

**INFLUENCE OF LIQUID PLANT GROWTH PROMOTING
RHIZOMICROBIAL CONSORTIA ON GROWTH, YIELD AND
QUALITY OF STRAWBERRY (*Fragaria × ananassa* Duch.)
UNDER NATURALLY VENTILATED POLYHOUSE**

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SHIVAMOGGA
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Thesis submitted to the

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**DEPARTMENT OF FRUIT SCIENCE
COLLEGE OF HORTICULTURE, MUDIGERE
UNIVERSITY OF AGRICULTURAL AND HORTICULTURAL SCIENCES
SHIVAMOGGA**

CERTIFICATE

This is to certify that the thesis entitled '**INFLUENCE OF LIQUID PLANT GROWTH PROMOTING RHIZOMICROBIAL CONSORTIA ON GROWTH, YIELD AND QUALITY OF STRAWBERRY (*Fragaria x ananassa* Duch.) UNDER NATURALLY VENTILATED POLYHOUSE**' submitted in partial fulfillment of the requirements for the award of the degree of **MASTER OF SCIENCE (HORTICULTURE) in FRUIT SCIENCE** to the College of Horticulture, Mudigere, University of Agricultural and Horticultural Sciences, Shivamogga is a bonafide record of research work carried out by **Ms. NISARGA, G., ID. NO. MH2TAF0116** (nisargablrl@gmail.com) during the period of study in this university under my guidance and supervision and no part of this thesis has previously formed the basis for the award of any other degree, diploma, associateship, fellowship or any other similar titles.

**Mudigere
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(NISARGA, G.)

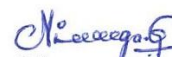
Influence of liquid plant growth promoting rhizomicrobial consortia on growth, yield and quality of strawberry (*Fragaria* × *ananassa* Duch.) under naturally ventilated polyhouse

(NISARGA, G.)

ABSTRACT

An experiment was conducted to study the influence of liquid plant growth promoting rhizomicrobial consortia on growth, yield and quality of strawberry (*Fragaria* × *ananassa* Duch.) under naturally ventilated polyhouse at the Department of Fruit Science, College of Horticulture, Mudigere during 2017-18. The experiment was laid out in Completely Randomized Design with eleven treatment replicated thrice. Significant differences were observed among treatments tested for different parameters. The maximum plant height (34.00 cm), number of trifoliate leaves (34.03), plant spread for North-South and East-West directions (44.67 and 43.33 cm respectively), number of crowns (4.93 plant⁻¹), leaf area (140.17 cm²) leaf area index (1.46), total dry weight (33.63 g plant⁻¹) and total chlorophyll content (2.36 mg g⁻¹ of fresh weight) was recorded in the treatment 75 % RDF through fertigation (112.5:75:90 kg ha⁻¹) + *Azotobacter* + PSB + KSB at 250 ml acre⁻¹. Among the yield parameters, minimum number of days taken for berry maturity (25.00 days), highest number of berries per plant (21.00), berry weight (20.90 g), fruit volume (21.67 cc), fruit length (4.78 cm) fruit diameter (3.90 cm) and high yield of 387.67 g plant⁻¹ was found higher in the above treatment. Among fruit quality parameters maximum ascorbic acid content (68.83 mg/100 g), minimum titratable acidity (0.68 %) and sugars to acid ratio (12.00), total sugar content (8.20 %) and higher benefit cost ratio (2.90) was also noticed in the same treatment. Based on the results the plants supplied with 75% RDF through fertigation along with *Azotobacter*, PSB and KSB in liquid form showed promising results with respect to growth, yield and quality parameters.

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ನೈಸರ್ಗಿಕ ಹಸಿರು ಮನೆಯಲ್ಲಿ ಸ್ವಾಭಾವಿಕ (ಪ್ರಗೇರಿಯ × ಅನಾನಸ ಡಚ್.) ಬೆಳವಣಿಗೆ, ಇಳುವರಿ ಹಾಗೂ ಗುಣಮಟ್ಟದ ಮೇಲೆ ದ್ರವ ರೂಪದ ಸಸ್ಯ ಬೆಳವಣಿಗೆ ಪ್ರಚೋದಕ ರೈಜೋಬಿಯಂ ಸೂಕ್ಷ್ಮಜೀವಿ ಸಮೂಹದ ಪ್ರಭಾವ

(ನಿಸರ್ಗ, ಜೆ.)

