 3.63, 3.55, 3.44, 3.29, 3.66, 3.28, 3.71 and 3.50, respectively). However during 2014, maximum number of crowns (5.17) were recorded from T_{15} which was statistically at par with T_3, T_5, T_6, T_9, T_{12}, T_{17} and T_{18} (4.70, 4.78, 4.80, 4.74, 4.74, 4.78 and 4.88, respectively), while minimum number of crowns (3.60) were recorded from T_{19} which was statistically at par with T_1, T_{10} and T_{13} (3.78, 4.12 and 4.11 respectively).

The interaction study between GA_3 and plant growth promoting rhizobacteria as presented in Table 67(b) revealed non- significant effect on number of crowns per plant during both the years of study. However, the different concentrations of GA_3

Table 67(a). Effect of GA_3 and plant growth promoting rhizobacteria on number of crowns per plant of strawberry cultivar Chandler

Treatments		Number of crowns/ plant		
		2013	2014	Pooled
T_1	GA_3 @ 25 ppm	3.22	3.78	3.50
T_2	GA_3 @ 50 ppm	3.63	4.16	3.90
T_3	GA_3 @ 75 ppm	3.91	4.70	4.30
T_4	$S_1 + GA_3$ @ 25 ppm	3.55	4.38	3.97
T_5	$S_1 + GA_3$ @ 50 ppm	3.88	4.78	4.33
T_6	$S_1 + GA_3$ @ 75 ppm	4.24	4.80	4.52
T_7	$S_2 + GA_3$ @ 25 ppm	3.44	4.17	3.81
T_8	S2+ GA_3 @ 50 ppm	4.13	4.50	4.32
T_9	$S_2 + GA_3$ @ 75 ppm	4.95	4.74	4.85
T_{10}	$S_3 + GA_3$ @ 25 ppm	3.29	4.12	3.71
T_{11}	$S_3 + GA_3$ @ 50 ppm	3.66	4.40	4.03
T_{12}	$S_3 + GA_3$ @ 75 ppm	3.98	4.74	4.36
T_{13}	$S_4 + GA_3$ @ 25 ppm	3.28	4.11	3.69
T_{14}	$S_4 + GA_3$ @ 50 ppm	3.71	4.54	4.12
T_{15}	$S_4 + GA_3$ @ 75 ppm	4.33	5.17	4.75
T_{16}	$S_5 + GA_3$ @ 25 ppm	3.50	4.33	3.92
T_{17}	$S_5 + GA_3$ @ 50 ppm	4.06	4.78	4.42
T_{18}	$S_5 + GA_3$ @ 75 ppm	4.13	4.88	4.50
T_{19}	Control	3.15	3.60	3.38
$CD_{0.05}$		0.71	0.55	0.49

Table 67(b). Interaction effect of GA_3 and plant growth promoting rhizobacteria on number of crowns per plant of strawberry cultivar Chandler

Treatment	Number of crowns / plant											
	2013				2014				Pooled			
	G_1	G_2	G_3	MEAN	G_1	G_2	G_3	MEAN	G_1	G_2	G_3	MEAN
S_1	3.55	3.88	4.24	3.89	4.38	4.78	4.80	4.65	3.97	4.33	4.52	4.27
S_2	3.44	4.13	4.95	4.18	4.17	4.50	4.74	4.47	3.81	4.32	4.85	4.32
S_3	3.29	3.66	3.98	3.64	4.12	4.40	4.74	4.42	3.71	4.03	4.36	4.03
S_4	3.28	3.71	4.33	3.77	4.11	4.54	5.17	4.61	3.69	4.12	4.75	4.19
S_5	3.50	4.06	4.13	3.90	4.33	4.78	4.88	4.66	3.92	4.42	4.50	4.28
MEAN	3.41	3.89	4.33		4.22	4.60	4.87		3.82	4.24	4.60	
$CD_{0.05}$ for S : NS					$CD_{0.05}$ for S : NS				$CD_{0.05}$ for S : NS			
$CD_{0.05}$ for G : 0.30					$CD_{0.05}$ for G : 0.26				$CD_{0.05}$ for G : 0.23			
$CD_{0.05}$ for SxG : NS					$CD_{0.05}$ for SxG : NS				$CD_{0.05}$ for SxG : NS			

showed significant effect on number of crowns per plant as the maximum number of crowns per plant (4.60) were recorded from G_3 (GA_3 @ 75 ppm) and minimum from G_1 (GA_3 @25 ppm). A similar trend was observed during both the years of study.

4.2.1.5 Number of runners per plant

It is evident from data given in Tables 68(a) and (b) that GA_3 and plant growth promoting rhizobacteria had a significant effect on number of runners per plant of strawberry. The pooled data as depicted in Table 68(a) revealed that the maximum number of runners per plant (36.04) were recorded from T_{18} while the minimum number of runners per plant were produced in T_{19} (20.71) which was statistically at par with T_1 (21.38). A similar trend was observed during both the years of investigations.

The pooled data on interaction study between GA_3 and plant growth promoting rhizobacteria as presented in Table 68(b) revealed that maximum number of runners per plant were recorded from S_5G_3 (36.04) and minimum from S_2G_1 (22.39). A similar trend was observed during both the years of study except that the minimum number of runners per plant were recorded from S_3G_1 (19.37) during 2014. Pooled data further revealed that the isolate S_4 was most effective in producing the number of runners per plant (29.85) as compared to other isolates of plant growth promoting rhizobacteria under study. A similar trend was observed during 2014 while during 2013, S_1 (32.33) was reported to be most effective. Among different concentrations of GA_3, G_3 (GA_3 @ 75 ppm) was best in producing maximum number of runners per plant and G_1 (GA_3 @ 25 ppm) had produced minimum number of runners per plant (24.84).

T_{19} = Control

T_1 = GA_3 @ 25 ppm

T_{18}= S_5 + G_3

Plate 6. Effect of GA_3 and plant growth promoting rhizobacteria on number of runners of strawberry cv. Chandler

Table 68(a). Effect of GA_3 and plant growth promoting rhizobacteria on number of runners per plant of strawberry cultivar Chandler

Treatments		Number of runners/ plant		
		2013	2014	Pooled
T_1	GA_3 @ 25 ppm	23.75	19.00	21.38
T_2	GA_3 @ 50 ppm	25.21	19.88	22.54
T_3	GA_3 @ 75 ppm	28.42	23.08	25.75
T_4	$S_1 + GA_3$ @ 25 ppm	29.86	24.53	27.20
T_5	$S_1 + GA_3$ @ 50 ppm	30.75	25.42	28.08
T_6	$S_1 + GA_3$ @ 75 ppm	36.38	30.92	33.65
T_7	$S_2 + GA_3$ @ 25 ppm	24.04	20.74	22.39
T_8	$S_2 + GA_3$ @ 50 ppm	32.08	26.58	29.33
T_9	$S_2 + GA_3$ @ 75 ppm	35.18	29.85	32.52
T_{10}	$S_3 + GA_3$ @ 25 ppm	26.74	19.37	23.06
T_{11}	$S_3 + GA_3$ @ 50 ppm	28.09	22.75	25.42
T_{12}	$S_3 + GA_3$ @ 75 ppm	28.83	23.97	26.40
T_{13}	$S_4 + GA_3$ @ 25 ppm	30.54	25.21	27.88
T_{14}	$S_4 + GA_3$ @ 50 ppm	32.09	26.92	32.09
T_{15}	$S_4 + GA_3$ @ 75 ppm	32.25	32.09	29.58
T_{16}	$S_5 + GA_3$ @ 25 ppm	25.57	21.73	23.65
T_{17}	$S_5 + GA_3$ @ 50 ppm	30.31	24.98	27.64
T_{18}	$S_5 + GA_3$ @ 75 ppm	38.38	33.71	36.04
T_{19}	Control	23.00	18.42	20.71
$CD_{0.05}$		1.50	1.85	1.42

Table 68(b). Interaction effect of GA_3 and plant growth promoting rhizobacteria on number of runners per plant of strawberry cultivar Chandler

Treatment	Number of runners/ plant											
	2013				2014				Pooled			
	G_1	G_2	G_3	MEAN	G_1	G_2	G_3	MEAN	G_1	G_2	G_3	MEAN
S_1	29.86	30.75	36.38	32.33	24.53	25.42	30.92	26.95	27.20	28.08	33.65	29.64
S_2	24.04	32.08	35.18	30.44	20.74	26.58	29.85	25.73	22.39	29.33	32.52	28.08
S_3	26.74	28.09	28.83	27.89	19.37	22.75	23.97	22.03	23.06	25.42	26.40	24.96
S_4	30.54	32.09	32.25	31.63	25.21	26.92	32.09	28.07	27.88	29.51	32.17	29.85
S_5	25.57	30.31	38.38	31.42	21.73	24.98	33.71	26.81	23.65	27.64	36.04	29.11
MEAN	27.35	30.66	34.20		22.32	25.33	30.11		24.84	28.00	32.16	
$CD_{0.05}$ for S : 0.95					$CD_{0.05}$ for S : 1.14				$CD_{0.05}$ for S : 0.88			
$CD_{0.05}$ for G : 0.74					$CD_{0.05}$ for G : 0.88				$CD_{0.05}$ for G : 0.68			
$CD_{0.05}$ for SxG : 1.64					$CD_{0.05}$ for SxG : 1.98				$CD_{0.05}$ for SxG : 1.52			

4.2.1.6 Plant biomass on fresh weight basis

The effect of GA_3 and plant growth promoting rhizobacteria on plant biomass on fresh weight basis is presented in Tables 69(a) and (b) which shows that the plant biomass on fresh weight basis was significantly influenced by GA_3 and plant growth promoting rhizobacteria. The pooled values expressed the maximum plant biomass on fresh weight basis (43.72 g/ plant) was observed in plants treated with S_1 in combination with GA_3 @ 75 ppm (T_6) which

Table 69(a). Effect of GA_3 and plant growth promoting rhizobacteria on plant biomass on fresh weight basis of strawberry cultivar Chandler

Treatments		Plant biomass on fresh wt. basis (g/ plant)		
		2013	2014	Pooled
T_1	GA_3 @ 25 ppm	34.19	36.88	35.54
T_2	GA_3 @ 50 ppm	35.83	37.82	36.83
T_3	GA_3 @ 75 ppm	36.35	38.99	37.67
T_4	$S_1 + GA_3$ @ 25 ppm	37.92	39.82	38.87
T_5	$S_1 + GA_3$ @ 50 ppm	38.57	41.06	39.82
T_6	$S_1 + GA_3$ @ 75 ppm	43.42	44.02	43.72
T_7	$S_2 + GA_3$ @ 25 ppm	37.40	39.98	38.69
T_8	$S_2 + GA_3$ @ 50 ppm	38.28	40.69	39.49
T_9	$S_2 + GA_3$ @ 75 ppm	42.67	43.15	42.91
T_{10}	$S_3 + GA_3$ @ 25 ppm	36.73	38.33	37.53
T_{11}	$S_3 + GA_3$ @ 50 ppm	37.65	40.42	39.04
T_{12}	$S_3 + GA_3$ @ 75 ppm	41.27	42.07	41.67
T_{13}	$S_4 + GA_3$ @ 25 ppm	39.30	40.09	39.70
T_{14}	$S_4 + GA_3$ @ 50 ppm	41.42	42.43	41.92
T_{15}	$S_4 + GA_3$ @ 75 ppm	43.35	42.71	43.03
T_{16}	$S_5 + GA_3$ @ 25 ppm	37.15	38.40	37.78
T_{17}	$S_5 + GA_3$ @ 50 ppm	38.72	40.52	39.62
T_{18}	$S_5 + GA_3$ @ 75 ppm	40.25	41.65	40.95
T_{19}	Control	31.47	32.76	32.12
$CD_{0.05}$		1.56	1.34	1.12

Table 69(b). Interaction effect of GA_3 and plant growth promoting rhizobacteria on plant biomass on fresh weight basis of strawberry cultivar Chandler

Treatment	Plant biomass on fresh weight basis (g/plant)											
	2013				2014				Pooled			
	G_1	G_2	G_3	MEAN	G_1	G_2	G_3	MEAN	G_1	G_2	G_3	MEAN
S_1	37.92	38.57	43.42	39.97	39.82	41.06	44.02	41.63	38.87	39.82	43.72	40.80
S_2	37.40	38.28	42.67	39.45	39.98	40.69	43.15	41.28	38.69	39.49	42.91	40.36
S_3	36.73	37.65	41.27	38.55	38.33	40.42	42.07	40.28	37.53	39.04	41.67	39.41
S_4	39.30	41.42	43.35	41.36	40.09	42.43	42.71	41.74	39.70	41.92	43.03	41.55
S_5	37.15	38.72	40.25	38.71	38.40	40.52	41.65	40.19	37.78	39.62	40.95	39.45
MEAN	37.70	38.93	42.19		39.33	41.02	42.72		38.51	39.98	42.46	
$CD_{0.05}$ for S : 0.85					$CD_{0.05}$ for S : 0.67				$CD_{0.05}$ for S : 0.51			
$CD_{0.05}$ for G : 0.66					$CD_{0.05}$ for G : 0.52				$CD_{0.05}$ for G : 0.40			
$CD_{0.05}$ for SxG : NS					$CD_{0.05}$ for SxG : NS				$CD_{0.05}$ for SxG : 0.89			

was statistically at par with T_9 and T_{15} (42.91 and 43.03 g/ plant, respectively), whereas minimum plant biomass was recorded from T_{19} (32.12 g/ plant). A similar trend was observed during 2013 and 2014.

The interaction study between GA_3 and plant growth promoting rhizobacteria as presented in Table 69(b), reveals non-significant effect during both the years of study. However, pooled study showed significant effect of interaction where maximum plant

biomass on fresh weight basis (43.72 g/ plant) was recorded in S_1G_3 treatment combination which was statistically at par with S_2G_3 and S_4G_3 ((42.91 and 43.03 g/ plant, respectively) whereas, minimum plant biomass on fresh weight basis (37.53 g/ plant) was obtained in S_3G_1 treatment combination which was statistically at par with S_5G_1 (37.78 g/ plant) treatment combination. The individual effect of GA_3 and plant growth promoting rhizobacteria shows significant results as presented in Table 69(b) which reveals that S_4 (41.55 g/ plant) was most effective plant growth promoting rhizobacteria isolate as compared to other isolates. In case of GA_3 treatments, GA_3 @ 75 ppm was reported to be best concentration followed by GA_3 @ 50 ppm during both the years of study.

4.2.1.7 Plant biomass on dry weight basis

From the perusal of data presented in Tables 70(a), it is clear that GA_3 and plant growth promoting rhizobacteria influenced the plant biomass on dry weight basis significantly. The pooled value for maximum plant biomass on dry weight basis (13.21 g/ plant) was recorded in T_{15} which was statistically at par with T_6, T_9, T_{12} and T_{14} (12.74, 13.03, 12.51 and 12.71 g/ plant, respectively), whereas minimum plant biomass on dry weight basis was recorded from T_{19} (10.53 g/ plant). A similar trend was observed during both the years of investigations.

Table 70(a). Effect of GA_3 and plant growth promoting rhizobacteria on plant biomass on dry weight basis of strawberry cultivar Chandler

Treatments		Plant biomass on dry weight (g/ plant)		
		2013	2014	Pooled
T_1	GA_3 @ 25 ppm	11.09	11.79	11.44
T_2	GA_3 @ 50 ppm	11.50	12.23	11.87
T_3	GA_3 @ 75 ppm	11.84	12.37	12.11
T_4	$S_1 + GA_3$ @ 25 ppm	11.66	12.12	11.89
T_5	$S_1 + GA_3$ @ 50 ppm	11.94	12.70	12.32
T_6	$S_1 + GA_3$ @ 75 ppm	12.52	12.97	12.74
T_7	$S_2 + GA_3$ @ 25 ppm	11.39	11.65	11.52
T_8	$S_2 + GA_3$ @ 50 ppm	12.03	12.39	12.21
T_9	$S_2 + GA_3$ @ 75 ppm	12.80	13.25	13.03
T_{10}	$S_3 + GA_3$ @ 25 ppm	11.26	12.25	11.75
T_{11}	$S_3 + GA_3$ @ 50 ppm	11.68	12.80	12.24
T_{12}	$S_3 + GA_3$ @ 75 ppm	12.09	12.92	12.51
T_{13}	$S_4 + GA_3$ @ 25 ppm	11.55	12.63	12.09
T_{14}	$S_4 + GA_3$ @ 50 ppm	12.30	13.11	12.71
T_{15}	$S_4 + GA_3$ @ 75 ppm	13.04	13.37	13.21
T_{16}	$S_5 + GA_3$ @ 25 ppm	11.19	12.07	11.63
T_{17}	$S_5 + GA_3$ @ 50 ppm	11.61	12.34	11.97
T_{18}	$S_5 + GA_3$ @ 75 ppm	12.11	12.79	12.45
T_{19}	Control	10.00	11.05	10.53
$CD_{0.05}$		1.22	0.69	0.73

Table 70(b). Interaction effect of plant growth promoting rhizobacteria and GA_3 on plant biomass on dry weight basis of strawberry cultivar Chandler

Treatment	Plant biomass on dry weight basis (g/ plant)											
	2013				2014				Pooled			
	G_1	G_2	G_3	MEAN	G_1	G_2	G_3	MEAN	G_1	G_2	G_3	MEAN
S_1	11.66	11.94	12.52	12.04	12.12	12.70	12.97	12.60	11.89	12.32	12.74	12.32
S_2	11.39	12.03	12.80	12.07	11.65	12.39	13.25	12.43	11.52	12.21	13.03	12.25
S_3	11.26	11.68	12.09	11.68	12.25	12.80	12.92	12.66	11.75	12.24	12.51	12.17
S_4	11.55	12.30	13.04	12.30	12.63	13.11	13.37	13.04	12.09	12.71	13.21	12.67
S_5	11.19	11.61	12.11	11.64	12.07	12.34	12.79	12.40	11.63	11.97	12.45	12.02
MEAN	11.41	11.91	12.51		12.14	12.67	13.06		11.78	12.29	12.79	
$CD_{0.05}$ for S : NS					$CD_{0.05}$ for S : 0.44				$CD_{0.05}$ for S : NS			
$CD_{0.05}$ for G : 0.62					$CD_{0.05}$ for G : 0.34				$CD_{0.05}$ for G : 0.36			
$CD_{0.05}$ for SxG : NS					$CD_{0.05}$ for SxG : NS				$CD_{0.05}$ for SxG : NS			

It is evident from the Table 70(b) that the GA_3 and plant growth promoting rhizobacteria interactions had non- significant effect on plant biomass on dry weight basis during both the years of study. Among different isolates under study, S_4 followed by S_1 was proved to be most effective isolate, whereas GA_3 @ 75 ppm followed by GA_3 @ 50 ppm was observed to be most effective GA_3 treatment in increasing plant biomass on dry weight basis during both the years of study.

4.2.2 Yield parameters

4.2.2.1 Date of first flowering

The dates related to opening of first flower are given in Table 71(a). The effect of GA_3 and plant growth promoting rhizobacteria on first flower opening dates had shown greater variation ranging from 24th February to 8th March during 2013 and 7th February to 27th February during 2014. The flowering was earliest in T_9 (24th February) followed by T_6 and T_{15} (27nd February, respectively) and late in T_1 (8th March) followed by T_{16} (7th March) during 2013 whereas, it was earliest (7th February) in T_{12} followed by T_9 (9th February) and late in T_1 (27th February) followed by T_4 (26th February) during 2014. Results further expressed that the earliest flowering was recorded in the treatments in which GA_3 (25, 50 and 75 ppm) was applied in combination with plant growth promoting rhizobacteria during both the years of study.

Table 71(a). Effect of GA_3 and plant growth promoting rhizobacteria on date of first flowering in strawberry cultivar Chandler

Treatments		Date of first flowering	
		2013	2014
T_1	GA_3 @ 25 ppm	MAR. 8	27 FEB.
T_2	GA_3 @ 50 ppm	MAR. 4	22 FEB
T_3	GA_3 @ 75 ppm	MAR. 3	10 FEB.
T_4	$S_1 + GA_3$ @ 25 ppm	MAR. 6	26 FEB
T_5	$S_1 + GA_3$ @ 50 ppm	MAR. 5	25 FEB.
T_6	$S_1 + GA_3$ @ 75 ppm	FEB. 27	20 FEB.
T_7	$S_2 + GA_3$ @ 25 ppm	MAR. 6	18 FEB.
T_8	S2+ GA_3 @ 50 ppm	FEB. 28	16 FEB.
T_9	$S_2 + GA_3$ @ 75 ppm	FEB. 24	9 FEB.
T_{10}	$S_3 + GA_3$ @ 25 ppm	MAR. 5	19 FEB.
T_{11}	$S_3 + GA_3$ @ 50 ppm	MAR. 5	16 FEB.
T_{12}	$S_3 + GA_3$ @ 75 ppm	MAR. 4	7 FEB.
T_{13}	$S_4 + GA_3$ @ 25 ppm	MAR. 6	19 FEB.
T_{14}	$S_4 + GA_3$ @ 50 ppm	MAR. 4	23 FEB.
T_{15}	$S_4 + GA_3$ @ 75 ppm	FEB. 27	17 FEB.
T_{16}	$S_5 + GA_3$ @ 25 ppm	MAR. 7	17 FEB.
T_{17}	$S_5 + GA_3$ @ 50 ppm	MAR. 2	15 FEB.
T_{18}	$S_5 + GA_3$ @ 75 ppm	FEB. 28	12 FEB.
T_{19}	Control	MAR. 4	18 FEB.

4.2.2.2 Duration of flowering

The data pertaining to duration of flowering as influenced by GA_3 and plant growth promoting rhizobacteria are presented in Appendix-II [Table 72(a) and (b)]. The pooled data given in Table 72(a) revealed that maximum flowering duration (86.67 days) was observed in T_9 which was statistically at par with T_{12} (85.83 days), whereas minimum flowering duration was recorded in T_{19} (59.67 days). During 2013, maximum flowering duration (63.67 days) was recorded in T_{15} statistically at par with T_6 (62.33 days) and T_9 (63.33 days) and minimum (47.67 days) in T_{19} (Fig. 5). However during 2014, flowering duration was maximum in T_{12} (111.00 days) which was statistically at par with T_9 (110.00 days) and minimum flowering duration was observed in T_{19} (71.67 days).

The data on interaction study between GA_3 and plant growth promoting rhizobacteria is depicted in Table 72(b) revealed that the maximum duration of flowering was noted in S_2G_3 (86.67 days) which was statistically at par with S_3G_3 (85.83 days), whereas minimum flowering duration was recorded from S_2G_3 and S_3G_3 (74.00 days respectively) which was statistically at par with S_1G_1 (74.67 days) and S_4G_1 (74.50 days).

Fig. 5. Effect of GA_3 and plant growth promoting rhizobacteria on duration of flowering of strawberry cv. Chandler

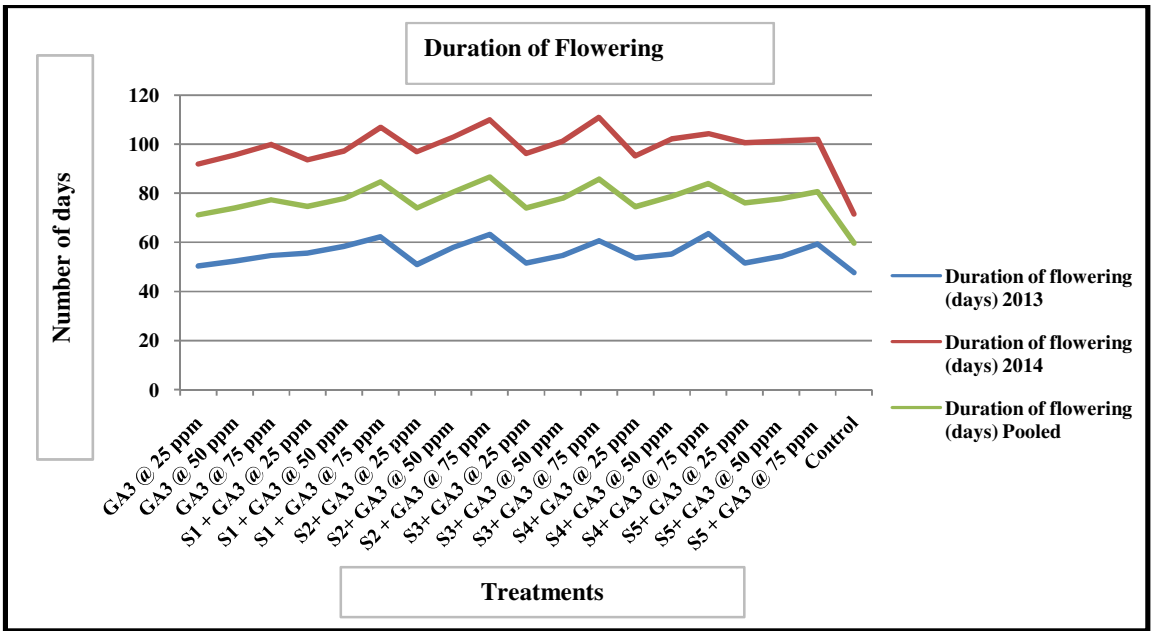
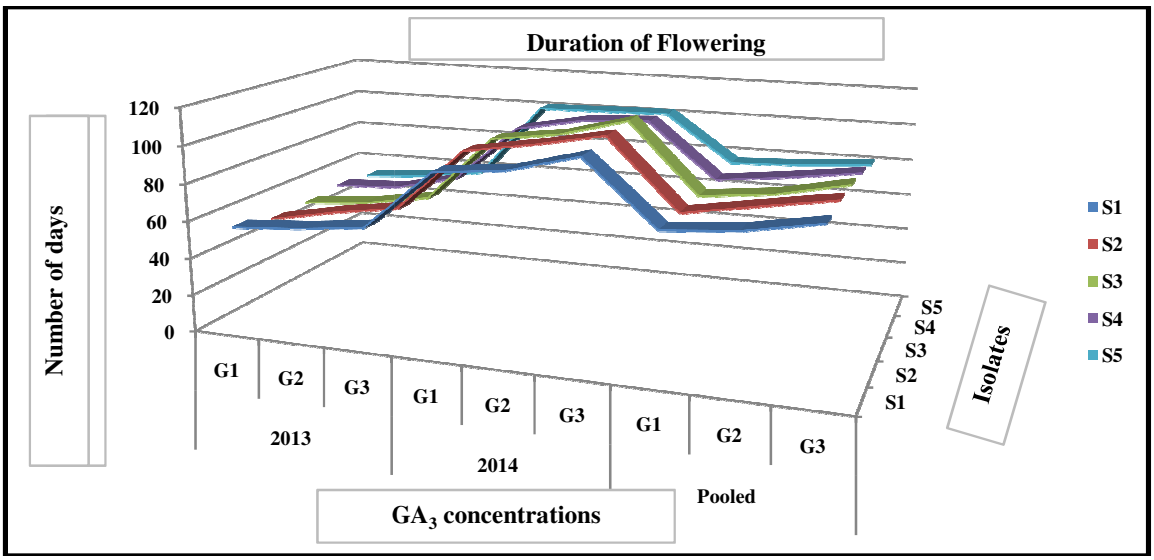


Fig. 6. Interaction effect of GA_3 and plant growth promoting rhizobacteria on duration of flowering of strawberry cv. Chandler



During 2013, flowering duration (63.67 days) was longest under S_4G_3 which was statistically at par with S_1G_3 (62.33 days) and S_2G_3 (63.33 days), whereas shortest flowering duration (51.00 days) was recorded in S_2G_1 which was statistically at par with S_3G_1 and S_5G_1 (51.67 days respectively). However during 2014, the flowering duration was observed

significantly maximum from S_3G_3 (111.00 days) and minimum from S_1G_1 (93.67 days). Among different isolates of plant growth promoting rhizobacteria under study, S_2 (80.39 days) was recorded to be the best isolate. However, during 2013, S_1 (58.78 days) and during 2014, S_2 (103.33 days) were observed to be best isolates, whereas G_3 was most effective as compared to other concentrations during both the years of study (Fig. 6).

4.2.2.3 Date of first harvesting

The dates of first harvesting presented in Table 73(a) varied from 5th to 13th April during 2013 and 31st March to 9th April during 2014. The earliest harvesting (5th April) was recorded in T_1 and T_7 followed by T_2 T_3, T_4 and T_{16} (6th April, respectively), whereas harvesting was late in T_{15} (13th April) followed by T_{12} and T_{18} (12th April, respectively) during 2013. In 2014, the harvesting was earliest in T_4 (31st March) followed by T_{16} (1st April), while late in T_9, T_{15} and T_{18} (9th April, respectively). This study showed that the harvesting was recorded earliest from the treatments in which plant growth promoting rhizobacteria were applied in combination with GA_3 @ 25 ppm, whereas harvesting was late in treatments in which plants were inoculated with rhizobacterial isolates in combination with GA_3 @ 75 ppm.

Table 73(a). Effect of GA_3 and plant growth promoting rhizobacteria on date of first harvesting in strawberry cultivar Chandler

Treatments		Date of first harvesting	
		2013	2014
T_1	GA_3 @ 25 ppm	APR. 5	APR. 4
T_2	GA_3 @ 50 ppm	APR. 6	APR. 5
T_3	GA_3 @ 75 ppm	APR.6	APR. 7
T_4	$S_1 + GA_3$ @ 25 ppm	APR. 6	MAR. 31
T_5	$S_1 + GA_3$ @ 50 ppm	APR. 8	APR. 2
T_6	$S_1 + GA_3$ @ 75 ppm	APR. 9	APR. 3
T_7	$S_2 + GA_3$ @ 25 ppm	APR. 5	APR. 7
T_8	S2+ GA_3 @ 50 ppm	APR. 7	APR. 8
T_9	$S_2 + GA_3$ @ 75 ppm	APR. 9	APR. 9
T_{10}	$S_3 + GA_3$ @ 25 ppm	APR. 9	APR. 2
T_{11}	$S_3 + GA_3$ @ 50 ppm	APR. 11	APR. 4
T_{12}	$S_3 + GA_3$ @ 75 ppm	APR. 12	APR. 6
T_{13}	$S_4 + GA_3$ @ 25 ppm	APR. 7	APR. 5
T_{14}	$S_4 + GA_3$ @ 50 ppm	APR. 9	APR. 5
T_{15}	$S_4 + GA_3$ @ 75 ppm	APR. 13	APR. 9
T_{16}	$S_5 + GA_3$ @ 25 ppm	APR. 6	APR. 1
T_{17}	$S_5 + GA_3$ @ 50 ppm	APR. 11	APR. 3
T_{18}	$S_5 + GA_3$ @ 75 ppm	APR. 12	APR. 9
T_{19}	Control	APR. 8	APR. 5

4.2.2.4 Duration of harvesting

The data on duration of harvesting as influenced by GA_3 and plant growth promoting rhizobacteria are given in Table 75(a) and (b). The pooled data given in Table 75(a) revealed that the duration of harvesting varies from 29.11 to 42.28 days. The maximum harvesting duration was recorded in T_3 (42.28 days) and minimum in T_{19} (29.11 days). A similar trend was observed during both the years of investigations.

Table 74(a). Effect of GA_3 and plant growth promoting rhizobacteria on duration of flowering in strawberry cultivar Chandler

Treatments		Duration of harvesting (days)		
		2013	2014	Pooled
T_1	GA_3 @ 25 ppm	37.67	39.56	38.61
T_2	GA_3 @ 50 ppm	40.33	42.00	41.17
T_3	GA_3 @ 75 ppm	40.67	43.89	42.28
T_4	$S_1 + GA_3$ @ 25 ppm	31.00	36.11	33.56
T_5	$S_1 + GA_3$ @ 50 ppm	34.33	38.67	36.50
T_6	$S_1 + GA_3$ @ 75 ppm	38.33	41.33	39.83
T_7	$S_2 + GA_3$ @ 25 ppm	29.67	33.00	31.33
T_8	S2+ GA_3 @ 50 ppm	30.00	35.33	32.67
T_9	$S_2 + GA_3$ @ 75 ppm	33.00	37.67	35.33
T_{10}	$S_3 + GA_3$ @ 25 ppm	29.00	32.89	30.95
T_{11}	$S_3 + GA_3$ @ 50 ppm	30.33	35.33	32.83
T_{12}	$S_3 + GA_3$ @ 75 ppm	31.89	41.33	36.61
T_{13}	$S_4 + GA_3$ @ 25 ppm	31.33	34.00	32.67
T_{14}	$S_4 + GA_3$ @ 50 ppm	34.17	36.33	35.25
T_{15}	$S_4 + GA_3$ @ 75 ppm	36.67	40.33	38.50
T_{16}	$S_5 + GA_3$ @ 25 ppm	30.33	33.56	31.95
T_{17}	$S_5 + GA_3$ @ 50 ppm	32.00	38.00	35.00
T_{18}	$S_5 + GA_3$ @ 75 ppm	37.33	40.00	38.67
T_{19}	Control	28.00	30.22	29.11
$CD_{0.05}$		1.54	1.38	1.10

Table 74(b). Interaction effect of GA_3 and plant growth promoting rhizobacteria on duration of harvesting of strawberry cultivar Chandler

Treatment	Duration of harvesting (days)											
	2013				2014				Pooled			
	G_1	G_2	G_3	MEAN	G_1	G_2	G_3	MEAN	G_1	G_2	G_3	MEAN
S_1	31.00	34.33	38.33	34.56	36.11	38.67	41.33	38.70	33.56	36.50	39.83	36.63
S_2	29.67	30.00	33.00	30.89	33.00	35.33	37.67	35.33	31.33	32.67	35.33	33.11
S_3	29.00	30.33	31.89	30.41	32.89	35.33	41.33	36.52	30.95	32.83	36.61	33.46
S_4	31.33	34.17	36.67	34.06	34.00	36.33	40.33	36.89	32.67	35.25	38.50	35.47
S_5	30.33	32.00	37.33	33.22	33.56	38.00	40.00	37.19	31.95	35.00	38.67	35.20
MEAN	30.27	32.17	35.44		33.91	36.73	40.13		32.09	34.45	37.79	
$CD_{0.05}$ for S : 0.82					$CD_{0.05}$ for S : 0.84				$CD_{0.05}$ for S : 0.60			
$CD_{0.05}$ for M : 0.63					$CD_{0.05}$ for M : 0.65				$CD_{0.05}$ for M : 0.48			
$CD_{0.05}$ for SxM : 1.41					$CD_{0.05}$ for SxM : 1.45				$CD_{0.05}$ for SxM : NS			

The interaction study between GA_3 and plant growth promoting rhizobacteria exerted significant effect on the duration of harvesting during both the years of study as presented in Table 65(b). However the pooled data revealed non-significant effect on harvesting duration. During 2013, the maximum harvesting duration was recorded from S_1G_3 (38.33 days) which was statistically at par with S_4G_3 and S_5G_3 (36.67 and 37.33 days), whereas minimum harvesting duration was recorded from S_3G_1 (29.00 days). During 2014, the maximum duration of harvesting was recorded from S_1G_3 and S_3G_3 (41.33 days, respectively) which was statistically at par with S_4G_3 and S_5G_3 (40.33 and 40.00 days) and minimum from S_3G_1 (32.89 days). Among different isolates under study, the isolate S_1 and among GA_3 applications, G_3 (GA_3 @75 ppm) were most effective in extending the harvesting duration as compared to other treatments during both the years of study.

4.2.2.5 Number of fruits per plant

The data pertaining to the effect of GA_3 and plant growth promoting rhizobacteria on number of fruits per plant are given in Table 73 (a) to (b). The pooled data given in Table 73 (a) revealed that the maximum number of fruits per plant (21.42) were recorded in T_9 which was statistically at par with T_6 and T_{15} (20.70 and 20.59) and minimum in T_{19} (14.70) as compared to other treatments. During 2013, maximum number of fruits per plant recorded from T_9 (19.73) was statistically at par with T_7 and T_8 (18.20 and 18.47 fruits/ plant), whereas during 2014, the maximum number of fruits per plant were obtained from T_{12} (24.00) which was statistically at par with T_6, T_9, T_{11} and T_{15} (23.67, 23.11, 23.44and 23.78 fruits/ plant, respectively). A similar trend was observed for minimum number of fruits per plant during both the years of study.

The interactive effect of GA_3 and plant growth promoting rhizobacteria as presented in Table 73(b) exhibited significant effect on number of fruits per plant of strawberry cultivar Chandler. However, the effect was non-significant during 2013. Pooled data revealed that the maximum number of fruits per plant (21.42) was recorded from S_2G_3 treatment interaction and minimum from S_3G_1 (17.20). A similar trend was observed during 2013. Whereas, during 2014, the maximum number of fruits per plant (24.00) were recorded from S_3G_3 and minimum number of fruits per plant were recorded from S_3G_1 (19.00) treatment interaction. Among different plant growth promoting rhizobacteria isolates under study, S_2 (20.33) was reported to be most effective in enhancing number of fruits per plant as pooled value. A similar trend was observed during 2013, but during 2014, S_1 (22.70) was reported to be most

effective. However, among different concentrations of GA_3 application, G_3 (GA_3 @75 ppm) was found to be most effective followed by G_2 (GA_3 @50 ppm) during both the years of study.

Table 75(a). Effect of GA_3 and plant growth promoting rhizobacteria on number of fruits per plant of strawberry cultivar Chandler

Treatments		Number of fruits/ plant		
		2013	2014	Pooled
T_1	GA_3 @ 25 ppm	14.97	18.89	16.93
T_2	GA_3 @ 50 ppm	15.13	20.78	17.96
T_3	GA_3 @ 75 ppm	16.20	21.56	18.88
T_4	$S_1 + GA_3$ @ 25 ppm	17.17	22.00	19.58
T_5	$S_1 + GA_3$ @ 50 ppm	17.40	22.44	19.92
T_6	$S_1 + GA_3$ @ 75 ppm	17.73	23.67	20.70
T_7	$S_2 + GA_3$ @ 25 ppm	18.20	20.89	19.55
T_8	$S_2 + GA_3$ @ 50 ppm	18.47	21.55	20.01
T_9	$S_2 + GA_3$ @ 75 ppm	19.73	23.11	21.42
T_{10}	$S_3 + GA_3$ @ 25 ppm	15.40	19.00	17.20
T_{11}	$S_3 + GA_3$ @ 50 ppm	16.03	23.44	19.74
T_{12}	$S_3 + GA_3$ @ 75 ppm	16.27	24.00	20.13
T_{13}	$S_4 + GA_3$ @ 25 ppm	16.10	20.89	18.50
T_{14}	$S_4 + GA_3$ @ 50 ppm	16.93	22.22	19.58
T_{15}	$S_4 + GA_3$ @ 75 ppm	17.40	23.78	20.59
T_{16}	$S_5 + GA_3$ @ 25 ppm	16.00	19.67	17.83
T_{17}	$S_5 + GA_3$ @ 50 ppm	16.53	20.56	18.55
T_{18}	$S_5 + GA_3$ @ 75 ppm	17.47	22.78	20.12
T_{19}	Control	13.62	15.78	14.70
$CD_{0.05}$		1.74	0.97	1.12

Table 75(b). Effect of GA_3 and plant growth promoting rhizobacteria on number of fruits per plant of strawberry cultivar Chandler

Treatment	Number of fruits/ plant											
	2013				2014				Pooled			
	G_1	G_2	G_3	MEAN	G_1	G_2	G_3	MEAN	G_1	G_2	G_3	MEAN
S_1	17.17	17.40	17.73	17.43	22.00	22.44	23.67	22.70	19.58	19.92	20.70	20.07
S_2	18.20	18.47	19.73	18.80	20.89	21.55	23.11	21.85	19.55	20.01	21.42	20.33
S_3	15.40	16.03	16.27	15.90	19.00	23.44	24.00	22.15	17.20	19.74	20.13	19.02
S_4	16.10	16.93	17.40	16.81	20.89	22.22	23.78	22.30	18.50	19.58	20.59	19.55
S_5	16.00	16.53	17.47	16.67	19.67	20.56	22.78	21.00	17.83	18.55	20.12	18.83
MEAN	16.57	17.07	17.72		20.49	22.04	23.47		18.53	19.56	20.59	
$CD_{0.05}$ for S : 1.10					$CD_{0.05}$ for S : 0.56				$CD_{0.05}$ for S : 0.62			
$CD_{0.05}$ for G : 0.85					$CD_{0.05}$ for G : 0.43				$CD_{0.05}$ for G : 0.48			
$CD_{0.05}$ for SxG : NS					$CD_{0.05}$ for SxG : 0.97				$CD_{0.05}$ for SxG : 2.20			

4.2.2.6 Fruit yield per plant

The application of GA_3 and plant growth promoting rhizobacteria significantly influenced the fruit yield per plant [Table 76(a) and (b)]. The pooled data given in Table

76(a) revealed that fruit yield per plant (412.46 g) was highest in T_6 and lowest in T_{19} (209.41 g). A similar trend was observed for minimum fruit yield per plant during both the years of study (151.73 and 267.09 g). However, during 2013, maximum fruit yield per plant (260.93 g) was recorded from T_9 whereas the maximum fruit yield per plant (586.57 g) was recorded in T_{12} during 2014.

The data on interaction study between GA_3 and plant growth promoting rhizobacteria as presented in Table 76(b) showed significant effect on fruit yield per plant of strawberry cultivar Chandler. The pooled data revealed that the maximum fruit yield per plant (412.46 g) was recorded from S_1G_3 treatment interaction whereas minimum fruit yield per plant (312.38 g) was recorded from S_5G_1 treatment interaction. During 2013, significantly highest fruit yield per plant (260.93 g) was recorded from S_2G_3 treatment interaction and minimum from S_5G_1 (181.24 g) treatment interaction, whereas during 2014, maximum fruit yield per plant (586.57 g) was recorded from S_3G_3 and minimum from S_2G_1 (403.86 g) treatment interaction. Among different isolates of plant growth promoting rhizobacteria under study, the isolate S_1 (378.29 g) was most effective in increasing fruit yield per plant as pooled value. A similar trend was observed during 2014 while during 2013, S_2 (243.67 g) was found to be most effective.