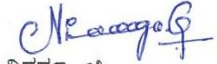
ಸಾರಾಂಶ

ತೋಟಗಾರಿಕೆ ಮಹಾವಿದ್ಯಾಲಯ, ಮೂಡಿಗೆರೆಯ ಹಣ್ಣು ವಿಜ್ಞಾನ ವಿಭಾಗದ ನೈಸರ್ಗಿಕ ಹಸಿರು ಮನೆಯ ೨೦೧೭-೧೮ರ ಅವಧಿಯಲ್ಲಿ ಸ್ವಾಭಾವಿಕ ಬೆಳವಣಿಗೆ, ಇಳುವರಿ ಹಾಗೂ ಗುಣಮಟ್ಟದ ಮೇಲೆ ದ್ರವ ರೂಪದ ಸಸ್ಯ ಬೆಳವಣಿಗೆ ಪ್ರಚೋದಕ ರೈಜೋಬಿಯಂ ಸೂಕ್ಷ್ಮಜೀವಿ ಸಮೂಹದ ಪ್ರಭಾವವನ್ನು ಕುರಿತು ಅಧ್ಯಯನವನ್ನು ನಡೆಸಲಾಯಿತು. ಈ ಪ್ರಯೋಗವನ್ನು ಯಾದೃಚ್ಛಿಕ ವಿನ್ಯಾಸದಲ್ಲಿ ಮೂರು ಪ್ರಕೃತಿಗಳಲ್ಲಿ ಹನ್ನೊಂದು ಉಪಚಾರಗಳೊಂದಿಗೆ ಹೊಂದಿಸಲಾಗಿದೆ. ಈ ಅಧ್ಯಯನದ ಪ್ರಕಾರ ರಸಾವರಿಯ ಮೂಲಕ ಶಿಫಾರಸ್ಸು ಮಾಡಿದ ೭೫ % ನಿಗದಿತ ಗೊಬ್ಬರದ ಪ್ರಮಾಣದ (೧೧೨.೫:೭೫:೯೦ ಕೆ.ಜಿ. ಸಾ.ರಂ.ಪೋ/ಹೆ) ಜೊತೆಗೆ ಅಜಟೋಬ್ಯಾಕ್ಟರ್, ರಂಜಕ ಕರಗಿಸುವ ಬ್ಯಾಕ್ಟೀರಿಯಾ ಮತ್ತು ಪೊಟ್ಯಾಶಿಯಂ ಕರಗಿಸುವ ಬ್ಯಾಕ್ಟೀರಿಯಾವನ್ನು (೨೫೦ ಮಿ.ಲೀ/ಎಕರೆ) ಉಪಚರಿಸಲ್ಪಟ್ಟ ಗಿಡಗಳು ಉತ್ತಮ ಫಲಿತಾಂಶಗಳನ್ನು ನೀಡಿವೆ. ಅತ್ಯಧಿಕ ಸಸ್ಯದ 'ಎತ್ತರ (೩೪.೦೦ ಸೆಂ. ಮೀ), ಎಲೆಗಳ ಸಂಖ್ಯೆ (೩೪.೦೩), ಸಸ್ಯ ಹರಡುವಿಕೆಯ ವಿಸ್ತಾರ ಉತ್ತರ-ದಕ್ಷಿಣ ಮತ್ತು ಪೂರ್ವ - ಪಶ್ಚಿಮ ಕ್ರಮವಾಗಿ (೪೪.೬೭ ಮತ್ತು ೪೩. ೩೩ ಸೆಂ.