Table 76(a). Effect of GA_3 and plant growth promoting rhizobacteria on fruit yield per plant of strawberry cultivar Chandler

Treatments		Fruit yield/ plant (g)		
		2013	**2014**	**Pooled**
T_1	GA_3 @ 25 ppm	183.67	355.82	269.74
T_2	GA_3 @ 50 ppm	192.00	443.87	317.93
T_3	GA_3 @ 75 ppm	210.04	484.52	347.28
T_4	$S_1 + GA_3$ @ 25 ppm	217.67	486.10	351.89
T_5	$S_1 + GA_3$ @ 50 ppm	229.67	511.42	370.54
T_6	$S_1 + GA_3$ @ 75 ppm	254.20	570.71	412.46
T_7	$S_2 + GA_3$ @ 25 ppm	229.67	403.86	316.76
T_8	S2+ GA_3 @ 50 ppm	240.41	471.77	356.09
T_9	$S_2 + GA_3$ @ 75 ppm	260.93	512.52	386.72
T_{10}	$S_3 + GA_3$ @ 25 ppm	193.19	459.36	326.28
T_{11}	$S_3 + GA_3$ @ 50 ppm	209.46	467.95	338.70
T_{12}	$S_3 + GA_3$ @ 75 ppm	217.68	586.57	402.13
T_{13}	$S_4 + GA_3$ @ 25 ppm	195.61	472.70	334.16
T_{14}	$S_4 + GA_3$ @ 50 ppm	208.89	549.41	379.15
T_{15}	$S_4 + GA_3$ @ 75 ppm	216.83	513.97	365.40
T_{16}	$S_5 + GA_3$ @ 25 ppm	181.24	443.51	312.38
T_{17}	$S_5 + GA_3$ @ 50 ppm	203.17	459.50	331.34
T_{18}	$S_5 + GA_3$ @ 75 ppm	238.61	488.48	363.54
T_{19}	Control	151.73	267.09	209.41
$CD_{0.05}$		1.83	1.78	1.72

Table 76(b). Effect of GA_3 and plant growth promoting rhizobacteria on fruit yield per plant of strawberry cultivar Chandler

Treatment	Fruit yield/ plant (g)											
	2013				2014				Pooled			
	G_1	G_2	G_3	MEAN	G_1	G_2	G_3	MEAN	G_1	G_2	G_3	MEAN
S_1	217.67	229.67	254.20	233.84	486.10	511.42	570.71	522.74	351.89	370.54	412.46	378.29
S_2	229.67	240.41	260.93	243.67	403.86	471.77	512.52	462.71	316.76	356.09	386.72	353.19
S_3	193.19	209.46	217.68	206.78	459.36	467.95	586.57	504.63	326.28	338.70	402.13	355.70
S_4	195.61	208.89	216.83	207.11	472.70	549.41	513.97	512.03	334.16	379.15	365.40	359.57
S_5	181.24	203.17	238.61	207.67	443.51	459.50	488.48	463.83	312.38	331.34	363.54	335.75
MEAN	203.48	218.32	237.65		453.11	492.01	534.45		328.29	355.16	386.05	
$CD_{0.05}$ for S : 0.43					$CD_{0.05}$ for S : 0.61				$CD_{0.05}$ for S : 0.39			
$CD_{0.05}$ for G : 0.33					$CD_{0.05}$ for G : 0.47				$CD_{0.05}$ for G : 0.30			
$CD_{0.05}$ for SxG : 0.74					$CD_{0.05}$ for SxG : 1.06				$CD_{0.05}$ for SxG : 0.67			

Among different doses of GA_3 application, G_3 (GA_3 @ 75 ppm) was found to be most effective followed by G_2 (GA_3 @ 50 ppm) during both the years of study.

4.2.2.7 Fruit yield per hectare

The data on fruit yield per hectare as influenced by GA_3 and plant growth promoting rhizobacteria are given in Appendix- II [Table 77(a) to (b)]. The pooled data given in Table 76(a) revealed that highest fruit yield per hectare (33.00 t/ha) was registered in T_6 and lowest in T_{19} (16.75 t/ha). During 2013, maximum fruit yield per hectare (20.87 t/ha) was recorded from T_9, whereas during 2014, the maximum fruit yield per hectare (46.92 t/ha) was recorded in T_{12}. However, the minimum fruit yield per hectare was noted in T_{19} during both the years of study (12.14 and 21.37 t/ha, respectively).

The data on interaction study as presented in Table 77(b) showed significant effect on fruit yield per hectare of strawberry cultivar Chandler. The pooled data revealed that the maximum fruit yield per hectare (33.00 t/ha) was recorded from S_1G_3 treatment interaction whereas minimum fruit yield per plant (24.99 t/ha) was recorded from S_5G_1 interaction. During 2013, highest fruit yield per hectare (20.87 t/ha) was recorded from S_2G_3 and lowest from S_5G_1 (14.5 t/ha) interaction, whereas during 2014, the maximum fruit yield per hectare (46.93 t/ha) was recorded from S_3G_3 and minimum from S_2G_1 (32.31 t/ha) treatment interaction. Among different isolates of plant growth promoting rhizobacteria, S_1 (30.26 t/ha) was reported to be most effective isolate in increasing fruit yield per hectare.

Fig. 7. Effect of GA_3 and plant growth promoting rhizobacteria on fruit yield per hectare of strawberry cultivar Chandler

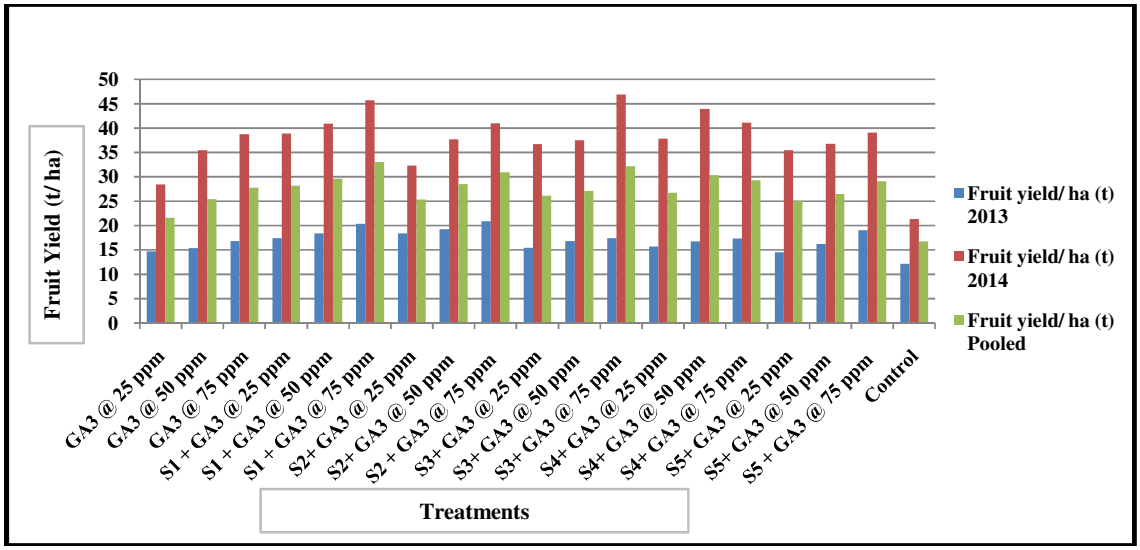
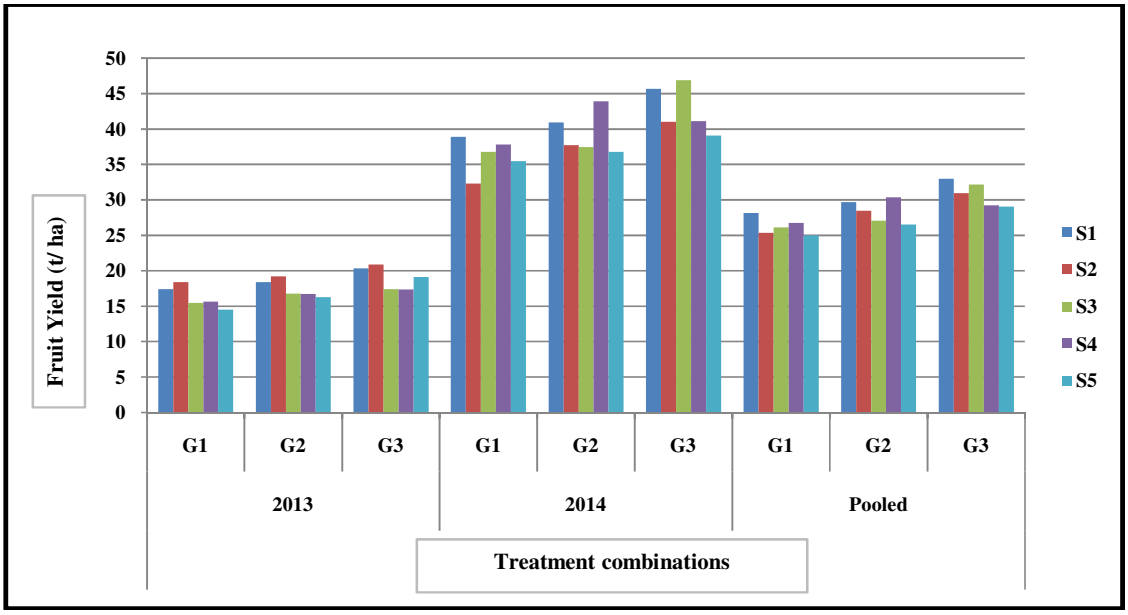


Fig. 8. Interaction effect of GA_3 and plant growth promoting rhizobacteria on fruit yield per hectare of strawberry cultivar Chandler



A similar trend was observed during 2014 while during 2013, S_2 (19.49 t/ha) was found to be most effective. Among different doses of GA_3 application, G_3 (GA_3 @75 ppm) was found to be most effective followed by its lower concentrations during both the years of study.

4.2.3 Fruit quality parameters

4.2.3.1 Fruit weight

It is evident from the Table 78(a) and (b) that the GA_3 and plant growth promoting rhizobacteria had a significant effect on fruit weight. Pooled data given in Table 78(a) revealed that maximum fruit weight was noted in T_6 (20.89 g) which was statistically at par with T_{11}, T_{12} and T_{15} (20.32, 20.45 and 20.67 g, respectively) and minimum fruit weight was recorded in T_{19} (15.76 g). A similar trend was observed during 2013, but the maximum fruit weight (17.61 g) observed in T_6 was statistically at par with T_5, T_9, T_{15} and T_{18} (16.64, 16.68, 16.59 and 16.99 g, respectively). However, during 2014, maximum fruit weight was recorded

Table 78(a). Effect of GA_3 and plant growth promoting rhizobacteria on fruit weight of strawberry cultivar Chandler

Treatments		Fruit weight (g)		
		2013	2014	Pooled
T_1	GA_3 @ 25 ppm	15.09	18.96	17.02
T_2	GA_3 @ 50 ppm	15.71	21.48	18.60
T_3	GA_3 @ 75 ppm	16.14	22.44	19.29
T_4	$S_1 + GA_3$ @ 25 ppm	16.13	22.21	19.17
T_5	$S_1 + GA_3$ @ 50 ppm	16.64	22.72	19.68
T_6	$S_1 + GA_3$ @ 75 ppm	17.61	24.17	20.89
T_7	$S_2 + GA_3$ @ 25 ppm	16.02	19.43	17.72
T_8	$S_2 + GA_3$ @ 50 ppm	16.42	21.95	19.18
T_9	$S_2 + GA_3$ @ 75 ppm	16.68	22.50	19.59
T_{10}	$S_3 + GA_3$ @ 25 ppm	15.95	20.45	18.20
T_{11}	$S_3 + GA_3$ @ 50 ppm	16.42	24.21	20.32
T_{12}	$S_3 + GA_3$ @ 75 ppm	16.32	24.59	20.45
T_{13}	$S_4 + GA_3$ @ 25 ppm	15.64	21.64	18.64
T_{14}	$S_4 + GA_3$ @ 50 ppm	15.72	22.72	19.22
T_{15}	$S_4 + GA_3$ @ 75 ppm	16.59	24.74	20.67
T_{16}	$S_5 + GA_3$ @ 25 ppm	14.72	21.50	18.11
T_{17}	$S_5 + GA_3$ @ 50 ppm	15.62	22.42	19.02
T_{18}	$S_5 + GA_3$ @ 75 ppm	16.99	22.79	19.89
T_{19}	Control	14.52	17.00	15.76
$CD_{0.05}$		1.07	1.56	0.91

Table 78(b). Interaction effect of GA_3 and plant growth promoting rhizobacteria on fruit weight of strawberry cultivar Chandler

Treatment	Fruit weight (g)											
	2013				2014				Pooled			
	G_1	G_2	G_3	MEAN	G_1	G_2	G_3	MEAN	G_1	G_2	G_3	MEAN
S_1	16.13	16.64	17.61	16.79	22.21	22.72	24.17	23.03	19.17	19.68	20.89	19.91
S_2	16.02	16.42	16.68	16.37	19.43	21.95	22.50	21.29	17.72	19.18	19.59	18.83
S_3	15.95	16.42	16.32	16.23	20.45	24.21	24.59	23.08	18.20	20.32	20.45	19.66
S_4	15.64	15.72	16.59	15.98	21.64	22.72	24.74	23.03	18.64	19.22	20.67	19.51
S_5	14.72	15.62	16.99	15.78	21.50	22.42	22.79	22.24	18.11	19.02	19.89	19.01
MEAN	15.69	16.16	16.84		21.05	22.80	23.76		18.37	19.48	20.30	
$CD_{0.05}$ for S : 0.57					$CD_{0.05}$ for S : 0.79				$CD_{0.05}$ for S : 0.48			
$CD_{0.05}$ for G : 0.44					$CD_{0.05}$ for G : 0.61				$CD_{0.05}$ for G : 0.37			
$CD_{0.05}$ for SxG : NS					$CD_{0.05}$ for SxG : 1.37				$CD_{0.05}$ for SxG : NS			

in T_{15} (24.74 g) which was statistically at par with T_6, T_{11} and T_{12} (24.17, 24.21 and 24.59 g, respectively) and minimum in T_{19} (17.00 g).

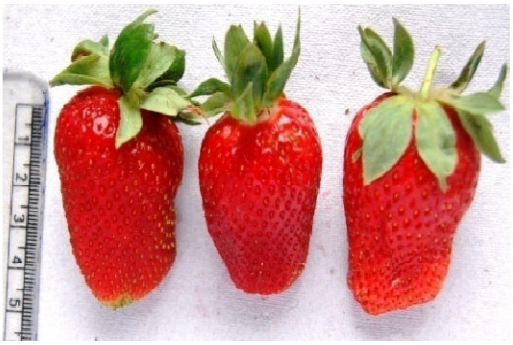
The interaction study between GA_3 and plant growth promoting rhizobacteria as presented in Table 78(b) exerted non-significant effect on fruit weight of strawberry while the interaction effect was significant during 2014. During 2014, maximum fruit weight (24.74 g) was obtained from S_4G_3 treatment interaction which statistically at par with S_1G_3, S_3G_2 and S_3G_3 (24.17, 24.21, 24.59 g, respectively) and minimum fruit weight was recorded from S_2G_1 (19.43 g). Results further shows that S_1 was most effective isolate, while during 2014, the isolate S_3 was reported to be most efficient as compared to other isolates under study. Among different concentrations of GA_3, GA_3 @ 75 ppm was best followed by its lower concentrations during both the years of study.

4.2.3.2 Fruit length

The perusal of data presented in Table 79(a) and (b) revealed that GA_3 and plant growth promoting rhizobacteria treatments had significant effect on fruit length. On the basis of pooled mean value given in Table 79(a), maximum fruit length (44.68 mm) was recorded in T_{12} and minimum fruit length (36.96 mm) was recorded in T_{19}. During 2013, fruit length was maximum in T_9 (40.21 mm) which was statistically at par with T_{12} (40.16 mm), while it was maximum in T_{15} (50.38 mm) during 2014. The minimum fruit length was recorded in T_{19} during both the years of study.

The results related to interaction effect given in Table 79(b) reveals that GA_3 and plant growth promoting rhizobacteria also had a significant effect on fruit length of strawberry. The pooled data given in this table expressed that the maximum fruit length was recorded from S_3G_3 (44.68 mm) and minimum from S_5G_1 (39.25 mm). However, during 2013, the fruit length was maximum under S_2G_3 (40.21 mm) treatment interaction which was statistically at par with S_3G_3 (40.16 mm) and minimum fruit length was recorded from S_5G_1 (33.77 mm) treatment interaction. During 2014, the maximum fruit length was recorded from S_4G_3 (50.38 mm) and minimum from S_3G_1 (44.03 mm). Results further showed that S_2 (38.12 mm) was most effective isolate during 2013 while S_4 (47.72 mm) was reported to be most effective during 2014 as compared to other isolates under study. G_3 (GA_3 @ 75 ppm) was reported as best concentration of GA_3 during both the years of study.

T_{19} = Control



T_1 = GA_3 @ 25 ppm

$T_{12} = S_3 + G_3$

Plate 7. Effect of GA_3 and plant growth promoting rhizobacteria on fruit size of strawberry cv. Chandler

Table 79(a). Effect of GA_3 and plant growth promoting rhizobacteria on fruit length of strawberry cultivar Chandler

Treatments		Fruit length (mm)		
		2013	2014	Pooled
T_1	GA_3 @ 25 ppm	34.05	43.83	38.94
T_2	GA_3 @ 50 ppm	34.59	45.12	39.86
T_3	GA_3 @ 75 ppm	35.71	47.34	41.53
T_4	$S_1 + GA_3$ @ 25 ppm	34.98	44.61	39.80
T_5	$S_1 + GA_3$ @ 50 ppm	35.69	46.77	41.23
T_6	$S_1 + GA_3$ @ 75 ppm	38.28	48.08	43.18
T_7	$S_2 + GA_3$ @ 25 ppm	36.30	45.61	40.96
T_8	$S_2 + GA_3$ @ 50 ppm	37.85	46.75	42.30
T_9	$S_2 + GA_3$ @ 75 ppm	40.21	48.10	44.15
T_{10}	$S_3 + GA_3$ @ 25 ppm	34.84	44.03	39.44
T_{11}	$S_3 + GA_3$ @ 50 ppm	35.48	45.20	40.34
T_{12}	$S_3 + GA_3$ @ 75 ppm	40.16	49.20	44.68
T_{13}	$S_4 + GA_3$ @ 25 ppm	36.35	45.24	40.80
T_{14}	$S_4 + GA_3$ @ 50 ppm	37.06	47.54	42.30
T_{15}	$S_4 + GA_3$ @ 75 ppm	37.37	50.38	43.88
T_{16}	$S_5 + GA_3$ @ 25 ppm	33.77	44.73	39.25
T_{17}	$S_5 + GA_3$ @ 50 ppm	34.97	47.17	41.07
T_{18}	$S_5 + GA_3$ @ 75 ppm	36.89	47.87	42.38
T_{19}	Control	33.02	40.89	36.96
$CD_{0.05}$		0.99	0.53	0.51

Table 79(b). Interaction effect of GA_3 and plant growth promoting rhizobacteria on fruit length of strawberry cultivar Chandler

Treatment	Fruit length (mm)											
	2013				2014				Pooled			
	G_1	G_2	G_3	MEAN	G_1	G_2	G_3	MEAN	G_1	G_2	G_3	MEAN
S_1	34.98	35.69	38.28	36.32	44.61	46.77	48.08	46.49	39.80	41.23	43.18	41.40
S_2	36.30	37.85	40.21	38.12	45.61	46.75	48.10	46.82	40.96	42.30	44.15	42.47
S_3	34.84	35.48	40.16	36.83	44.03	45.20	49.20	46.14	39.44	40.34	44.68	41.49
S_4	36.35	37.06	37.37	36.93	45.24	47.54	50.38	47.72	40.80	42.30	43.88	42.32
S_5	33.77	34.97	36.89	35.21	44.73	47.17	47.87	46.59	39.25	41.07	42.38	40.90
MEAN	35.25	36.21	38.58		44.84	46.69	48.73		40.05	41.45	43.65	
$CD_{0.05}$ for S : 0.48					$CD_{0.05}$ for S : 0.34				$CD_{0.05}$ for S : 0.26			
$CD_{0.05}$ for G : 0.37					$CD_{0.05}$ for G : 0.26				$CD_{0.05}$ for G : 0.20			
$CD_{0.05}$ for SxG : 0.83					$CD_{0.05}$ for SxG : 0.59				$CD_{0.05}$ for SxG : 0.44			

4.2.3.3 Fruit diameter

It is apparent from the Table 80(a) that GA_3 and plant growth promoting rhizobacteria had significant effect on fruit diameter of strawberry. The pooled data analysis revealed that the fruit diameter was maximum in T_6 (29.75 mm) which was statistically at par with T_9, T_{12} and T_{15} (29.38, 29.65 and 29.25 mm, respectively), while minimum fruit diameter was observed in T_{19} (25.77 mm). During 2013, the maximum fruit diameter was recorded in T_{12}

(27.48 mm) which was statistically at par with T_9 (26.90 mm) whereas during 2014, fruit diameter was highest in T_6 (33.37 mm). The fruit diameter was minimum in T_{19} during both the years of study.

The interaction effect of GA_3 and plant growth promoting rhizobacteria on fruit diameter was non-significant, while the interaction effect was significant during 2014 as presented in Table 80(b). However, the pooled value given in this table revealed that S_1G_3 treatment interaction produced maximum fruit diameter (29.75 mm),

Table 80(a). Effect of GA_3 and plant growth promoting rhizobacteria on fruit diameter of strawberry cultivar Chandler

Treatments		Fruit diameter (mm)		
		2013	2014	Pooled
T_1	GA_3 @ 25 ppm	24.20	28.03	26.12
T_2	GA_3 @ 50 ppm	25.12	30.17	27.64
T_3	GA_3 @ 75 ppm	25.97	30.95	28.46
T_4	$S_1 + GA_3$ @ 25 ppm	24.85	29.74	27.29
T_5	$S_1 + GA_3$ @ 50 ppm	25.20	30.59	27.89
T_6	$S_1 + GA_3$ @ 75 ppm	26.12	33.37	29.75
T_7	$S_2 + GA_3$ @ 25 ppm	25.38	28.28	26.83
T_8	$S_2 + GA_3$ @ 50 ppm	25.82	30.36	28.09
T_9	$S_2 + GA_3$ @ 75 ppm	26.90	31.87	29.38
T_{10}	$S_3 + GA_3$ @ 25 ppm	25.59	29.73	27.66
T_{11}	$S_3 + GA_3$ @ 50 ppm	25.70	31.00	28.35
T_{12}	$S_3 + GA_3$ @ 75 ppm	27.48	31.81	29.65
T_{13}	$S_4 + GA_3$ @ 25 ppm	24.59	30.74	27.66
T_{14}	$S_4 + GA_3$ @ 50 ppm	25.76	31.03	28.39
T_{15}	$S_4 + GA_3$ @ 75 ppm	26.29	32.21	29.25
T_{16}	$S_5 + GA_3$ @ 25 ppm	25.06	30.28	27.67
T_{17}	$S_5 + GA_3$ @ 50 ppm	25.23	31.00	28.12
T_{18}	$S_5 + GA_3$ @ 75 ppm	26.03	31.55	28.79
T_{19}	Control	23.71	27.83	25.77
$CD_{0.05}$		0.93	1.03	0.67

Table 80(b). Interaction effect of GA_3 and plant growth promoting rhizobacteria on fruit diameter of strawberry cultivar Chandler

Treatment	Fruit diameter (mm)											
	2013				2014				Pooled			
	G_1	G_2	G_3	MEAN	G_1	G_2	G_3	MEAN	G_1	G_2	G_3	MEAN
S_1	24.85	25.20	26.12	25.39	29.74	30.59	33.37	31.23	27.29	27.89	29.75	28.31
S_2	25.38	25.82	26.90	26.04	28.28	30.36	31.87	30.17	26.83	28.09	29.38	28.10
S_3	25.59	25.70	27.48	26.26	29.73	31.00	31.81	30.85	27.66	28.35	29.65	28.55
S_4	24.59	25.76	26.29	25.54	30.74	31.03	32.21	31.33	27.66	28.39	29.25	28.44
S_5	25.06	25.23	26.03	25.44	30.28	31.00	31.55	30.94	27.67	28.12	28.79	28.19
MEAN	25.09	25.54	26.57		29.75	30.80	32.16		27.42	28.17	29.36	
$CD_{0.05}$ for S : 0.58					$CD_{0.05}$ for S : 0.64				$CD_{0.05}$ for S : NS			
$CD_{0.05}$ for G : 0.45					$CD_{0.05}$ for G : 0.49				$CD_{0.05}$ for G : 0.32			
$CD_{0.05}$ for SxG : NS					$CD_{0.05}$ for SxG : 1.10				$CD_{0.05}$ for SxG : NS			

whereas, minimum fruit diameter was recorded in S_2G_1 (26.83 mm). A similar trend was observed during 2014. Results on interaction effect further showed that S_3 (26.26 mm) was significantly effective isolate for increasing fruit diameter during 2013 whereas, the isolate S_4 (31.33 mm) was found to be most effective during 2014 as compared to other isolates under study. G_3 (GA_3 @ 75 ppm) was found to be most effective GA_3 treatment followed by G_2 (GA_3 @ 50 ppm) during both the years of study.

4.2.3.4 Total soluble solids

The data related to fruit total soluble solids as affected by GA_3 and plant growth promoting rhizobacteria are presented in Table 81(a) and (b). From pooled data given in Table 81(a), it is revealed that highest total soluble solids were recorded with T_{10} (10.52 ^{0}Brix) which was statistically at par with T_{11} and T_{16} (10.33 and 10.17 ^{0}Brix), whereas minimum total soluble solids were recorded from T_3 (7.99 ^{0}Brix) which was statistically at par with T_2 (8.22 ^{0}Brix) when compared with control. A similar trend was observed during 2013 and 2014.

The interaction study between GA_3 and plant growth promoting rhizobacteria exerted the non- significant effect on total soluble solid content, but the interaction effect was significant during 2014. During 2014, the maximum total soluble solids were recorded with

Table 81(a). Effect of GA_3 and plant growth promoting rhizobacteria on fruit TSS of strawberry cultivar Chandler

Treatments		TSS (^{0}Brix)		
		2013	2014	Pooled
T_1	GA_3 @ 25 ppm	9.53	8.58	9.06
T_2	GA_3 @ 50 ppm	9.14	7.30	8.22
T_3	GA_3 @ 75 ppm	8.76	7.21	7.99
T_4	$S_1 + GA_3$ @ 25 ppm	10.04	9.82	9.93
T_5	$S_1 + GA_3$ @ 50 ppm	9.72	8.93	9.33
T_6	$S_1 + GA_3$ @ 75 ppm	9.40	8.71	9.06
T_7	$S_2 + GA_3$ @ 25 ppm	10.12	9.35	9.73
T_8	$S_2 + GA_3$ @ 50 ppm	9.28	9.20	9.24
T_9	$S_2 + GA_3$ @ 75 ppm	9.20	9.10	9.15
T_{10}	$S_3 + GA_3$ @ 25 ppm	10.97	10.07	10.52
T_{11}	$S_3 + GA_3$ @ 50 ppm	10.83	9.84	10.33
T_{12}	$S_3 + GA_3$ @ 75 ppm	9.69	9.47	9.58
T_{13}	$S_4 + GA_3$ @ 25 ppm	10.45	9.00	9.73
T_{14}	$S_4 + GA_3$ @ 50 ppm	9.92	8.94	9.43
T_{15}	$S_4 + GA_3$ @ 75 ppm	8.99	8.33	8.66
T_{16}	$S_5 + GA_3$ @ 25 ppm	10.41	9.93	10.17
T_{17}	$S_5 + GA_3$ @ 50 ppm	9.85	9.37	9.61
T_{18}	$S_5 + GA_3$ @ 75 ppm	9.61	8.32	8.97
T_{19}	Control	9.57	9.43	9.50
$CD_{0.05}$		0.87	0.47	0.45

Table 81(b). Interaction effect of GA_3 and plant growth promoting rhizobacteria on fruit TSS of strawberry cultivar Chandler

Treatment	TSS (^{0}Brix)											
	2013				2014				Pooled			
	G_1	G_2	G_3	MEAN	G_1	G_2	G_3	MEAN	G_1	G_2	G_3	MEAN
S_1	10.04	9.72	9.40	9.72	9.82	8.93	8.71	9.15	9.93	9.33	9.06	9.44
S_2	10.12	9.28	9.20	9.53	9.35	9.20	9.10	9.22	9.73	9.24	9.15	9.37
S_3	10.97	10.83	9.69	10.50	10.07	9.84	9.47	9.79	10.52	10.33	9.58	10.14
S_4	10.45	9.92	8.99	9.79	9.00	8.94	8.33	8.76	9.73	9.43	8.66	9.27
S_5	10.41	9.85	9.61	9.96	9.93	9.37	8.32	9.21	10.17	9.61	8.97	9.58
MEAN	10.40	9.92	9.38		9.63	9.26	8.79		10.02	9.59	9.08	
$CD_{0.05}$ for S : 0.45					$CD_{0.05}$ for S : 0.18				$CD_{0.05}$ for S : 0.25			
$CD_{0.05}$ for G : 0.35					$CD_{0.05}$ for G : 0.14				$CD_{0.05}$ for G : 0.20			
$CD_{0.05}$ for SxG : NS					$CD_{0.05}$ for SxG : 0.32				$CD_{0.05}$ for SxG : NS			

S_3G_1 (10.07 ^{0}Brix) which was statistically at par with S_1G_1, S_3G_2 and S_5G_1 (9.82, 9.84 and 9.93 ^{0}Brix, respectively), while minimum total soluble solids were recorded with S_5G_3 (8.32 ^{0}Brix) statistically at par with S_4G_3 (8.33 ^{0}Brix). Among different plant growth promoting isolates, S_3 was found to be most effective isolate for increasing total soluble solids, whereas G_1 (GA_3 @ 25 ppm) was found to be most effective GA_3 treatment during both the years of study.

4.2.3.5 Acidity

The GA_3 and plant growth promoting rhizobacteria had significantly influenced the fruit acidity in strawberry cultivar Chandler [Table 82(a)]. The pooled values showed that the maximum acidity (1.86 %) was obtained from T_{15} which was statistically at par with T_2, T_3, T_6, T_9 and T_{12} (1.72, 1.84, 1.77, 1.76 and 1.72 %, respectively) and minimum fruit acidity was recorded from T_{19} (1.11 %) statistically at par with T_{10}, T_{13}, T_{16} and T_{17} (1.26, 1.24, 1.16 and 1.25 %, respectively). A similar trend was observed during 2014 except that the maximum acid content (2.18 %) noted in T_{15} was also at par with T_5, but not at par with T_{12}. However, during 2013, fruit acidity was maximum in T_{12} (1.70 %) which was statistically at par with T_2, T_3, T_6, T_8, T_9 and T_{15} (1.45, 1.57, 1.50, 1.48, 1.61 and 1.54 %, respectively) whereas, minimum in T_{19} (1.09 %) which was statistically at par with T_1, T_4, T_5, T_{10}, T_{11}, T_{13}, T_{14}, T_{16} and T_{17} (1.24, 1.16, 1.29, 1.19, 1.34, 1.21, 1.35, 1.14 and 1.21 %, respectively).

The GA_3 and Plant growth promoting rhizobacteria interaction had non-significant effect on fruit acidity. However, the pooled value for maximum fruit acidity was recorded in S_4G_3 (1.86%) and minimum fruit acidity was recorded in S_5G_1 (1.16 %) treatment interaction.

Table 82(a). Effect of GA_3 and plant growth promoting rhizobacteria on fruit acidity of strawberry cultivar Chandler

Treatments		Acidity (%)		
		2013	2014	Pooled
T_1	GA_3 @ 25 ppm	1.24	1.71	1.48
T_2	GA_3 @ 50 ppm	1.45	1.98	1.72
T_3	GA_3 @ 75 ppm	1.57	2.12	1.84
T_4	$S_1 + GA_3$ @ 25 ppm	1.16	1.69	1.43
T_5	$S_1 + GA_3$ @ 50 ppm	1.29	1.95	1.62
T_6	$S_1 + GA_3$ @ 75 ppm	1.50	2.05	1.77
T_7	$S_2 + GA_3$ @ 25 ppm	1.43	1.57	1.50
T_8	$S_2 + GA_3$ @ 50 ppm	1.48	1.81	1.64
T_9	$S_2 + GA_3$ @ 75 ppm	1.61	1.90	1.76
T_{10}	$S_3 + GA_3$ @ 25 ppm	1.19	1.33	1.26
T_{11}	$S_3 + GA_3$ @ 50 ppm	1.34	1.66	1.50
T_{12}	$S_3 + GA_3$ @ 75 ppm	1.70	1.74	1.72
T_{13}	$S_4 + GA_3$ @ 25 ppm	1.21	1.27	1.24
T_{14}	$S_4 + GA_3$ @ 50 ppm	1.35	1.74	1.55
T_{15}	$S_4 + GA_3$ @ 75 ppm	1.54	2.18	1.86
T_{16}	$S_5 + GA_3$ @ 25 ppm	1.14	1.17	1.16
T_{17}	$S_5 + GA_3$ @ 50 ppm	1.21	1.30	1.25
T_{18}	$S_5 + GA_3$ @ 75 ppm	1.43	1.47	1.45
T_{19}	Control	1.09	1.12	1.11
$CD_{0.05}$		0.26	0.28	0.20

Table 82(b). Interaction effect of GA_3 and plant growth promoting rhizobacteria on fruit acidity of strawberry cultivar Chandler

Treatment	Acidity (%)											
	2013				2014				Pooled			
	G_1	G_2	G_3	MEAN	G_1	G_2	G_3	MEAN	G_1	G_2	G_3	MEAN
S_1	1.16	1.29	1.50	1.31	1.69	1.95	2.05	1.90	1.43	1.62	1.77	1.61
S_2	1.43	1.48	1.61	1.51	1.57	1.81	1.90	1.76	1.50	1.64	1.76	1.63
S_3	1.19	1.34	1.70	1.41	1.33	1.66	1.74	1.58	1.26	1.50	1.72	1.49
S_4	1.21	1.35	1.54	1.37	1.27	1.74	2.18	1.73	1.24	1.55	1.86	1.55
S_5	1.14	1.21	1.43	1.26	1.17	1.30	1.47	1.31	1.16	1.25	1.45	1.29
MEAN	1.23	1.33	1.56		1.41	1.69	1.87		1.32	1.51	1.71	
$CD_{0.05}$ for S : 0.16					$CD_{0.05}$ for S : 0.17				$CD_{0.05}$ for S : 0.13			
$CD_{0.05}$ for G : 0.13					$CD_{0.05}$ for G : 0.13				$CD_{0.05}$ for G : 0.10			
$CD_{0.05}$ for SxG : NS					$CD_{0.05}$ for SxG : NS				$CD_{0.05}$ for SxG : NS			

A similar trend was observed during 2014, while during 2013, maximum acidity was recorded from S_3G_3 (1.70 %) treatment interaction and minimum fruit acidity was obtained from S_5G_1 (1.14 %) treatment interaction. Among different plant growth promoting rhizobacteria isolates, S_2 was reported to be most effective, however during 2014, S_1 (1.90 %) was most effective in increasing fruit acidity. The per cent fruit acidity was recorded lowest with the application of S_5 and G_1 (GA_3 @ 25 ppm during both the years of study.

4.2.3.6 TSS: acid ratio

The data related to TSS: acid ratio is given in Table 83(a) and (b). The pooled data depicted in Table 83(a) revealed that T_{16} had significantly higher TSS: acid ratio (8.80) which was significantly at par with T_{10}, T_{13} and T_{19} (8.39, 8.03 and 8.60,

Table 83(a). Effect of GA_3 and plant growth promoting rhizobacteria on fruit TSS: acid ratio of strawberry cultivar Chandler

Treatments		TSS: acid ratio		
		2013	2014	Pooled
T_1	GA_3 @ 25 ppm	7.73	5.11	6.42
T_2	GA_3 @ 50 ppm	6.39	3.68	5.04
T_3	GA_3 @ 75 ppm	5.64	3.41	4.52
T_4	$S_1 + GA_3$ @ 25 ppm	8.66	5.80	7.23
T_5	$S_1 + GA_3$ @ 50 ppm	7.54	4.60	6.07
T_6	$S_1 + GA_3$ @ 75 ppm	6.70	4.27	5.49
T_7	$S_2 + GA_3$ @ 25 ppm	7.16	6.38	6.77
T_8	$S_2 + GA_3$ @ 50 ppm	6.30	5.11	5.71
T_9	$S_2 + GA_3$ @ 75 ppm	5.76	5.22	5.49
T_{10}	$S_3 + GA_3$ @ 25 ppm	9.22	7.57	8.39
T_{11}	$S_3 + GA_3$ @ 50 ppm	8.09	6.00	7.05
T_{12}	$S_3 + GA_3$ @ 75 ppm	5.93	5.51	5.72
T_{13}	$S_4 + GA_3$ @ 25 ppm	8.96	7.09	8.03
T_{14}	$S_4 + GA_3$ @ 50 ppm	7.34	5.14	6.24
T_{15}	$S_4 + GA_3$ @ 75 ppm	5.99	3.83	4.91
T_{16}	$S_5 + GA_3$ @ 25 ppm	9.10	8.51	8.80
T_{17}	$S_5 + GA_3$ @ 50 ppm	8.15	7.27	7.71
T_{18}	$S_5 + GA_3$ @ 75 ppm	6.72	5.65	6.18
T_{19}	Control	8.74	8.46	8.60
$CD_{0.05}$		1.44	1.01	0.93

Table 83(b). Interaction effect of GA_3 and plant growth promoting rhizobacteria on fruit TSS: acid ratio of strawberry cultivar Chandler

Treatment	TSS: acid ratio											
	2013				2014				Pooled			
	G_1	G_2	G_3	MEAN	G_1	G_2	G_3	MEAN	G_1	G_2	G_3	MEAN
S_1	8.66	7.54	6.70	7.63	5.80	4.60	4.27	4.89	7.23	6.07	5.49	6.26
S_2	7.16	6.30	5.76	6.41	6.38	5.11	5.22	5.57	6.77	5.71	5.49	5.99
S_3	9.22	8.09	5.93	7.75	7.57	6.00	5.51	6.36	8.39	7.05	5.72	7.05
S_4	8.96	7.34	5.99	7.43	7.09	5.14	3.83	5.35	8.03	6.24	4.91	6.39
S_5	9.10	8.15	6.72	7.99	8.51	7.27	5.65	7.14	8.80	7.71	6.18	7.57
MEAN	8.62	7.49	6.22		7.07	5.63	4.90		7.85	6.56	5.56	
$CD_{0.05}$ for S : 0.83					$CD_{0.05}$ for S : 0.64				$CD_{0.05}$ for S : 0.59			
$CD_{0.05}$ for G : 0.64					$CD_{0.05}$ for G : 0.50				$CD_{0.05}$ for G : 0.46			
$CD_{0.05}$ for SxG : NS					$CD_{0.05}$ for SxG : NS				$CD_{0.05}$ for SxG : NS			

respectively) while lowest TSS: acid ratio was recorded from T_3 (4.52) which was statistically at par with T_2 and T_{15} (5.02 and 4.91, respectively). A similar trend was recorded during 2014 except that the maximum TSS: acid ratio (8.51) noted in T_{16} was not statistically at par with T_{13}. However during 2013, the TSS: acid ratio was maximum in T_{10} (9.22) which was significantly at par with T_4, T_{11}, T_{13}, T_{16}, T_{17} and T_{19} (8.66, 8.09, 8.96, 9.10, 8.15 and 8.74, respectively) and the minimum fruit TSS: acid ratio was obtained from T_3 (5.64) which was statistically at par with T_2, T_6, T_8, T_9, T_{12}, T_{15} and T_{18} (6.39, 6.70, 6.30, 5.76, 5.93, 5.99 and 6.72, respectively).

The interaction study between GA_3 and plant growth promoting rhizobacteria exerted non-significant effect on TSS: acid ratio during both the years of study. However, the pooled values given in Table 83(b) revealed that the highest TSS: acid ratio was obtained from S_5G_1 (8.80) and minimum from S_4G_3 (4.91) treatment interaction. On the basis of individual effect, S_5 isolate was found to be most effective in increasing TSS: acid ratio than other isolates and among different concentrations of GA_3, G_1 (GA_3@ 25 ppm) was found to be most effective followed by G_2 (GA_3@ 50 ppm) during both the years of study.

4.2.3.7 Total sugars

The data on total sugars content of strawberry fruit as influenced by different GA_3 and plant growth promoting rhizobacteria are given in Table 84(a) and (b). The pooled data analysis given in Table 84(a) indicates that the highest total sugars were with T_{12} (7.43 %) which was significantly at par with T_6 (7.32 %), whereas T_{19} had significantly lowest total sugars (5.70 %). A similar trend was observed during 2013 except that highest total sugars (7.98 %) noted in T_{12} were not significantly at par with T_6. However during 2014, total sugars were found maximum under T_6 (7.43 %) treatment which was statistically at par with T_9 (7.08 %) and significantly lowest under in T_{19} (5.45 %) treatment.

The cumulative effect of GA_3 and plant growth promoting rhizobacteria treatments on total sugars was found to be non-significant, whereas the effect was significant during 2013 [Table 84(b)]. However, the highest total sugars were recorded from S_3G_3 (7.43 %) and lowest from S_4G_1 (5.92 %) treatment interaction as pooled value. A similar trend was observed during 2013. Furthermore, results on individual effect as presented in this table shows that on an average, S_3 (6.86 %) was

Table 84(a). Effect of GA_3 and plant growth promoting rhizobacteria on fruit total sugars of strawberry cultivar Chandler

Treatments		Total sugars (%)		
		2013	2014	Pooled
T_1	GA_3 @ 25 ppm	6.03	5.57	5.80
T_2	GA_3 @ 50 ppm	6.17	5.70	5.94
T_3	GA_3 @ 75 ppm	6.65	5.98	6.31
T_4	$S_1 + GA_3$ @ 25 ppm	6.31	6.10	6.20
T_5	$S_1 + GA_3$ @ 50 ppm	7.15	6.69	6.92
T_6	$S_1 + GA_3$ @ 75 ppm	7.21	7.43	7.32
T_7	$S_2 + GA_3$ @ 25 ppm	6.27	6.03	6.15
T_8	$S_2 + GA_3$ @ 50 ppm	6.72	6.60	6.66
T_9	$S_2 + GA_3$ @ 75 ppm	6.84	7.08	6.96
T_{10}	$S_3 + GA_3$ @ 25 ppm	6.14	6.26	6.20
T_{11}	$S_3 + GA_3$ @ 50 ppm	7.24	6.67	6.96
T_{12}	$S_3 + GA_3$ @ 75 ppm	7.98	6.88	7.43
T_{13}	$S_4 + GA_3$ @ 25 ppm	6.08	5.75	5.92
T_{14}	$S_4 + GA_3$ @ 50 ppm	7.01	6.02	6.51
T_{15}	$S_4 + GA_3$ @ 75 ppm	7.10	6.89	7.00
T_{16}	$S_5 + GA_3$ @ 25 ppm	6.34	5.64	5.99
T_{17}	$S_5 + GA_3$ @ 50 ppm	6.67	6.13	6.40
T_{18}	$S_5 + GA_3$ @ 75 ppm	6.77	6.62	6.70
T_{19}	Control	5.95	5.45	5.70
$CD_{0.05}$		0.51	0.49	0.37

Table 84(b). Interaction effect of GA_3 and plant growth promoting rhizobacteria on fruit total sugars of strawberry cultivar Chandler

Treatment	Total sugars (%)											
	2013				2014				Pooled			
	G_1	G_2	G_3	MEAN	G_1	G_2	G_3	MEAN	G_1	G_2	G_3	MEAN
S_1	6.31	7.15	7.21	6.89	6.10	6.69	7.43	6.74	6.20	6.92	7.32	6.82
S_2	6.27	6.72	6.84	6.61	6.03	6.60	7.08	6.57	6.15	6.66	6.96	6.59
S_3	6.14	7.24	7.98	7.12	6.26	6.67	6.88	6.61	6.20	6.96	7.43	6.86
S_4	6.08	7.01	7.10	6.73	5.75	6.02	6.89	6.22	5.92	6.51	7.00	6.48
S_5	6.34	6.67	6.77	6.59	5.64	6.13	6.62	6.13	5.99	6.40	6.70	6.36
MEAN	6.23	6.96	7.18		5.96	6.42	6.98		6.09	6.69	7.08	
$CD_{0.05}$ for S : 0.23					$CD_{0.05}$ for S : 0.32				$CD_{0.05}$ for S : 0.21			
$CD_{0.05}$ for G : 0.18					$CD_{0.05}$ for G : 0.25				$CD_{0.05}$ for G : 0.16			
$CD_{0.05}$ for SxG : 0.39					$CD_{0.05}$ for SxG : 0.55				$CD_{0.05}$ for SxG : 0.36			

found to be most effective bacterial isolate for enhancing total sugars followed by S_1 (6.82 %). A similar trend was observed during 2013. However, S_1 (6.74 %) was observed best bacterial isolate during 2014 as compared to other isolates under study. Among different concentrations of GA_3, G_3 (GA_3 @ 75 ppm) was found to be best for increasing total sugars content.