ಮೀ.), ಚಿಗುರುಗಳ ಸಂಖ್ಯೆ (೪.೯೩/ಸಸ್ಯ), ಎಲೆಯ ವಿಸ್ತೀರ್ಣ (೧೪೦.೧೭ ಸೆಂ. ಮೀ.), ಎಲೆಯ ವಿಸ್ತೀರ್ಣ ಸೂಚಕ (೧.೪೬), ಒಟ್ಟು ಒಣ ತೂಕ (೩೩.೬೩ ಗ್ರಾಂ), ಪತ್ರಹರಿತ್ತು ಪ್ರಮಾಣ (೨.೩೬ ಮಿ. ಗ್ರಾಂ. /೧೦೦ ಗ್ರಾಂ) ಹಾಗೂ ಹೂವು ಬಿಡಲು ಕನಿಷ್ಠ ದಿನಗಳನ್ನು (೨೫.೦೦) ತೆಗೆದುಕೊಂಡಿದ್ದು ಪ್ರತಿ ಸಸ್ಯಕ್ಕೆ ಅತಿ ಹೆಚ್ಚು ಹಣ್ಣುಗಳು (೨೧.೦೦), ಹಣ್ಣಿನತೂಕ (೨೦.೯೦ ಗ್ರಾಂ.) ಮತ್ತು ಹಣ್ಣಿನ ಪರಿಮಾಣ (೨೧.೬೭ ಸಿ.ಸಿ), ಹಣ್ಣಿನ ಉದ್ದ (೪.೭೮ ಸೆಂ.ಮೀ.) ಮತ್ತು ಹಣ್ಣಿನ ವ್ಯಾಸ (೩.೯೦ ಸೆಂ. ಮೀ.) ಹೊಂದಿದ್ದು, ಒಂದು ಗಿಡಕ್ಕೆ ಹೆಚ್ಚಿನ ಇಳುವರಿ (೩೮೭.೬೭ ಗ್ರಾಂ.) ಹಾಗೂ ರಾಸಾಯನಿಕ ಗುಣಗಳಲ್ಲಿ ಅತಿ ಹೆಚ್ಚು ಅಸೋರ್ಬಿಕ್ ಆಮ್ಲ (೬೮.೮೩ %), ಟ್ರೈಟೀಕರಣ ಆಮ್ಲ (೦.೬೮ %), ಸಕ್ಕರೆ ಆಮ್ಲ ಅನುಪಾತ (೧೨.೦೦), ಒಟ್ಟು ಸಕ್ಕರೆಯ ಪ್ರಮಾಣ (೮.೨೦ %) ಮತ್ತು ಹೆಚ್ಚಿನ ಆದಾಯ ಖರ್ಚು ಅನುಪಾತ (೨.೯೦) ರಸಾವರಿಯ ಮುಖಾಂತರ ಮಾಡಿದ ಶಿಫಾರಸ್ಸು ಮಾಡಿದ ೭೫ % ನಿಗದಿತ ಗೊಬ್ಬರದ ಪ್ರಮಾಣ ಮತ್ತು ಅಜಟೋಬ್ಯಾಕ್ಟರ್ + ರಂಜಕ ಕರಗಿಸುವ ಬ್ಯಾಕ್ಟೀರಿಯಾ + ಪೊಟ್ಯಾಶಿಯಂ ಕರಗಿಸುವ ಬ್ಯಾಕ್ಟೀರಿಯಾ ಒದಗಿಸಿದ ಗಿಡಗಳಲ್ಲಿ ದಾಖಲಾಗಿದೆ.