4.2.3.8 Reducing sugars

The data on reducing sugars as presented in Table 85(a) showed significant effect of GA_3 and plant growth promoting rhizobacteria, but their interaction effect was non-

significant as presented in Table 85(b). The pooled data depicted in Table 85(a) reveals that maximum reducing sugars were obtained from T_{15} (5.03 %) which was statistically at par with T_5, T_6, T_8, T_9, T_{12} and T_{18} (4.81, 4.94, 4.72, 4.92, 5.00 and 5.03 % respectively), whereas minimum reducing sugars were recorded from T_{19} (4.01 %) treatment. A similar trend was observed during 2013 except that the maximum reducing sugars (5.34 %) recorded from T_{15} were significantly at par with only T_{12}, T_{14} and T_{18} (4.83, 4.84 and 5.05 %, respectively). However during 2014, reducing sugars were maximum in T_9 (5.26 %) which were significantly at par with T_5, T_6, T_8, T_{11}, T_{12}, T_{15} and T_{18} (4.97, 5.10, 5.00, 4.72, 5.16, 4.73 and 5.00 %, respectively), while minimum reducing sugars were recorded from T_{19} (4.00 %) which was at par with T_1, T_2, T_3, T_4, T_7, T_{13}, T_{14}, T_{16} and T_{17} (4.08, 4.17, 4.39, 4.20, 4.18, 4.02, 4.21, 4.15 and 4.34 %, respectively).

The cummulative effect of GA_3 and plant growth promoting rhizobacteria as presented in Table 85(b) found to be non-significant with respect to reducing sugars. However, the pooled values showed maximum reducing sugars (5.03 %) were obtained from S_4G_3 treatment interaction and minimum from S_2G_1 (4.24 %) treatment interaction. A similar trend was observed for maximum reducing sugars during 2013 while minimum reducing

Table 85(a). Effect of GA_3 and plant growth promoting rhizobacteria on fruit reducing sugars of strawberry cultivar Chandler

Treatments		Reducing sugars (%)		
		2013	2014	Pooled
T_1	GA_3 @ 25 ppm	4.15	4.08	4.12
T_2	GA_3 @ 50 ppm	4.39	4.17	4.28
T_3	GA_3 @ 75 ppm	4.54	4.39	4.47
T_4	$S_1 + GA_3$ @ 25 ppm	4.34	4.20	4.27
T_5	$S_1 + GA_3$ @ 50 ppm	4.65	4.97	4.81
T_6	$S_1 + GA_3$ @ 75 ppm	4.78	5.10	4.94
T_7	$S_2 + GA_3$ @ 25 ppm	4.31	4.18	4.24
T_8	$S_2 + GA_3$ @ 50 ppm	4.44	5.00	4.72
T_9	$S_2 + GA_3$ @ 75 ppm	4.58	5.26	4.92
T_{10}	$S_3 + GA_3$ @ 25 ppm	4.29	4.60	4.44
T_{11}	$S_3 + GA_3$ @ 50 ppm	4.43	4.72	4.57
T_{12}	$S_3 + GA_3$ @ 75 ppm	4.83	5.16	5.00
T_{13}	$S_4 + GA_3$ @ 25 ppm	4.61	4.02	4.32
T_{14}	$S_4 + GA_3$ @ 50 ppm	4.84	4.21	4.52
T_{15}	$S_4 + GA_3$ @ 75 ppm	5.34	4.76	5.03
T_{16}	$S_5 + GA_3$ @ 25 ppm	4.73	4.15	4.44
T_{17}	$S_5 + GA_3$ @ 50 ppm	4.78	4.34	4.56
T_{18}	$S_5 + GA_3$ @ 75 ppm	5.05	5.00	5.03
T_{19}	Control	4.02	4.00	4.01
$CD_{0.05}$		0.53	0.55	0.43

Table 85(b). Interaction effect of GA_3 and plant growth promoting rhizobacteria on fruit reducing sugars of strawberry cultivar Chandler

Treatment	Reducing sugars (%)											
	2013				2014				Pooled			
	G_1	G_2	G_3	MEAN	G_1	G_2	G_3	MEAN	G_1	G_2	G_3	MEAN
S_1	4.34	4.65	4.78	4.59	4.20	4.97	5.10	4.76	4.27	4.81	4.94	4.67
S_2	4.31	4.44	4.58	4.44	4.18	5.00	5.26	4.81	4.24	4.72	4.92	4.63
S_3	4.29	4.43	4.83	4.51	4.60	4.72	5.16	4.83	4.44	4.57	5.00	4.67
S_4	4.61	4.84	5.34	4.93	4.02	4.21	4.76	4.33	4.32	4.52	5.03	4.63
S_5	4.73	4.78	5.05	4.85	4.15	4.34	5.00	4.49	4.44	4.56	5.03	4.67
MEAN	4.45	4.63	4.92		4.23	4.65	5.06		4.34	4.64	4.98	
$CD_{0.05}$ for S : 0.28					$CD_{0.05}$ for S : 0.35				$CD_{0.05}$ for S : NS			
$CD_{0.05}$ for G : 0.22					$CD_{0.05}$ for G : 0.27				$CD_{0.05}$ for G : 0.20			
$CD_{0.05}$ for SxG : NS					$CD_{0.05}$ for SxG : NS				$CD_{0.05}$ for SxG : NS			

sugars (4.29 %) were recorded from S_3G_1. During 2014, reducing sugars were highest in S_2G_3 (5.26 %) and lowest in S_4G_1 (4.02%) treatment interactions. Results further showed that among individual effect of different isolates of plant growth promoting rhizobacteria, S_1, S_3 and S_5 (4.67 %) were most effective isolates. However during 2013, S_4 (4.93 %) was reported to be best which was statistically at par with S_5 (4.83 %), whereas during 2014, S_3 (4.83 %) was found to be best which was statistically at par with S_1 (4.76 %) and S_2 (4.81 %). Among GA_3 treatments, G_3 (GA_3 @ 75 ppm) was proved as best treatment for increased reducing sugars during both the years of study.

4.2.3.9 Non-reducing sugars

The pooled data given in Table 86(a) showed a significant effect of GA_3 and plant growth promoting rhizobacteria treatments on non-reducing sugars of strawberry cultivar Chandler. The non-reducing sugars were maximum in T_{12} (2.32 %) which was significantly at par with T_6 and T_{11} (2.26 % respectively), whereas minimum total sugars (1.48 %) were obtained under T_{16} treatment which was significantly at par with T_1, T_2, T_3, T_{10}, T_{13}, T_{17}, T_{18} and T_{19} (1.60, 1.57, 1.75, 1.67, 1.52, 1.74, 1.59 and 1.61 %, respectively). A similar trend was observed in 2013 except that the lowest non-reducing (1.40 %) was noted in T_{13} treatment. However during 2014, non-reducing sugars were found maximum under T_6 (2.22 %) treatment which was statistically at par with T_4, T_{11} and T_{15} (1.81, 1.86 and 2.05 %, respectively), while lowest non-reducing sugars were obtained under T_{19} (1.38 %) treatment which was statistically at par with all the treatments except maximum values.

Table 86(a). Effect of GA_3 and plant growth promoting rhizobacteria on fruit non reducing sugars of strawberry cultivar Chandler

Treatments		Non-reducing sugars (%)		
		2013	2014	Pooled
T_1	GA_3 @ 25 ppm	1.79	1.42	1.60
T_2	GA_3 @ 50 ppm	1.69	1.46	1.57
T_3	GA_3 @ 75 ppm	2.00	1.50	1.75
T_4	$S_1 + GA_3$ @ 25 ppm	1.87	1.81	1.84
T_5	$S_1 + GA_3$ @ 50 ppm	2.38	1.64	2.01
T_6	$S_1 + GA_3$ @ 75 ppm	2.31	2.22	2.26
T_7	$S_2 + GA_3$ @ 25 ppm	1.86	1.76	1.81
T_8	$S_2 + GA_3$ @ 50 ppm	2.16	1.52	1.84
T_9	$S_2 + GA_3$ @ 75 ppm	2.14	1.73	1.94
T_{10}	$S_3 + GA_3$ @ 25 ppm	1.76	1.58	1.67
T_{11}	$S_3 + GA_3$ @ 50 ppm	2.67	1.86	2.26
T_{12}	$S_3 + GA_3$ @ 75 ppm	3.00	1.64	2.32
T_{13}	$S_4 + GA_3$ @ 25 ppm	1.40	1.64	1.52
T_{14}	$S_4 + GA_3$ @ 50 ppm	2.06	1.72	1.89
T_{15}	$S_4 + GA_3$ @ 75 ppm	1.68	2.05	1.86
T_{16}	$S_5 + GA_3$ @ 25 ppm	1.54	1.42	1.48
T_{17}	$S_5 + GA_3$ @ 50 ppm	1.79	1.70	1.74
T_{18}	$S_5 + GA_3$ @ 75 ppm	1.63	1.55	1.59
T_{19}	Control	1.84	1.38	1.61
$CD_{0.05}$		0.53	0.43	0.28

Table 86(b). Interaction effect of GA_3 and plant growth promoting rhizobacteria on fruit non-reducing sugars of strawberry cultivar Chandler

Treatment	Non- reducing sugars (%)											
	2013				2014				Pooled			
	G_1	G_2	G_3	MEAN	G_1	G_2	G_3	MEAN	G_1	G_2	G_3	MEAN
S_1	1.87	2.38	2.31	2.19	1.81	1.64	2.22	1.89	1.84	2.01	2.26	2.04
S_2	1.86	2.16	2.14	2.06	1.76	1.52	1.73	1.67	1.81	1.84	1.94	1.86
S_3	1.76	2.67	3.00	2.48	1.58	1.86	1.64	1.69	1.67	2.26	2.32	2.08
S_4	1.40	2.06	1.68	1.71	1.64	1.72	2.05	1.80	1.52	1.89	1.86	1.76
S_5	1.54	1.79	1.63	1.65	1.42	1.70	1.55	1.55	1.48	1.74	1.59	1.60
MEAN	1.69	2.21	2.15		1.64	1.69	1.84		1.66	1.95	1.99	
$CD_{0.05}$ for S : 0.32					$CD_{0.05}$ for S : NS				$CD_{0.05}$ for S : 0.17			
$CD_{0.05}$ for G : 0.25					$CD_{0.05}$ for G : NS				$CD_{0.05}$ for G : 0.13			
$CD_{0.05}$ for SxG : NS					$CD_{0.05}$ for SxG : NS				$CD_{0.05}$ for SxG : NS			

The interaction study between GA_3 and plant growth promoting rhizobacteria as presented in Table 86(b) reveals non-significant effect on non-reducing sugars. However, the pooled data revealed that the highest non-reducing sugars were obtained from S_3G_3 (2.32 %) and lowest from S_5G_1 (1.48 %). A similar trend was observed for maximum non-reducing sugars (3.00 %) obtained from S_3G_3 during 2013, but the minimum non-reducing sugars were obtained from S_4G_1 (1.40 %). However, during 2014, the non-reducing sugars were recorded maximum from S_1G_3 (2.22 %) and minimum from S_5G_1 (1.42 %). On comparison with

individual effect of different plant growth promoting rhizobacteria isolates under study, S_3 (2.48 %) was proved as most effective during 2013 while S_1 (1.89 %) was proved to be best during 2014. Among GA_3 treatments, G_3 was best treatment followed by G_2 during both the years of study.

4.2.3.10 Ascorbic acid content

The perusal of data given in Table 87(a) and (b) reveals that GA_3 and plant growth promoting rhizobacteria had a significant effect on ascorbic acid content of strawberry cultivar Chandler. The pooled data given in Table 87(a) showed that ascorbic acid was significantly highest in T_6 (65.93 mg/100 g) and lowest in T_{19} (46.87 mg/100 g). A similar trend was observed during both the years of study.

The data on cumulative effect between GA_3 and plant growth promoting rhizobacteria on fruit ascorbic acid is given in Table 87(b). The pooled values revealed that the significantly maximum ascorbic acid content was obtained from S_1G_3 (65.93 mg/100 g), while minimum ascorbic acid content was obtained from S_2G_1 (48.20 mg/ 100 g). A similar trend was observed during both the years of study except that the ascorbic acid content was

Table 87(a). Effect of GA_3 and plant growth promoting rhizobacteria on fruit ascorbic acid of strawberry cultivar Chandler

Treatments		Ascorbic acid (mg/100g)		
		2013	2014	Pooled
T_1	GA_3 @ 25 ppm	42.33	53.53	47.93
T_2	GA_3 @ 50 ppm	45.47	57.40	51.43
T_3	GA_3 @ 75 ppm	46.83	59.80	53.32
T_4	$S_1 + GA_3$ @ 25 ppm	43.42	55.27	49.34
T_5	$S_1 + GA_3$ @ 50 ppm	51.50	69.38	60.44
T_6	$S_1 + GA_3$ @ 75 ppm	58.20	73.65	65.93
T_7	$S_2 + GA_3$ @ 25 ppm	41.57	54.83	48.20
T_8	$S_2 + GA_3$ @ 50 ppm	43.33	62.20	52.77
T_9	$S_2 + GA_3$ @ 75 ppm	54.20	72.50	63.35
T_{10}	$S_3 + GA_3$ @ 25 ppm	48.20	53.20	50.70
T_{11}	$S_3 + GA_3$ @ 50 ppm	50.20	57.73	53.97
T_{12}	$S_3 + GA_3$ @ 75 ppm	58.05	58.20	58.13
T_{13}	$S_4 + GA_3$ @ 25 ppm	43.03	54.67	48.85
T_{14}	$S_4 + GA_3$ @ 50 ppm	46.67	62.20	54.43
T_{15}	$S_4 + GA_3$ @ 75 ppm	57.72	69.42	63.57
T_{16}	$S_5 + GA_3$ @ 25 ppm	45.58	68.20	56.89
T_{17}	$S_5 + GA_3$ @ 50 ppm	55.42	69.18	62.30
T_{18}	$S_5 + GA_3$ @ 75 ppm	57.95	71.27	64.61
T_{19}	Control	41.00	52.73	46.87
$CD_{0.05}$		1.93	1.83	1.12

Table 87(b). Interaction effect of GA_3 and plant growth promoting rhizobacteria on fruit ascorbic acid of strawberry cultivar Chandler

Treatment	Ascorbic acid (mg/100g)											
	2013				2014				Pooled			
	G_1	G_2	G_3	MEAN	G_1	G_2	G_3	MEAN	G_1	G_2	G_3	MEAN
S_1	43.42	51.50	58.20	51.04	55.27	69.38	73.65	66.10	49.34	60.44	65.93	58.57
S_2	41.57	43.33	54.20	46.37	54.83	62.20	72.50	63.18	48.20	52.77	63.35	54.77
S_3	48.20	50.20	58.05	52.15	53.20	57.73	58.20	56.38	50.70	53.97	58.13	54.26
S_4	43.03	46.67	57.72	49.14	54.67	62.20	69.42	62.09	48.85	54.43	63.57	55.62
S_5	45.58	55.42	57.95	52.98	68.20	69.18	71.27	69.55	56.89	62.30	64.61	61.27
MEAN	44.36	49.42	57.22		57.23	64.14	69.01		50.80	56.78	63.12	
$CD_{0.05}$ for S : 1.14					$CD_{0.05}$ for S : 1.17				$CD_{0.05}$ for S : 0.68			
$CD_{0.05}$ for G : 0.88					$CD_{0.05}$ for G : 0.91				$CD_{0.05}$ for G : 0.53			
$CD_{0.05}$ for SxG : 1.97					$CD_{0.05}$ for SxG : 2.03				$CD_{0.05}$ for SxG : 1.18			

minimum under S_3G_1 (53.20 mg/100 g) during 2014. Results further shows that the S_5 was most effective isolate and, G_3 was best GA_3 treatment responsible for increased ascorbic acid content in strawberry cultivar Chandler during both the years of study.

4.1.3.11 Anthocyanin content

The anthocyanin content of strawberry fruits was significantly improved by different GA_3 and plant growth promoting rhizobacteria treatments as compared to the control which are presented in Table 88(a) and (b). The pooled values shown in Table 88(a) reveals that the anthocyanin content was significantly highest in T_8 (41.62 mg/100 ml) treatment which was statistically at par with T_5 and T_{11} (41.30 and 41.21 mg/100 ml) and lowest in T_{19} (27.90 mg/100 ml) treatment. A similar trend was observed during 2014 whereas during 2013, maximum anthocyanin content was recorded from T_{11} (41.05 mg/100 ml) which was statistically at par with T_5 and T_8 (40.98 and 40.83 mg/100 ml) and minimum anthocyanin content was observed under T_{19} treatment (27.50 mg/100 ml).

The interaction study between GA_3 and plant growth promoting rhizobacteria also exerted a significant effect on anthocyanin content of strawberry as shown in Table 88(b). The pooled value for maximum anthocyanin content was obtained from S_2G_2 (41.62 mg/100 ml) which was statistically at par with S_1G_2 and S_3G_2 (41.30 and 41.21 mg/100 ml, respectively), while significantly minimum anthocyanin content was recorded from S_2G_3 (29.66 mg/100 ml) treatment interaction. A similar trend was observed during 2014, whereas during 2013, the anthocyanin content was maximum under S_3G_2 (41.05 mg/100 ml) treatment interaction which was statistically at par with S_1G_2 and S_2G_2 (40.98 and 40.83 mg/100 ml, respectively) and minimum was obtained from S_2G_3 (29.46 mg/100 ml). Furthermore, on

comparing individual effect, it was observed that the S_3 was proved to be most effective isolate for increased anthocyanin content than other plant growth promoting rhizobacterial isolates and G_2 was found to be best GA_3 treatment for increased anthocyanin content.

Table 88(a). Effect of GA_3 and plant growth promoting rhizobacteria on fruit anthocyanin content of strawberry cultivar Chandler

Treatments		Anthocyanin content (mg/100 ml)		
		2013	2014	Pooled
T_1	GA_3 @ 25 ppm	31.11	34.48	32.80
T_2	GA_3 @ 50 ppm	36.92	37.25	37.08
T_3	GA_3 @ 75 ppm	29.12	30.23	29.68
T_4	$S_1 + GA_3$ @ 25 ppm	37.93	39.72	38.83
T_5	$S_1 + GA_3$ @ 50 ppm	40.98	41.62	41.30
T_6	$S_1 + GA_3$ @ 75 ppm	32.47	33.50	32.98
T_7	$S_2 + GA_3$ @ 25 ppm	31.11	33.24	32.18
T_8	$S_2 + GA_3$ @ 50 ppm	40.83	42.40	41.62
T_9	$S_2 + GA_3$ @ 75 ppm	29.46	29.85	29.66
T_{10}	$S_3 + GA_3$ @ 25 ppm	39.17	40.10	39.63
T_{11}	$S_3 + GA_3$ @ 50 ppm	41.05	41.36	41.21
T_{12}	$S_3 + GA_3$ @ 75 ppm	38.27	38.80	38.54
T_{13}	$S_4 + GA_3$ @ 25 ppm	35.10	36.00	35.55
T_{14}	$S_4 + GA_3$ @ 50 ppm	35.62	36.95	36.29
T_{15}	$S_4 + GA_3$ @ 75 ppm	34.20	35.00	34.60
T_{16}	$S_5 + GA_3$ @ 25 ppm	37.97	38.30	38.13
T_{17}	$S_5 + GA_3$ @ 50 ppm	39.00	40.03	39.52
T_{18}	$S_5 + GA_3$ @ 75 ppm	35.97	37.31	36.64
T_{19}	Control	27.50	28.30	27.90
$CD_{0.05}$		1.66	1.50	1.18

Table 88(b). Interaction effect of GA_3 and plant growth promoting rhizobacteria on fruit anthocyanin content of strawberry cultivar Chandler

Treatment	Anthocyanin content (mg/100 ml)											
	2013				2014				Pooled			
	G_1	G_2	G_3	MEAN	G_1	G_2	G_3	MEAN	G_1	G_2	G_3	MEAN
S_1	37.93	40.98	32.47	37.13	39.72	41.62	33.50	38.28	38.83	41.30	32.98	37.70
S_2	31.11	40.83	29.46	33.80	33.24	42.40	29.85	35.16	32.18	41.62	29.66	34.48
S_3	39.17	41.05	38.27	39.50	40.10	41.36	38.80	40.09	39.63	41.21	38.54	39.79
S_4	35.10	35.62	34.20	34.97	36.00	36.95	35.00	35.98	35.55	36.29	34.60	35.48
S_5	37.97	39.00	35.97	37.65	38.30	40.03	37.31	38.55	38.13	39.52	36.64	38.10
MEAN	36.26	39.50	34.07		37.47	40.47	34.89		36.86	39.99	34.48	
$CD_{0.05}$ for S : 0.89					$CD_{0.05}$ for S : 0.92				$CD_{0.05}$ for S : 0.64			
$CD_{0.05}$ for G : 0.69					$CD_{0.05}$ for G : 0.71				$CD_{0.05}$ for G : 0.50			
$CD_{0.05}$ for SxG : 1.55					$CD_{0.05}$ for SxG : 1.60				$CD_{0.05}$ for SxG : 1.12			

4.2.4 Physiological parameters

4.2.4.1 Chlorophyll content

The data on the effect of GA_3 and plant growth promoting rhizobacteria on chlorophyll content are presented in Table 89(a) and (b). It is apparent from the pooled data

given in Table 89(a) that chlorophyll content was highest in T_9 (3.18 mg/g) which was statistically at par with T_{18} (3.17 mg/g) and significantly lowest in T_{19} (2.50 mg/g). A similar trend was observed during 2014 whereas during 2013, the maximum chlorophyll content (3.21 mg/g) was recorded in T_{18} which was statistically at par with T_9 (3.16 mg/g) and minimum in T_{19} treatment (2.44 mg/g).

The interaction study between GA_3 and plant growth promoting rhizobacteria also exerted a significant effect on chlorophyll content as presented in Table 89(b). The pooled data revealed that the maximum chlorophyll content (3.18 mg/g) was obtained from S_2G_3 which was statistically at par with S_5G_3 (3.17 mg/g), whereas

Table 89(a). Effect of GA_3 and plant growth promoting rhizobacteria on leaf chlorophyll content of strawberry cultivar Chandler

Treatments		Chlorophyll content (mg/g)		
		2013	2014	Pooled
T_1	GA_3 @ 25 ppm	2.53	2.71	2.62
T_2	GA_3 @ 50 ppm	2.83	2.87	2.85
T_3	GA_3 @ 75 ppm	2.88	2.94	2.91
T_4	$S_1 + GA_3$ @ 25 ppm	3.00	3.03	3.01
T_5	$S_1 + GA_3$ @ 50 ppm	3.03	3.07	3.05
T_6	$S_1 + GA_3$ @ 75 ppm	3.06	3.10	3.08
T_7	$S_2 + GA_3$ @ 25 ppm	2.97	2.93	2.95
T_8	$S_2 + GA_3$ @ 50 ppm	3.04	3.05	3.05
T_9	$S_2 + GA_3$ @ 75 ppm	3.16	3.19	3.18
T_{10}	$S_3 + GA_3$ @ 25 ppm	2.80	2.73	2.77
T_{11}	$S_3 + GA_3$ @ 50 ppm	2.85	2.89	2.87
T_{12}	$S_3 + GA_3$ @ 75 ppm	3.08	2.99	3.04
T_{13}	$S_4 + GA_3$ @ 25 ppm	2.79	2.85	2.82
T_{14}	$S_4 + GA_3$ @ 50 ppm	2.83	2.88	2.86
T_{15}	$S_4 + GA_3$ @ 75 ppm	2.90	2.97	2.94
T_{16}	$S_5 + GA_3$ @ 25 ppm	2.69	2.76	2.73
T_{17}	$S_5 + GA_3$ @ 50 ppm	2.87	2.90	2.89
T_{18}	$S_5 + GA_3$ @ 75 ppm	3.21	3.12	3.17
T_{19}	Control	2.44	2.56	2.50
$CD_{0.05}$		0.12	0.10	0.08

Table 89(b). Interaction effect of GA_3 and plant growth promoting rhizobacteria on leaf chlorophyll content of strawberry cultivar Chandler

Treatment	Chlorophyll content (mg/g)											
	2013				2014				Pooled			
	G_1	G_2	G_3	MEAN	G_1	G_2	G_3	MEAN	G_1	G_2	G_3	MEAN
S_1	3.00	3.03	3.06	3.03	3.03	3.07	3.10	3.06	3.01	3.05	3.08	3.05
S_2	2.97	3.04	3.16	3.05	2.93	3.05	3.19	3.06	2.95	3.05	3.18	3.06
S_3	2.80	2.85	3.08	2.91	2.73	2.89	2.99	2.87	2.77	2.87	3.04	2.89
S_4	2.79	2.83	2.90	2.84	2.85	2.88	2.97	2.90	2.82	2.86	2.94	2.87
S_5	2.69	2.87	3.21	2.92	2.76	2.90	3.12	2.93	2.73	2.89	3.17	2.93
MEAN	2.85	2.92	3.08		2.86	2.96	3.07		2.86	2.94	3.08	
$CD_{0.05}$ for S : 0.08					$CD_{0.05}$ for S : 0.06				$CD_{0.05}$ for S : 0.04			
$CD_{0.05}$ for G : 0.06					$CD_{0.05}$ for G : 0.05				$CD_{0.05}$ for G : 0.05			
$CD_{0.05}$ for SxG : 0.13					$CD_{0.05}$ for SxG : 0.10				$CD_{0.05}$ for SxG : 0.09			

minimum chlorophyll content was recorded from S_5G_1 (2.73 mg/g) which was statistically at par with S_3G_1 and S_4G_1 (2.77 and 2.82 mg/g, respectively). During 2013, maximum chlorophyll content was recorded from S_5G_3 (3.21 mg/g) treatment interaction which was significantly at par with S_2G_3 and S_3G_3 (3.16 and 3.08 mg/g, respectively), whereas minimum chlorophyll content was obtained from S_5G_1 (2.69 mg/g) statistically at par with S_3G_1 and S_4G_1 (2.80 and 2.79 mg/g, respectively). However during 2014, maximum chlorophyll content (3.19 mg/g) was observed under S_2G_3 treatment interaction which was significantly at par with S_1G_3 and S_5G_3 (3.10 and 3.12 mg/g, respectively), whereas minimum was recorded from S_3G_1 (2.73 mg/g) statistically at par with S_5G_1 (2.76 mg/g) treatment interaction. Furthermore study reveals that among individual effect of different plant growth promoting rhizobacteria isolates, S_2 was most effective followed by S_1, whereas among GA_3 treatments, G_3 was found to be most effective during both the years of study.

4.2.4.2 Photosynthesis

The rate of photosynthesis was significantly influenced by GA_3 and plant growth promoting rhizobacteria [Table 90(a) and (b)]. The pooled data given in Table 90(a) showed that significantly higher rate of photosynthesis was noted in T_{15} (10.59 μ mol/m^2/s) and lowest in T_{19} (5.86 μ mol/m^2/s). A related trend was observed for interactions study during 2013 and 2014.

Table 90(a). Effect of GA_3 and plant growth promoting rhizobacteria on photosynthesis of strawberry cultivar Chandler

Treatments		Photosynthesis (μ mol/m^2/s)		
		2013	**2014**	**Pooled**
T_1	GA_3 @ 25 ppm	6.01	6.40	6.21
T_2	GA_3 @ 50 ppm	6.29	6.80	6.55
T_3	GA_3 @ 75 ppm	7.75	8.03	7.89
T_4	$S_1 + GA_3$ @ 25 ppm	6.69	7.10	6.90
T_5	$S_1 + GA_3$ @ 50 ppm	7.53	7.91	7.72
T_6	$S_1 + GA_3$ @ 75 ppm	8.95	9.45	9.20
T_7	$S_2 + GA_3$ @ 25 ppm	7.12	7.54	7.33
T_8	$S_2 + GA_3$ @ 50 ppm	7.64	8.31	7.98
T_9	$S_2 + GA_3$ @ 75 ppm	9.17	10.33	9.75
T_{10}	$S_3 + GA_3$ @ 25 ppm	6.20	6.75	6.47
T_{11}	$S_3 + GA_3$ @ 50 ppm	6.57	7.07	6.82
T_{12}	$S_3 + GA_3$ @ 75 ppm	7.30	8.11	7.70
T_{13}	$S_4 + GA_3$ @ 25 ppm	7.21	7.73	7.47
T_{14}	$S_4 + GA_3$ @ 50 ppm	7.80	8.30	8.05
T_{15}	$S_4 + GA_3$ @ 75 ppm	10.14	11.03	10.59
T_{16}	$S_5 + GA_3$ @ 25 ppm	6.76	7.10	6.93
T_{17}	$S_5 + GA_3$ @ 50 ppm	7.06	7.59	7.33
T_{18}	$S_5 + GA_3$ @ 75 ppm	9.03	8.83	8.93
T_{19}	Control	5.70	6.01	5.86
$CD_{0.05}$		0.22	0.20	0.18

Table 90(b). Interaction effect of GA_3 and plant growth promoting rhizobacteria on leaf photosynthesis of strawberry cultivar Chandler

Treatment	Photosynthesis (µ mol/m^2/s)											
	2013				2014				Pooled			
	G_1	G_2	G_3	MEAN	G_1	G_2	G_3	MEAN	G_1	G_2	G_3	MEAN
S_1	6.69	7.53	8.95	7.72	7.10	7.91	9.45	8.15	6.90	7.72	9.20	7.94
S_2	7.12	7.64	9.17	7.98	7.54	8.31	10.33	8.73	7.33	7.98	9.75	8.35
S_3	6.20	6.57	7.30	6.69	6.75	7.07	8.11	7.31	6.47	6.82	7.70	7.00
S_4	7.21	7.80	10.14	8.38	7.73	8.30	11.03	9.02	7.47	8.05	10.59	8.70
S_5	6.76	7.06	9.03	7.62	7.10	7.59	8.83	7.84	6.93	7.33	8.93	7.73
MEAN	6.79	7.32	8.92		7.24	7.84	9.55		7.02	7.58	9.23	
$CD_{0.05}$ for S : 0.12					$CD_{0.05}$ for S : 0.12				$CD_{0.05}$ for S : 0.10			
$CD_{0.05}$ for G : 0.09					$CD_{0.05}$ for G : 0.09				$CD_{0.05}$ for G : 0.08			
$CD_{0.05}$ for SxG : 0.20					$CD_{0.05}$ for SxG : 0.21				$CD_{0.05}$ for SxG : 0.18			

The interactions effect between GA_3 and plant growth promoting rhizobacteria was also significant with respect to the rate of photosynthesis as presented in Table 90(b). The significantly maximum rate of photosynthesis (10.59 µ mol/m^2/s) was noted from S_4G_3 and minimum from S_3G_1 (6.47 µ mol/m^2/s). Again, a similar trend was observed for interactions study during 2013 and 2014. Among different plant growth promoting isolates under study, S_4 was found to be most effective for improving photosynthetic rate and G_3 (GA_3 @ 75 ppm) as best GA_3 treatment than others during both the years of study.

4.2.4.3 Stomatal conductance

The data pertaining to stomatal conductance as affected by GA_3 and plant growth promoting rhizobacteria are presented in Table 91(a) and (b). The pooled data given in Table 91(a) reveals that significantly highest stomatal conductance (0.658 m mol/s) was recorded from T_{18}, whereas lowest stomatal conductance (0.404 m mol/s) was recorded from T_{19} which was statistically at par with T_1 and T_2 (0.416 and 0.423 m mol/s, respectively). A similar trend was observed during both the years of investigations.

The values on cumulative effect between GA_3 and plant growth promoting rhizobacteria are presented in Table 91(b) showing significant effect on stomatal conductance. The pooled data given in this Table reveals that highest stomatal conductance (0.658 m mol/s) was recorded from S_5G_3 treatment interaction and lowest from S_1G_1 (0.428 m mol/s). A similar trend was observed during both the years of study. Among different isolates of plant growth promoting rhizobacteria, S_5 showed significantly higher individual effect on stomatal conductance, while G_3 (GA_3 @ 75 ppm) was recorded as most effective GA_3 treatment during both the years of study.

Table 91(a). Effect of GA_3 and plant growth promoting rhizobacteria on stomatal conductance of strawberry cultivar Chandler

Treatments		Stomatal conductance (m mol/s)		
		2013	2014	Pooled
T_1	GA_3 @ 25 ppm	0.389	0.443	0.416
T_2	GA_3 @ 50 ppm	0.397	0.450	0.423
T_3	GA_3 @ 75 ppm	0.408	0.462	0.435
T_4	$S_1 + GA_3$ @ 25 ppm	0.399	0.457	0.428
T_5	$S_1 + GA_3$ @ 50 ppm	0.410	0.471	0.440
T_6	$S_1 + GA_3$ @ 75 ppm	0.426	0.480	0.453
T_7	$S_2 + GA_3$ @ 25 ppm	0.415	0.466	0.441
T_8	$S_2 + GA_3$ @ 50 ppm	0.461	0.514	0.488
T_9	$S_2 + GA_3$ @ 75 ppm	0.476	0.529	0.502
T_{10}	$S_3 + GA_3$ @ 25 ppm	0.412	0.468	0.440
T_{11}	$S_3 + GA_3$ @ 50 ppm	0.428	0.482	0.455
T_{12}	$S_3 + GA_3$ @ 75 ppm	0.444	0.496	0.470
T_{13}	$S_4 + GA_3$ @ 25 ppm	0.449	0.502	0.475
T_{14}	$S_4 + GA_3$ @ 50 ppm	0.477	0.527	0.502
T_{15}	$S_4 + GA_3$ @ 75 ppm	0.514	0.562	0.538
T_{16}	$S_5 + GA_3$ @ 25 ppm	0.475	0.527	0.501
T_{17}	$S_5 + GA_3$ @ 50 ppm	0.508	0.556	0.532
T_{18}	$S_5 + GA_3$ @ 75 ppm	0.636	0.680	0.658
T_{19}	Control	0.381	0.428	0.404
$CD_{0.05}$		0.020	0.041	0.020

Table 91(b). Interaction effect of GA_3 and plant growth promoting rhizobacteria on stomatal conductance of strawberry cultivar Chandler

Treatment	Stomatal conductance (m mol/s)											
	2013				2014				Pooled			
	G_1	G_2	G_3	MEAN	G_1	G_2	G_3	MEAN	G_1	G_2	G_3	MEAN
S_1	0.399	0.410	0.426	0.412	0.457	0.471	0.480	0.469	0.428	0.440	0.453	0.440
S_2	0.415	0.461	0.476	0.450	0.466	0.514	0.529	0.503	0.441	0.488	0.502	0.477
S_3	0.412	0.428	0.444	0.428	0.468	0.482	0.496	0.482	0.440	0.455	0.470	0.455
S_4	0.449	0.477	0.514	0.480	0.502	0.527	0.562	0.530	0.475	0.502	0.538	0.505
S_5	0.475	0.508	0.636	0.540	0.527	0.556	0.680	0.588	0.501	0.532	0.658	0.564
MEAN	0.430	0.457	0.499		0.484	0.510	0.549		0.457	0.483	0.524	
$CD_{0.05}$ for S : 0.007					$CD_{0.05}$ for S : 0.012				$CD_{0.05}$ for S : 0.004			
$CD_{0.05}$ for G : 0.005					$CD_{0.05}$ for G : 0.010				$CD_{0.05}$ for G : 0.003			
$CD_{0.05}$ for SxG : 0.012					$CD_{0.05}$ for SxG : 0.021				$CD_{0.05}$ for SxG : 0.007			

4.2.4.4 Stomatal resistance

It is evident from the Table 92(a) and (b) that GA_3 and plant growth promoting rhizobacteria had significantly influenced the stomatal resistance in strawberry cultivar Chandler when compared with control. The lowest pooled stomatal resistance was recorded in T_{18} (0.571 S cm^{-1}) which was statistically at par with T_9 (0.610 S cm^{-1}) and highest in T_{19} (1.228 S cm^{-1}) treatment which was statistically at par with T_1 (1.208 S cm^{-1}). A similar trend was observed during both the years of study.

Table 92(a). Effect of GA_3 and plant growth promoting rhizobacteria on stomatal resistance of strawberry cultivar Chandler

Treatments		Stomatal resistance (S cm-1)		
		2013	2014	Pooled
T_1	GA_3 @ 25 ppm	1.225	1.191	1.208
T_2	GA_3 @ 50 ppm	1.058	1.069	1.063
T_3	GA_3 @ 75 ppm	0.802	0.876	0.839
T_4	$S_1 + GA_3$ @ 25 ppm	0.924	0.991	0.957
T_5	$S_1 + GA_3$ @ 50 ppm	0.690	0.851	0.771
T_6	$S_1 + GA_3$ @ 75 ppm	0.657	0.624	0.640
T_7	$S_2 + GA_3$ @ 25 ppm	1.104	0.899	1.002
T_8	$S_2 + GA_3$ @ 50 ppm	0.973	0.703	0.838
T_9	$S_2 + GA_3$ @ 75 ppm	0.604	0.616	0.610
T_{10}	$S_3 + GA_3$ @ 25 ppm	1.184	1.151	1.168
T_{11}	$S_3 + GA_3$ @ 50 ppm	0.855	1.022	0.938
T_{12}	$S_3 + GA_3$ @ 75 ppm	0.669	0.795	0.732
T_{13}	$S_4 + GA_3$ @ 25 ppm	1.031	1.052	1.041
T_{14}	$S_4 + GA_3$ @ 50 ppm	1.007	0.898	0.952
T_{15}	$S_4 + GA_3$ @ 75 ppm	0.762	0.712	0.737
T_{16}	$S_5 + GA_3$ @ 25 ppm	0.937	0.938	0.937
T_{17}	$S_5 + GA_3$ @ 50 ppm	0.667	0.640	0.653
T_{18}	$S_5 + GA_3$ @ 75 ppm	0.552	0.590	0.571
T_{19}	Control	1.256	1.199	1.228
$CD_{0.05}$		0.041	0.061	0.041

Table 92(b). Interaction effect of GA_3 and plant growth promoting rhizobacteria on stomatal resistance of strawberry cultivar Chandler

Treatment	Stomatal resistance (S cm^{-1})											
	2013				2014				Pooled			
	G_1	G_2	G_3	MEAN	G_1	G_2	G_3	MEAN	G_1	G_2	G_3	MEAN
S_1	0.924	0.690	0.657	0.757	0.991	0.851	0.624	0.822	0.957	0.771	0.640	0.789
S_2	1.104	0.973	0.604	0.894	0.899	0.703	0.616	0.740	1.002	0.838	0.610	0.817
S_3	1.184	0.855	0.669	0.903	1.151	1.022	0.795	0.989	1.168	0.938	0.732	0.946
S_4	1.031	1.007	0.762	0.933	1.052	0.898	0.712	0.887	1.041	0.952	0.737	0.910
S_5	0.937	0.667	0.552	0.718	0.938	0.640	0.590	0.722	0.937	0.653	0.571	0.720
MEAN	1.036	0.838	0.649		1.006	0.823	0.667		1.021	0.831	0.658	
$CD_{0.05}$ for S : 0.021					$CD_{0.05}$ for S : 0.029				$CD_{0.05}$ for S : 0.019			
$CD_{0.05}$ for G : 0.016					$CD_{0.05}$ for G : 0.023				$CD_{0.05}$ for G : 0.014			
$CD_{0.05}$ for SxG : 0.036					$CD_{0.05}$ for SxG : 0.051				$CD_{0.05}$ for SxG : 0.032			

The data depicted in Table 92(b) showed that values of stomatal resistance differed significantly with respect to interaction between GA_3 and plant growth promoting rhizobacteria. The pooled data reveals that significantly highest stomatal resistance was recorded from S_3G_1 (1.168 S cm^{-1}) and lowest stomatal resistance from S_5G_3 (0.571 S cm^{-1}) treatment interactions. Again, a similar trend was observed during both the years of investigation. Furthermore, results showed that the GA_3 application at 75 ppm (G_3) decreased

the stomatal resistance (0.658 S cm^{-1}) as compared to other GA_3 treatments. Among different plant growth promoting rhizobacteria isolates, S_5 was found to effective in decreasing the stomatal resistance during both the years of study.

4.2.4.5 Transpiration rate

The perusal of data given in Table 93(a) and (b) reveals that the GA_3 and plant growth promoting rhizobacteria had significantly influenced the transpiration rate in

Table 93(a). Effect of GA_3 and plant growth promoting rhizobacteria on leaf transpiration rate of strawberry cultivar Chandler

Treatments		Transpiration rate (m mol/m^2/s)		
		2013	2014	Pooled
T_1	GA_3 @ 25 ppm	26.35	25.69	26.02
T_2	GA_3 @ 50 ppm	26.63	25.94	26.29
T_3	GA_3 @ 75 ppm	27.54	27.01	27.28
T_4	S_1 + GA_3 @ 25 ppm	27.36	26.69	27.02
T_5	S_1 + GA_3 @ 50 ppm	27.78	27.12	27.45
T_6	S_1 + GA_3 @ 75 ppm	28.86	28.86	28.86
T_7	S_2+ GA_3 @ 25 ppm	26.49	26.79	26.64
T_8	S_2+ GA_3 @ 50 ppm	27.20	27.64	27.42
T_9	S_2 + GA_3 @ 75 ppm	31.20	30.53	30.86
T_{10}	S_3+ GA_3 @ 25 ppm	26.48	25.82	26.15
T_{11}	S_3+ GA_3 @ 50 ppm	27.42	26.60	27.01
T_{12}	S_3+ GA_3 @ 75 ppm	28.00	27.30	27.65
T_{13}	S_4+ GA_3 @ 25 ppm	26.80	26.42	26.61
T_{14}	S_4+ GA_3 @ 50 ppm	27.08	26.90	26.99
T_{15}	S_4+ GA_3 @ 75 ppm	27.64	27.47	27.56
T_{16}	S_5+ GA_3 @ 25 ppm	27.33	26.72	27.03
T_{17}	S_5+ GA_3 @ 50 ppm	28.01	27.68	27.85
T_{18}	S_5 + GA_3 @ 75 ppm	33.58	32.51	33.04
T_{19}	Control	25.86	25.20	25.53
$CD_{0.05}$		0.83	0.77	0.65

Table 93(b). Interaction effect of GA_3 and plant growth promoting rhizobacteria on leaf transpiration rate of strawberry cultivar Chandler

Treatment	Transpiration rate (m mol/m^2/s)											
	2013				2014				Pooled			
	G_1	G_2	G_3	MEAN	G_1	G_2	G_3	MEAN	G_1	G_2	G_3	MEAN
S_1	27.36	27.78	28.86	28.00	26.69	27.12	28.86	27.56	27.02	27.45	28.86	27.78
S_2	26.49	27.20	31.20	28.30	26.79	27.64	30.53	28.32	26.64	27.42	30.86	28.31
S_3	26.48	27.42	28.00	27.30	25.82	26.60	27.30	26.57	26.15	27.01	27.65	26.94
S_4	26.80	27.08	27.64	27.18	26.42	26.90	27.47	26.93	26.61	26.99	27.56	27.05
S_5	27.33	28.01	33.58	29.64	26.72	27.68	32.51	28.97	27.03	27.85	33.04	29.31
MEAN	26.89	27.50	29.86		26.49	27.19	29.33		26.69	27.34	29.60	
$CD_{0.05}$ for S : 0.48					$CD_{0.05}$ for S : 0.48				$CD_{0.05}$ for S : 0.37			
$CD_{0.05}$ for G : 0.37					$CD_{0.05}$ for G : 0.37				$CD_{0.05}$ for G : 0.29			
$CD_{0.05}$ for SxG : 0.83					$CD_{0.05}$ for SxG : 0.83				$CD_{0.05}$ for SxG : 0.64			

strawberry cultivar Chandler. The pooled data given in Table 93(a) showed that T_{18} had significantly highest transpiration rate (33.04 m mol/m^2/s) as compared to other treatments, whereas lowest transpiration rate was observed in T_{19} (25.53 m mol/m^2/s) which was statistically at par with T_1 and T_{10} (26.02 and 26.15 m mol/m^2/s, respectively). A similar trend was observed during both the years of study.

The data on interaction effect between GA_3 and plant growth promoting rhizobacteria are presented in Table 93(b). The pooled values revealed that the significantly maximum transpiration rate was recorded from S_5G_3 (33.04 m mol/m^2/s), whereas the transpiration rate was lowest in S_3G_1 (26.15 m mol/m^2/s) and was statistically at par S_2G_1 and S_4G_1 (26.64 and 26.61 m mol/ m^2/s, respectively). The results further indicates that the transpiration rate was increased in plants inoculated with S_5 as compared to other plant growth promoting rhizobacteria isolates and also showed increased transpiration rate with the application of GA_3 at 75 ppm (G_3) as compared to other GA_3 treatments. A similar trend was observed during 2013 and 2014 under study.

4.2.5 Leaf nutrients

4.2.5.1 Nitrogen

Leaf nutrient status of strawberry cultivar Chandler was significantly influenced by different concentrations of GA_3 (25, 50 and 75 ppm) and plant growth promoting rhizobacteria. The pooled data as presented in Table 94(a) revealed that significantly highest leaf nitrogen content (2.70 %) was recorded in T_6 treatment whereas, minimum content (2.05 %) was recorded in T_{19} which was statistically at par with T_1 (2.11 %). A similar trend was also observed during 2013, however, the minimum leaf nitrogen content (2.04 %) observed in T_{19} was at par with T_1, T_4, T_7 and T_{13} (2.08, 2.16, 2.14 and 2.12 %). During 2014, highest leaf nitrogen content (2.63 %) was recorded under T_9 treatment which was statistically at par with T_6, T_{12} and T_{18} (261, 2.60 and 2.54 %) and minimum leaf nitrogen content was observed in T_{19} (2.07 %) statistically at par with T_1 (2.14 %).

The cummulative effect between GA_3 and plant growth promoting rhizobacteria presented in Table 94(b) revealed significant effect during 2013, while it was non-significant during 2014. The pooled data given in Table 94(b) reveals that the leaf nitrogen content (2.70 %) was recorded from interaction of S_1G_3 treatment, whereas lowest was recorded from S_4G_1

(2.18 %) statistically at par with S_1G_1 (2.23 %), S_2G_1 (2.26 %) and S_5G_1 (2.23 %) treatment interactions. A similar trend was also followed during 2013. However, during 2014, highest

Table 94(a). Effect of GA_3 and plant growth promoting rhizobacteria on leaf nitrogen content of strawberry cultivar Chandler

Treatments		Nitrogen (%)		
		2013	2014	Pooled
T_1	GA_3 @ 25 ppm	2.08	2.14	2.11
T_2	GA_3 @ 50 ppm	2.21	2.32	2.26
T_3	GA_3 @ 75 ppm	2.40	2.40	2.40
T_4	$S_1 + GA_3$ @ 25 ppm	2.16	2.29	2.23
T_5	$S_1 + GA_3$ @ 50 ppm	2.42	2.48	2.45
T_6	$S_1 + GA_3$ @ 75 ppm	2.78	2.61	2.70
T_7	$S_2 + GA_3$ @ 25 ppm	2.14	2.38	2.26
T_8	$S_2 + GA_3$ @ 50 ppm	2.43	2.57	2.50
T_9	$S_2 + GA_3$ @ 75 ppm	2.49	2.63	2.56
T_{10}	$S_3 + GA_3$ @ 25 ppm	2.28	2.27	2.28
T_{11}	$S_3 + GA_3$ @ 50 ppm	2.35	2.39	2.37
T_{12}	$S_3 + GA_3$ @ 75 ppm	2.46	2.60	2.53
T_{13}	$S_4 + GA_3$ @ 25 ppm	2.12	2.25	2.18
T_{14}	$S_4 + GA_3$ @ 50 ppm	2.35	2.36	2.36
T_{15}	$S_4 + GA_3$ @ 75 ppm	2.51	2.50	2.51
T_{16}	$S_5 + GA_3$ @ 25 ppm	2.20	2.26	2.23
T_{17}	$S_5 + GA_3$ @ 50 ppm	2.37	2.48	2.43
T_{18}	$S_5 + GA_3$ @ 75 ppm	2.42	2.54	2.48
T_{19}	Control	2.04	2.07	2.05
$CD_{0.05}$		0.12	0.10	0.08

Table 94(b). Interaction effect of GA_3 and plant growth promoting rhizobacteria on leaf nitrogen content of strawberry cultivar Chandler

Treatment	Nitrogen (%)											
	2013				2014				Pooled			
	G_1	G_2	G_3	MEAN	G_1	G_2	G_3	MEAN	G_1	G_2	G_3	MEAN
S_1	2.16	2.42	2.78	2.45	2.29	2.48	2.61	2.46	2.23	2.45	2.70	2.46
S_2	2.14	2.43	2.49	2.35	2.38	2.57	2.63	2.53	2.26	2.50	2.56	2.44
S_3	2.28	2.35	2.46	2.36	2.27	2.39	2.60	2.42	2.28	2.37	2.53	2.39
S_4	2.12	2.35	2.51	2.33	2.25	2.36	2.50	2.37	2.18	2.36	2.51	2.35
S_5	2.20	2.37	2.42	2.33	2.26	2.48	2.54	2.43	2.23	2.43	2.48	2.38
MEAN	2.18	2.38	2.53		2.29	2.46	2.58		2.23	2.42	2.56	
$CD_{0.05}$ for S : 0.07					$CD_{0.05}$ for S : 0.06				$CD_{0.05}$ for S : 0.05			
$CD_{0.05}$ for G : 0.06					$CD_{0.05}$ for G : 0.05				$CD_{0.05}$ for G : 0.04			
$CD_{0.05}$ for SxG : 0.13					$CD_{0.05}$ for SxG : NS				$CD_{0.05}$ for SxG : 0.09			

leaf nitrogen content (2.63 %) was obtained from S_2G_3 and lowest from S_4G_1 (2.25 %). Among different plant growth promoting rhizobacteria isolates under study, S_1 (2.46 %) was found to be most effective and similar pattern was also observed during 2013, whereas, during 2014, S_2 was reported to be most effective than other isolates under study.

Furthermore, G_3 (2.46 %) was best GA_3 treatment followed by G_2 (2.42 %) for increasing nitrogen content and similar trend was observed during both the years of study.

4.2.5.2 Phosphorus

The data presented in Table 95(a) and (b) revealed that all GA_3 and plant growth promoting rhizobacteria treatments resulted in an increase in leaf phosphorus content. It is apparent from the pooled data given in Table 95(a) that highest leaf phosphorus content (0.287 %) was found in T_{18} which was statistically at par with T_5, T_6, T_9, T_{15} and T_{17} recording 0.269, 0.285, 0.267, 0.280 and 0.276 per cent respectively, whereas, lowest leaf phosphorus content was observed in T_{19} statistically at par with T_1 (0.219 %). A similar trend was observed during both the years of study.

The data on interaction effect between GA_3 and plant growth promoting rhizobacteria is presented in Table 95(b) which reveals non-significant effect on leaf phosphorus content of strawberry cultivar Chandler. However, highest leaf phosphorus content was recorded from S_5G_3 (0.287 %) and lowest from S_3G_1 (0.227%) as pooled value.

Table 95(a). Effect of GA_3 and plant growth promoting rhizobacteria on leaf phosphorus content of strawberry cultivar Chandler

Treatments		Phosphorus (%)		
		2013	2014	Pooled
T_1	GA_3 @ 25 ppm	0.218	0.221	0.219
T_2	GA_3 @ 50 ppm	0.230	0.235	0.232
T_3	GA_3 @ 75 ppm	0.252	0.256	0.254
T_4	$S_1 + GA_3$ @ 25 ppm	0.253	0.261	0.257
T_5	$S_1 + GA_3$ @ 50 ppm	0.268	0.269	0.269
T_6	$S_1 + GA_3$ @ 75 ppm	0.282	0.288	0.285
T_7	$S_2 + GA_3$ @ 25 ppm	0.229	0.234	0.232
T_8	$S_2 + GA_3$ @ 50 ppm	0.236	0.241	0.238
T_9	$S_2 + GA_3$ @ 75 ppm	0.264	0.270	0.267
T_{10}	$S_3 + GA_3$ @ 25 ppm	0.223	0.231	0.227
T_{11}	$S_3 + GA_3$ @ 50 ppm	0.245	0.252	0.248
T_{12}	$S_3 + GA_3$ @ 75 ppm	0.254	0.266	0.260
T_{13}	$S_4 + GA_3$ @ 25 ppm	0.248	0.253	0.251
T_{14}	$S_4 + GA_3$ @ 50 ppm	0.255	0.256	0.256
T_{15}	$S_4 + GA_3$ @ 75 ppm	0.278	0.281	0.280
T_{16}	$S_5 + GA_3$ @ 25 ppm	0.250	0.257	0.254
T_{17}	$S_5 + GA_3$ @ 50 ppm	0.273	0.279	0.276
T_{18}	$S_5 + GA_3$ @ 75 ppm	0.282	0.291	0.287
T_{19}	Control	0.205	0.217	0.211
$CD_{0.05}$		0.041	0.020	0.020

Table 95(b). Interaction effect of GA_3 and plant growth promoting rhizobacteria on leaf phosphorus content of strawberry cultivar Chandler

Treatment	Phosphorus (%)											
	2013				2014				Pooled			
	G_1	G_2	G_3	MEAN	G_1	G_2	G_3	MEAN	G_1	G_2	G_3	MEAN
S_1	0.253	0.268	0.282	0.268	0.261	0.269	0.288	0.273	0.257	0.269	0.285	0.270
S_2	0.229	0.236	0.264	0.243	0.234	0.241	0.270	0.248	0.232	0.238	0.267	0.246
S_3	0.223	0.245	0.254	0.241	0.231	0.252	0.266	0.250	0.227	0.248	0.260	0.245
S_4	0.248	0.255	0.278	0.261	0.253	0.256	0.281	0.263	0.251	0.256	0.280	0.262
S_5	0.250	0.273	0.282	0.268	0.257	0.279	0.291	0.276	0.254	0.276	0.287	0.272
MEAN	0.241	0.255	0.272		0.247	0.259	0.279		0.244	0.257	0.276	
$CD_{0.05}$ for S : 0.021					$CD_{0.05}$ for S : 0.013				$CD_{0.05}$ for S : 0.015			
$CD_{0.05}$ for G : 0.016					$CD_{0.05}$ for G : 0.010				$CD_{0.05}$ for G : 0.010			
$CD_{0.05}$ for SxG : NS					$CD_{0.05}$ for SxG : NS				$CD_{0.05}$ for SxG : NS			

A similar trend was observed during both the years of study. Among different plant growth promoting rhizobacteria isolates, S_5 was found most effective in increasing leaf phosphorus content (0.272 %) followed by S_1 (0.270 %), while G_3 (0.276 %) was best among GA_3 treatments. Again, a similar trend was observed during both the years of study.

4.2.5.3 Potassium

Leaf potassium content was significantly influenced by different GA_3 and plant growth promoting rhizobacteria treatments as presented in Table 96(a) during both the years of study. Among the different treatments, the pooled value given in this table revealed that T_6 was found to be most effective which increased leaf potassium content to 1.67 per cent which was statistically at par with T_4, T_5, T_{12}, T_{15} and T_{18} recording 1.59, 1.63, 1.63, 1.62 and 1.66 per cent whereas, the lowest value of 1.29 per cent leaf potassium content was recorded in T_{19} statistically at par with T_1 (1.37 %). Similar trend was recorded during both the years of study.

The interaction study between GA_3 and plant growth promoting rhizobacteria did not showed any significant effect on per cent leaf potassium content of strawberry cultivar Chandler as presented in Table 96(b). However, highest leaf potassium content was recorded from S_1G_3 (1.67 %) and lowest from S_4G_1 (1.44 %). A similar trend was recorded during both the years of study. Furthermore, among different plant growth promoting rhizobacteria isolates under study, S_1 was found to be best during both the years of study (1.60 % during 2013 and 1.66 % during 2014) and G_3 (1.63 %) was reported to be best GA_3 treatment as compared to other GA_3 treatments.

Table 96(a). Effect of GA_3 and plant growth promoting rhizobacteria on leaf potassium content of strawberry cultivar Chandler

Treatments		Potassium (%)		
		2013	2014	Pooled
T_1	GA_3 @ 25 ppm	1.35	1.38	1.37
T_2	GA_3 @ 50 ppm	1.40	1.41	1.40
T_3	GA_3 @ 75 ppm	1.43	1.50	1.46
T_4	$S_1 + GA_3$ @ 25 ppm	1.56	1.63	1.59
T_5	$S_1 + GA_3$ @ 50 ppm	1.61	1.65	1.63
T_6	$S_1 + GA_3$ @ 75 ppm	1.63	1.71	1.67
T_7	$S_2 + GA_3$ @ 25 ppm	1.45	1.48	1.46
T_8	$S_2 + GA_3$ @ 50 ppm	1.51	1.52	1.51
T_9	$S_2 + GA_3$ @ 75 ppm	1.54	1.62	1.58
T_{10}	$S_3 + GA_3$ @ 25 ppm	1.41	1.49	1.45
T_{11}	$S_3 + GA_3$ @ 50 ppm	1.54	1.56	1.55
T_{12}	$S_3 + GA_3$ @ 75 ppm	1.61	1.64	1.63
T_{13}	$S_4 + GA_3$ @ 25 ppm	1.40	1.47	1.44
T_{14}	$S_4 + GA_3$ @ 50 ppm	1.47	1.53	1.50
T_{15}	$S_4 + GA_3$ @ 75 ppm	1.56	1.67	1.62
T_{16}	$S_5 + GA_3$ @ 25 ppm	1.47	1.50	1.48
T_{17}	$S_5 + GA_3$ @ 50 ppm	1.48	1.59	1.54
T_{18}	$S_5 + GA_3$ @ 75 ppm	1.62	1.69	1.66
T_{19}	Control	1.26	1.32	1.29
$CD_{0.05}$		0.10	0.12	0.08

Table 96(b). Interaction effect of GA_3 and plant growth promoting rhizobacteria on leaf potassium content of strawberry cultivar Chandler

Treatment	Potassium (%)											
	2013				2014				Pooled			
	G_1	G_2	G_3	MEAN	G_1	G_2	G_3	MEAN	G_1	G_2	G_3	MEAN
S_1	1.56	1.61	1.63	1.60	1.63	1.65	1.71	1.66	1.59	1.63	1.67	1.63
S_2	1.45	1.51	1.54	1.50	1.48	1.52	1.62	1.54	1.46	1.51	1.58	1.52
S_3	1.41	1.54	1.61	1.52	1.49	1.56	1.64	1.56	1.45	1.55	1.63	1.54
S_4	1.40	1.47	1.56	1.47	1.47	1.53	1.67	1.56	1.44	1.50	1.62	1.52
S_5	1.47	1.48	1.62	1.52	1.50	1.59	1.69	1.59	1.48	1.54	1.66	1.56
MEAN	1.46	1.52	1.59		1.51	1.57	1.67		1.48	1.55	1.63	
$CD_{0.05}$ for S : 0.07					$CD_{0.05}$ for S : 0.05				$CD_{0.05}$ for S : 0.04			
$CD_{0.05}$ for G : 0.05					$CD_{0.05}$ for G : 0.04				$CD_{0.05}$ for G : 0.03			
$CD_{0.05}$ for SxG : NS					$CD_{0.05}$ for SxG : NS				$CD_{0.05}$ for SxG : NS			

4.2.5.4 Calcium

The perusal of data given in Table 97(a) revealed that the leaf calcium content was significantly affected by GA_3 and plant growth promoting rhizobacteria. The pooled values showed that the highest leaf calcium content (1.43 %) was obtained from T_{18} which was statistically at par with T_5, T_6, T_9, T_{12}, T_{15} and T_{17} treatments recording 1.37, 1.41, 1.38, 1.37, 1.39 and 1.37 per cent, respectively, while significantly lowest content of leaf calcium (1.11 %) was obtained from T_{19}. A similar trend was observed during both the years of study

except that the highest leaf calcium content (1.42 %) during 2013 was also at par with T_3, T_4, T_8, T_{11}, T_{14} and T_{16} (1.32, 1.33, 1.32, 1.32, 1.34 and 1.32 %, respectively).

The pooled values for interaction between GA_3 and plant growth promoting rhizobacteria had shown non-significant effect on leaf calcium content [Table 97(b)].

Table 97(a). Effect of GA_3 and plant growth promoting rhizobacteria on leaf calcium content of strawberry cultivar Chandler

Treatments		Calcium (%)		
		2013	2014	Pooled
T_1	GA_3 @ 25 ppm	1.25	1.30	1.28
T_2	GA_3 @ 50 ppm	1.29	1.32	1.30
T_3	GA_3 @ 75 ppm	1.32	1.37	1.34
T_4	$S_1 + GA_3$ @ 25 ppm	1.33	1.34	1.34
T_5	$S_1 + GA_3$ @ 50 ppm	1.36	1.38	1.37
T_6	$S_1 + GA_3$ @ 75 ppm	1.40	1.42	1.41
T_7	$S_2 + GA_3$ @ 25 ppm	1.28	1.30	1.29
T_8	$S_2 + GA_3$ @ 50 ppm	1.32	1.34	1.33
T_9	$S_2 + GA_3$ @ 75 ppm	1.37	1.40	1.38
T_{10}	$S_3 + GA_3$ @ 25 ppm	1.30	1.31	1.30
T_{11}	$S_3 + GA_3$ @ 50 ppm	1.32	1.35	1.34
T_{12}	$S_3 + GA_3$ @ 75 ppm	1.35	1.38	1.37
T_{13}	$S_4 + GA_3$ @ 25 ppm	1.31	1.34	1.33
T_{14}	$S_4 + GA_3$ @ 50 ppm	1.34	1.37	1.36
T_{15}	$S_4 + GA_3$ @ 75 ppm	1.38	1.39	1.39
T_{16}	$S_5 + GA_3$ @ 25 ppm	1.32	1.33	1.33
T_{17}	$S_5 + GA_3$ @ 50 ppm	1.36	1.37	1.37
T_{18}	$S_5 + GA_3$ @ 75 ppm	1.42	1.44	1.43
T_{19}	Control	1.09	1.12	1.11
$CD_{0.05}$		0.10	0.08	0.06

Table 97(b). Interaction effect of GA_3 and plant growth promoting rhizobacteria on leaf calcium content of strawberry cultivar Chandler

Treatment	Calcium (%)											
	2013				2014				Pooled			
	G_1	G_2	G_3	MEAN	G_1	G_2	G_3	MEAN	G_1	G_2	G_3	MEAN
S_1	1.33	1.36	1.40	1.36	1.34	1.38	1.42	1.38	1.34	1.37	1.41	1.37
S_2	1.28	1.32	1.37	1.32	1.30	1.34	1.40	1.35	1.29	1.33	1.38	1.33
S_3	1.30	1.32	1.35	1.32	1.31	1.35	1.38	1.35	1.30	1.34	1.37	1.34
S_4	1.31	1.34	1.38	1.35	1.34	1.37	1.39	1.37	1.33	1.36	1.39	1.36
S_5	1.32	1.36	1.42	1.37	1.33	1.37	1.44	1.38	1.33	1.37	1.43	1.38
MEAN	1.31	1.34	1.38		1.32	1.36	1.41		1.32	1.35	1.40	
$CD_{0.05}$ for S : NS					$CD_{0.05}$ for S : NS				$CD_{0.05}$ for S : 0.03			
$CD_{0.05}$ for G : 0.05					$CD_{0.05}$ for G : 0.03				$CD_{0.05}$ for G : 0.02			
$CD_{0.05}$ for SxG : NS					$CD_{0.05}$ for SxG : NS				$CD_{0.05}$ for SxG : NS			

However, the highest leaf calcium content (1.43 %) was recorded from S_5G_3 and lowest from S_2G_1 (1.29 %). A similar trend was also observed during both the years of study. The different isolates of plant growth promoting rhizobacteria had also shown non-significant effect on leaf calcium content during both the years of study. On overall basis, S_5 was proved to be most effective in increasing leaf calcium content (1.38 %) followed by S_1 (1.37 %). The GA_3 treatments had significant effect on leaf calcium content and G_3 (GA_3 @75 ppm) was found to be best followed by G_2 (GA_3 @ 50 ppm) during both years of study.

4.2.5.5 Magnesium

It is evident from the data given in Table 98(a) that GA_3 and plant growth promoting rhizobacteria had a significant effect on leaf magnesium content of strawberry cultivar Chandler. The pooled values given in Table 98(a) showed that the leaf magnesium content was highest (0.351 %) in T_{18} which was statistically at par with T_6, T_{15} and T_{17} (0.333, 0.334 and 0.333 %, respectively), whereas minimum (0.284 %) was recorded in T_{19} which was statistically at par with T_1 (0.294 %). A similar trend was observed during both the years of study except that during 2014, the treatments T_3, T_4, T_5, T_{11}, T_{12}, T_{13}, T_{14}, T_{15}, T_{16} and T_{17} (0.315, 0.319, 0.322, 0.316, 0.321, 0.314, 0.323, 0.334, 0.321 and 0.337 %, respectively) were also at par with highest leaf magnesium content 0.354 per cent recorded in T_{18} as well as lowest leaf magnesium content (0.297 %) observed in T_{19} treatment.

Table 98(a). Effect of GA_3 and plant growth promoting rhizobacteria on leaf magnesium content of strawberry cultivar Chandler

Treatments		Magnesium (%)		
		2013	2014	Pooled
T_1	GA_3 @ 25 ppm	0.288	0.301	0.294
T_2	GA_3 @ 50 ppm	0.306	0.308	0.307
T_3	GA_3 @ 75 ppm	0.314	0.315	0.315
T_4	$S_1 + GA_3$ @ 25 ppm	0.317	0.319	0.318
T_5	$S_1 + GA_3$ @ 50 ppm	0.326	0.322	0.324
T_6	$S_1 + GA_3$ @ 75 ppm	0.334	0.331	0.333
T_7	$S_2 + GA_3$ @ 25 ppm	0.309	0.305	0.307
T_8	$S_2 + GA_3$ @ 50 ppm	0.318	0.311	0.315
T_9	$S_2 + GA_3$ @ 75 ppm	0.329	0.329	0.329
T_{10}	$S_3 + GA_3$ @ 25 ppm	0.302	0.310	0.306
T_{11}	$S_3 + GA_3$ @ 50 ppm	0.319	0.316	0.318
T_{12}	$S_3 + GA_3$ @ 75 ppm	0.322	0.321	0.322
T_{13}	$S_4 + GA_3$ @ 25 ppm	0.318	0.314	0.316
T_{14}	$S_4 + GA_3$ @ 50 ppm	0.323	0.323	0.323
T_{15}	$S_4 + GA_3$ @ 75 ppm	0.334	0.334	0.334
T_{16}	$S_5 + GA_3$ @ 25 ppm	0.303	0.321	0.312
T_{17}	$S_5 + GA_3$ @ 50 ppm	0.328	0.337	0.333
T_{18}	$S_5 + GA_3$ @ 75 ppm	0.347	0.354	0.351
T_{19}	Control	0.270	0.297	0.284
$CD_{0.05}$		0.020	0.041	0.020

Table 98(b). Interaction effect of GA_3 and plant growth promoting rhizobacteria on leaf magnesium content of strawberry cultivar Chandler

Treatment	Magnesium (%)											
	2013				2014				Pooled			
	G_1	G_2	G_3	MEAN	G_1	G_2	G_3	MEAN	G_1	G_2	G_3	MEAN
S_1	0.317	0.326	0.334	0.326	0.319	0.322	0.331	0.324	0.318	0.324	0.333	0.325
S_2	0.309	0.318	0.329	0.319	0.305	0.311	0.329	0.315	0.307	0.315	0.329	0.317
S_3	0.302	0.319	0.322	0.314	0.310	0.316	0.321	0.316	0.306	0.318	0.322	0.315
S_4	0.318	0.323	0.334	0.325	0.314	0.323	0.334	0.324	0.316	0.323	0.334	0.324
S_5	0.303	0.328	0.347	0.326	0.321	0.337	0.354	0.337	0.312	0.333	0.351	0.332
MEAN	0.310	0.323	0.333		0.314	0.322	0.334		0.312	0.322	0.334	
$CD_{0.05}$ for S : 0.004					$CD_{0.05}$ for S : 0.011				$CD_{0.05}$ for S : 0.006			
$CD_{0.05}$ for G : 0.003					$CD_{0.05}$ for G : 0.009				$CD_{0.05}$ for G : 0.005			
$CD_{0.05}$ for SxG : 0.008					$CD_{0.05}$ for SxG : NS				$CD_{0.05}$ for SxG : NS			

The data on interaction between GA_3 and plant growth promoting rhizobacteria as presented in Table 98(b) had shown non- significant effect on leaf magnesium content of strawberry cultivar Chandler, while, effect was significant during 2013. However, highest leaf magnesium content (0.351 %) was recorded from S_5G_3 and lowest (0.306 %) from S_3G_1 treatment interactions as pooled value. A similar trend was recorded during both the years of study, but the leaf magnesium content was lowest (0.305 %) under S_2G_1 during 2014. The individual effect of GA_3 and different plant growth promoting rhizobacteria on leaf magnesium content was significant, where, S_5 found to be most effective as it increased leaf magnesium content (0.332 %) followed by S_1 (0.325 %) and G_3 was recorded to be most effective among GA_3 treatments. A similar trend was observed during both the years of study.

4.2.5.6 Zinc

The perusal of data presented in Table 99(a) reveals that GA_3 and plant growth promoting rhizobacteria had a significant effect on leaf zinc content. The pooled values given in Table 99(a) revealed that the leaf zinc content ranged from low 20.91 to as high as 27.05 ppm. The highest leaf zinc content of 27.05 ppm was recorded from T_{18} which was statistically at par with T_6, T_9 and T_{12} (26.73, 26.72 and 26.63 ppm, respectively), whereas significantly lowest leaf zinc content was recorded in T_{19} (20.91 ppm). A similar trend was observed during 2014 whereas, during 2013, highest leaf zinc content was obtained from T_6 (26.72 ppm) which was statistically at par with T_{12} (27.57 ppm), whereas leaf zinc content was significantly highest in T_8, T_9, T_{12} T_{15} and T_{18} (25.66, 26.43, 26.12, 25.58 and 26.71 ppm, respectively). The leaf zinc content was significantly lowest in T_{19} during both the years of study (20.66 ppm during 2013 and 21.16 ppm during 2014). Other treatments had

also shown significant increase in leaf zinc content in strawberry cultivar Chandler as compared to control.

Table 99(a). Effect of GA_3 and plant growth promoting rhizobacteria on leaf zinc content of strawberry cultivar Chandler

Treatments		Zn (ppm)		
		2013	2014	Pooled
T_1	GA_3 @ 25 ppm	22.54	24.05	23.30
T_2	GA_3 @ 50 ppm	24.33	24.78	24.56
T_3	GA_3 @ 75 ppm	25.40	26.22	25.81
T_4	$S_1 + GA_3$ @ 25 ppm	24.64	24.88	24.76
T_5	$S_1 + GA_3$ @ 50 ppm	25.02	25.78	25.40
T_6	$S_1 + GA_3$ @ 75 ppm	26.72	26.74	26.73
T_7	$S_2 + GA_3$ @ 25 ppm	23.07	24.29	23.68
T_8	$S_2 + GA_3$ @ 50 ppm	25.66	25.93	25.80
T_9	$S_2 + GA_3$ @ 75 ppm	26.43	27.00	26.72
T_{10}	$S_3 + GA_3$ @ 25 ppm	24.23	25.40	24.81
T_{11}	$S_3 + GA_3$ @ 50 ppm	25.14	26.20	25.67
T_{12}	$S_3 + GA_3$ @ 75 ppm	26.12	27.15	26.63
T_{13}	$S_4 + GA_3$ @ 25 ppm	23.36	24.10	23.73
T_{14}	$S_4 + GA_3$ @ 50 ppm	24.75	25.25	25.00
T_{15}	$S_4 + GA_3$ @ 75 ppm	25.58	26.27	25.92
T_{16}	$S_5 + GA_3$ @ 25 ppm	24.86	25.16	25.01
T_{17}	$S_5 + GA_3$ @ 50 ppm	25.30	25.83	25.56
T_{18}	$S_5 + GA_3$ @ 75 ppm	26.71	27.40	27.05
T_{19}	Control	20.66	21.16	20.91
$CD_{0.05}$		1.26	1.05	0.85

Table 99(b). Interaction effect of GA_3 and plant growth promoting rhizobacteria on leaf zinc content of strawberry cultivar Chandler

Treatment	Zinc (ppm)											
	2013				2014				Pooled			
	G_1	G_2	G_3	MEAN	G_1	G_2	G_3	MEAN	G_1	G_2	G_3	MEAN
S_1	24.64	25.02	26.72	25.46	24.88	25.78	26.74	25.80	24.76	25.40	26.73	25.63
S_2	23.07	25.66	26.43	25.05	24.29	25.93	27.00	25.74	23.68	25.80	26.72	25.40
S_3	24.23	25.14	26.12	25.16	25.40	26.20	27.15	26.25	24.81	25.67	26.63	25.71
S_4	23.36	24.75	25.58	24.56	24.10	25.25	26.27	25.21	23.73	25.00	25.92	24.89
S_5	24.86	25.30	26.71	25.62	25.16	25.83	27.40	26.13	25.01	25.56	27.05	25.88
MEAN	24.03	25.17	26.31		24.77	25.80	26.91		24.40	25.49	26.61	
$CD_{0.05}$ for S : NS					$CD_{0.05}$ for S : 0.64				$CD_{0.05}$ for S : 0.54			
$CD_{0.05}$ for G : 0.62					$CD_{0.05}$ for G : 0.49				$CD_{0.05}$ for G : 0.42			
$CD_{0.05}$ for SxG : NS					$CD_{0.05}$ for SxG : NS				$CD_{0.05}$ for SxG : NS			

The data on interaction effect between GA_3 and plant growth promoting rhizobacteria had shown non-significant effect on leaf zinc content as presented in Table 99(b). The pooled values showed that highest leaf zinc content (27.05 ppm) was obtained from S_5G_3 treatment interaction whereas, lowest leaf zinc content (23.68 ppm) was recorded from S_2G_1 treatment

interaction. A similar trend was recorded during both the years of study except that the leaf zinc content (24.10 ppm) was lowest in S_4G_1 treatment interaction during 2014. Among different plant growth promoting rhizobacteria isolates under study, S_5 (25.88 ppm) was reported to be most effective and G_3 (GA_3 @ 75 ppm) was recorded as best GA_3 treatment for increased leaf zinc content in strawberry. A similar pattern was recorded during both the years of study.

4.2.5.7 Iron

The data pertaining to leaf iron content as affected by GA_3 and plant growth promoting rhizobacteria are presented in Table 100(a) and (b). The pooled data given in Table 100(a) showed the significant effect of different treatments on iron content of strawberry leaves. The iron content (116.67 ppm) was significantly highest in T_{18} and lowest in T_{19} (63.84 ppm) treatment. A similar trend was recorded during both the years of study.

The values related to cummulative effect between GA_3 and plant growth promoting rhizobacteria were presented in Table 100(b) which shows that significantly highest leaf iron content (116.67 ppm) was obtained from S_5G_3 treatment interaction whereas, lowest leaf iron content (84.25 ppm) was recorded from S_3G_1 which was par with S_2G_1 (84.45 ppm)

Table 100(a). Effect of plant growth promoting rhizobacteria and GA_3 on leaf iron content of strawberry cultivar Chandler

Treatments		Iron (ppm)		
		2013	**2014**	**Pooled**
T_1	GA_3 @ 25 ppm	73.30	84.70	79.00
T_2	GA_3 @ 50 ppm	79.33	86.62	82.98
T_3	GA_3 @ 75 ppm	88.66	91.82	90.24
T_4	$S_1 + GA_3$ @ 25 ppm	84.13	94.15	89.14
T_5	$S_1 + GA_3$ @ 50 ppm	95.34	99.63	97.48
T_6	$S_1 + GA_3$ @ 75 ppm	106.54	114.20	110.37
T_7	$S_2 + GA_3$ @ 25 ppm	80.07	88.83	84.45
T_8	$S_2 + GA_3$ @ 50 ppm	98.36	100.94	99.65
T_9	$S_2 + GA_3$ @ 75 ppm	102.05	106.73	104.39
T_{10}	$S_3 + GA_3$ @ 25 ppm	79.63	88.86	84.25
T_{11}	$S_3 + GA_3$ @ 50 ppm	83.31	92.43	87.87
T_{12}	$S_3 + GA_3$ @ 75 ppm	107.64	111.04	109.34
T_{13}	$S_4 + GA_3$ @ 25 ppm	85.08	90.07	87.58
T_{14}	$S_4 + GA_3$ @ 50 ppm	95.07	96.26	95.66
T_{15}	$S_4 + GA_3$ @ 75 ppm	104.21	108.36	106.29
T_{16}	$S_5 + GA_3$ @ 25 ppm	86.04	94.57	90.30
T_{17}	$S_5 + GA_3$ @ 50 ppm	96.03	104.06	100.05
T_{18}	$S_5 + GA_3$ @ 75 ppm	112.82	120.51	116.67
T_{19}	Control	61.78	65.90	63.84
$CD_{0.05}$		1.12	1.32	0.97

Table 100(b). Interaction effect of GA_3 and plant growth promoting rhizobacteria on leaf iron content of strawberry cultivar Chandler

Treatment	Iron (ppm)											
	2013				2014				Pooled			
	G_1	G_2	G_3	MEAN	G_1	G_2	G_3	MEAN	G_1	G_2	G_3	MEAN
S_1	84.13	95.34	106.54	95.34	94.15	99.63	114.20	102.66	89.14	97.48	110.37	99.00
S_2	80.07	98.36	102.05	93.49	88.83	100.94	106.73	98.83	84.45	99.65	104.39	96.16
S_3	79.63	83.31	107.64	90.19	88.86	92.43	111.04	97.45	84.25	87.87	109.34	93.82
S_4	85.08	95.07	104.21	94.79	90.07	96.26	108.36	98.23	87.58	95.66	106.29	96.51
S_5	86.04	96.03	112.82	98.30	94.57	104.06	120.51	106.38	90.30	100.05	116.67	102.34
MEAN	82.99	93.62	106.65		91.29	98.66	112.17		87.14	96.14	109.41	
$CD_{0.05}$ for S : 0.69					$CD_{0.05}$ for S : 0.78				$CD_{0.05}$ for S : 0.59			
$CD_{0.05}$ for G : 0.54					$CD_{0.05}$ for G : 0.60				$CD_{0.05}$ for G : 0.46			
$CD_{0.05}$ for SxG : 1.20					$CD_{0.05}$ for SxG : 1.34				$CD_{0.05}$ for SxG : 1.03			

treatment interaction as pooled values. A similar trend was also observed during both years of study except that during 2014, minimum leaf iron content (88.83 ppm) was obtained from S_2G_1 treatment interaction which was statistically at par with S_3G_1 (88.86 ppm). The individual effect of different plant growth promoting rhizobacteria isolates and GA_3 treatments as presented in this Table also reveals that S_5 was most effective for increased leaf iron content (102.34 ppm) as compared to other plant growth promoting rhizobacteria isolates whereas, among GA_3 application, G_3 (GA_3 @ 75 ppm) was recorded as best GA_3 treatment as pooled data. A similar trend was observed during both the years of study.

4.2.5.8 Manganese

The data pertaining to leaf manganese content was given in Table 101(a) and (b). The significantly highest pooled leaf manganese content (84.77 ppm) was recorded from T_9 and lowest from T_{19} (51.00 ppm). A similar trend was observed during 2014, whereas during 2013, maximum leaf manganese content (82.64 ppm) was recorded in T_{18} treatment and minimum (50.33 ppm) in T_{19} treatment [Table 101(a)].

The pooled values for the interaction effect between GA_3 and plant growth promoting rhizobacteria as presented in Table 101(b) had also shown significant effect on leaf manganese content. The pooled leaf manganese (84.77 ppm) content was significantly highest in S_2G_3 and lowest in S_2G_1 (57.19 ppm). A similar trend was also recorded during 2014 while the leaf manganese content was highest in S_5G_3 (82.64 ppm) and minimum in S_2G_1 (56.52 ppm) treatment interaction during 2013. Among different isolates of plant growth promoting rhizobacteria, S_5 (73.89 ppm) was observed to be most effective as pooled

value and a similar trend was observed during both the years of study. However, among GA_3 treatments, G_3 (GA_3 @75 ppm) was reported to be best followed by G_2 (GA_3 @ 50 ppm) during both the years of study (i.e. 75.88 ppm during 2013 and 81.08 ppm during 2014).

Table 101(a). Effect of GA_3 and plant growth promoting rhizobacteria on leaf manganese content of strawberry cultivar Chandler

Treatments		Manganese (ppm)		
		2013	2014	Pooled
T_1	GA_3 @ 25 ppm	52.89	53.90	53.39
T_2	GA_3 @ 50 ppm	54.15	57.29	55.72
T_3	GA_3 @ 75 ppm	57.39	58.64	58.01
T_4	$S_1 + GA_3$ @ 25 ppm	59.01	59.74	59.38
T_5	$S_1 + GA_3$ @ 50 ppm	61.41	63.90	62.66
T_6	$S_1 + GA_3$ @ 75 ppm	65.72	68.10	66.91
T_7	$S_2 + GA_3$ @ 25 ppm	56.52	57.86	57.19
T_8	$S_2 + GA_3$ @ 50 ppm	62.35	69.00	65.68
T_9	$S_2 + GA_3$ @ 75 ppm	80.41	89.13	84.77
T_{10}	$S_3 + GA_3$ @ 25 ppm	66.07	68.43	67.25
T_{11}	$S_3 + GA_3$ @ 50 ppm	70.77	74.00	72.39
T_{12}	$S_3 + GA_3$ @ 75 ppm	75.89	83.20	79.55
T_{13}	$S_4 + GA_3$ @ 25 ppm	59.33	62.88	61.11
T_{14}	$S_4 + GA_3$ @ 50 ppm	69.61	71.23	70.42
T_{15}	$S_4 + GA_3$ @ 75 ppm	74.71	78.40	76.55
T_{16}	$S_5 + GA_3$ @ 25 ppm	61.38	66.50	63.94
T_{17}	$S_5 + GA_3$ @ 50 ppm	69.91	76.34	73.13
T_{18}	$S_5 + GA_3$ @ 75 ppm	82.64	86.57	84.61
T_{19}	Control	50.33	51.67	51.00
$CD_{0.05}$		1.10	1.05	0.77

Table 101(b). Interaction effect of GA_3 and plant growth promoting rhizobacteria on leaf manganese content of strawberry cultivar Chandler

Treatment	Manganese (ppm)											
	2013				2014				Pooled			
	G_1	G_2	G_3	MEAN	G_1	G_2	G_3	MEAN	G_1	G_2	G_3	MEAN
S_1	59.01	61.41	65.72	62.05	59.74	63.90	68.10	63.91	59.38	62.66	66.91	62.98
S_2	56.52	62.35	80.41	66.43	57.86	69.00	89.13	72.00	57.19	65.68	84.77	69.21
S_3	66.07	70.77	75.89	70.91	68.43	74.00	83.20	75.21	67.25	72.39	79.55	73.06
S_4	59.33	69.61	74.71	67.88	62.88	71.23	78.40	70.84	61.11	70.42	76.55	69.36
S_5	61.38	69.91	82.64	71.31	66.50	76.34	86.57	76.47	63.94	73.13	84.61	73.89
MEAN	60.46	66.81	75.88		63.08	70.89	81.08		61.77	68.85	78.48	
$CD_{0.05}$ for S : 0.65					$CD_{0.05}$ for S : 0.67				$CD_{0.05}$ for S : 0.45			
$CD_{0.05}$ for G : 0.50					$CD_{0.05}$ for G : 0.52				$CD_{0.05}$ for G : 0.35			
$CD_{0.05}$ for SxG : 1.12					$CD_{0.05}$ for SxG : 1.16				$CD_{0.05}$ for SxG : 0.78			

4.2.5.9 Copper

The perusal of data given in Table 102(a) and (b) revealed significant effect of GA_3 and plant growth promoting rhizobacteria on leaf copper content of strawberry cultivar

Chandler. The highest pooled leaf copper content (6.92 ppm) was recorded from T_{12} while, lowest (4.88 ppm) was obtained from T_{19} as presented in Table 102(a). A similar trend was recorded during both the years of study. However during 2014, the highest leaf copper content (6.97 ppm) recorded in T_{12} was significantly at par with T_6, T_9, T_{14} and T_{15} (6.70, 6.87, 6.81 and 6.95 ppm, respectively) and lowest leaf copper content (5.14 ppm) recorded in T_{19} was at par with T_1 (5.40 ppm). The interaction study between GA_3 and plant growth promoting rhizobacteria has also shown significant effect on leaf copper content of strawberry cultivar Chandler as presented in Table 102(b).