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Introduction

I INTRODUCTION

Strawberry (*Fragaria* × *ananassa* Duch.) of Rosaceae family is one of the most delicious and refreshing soft fruits of the world and all the cultivated varieties are octaploid ($2n=56$). The cultivated strawberry (*Fragaria* × *ananassa*), is a hybrid of two native American species; *Fragaria chiloensis* and *Fragaria virginiana*, was first developed in France during the seventeenth century. The fruits are widely acclaimed for pleasant flavour, conspicuous colour and varied blend of taste. The crop is mainly grown in the temperate climate, but now it is being successfully grown under subtropical and tropical climate. Owing to its medicinal properties (anticarcinogenic, antidiabetic and antioxidant), it is gaining popularity among all age group of consumers (Asery Ram and Patel, 2003). The berries are highly perishable and generally used for making jam, juices and other quality products beside table consumption. The crop has gained the status of being one of the most important soft fruit of the world after grape. Among the fruits, it gives quickest returns in shortest possible time.

Strawberry plant is a short statured perennial herb in which the stem is compressed into a resettled crown. The crown produces trifoliate leaves at the close interval along stem axis but single leaf before the emergence of the flower. In general, the inflorescence is white in colour form terminally and the vegetative growth is continued by an uppermost axillary bud of the crown. Botanically, strawberry is an aggregate fruit (Etaerio of achenes) and propagated through runners as well as tissue culture plants which offer quicker returns on capital investment. One cup of strawberries weighs approximately 144 gram which contains 45-50 calories. Strawberries contain over 90 per cent water, 7 per cent of carbohydrates, 2 per cent fibre, less than 1 per cent each of protein and fat. The fresh ripe fruit of strawberry is a rich source of vitamins and minerals. The fruit has a fairly good source of vitamin A (60 IU/100gm), vitamin C (30-120 mg/100gm), pectin (0.55 %), iron (beneficial to anaemic patients), potassium, calcium and phosphorous and also possess anticancer compound called ellagic acid (Wange and Kzlogoz, 1998). Fruit also contain total soluble solids (7-12 %), total sugars (5.0 %) and acids (0.90-1.85 %).

In India, strawberry was first introduced at Regional Research Station, Shimla by National Bureau for Plant Genetic Resources. At present, strawberries are being grown in Shimla, Bilaspur, Kangra, Kullu, Palampur (Himachal Pradesh), Dehradun, Nainital, Srinagar parts of West Bengal and extended to Pune and Mahabaleshwar (Maharashtra), Bengaluru and Coorg (Karnataka) mainly cultivated as winter season crop from November to March. In India, Maharashtra is leading in strawberry production.

Strawberry can be cultivated in almost all regions *i.e.* from arctic to tropic regions (Hancock, 1999). Being a non-climacteric crop, fruits mature only on the plant (Cordenunsi *et al.*, 2005) and based on bearing seasons it is grouped into three categories as to June bearing, ever-bearing and day-neutral strawberries.

Selecting a good site with suitable soil is the first important step in the successful growing of any crop. Strawberry being a surface feeder requires optimum moisture and temperature conditions in the upper layer of the soil. These conditions have great influence on sustainable growth and development of the crop. The crop adopts itself on a variety of soils ranging from heavy clay to gravel soil, but prefers light porous soils, that are rich in humus as its roots are mostly confined to the top 15-30 cm layers of soil. In light soils, frequent irrigation is required for proper establishment of the runners and also to maintain good berry size and fruit quality. It prefers slightly acidic soils with a p^H range of 5.8-6.5. Flowering in strawberry is strongly influenced by photoperiod, temperature and interaction of both. In the subtropical region, flowering occurs in short light period (10 hours) with a long dark period (14 hours). An optimum growing temperature of 15°C is mostly for most of the cultivars and species, though it grows well at a temperature ranges between 20°C and 26°C.

A profitable crop production is based entirely on balanced plant nutrition under suitable agro ecological condition. Hence, there is need to develop a suitable method of application of fertilizer, which will improve quality and quantity of crop production. Fertigation is the application of water soluble solid or liquid fertilizer formulations through drip irrigation system and very effective method of fertilization in modern intensive agriculture systems. Fertigation also gives advantages such as minimum losses of nitrogen due to leaching, control of nutrient concentration in soil solution and saving in application cost. Thus, fertigation becomes prerogative for increasing the yield of the crops under drip irrigation.

In recent years, the use of chemical fertilizers has increased tremendously as it is an essential part of the crop production for getting higher yields. However, chemical fertilizers are not eco-friendly and their prices are also high. More than 50 per cent of chemical fertilizers used goes waste and pollutes the environment causing health hazards and affects the soil health. There is need to seek alternative nutrient sources that are cheap and eco-friendly so that farmers can reduce the investment made on fertilizers leading to ecologically sustainable farming. In this regard, the use of microbial consortia (*Azotobacter*, phosphorous solubilising bacteria and potassium solubilising bacteria) has a better perspective since they are cheaper and eco-friendly. Microbial consortia is nothing but biofertilizers containing carrier based micro-organisms which helps to enhance the productivity through biological nitrogen

fixation or solubilization of insoluble phosphate and mobilising potassium and makes it available for plants. They also help in the production of hormones, vitamins and other growth factors required for plant growth (Pindi and Satyanarayana, 2012). Microbial consortia are useful in increasing yield, quality and production of a crop when they are used in combination with organic and inorganic fertilizers in a balanced proportion.