Table 102(a). Effect of GA_3 and plant growth promoting rhizobacteria on leaf copper content of strawberry cultivar Chandler

Treatments		Copper (ppm)		
		2013	2014	Pooled
T_1	GA_3 @ 25 ppm	4.87	5.40	5.14
T_2	GA_3 @ 50 ppm	5.21	5.69	5.45
T_3	GA_3 @ 75 ppm	5.79	6.21	6.00
T_4	$S_1 + GA_3$ @ 25 ppm	5.44	6.14	5.79
T_5	$S_1 + GA_3$ @ 50 ppm	5.58	6.53	6.06
T_6	$S_1 + GA_3$ @ 75 ppm	5.90	6.70	6.30
T_7	$S_2 + GA_3$ @ 25 ppm	5.34	6.25	5.80
T_8	$S_2 + GA_3$ @ 50 ppm	5.51	6.59	6.05
T_9	$S_2 + GA_3$ @ 75 ppm	6.30	6.87	6.59
T_{10}	$S_3 + GA_3$ @ 25 ppm	5.05	5.66	5.36
T_{11}	$S_3 + GA_3$ @ 50 ppm	5.38	5.93	5.65
T_{12}	$S_3 + GA_3$ @ 75 ppm	6.87	6.97	6.92
T_{13}	$S_4 + GA_3$ @ 25 ppm	5.30	6.57	5.93
T_{14}	$S_4 + GA_3$ @ 50 ppm	5.91	6.81	6.36
T_{15}	$S_4 + GA_3$ @ 75 ppm	6.03	6.95	6.49
T_{16}	$S_5 + GA_3$ @ 25 ppm	5.45	5.82	5.64
T_{17}	$S_5 + GA_3$ @ 50 ppm	5.46	6.05	5.76
T_{18}	$S_5 + GA_3$ @ 75 ppm	6.00	6.47	6.23
T_{19}	Control	4.62	5.14	4.88
$CD_{0.05}$		0.20	0.28	0.14

Table 102(b). Interaction effect of GA_3 and plant growth promoting rhizobacteria on leaf copper content of strawberry cultivar Chandler

Treatment	Copper (ppm)											
	2013				2014				Pooled			
	G_1	G_2	G_3	MEAN	G_1	G_2	G_3	MEAN	G_1	G_2	G_3	MEAN
S_1	5.44	5.58	5.90	5.64	6.14	6.53	6.70	6.46	5.79	6.06	6.30	6.05
S_2	5.34	5.51	6.30	5.72	6.25	6.59	6.87	6.57	5.80	6.05	6.59	6.15
S_3	5.05	5.38	6.87	5.77	5.66	5.93	6.97	6.18	5.36	5.65	6.92	5.98
S_4	5.30	5.91	6.03	5.74	6.57	6.81	6.95	6.78	5.93	6.36	6.49	6.26
S_5	5.45	5.46	6.00	5.64	5.82	6.05	6.47	6.11	5.64	5.76	6.23	5.88
MEAN	5.32	5.57	6.22		6.09	6.38	6.79		5.70	5.98	6.51	
$CD_{0.05}$ for S : 0.08					$CD_{0.05}$ for S : 0.05				$CD_{0.05}$ for S : 0.05			
$CD_{0.05}$ for G : 0.06					$CD_{0.05}$ for G : 0.04				$CD_{0.05}$ for G : 0.04			
$CD_{0.05}$ for SxG : 0.14					$CD_{0.05}$ for SxG : 0.08				$CD_{0.05}$ for SxG : 0.09			

The pooled values has shown that the significantly highest leaf copper content (6.92 ppm) was recorded from S_3G_3 treatment interaction and minimum leaf copper content was recorded from S_3G_1 (5.36 ppm) treatment interaction. A similar trend was observed during both the years of study. The overall individual effect of S_4 was recorded to be best for increased leaf copper content (6.26 ppm) in strawberry cultivar Chandler among different plant growth promoting isolates under study and, a similar trend was observed during 2013 and 2014. Among GA_3 treatments, G_3 (GA_3 @ 75 ppm) was found to be best followed by G_2 (GA_3 @ 50 ppm) during both the years of study.

Chapter-5

DISCUSSION

Strawberry (*Fragaria* × *ananassa* Duch.) is a highly valued short duration fruit crop, giving the quick returns globally and is most important species among berry fruits. The modern strawberry cultivation targeting high yield and quality requires extensive use of expensive inorganic fertilizers creating environmental problems. It also degrades physico-chemical and biological properties of soil as well as plants. Thus, the improved management practices including use of plant growth promoting rhizobacteria and plant growth regulators are becoming a resurgence of interest in sustainable and organic cultural practices (Esitken *et al.*, 2005).

The present investigation entitled "Studies on the effect of plant growth promoting rhizobacteria and GA_3 on plant growth, fruiting and soil health of strawberry (*Fragaria x ananassa* Duch.) cultivar Chandler" was conducted at Model Farm, Directorate of Research, Dr Y S Parmar university of Horticulture and Forestry, Nauni, Solan, Himachal Pradesh during 2013 and 2014. The salient findings of present studies are discussed under appropriate heads as given below:

5.1 Experiment-I: To study the effect of plant growth promoting rhizobacteria (PGPR) on plant growth, yield, quality, leaf nutrient status and soil health

5.1.1 Growth parameters

The various plant growth promoting rhiozbacteria treatments produced significant differences in plant growth parameters such as plant height, spread, leaf area, number of crowns, number of runners and plant biomass over control in strawberry plants.

It is observed from the present investigations that the plant height and plant spread were maximum in T_3 treatment in which strawberry plants were treated with S_1 isolate of plant growth promoting rhizobacteria [Table 1(a) to 2(b)] as compared to untreated plants. The findings are in line with reports of Rana and Chandel (2003), Karlidag *et al.* (2007), Kirad *et al.* (2009), Seo *et al.* (2009), Tripathi and Gupta (2012), Pandit *et al.* (2013) and Tripathi *et al.* (2014) who also recorded increased plant height and spread with the

application of plant growth promoting rhizobacteria. Production of plant growth regulators such as auxin, gibberellins and cytokinins by the plant growth promoting rhizobacteria has been suggested as possible mechanisms of action affecting plant growth. Various studies have shown the improvement in plant growth in response to root inoculation with various microbial inoculants capable of producing plant growth regulators (Zahir *et al.* 2004). The enhanced growth of plants may also be due to increased nitrogen fixation, phosphate solubilization and increased better utilization of these nutrients in the presence of these rhizobacteria, alongwith better development of root system and increased photosynthesis. Furthermore, plant growth promoting rhizobacteria may also increase plant growth through improvement of soil physical, chemical and biological properties which provide better environment for nutrient uptake and translocation by the plants as reported by Yadav *et al.* (2010).

The maximum leaf area and plant biomass on fresh weight basis as well as dry weight basis [Table 3 (a & b), 6 (a) to 7(b)] were recorded in plants treated with S_5 isolate when applied as root dip + foliar application method. These results are in agreement with the work of Orhan *et al.* (2006), Malusa (2007), Pirlak and Kose (2009), Pedraza *et al.* (2010) and Karlidag *et al.* (2013). They reported increased leaf areas and plant biomass with the application of plant growth promoting rhizobacteria. The increase in leaf area and plant biomass could be attributed to increased mineral nutrition and the possibility of plant growth promoting rhizobacteria to produce plant growth hormones, increased photosynthesis, better root development, better translocation of water and nutrients, uptake and efficient utilization of nutrients.

The number of crowns per plant were maximum in T_9 and number of runners per plant were maximum in T_{12} [Table 4 (a) to 5(b)]. Pirlak and Kose (2010) also found that foliar + root application of PGPR strains significantly increased the number of crowns and number of usable runner plant per plant with the application of plant growth promoting rhizobacteria such as *Pseudomonas* BA-8, *Bacillus* OSU-142 and *Bacillus* M-3. Similarily, Pirlak and Kose (2009), Yadav *et al*. (2010), Tripathi and Gupta (2012) and Tripathi *et al.* (2014) also observed significantly increased number of crowns and runners per plant with application of plant growth promoting rhizobacteria which may possibly be due to production of a growth substance especially cytokinins. Such assumptions gain support from Jeon *et al*. (2003) and Zhang *et al.* (2003) who reported that cytokinins help in development of side buds and

increase in branching. Further, root + foliar application of plant growth promoting rhizobacteria increases the number of bacteria in the rhizosphere which may convert organic and inorganic substances into nutrient directly available to the plants resulting in more growth and production of crowns and runners.

5.1.2 Yield parameters

The earliest flowering and harvesting were recorded in plants inoculated with plant growth promoting rhizobacterial isolate S_5 when applied through root dip+ foliar application method as compared to the plants which were treated with plant growth promoting rhizobacteria through root dip or foliar application method. The results are in confirmation with the work of El Rewainy and Abd Alla (2005), Pirlak and Kose (2009), Tripathi and Gupta (2012) and Tripathi *et al.* (2014) who also reported earliest flowering and harvesting with application of plant growth promoting rhizobacteria isolates.

The maximum flowering duration was recorded in T_{15} [Table 9(a)] whereas, it was minimum in T_5. The harvesting duration was maximum in T_6 and minimum in T_{16} [Table 11(a)]. Yadav *et al.* (2008), Tripathi and Gupta (2012) and Tripathi *et al.* (2014) also reported maximum flowering and harvesting durations with the application of plant growth promoting rhizobacteria as compared to control which are also in line with the present findings.

The results further showed that yield per plant significantly increased by all bacterial treatments in comparison to control. The highest number of fruits per plant were recorded in T_3 [Table 12(a)] whereas, fruit yield per plant and yield per hectare were maximum in T_{12} [Table 13(a) & 14(a)].

Differences in yield effect in this study may be explained by the properties of plant growth promoting rhizobacterial strains. The production of auxin and cytokinin by the different bacterial inoculants may affect floral induction and growth of strawberry directly or indirectly. Plant hormones especially, auxin and cytokinins have greater role in flower induction and development. The bacteria may have affected directly or indirectly the cytokinin and polyamine levels in treated plants. Cytokinins may have enhanced the floral induction directly as well as encouraging polyamine synthesis in the leaves and shoot apex. It is well known that cytokinins are essential for flower induction (Bernier *et al*., 1993). Moreover, cytokinins stimulate polyamines synthesis and polyamines have also been determined as necessary for flower initiations in strawberry (Tarenghi and Martin, 1995). In

addition to cytokinin and polyamines, more carbohydrate production in the plant treated with plant growth promoting rhizobacteria could also be instrumental in promoting flower induction. It has been reported that synthesis of carbohydrate in the leaves has significant impact on synthesis of cytokinin and flower induction in plants (Bernier *et al.,* 1993). Having greater leaf area and higher photosynthetic rate of the plants treated with rhizobacteria in enabling to produce more carbohydrate and the cytokinin may have encouraged flowering. The increase in number of fruits and yield can also be attributed to improved growth traits and yield components such as more number of flowers, fruit set, weight and size and ultimately resulted in higher yield. The results are in congruence with the findings of Umar *et al.* (2008), Seo *et al.* (2009), Pirlak and Kose (2009), Esitken *et al.* (2010), Karldag *et al*. (2013), Pandit *et al.* (2013), Tripathi and Gupta (2012), Ipek *et al*. (2014) and Tripathi *et al.* (2014).

5.1.3 Fruit quality parameters

The results of present study reveal that the fruit weight and size were significantly increased in strawberry plants treated with the application of plant growth promoting rhizobacteria as compared to untreated plants. Maximum fruit weight was recorded with treatment T_{12} whereas, fruit length was maximum in T_9 and diameter in T_6 [Table 15(a) to 17(b)]. It may be due to the root and foliar bacterial applications that stimulated fruit development presumably through the effect of IAA and GA_3. Thus, production of IAA and GA_3 by these isolates may have positive effects on fruit size and weight. Furthermore, this might be due to better root proliferation, better uptake of nutrients and water, increased leaf area, more photosynthesis, enhanced carbohydrates, accumulation and efficient partitioning of photosynthates towards the sink. These findings are also in accordance with those of Rana and Chandel (2003),Yadav *et al.* (2010), Ertuk *et al.*(2012), Tripathi and Gupta (2012) and Tripathi *et al.* (2014).

The increased total soluble solids, sugars, TSS: acid ratio, anthocyanin content and decreased acidity and ascorbic acid content were recorded in plants treated with isolates of plant growth promoting rhizobacteria when applied through root dip method and it varies with different plant growth promoting isolates and their application methods. The fruit TSS, TSS: acid ratio, total sugars and reducing sugars were highest in strawberry plants treated with S_5 isolate (T_{13}) while, the effect of rhizobacterial inoculation on non-reducing sugars was non-significant. The acidity and ascorbic acid content were highest in control (T_{16}) and

the lowest in plants treated with S_3 isolate (T_7) and S_1 isolate (T_1), respectively. The anthocyanin content was highest in plants treated with S_1 isolate (T_1) and minimum in control (T_{16}) [Table 18(a) to 25(b)]. The increase in total soluble solids, sugars and anthocyanin can presumely be due to the more availability of assimilate as a result of increased photosynthesis and nutrient availability to the fruit plants as results of application of plant growth promoting rhizobacteria. Contrary, the decrease in acidity and ascorbic may be due to increase in accumulation of more assimilate or total soluble solids. Similar results for decrease in acidity and ascorbic acid with the application of plant growth promoting rhizobacteria also observed by the Esitken *et al.* (2010) where control treatment (0.70 % and 71.58 mg/100 ml, respectively) provided the highest per cent acidity and vitamin C content. The results are in conformity with the findings of Pirlak and Kose (2009) who reported that the root application of plant growth promoting rhizobacteria (PGPR) strains significantly increased total soluble solids (8.15 %), total sugar (5.90 %) and reducing sugar (4.69 %) but decreased titratable acidity (0.82 %) in strawberry cultivar Selva. Umar *et al.* (2009) recorded increased anthocyanin content (0.191 OD) with the application of *Azotobacter* in combination with FYM + urea in strawberry. The results of present study related to fruit quality are substantiated by the observations of Kirad *et al.* (2010), Triapthi and Gupta (2012), Tripathi *et al.* (2014).

5.1.4 Physiological parameters

Maximum chlorophyll content, rate of photosynthesis, stomatal conductance, transpiration rate and minimum stomatal resistance were recorded in plants treated with plant growth promoting rhizobacteria as compared to untreated plants. These physiological parameters were highest in plants treated with S_5 applied through root dip+ foliar application method (T_{15}) and lowest in control (T_{16}), whereas, the stomatal resistance was lowest in plants inoculated with S_5 strains (T_{15}) and highest in control (T_{16}) [Table 26(a) to 30(b)]. Godara (1993) also observed increased chlorophyll content in plants inoculated with *Azotobacter* as compared to uninoculated peach plants.

The increase in leaf chlorophyll might be result of increased leaf area, balanced nutritional environment in the soil and thus kept iron physiologically active for chlorophyll synthesis in certain plants (El Morshedy 1997). The increase in photosynthesis, stomatal conductance and transpiration rate, and decreased stomatal resistance can be attributed to increased leaf area, chlorophyll content and strong source- sink relationship as reported by De

Veau *et al.* (1990). These findings are also in agreement with the findings of Osman and El-rhman (2010), Singh *et al*. (2012), Karlidag *et al.* (2013) and Stefan *et al.* (2013) and reported increased chlorophyll, photosynthesis and transpiration rate with rhizobacterial inoculation. The rhizobacterial strains may improve physiological efficiency by production of plant growth hormones such as gibberellins. Yuan and Xu (2001) reported that the stimulatory effect on photosynthesis was due to increase in Rubisco content and activity, and GA_3 stimulates the synthesis of Rubisco protein at translational rather than transcriptional level. Plant growth hormones produced by rhizobacterial strains have also been found to increase the N-use efficiency and activities of nitrate reductase (NR) and carbonic anhydrase (CA) of plants. The increased N utilization by plants also help in increased photosynthesis. The increase in photosynthesis, stomatal conductance, transpiration rate and decreased stomatal resistance may be result of increased chlorophyll content, stomatal opening and CO_2 assimilation (Misratia *et al*., 2013).

5.1.5 Leaf nutrient status

The nutrient element concentration in leaves of plants treated with plant growth promoting rhizobacterial strains may provide important information about the effect of these rhizobacteria on nutrient element uptake. Generally, the enhancement in macronutrients and micronutrients are more pronounced in plant growth promoting rhizobacterial inoculation and resulted in significant increase in macronutrients and micronutrient contents of leaf. Application of plant growth promoting rhizobacteria resulted in increased nutrient element (N, P, K, Ca, Mg, Zn, Fe, Cu and Mn) content in strawberry leaf (Ipek *et al.*, 2014).

Present study indicates that the leaf nutrient status of strawberry was increased with the application of plant growth promoting rhizobacteria. The leaf nitrogen content was highest in T_6 whereas, leaf phosphorus, potassium and magnesium content were highest in T_3. The calcium content was highest in T_{15} [Table 31(a) to 35(b)]. The increase in leaf nitrogen may be due to enhanced nitrogen supply due to nitrogen fixation by rhizobacterial strains. This increased nitrogen supply can be attributing to better metabolic activities and high protein synthesis. These observations are supported by Rathi and Bist (2004) and Esitken *et al.* (2006). The increase in leaf macronutrients may be due to phosphate solubilizing, mineralizing other organic or inorganic nutrients and phytohormone producing capacity of plant growth promoting rhizobacterial strains which stimulated leaf nutrient content. The results are in line with the findings of Gryndler *et al.* (2002), Aseri *et al*. (2008), Singh and Singh (2009) Karlidag *et al.* (2013) and Osman and El-rhman (2010). Further, bacterial

inoculation of soil decreased the pH of the soil. Decreased soil pH stimulated the availability of plant nutrient element (PNE) such as P and Ca (Orhan *et al.*, 2006). Moreover bacterial inoculation could prevent formulation of Ca-P complex and resulted into higher uptake of Ca-P to the plant.

The micronutrients like zinc and iron content were highest in T_{12} and, the copper content was highest in T_6 whereas, manganese content was highest in T_3. The increase in micronutrient content may be due to increase in improved nutrient uptake by plants, plant growth, root surface area or the general root architecture, production of siderophores and plant growth regulators. The results are in line with the findings of Esitken *et al.* (2006), Aseri *et al*. (2008), Singh and Singh (2009), Bhattacharyya and Jha (2012), Karlidag *et al.* (2013) and Ipek *et al.* (2014). Plant growth promoting rhizobacteria reported to produce many organic and inorganic acid such as acetic acid, glycolic, mavlonic, oxalic, formic and abscisic acid and decrease the soil pH which play a crucial role in nutrient acquisition (Zn, Fe, Cu and Mn) by plants growing in low nutrient soils and their release in response to nutrient starvation differs between plant species (Ae *et al.*, 1990 and Fox and Comeford, 1990). The concentrations of fumaric, malic and citric acids can also chelate Zn, Fe, Cu and Mn in Zinc, iron, copper and manganese oxides, thus making them available for uptake by the plant (Ohwaki and Hirata, 1992 and Marschner, 1995).

The data suggested that some PGPR strains had a very high nutritional potential and their mineral content was even greater when applied to plants as compared to control. Direct enhancement of mineral uptake due to increases in specific ion fluxes at the root surface in the presence of PGPR has been reported by Bertrand *et al*. (2000). The increase in leaf nutrient element may be due to improved phosphate and nitrate nutrition, production of considerable amounts of growth stimulating substances like auxin, gibberellins and cytokinins by plant growth promoting rhizobacteria, which help in improving the plant vigour and produce antifungal substances (Zahir *et al.*, 2004) and enhanced solubility, availability and uptake of nutrients by the plants. Auxins excreted by rhizobacteria can improve root growth, resulting in an increased uptake of essential nutrients (Vikram, 2007). Furthermore, plant developmental processes are controlled by internal signals that depend on the adequate supply of mineral nutrition by soil to roots. Thus, plants take up most of their mineral nutrients through the rhizosphere, where microorganisms interact with plant products in root exudates. Plant root exudates consist of a complex mixture of organic acid anions, phyto-siderophores, sugars, vitamins, amino acids, purines, nucleosides, inorganic ions, enzymes

and root border cells which have major direct or indirect effect on the acquisition of mineral nutrients required for plant growth (Bottini *et al.*, 2004 and Turan *et al*., 2012). The decrease in soil pH may also helps in increased uptake of macro and micronutrients leading to increase in the plant nutrient status.

5.1.6 Soil nutrient status

In present study, every recorded parameter for soil nutrient status except soil pH were significantly influenced by plant growth promoting. However, there was a decrease in soil pH in all the treatments and, minimum soil pH was recorded in T_3 and maximum in control (T_{16}) [Table 40(a) & (b)] which shows that the decrease in soil pH may be due to the production of various organic and inorganic acids by micro-organisms. Application of plant growth promoting rhizobacteria has also decreased the organic carbon content in which minimum organic carbon was recorded in T_3 and maximum in T_{16} [Table 42(a & b)]. This decrease in organic carbon content may be due to decomposition brought about by these microbes. These findings are supported by Gogoi *et al.* (2004), Coyne (2004), Somani and Dadhich (2005), Turan *et al.* (2006), Yadav (2006) and Zargar *et al.* (2008).

The increased EC and available nitrogen content were recorded in T_6, whereas the phosphorus content was highest in T_3 and potassium content in T_9. The electrical conductivity and nutrient contents were minimum in T_{16} [Table 41 (a & b), 43(a) to 45(b)]. The increase in available nitrogen and phosphorus content may be due to increased biological nitrogen fixation and phosphate solubilization by micro-organisms. Some bacteria have the ability to solubilize inorganic P due to chelation, exchange reaction, phosphate production, excretion of organic acids which decreases soil pH and render the insoluble phosphate into soluble form. Generally, the solubility of calcium phosphates and magnesium also increases with decreasing pH. The increase in potassium content upon bacterial inculation may be due to increase dissolution rate of silicates and minerals which releases K, production of enzymes like chitinase and cellulases that causes breakdown of minerals and, increased root exudation accompanied by accelerated microbial proliferation and respiration which may lead to O_2 depletion in the rhizosphere and facilitate dinitrification specifically as reported by Mishustin *et al.* (1981) and Barker *et al*. (1997). These findings are in agreement with the work of Dwivedi *et al.* (1999), Cackamacki *et al.* (2007) Yadav (2006), Singh *et al.* (2010), Umar *et al.* (2010) and Esitken *et al*. (2010).

The highest soil zinc and manganese content were recorded in T_9 whereas, iron content was highest in T_6 and copper in T_3 as compared to control [Table 46(a) to 49(b)]. This increase may also explained by organic acids production by plants and bacteria in the rhizosphere, which decrease soil pH and stimulate the availability of Zn, Fe, Cu and Mn. The results of present study are in substantiated with the findings of Orhan *et al*. (2006), Umar *et al.* (2010), Singh *et al.* (2010) and Esitken *et al*. (2010). The increase in soil EC and nutrient status might be due to the fact that the micro-organisms possess the ability of formation of enzyme complex, mobilizing the unavailable forms of nutrient elements especially increased biological nitrogen fixation, phosphate solubilization, iron chelating siderophore production, increased EC and cation exchange capacity by which nutrients become available for absorption by roots.

5.1.7 Soil biological properties

The results of present study inferred that the applied isolates of PGPR had stimulating effect on micro-organisms growth in soil as well as root. The inoculation with S_1 isolate (T_3) had significantly increased the total rhizobacterial counts on nutrient agar, pikovskaya (PVK), chromoazurol-S (CAS) and Jensen's medium and, the per cent phosphate solubilizing, siderophore producing and nitrogen fixing rhizobacteria were also increased with it when applied through root dip + foliar application method as compared to other treatments [Table 50(a) to 56(b)]. The findings are in line with the work of Godara (1993), Gogoi *et al.* (2004), Cakmacki *et al*. (2007), Aseri *et al.* (2008), Raj and Sharma (2009), Seo *et al.* (2009) and Pesakovic *et al.* (2013) who also reported increased rhizobacterial population with PGPR inoculation.

The total endorhizobacterial counts on nutrient agar, pikovskaya (PVK), chromoazurol- S (CAS) and Jensen's medium and, the per cent phosphate solubilizing and siderophore producing endorhizobacteria were also maximum in $T_{3,}$ but the per cent nitrogen fixing endorhizobacteria were maximum in T_6 as compared to control [Table 57(a) to 63(b)]. The increase in rhizobacterial counts may be due to favourable environmental conditions for growth and their rapid multiplication rate as created by plant growth promoting rhizobacteria. The results of present study are in agreement with the observations of Subba Rao (1993), Aseri *et al.* (2008), Seo *et al.* (2009), Archina (2008), Jarak *et al.* (2012) and Pesakovic *et al.* (2013) who reported increased microbial population with bacterial inoculation in strawberry. Furthermore, the rhizosphere is known to be a zone of increased microbial activity and

consequently enzyme activity. Because of the intensive and extensive interactions in the rhizosphere, microbial activity and population size have the positive effects of inoculated microorganisms. This may be due to high concentration of easily degradable substrates in root exudates leading to more proliferation of microorganisms in rhizosphere (Bais *et al.,* 2006) and thus plant create its specific microflora that may have neutral, deleterious or beneficial effects on the plant.

5.2 Experiment-II: To study the effect of GA_3 and plant growth promoting rhizobacteria on plant growth, yield, quality and leaf nutrient status

5.2.1 Plant growth parameters

The growth regulators have registered significant increase in the plant height and plant spread of strawberry cv. Chandler [Table 64(a) and 65(a)]. The maximum plant height and spread were recorded with the application of GA_3 75 ppm in combination with plant growth promoting rhizobacterial isolates S_4 and S_3, respectively. The increase may be due to the effect GA_3 promotes shoot growth by stimulating rapid cell division and elongation of plant stem and shoots (Turner, 1963). The PGPR are known to produce plant growth hormones and to regulate many enzymatic reactions which are leading to enhancement of plant metabolism and formation of new cells consequently increasing stem length. The results of present study for increase in plant height and spread after GA_3 application are in line with the work of Sangwook *et al.* (1996), Paroussi *et al.* (2002a), Mir *et al.* (2004), Tripathi and Shukla (2006), Litwinczuk *et al*. (2009), Sharma and Singh (2009), Singh and Tripathi (2010), Al Madhagi *et al*. (2011), Jamal *et al.* (2012), Hossain (2012), Saied *et al.* (2012) and Qureshi *et al.* (2013).

In the present investigations, application of GA_3 75 ppm in combination with plant growth promoting rhizobacterial isolates increased the leaf area (T_{18}), the number of crowns per plant (T_9) and number of runners per plant (T_{18}) as compared to control (T_{19}) [Table 66(a) to 68(b)]. Similar results were expressed by Dwivedi *et al.* (1999), Paroussi *et al.* (2002a), Perez *et al.* (2009), Singh and Singh (2009), Kumar *et al.* (2012b) and Jamal *et al.* (2012) in strawberry. The finding is also in conformation with the work of Sharma and Singh (1990) in Pusa Early Dwarf cultivar of strawberry. Exogenous applications of GA_3 have also been reported to promote runner production (Guttridge, 1956 and Pankov, 1992). The possible

reason may be that GA_3 application increases the cell number and cell enlargement which might have resulted in increased leaf area, crowns number and runner production. Increased leaf area may also be due to increased length of upper and lower epidermal cells in leaf lamina (Pathak and Singh, 1976). The present findings are in line with the work of Mohammed *et al.* (1990), Pankov (1992), Sangwook *et al.* (1996), Turemis and Kaska (1997), Dwivedi *et al.* (1999), Mir *et al.* (2004), Kumar *et al.* (2008) and Singh and Tripathi (2010). In present study, the synergistic combination of GA_3 and plant growth promoting rhizobacteria consistently enhanced leaf area, crowns and runner production.

The plant biomass was higher in plants treated with GA_3 at 75 ppm in combination with plant growth promoting rhizobacterial isolate S_4 (T_{15}) [Table 69(a) to 70(b)]. This increase in plant biomass by the application of GA_3 may be due to accumulation of the biosynthetic compounds, which have positive roles in the formation and division of cells and leading to produce thicker and heavier plant roots and shoots. GA_3 treated plants might have increased the CO_2 fixation by the enhanced activity of carbonic anhydrase (CA) which ultimately might be responsible for the increase in fresh and dry mass of treated plants. The increase in plant dry matter may also be attributed to increase in leaf area and number of leaves. Similar results were obtained by Al Madhagi *et al*. (2011), Eshghi *et al.* (2012) and Quershi *et al.* (2013) on strawberry plants and Dar *et al.* (2015) in fenugreek. PGPR are also known to produce plant growth regulators like auxins, gibberellins and cytokinin which has synergistic effect on increasing plant biomass.

Furtehrmore, GA_3 serve manifold growth related functions in plants by enhancing DNA replication, transcription and different enzymatic systems. It is already stated that GA_3 occupies a prominent position in mediating a variety of plant physiological processes including translocation of food material and synthesis of mRNA coding for hydrolytic enzymes. The major metabolic processes influenced in the hormone treated plants are the C-assimilation, distribution of metabolites into the plant organs, and subsequent utilization by biosynthetic pathways.

5.2.2 Yield parameters

The results in Table 71(a) indicated that the flowering time decreased from the planting date and it takes minimum days to produce the first flower as a result of spraying GA_3 75 ppm alone or in combination with plant growth promoting rhizobacteria which was

closely followed by GA_3 50 ppm alone or in combination with plant growth promoting rhizobacteria indicating that the GA_3 resulted in earlier flowering. The present results are in conformity with work of Ozguven and Kaska (1992), Tehranifar and Battey (1997), Paroussi *et al.* (2002) Singh and Singh, (2006) and Sharma and Singh (2009). It is generally accepted that gibberellins are effective in promoting flowering. Due to the fact that, GA_3 and plant growth promoting rhizobacterial application increased the levels of endogenous gibberellins and plays an important role on breaking dormancy (Wareing and Phillips, 1981).

The earliest harvesting was recorded in plant treated with GA_3 at 25 ppm study, while longest flowering and harvesting duration was noted in plants treated with GA_3 at 75 ppm alone or in combination with plant growth promoting rhizobacteria isolates which showed synergistic effect on each other. The duration of flowering was recorded longest in T_9, while harvesting duration was longest in T_3 [Table 72(a & b), 74(a) to 75(b)]. Banday *et al*. (2005) also reported that the application of 40 ppm GA_3 had reduced the number of days to maturation and resulted in early harvesting in strawberry cultivars 'Confitura' and 'Brighton'. The same result with different concentration was obtained by Mohammad *et al*. (1990) when GA_3 at 0, 10, 25, 50 or 100 ppm concentration applied on strawberry *cv*. Murree and also found that the longest productive period of strawberry was 41 day, which was obtained with 50 ppm GA_3. Similar observations were observed by the D'Anna and Accardi (1990).

In present study, the increased number of fruits per plant of strawberry was obtained with the application of GA_3 75 ppm in combination with S_2 isolate of plant growth promoting rhizobacteria (T_9) [Table 73(a & b)]. It could be due to the fact that GA_3 application accelerated the development of differentiated inflorescence. Further, GA_3 also reported to increase fruit set and hence number of berries per plant. The results are in conformity with the work of Sharma and Singh (1990), Camargo *et al.* (1995), Tehranifar and Battey (1997), Rana (2001), Hossain (2012), Jamal *et al.* (2012) and Qureshi *et al.* (2013) who reported an increase in the fruit number after GA_3 application of strawberry.

Significant variation in fruit yield per plant and fruit yield per hectare were recorded in plants subjected to GA_3 in combination with plant growth promoting rhizobacteria, where maximum yield per plant and per hectare were recorded in T_6 [Table 76(a) to 77(b)]. The present findings are supported by the work of Pankov (1992), El Shabasi *et al.* (2009), Kumar *et al.*, (2012a) and Lolaei *et al.* (2013) in Washington navel orange. The application of GA_3 75 ppm along with different isolates of plant growth promoting rhizobacteria has shown

synergistic effect on fruit yield by increasing endogenous level of GA_3. It appears that GA had resulted in production of large number of flowers with rapid elongation of peduncle, leading to full development of flower buds having all functional reproductive parts which increased fruit set and higher number of berries per plant (Voyiatzis and Paraskevopoulou, 2002). Higher concentration of GA_3 (75 ppm) in combination with isolates of plant growth promoting rhizobacteria resulted in increased yield, which may also be due to formation of more metabolites by larger leaves in these plants, resulting an increase in flowering, fruit set, fruit weight and size. These results are in consonance with the work of other workers in strawberry (Singh *et al.*, 2012; Zakharova, 1979; Pathak and Singh, 1971; Singh and Phogat, 1983; Sharma and Singh, 1990 and Mohammed *et al.* 1990).

5.2.3 Fruit quality parameters

Application of GA_3 at 75 ppm alone and in combination with plant growth promoting isolates significantly increased the fruit size and weight in the strawberry plants. The maximum fruit weight and diameter was recorded in T_6 while, fruit length was maximum in T_{12} [Table 78(a) to 80(b)]. Tehranifar and Battey (1997) obtained significantly higher fruit weight with 75 ppm GA_3 application. The increase in size and weight with the application of GA_3 may be due to increased size of plant and leaf, and higher chlorophyll content which in turn may have enhanced the photosynthetic activities and resulted into accumulation of more carbohydrates. Similar results are also reported by Anwar *et al.* (1990), Choi *et al.* (2002), Tripathi and Shukla (2006) in different cultivars of strawberry.

The maximum total soluble solids and TSS: acid ratio were recorded in plants treated with GA_3 @ 25 ppm in combination with isolates of plant growth promoting rhizobacteria and it varies with GA_3 concentrations and plant growth promoting isolates. The TSS was highest in T_{10} and acidity in T_{15} whereas, TSS: acid ratio was maximum in T_{16} and the ascorbic acid content was highest in T_6. The TSS and TSS: acid ratio was decreased, while acidity and ascorbic acid content were increased with increase in GA_3 concentration. Significantly higher acidity levels were recorded with GA_3 at 75 and 50 ppm but, the effect of higher concentration of GA_3 75 ppm was more pronounced [Table 81(a) to 83(b), 87(a & b)]. It was shown by Sharma & Singh (2009) that gibberellic acid when sprayed alone or in combination on strawberry slightly decreased total soluble solids. Gholami *et al.* (2009) also observed reduced TSS in sweet cherry with the application of GA_3. Besides, Singh and Phogat (1983) reported increased acidity in strawberry when treated with GA_3 at 75 or 50 ppm. Chutichudet *et al*. (2006) also observed that GA_3 application increased the titratable

acidity percentage in mango. The combined application of GA_3 with plant growth promoting rhizobacteria can produce effects on ascorbic acid contents of strawberries and that may be due to their synergetic effect. Similar results were found in a study done by Asrey *et al*. (2004).

The sugar content of strawberry fruits was significantly influenced by GA_3 and plant growth promoting rhizobacteria. The per cent sugars were observed to be highest when plants were treated with GA_3 (75 ppm) alone or in combination with plant growth promoting rhizobacteria over the control. The highest total and non- reducing sugars were recorded in T_{12} whereas reducing sugars were maximum in T_{15} [Table 84(a) to 86(b)]. Higher sugars content under the influence of GA_3 could be attributed to increased leaf area, plant spread and consequently more synthesis of carbohydrates and other metabolites and their translocation to the fruit tissue. Increase in total sugars per cent by GA_3 in *Fragaria* sp. has also been reported by Singh and Phogat (1983). Similar result were reported by Rana (2001) and Singh and Tripathi (2010) in strawberry.

Present study reveals that the maximum fruit anthocyanin content was found in strawberry plants treated with GA_3 at 50 ppm in combination with S_2 isolate of plant growth promoting rhizobacteria (T_8) [Table 88(a)]. The results are in conformation with the findings of Moneruzzaman *et al.* (2011) who reported highest anthocyanin content by 50 and 100 ppm GA_3 treatment in wax apple (S*yzygium samarangense* var. Red Jambu air madu) followed by 100 and 20 mg/L treatment, whereas untreated control fruits showed the lowest anthocyanin. Thakur *et al.* (1991), Montero *et al.* (1999) and Roussos *et al.* (2009) also reported similar results in strawberry. Montero *et al.* (1999) had also suggested that gibberellic acid increased the anthocyanin content by affecting the phenylalanine ammonia lyase (PAL), tyrosine ammonia lyase (TAL) acitivity. The similar findings were observed by Schwab and Raab (2004). Further, the higher anthocyanin observed in the present study could be due to higher accumulation of carbohydrates due to increased photosynthesis or higher sink strength or assimilate supply under the influence of plant growth regulators.

5.2.4 Physiological parameters

The present study indicates that the physiological parameters were significantly influenced with the application of GA_3 alone or in combination with plant growth promoting rhizobacteria and these parameters differ with the concentration of GA_3 and types of plant growth promoting isolates. The GA_3 at 75 ppm along with plant growth promoting

rhizobacterial isolates significantly increased the chlorophyll content, photosynthesis, transpiration and stomatal conductance while there is a decrease in stomatal resistance. The chlorophyll content was maximum in T_9 and the rate of photosynthesis was maximum in T_{15} whereas, maximum transpiration rate, stomatal conductance and minimum stomatal resistance were recorded in T_{18} [Table 89(a) to 93(b)]. GA_3 have been employed to improve the physiological efficiency of plants by modifying the balance between photosynthesis and respiration, affecting stomatal aperture or the activity of photosynthetic enzymes. GA_3 has been found to increase the photosynthetic rate in leaves of plants. It has been suggested that GA_3 treatment could lead to changes in plastid development and chloroplast structure (Iqbal *et al.*, 2011). Besides, the higher chlorophyll content may be due to increased leaf area, greater synthesis and translocation of assimilates and water by gibberellins, which delays the degradation of chlorophyll in leaves. The results of present study are in harmony with the findings of Khan *et al*. (1998), Shun Du Yao (2000), Singh and Singh (2009) and Moneruzzaman *et al.* (2011).

Furthermore, application of GA_3 in combination with plant growth promoting rhizobacteria significantly increased photosynthesis because of increased vegetative growth and uptake of nutrients which are components of many metabolically active compounds and participate in several physiological and biochemical functions. The present results are also in corroborate with the findings of Ashraf *et al.* (2002) in wheat, Yuan and Xu (2001) in broad bean and soybean, and Misratia *et al.* (2013) in rice.

5.2.5 Leaf nutrient status

In present study, increased leaf nutrient contents were recorded in plants treated with GA_3 in combination with plant growth promoting rhizobacteria. The leaf nitrogen and potassium content were highest in plants treated with S_1 isolate in combination with GA_3 at 75 ppm (T_6), whereas the phosphorus, calcium and magnesium were highest in plants treated with S_5 isolate in combination with GA_3 at 75 ppm (T_{18}) [Table 93(a) to 97(b)]. These results are in accordance with the findings of Monge *et al.* (1994) in peach, Verma *et al.* (2005) in plum, Singh and Singh (2009) in strawberry, Stino *et al.* (2011) in pear and Shahin *et al.* (2010) in apple. The increase in leaf nitrogen content as affected by GA_3 was also reported by Garner *et al.* (2009) in 'Hass' avocado.

The micronutrients viz., zinc and iron content were highest in plants treated with S_5 isolate in combination with GA_3 at 75 ppm (T_{18}) whereas, the manganese content was maximum in plants treated with S_2 isolate in combination with GA_3 at 75 ppm (T_9) and copper content was maximum in S_3 isolate in combination with GA_3 at 75 ppm (T_{12}) [Table 98(a) to 102(b)]. The results regarding to the effects of gibberellic acid on leaf micronutrients are in agreement with those obtained by Monge *et al.* (1994) in peach, El Seginy *et al.* (2000) in pear and Shahin *et al.* (2010) in apple.

Studies indicated that GA_3 increases the use efficiency of nutrients. Eid and Abou-Leila (2006) also reported that GA_3 treatment increased the uptake of N, P, K, Mg, Fe, Zn, Mn and Cu content, thereby increasing the mineral nutrient status of the plant. Enhancement in leaf-nutrients by GA_3 alone or in combination with plant growth promoting rhizobacterial application could be attributed to compositional or chemical change in plants, increased photosynthesis, soil nutrient status and enhanced root membrane permeability and root surface area, which might ultimately facilitate the absorption or uptake, transportation and utilization of mineral nutrients. The increased nutrient content enhanced photosynthetic potential of leaves and source strength. Thus, it leads to improved translocation of photosynthates and other metabolites to the sinks that might have contributed to the improved nutrient content of GA_3 treated plants.

Chapter-6

SUMMARY AND CONCLUSION

The present investigation entitled "Studies on the effect of plant growth promoting rhizobacteria and GA_3 on plant growth, fruiting and soil health of strawberry (*Fragaria x ananassa* Duch.) cultivar Chandler" was carried out at Model Farm of Directorate of Research, Dr Y S Parmar university of Horticulture and Forestry, Nauni, District Solan, Himachal Pradesh in the year 2013 and 2014. The results obtained during the course of study are briefly summarized and concluded as under:

6.1 Experiment-1: To study the effect of plant growth promoting rhizobacteria (PGPR) on growth, yield, quality, leaf nutrient status and soil health

6.1.1 Plant growth parameters

6.1.1.1 Plant growth parameters were significantly influenced by plant growth promoting rhizobacteria. The plant height and plant spread were maximum in T_3 treatment and minimum in T_{16}. The interaction effect (S x M) was non-significant for plant height. However, the plants under S_1M_3 treatment interaction had maximum plant height and spread. Maximum leaf area and plant biomass on fresh weight basis as well as dry weight basis were recorded in T_{15} and minimum in T_{16}. Furthermore, the S_5M_3 treatment interaction had maximum leaf area and plant biomass (fresh weight basis and dry weight basis).

6.1.1.2 The number of crowns per plant were maximum in T_9 and number of runners per plant were maximum in T_{12} whereas minimum in T_{16} respectively. The interaction effect (SxM) was significant for number of runners per plant, where, S_4M_3 had significantly highest number of runners per plant.

6.1.1.3 Among different isolates of plant growth promoting rhizobacteria influencing plant growth, S_4 was recorded to be most effictive isolate resulted in maximum plant height and number of runners, whereas S_2 for plant spread, S_5 for leaf area and plant biomass on fresh weight basis as well as dry weight basis, and S_3 for number of crowns per

plant observed most efficient isolates. Among their application methods, M_3 (root+ foliar application method) was found as best method.

6.1.2 Yield parameters

6.1.2.1 The flowering and harvesting were earliest in T_{15} and late in T_5 during 2013. During 2014, the flowering was earliest in T_3 and T_{16} and late in T_{11} whereas, harvesting was earliest in T_{12} and late in T_8 and T_{14}.

6.1.2.2 The maximum flowering duration was recorded in T_{15} whereas it was minimum in T_5. Furthermore, the harvesting duration was maximum in T_6 and minimum in T_{16}. The interaction S_5M_3 had maximum flowering duration whereas S_2M_3 had maximum harvesting duration. Among the different isolates of plant growth promoting rhizobacteria, S_5 was most efficient isolate for extended flowering and harvesting durations.

6.1.2.3 The highest number of fruits per plant were recorded in T_3 whereas, fruit yield per plant and yield per hectare were maximum in T_{12}. The number of fruits, yield per plant and yield per hectare were minimum in T_{16}. The treatment interaction S_1M_3 had maximum number fruits per plant and S_4M_3 had maximum fruit yield per plant as well as yield per hectare. Among different isolates, S_1 was found to be most effective for increased number of fruits per plant whereas S_3 was recorded to be best for enhanced fruit yield per plant as well as yield per hectare.

6.1.2.3 Among different application methods of plant growth promoting rhizobacteria, M_3 (root + foliar application method) was recorded most efficient application method in case of yield parameters.

6.1.3 Fruit quality parameters

6.1.3.1 The fruit weight was maximum in T_{12} while, fruit length was maximum in T_9 and fruit diameter in T_6. The minimum fruit weight, length and diameter were recorded in T_{16}. The pooled data for interaction study on fruit weight and diameter showed significant effect while it was non-significant in case of fruit length. However, the interactions S_4M_3, S_3M_3 and S_2M_3 had maximum fruit weight, fruit length and diameter, respectively. Among different isolates under study, S_4 was assumed to be most effective isolate for increased fruit weight and S_2 for increased fruit length and

diameter, whereas, M_3 (root + foliar application method) was best application method for plant growth promoting rhizobacteria as it resulted in maximum fruit weight, length and diameter.

6.1.3.2 The maximum total soluble solids and TSS: acid ratio were recorded in T_{13} and minimum in T_{16} whereas, acidity was maximum in T_{16} and minimum in T_7. The interaction S_5M_1 had maximum total soluble solids and TSS: acid ratio, whereas acidity was maximum in S_2M_2 treatment interaction and minimum in S_3M_1. The isolate S_5 was effective for increased total soluble solids and TSS: acid ratio while, S_3 was most effective for minimizing the acidity. Among their application methods, M_1 (root dip method) was recorded to be most effective application method for increased total soluble solids, TSS: acid ratio and minimum acidity.

6.1.3.3 The plant growth promoting rhizobacteria had shown significant effect on sugars viz. total sugars and reducing sugars, which were maximum in T_{13} and minimum in T_{16} whereas, the effect was non-significant for non-reducing sugars. The interaction effect of plant growth promoting rhizobacteria and their application methods with respect to sugar contents was significant only during 2014, in which, maximum total sugars and non-reducing sugars were obtained from S_5M_1 and reducing sugars were maximum in S_1M_1, whereas, total sugars and non-reducing sugars were minimum in S_4M_2. The reducing sugars were minimum in S_3M_2. The S_1 and S_5 was observed as efficient plant growth promoting rhizobacteria isolate and M_1 (root dip) as effective application method for increased sugar contents in strawberry.

6.1.3.4 The highest ascorbic acid content was recorded in T_{16} and lowest in T_1. The interaction S_4M_2 also had highest ascorbic acid content whereas, the content was lowest in S_1M_1. The isolates S_3 was most effective for increasing ascorbic acid and S_1 was least effective. Among application methods, M_2 (foliar application method) was assumed to be best for enhancing ascorbic acid content.

6.1.3.5 The anthocyanin content was maximum in T_1 and minimum in T_{16}. Among interactions, S_1M_1 had maximum anthocyanin content whereas, S_2M_2 had minimum content of anthocyanin. Furthermore, S_4 was most effective isolate and, M_1 (root dip) was best application method responsible for increased anthocyanin content in strawberry cultivar Chandler.

6.1.4 Physiological parameters

6.1.4.1 Maximum chlorophyll content, rate of photosynthesis, stomatal conductance, transpiration rate and minimum stomatal resistance were recorded in T_{15} while, minimum chlorophyll content, rate of photosynthesis, stomatal conductance, transpiration rate and maximum stomatal resistance were recorded in T_{16}. Among interaction effect of plant growth promoting rhizobacteria and their application methods, S_5M_3 had maximum chlorophyll content, rate of photosynthesis, stomatal conductance, transpiration rate and minimum stomatal resistance while, the stomatal resistance was maximum in S_1M_1. Among different isolates, S_5 isolate was most efficient whereas, among application methods, M_3 (root + foliar application method) was best application method for increased chlorophyll content, photosynthetic rate, stomatal conductance transpiration rate and decreased stomatal resistance.

6.1.5 Leaf nutrient content

6.1.5.1 The leaf nitrogen content was highest in T_6 and, phosphorus, potassium and magnesium contents were highest in T_3. The calcium content was highest in T_{15} while, these nutrient elements were lowest in T_{16}. The interaction effect of plant growth promoting rhizobacteria and their application methods was significant for leaf nitrogen content where, maximum leaf nitrogen content was recorded in S_2M_3 and minimum in S_3M_2 treatment interaction. However, the effect was non-significant for leaf phosphorus, potassium, calcium and magnesium content. Among different isolates of plant growth promoting rhizobacteria, S_2 was found to be efficient isolate in increasing leaf nitrogen content whereas, S_1 was very effective for increasing leaf phosphorus, potassium, calcium and magnesium contents. Among application methods, M_3 (root dip + foliar application method) was most effective method.

6.1.5.2 Among micronutrients, zinc and iron content were recorded highest in T_{12} whereas, copper content was highest in T_6 and manganese in T_3. The interaction effect was significant for micronutrients (Zn, Fe, Cu and Mn). The interaction S_4M_3 had maximum zinc and iron whereas, S_2M_3 had maximum leaf copper content and, S_1M_3 had maximum manganese content. S_1 was proved to be very effective for increased leaf zinc, iron and manganese content and S_2 for copper content.

6.1.6 Soil nutrient content

6.1.6.1 The plant growth promoting rhizobacteria had significant effect on soil electrical conductivity and organic carbon but the effect was non-significant in case of soil pH. However, the soil pH and organic carbon were maximum in T_{16} and minimum in T_3. The soil electrical conductivity was maximum in T_{15} and minimum in T_{16}. Interaction S_4M_2 had maximum soil pH and S_5M_3 had maximum electrical conductivity whereas organic carbon was maximum in S_4M_1 and minimum in S_1M_3 treatment interaction. Among isolates, S_4 was most effective resulted in maximum soil pH and organic carbon content while, minimum were recorded from S_1. The electrical conductivity resulted maximum with S_3 and minimum with S_4 isolate. Among application methods, M_3 (root dip + foliar application method) was the best method.

6.1.6.2 The soil macronutrients were significantly influenced by plant growth promoting rhizobacteria, where highest available nitrogen content was noted in T_6 and phosphorus content in T_3. The available potassium content was highest in T_9. The nutrient contents were lowest in T_{16}. Among interaction effect, S_2M_3 had maximum available nitrogen whereas, S_1M_3 had maximum phosphorus content and, the available potassium content was highest in S_3M_3. Among different isolates, S_2 resulted in maximum available nitrogen and phosphorus content while, S_3 was most effective for higher available potassium content in soil. Among application methods, M_3 was proved most effective for increased macronutrient content.

6.1.6.3 The soil micronutrients were also significantly influenced by plant growth promoting rhizobacteria and their application methods. The zinc and manganese contents of soil were highest in T_9 whereas, iron was highest in T_6 and copper in T_3. The micronutrients were lowest in T_{16} (control). Among interactions, S_3M_3 had maximum zinc, copper and manganese contents whereas, iron content was maximum in S_2M_3. Among different isolates, S_3 was most effective isolate for improved zinc, iron and manganese contents. The maximum copper content was obtained with the application of S_1 isolate. Among application methods, M_3 (root dip+ foliar application method) was proved most effective for increased micronutrient contents.

6.1.7 Soil biological properties

6.1.7.1 The total rhizobacterial counts on nutrient agar, pikovskaya (PVK), chromoazurol- S (CAS) and Jensen's medium and the per cent phosphate solubilizing, siderophore producing and nitrogen fixing rhizobacteria were maximum in T_3 whereas, the rhizobacterial counts were minimum in T_{16}. Among interaction effect of plant growth promoting rhizobacteria and their application methods, S_1M_3 had maximum rhizobacterial counts while it was minimum in S_4M_2. Furthermore, S_1 was most efficient isolate and M_3 (root dip + foliar application method) was best application method in increasing rhizobacterial counts.

6.1.7.2 The endorhizobacteria counts also followed similar trend as rhizobacterial counts except that the nitrogen fixing endorhizobacteria were maximum in T_6 and interaction S_2M_3 had maximum nitrogen fixing endorhizobacterial count as well as per cent nitrogen fixing endorhizobacteria. Furthermore, S_3 was best isolate and M_3 was best application method as these resulted in maximum nitrogen fixing endorhizobacterial counts.

6.1 Experiment-2: To study the effect of GA_3 and plant growth promoting rhizobacteria (PGPR) on growth, yield, quality and leaf nutrient status

6.2.1 Plant growth parameters

6.2.1.1 The maximum plant height and plant biomass on dry weight basis were observed in T_{15}, while plant biomass on fresh weight basis was maximum in T_6 as compared to control (T_{19}). Among the interactions, S_4G_3 had maximum plant height and plant biomass on dry weight basis whereas plant biomass on fresh weight basis was maximum in S_1G_3.

6.2.1.2 The plant spread was maximum in T_{12} and, the leaf area and number of runners per plant were maximum in T_{18} whereas, the number of crowns per plant were maximum in T_9 as compared to control (T_{19}). The interaction S_3G_3 had maximum plant spread whereas S_5G_3 had maximum leaf area and number of runners per plant. However, the interaction was non-significant for number of crowns per plant.

6.2.1.3 Among plant growth promoting rhizobacterial isolates under study, S_4 was most efficient isolate for enhanced plant height, leaf area, number of runners per plant and

plant biomass on dry weight basis whereas, S_3 was effective in increasing plant spread, S_5 in increasing number of crowns per plant and S_1 for increasing plant biomass on fresh weight basis. Among, GA_3 concentrations, G_3 (GA_3 75 ppm) was observed as best treatment for improved plant growth parameters.

6.2.2 Yield parameters

6.2.2.1 The flowering was earliest in T_9 during 2013 and T_{12} during 2014 whereas, late in T_1 during both the years of study. However, harvesting was earliest in T_1 and T_7 and late in T_{15} during 2013 while, during 2014, it was earliest in T_4 and late in T_9, T_{15} and T_{18}.

6.2.2.2 The maximum duration of flowering was recorded in T_9 and harvesting duration was maximum in T_3 whereas, the durations were minimum in T_{19} (control). Among interactions, S_3G_3 had maximum flowering duration. The pooled interaction effect was non-significant for harvesting duration. However, it was significant during both the years of investigation. Thus, S_5G_3 and S_1G_3 had maximum harvesting durations during 2013 and 2014, respectively. Furthermore, S_2 was most effective isolate for longest flowering duration and S_1 for longest harvesting duration. Among GA_3 treatments, G_3 (GA_3 75 ppm) was best treatment.

6.2.2.3 The number of fruits per plant were maximum in T_9 whereas, fruit yield per plant and yield per hectare were maximum in T_6. These were minimum in T_{19}. Among GA_3 and plant growth promoting rhizobacteria combinations, S_2G_3 had maximum number of fruits whereas, S_1G_3 had maximum fruit yield per plant and yield per hectare. The S_2 isolate produced maximum number of fruits per plant and S_1 for improved yield per plant as well as per hectare. Among GA_3 treatments, G_3 (GA_3 75 ppm) was proved best treatment for yield parameters.

6.2.3 Fruit quality parameters

6.2.3.1 The fruit weight and diameter were maximum in T_6 whereas, fruit length was maximum in T_{12}. The fruit weight, length and diameter were minimum in T_{19} (control). The data on interaction study between GA_3 and plant growth promoting rhizobacteria has revealed non-significant on fruit weight. However, the effect was significant during 2014 in which S_4G_3 had maximum fruit weight and minimum in S_2G_1. The interaction effect was significant for fruit length and diameter where, S_3G_3

had maximum fruit length and S_1G_3 had maximum fruit diameter. Furthermore, among different isolates, S_1 was most efficient isolate resulted in increased fruit weight, S_2 in fruit length and S_3 in fruit diameter. G_3 (GA_3 75 ppm) was observed as best treatment for increased fruit weight, length and diameter.

6.2.3.2 The highest total soluble solids (TSS) were observed in T_{10} and lowest in T_3 whereas, the acidity was maximum in T_{15} and minimum in T_{19}. Among interaction effect of GA_3 and plant growth promoting rhizobacteria, S_3G_1 treatment interaction had maximum total soluble solids (TSS) whereas, S_4G_3 had maximum acidity and minimum total soluble solid content. S_5G_1 resulted in minimum acid content. Furthermore, S_3 isolate and G_1 (GA_3 25 ppm) produced maximum total soluble solids and decreased the acid content.

6.2.3.3 The TSS: acid ratio was highest in T_{16} and lowest in T_3. The interaction S_5G_1 also had maximum TSS: acid ratio and S_4G_3 had minimum. Among individual effect of GA_3 treatment and plant growth promoting rhizobacteria strains under study, G_1 (GA_3 25 ppm) and S_5 isolate were resulted in maximum TSS: acid ratio.

6.2.3.4 The total sugars and non- reducing sugars were maximum in T_{12} whereas, reducing sugars were maximum in T_{15}. The sugars were minimum in T_{19}. The interaction effect was non- significant for sugars content. However, maximum total sugars and non-reducing sugars were resulted from S_3G_3 and reducing sugars from S_4G_3 treatment interaction. Among different isolates, S_3 (for total sugars and non-reducing sugars) and S_5 (for reducing sugars) were most effective while, G_3 (GA_3 75 ppm) was effective among treatment in increasing sugars content.

6.2.3.5 The highest ascorbic acid content was recorded in T_6 and lowest in T_{19}. The interaction S_1G_3 also had maximum ascorbic acid content and had minimum was in S_2G_1. Among different isolates, S_5 and among GA_3 treatments, G_3 (GA_3 75 ppm) resulted in increased ascorbic acid content.

6.2.3.5 The anthocyanin content was maximum in T_8 and minimum in T_{19}. Among GA_3 and plant growth promoting rhizobacteria combinations, S_2G_2 had maximum anthocyanin content and S_2G_3 had minimum. Among different isolates, S_3 and among GA_3 treatments, G_2 (GA_3 50 ppm) were resulted in maximum anthocyanin content.

6.2.4 Physiological parameters

6.2.4.1 The T_9 treatment has resulted in maximum chlorophyll content as compared to other treatments and control (T_{19}). The interaction S_2G_3 had maximum chlorophyll content and S_5G_1 had minimum content. Among isolates of plant growth promoting rhizobacteria under study, S_2 was most efficient isolate resulted in increased chlorophyll content. GA_3 75 ppm concentration also resulted in increased chlorophyll content in leaves of strawberry cultivar Chandler.

6.2.4.2 The maximum rate of photosynthesis was recorded in T_{15} and minimum in T_{19}. Among different interactions, S_4G_3 had maximum photosynthetic rate and S_3G_1 had minimum. Among isolates, S_4 was most effective isolate resulted in maximizing the photosynthetic rate.

6.2.4.3 The maximum stomatal conductance, transpiration rate and minimum stomatal resistance were recorded in T_{18}, whereas, the minimum stomatal conductance, transpiration rate and maximum stomatal resistance were recorded in T_{19} (control). Among interaction effect, S_5G_3 and among different isolates, S_5 resulted in maximum stomatal conductance, transpiration rate and minimum stomatal resistance. Furthermore, among GA_3 treatments, G_3 (GA_3 @ 75 ppm) was reported to be most effective in case of enhanced rate of physiological parameters.

6.2.5 Leaf nutrient status

6.2.5.1 The leaf nitrogen and potassium content of strawberry were highest in T_6 whereas, the phosphorus, calcium and magnesium content were highest in T_{18} treatment. The minimum leaf nutrients were noted in T_{19} (control). The interaction effect of GA_3 and plant growth promoting rhizobacteria was significant for leaf nitrogen content where, maximum nitrogen was recorded from S_1G_3. However, the effect was non-significant for leaf phosphorus, potassium, calcium and magnesium contents.

6.2.5.2 Highest zinc and iron contents were recorded in T_{18} treatment, whereas the manganese content was highest in T_9 and copper content in T_{12} treatment. Among interactions, the effect was non-significant for leaf zinc content in strawberry, however, the effect was significant for iron, manganese and copper contents where,

maximum iron content was recorded in S_5G_3 and manganese content in S_2G_3 while, S_3G_3 had maximum copper content.

6.2.5.3 Among different isolates of plant growth promoting rhizobacteria, S_1 was most efficient isolate resulted in maximum leaf nitrogen and potassium whereas, S_5 was efficient in increasing phosphorus, calcium, magnesium, zinc, iron and manganese contents. Furthermore, maximum copper was recorded in plants treated with S_4 isolate. Among GA_3 treatments, G_3 (GA_3 75 ppm) was proved to be best treatment in increasing leaf nutrient content.

On the basis of forgoing results, it may be inferred that different isolates of plant growth promoting rhizobacteria under study applied as root dip+ foliar application method showed great potential to affect plant growth, yield, fruit quality, leaf nutrients and soil nutrient status of strawberry cultivar Chandler. Furthermore, the application of these isolates in combination with GA_3 has also revealed most promising results in all respective parameters under study as compared to individual application of these isolates as well as GA_3 and control. However, growth, yield and nutrient responses were variable and depended on the inoculants, application methods and GA_3 treatment. S_1, S_3 and S_4, alone applied as root dip + foliar application methods or in combination with GA_3 at 75 ppm as foliar application method, were recorded to be most effective isolates with respect to plant height, spread and number of crowns per plant, respectively whereas, S_4 and S_5 was effective in increasing leaf area and number of runners per plant, respectively. All the isolates alone or in combination with GA_3 resulted in early flowering, harvesting, longest flowering and harvesting durations and yield as compared to the control. The number of fruits and yield per plant were recorded highest with the individual application of S_1, S_2 and S_4 through root dip + foliar application method or in combination with 75 ppm GA_3. In case of fruit quality, the strains S_1, S_3, S_4 and S_5 resulted in increased fruit quality viz., fruit weight, size, TSS, acidity, sugars and ascorbic acid. The TSS and sugars were maximum when these isolates were applied alone through root dip or in combination with 25 ppm GA_3. The increase in GA_3 concentrations resulted in decreased TSS and sugar content, and increase in acidity and ascorbic acid content. The anthocyanin content was maximum with the application of S_1 and S_2 through root dip followed by root dip + foliar application method or in combination with 50 ppm GA_3 but showed a decline at higher GA_3 concentration. Results further showed that the leaf nutrient status (N, P, K, Ca, Mg, Zn, Fe, Cu and Mn) were also increased with the application of S_1,

S_2 and S_5 when applied through root dip + foliar application method or in combination with GA_3 at 75 ppm. However, increased soil nutrient status and soil biological properties (available N, P, K, Zn, Fe, Cu, Mn, total rhizobacteria and endo-rhizobacteria, phosphate solubilizing, siderophore producing and nitrogen fixing bacteria were also observed with the application of these isolates when applied through root dip + foliar application methods. Results further shows that these applications are safe, effective and can be easily adopted by growers. Therefore, these can be utilized for sustainable and ecological fruit production and the use of chemical fertilizers can be reduced to a great extent.

Chapter-7

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Title of the Thesis	:	**Studies on the effect of plant growth promoting rhizobacteria and GA_3 on plant growth, fruiting and soil health of strawberry (*Fragaria×ananassa* Duch.) cultivar Chandler**
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Major Field	:	Fruit Science
Minor Field (s)	:	Plant Physiology
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Year of Award of Degree	:	2015
No. of Pages in Thesis	:	232+III
No. of words in Abstract	:	531

ABSTRACT

The present investigations entitled "Studies on the effect of plant growth promoting rhizobacteria and GA_3 on plant growth, fruiting and soil health of strawberry cultivar Chandler" were conducted in the experimental area of Dr. Y. S. Parmar University of Horticulture and Forestry, Nauni, Solan, during the year 2013 and 2014. The studies were conducted under two different experiments, with the objectives to study the effect of plant growth promoting rhizobacteria on plant growth, yield, quality, leaf nutrient status and soil health, and to study the effect of GA_3 and its combinations with plant growth promoting rhizobacteria on plant growth, yield, quality and leaf nutrient status. The experiments were laid out in randomized block design consisting 35 treatments along with control and replicated thrice. In the present investigation, Experiment-1 included the application of five different isolates of plant growth promoting rhizobacteria (S_1: *Bacillus licheniformis* CKA 1, S_2: *Bacillus subtilis* CB 8 A, S_3: *Bacillus sp.* RG1, S_4: *Bacillus sp.* S_1 and S_5: *Bacillus sp.* S_2) to the strawberry plants through root dip (at the time of planting), foliar application (20 days before expected flowering) and root dip+ foliar application methods, while in Experiment- II, different concentrations of GA_3 (25, 50 and 75 ppm) alone or in combinations with these isolates applied as foliar application. Among the different treatment combinations, S_1, S_3 and S_4, alone applied as root dip + foliar application methods or in combination with GA_3 @ 75 ppm as foliar application method, were recorded to be most effective isolates with respect to plant height, spread and number of crowns per plant, whereas S_4 and S_5 was effective in increasing leaf area and number of runners per plant. All the isolates alone or in combination with GA_3 resulted in early flowering, harvesting, longest flowering and harvesting durations and yield as compared to the control. The number of fruits and yield per plant were recorded highest with the individual application of S_1, S_2 and S_4 through root dip + foliar application method or in combination with 75 ppm GA_3. In case of fruit quality, the isolates S_1, S_3 and S_5 resulted in increased fruit quality viz., fruit weight, size, TSS, acidity, sugars and ascorbic acid. The TSS and sugars were maximum when these isolates were applied alone through root dip or in combination with 25 ppm GA_3. The increase in GA_3 concentrations resulted in decreased TSS and sugar content, and increase in acidity and ascorbic acid content. The anthocyanin content was maximum with the application of S_1 and S_2 through root dip method or in combination with 50 ppm GA_3 but showed a decline in content at higher GA_3 concentration. Results further showed that the leaf nutrient status (N, P, K, Ca, Mg, Zn, Fe, Cu and Mn) were also increased with the application of S_1, S_2 and S_5 when applied through root dip + foliar application method or in combination with GA_3 @ 75 ppm. However, improved soil health and soil biological properties (available N, P, K, Zn, Fe, Cu, Mn, total rhizobacteria and endo-rhizobacteria, phosphate solubilizing, siderophore producing and nitrogen fixing bacteria) were also observed with the application of these isolates when applied through root dip + foliar application methods.

Signature of the Major Advisor **Signature of the Student**

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APPENDIX-I

AGRO-METEOROLOGICAL DATA

Month (s)	Temperature (^{0}C)						Average relative humidity (%)	
	2013			2014			2013	2014
	Maximum	Minimum	Mean	Maximum	Minimum	Mean		
January	17.60	1.10	9.35	17.40	2.60	10.00	53.00	62.00
February	17.80	4.50	11.15	17.30	3.40	10.35	60.00	68.20
March	24.30	8.30	16.30	21.10	7.20	14.15	50.50	59.90
April	26.90	11.50	19.20	26.30	10.40	18.35	45.30	52.00
May	32.10	15.50	23.80	30.00	14.40	22.20	47.00	57.00
June	28.50	18.60	23.55	32.60	17.80	25.20	68.80	58.00
July	28.30	19.70	24.00	28.10	19.20	23.65	76.30	76.00
August	27.40	19.40	23.40	28.80	18.60	23.70	81.10	72.00
September	26.80	15.70	21.25	27.90	16.10	22.00	70.60	71.00
October	26.10	12.40	19.25	25.70	10.30	18.00	67.30	60.00
November	23.50	5.80	14.65	23.60	5.70	14.65	54.30	49.00
December	13.40	5.00	9.20	19.70	2.40	11.05	59.70	58.00

Source: Dept. of Environment Science, Dr Y S Parmar UHF, Nauni, Solan (H.P.)

APPENDIX - II

Table 9(a). Effect of plant growth promoting rhizobacteria on duration of flowering of strawberry cultivar Chandler

Treatments		Duration of flowering (days)		
		2013	**2014**	**Pooled**
T_1	S_1 + Root dip method	69.00	110.67	89.83
T_2	S_1+ Foliar application	56.67	106.33	81.50
T_3	S_1 + Root dip method + Foliar application	72.33	112.87	92.60
T_4	S_2+ Root dip method	58.00	106.17	82.08
T_5	S_2+ Foliar application	57.00	103.67	80.33
T_6	S_2 + Root dip method + Foliar application	68.00	108.33	88.17
T_7	S_3 + Root dip method	61.67	110.33	86.00
T_8	S_3+ Foliar application	60.67	104.67	82.67
T_9	S_3 + Root dip method + Foliar application	64.00	110.30	87.15
T_{10}	S_4+ Root dip method	65.33	103.67	84.50
T_{11}	S_4+ Foliar application	60.67	100.67	80.67
T_{12}	S_4 + Root dip method + Foliar application	66.00	105.33	85.67
T_{13}	S_5 + Root dip method	70.33	106.67	88.50
T_{14}	S_5+ Foliar application	62.33	103.00	82.67
T_{15}	S_5 + Root dip method + Foliar application	78.33	109.00	93.67
T_{16}	Control	71.33	107.33	89.33
$CD_{0.05}$		1.96	2.19	1.37

Table 9(b). Interaction effect of plant growth promoting rhizobacteria and their application methods on duration of flowering of strawberry cultivar Chandler

Treatment	Duration of flowering (days)											
	2013				**2014**				**Pooled**			
	M_1	**M_2**	**M_3**	**MEAN**	**M_1**	**M_2**	**M_3**	**MEAN**	**M_1**	**M_2**	**M_3**	**MEAN**
S_1	69.00	56.67	72.33	66.00	110.67	106.33	112.87	109.96	89.83	81.50	92.60	87.98
S_2	58.00	57.00	68.00	61.00	106.17	103.67	108.33	106.06	82.08	80.33	88.17	83.53
S_3	61.67	60.67	64.00	62.11	110.33	104.67	110.30	108.43	86.00	82.67	87.15	85.27
S_4	65.33	60.67	66.00	64.00	103.67	100.67	105.33	103.22	84.50	80.67	85.67	83.61
S_5	70.33	62.33	78.33	70.33	106.67	103.00	109.00	106.22	88.50	82.67	93.67	88.28
MEAN	64.87	59.47	69.73		107.50	103.67	109.17		86.18	81.57	89.45	
$CD_{0.05}$ for S : 1.14					$CD_{0.05}$ for S : 1.31				$CD_{0.05}$ for S : 0.81			
$CD_{0.05}$ for M : 0.88					$CD_{0.05}$ for M : 1.01				$CD_{0.05}$ for M : 0.63			
$CD_{0.05}$ for SxM : 1.97					$CD_{0.05}$ for SxM : NS				$CD_{0.05}$ for SxM : 1.40			

Table 14(a). Effect of plant growth promoting rhizobacteria on yield per hectare of strawberry cultivar Chandler

Treatments		Yield / ha (t)		
		2013	**2014**	**Pooled**
T_1	S_1 + Root dip method	15.37	30.15	22.76
T_2	S_1+ Foliar application	18.36	31.49	24.92
T_3	S_1 + Root dip method + Foliar application	18.74	36.54	27.64
T_4	S_2+ Root dip method	14.94	25.83	20.39
T_5	S_2+ Foliar application	17.18	28.56	22.87
T_6	S_2 + Root dip method + Foliar application	17.88	34.72	26.30
T_7	S_3 + Root dip method	14.81	33.84	24.32
T_8	S_3+ Foliar application	16.96	35.78	26.37
T_9	S_3 + Root dip method + Foliar application	17.13	39.22	28.17
T_{10}	S_4+ Root dip method	14.58	28.56	21.57
T_{11}	S_4+ Foliar application	16.72	34.28	25.50
T_{12}	S_4 + Root dip method + Foliar application	16.83	41.76	29.30
T_{13}	S_5 + Root dip method	17.76	26.69	22.23
T_{14}	S_5+ Foliar application	20.15	29.42	24.78
T_{15}	S_5 + Root dip method + Foliar application	20.29	33.81	27.05
T_{16}	Control	11.71	20.32	16.02
$CD_{0.05}$		1.55	1.61	1.45

Table 14(b). Interaction effect of plant growth promoting rhizobacteria and their application methods on yield per hectare of strawberry cultivar Chandler

Treatment	Yield / ha (t)											
	2013				**2014**				**Pooled**			
	M_1	**M_2**	**M_3**	**MEAN**	**M_1**	**M_2**	**M_3**	**MEAN**	**M_1**	**M_2**	**M_3**	**MEAN**
S_1	15.37	18.36	18.74	17.49	30.15	31.49	36.54	32.73	22.76	24.92	27.64	25.11
S_2	14.94	17.18	17.88	16.66	25.83	28.56	34.72	29.70	20.39	22.87	26.30	23.18
S_3	14.81	16.96	17.13	16.30	33.84	35.78	39.22	36.28	24.32	26.37	28.17	26.29
S_4	14.58	16.72	16.83	16.04	28.56	34.28	41.76	34.87	21.57	25.50	29.30	25.45
S_5	17.76	20.15	20.29	19.40	26.69	29.42	33.81	29.97	22.23	24.78	27.05	24.69
MEAN	15.49	17.87	18.17		29.02	31.90	37.21		22.25	24.89	27.69	
$CD_{0.05}$ for S : 0.91					$CD_{0.05}$ for S : 0.96				$CD_{0.05}$ for S : 0.63			
$CD_{0.05}$ for M : 0.70					$CD_{0.05}$ for M : 0.74				$CD_{0.05}$ for M : 0.48			
$CD_{0.05}$ for SxM : NS					$CD_{0.05}$ for SxM : 1.67				$CD_{0.05}$ for SxM : 1.08			

Table 72(a). Effect of GA_3 and plant growth promoting rhizobacteria on duration of flowering in strawberry cultivar Chandler

Treatments		Duration of flowering (days)		
		2013	2014	Pooled
T_1	GA_3 @ 25 ppm	50.33	92.00	71.17
T_2	GA_3 @ 50 ppm	52.33	95.67	74.00
T_3	GA_3 @ 75 ppm	54.67	100.00	77.33
T_4	S_1 + GA_3 @ 25 ppm	55.67	93.67	74.67
T_5	S_1 + GA_3 @ 50 ppm	58.33	97.33	77.83
T_6	S_1 + GA_3 @ 75 ppm	62.33	107.00	84.67
T_7	S_2+ GA_3 @ 25 ppm	51.00	97.00	74.00
T_8	S2+ GA_3 @ 50 ppm	58.00	103.00	80.50
T_9	S_2 + GA_3 @ 75 ppm	63.33	110.00	86.67
T_{10}	S_3+ GA_3 @ 25 ppm	51.67	96.33	74.00
T_{11}	S_3+ GA_3 @ 50 ppm	54.67	101.33	78.00
T_{12}	S_3+ GA_3 @ 75 ppm	60.67	111.00	85.83
T_{13}	S_4+ GA_3 @ 25 ppm	53.67	95.33	74.50
T_{14}	S_4+ GA_3 @ 50 ppm	55.33	102.33	78.83
T_{15}	S_4+ GA_3 @ 75 ppm	63.67	104.33	84.00
T_{16}	S_5+ GA_3 @ 25 ppm	51.67	100.67	76.17
T_{17}	S_5+ GA_3 @ 50 ppm	54.33	101.33	77.83
T_{18}	S_5 + GA_3 @ 75 ppm	59.33	102.00	80.67
T_{19}	Control	47.67	71.67	59.67
$CD_{0.05}$		1.83	1.38	1.12

Table 72(b). Interaction effect of GA_3 and plant growth promoting rhizobacteria on duration of flowering of strawberry cultivar Chandler

Treatment	Duration of flowering (days)											
	2013				2014				Pooled			
	G_1	G_2	G_3	MEAN	G_1	G_2	G_3	MEAN	G_1	G_2	G_3	MEAN
S_1	55.67	58.33	62.33	58.78	93.67	97.33	107.00	99.33	74.67	77.83	84.67	79.06
S_2	51.00	58.00	63.33	57.44	97.00	103.00	110.00	103.33	74.00	80.50	86.67	80.39
S_3	51.67	54.67	60.67	55.67	96.33	101.33	111.00	102.89	74.00	78.00	85.83	79.28
S_4	53.67	55.33	63.67	57.56	95.33	102.33	104.33	100.67	74.50	78.83	84.00	79.11
S_5	51.67	54.33	59.33	55.11	100.67	101.33	102.00	101.33	76.17	77.83	80.67	78.22
MEAN	52.73	56.13	61.87		96.60	101.07	106.87		74.67	78.60	84.37	
$CD_{0.05}$ for S : 1.13					$CD_{0.05}$ for S : 0.53				$CD_{0.05}$ for S : 0.64			
$CD_{0.05}$ for M : 0.87					$CD_{0.05}$ for M : 0.41				$CD_{0.05}$ for M : 0.50			
$CD_{0.05}$ for SxM : 1.95					$CD_{0.05}$ for SxM : 0.92				$CD_{0.05}$ for SxM : 1.11			

Table 77(a). Effect of GA_3 and plant growth promoting rhizobacteria on yield per hectare of strawberry cultivar Chandler

Treatments		Fruit yield/ ha (t)		
		2013	2014	Pooled
T_1	GA_3 @ 25 ppm	14.69	28.47	21.58
T_2	GA_3 @ 50 ppm	15.36	35.51	25.43
T_3	GA_3 @ 75 ppm	16.80	38.76	27.78
T_4	S_1 + GA_3 @ 25 ppm	17.41	38.89	28.15
T_5	S_1 + GA_3 @ 50 ppm	18.37	40.92	29.65
T_6	S_1 + GA_3 @ 75 ppm	20.34	45.66	33.00
T_7	S_2+ GA_3 @ 25 ppm	18.37	32.31	25.34
T_8	S2+ GA_3 @ 50 ppm	19.23	37.74	28.49
T_9	S_2 + GA_3 @ 75 ppm	20.87	41.00	30.94
T_{10}	S_3+ GA_3 @ 25 ppm	15.46	36.75	26.10
T_{11}	S_3+ GA_3 @ 50 ppm	16.76	37.44	27.10
T_{12}	S_3+ GA_3 @ 75 ppm	17.41	46.92	32.17
T_{13}	S_4+ GA_3 @ 25 ppm	15.65	37.82	26.73
T_{14}	S_4+ GA_3 @ 50 ppm	16.71	43.95	30.33
T_{15}	S_4+ GA_3 @ 75 ppm	17.35	41.12	29.23
T_{16}	S_5+ GA_3 @ 25 ppm	14.50	35.48	24.99
T_{17}	S_5+ GA_3 @ 50 ppm	16.25	36.76	26.51
T_{18}	S_5 + GA_3 @ 75 ppm	19.09	39.08	29.08
T_{19}	Control	12.14	21.37	16.75
$CD_{0.05}$		1.54	1.40	1.10

Table 77(b). Effect of GA_3 and plant growth promoting rhizobacteria on fruit yield per hectare of strawberry cultivar Chandler

Treatment	Fruit yield/ ha (t)											
	2013				2014				Pooled			
	G_1	G_2	G_3	MEAN	G_1	G_2	G_3	MEAN	G_1	G_2	G_3	MEAN
S_1	17.41	18.37	20.34	18.71	38.89	40.92	45.66	41.82	28.15	29.65	33.00	30.26
S_2	18.37	19.23	20.87	19.49	32.31	37.74	41.00	37.02	25.34	28.49	30.94	28.26
S_3	15.46	16.76	17.41	16.54	36.75	37.44	46.92	40.37	26.10	27.10	32.17	28.46
S_4	15.65	16.71	17.35	16.57	37.82	43.95	41.12	40.96	26.73	30.33	29.23	28.77
S_5	14.50	16.25	19.09	16.61	35.48	36.76	39.08	37.11	24.99	26.51	29.08	26.86
MEAN	16.28	17.47	19.01		36.25	39.36	42.76		26.26	28.41	30.88	
$CD_{0.05}$ for S : 0.34					$CD_{0.05}$for S : 0.49				$CD_{0.05}$for S : 0.31			
$CD_{0.05}$for G : 0.26					$CD_{0.05}$for G : 0.38				$CD_{0.05}$for G : 0.24			
$CD_{0.05}$for SxG : 0.59					$CD_{0.05}$for SxG : 0.85				$CD_{0.05}$for SxG : 0.54			

APPENDIX - III

EXPERIMENT- I

ANALYSIS OF VARIENCE (ANOVA) FOR PLANT GROWTH PARAMETERS
ANOVA for Plant height (cm) [Table 1(a) & (b)]

Sources of variation	DF	2013		2014		Pooled	
		SS	MSS	SS	MSS	SS	MSS
Treatments	15	179.45	11.96	115.00	7.67	128.32	8.55
Replications	2	86.91	43.46	121.62	60.81	1.47	0.73
Error	30	51.14	1.70	27.43	0.91	21.62	0.72
Total	47	317.51		264.05		151.41	
Interactions							
Replications	2	79.65	39.82	115.00	57.50	1.34	0.67
Strains (S)	4	26.67	6.67	6.96	1.74	4.18	1.05
Methods of application (M)	2	108.47	54.24	65.38	32.69	85.28	42.64
S x M	8	21.08	2.63	15.81	1.98	13.84	1.73
Error	28	50.94	1.82	26.90	0.96	21.32	0.76
Total	44	286.81		230.05		125.96	

*Significant at 5% level of significance

ANOVA for Plant spread (cm) [Table 2(a) & (b)]

Sources of variation	DF	2013		2014		Pooled	
		SS	MSS	SS	MSS	SS	MSS
Treatments	15	229.66	15.31	356.58	23.77	275.07	18.34
Replications	2	57.01	28.51	175.75	87.87	8.35	4.17
Error	30	39.48	1.32	33.15	1.10	22.17	0.74
Total	47	326.14		565.48		305.58	
Interactions							
Replications	2	60.90	30.45	167.70	83.85	6.93	3.47
Strains (S)	4	58.62	14.66	52.13	13.03	46.97	11.74
Methods of application (M)	2	114.29	57.14	171.43	85.72	139.89	69.94
S x M	8	17.61	2.20	33.83	4.23	22.48	2.81
Error	28	34.73	1.24	32.71	1.17	21.56	0.77
Total	44	286.16		457.80		237.84	

*Significant at 5% level of significance

ANOVA for Leaf area (cm^2) [Table 3(a) & (b)]

Sources of variation	DF	2013		2014		Pooled	
		SS	MSS	SS	MSS	SS	MSS
Treatments	15	3202.47	213.50	3331.04	222.07	3260.17	217.34
Replications	2	424.83	212.41	178.18	89.09	288.23	144.11
Error	30	94.41	3.15	24.65	0.82	31.23	1.04
Total	47	3721.71		3533.87		3579.63	
Interactions							
Replications	2	384.45	192.22	146.48	73.24	251.37	125.68
Strains (S)	4	1646.79	411.70	1565.20	391.30	1604.45	401.11
Methods of application (M)	2	834.41	417.21	1005.44	502.72	917.87	458.93
S x M	8	313.59	39.20	385.17	48.15	346.57	43.32
Error	28	91.48	3.27	11.18	0.40	24.01	0.86
Total	44	3270.72		3113.47		3144.27	

*Significant at 5% level of significance

ANOVA for Number of crowns per plant [Table 4(a) & (b)]

Sources of variation	DF	2013		2014		Pooled	
		SS	MSS	SS	MSS	SS	MSS
Treatments	15	5.78	0.39	5.99	0.40	5.85	0.39
Replications	2	8.40	4.20	7.88	3.94	0.00	0.00
Error	30	2.78	0.09	2.31	0.08	1.12	0.04
Total	47	16.96		16.17		6.97	
Interactions							
Replications	2	7.56	3.78	6.76	3.38	0.01	0.01
Strains (S)	4	2.31	0.58	2.44	0.61	2.37	0.59
Methods of application (M)	2	2.09	1.05	2.47	1.23	2.27	1.13
S x M	8	0.17	0.02	0.11	0.01	0.12	0.02
Error	28	2.73	0.10	1.88	0.07	1.05	0.04
Total	44	14.87		13.66		5.83	

*Significant at 5% level of significance

ANOVA for Number of runners per plant [Table 5(a) & (b)]

Sources of variation	DF	2013		2014		Pooled	
		SS	MSS	SS	MSS	SS	MSS
Treatments	15	1737.54	115.84	1265.38	84.36	1479.22	98.61
Replications	2	400.99	200.50	349.92	174.96	374.57	187.28
Error	30	87.13	2.90	57.16	1.91	53.10	1.77
Total	47	2225.67		1672.47		1906.88	
Interactions							
Replications	2	403.46	201.73	357.52	178.76	379.72	189.86
Strains (S)	4	342.77	85.69	291.90	72.97	315.12	78.78
Methods of application (M)	2	771.08	385.54	666.88	333.44	717.63	358.81
S x M	8	216.35	27.04	153.16	19.14	181.27	22.66
Error	28	79.29	2.83	47.02	1.68	44.15	1.58
Total	44	1812.95		1516.48		1637.89	

*Significant at 5% level of significance

ANOVA for Plant biomass on fresh weight basis (g/plant) [Table 6(a) & (b)]

Sources of variation	DF	2013		2014		Pooled	
		SS	MSS	SS	MSS	SS	MSS
Treatments	15	490.58	32.71	584.55	38.97	505.80	33.72
Replications	2	208.20	104.10	223.11	111.56	215.00	107.50
Error	30	63.38	2.11	47.06	1.57	12.64	0.42
Total	47	762.17		854.72		733.44	
Interactions							
Replications	2	202.14	101.07	205.05	102.52	202.79	101.39
Strains (S)	4	16.75	4.19	152.14	38.03	56.59	14.15
Methods of application (M)	2	278.40	139.20	291.67	145.83	284.34	142.17
S x M	8	12.89	1.61	5.04	0.63	6.61	0.83
Error	28	62.41	2.23	45.30	1.62	12.30	0.44
Total	44	572.59		699.19		562.63	

*Significant at 5% level of significance

ANOVA for Plant biomass on dry weight basis (g/plant) [Table 7(a) & (b)]

Sources of variation	DF	2013		2014		Pooled	
		SS	MSS	SS	MSS	SS	MSS
Treatments	15	52.70	3.51	42.70	2.85	44.82	2.99
Replications	2	143.02	71.51	24.11	12.06	71.15	35.57
Error	30	17.63	0.59	12.21	0.41	9.27	0.31
Total	47	213.36		79.02		125.24	
Interactions							
Replications	2	120.60	60.30	19.74	9.87	59.44	29.72
Strains (S)	4	5.21	1.30	3.98	0.99	3.71	0.93
Methods of application (M)	2	13.15	6.58	12.85	6.42	12.95	6.48
S x M	8	1.99	0.25	2.39	0.30	0.41	0.05
Error	28	10.97	0.39	8.46	0.30	4.43	0.16
Total	44	151.92		47.41		80.94	

*Significant at 5% level of significance

ANALYSIS OF VARIENCE (ANOVA) FOR YIELD PARAMETERS

ANOVA for Duration of flowering (days) [Table 9(a) & (b)]

Sources of variation	DF	2013		2014		Pooled	
		SS	MSS	SS	MSS	SS	MSS
Treatments	15	1695.81	113.05	488.99	32.60	783.34	52.22
Replications	2	399.29	199.65	116.66	58.33	21.13	10.56
Error	30	41.38	1.38	51.69	1.72	20.36	0.68
Total	47	2136.48		657.33		824.82	
Interactions							
Replications	2	388.98	194.49	108.48	54.24	21.67	10.84
Strains (S)	4	488.76	122.19	236.80	59.20	189.83	47.46
Methods of application (M)	2	791.24	395.62	238.61	119.31	470.66	235.33
S x M	8	291.64	36.46	12.70	1.59	86.39	10.80
Error	28	39.02	1.39	51.20	1.83	19.65	0.70
Total	44	1999.64		647.80		788.21	

*Significant at 5% level of significance

ANOVA for Duration of harvesting (days) [Table 11(a) & (b)]

Sources of variation	DF	2013		2014		Pooled	
		SS	MSS	SS	MSS	SS	MSS
Treatments	15	772.99	51.53	553.45	36.90	595.89	39.73
Replications	2	138.62	69.31	110.70	55.35	0.40	0.20
Error	30	31.79	1.06	12.47	0.42	11.88	0.40
Total	47	943.40		676.62		608.17	
Interactions							
Replications	2	136.96	68.48	102.68	51.34	0.62	0.31
Strains (S)	4	52.48	13.12	36.64	9.16	9.30	2.33
Methods of application (M)	2	550.68	275.34	381.41	190.71	461.47	230.73
S x M	8	51.32	6.42	40.42	5.05	18.71	2.34
Error	28	29.95	1.07	11.82	0.42	11.37	0.41
Total	44	821.40		572.98		501.46	

*Significant at 5% level of significance

ANOVA for Number of fruits per plant [Table 12(a) & (b)]

Sources of variation	DF	2013		2014		Pooled	
		SS	MSS	SS	MSS	SS	MSS
Treatments	15	72.78	4.85	302.45	20.16	133.67	8.91
Replications	2	4.25	2.12	84.16	42.08	29.48	14.74
Error	30	46.55	1.55	13.68	0.46	15.16	0.51
Total	47	123.58		400.29		178.31	
Interactions							
Replications	2	7.05	3.52	77.35	38.68	30.21	15.11
Strains (S)	4	21.61	5.40	155.49	38.87	45.32	11.33
Methods of application (M)	2	25.03	12.52	69.73	34.86	43.69	21.84
S x M	8	1.52	0.19	12.02	1.50	2.17	0.27
Error	28	39.59	1.41	13.44	0.48	13.42	0.48
Total	44	94.81		328.03		134.81	

*Significant at 5% level of significance

ANOVA for Fruit yield per plant (g) [Table 13(a) & (b)]

Sources of variation	DF	2013		2014		Pooled	
		SS	MSS	SS	MSS	SS	MSS
Treatments	15	33849.12	2256.61	205389.93	13692.66	79205.29	5280.35
Replications	2	429.69	214.84	148.99	74.49	270.65	135.32
Error	30	40.38	1.35	43.61	1.45	19.12	0.64
Total	47	34319.19		205582.53		79495.06	
Interactions							
Replications	2	415.57	207.79	142.45	71.23	260.63	130.32
Strains (S)	4	10365.22	2591.30	47686.14	11921.54	7387.79	1846.95
Methods of application (M)	2	10105.37	5052.68	80964.83	40482.42	34654.17	17327.08
S x M	8	254.00	31.75	9240.89	1155.11	2125.82	265.73
Error	28	38.75	1.38	43.39	1.55	18.36	0.66
Total	44	21178.91		138077.71		44446.76	

*Significant at 5% level of significance

ANOVA for Fruit yield per hectare (t) [Table 14(a) & (b)]

Sources of variation	DF	2013		2014		Pooled	
		SS	MSS	SS	MSS	SS	MSS
Treatments	15	216.63	14.44	1314.51	87.63	506.92	33.79
Replications	2	107.60	53.80	15.12	7.56	50.84	25.42
Error	30	25.85	0.86	27.83	0.93	22.54	0.75
Total	47	350.08		1357.45		580.30	
Interactions							
Replications	2	113.02	56.51	15.70	7.85	53.24	26.62
Strains (S)	4	66.33	16.58	305.19	76.30	47.28	11.82
Methods of application (M)	2	64.68	32.34	518.19	259.09	221.80	110.90
S x M	8	1.63	0.20	59.14	7.39	13.60	1.70
Error	28	20.32	0.73	27.20	0.97	20.07	0.72
Total	44	265.99		925.42		356.00	

*Significant at 5% level of significance

ANALYSIS OF VARIENCE (ANOVA) FOR FRUIT QUALITY PARAMETERS

ANOVA for Fruit weight (g) [Table 15(a) & (b)]

Sources of variation	DF	2013		2014		Pooled	
		SS	MSS	SS	MSS	SS	MSS
Treatments	15	35.54	2.37	209.38	13.96	67.10	4.47
Replications	2	26.54	13.27	41.36	20.68	33.52	16.76
Error	30	8.56	0.29	5.72	0.19	4.33	0.14
Total	47	70.63		256.46		104.95	
Interactions							
Replications	2	25.11	12.55	37.86	18.93	31.12	15.56
Strains (S)	4	13.24	3.31	104.88	26.22	15.12	3.78
Methods of application (M)	2	8.28	4.14	42.03	21.02	21.33	10.67
S x M	8	1.73	0.22	16.72	2.09	4.29	0.54
Error	28	7.50	0.27	5.14	0.18	3.56	0.13
Total	44	55.87		206.63		75.42	

*Significant at 5% level of significance

ANOVA for Fruit length (mm) [Table 16(a) & (b)]

Sources of variation	DF	2013		2014		Pooled	
		SS	MSS	SS	MSS	SS	MSS
Treatments	15	118.46	7.90	187.630	12.50867	101.86	6.79
Replications	2	52.35	26.17	84.172	42.08623	67.32	33.66
Error	30	17.79	0.59	14.119	0.47062	10.10	0.34
Total	47	188.60		285.921		179.27	
Interactions							
Replications	2	25.11	12.55	37.86	18.93	31.12	15.56
Strains (S)	4	13.24	3.31	104.88	26.22	15.12	3.78
Methods of application (M)	2	8.28	4.14	42.03	21.02	21.33	10.67
S x M	8	1.73	0.22	16.72	2.09	4.29	0.54
Error	28	7.50	0.27	5.14	0.18	3.56	0.13
Total	44	55.87		206.63		75.42	

*Significant at 5% level of significance

ANOVA for Fruit diameter (mm) [Table 17(a) & (b)]

Sources of variation	DF	2013		2014		Pooled	
		SS	MSS	SS	MSS	SS	MSS
Treatments	15	34.86	2.32	164.48	10.97	62.68	4.18
Replications	2	22.74	11.37	49.68	24.84	34.91	17.45
Error	30	9.78	0.33	8.56	0.29	4.04	0.13
Total	47	67.38		222.72		101.63	
Interactions							
Replications	2	51.64	25.82	78.43	39.22	64.33	32.17
Strains (S)	4	16.10	4.02	97.94	24.48	10.28	2.57
Methods of application (M)	2	29.02	14.51	29.07	14.54	29.04	14.52
S x M	8	13.69	1.71	3.75	0.47	4.29	0.54
Error	28	17.14	0.61	14.05	0.50	9.91	0.35
Total	44	127.58		223.25		117.85	

*Significant at 5% level of significance

ANOVA for Fruit TSS (^{0}Brix) [Table 18(a) & (b)]

Sources of variation	DF	2013		2014		Pooled	
		SS	MSS	SS	MSS	SS	MSS
Treatments	15	14.25	0.95	28.24	1.88	17.61	1.17
Replications	2	20.15	10.07	23.76	11.88	21.88	10.94
Error	30	4.98	0.17	5.92	0.20	2.70	0.09
Total	47	39.38		57.93		42.19	
Interactions							
Replications	2	19.90	9.95	20.12	10.06	19.94	9.97
Strains (S)	4	1.73	0.43	4.28	1.07	2.33	0.58
Methods of application (M)	2	8.21	4.11	8.56	4.28	7.93	3.97
S x M	8	1.34	0.17	4.71	0.59	1.10	0.14
Error	28	4.70	0.17	4.90	0.17	2.64	0.09
Total	44	35.89		42.56		33.95	

*Significant at 5% level of significance

ANOVA for Fruit acidity (%) [Table 19(a) & (b)]

Sources of variation	DF	2013		2014		Pooled	
		SS	MSS	SS	MSS	SS	MSS
Treatments	15	1.49	0.10	5.98	0.40	2.71	0.18
Replications	2	1.83	0.92	0.85	0.43	1.30	0.65
Error	30	0.48	0.02	0.63	0.02	0.28	0.01
Total	47	3.81		7.46		4.28	
Interactions							
Replications	2	1.62	0.81	0.81	0.40	1.17	0.59
Strains (S)	4	0.24	0.06	1.08	0.27	0.19	0.05
Methods of application (M)	2	0.53	0.26	1.99	0.99	1.02	0.51
S x M	8	0.17	0.02	0.77	0.10	0.28	0.03
Error	28	0.44	0.02	0.63	0.02	0.26	0.01
Total	44	2.99		5.28		2.93	

*Significant at 5% level of significance

ANOVA for TSS: acid ratio [Table 20(a) & (b)]

Sources of variation	DF	2013		2014		Pooled	
		SS	MSS	SS	MSS	SS	MSS
Treatments	15	51.59	3.44	217.75	14.52	99.32	6.62
Replications	2	10.19	5.09	0.66	0.33	4.01	2.01
Error	30	10.90	0.36	21.69	0.72	7.74	0.26
Total	47	72.68		240.10		111.07	
Interactions							
Replications	2	9.24	4.62	0.99	0.49	4.06	2.03
Strains (S)	4	3.12	0.78	41.26	10.31	9.06	2.27
Methods of application (M)	2	29.09	14.54	88.13	44.07	49.84	24.92
S x M	8	5.68	0.71	36.76	4.60	10.78	1.35
Error	28	10.85	0.39	20.84	0.74	7.56	0.27
Total	44	57.98		187.98		81.30	

*Significant at 5% level of significance

ANOVA for Total sugars (%) [Table 21(a) & (b)]

Sources of variation	DF	2013		2014		Pooled	
		SS	MSS	SS	MSS	SS	MSS
Treatments	15	14.07	0.94	26.04	1.74	14.85	0.99
Replications	2	15.76	7.88	2.77	1.39	7.92	3.96
Error	30	4.99	0.17	1.28	0.04	1.79	0.06
Total	47	34.82		30.10		24.57	
Interactions							
Replications	2	15.13	7.57	2.83	1.42	7.75	3.88
Strains (S)	4	2.65	0.66	7.23	1.81	0.97	0.24
Methods of application (M)	2	5.44	2.72	11.07	5.53	7.99	3.99
S x M	8	1.55	0.19	2.46	0.31	1.04	0.13
Error	28	4.95	0.18	1.20	0.04	1.74	0.06
Total	44	29.73		24.79		19.49	

*Significant at 5% level of significance

ANOVA for Reducing sugars (%) [Table 22(a) & (b)]

Sources of variation	DF	2013		2014		Pooled	
		SS	MSS	SS	MSS	SS	MSS
Treatments	15	14.37	0.96	15.32	1.02	11.63	0.78
Replications	2	15.57	7.79	2.02	1.01	7.19	3.60
Error	30	5.34	0.18	0.66	0.02	1.80	0.06
Total	47	35.28		18.00		20.62	
Interactions							
Replications	2	15.95	7.97	1.92	0.96	7.22	3.61
Strains (S)	4	3.50	0.88	4.23	1.06	1.00	0.25
Methods of application (M)	2	7.78	3.89	7.01	3.50	7.30	3.65
S x M	8	0.64	0.08	0.57	0.07	0.38	0.05
Error	28	4.85	0.17	0.65	0.02	1.65	0.06
Total	44	32.72		14.38		17.55	

*Significant at 5% level of significance

ANOVA for Non- reducing sugars (%) [Table 23(a) & (b)]

Sources of variation	DF	2013		2014		Pooled	
		SS	MSS	SS	MSS	SS	MSS
Treatments	15	10.09	0.67	3.58	0.24	2.20	0.15
Replications	2	0.50	0.25	0.05	0.03	0.14	0.07
Error	30	8.83	0.29	1.96	0.07	3.18	0.11
Total	47	19.42		5.59		5.52	
Interactions							
Replications	2	0.52	0.26	0.08	0.04	0.14	0.07
Strains (S)	4	8.33	2.08	0.93	0.23	1.34	0.34
Methods of application (M)	2	0.40	0.20	0.54	0.27	0.02	0.01
S x M	8	1.10	0.14	1.96	0.25	0.63	0.08
Error	28	8.61	0.31	1.90	0.07	3.15	0.11
Total	44	18.96		5.42		5.29	

*Significant at 5% level of significance

ANOVA for Ascorbic acid (mg/100g) [Table 24(a) & (b)]

Sources of variation	DF	2013		2014		Pooled	
		SS	MSS	SS	MSS	SS	MSS
Treatments	15	2041.13	136.08	2414.24	160.95	1621.89	108.13
Replications	2	186.04	93.02	104.34	52.17	142.15	71.07
Error	30	12.25	0.41	9.41	0.31	6.68	0.22
Total	47	2239.43		2527.99		1770.71	
Interactions							
Replications	2	167.84	83.92	96.42	48.21	129.59	64.80
Strains (S)	4	858.41	214.60	1508.54	377.14	608.43	152.11
Methods of application (M)	2	616.66	308.33	367.51	183.75	484.04	242.02
S x M	8	145.88	18.23	72.29	9.04	86.67	10.83
Error	28	11.15	0.40	9.32	0.33	6.25	0.22
Total	44	1799.93		2054.08		1314.99	

*Significant at 5% level of significance

ANOVA for Anthocyanin content (mg/ 100 ml) [Table 25(a) & (b)]

Sources of variation	DF	2013		2014		Pooled	
		SS	MSS	SS	MSS	SS	MSS
Treatments	15	832.47	55.50	871.09	58.07	848.84	56.59
Replications	2	110.67	55.34	120.17	60.08	115.37	57.68
Error	30	22.18	0.74	24.94	0.83	12.00	0.40
Total	47	965.32		1016.19		976.21	
Interactions							
Replications	2	105.46	52.73	100.08	50.04	102.73	51.37
Strains (S)	4	61.32	15.33	75.78	18.95	67.64	16.91
Methods of application (M)	2	558.22	279.11	573.73	286.86	565.90	282.95
S x M	8	84.06	10.51	76.11	9.51	78.27	9.78
Error	28	21.59	0.77	16.38	0.58	9.58	0.34
Total	44	830.66		842.08		824.12	

*Significant at 5% level of significance

ANALYSIS OF VARIENCE (ANOVA) FOR PHYSIOLOGICAL PARAMETERS

ANOVA for Chlorophyll content (mg/g) [Table 26(a) & (b)]

Sources of variation	DF	2013		2014		Pooled	
		SS	MSS	SS	MSS	SS	MSS
Treatments	15	0.99	0.07	1.27	0.08	1.08	0.07
Replications	2	0.19	0.10	0.27	0.13	0.00	0.00
Error	30	0.13	0.00	0.19	0.01	0.10	0.00
Total	47	1.31		1.73		1.18	
Interactions							
Replications	2	0.14	0.07	0.23	0.12	0.003	0.002
Strains (S)	4	0.16	0.04	0.15	0.04	0.149	0.037
Methods of application (M)	2	0.55	0.28	0.82	0.41	0.676	0.338
S x M	8	0.11	0.01	0.10	0.01	0.075	0.009
Error	28	0.08	0.00	0.19	0.01	0.091	0.003
Total	44	1.05		1.49		0.994	

*Significant at 5% level of significance

ANOVA for Photosynthesis (µ mol/m^2/s) [Table 27(a) & (b)]

Sources of variation	DF	2013		2014		Pooled	
		SS	MSS	SS	MSS	SS	MSS
Treatments	15	62.63	4.18	62.58	4.17	62.60	4.17
Replications	2	0.81	0.40	0.27	0.14	0.50	0.25
Error	30	3.56	0.12	1.95	0.06	2.28	0.08
Total	47	67.00		64.80		65.39	
Interactions							
Replications	2	0.66	0.33	0.20	0.10	0.39	0.20
Strains (S)	4	14.93	3.73	14.94	3.73	14.93	3.73
Methods of application (M)	2	25.90	12.95	25.87	12.93	25.88	12.94
S x M	8	12.91	1.61	12.88	1.61	12.90	1.61
Error	28	3.51	0.13	1.87	0.07	2.22	0.08
Total	44	57.91		55.75		56.33	

*Significant at 5% level of significance

ANOVA for Stomatal conductance (m mol/s) [Table 28(a) & (b)]

Sources of variation	DF	2013		2014		Pooled	
		SS	MSS	SS	MSS	SS	MSS
Treatments	15	1.57E-01	1.05E-02	1.33E-01	8.89E-03	1.38E-01	9.23E-03
Replications	2	3.22E-04	1.61E-04	1.26E-04	6.30E-05	1.96E-04	9.78E-05
Error	30	1.38E-02	4.61E-04	8.24E-03	2.75E-04	5.68E-03	1.89E-04
Total	47	1.72E-01		1.42E-01		1.44E-01	
Interactions							
Replications	2	1.78E-04	8.88E-05	1.10E-04	5.51E-05	1.27E-04	6.34E-05
Strains (S)	4	4.34E-02	1.08E-02	5.17E-02	1.29E-02	4.51E-02	1.13E-02
Methods of application (M)	2	6.11E-02	3.05E-02	4.07E-02	2.04E-02	4.95E-02	2.48E-02
S x M	8	2.69E-02	3.37E-03	1.29E-02	1.61E-03	1.68E-02	2.10E-03
Error	28	1.36E-02	4.84E-04	8.24E-03	2.94E-04	5.59E-03	2.00E-04
Total	44	1.45E-01		1.14E-01		1.17E-01	

*Significant at 5% level of significance

ANOVA for Stomatal resistance (S cm^{-1}) [Table 29(a) & (b)]

Sources of variation	DF	2013		2014		Pooled	
		SS	MSS	SS	MSS	SS	MSS
Treatments	15	1.841	0.123	1.726	0.115	1.736	0.116
Replications	2	0.030	0.015	0.010	0.005	0.018	0.009
Error	30	0.062	0.002	0.037	0.001	0.022	0.001
Total	47	1.932		1.774		1.776	
Interactions							
Replications	2	0.033	0.017	0.010	0.005	0.020	0.010
Strains (S)	4	0.941	0.235	1.140	0.285	1.027	0.257
Methods of application (M)	2	0.471	0.236	0.366	0.183	0.417	0.208
S x M	8	0.066	0.008	0.055	0.007	0.039	0.005
Error	28	0.058	0.002	0.037	0.001	0.020	0.001
Total	44	1.569		1.609		1.523	

*Significant at 5% level of significance

ANOVA for Transpiration rate (S cm^{-1}) [Table 30(a) & (b)]

Sources of variation	DF	2013		2014		Pooled	
		SS	MSS	SS	MSS	SS	MSS
Treatments	15	955.16	63.68	787.83	52.52	851.73	56.78
Replications	2	28.89	14.44	22.95	11.47	19.50	9.75
Error	30	3.41	0.11	5.27	0.18	2.47	0.08
Total	47	987.46		816.05		873.71	
Interactions							
Replications	2	24.152	12.076	20.67	10.34	16.94	8.47
Strains (S)	4	523.885	130.971	449.77	112.44	473.83	118.46
Methods of application (M)	2	250.440	125.220	194.72	97.36	221.10	110.55
S x M	8	61.654	7.707	57.68	7.21	55.07	6.88
Error	28	1.922	0.069	5.08	0.18	1.86	0.07
Total	44	862.052		727.92		768.79	

*Significant at 5% level of significance

ANALYSIS OF VARIENCE (ANOVA) FOR LEAF NUTRIETN STATUS

ANOVA for Leaf nitrogen content (%) [Table 31(a) & (b)]

Sources of variation	DF	2013		2014		Pooled	
		SS	MSS	SS	MSS	SS	MSS
Treatments	15	1.72	0.11	2.13	0.14	1.88	0.13
Replications	2	0.12	0.06	0.01	0.00	0.03	0.02
Error	30	0.11	0.00	0.19	0.01	0.09	0.00
Total	47	1.96		2.33		2.00	
Interactions							
Replications	2	0.14	0.07	0.01	3.66E-03	0.04	0.02
Strains (S)	4	0.56	0.14	0.66	0.16	0.59	0.15
Methods of application (M)	2	0.79	0.40	0.99	0.49	0.88	0.44
S x M	8	0.15	0.02	0.17	0.02	0.14	0.02
Error	28	0.10	0.00	0.19	0.01	0.09	0.00
Total	44	1.73		2.00		1.73	

*Significant at 5% level of significance

ANOVA for Leaf phosphorus content (%) [Table 32(a) & (b)]

Sources of variation	DF	2013		2014		Pooled	
		SS	MSS	SS	MSS	SS	MSS
Treatments	15	2.19E-02	1.46E-03	2.3E-02	1.5E-03	2.23E-02	1.48E-03
Replications	2	9.35E-04	4.68E-04	7.7E-04	3.9E-04	8.50E-04	4.25E-04
Error	30	5.95E-03	1.98E-04	1.1E-02	3.8E-04	5.16E-03	1.72E-04
Total	47	2.88E-02		3.5E-02		2.83E-02	
Interactions							
Replications	2	6.08E-04	3.04E-04	6.60E-04	3.30E-04	6.12E-04	3.06E-04
Strains (S)	4	6.31E-03	1.58E-03	5.07E-03	1.27E-03	5.61E-03	1.40E-03
Methods of application (M)	2	8.11E-03	4.05E-03	9.85E-03	4.93E-03	8.96E-03	4.48E-03
S x M	8	3.55E-04	4.44E-05	1.09E-03	1.36E-04	6.05E-04	7.57E-05
Error	28	4.63E-03	1.65E-04	1.10E-02	3.91E-04	4.93E-03	1.76E-04
Total	44	2.00E-02		2.76E-02		2.07E-02	

*Significant at 5% level of significance

ANOVA for Leaf potassium content (%) [Table 33(a) & (b)]

Sources of variation	DF	2013		2014		Pooled	
		SS	MSS	SS	MSS	SS	MSS
Treatments	15	0.57	0.04	0.37	0.02	0.45	0.03
Replications	2	0.28	0.14	0.02	0.01	0.05	0.03
Error	30	0.31	0.01	0.33	0.01	0.23	0.01
Total	47	1.16		0.72		0.73	
Interactions							
Replications	2	0.26	0.13	0.01	0.00	0.05	0.03
Strains (S)	4	0.17	0.04	0.13	0.03	0.15	0.04
Methods of application (M)	2	0.25	0.12	0.13	0.07	0.18	0.09
S x M	8	0.03	0.00	0.02	0.00	0.01	0.00
Error	28	0.28	0.01	0.27	0.01	0.19	0.01
Total	44	0.99		0.55		0.58	

*Significant at 5% level of significance

ANOVA for Leaf calcium content (%) [Table 34(a) & (b)]

Sources of variation	DF	2013		2014		Pooled	
		SS	MSS	SS	MSS	SS	MSS
Treatments	15	0.44	0.03	0.21	0.01	0.31	0.02
Replications	2	0.05	0.03	0.11	0.05	0.08	0.04
Error	30	0.06	0.00	0.18	0.01	0.08	2.69E-03
Total	47	0.55		0.50		0.47	
Interactions							
Replications	2	0.05	0.02	0.09	0.05	0.07	0.03
Strains (S)	4	0.02	0.01	0.02	0.00	0.02	0.01
Methods of application (M)	2	0.07	0.03	0.05	0.03	0.06	0.03
S x M	8	0.01	7.18E-04	3.19E-03	3.98E-04	3.79E-03	4.73E-04
Error	28	0.06	2.08E-03	0.16	0.01	0.07	2.66E-03
Total	44	0.21		0.33		0.23	

*Significant at 5% level of significance

ANOVA for Leaf magnesium content (%) [Table 35(a) & (b)]

Sources of variation	DF	2013		2014		Pooled	
		SS	MSS	SS	MSS	SS	MSS
Treatments	15	2.22E-02	1.48E-03	2.25E-02	1.50E-03	2.22E-02	1.48E-03
Replications	2	2.06E-03	1.03E-03	1.08E-03	5.38E-04	1.15E-03	5.76E-04
Error	30	1.36E-02	4.53E-04	5.72E-03	1.91E-04	5.96E-03	1.99E-04
Total	47	3.79E-02		2.93E-02		2.94E-02	
Interactions							
Replications	2	1.54E-03	7.70E-04	1.29E-03	6.46E-04	1.29E-03	6.45E-04
Strains (S)	4	4.93E-03	1.23E-03	4.71E-03	1.18E-03	4.80E-03	1.20E-03
Methods of application (M)	2	7.82E-03	3.91E-03	7.67E-03	3.83E-03	7.74E-03	3.87E-03
S x M	8	6.55E-04	8.19E-05	8.85E-04	1.11E-04	6.77E-04	8.47E-05
Error	28	1.22E-02	4.37E-04	4.15E-03	1.48E-04	5.78E-03	2.06E-04
Total	44	2.72E-02		1.87E-02		2.03E-02	

*Significant at 5% level of significance

ANOVA for Leaf zinc content (ppm) [Table 36(a) & (b)]

Sources of variation	DF	2013		2014		Pooled	
		SS	MSS	SS	MSS	SS	MSS
Treatments	15	293.27	19.55	390.37	26.02	333.91	22.26
Replications	2	41.67	20.84	28.60	14.30	34.52	17.26
Error	30	12.44	0.41	12.07	0.40	5.93	0.20
Total	47	347.39		431.04		374.37	
Interactions							
Replications	2	36.46	18.23	23.70	11.85	29.53	14.77
Strains (S)	4	18.58	4.64	46.86	11.71	28.03	7.01
Methods of application (M)	2	134.21	67.10	173.93	86.97	153.18	76.59
S x M	8	21.16	2.65	27.91	3.49	22.45	2.81
Error	28	11.66	0.42	10.48	0.37	4.90	0.17
Total	44	222.07		282.88		238.09	

*Significant at 5% level of significance

ANOVA for Leaf iron content (ppm) [Table 37(a) & (b)]

Sources of variation	DF	2013		2014		Pooled	
		SS	MSS	SS	MSS	SS	MSS
Treatments	15	2786.00	185.73	5113.93	340.93	3775.86	251.72
Replications	2	55.45	27.72	51.71	25.86	53.51	26.75
Error	30	24.23	0.81	13.21	0.44	4.48	0.15
Total	47	2865.68		5178.85		3833.84	
Interactions							
Replications	2	61.78	30.89	41.17	20.59	50.87	25.44
Strains (S)	4	212.88	53.22	161.08	40.27	152.14	38.04
Methods of application (M)	2	1726.83	863.41	3648.09	1824.04	2583.25	1291.63
S x M	8	191.34	23.92	316.76	39.59	227.51	28.44
Error	28	16.99	0.61	7.38	0.26	3.84	0.14
Total	44	2209.81		4174.48		3017.62	

*Significant at 5% level of significance

ANOVA for Leaf manganese content (ppm) [Table 38(a) & (b)]

Sources of variation	DF	2013		2014		Pooled	
		SS	MSS	SS	MSS	SS	MSS
Treatments	15	1574.07	104.94	4130.96	275.40	2435.83	162.39
Replications	2	58.31	29.15	33.43	16.72	44.64	22.32
Error	30	15.42	0.51	20.26	0.68	5.56	0.19
Total	47	1647.80		4184.66		2486.03	
Interactions							
Replications	2	49.24	24.62	42.46	21.23	45.60	22.80
Strains (S)	4	51.48	12.87	1048.65	262.16	265.84	66.46
Methods of application (M)	2	1074.17	537.09	2186.25	1093.13	1564.34	782.17
S x M	8	62.07	7.76	186.60	23.32	69.92	8.74
Error	28	11.28	0.40	6.74	0.24	3.68	0.13
Total	44	1248.24		3470.70		1949.39	

*Significant at 5% level of significance

ANOVA for Leaf copper content (ppm) [Table 39(a) & (b)]

Sources of variation	DF	2013		2014		Pooled	
		SS	MSS	SS	MSS	SS	MSS
Treatments	15	6.13	0.41	20.08	1.34	10.61	0.71
Replications	2	0.10	0.05	0.06	0.03	3.25E-03	1.63E-03
Error	30	0.21	0.01	0.31	0.01	0.08	2.64E-03
Total	47	6.44		20.45		10.69	
Interactions							
Replications	2	0.10	0.05	0.04	0.02	4.16E-03	2.08E-03
Strains (S)	4	2.13	0.53	3.12	0.78	1.67	0.42
Methods of application (M)	2	2.10	1.05	11.93	5.96	5.90	2.95
S x M	8	0.92	0.11	1.39	0.17	0.93	0.12
Error	28	0.21	0.01	0.31	0.01	0.07	2.68E-03
Total	44	5.45		16.79		8.58	

*Significant at 5% level of significance

ANALYSIS OF VARIENCE (ANOVA) FOR SOIL NUTRIETN STATUS

ANOVA for Soil pH [Table 40(a) & (b)]

Sources of variation	DF	2013		2014		Pooled	
		SS	MSS	SS	MSS	SS	MSS
Treatments	15	1.23	0.08	1.15	0.08	1.18	0.08
Replications	2	0.55	0.28	0.26	0.13	0.37	0.18
Error	30	2.17	0.07	2.22	0.07	1.05	0.04
Total	47	3.95		3.62		2.60	
Interactions							
Replications	2	0.59	0.30	0.02	0.01	0.20	0.10
Strains (S)	4	0.31	0.08	0.33	0.08	0.32	0.08
Methods of application (M)	2	0.47	0.24	0.41	0.21	0.44	0.22
S x M	8	0.04	0.01	0.04	0.01	0.04	4.89E-03
Error	28	2.13	0.08	0.35	0.01	0.70	0.02
Total	44	3.55		1.16		1.69	

*Significant at 5% level of significance

ANOVA for Soil EC (dSm^{-1}) [Table 41(a) & (b)]

Sources of variation	DF	2013		2014		Pooled	
		SS	MSS	SS	MSS	SS	MSS
Treatments	15	0.053	0.004	0.051	0.003	0.049	0.003
Replications	2	0.007	0.004	8.27E-04	4.136E-04	8.80E-04	4.398E-04
Error	30	0.025	8.497E-04	0.037	0.001	0.018	5.97E-04
Total	47	0.086		0.089		0.068	
Interactions							
Replications	2	0.007	0.004	3.33E-04	1.66E-04	1.58E-03	7.92E-04
Strains (S)	4	0.007	0.002	6.00E-03	1.50E-03	5.53E-03	1.38E-03
Methods of application (M)	2	0.017	0.008	1.52E-02	7.58E-03	1.60E-02	8.00E-03
S x M	8	0.003	3.21E-04	5.14E-03	6.42E-04	2.06E-03	2.58E-04
Error	28	0.025	8.95E-04	3.10E-02	1.11E-03	1.59E-02	5.68E-04
Total	44	0.059		5.77E-02		4.11E-02	

*Significant at 5% level of significance

ANOVA for Organic carbon (%) [Table 42(a) & (b)]

Sources of variation	DF	2013		2014		Pooled	
		SS	MSS	SS	MSS	SS	MSS
Treatments	15	3.85	0.26	1.76	0.12	2.60	0.17
Replications	2	0.09	0.04	0.04	1.81E-02	0.06	0.03
Error	30	0.16	0.01	0.13	4.38E-03	0.08	2.58E-03
Total	47	4.102		1.93		2.73	
Interactions							
Replications	2	0.07	0.04	0.05	0.02	0.05	0.03
Strains (S)	4	0.83	0.21	0.31	0.08	0.52	0.13
Methods of application (M)	2	2.34	1.17	1.02	0.51	1.61	0.81
S x M	8	0.20	0.03	0.24	0.03	0.15	1.88E-02
Error	28	0.13	4.77E-03	0.20	7.28E-03	0.07	2.62E-03
Total	44	3.58		1.82		2.41	

*Significant at 5% level of significance

ANOVA for Available nitrogen (kg/ ha) [Table 43(a) & (b)]

Sources of variation	DF	2013		2014		Pooled	
		SS	MSS	SS	MSS	SS	MSS
Treatments	15	100669.03	6711.27	99950.46	6663.36	96788.32	6452.55
Replications	2	148.58	74.29	107.48	53.74	126.71	63.36
Error	30	48.73	1.62	43.92	1.46	24.96	0.83
Total	47	100866.34		100101.87		96939.99	
Interactions							
Replications	2	133.06	66.53	106.55	53.28	119.06	59.53
Strains (S)	4	8273.58	2068.39	5556.40	1389.10	5043.69	1260.92
Methods of application (M)	2	33302.77	16651.39	33801.57	16900.78	33467.22	16733.61
S x M	8	6786.68	848.34	6372.17	796.52	5018.56	627.32
Error	28	46.75	1.67	42.51	1.52	24.48	0.87
Total	44	48542.84		45879.21		43673.00	

*Significant at 5% level of significance

ANOVA for Available phosphorus (kg/ ha) [Table 44(a) & (b)]

Sources of variation	DF	2013		2014		Pooled	
		SS	MSS	SS	MSS	SS	MSS
Treatments	15	1354.92	90.33	1409.80	93.99	1347.66	89.84
Replications	2	18.08	9.04	10.99	5.49	14.16	7.08
Error	30	3.57	0.12	3.17	0.11	1.50	0.05
Total	47	1376.57		1423.96		1363.32	
Interactions							
Replications	2	17.22	8.61	10.53	5.26	13.55	6.77
Strains (S)	4	60.92	15.23	39.76	9.94	32.96	8.24
Methods of application (M)	2	524.41	262.21	520.43	260.21	521.59	260.79
S x M	8	84.37	10.55	73.61	9.20	63.21	7.90
Error	28	3.32	0.12	2.79	0.10	1.19	0.04
Total	44	690.25		647.11		632.49	

*Significant at 5% level of significance

ANOVA for Available potassium (kg/ ha) [Table 45(a) & (b)]

Sources of variation	DF	2013		2014		Pooled	
		SS	MSS	SS	MSS	SS	MSS
Treatments	15	26262.72	1750.85	42962.61	2864.17	33952.84	2263.52
Replications	2	237.03	118.52	85.18	42.59	148.46	74.23
Error	30	75.02	2.50	60.45	2.01	35.44	1.18
Total	47	26574.78		43108.24		34136.74	
Interactions							
Replications	2	214.82	107.41	74.29	37.14	133.62	66.81
Strains (S)	4	7579.88	1894.97	10900.94	2725.23	9164.89	2291.22
Methods of application (M)	2	11743.37	5871.68	16672.25	8336.13	14100.03	7050.02
S x M	8	2776.23	347.03	3945.73	493.22	3334.99	416.87
Error	28	43.03	1.54	57.26	2.04	23.43	0.84
Total	44	22357.32		31650.46		26756.97	

*Significant at 5% level of significance

ANOVA for Zinc content (ppm) [Table 46(a) & (b)]

Sources of variation	DF	2013		2014		Pooled	
		SS	MSS	SS	MSS	SS	MSS
Treatments	15	2.48	0.17	2.53	0.17	2.38	0.16
Replications	2	0.01	0.01	0.12	0.06	0.02	0.01
Error	30	0.46	0.02	0.35	0.01	0.28	0.01
Total	47	2.95		2.99		2.67	
Interactions							
Replications	2	0.04	0.02	0.04	0.02	3.67E-03	1.83E-03
Strains (S)	4	0.32	0.08	0.15	0.04	1.67E-01	4.17E-02
Methods of application (M)	2	0.26	0.13	0.56	0.28	3.91E-01	1.95E-01
S x M	8	0.04	0.01	0.09	1.09E-02	3.47E-02	4.34E-03
Error	28	0.30	0.01	0.06	2.28E-03	9.83E-02	3.51E-03
Total	44	0.97		0.90		6.94E-01	

*Significant at 5% level of significance

ANOVA for Iron content (ppm) [Table 47(a) & (b)]

Sources of variation	DF	2013		2014		Pooled	
		SS	MSS	SS	MSS	SS	MSS
Treatments	15	6649.08	443.27	12074.69	804.98	7898.41	526.56
Replications	2	148.82	74.41	188.79	94.40	29.88	14.94
Error	30	47.39	1.58	48.40	1.61	19.34	0.64
Total	47	6845.29		12311.88		7947.64	
Interactions							
Replications	2	144.92	72.46	183.40	91.70	29.48	14.74
Strains (S)	4	836.45	209.11	1630.90	407.73	138.62	34.65
Methods of application (M)	2	1796.37	898.19	2516.82	1258.41	2119.42	1059.71
S x M	8	253.59	31.70	315.34	39.42	120.99	15.12
Error	28	46.53	1.66	47.47	1.70	19.04	0.68
Total	44	3077.86		4693.93		2427.55	

*Significant at 5% level of significance

ANOVA for Manganese content (ppm) [Table 48(a) & (b)]

Sources of variation	DF	2013		2014		Pooled	
		SS	MSS	SS	MSS	SS	MSS
Treatments	15	2939.78	195.99	5053.81	336.92	3444.93	229.66
Replications	2	88.99	44.49	119.17	59.58	0.96	0.48
Error	30	34.04	1.13	28.46	0.95	20.83	0.69
Total	47	3062.81		5201.44		3466.73	
Interactions							
Replications	2	89.69	44.84	125.91	62.96	0.81	0.40
Strains (S)	4	955.77	238.94	648.42	162.11	524.83	131.21
Methods of application (M)	2	875.17	437.58	2946.41	1473.20	1749.51	874.75
S x M	8	533.37	66.67	554.51	69.31	439.89	54.99
Error	28	16.96	0.61	15.01	0.54	10.21	0.36
Total	44	2470.97		4290.26		2725.24	

*Significant at 5% level of significance

ANOVA for Copper content (ppm) [Table 49(a) & (b)]

Sources of variation	DF	2013		2014		Pooled	
		SS	MSS	SS	MSS	SS	MSS
Treatments	15	53.81	3.59	85.69	5.71	66.85	4.46
Replications	2	0.48	0.24	0.55	0.28	0.48	0.24
Error	30	1.28	0.04	1.79	0.06	0.71	0.02
Total	47	55.57		88.03		68.04	
Interactions							
Replications	2	0.44	0.22	0.34	0.17	0.39	0.19
Strains (S)	4	14.08	3.52	16.04	4.01	14.88	3.72
Methods of application (M)	2	21.84	10.92	42.56	21.28	31.35	15.67
S x M	8	7.09	0.89	7.09	0.89	5.58	0.70
Error	28	1.28	0.05	0.51	0.02	0.39	0.01
Total	44	44.73		66.55		52.58	

*Significant at 5% level of significance

ANALYSIS OF VARIENCE (ANOVA) FOR SOIL BIOLOGICVAL PROPERTIES

ANOVA for Total rhizobacterial counts on nutrient agar (x10^5 cfu/ g soil) [Table 50(a) & (b)]

Sources of variation	DF	2013		2014		Pooled	
		SS	MSS	SS	MSS	SS	MSS
Treatments	15	66386.69	4425.78	86566.06	5771.07	75864.28	5057.62
Replications	2	66.45	33.23	52.02	26.01	59.01	29.51
Error	30	22.94	0.76	46.35	1.55	22.18	0.74
Total	47	66476.09		86664.43		75945.48	
Interactions							
Replications	2	69.33	34.66	59.54	29.77	64.29	32.14
Strains (S)	4	4790.00	1197.50	5045.46	1261.36	4856.50	1214.12
Methods of application (M)	2	13389.21	6694.60	21506.81	10753.40	17190.60	8595.30
S x M	8	1458.36	182.29	948.21	118.53	1089.64	136.20
Error	28	14.07	0.50	36.97	1.32	14.11	0.50
Total	44	19720.96		27596.98		23215.13	

*Significant at 5% level of significance

ANOVA for Total rhizobacterial counts on PVK medium (x10^5 cfu/g soil) [Table 51(a) & (b)]

Sources of variation	DF	2013		2014		Pooled	
		SS	MSS	SS	MSS	SS	MSS
Treatments	15	61661.45	4110.76	92568.41	6171.23	75963.80	5064.25
Replications	2	156.20	78.10	131.61	65.80	143.59	71.80
Error	30	45.15	1.51	37.96	1.27	19.29	0.64
Total	47	61862.81		92737.98		76126.68	
Interactions							
Replications	2	160.12	80.06	124.19	62.10	141.58	70.79
Strains (S)	4	5619.45	1404.86	7456.02	1864.00	6418.44	1604.61
Methods of application (M)	2	20912.36	10456.18	28156.86	14078.43	24400.16	12200.08
S x M	8	416.58	52.07	212.33	26.54	90.32	11.29
Error	28	38.33	1.37	37.91	1.35	17.52	0.63
Total	44	27146.84		35987.31		31068.02	

*Significant at 5% level of significance

ANOVA for Total rhizobacterial counts on CAS medium (x10^4 cfu/g soil) [Table 52(a) & (b)]

Sources of variation	DF	2013		2014		Pooled	
		SS	MSS	SS	MSS	SS	MSS
Treatments	15	5225.14	348.34	4342.72	289.51	4636.81	309.12
Replications	2	25.92	12.96	154.18	77.09	76.63	38.32
Error	30	38.92	1.30	36.72	1.22	15.38	0.51
Total	47	5289.98		4533.62		4728.82	
Interactions							
Replications	2	25.86	12.93	156.81	78.41	77.50	38.75
Strains (S)	4	345.82	86.46	396.90	99.23	367.08	91.77
Methods of application (M)	2	4138.73	2069.36	3025.53	1512.76	3470.20	1735.10
S x M	8	257.44	32.18	179.44	22.43	194.39	24.30
Error	28	38.40	1.37	32.61	1.16	13.67	0.49
Total	44	4806.25		3791.29		4122.84	

*Significant at 5% level of significance

ANOVA for Total rhizobacterial counts on Jensen's medium (x10^5 cfu/g soil) [Table 53(a) & (b)]

Sources of variation	DF	2013		2014		Pooled	
		SS	MSS	SS	MSS	SS	MSS
Treatments	15	67540.49	4502.70	85175.55	5678.37	75475.25	5031.68
Replications	2	398.55	199.27	277.68	138.84	335.39	167.70
Error	30	31.41	1.05	45.25	1.51	18.95	0.63
Total	47	67970.46		85498.48		75829.59	
Interactions							
Replications	2	350.38	175.19	251.65	125.82	298.84	149.42
Strains (S)	4	1667.15	416.79	4113.35	1028.34	2519.87	629.97
Methods of application (M)	2	26231.70	13115.85	28305.24	14152.62	27257.90	13628.95
S x M	8	697.95	87.24	318.94	39.87	257.09	32.14
Error	28	22.13	0.79	43.08	1.54	15.61	0.56
Total	44	28969.31		33032.27		30349.31	

*Significant at 5% level of significance

ANOVA for Per cent phosphorus solubilizing bacteria [Table 54(a) & (b)]

Sources of variation	DF	2013		2014		Pooled	
		SS	MSS	SS	MSS	SS	MSS
Treatments	15	3153.46	210.23	4557.40	303.83	3677.00	245.13
Replications	2	35.74	17.87	56.97	28.48	42.12	21.06
Error	30	5.69	0.19	15.35	0.51	6.16	0.21
Total	47	3194.89		4629.72		3725.28	
Interactions							
Replications	2	0.18	0.09	0.15	0.07	0.16	0.08
Strains (S)	4	1.35	0.34	0.43	0.11	0.78	0.19
Methods of application (M)	2	1.79	0.90	2.69	1.34	2.15	1.07
S x M	8	0.07	0.01	0.36	0.05	0.11	0.01
Error	28	0.02	7.90E-04	0.02	7.91E-04	0.01	4.82E-04
Total	44	3.41		3.66		3.21	

*Significant at 5% level of significance

ANOVA for Per cent siderophore producing bacteria [Table 55(a) & (b)]

Sources of variation	DF	2013		2014		Pooled	
		SS	MSS	SS	MSS	SS	MSS
Treatments	15	2981.09	198.74	2944.10	196.27	2948.48	196.57
Replications	2	22.98	11.49	49.44	24.72	34.73	17.36
Error	30	18.07	0.60	15.98	0.53	10.62	0.35
Total	47	3022.14		3009.51		2993.82	
Interactions							
Replications	2	0.22	0.11	0.30	0.15	0.25	0.13
Strains (S)	4	3.81	0.95	2.88	0.72	3.31	0.83
Methods of application (M)	2	3.24	1.62	3.20	1.60	3.22	1.61
S x M	8	1.03	0.13	0.66	0.08	0.82	0.10
Error	28	0.04	1.31E-03	0.07	2.49E-03	0.03	1.03E-03
Total	44	8.33		7.11		7.63	

*Significant at 5% level of significance

ANOVA for Per cent nitrogen fixing bacteria [Table 56(a) & (b)]

Sources of variation	DF	2013		2014		Pooled	
		SS	MSS	SS	MSS	SS	MSS
Treatments	15	3623.33	241.56	4788.11	319.21	3987.29	265.82
Replications	2	18.15	9.07	69.26	34.63	31.90	15.95
Error	30	14.55	0.48	73.59	2.45	16.31	0.54
Total	47	3656.02		4930.95		4035.50	
Interactions							
Replications	2	0.13	0.07	0.21	0.11	0.17	0.09
Strains (S)	4	0.56	0.14	0.89	0.22	0.57	0.14
Methods of application (M)	2	4.73	2.36	3.34	1.67	3.97	1.99
S x M	8	0.13	0.02	0.41	0.05	0.11	0.01
Error	28	0.02	8.38E-04	0.06	2.29E-03	0.02	7.16E-04
Total	44	5.58		4.91		4.85	

*Significant at 5% level of significance

ANOVA for Total endorhizobacterial counts on nutrient agar (x10^1 cfu/g root) [Table 57(a) & (b)]

Sources of variation	DF	2013		2014		Pooled	
		SS	MSS	SS	MSS	SS	MSS
Treatments	15	2963.27	197.55	2822.65	188.18	2847.84	189.86
Replications	2	74.84	37.42	96.58	48.29	85.22	42.61
Error	30	37.16	1.24	41.03	1.37	23.99	0.80
Total	47	3075.27		2960.26		2957.05	
Interactions							
Replications	2	96.04	48.02	73.88	36.94	84.00	42.00
Strains (S)	4	3413.15	853.29	4921.70	1230.43	4067.70	1016.93
Methods of application (M)	2	14588.84	7294.42	21153.17	10576.58	17702.65	8851.32
S x M	8	208.26	26.03	411.89	51.49	63.07	7.88
Error	28	5.11	0.18	13.14	0.47	5.27	0.19
Total	44	18311.39		26573.78		21922.69	

*Significant at 5% level of significance

ANOVA for Total endorhizobacterial counts on PVK medium (x10^2 cfu/g root) [Table 58(a) & (b)]

Sources of variation	DF	2013		2014		Pooled	
		SS	MSS	SS	MSS	SS	MSS
Treatments	15	55100.74	3673.38	94503.31	6300.22	72400.16	4826.68
Replications	2	196.57	98.29	111.95	55.98	151.29	75.65
Error	30	28.06	0.94	24.63	0.82	11.49	0.38
Total	47	55325.37		94639.89		72562.95	
Interactions							
Replications	2	174.67	87.34	93.96	46.98	131.21	65.61
Strains (S)	4	7886.35	1971.59	5369.52	1342.38	6533.58	1633.39
Methods of application (M)	2	17219.96	8609.98	29186.88	14593.44	22594.52	11297.26
S x M	8	1007.42	125.93	505.93	63.24	410.46	51.31
Error	28	25.99	0.93	18.96	0.68	7.94	0.28
Total	44	26314.40		35175.25		29677.70	

*Significant at 5% level of significance

ANOVA for Total endorhizobacterial counts on CAS medium (x10^2 cfu/g root) [Table 59(a) & (b)]

Sources of variation	DF	2013		2014		Pooled	
		SS	MSS	SS	MSS	SS	MSS
Treatments	15	2963.27	197.55	2822.65	188.18	2847.84	189.86
Replications	2	74.84	37.42	96.58	48.29	85.22	42.61
Error	30	37.16	1.24	41.03	1.37	23.99	0.80
Total	47	3075.27		2960.26		2957.05	
Interactions							
Replications	2	71.53	35.77	91.30	45.65	80.83	40.42
Strains (S)	4	408.82	102.20	582.07	145.52	478.66	119.66
Methods of application (M)	2	1662.80	831.40	1456.03	728.01	1557.48	778.74
S x M	8	61.15	7.64	22.85	2.86	15.98	2.00
Error	28	36.66	1.31	40.59	1.45	23.94	0.86
Total	44	2240.96		2192.83		2156.89	

*Significant at 5% level of significance

ANOVA for Total endorhizobacterial counts on Jensen's medium (x10^2 cfu/g root) [Table 60(a) & (b)]

Sources of variation	DF	2013		2014		Pooled	
		SS	MSS	SS	MSS	SS	MSS
Treatments	15	74016.26	4934.42	94353.95	6290.26	82734.13	5515.61
Replications	2	100.39	50.20	114.59	57.30	107.26	53.63
Error	30	42.10	1.40	46.54	1.55	31.35	1.05
Total	47	74158.75		94515.09		82872.73	
Interactions							
Replications	2	113.52	56.76	129.79	64.90	121.50	60.75
Strains (S)	4	6639.24	1659.81	3570.96	892.74	4906.07	1226.52
Methods of application (M)	2	31054.59	15527.29	29891.69	14945.84	30439.12	15219.56
S x M	8	1277.24	159.66	728.17	91.02	628.04	78.51
Error	28	24.88	0.89	29.64	1.06	14.88	0.53
Total	44	39109.48		34350.25		36109.62	

*Significant at 5% level of significance

ANOVA for Per cent phosphorus solubilizing endorhizobacteria [Table 61(a) & (b)]

Sources of variation	DF	2013		2014		Pooled	
		SS	MSS	SS	MSS	SS	MSS
Treatments	15	1818.24	121.22	3776.75	251.78	2442.93	162.86
Replications	2	17.55	8.78	60.24	30.12	25.60	12.80
Error	30	6.01	0.20	36.24	1.21	6.04	0.20
Total	47	1841.80		3873.23		2474.57	
Interactions							
Replications	2	0.11	0.05	0.12	0.06	0.11	0.06
Strains (S)	4	1.09	0.27	0.84	0.21	0.93	0.23
Methods of application (M)	2	2.24	1.12	1.73	0.86	1.96	0.98
S x M	8	0.42	0.05	0.08	1.04E-02	0.07	9.22E-03
Error	28	0.04	1.53E-03	0.02	6.47E-04	0.02	6.29E-04
Total	44	3.90		2.79		3.09	

*Significant at 5% level of significance

ANOVA for Per cent siderophore producing endorhizobacteria [Table 62(a) & (b)]

Sources of variation	DF	2013		2014		Pooled	
		SS	MSS	SS	MSS	SS	MSS
Treatments	15	2712.78	180.85	2644.15	176.28	2673.02	178.20
Replications	2	43.78	21.89	16.41	8.20	28.63	14.32
Error	30	10.80	0.36	4.97	0.17	4.74	0.16
Total	47	2767.36		2665.53		2706.39	
Interactions							
Replications	2	0.231	0.115	0.084	0.042	0.148	0.074
Strains (S)	4	0.901	0.225	0.586	0.146	0.732	0.183
Methods of application (M)	2	2.047	1.023	1.969	0.984	2.008	1.004
S x M	8	0.074	0.009	0.041	0.005	0.050	0.006
Error	28	0.066	0.002	0.029	0.001	0.030	0.001
Total	44	3.319		2.709		2.967	

*Significant at 5% level of significance

ANOVA for Per cent nitrogen fixing endorhizobacteria [Table 63(a) & (b)]

Sources of variation	DF	2013		2014		Pooled	
		SS	MSS	SS	MSS	SS	MSS
Treatments	15	2364.35	157.62	3623.89	241.59	2840.11	189.34
Replications	2	19.22	9.61	37.25	18.63	24.92	12.46
Error	30	12.25	0.41	32.11	1.07	14.15	0.47
Total	47	2395.82		3693.25		2879.18	
Interactions							
Replications	2	0.15	0.08	0.14	0.07	0.15	0.07
Strains (S)	4	0.51	0.13	0.30	0.08	0.31	0.08
Methods of application (M)	2	3.83	1.92	4.15	2.07	3.98	1.99
S x M	8	0.20	0.02	0.13	0.02	0.10	0.01
Error	28	0.02	7.61E-04	0.04	1.35E-03	0.01	5.16E-04
Total	44	4.71		4.75		4.55	

*Significant at 5% level of significance

APPENDIX - III

EXPERIMENT- II

ANALYSIS OF VARIENCE (ANOVA) FOR PLANT GROWTH PARAMETERS

ANOVA for Plant height (cm) [Table 64(a) & (b)]

Sources of variation	DF	2013		2014		Pooled	
		SS	MSS	SS	MSS	SS	MSS
Treatments	18	333.84	18.55	132.26	7.35	196.47	10.91
Replications	2	60.35	30.17	187.42	93.71	9.17	4.58
Error	36	32.52	0.90	42.03	1.17	19.48	0.54
Total	56	426.70		361.71		225.11	
Interactions							
Replications	2	65.01	32.50	144.59	72.30	4.34	2.17
Strains (S)	4	58.27	14.57	8.19	2.05	16.21	4.05
Gibberellic acid (G)	2	116.22	58.11	62.06	31.03	86.71	43.36
S x G	8	30.12	3.77	4.36	0.54	7.29	0.91
Error	28	14.56	0.52	37.04	1.32	14.63	0.52
Total	44	284.18		256.24		129.18	

*Significant at 5% level of significance

ANOVA for Plant spread (cm) [Table 65(a) & (b)]

Sources of variation	DF	2013		2014		Pooled	
		SS	MSS	SS	MSS	SS	MSS
Treatments	18	296.10	16.45	943.68	52.43	453.67	25.20
Replications	2	108.00	54.00	127.71	63.85	0.36	0.18
Error	36	49.65	1.38	29.84	0.83	14.16	0.39
Total	56	453.74		1101.22		468.20	
Interactions							
Replications	2	84.92	42.46	79.22	39.61	0.06	0.03
Strains (S)	4	37.69	9.42	188.88	47.22	29.00	7.25
Gibberellic acid (G)	2	139.21	69.60	104.19	52.09	121.04	60.52
S x G	8	35.70	4.46	18.88	2.36	11.10	1.39
Error	28	35.87	1.28	7.70	0.27	10.71	0.38
Total	44	333.39		398.87		171.90	

*Significant at 5% level of significance

ANOVA for Leaf area (cm^2) [Table 66(a) & (b)]

Sources of variation	DF	2013		2014		Pooled	
		SS	MSS	SS	MSS	SS	MSS
Treatments	18	4511.22	250.62	3934.68	218.59	4188.56	232.70
Replications	2	137.95	68.97	217.16	108.58	174.79	87.40
Error	36	74.93	2.08	87.14	2.42	68.62	1.91
Total	56	4724.10		4238.98		4431.97	
Interactions							
Replications	2	101.99	50.99	146.22	73.11	122.82	61.41
Strains (S)	4	2072.04	518.01	1949.16	487.29	1999.09	499.77
Gibberellic acid (G)	2	1007.17	503.58	873.37	436.69	938.75	469.38
S x G	8	384.67	48.08	134.39	16.80	238.50	29.81
Error	28	68.64	2.45	43.48	1.55	48.84	1.74
Total	44	3634.50		3146.62		3348.00	

*Significant at 5% level of significance

ANOVA for Number of crowns per plant [Table 67(a) & (b)]

Sources of variation	DF	2013		2014		Pooled	
		SS	MSS	SS	MSS	SS	MSS
Treatments	18	11.29	0.63	8.58	0.48	9.02	0.50
Replications	2	2.28	1.14	29.69	14.84	8.92	4.46
Error	36	6.58	0.18	4.05	0.11	3.20	0.09
Total	56	20.14		42.32		21.14	
Interactions							
Replications	2	1.10	0.55	25.79	12.90	6.88	3.44
Strains (S)	4	1.41	0.35	0.44	0.11	0.48	0.12
Gibberellic acid (G)	2	6.27	3.13	3.12	1.56	4.55	2.28
S x G	8	0.98	0.12	0.48	0.06	0.49	0.06
Error	28	4.40	0.16	3.38	0.12	2.55	0.09
Total	44	14.16		33.22		14.96	

*Significant at 5% level of significance

ANOVA for Number of runners per plant [Table 68(a) & (b)]

Sources of variation	DF	2013		2014		Pooled	
		SS	MSS	SS	MSS	SS	MSS
Treatments	18	998.77	55.49	1096.06	60.89	1021.39	56.74
Replications	2	60.53	30.26	153.80	76.90	101.82	50.91
Error	36	29.70	0.82	44.33	1.23	25.60	0.71
Total	56	1088.99		1294.20		1148.80	
Interactions							
Replications	2	56.42	28.21	124.22	62.11	86.98	43.49
Strains (S)	4	108.06	27.02	194.89	48.72	144.64	36.16
Gibberellic acid (G)	2	352.25	176.13	462.86	231.43	404.42	202.21
S x G	8	184.71	23.09	78.00	9.75	115.71	14.46
Error	28	27.07	0.97	39.19	1.40	23.04	0.82
Total	44	728.52		899.15		774.80	

*Significant at 5% level of significance

ANOVA for Plant biomass on fresh wt. basis (g/plant) [Table 69(a) & (b)]

Sources of variation	DF	2013		2014		Pooled	
		SS	MSS	SS	MSS	SS	MSS
Treatments	18	516.10	28.67	364.29	20.24	428.55	23.81
Replications	2	118.04	59.02	69.98	34.99	92.42	46.21
Error	36	32.16	0.89	23.75	0.66	16.33	0.45
Total	56	666.29		458.02		537.29	
Interactions							
Replications	2	83.44	41.72	41.04	20.52	60.18	30.09
Strains (S)	4	46.32	11.58	19.84	4.96	29.95	7.49
Gibberellic acid (G)	2	161.55	80.77	86.39	43.20	119.11	59.56
S x G	8	13.86	1.73	7.85	0.98	9.46	1.18
Error	28	21.75	0.78	13.58	0.48	7.90	0.28
Total	44	326.92		168.71		226.60	

*Significant at 5% level of significance

ANOVA for Plant biomass on dry wt. basis (g/plant) [Table 70(a) & (b)]

Sources of variation	DF	2013		2014		Pooled	
		SS	MSS	SS	MSS	SS	MSS
Treatments	18	25.05	1.39	18.38	1.02	20.78	1.15
Replications	2	7.18	3.59	9.21	4.60	7.96	3.98
Error	36	19.72	0.55	6.32	0.18	6.88	0.19
Total	56	51.95		33.90		35.62	
Interactions							
Replications	2	6.14	3.07	6.65	3.33	6.25	3.12
Strains (S)	4	2.85	0.71	2.32	0.58	2.09	0.52
Gibberellic acid (G)	2	9.15	4.58	6.34	3.17	7.65	3.82
S x G	8	0.66	0.08	1.04	0.13	0.62	0.08
Error	28	19.17	0.68	5.93	0.21	6.60	0.24
Total	44	37.97		22.28		23.21	

*Significant at 5% level of significance

ANALYSIS OF VARIENCE (ANOVA) FOR YIELD PARAMETERS

ANOVA for Duration of flowering (days) [Table 72(a) & (b)]

Sources of variation	DF	2013		2014		Pooled	
		SS	MSS	SS	MSS	SS	MSS
Treatments	18	1150.18	63.90	3813.51	211.86	2045.51	113.64
Replications	2	391.72	195.86	119.92	59.96	19.57	9.78
Error	36	43.61	1.21	24.91	0.69	16.31	0.45
Total	56	1585.51		3958.34		2081.38	
Interactions							
Replications	2	147.29	108.2754	69.08	34.54	19.60	9.80
Strains (S)	4	20.19	14.84131	96.36	24.09	21.63	5.41
Gibberellic acid (G)	2	319.62	234.9615	794.98	397.49	714.08	357.04
S x G	8	5.87	4.316803	213.91	26.74	67.53	8.44
Error	28	1.36	1	8.42	0.30	12.27	0.44
Total	44	147.29	108.2754	1182.74		835.12	

*Significant at 5% level of significance

ANOVA for Duration of harvesting (days) [Table 74(a) & (b)]

Sources of variation	DF	2013		2014		Pooled	
		SS	MSS	SS	MSS	SS	MSS
Treatments	18	834.50	46.36	735.29	40.85	739.43	41.08
Replications	2	130.36	65.18	116.02	58.01	0.34	0.17
Error	36	31.04	0.86	25.28	0.70	15.51	0.43
Total	56	995.89		876.59		755.29	
Interactions							
Replications	2	91.36	45.68	96.59	48.30	0.31	0.16
Strains (S)	4	126.54	31.64	53.37	13.34	77.38	19.35
Gibberellic acid (G)	2	205.83	102.92	291.18	145.59	246.07	123.03
S x G	8	30.77	3.85	22.49	2.81	7.20	0.90
Error	28	20.03	0.72	21.14	0.75	11.60	0.41
Total	44	474.54		484.78		342.56	

*Significant at 5% level of significance

ANOVA for Number of fruits per plant [Table 75(a) & (b)]

Sources of variation	DF	2013		2014		Pooled	
		SS	MSS	SS	MSS	SS	MSS
Treatments	18	107.65	5.98	231.04	12.84	138.46	7.69
Replications	2	23.56	11.78	69.87	34.94	14.61	7.30
Error	36	39.48	1.10	12.52	0.35	16.44	0.46
Total	56	170.69		313.43		169.50	
Interactions							
Replications	2	18.13	9.07	57.74	28.87	14.79	7.39
Strains (S)	4	42.38	10.60	14.64	3.66	14.94	3.73
Gibberellic acid (G)	2	9.93	4.96	66.50	33.25	31.89	15.94
S x G	8	1.71	0.21	18.73	2.34	5.83	0.73
Error	28	36.16	1.29	9.46	0.34	13.75	0.49
Total	44	108.32		167.08		81.20	

*Significant at 5% level of significance

ANOVA for Fruit yield per plant (g) [Table 76(a) & (b)]

Sources of variation	DF	2013		2014		Pooled	
		SS	MSS	SS	MSS	SS	MSS
Treatments	18	38703.38	2150.19	289484.56	16082.48	118308.69	6572.71
Replications	2	55.36	27.68	110.37	55.18	2.46	1.23
Error	36	44.11	1.23	42.23	1.17	38.60	1.07
Total	56	38802.86		289637.16		118349.75	
Interactions							
Replications	2	66.71	33.36	67.18	33.59	0.01	0.01
Strains (S)	4	11202.76	2800.69	28349.19	7087.30	8338.57	2084.64
Gibberellic acid (G)	2	8808.59	4404.30	49660.08	24830.04	25061.29	12530.65
S x G	8	1434.09	179.26	22025.95	2753.24	5227.09	653.39
Error	28	5.43	0.19	11.23	0.40	4.49	0.16
Total	44	21517.59		100113.63		38631.46	

*Significant at 5% level of significance

ANOVA for Fruit yield per hectare (t) [Table 77(a) & (b)]

Sources of variation	DF	2013		2014		Pooled	
		SS	MSS	SS	MSS	SS	MSS
Treatments	18	252.46	14.03	1852.65	102.93	758.35	42.13
Replications	2	7.92	3.96	27.92	13.96	16.39	8.19
Error	36	31.10	0.86	25.96	0.72	15.88	0.44
Total	56	291.48		1906.52		790.62	
Interactions							
Replications	2	1.84	0.92	20.80	10.40	8.75	4.37
Strains (S)	4	75.58	18.90	181.46	45.37	53.14	13.29
Gibberellic acid (G)	2	56.16	28.08	317.72	158.86	160.24	80.12
S x G	8	9.10	1.14	140.97	17.62	33.84	4.23
Error	28	12.92	0.46	12.98	0.46	6.12	0.22
Total	44	155.61		673.93		262.10	

*Significant at 5% level of significance

ANALYSIS OF VARIANCE (ANOVA) FOR FRUIT QUALITY PARAMETERS

ANOVA for Fruit weight (g) [Table 78(a) & (b)]

Sources of variation	DF	2013		2014		Pooled	
		SS	MSS	SS	MSS	SS	MSS
Treatments	18	30.98	1.72	210.20	11.68	89.209	4.956062
Replications	2	25.14	12.57	130.95	65.47	10.334	5.167225
Error	36	15.40	0.43	31.96	0.89	11.149	0.30969
Total	56	71.52		373.10		110.692	
Interactions							
Replications	2	24.67	12.33	92.84	46.42	5.47	2.73
Strains (S)	4	5.42	1.35	21.91	5.48	7.35	1.84
Gibberellic acid (G)	2	9.92	4.96	56.76	28.38	28.10	14.05
S x G	8	3.98	0.50	14.46	1.81	3.18	0.40
Error	28	9.80	0.35	18.83	0.67	6.92	0.25
Total	44	53.78		204.79		51.02	

*Significant at 5% level of significance

ANOVA for Fruit length (mm) [Table 79(a) & (b)]

Sources of variation	DF	2013		2014		Pooled	
		SS	MSS	SS	MSS	SS	MSS
Treatments	18	211.45	11.75	263.12	14.62	211.90	11.77
Replications	2	81.51	40.75	44.61	22.31	61.67	30.84
Error	36	12.86	0.36	3.65	0.10	3.30	0.09
Total	56	305.82		311.38		276.87	
Interactions							
Replications	2	69.34	34.67	35.37	17.69	50.86	25.43
Strains (S)	4	40.08	10.02	12.69	3.17	15.83	3.96
Gibberellic acid (G)	2	88.21	44.11	113.16	56.58	99.20	49.60
S x G	8	20.11	2.51	14.79	1.85	9.78	1.22
Error	28	6.96	0.25	3.43	0.12	1.96	0.07
Total	44	224.71		179.45		177.63	

*Significant at 5% level of significance

ANOVA for Fruit diameter (mm) [Table 80(a) & (b)]

Sources of variation	DF	2013		2014		Pooled	
		SS	MSS	SS	MSS	SS	MSS
Treatments	18	42.84	2.38	108.92	6.05	63.57	3.53
Replications	2	55.30	27.65	61.96	30.98	0.13	0.07
Error	36	11.61	0.32	13.94	0.39	5.81	0.16
Total	56	109.75		184.82		69.51	
Interactions							
Replications	2	44.81	22.40	56.47	28.23	0.26	0.13
Strains (S)	4	5.46	1.37	7.46	1.86	1.18	0.29
Gibberellic acid (G)	2	17.07	8.54	43.77	21.89	28.73	14.37
S x G	8	2.12	0.26	9.97	1.25	2.63	0.33
Error	28	10.12	0.36	12.18	0.44	5.21	0.19
Total	44	79.58		129.85		38.01	

*Significant at 5% level of significance

ANOVA for Fruit TSS (^{0}Brix) [Table 81(a) & (b)]

Sources of variation	DF	2013		2014		Pooled	
		SS	MSS	SS	MSS	SS	MSS
Treatments	18	19.55	1.09	34.04	1.89	23.25	1.29
Replications	2	21.04	10.52	1.95	0.97	8.94	4.47
Error	36	10.08	0.28	2.24	0.06	2.58	0.07
Total	56	50.68		38.23		34.77	
Interactions							
Replications	2	14.68	7.34	2.52	1.26	7.32	3.66
Strains (S)	4	4.84	1.21	4.90	1.22	4.26	1.06
Gibberellic acid (G)	2	7.80	3.90	5.40	2.70	6.55	3.27
S x G	8	1.61	0.20	2.11	0.26	0.72	0.09
Error	28	6.05	0.22	1.02	0.04	1.91	0.07
Total	44	34.98		15.95		20.75	

*Significant at 5% level of significance

ANOVA for Fruit acidity (%) [Table 82(a) & (b)]

Sources of variation	DF	2013		2014		Pooled	
		SS	MSS	SS	MSS	SS	MSS
Treatments	18	1.68	0.09	5.66	0.31	2.95	0.16
Replications	2	1.33	0.67	1.30	0.65	1.31	0.65
Error	36	0.87	0.02	1.02	0.03	0.57	0.02
Total	56	3.88		7.97		4.82	
Interactions							
Replications	2	1.07	0.54	1.18	0.59	1.12	0.56
Strains (S)	4	0.32	0.08	1.80	0.45	0.69	0.17
Gibberellic acid (G)	2	0.85	0.42	1.63	0.81	1.17	0.59
S x G	8	0.10	0.01	0.42	0.05	0.14	0.02
Error	28	0.80	0.03	0.89	0.03	0.51	0.02
Total	44	3.13		5.91		3.63	

*Significant at 5% level of significance

ANOVA for TSS: acid ratio [Table 83(a) & (b)]

Sources of variation	DF	2013		2014		Pooled	
		SS	MSS	SS	MSS	SS	MSS
Treatments	18	79.02	4.39	123.82	6.88	90.51	5.03
Replications	2	3.81	1.90	9.33	4.67	6.24	3.12
Error	36	27.33	0.76	13.75	0.38	11.56	0.32
Total	56	110.15		146.90		108.30	
Interactions							
Replications	2	4.08	2.04	7.51	3.76	5.54	2.77
Strains (S)	4	13.46	3.37	28.61	7.15	14.91	3.73
Gibberellic acid (G)	2	43.23	21.62	36.75	18.37	39.45	19.72
S x G	8	4.21	0.53	5.55	0.69	3.89	0.49
Error	28	20.76	0.74	12.30	0.44	10.46	0.37
Total	44	85.76		90.73		74.26	

*Significant at 5% level of significance

ANOVA for Total sugars (%) [Table 84(a) & (b)]

Sources of variation	DF	2013		2014		Pooled	
		SS	MSS	SS	MSS	SS	MSS
Treatments	18	15.33	0.85	17.21	0.96	14.48	0.80
Replications	2	6.10	3.05	1.93	0.97	2.81	1.41
Error	36	3.28	0.09	3.24	0.09	1.76	0.05
Total	56	24.71		22.38		19.05	
Interactions							
Replications	2	4.88	2.44	1.84	0.92	2.28	1.14
Strains (S)	4	1.76	0.44	2.53	0.63	1.69	0.42
Gibberellic acid (G)	2	7.42	3.71	7.91	3.95	7.43	3.72
S x G	8	1.99	0.25	0.60	0.08	0.31	0.04
Error	28	1.55	0.06	3.05	0.11	1.28	0.05
Total	44	17.61		15.93		13.00	

*Significant at 5% level of significance

ANOVA for Reducing sugars (%) [Table 85(a) & (b)]

Sources of variation	DF	2013		2014		Pooled	
		SS	MSS	SS	MSS	SS	MSS
Treatments	18	5.51	0.31	0.30	0.02	10.12	0.56
Replications	2	4.17	2.08	0.23	0.11	5.01	2.50
Error	36	3.65	0.10	0.20	0.01	3.99	0.11
Total	56	13.33		0.73		19.12	
Interactions							
Replications	2	3.13	1.56	4.55	2.28	3.78	1.89
Strains (S)	4	1.65	0.41	1.82	0.46	0.02	0.01
Gibberellic acid (G)	2	1.64	0.82	5.04	2.52	3.09	1.54
S x G	8	0.28	0.03	0.81	0.10	0.29	0.04
Error	28	2.39	0.09	3.63	0.13	1.98	0.07
Total	44	9.07		15.85		9.16	

*Significant at 5% level of significance

ANOVA for Non-reducing sugars (%) [Table 86(a) & (b)]

Sources of variation	DF	2013		2014		Pooled	
		SS	MSS	SS	MSS	SS	MSS
Treatments	18	8.52	0.47	2.54	0.14	3.43	0.19
Replications	2	4.13	2.06	0.66	0.33	0.89	0.45
Error	36	3.77	0.10	2.28	0.06	1.04	0.03
Total	56	16.42		5.48		5.36	
Interactions							
Replications	2	3.36	1.68	0.48	0.24	0.71	0.36
Strains (S)	4	4.20	1.05	0.59	0.15	1.41	0.35
Gibberellic acid (G)	2	2.48	1.24	0.32	0.16	0.97	0.48
S x G	8	1.35	0.17	0.85	0.11	0.47	0.06
Error	28	3.05	0.11	2.22	0.08	0.91	0.03
Total	44	14.45		4.46		4.47	

*Significant at 5% level of significance

ANOVA for Ascorbic acid (mg/100 g)) [Table 87(a) & (b)]

Sources of variation	DF	2013		2014		Pooled	
		SS	MSS	SS	MSS	SS	MSS
Treatments	18	2088.13	116.01	2925.71	162.54	2129.70	118.32
Replications	2	210.05	105.02	77.48	38.74	135.66	67.83
Error	36	49.12	1.36	43.37	1.20	18.55	0.52
Total	56	2347.30		3046.56		2283.91	
Interactions							
Replications	2	179.10	89.55	67.05	33.53	116.33	58.16
Strains (S)	4	251.84	62.96	865.44	216.36	314.80	78.70
Gibberellic acid (G)	2	1259.71	629.86	1049.99	524.99	1138.36	569.18
S x G	8	119.47	14.93	364.79	45.60	160.69	20.09
Error	28	38.73	1.38	41.27	1.47	13.94	0.50
Total	44	1848.84		2388.53		1744.13	

*Significant at 5% level of significance

ANOVA for Anthocyanin content (mg/100 ml)) [Table 88(a) & (b)]

Sources of variation	DF	2013		2014		Pooled	
		SS	MSS	SS	MSS	SS	MSS
Treatments	18	983.01	54.61	922.06	51.23	944.97	52.50
Replications	2	101.06	50.53	95.48	47.74	98.11	49.06
Error	36	36.08	1.00	29.88	0.83	17.97	0.50
Total	56	1120.15		1047.42		1061.05	
Interactions							
Replications	2	84.02	42.01	86.68	43.34	85.31	42.65
Strains (S)	4	182.29	45.57	144.84	36.21	162.81	40.70
Gibberellic acid (G)	2	223.39	111.70	234.08	117.04	228.44	114.22
S x G	8	144.21	18.03	153.90	19.24	147.01	18.38
Error	28	23.96	0.86	25.49	0.91	12.48	0.45
Total	44	657.86		644.99		636.05	

*Significant at 5% level of significance

ANALYSIS OF VARIANCE (ANOVA) FOR PHYSIOLOGICAL PARAMETERS
ANOVA for Chlorophyll content (mg/g) [Table 89(a) & (b)]

Sources of variation	DF	2013		2014		Pooled	
		SS	MSS	SS	MSS	SS	MSS
Treatments	18	2.08	0.12	1.35	0.07	1.65	0.09
Replications	2	0.03	0.02	0.11	0.06	0.07	0.03
Error	36	0.18	0.01	0.12	0.00	0.08	0.00
Total	56	2.29		1.58		1.80	
Interactions							
Replications	2	0.03	0.02	0.11	0.06	0.07	0.03
Strains (S)	4	0.27	0.07	0.29	0.07	0.27	0.07
Gibberellic acid (G)	2	0.42	0.21	0.34	0.17	0.38	0.19
S x G	8	0.21	0.03	0.09	0.01	0.13	0.02
Error	28	0.18	0.01	0.11	3.87E-03	0.07	2.65E-03
Total	44	1.11		0.95		0.92	

*Significant at 5% level of significance

ANOVA for Photosynthesis (µ mol/m^2/s) [Table 90(a) & (b)]

Sources of variation	DF	2013		2014		Pooled	
		SS	MSS	SS	MSS	SS	MSS
Treatments	18	76.13	4.23	89.85	4.99	81.97	4.55
Replications	2	5.33E-03	2.66E-03	0.12	0.06	0.03	0.02
Error	36	0.60	0.02	0.54	1.49E-02	0.43	1.18E-02
Total	56	76.74		90.51		82.43	
Interactions							
Replications	2	0.02	1.05E-02	0.12	0.06	0.05	0.02
Strains (S)	4	14.12	3.53	16.88	4.22	15.11	3.78
Methods of application (M)	2	36.61	18.31	43.05	21.52	39.76	19.88
S x M	8	3.41	0.43	4.48	0.56	3.46	0.43
Error	28	0.41	1.47E-02	0.45	0.02	0.31	1.10E-02
Total	44	54.57		64.98		58.69	

*Significant at 5% level of significance

ANOVA for Stomatal conductance (m mol/s) [Table 91(a) & (b)]

Sources of variation	DF	2013		2014		Pooled	
		SS	MSS	SS	MSS	SS	MSS
Treatments	18	0.19	1.08E-02	0.18	0.01	0.19	1.04E-02
Replications	2	9.51E-04	4.76E-04	0.05	0.02	0.02	7.88E-03
Error	36	1.46E-03	4.05E-05	1.37E-02	3.81E-04	2.86E-03	7.94E-05
Total	56	0.20		0.24		0.21	
Interactions							
Replications	2	8.22E-04	4.11E-04	0.046	0.023	0.015	0.007
Strains (S)	4	0.091	0.023	0.080	0.020	0.085	0.021
Methods of application (M)	2	0.037	0.018	0.032	0.016	0.034	0.017
S x M	8	0.022	0.003	0.021	0.003	0.022	0.003
Error	28	1.41E-03	5.02E-05	0.005	1.62E-04	5.55E-04	1.98E-05
Total	44	0.152		0.184		0.157	

*Significant at 5% level of significance

ANOVA for Stomatal resistance (S cm^{-1}) [Table 92(a) & (b)]

Sources of variation	DF	2013		2014		Pooled	
		SS	MSS	SS	MSS	SS	MSS
Treatments	18	0.144	257.502	2.154	0.120	2.211	0.123
Replications	2	2.43E-04	0.435	0.046	0.023	0.013	0.006
Error	36	5.60E-04		0.040	1.10E-03	0.014	3.94E-04
Total	56	0.144	257.502	2.239		2.238	
Interactions							
Replications	2	3.82E-04	1.91E-04	0.037	0.019	0.008	0.004
Strains (S)	4	0.334	0.084	0.436	0.109	0.302	0.075
Methods of application (M)	2	1.124	0.562	0.862	0.431	0.989	0.494
S x M	8	0.182	0.023	0.050	0.006	0.049	0.006
Error	28	0.013	4.74E-04	0.026	9.29E-04	0.010	3.68E-04
Total	44	1.654		1.412		1.358	

*Significant at 5% level of significance

ANOVA for Transpiration rate (S cm^{-1}) [Table 93(a) & (b)]

Sources of variation	DF	2013		2014		Pooled	
		SS	MSS	SS	MSS	SS	MSS
Treatments	18	177.85	9.88	161.67	8.98	167.76	9.32
Replications	2	10.34	5.17	1.00	0.50	1.31	0.66
Error	36	9.29	0.26	7.98	0.22	5.59	0.16
Total	56	197.47		170.65		174.67	
Interactions							
Replications	2	12.75	6.38	0.25	0.13	2.41	1.21
Strains (S)	4	35.25	8.81	34.92	8.73	34.22	8.56
Methods of application (M)	2	73.48	36.74	66.05	33.02	69.68	34.84
S x M	8	43.72	5.46	27.74	3.47	34.81	4.35
Error	28	6.86	0.25	6.93	0.25	4.09	0.15
Total	44	172.07		135.88		145.21	

*Significant at 5% level of significance

ANALYSIS OF VARIENCE (ANOVA) FOR LEAF NUTRIETN STATUS
ANOVA for Leaf nitrogen content (%) [Table 94(a) & (b)]

Sources of variation	DF	2013		2014		Pooled	
		SS	MSS	SS	MSS	SS	MSS
Treatments	18	1.82	0.10	1.42	0.08	1.51	0.08
Replications	2	6.99E-03	3.50E-03	0.02	1.01E-02	1.62E-03	8.08E-04
Error	36	0.17	4.73E-03	0.11	3.04E-03	0.08	2.26E-03
Total	56	1.99		1.55		1.60	
Interactions							
Replications	2	7.82E-03	3.91E-03	0.02	9.21E-03	2.35E-03	1.18E-03
Strains (S)	4	0.10	0.02	0.13	0.03	0.07	0.02
Methods of application (M)	2	0.95	0.48	0.63	0.31	0.78	0.39
S x M	8	0.21	0.03	0.03	4.02E-03	0.07	8.64E-03
Error	28	0.17	5.99E-03	0.11	3.87E-03	0.08	2.86E-03
Total	44	1.43		0.91		1.01	

*Significant at 5% level of significance

ANOVA for Leaf phosphorus content (%) [Table 95(a) & (b)]

Sources of variation	DF	2013		2014		Pooled	
		SS	MSS	SS	MSS	SS	MSS
Treatments	18	0.03	1.46E-03	0.03	1.40E-03	0.03	1.43E-03
Replications	2	7.12E-03	3.56E-03	1.46E-03	7.30E-04	3.74E-03	1.87E-03
Error	36	1.42E-02	3.96E-04	5.58E-03	1.55E-04	7.23E-03	2.01E-04
Total	56	0.05		0.03		0.04	
Interactions							
Replications	2	0.007	0.003	1.14E-03	5.68E-04	0.003	0.002
Strains (S)	4	0.006	0.002	0.006	1.45E-03	0.006	0.002
Methods of application (M)	2	0.007	0.004	0.008	0.004	0.008	0.004
S x M	8	5.54E-04	6.93E-05	5.57E-04	6.97E-05	5.34E-04	6.67E-05
Error	28	0.013	4.74E-04	0.005	1.77E-04	0.007	2.34E-04
Total	44	0.034		0.020		0.024	

*Significant at 5% level of significance

ANOVA for Leaf potassium content (%) [Table 96(a) & (b)]

Sources of variation	DF	2013		2014		Pooled	
		SS	MSS	SS	MSS	SS	MSS
Treatments	18	0.546	0.030	0.645	0.036	0.581	0.032
Replications	2	0.031	0.015	0.015	0.008	0.018	0.009
Error	36	0.152	0.004	0.165	0.005	0.078	0.002
Total	56	0.728		0.825		0.677	
Interactions							
Replications	2	0.028	0.014	0.004	0.002	0.010	0.005
Strains (S)	4	0.085	0.021	0.087	0.022	0.083	0.021
Methods of application (M)	2	0.136	0.068	0.183	0.092	0.158	0.079
S x M	8	0.029	0.004	0.016	0.002	0.015	0.002
Error	28	0.148	0.005	0.080	0.003	0.058	0.002
Total	44	0.426		0.369		0.324	

*Significant at 5% level of significance

ANOVA for Leaf calcium content (%) [Table 97(a) & (b)]

Sources of variation	DF	2013		2014		Pooled	
		SS	MSS	SS	MSS	SS	MSS
Treatments	18	0.259	0.014	0.244	0.014	0.250	0.014
Replications	2	0.083	0.041	0.032	0.016	0.053	0.027
Error	36	0.121	0.003	0.080	0.002	0.051	1.42E-03
Total	56	0.462		0.357		0.355	
Interactions							
Replications	2	0.068	0.034	0.023	0.012	0.043	0.021
Strains (S)	4	0.015	0.004	0.012	0.003	0.013	0.003
Methods of application (M)	2	0.044	0.022	0.050	0.025	0.047	0.023
S x M	8	0.002	0.000	0.003	4.24E-04	0.002	2.87E-04
Error	28	0.107	0.004	0.037	1.31E-03	0.029	1.04E-03
Total	44	0.237		0.124		0.134	

*Significant at 5% level of significance

ANOVA for Leaf magnesium content (%) [Table 98(a) & (b)]

Sources of variation	DF	2013		2014		Pooled	
		SS	MSS	SS	MSS	SS	MSS
Treatments	18	0.017	9.18.E-04	0.010	5.63E-04	0.012	6.84E-04
Replications	2	0.002	8.83.E-04	0.003	0.002	0.002	1.16E-03
Error	36	0.008	2.25.E-04	0.004	1.19E-04	0.003	8.08E-05
Total	56	0.026		0.018		0.018	
Interactions							
Replications	2	4.12E-04	2.06E-04	3.65E-03	1.82E-03	1.61E-03	8.05E-04
Strains (S)	4	9.66E-04	2.42E-04	2.87E-03	7.17E-04	1.60E-03	4.00E-04
Methods of application (M)	2	4.03E-03	2.02E-03	3.10E-03	1.55E-03	3.52E-03	1.76E-03
S x M	8	8.89E-04	1.11E-04	5.58E-04	6.97E-05	6.25E-04	7.81E-05
Error	28	5.65E-04	2.02E-05	3.76E-03	1.34E-04	1.23E-03	4.40E-05
Total	44	6.86E-03		1.39E-02		8.59E-03	

*Significant at 5% level of significance

ANOVA for Leaf zinc content (ppm) [Table 99(a) & (b)]

Sources of variation	DF	2013		2014		Pooled	
		SS	MSS	SS	MSS	SS	MSS
Treatments	18	125.17	6.95	112.39	6.24	116.81	6.49
Replications	2	44.99	22.50	26.19	13.10	34.67	17.34
Error	36	21.02	0.58	14.66	0.41	9.57	0.27
Total	56	191.17		153.24		161.05	
Interactions							
Replications	2	35.48	17.74	19.90	9.95	27.03	13.52
Strains (S)	4	6.03	1.51	5.96	1.49	5.29	1.32
Methods of application (M)	2	38.92	19.46	34.53	17.27	36.69	18.34
S x M	8	5.54	0.69	1.43	0.18	2.85	0.36
Error	28	19.53	0.70	12.23	0.44	8.66	0.31
Total	44	105.49		74.05		80.52	

*Significant at 5% level of significance

ANOVA for Leaf iron content (ppm) [Table 100(a) & (b)]

Sources of variation	DF	2013		2014		Pooled	
		SS	MSS	SS	MSS	SS	MSS
Treatments	18	9373.61	520.76	8431.78	468.43	8789.43	488.30
Replications	2	73.14	36.57	49.85	24.92	60.92	30.46
Error	36	16.10	0.45	22.56	0.63	12.24	0.34
Total	56	9462.86		8504.19		8862.58	
Interactions							
Replications	2	58.18	29.09	33.62	16.81	45.06	22.53
Strains (S)	4	312.46	78.12	506.47	126.62	377.45	94.36
Methods of application (M)	2	4212.87	2106.43	3361.62	1680.81	3763.95	1881.98
S x M	8	409.13	51.14	187.41	23.43	271.47	33.93
Error	28	14.37	0.51	18.08	0.65	10.63	0.38
Total	44	5007.02		4107.19		4468.56	

*Significant at 5% level of significance

ANOVA for Leaf manganese content (ppm) [Table 101(a) & (b)]

Sources of variation	DF	2013		2014		Pooled	
		SS	MSS	SS	MSS	SS	MSS
Treatments	18	4653.87	258.55	6391.90	355.11	5448.88	302.72
Replications	2	48.42	24.21	60.66	30.33	54.23	27.12
Error	36	15.95	0.44	14.79	0.41	7.90	0.22
Total	56	4718.24		6467.35		5511.01	
Interactions							
Replications	2	38.27	19.14	46.98	23.49	42.46	21.23
Strains (S)	4	512.54	128.14	868.71	217.18	669.17	167.29
Methods of application (M)	2	1799.90	899.95	2443.21	1221.60	2108.95	1054.48
S x M	8	400.01	50.00	468.59	58.57	408.89	51.11
Error	28	12.55	0.45	13.35	0.48	6.14	0.22
Total	44	2763.27		3840.84		3235.62	

*Significant at 5% level of significance

ANOVA for Leaf copper content (ppm) [Table 102(a) & (b)]

Sources of variation	DF	2013		2014		Pooled	
		SS	MSS	SS	MSS	SS	MSS
Treatments	18	14.68	0.82	15.66	0.87	14.09	0.78
Replications	2	0.31	0.15	0.21	0.10	0.23	0.12
Error	36	0.57	0.02	1.05	0.03	0.30	0.01
Total	56	15.56		16.92		14.62	
Interactions							
Replications	2	0.285	0.143	0.087	0.043	0.171	0.086
Strains (S)	4	0.131	0.033	2.710	0.677	0.796	0.199
Methods of application (M)	2	6.544	3.272	3.749	1.875	5.020	2.510
S x M	8	2.511	0.314	1.069	0.134	1.596	0.199
Error	28	0.192	0.007	0.061	0.002	0.073	0.003
Total	44	9.664		7.676		7.656	

*Significant at 5% level of significance

CURRICULUM VITAE

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Certificate/ degree	**Class/ grade**	**Board/ University**	**Year**
Metric	First	H.P. Board, Dharamshala	2001
10+2	First	H.P. Board, Dharamshala	2004
B.Sc. (Horticulture)	First	Dr. Yashwant Singh Parmar, University of Horticulture and Forestry, Nauni, Solan	2009
M. Sc. (Horticulture)	First	- Do-	2011

Whether sponsored by some state/ Central Govt./Univ./SAARC	:	No
Scholarship/ Stipend/ Fellowship, any other financial assistance received during the study period	:	University Merit Scholarship

(K. Seema)