Liquid microbial consortia are the microbial preparations containing specific beneficial microorganisms which are capable of fixing or solubilizing or mobilizing plant nutrients by their biological activity (Sharma *et al.*, 2010). It facilitates the long survival of the organism than carrier based biofertilizers by providing suitable medium which is sufficient for the entire crop cycle. Carrier based biofertilizers (CBBF) are not so tolerant to temperature which is mostly unpredictable and uncertain in the crop fields while temperature tolerance is the other advantage of the liquid biofertilizers. The contamination can be controlled constructively by means of proper sterilization techniques and maintenance of intensive hygiene conditions by appropriate quality control measures in the case of liquid microbial consortia. However, the administration of liquid microbial consortia in the fields is comparatively easier than CBBF. The other disadvantages of CBBF like poor cell protection, labour intensity, dosage controversy, expensive package and very slow adaptation by the farming community are some of the strongest problems which are being solved by the liquid biofertilizers very effectively. Therefore, liquid microbial consortium are believed to be the best alternative for the conventional carrier based biofertilizers in the modern agriculture research community witnessing the enhanced crop yields, regaining soil health and sustainable global food production (Mahdi *et al.*, 2010).

Azotobacter is a free living bacteria capable of performing several metabolic activities, including atmospheric nitrogen fixation by conversion to ammonia and serves as potential biofertilizer for all non-leguminous plants. Similarly, phosphate solubilising bacteria have the ability to solubilize chemically fixed soil phosphorus and rock phosphate. They can also mineralize organic phosphorous compounds present in the organic manures and soil (Rodrigues and Fraga, 1999). Potash solubilizing bacteria has the ability to solubilize the potassium which can be easily absorbed by plants. It offers to the plant multifaceted benefits in terms of growth by mobilizing potash and making it available to crops. Thereby, it also enhances the efficiency of chemical fertilizer (Patel, 2011).

Many sources of organic options are available for sustainance of yield but obtaining high yields is a hard reality from the sole application of organic manures or biological products. Therefore, a judicious combined application of inorganic and

organic fertilizers or bio-fertilizers may be helpful in enhancing the fruit production of strawberry. Such efforts shall be helpful to maintain sustainable productivity and soil health. Among various available organic options, microbial consortia have the ability to mobilize the nutritionally important elements and are cost-effective and renewable.

Considering the importance of the nutritional aspect of strawberry, the present study entitled “Influence of liquid plant growth promoting rhizomicrobial consortia on growth, yield and quality of strawberry (*Fragaria* × *ananassa* Duch.) under naturally ventilated polyhouse” was taken up to find out the best combination of different microbial consortia for better growth and higher yield with the following objectives.

1. To study the effect of liquid plant growth promoting rhizomicrobial consortia on growth and yield of strawberry.
2. To know the effect of liquid plant growth promoting rhizomicrobial consortia on fruit quality of strawberry.
3. To work out the cost benefit ratio of strawberry as influenced by liquid plant growth promoting rhizomicrobial consortia.

Review of Literature

II REVIEW OF LITERATURE

Strawberry is one of the most important commercial fruit crop grown in temperate regions of the world for its delicate aroma and flavour. Among the various factors which contribute towards the growth and yield of strawberry, nutrition is the important aspect of crop production. A judicious combination of inorganic and organic fertilizers like microbial consortia may be helpful in increasing the fruit production in strawberry and also increase net returns per unit area as it markedly increases the yield. Microbial consortia are agriculturally important beneficial microorganisms which have the ability to mobilize nutritionally important elements and also release phytohormones especially auxins, gibberellins, cytokinins and antibiotic metabolites which in turn improved resistance against biotic and abiotic stress (Awasthi *et al.*, 1998).

In the present context, an attempt has been made in this chapter to review the available relevant literature related to the study and reviewed under the following headings.

2.1 Effect of fertigation and liquid plant growth promoting rhizomicrobial consortia on growth and yield.

2.1.1 Effect of fertigation on growth and yield.

Graneli *et al.* (1994) applied 200 kg N + 83 kg P + 216 kg K ha⁻¹ as soil application and 133 kg N + 55 kg P + 144 kg K ha⁻¹ through fertigation in kiwifruit cv. Hayward. They obtained higher fruit yield at higher fertilizer rate with fertigation than with the soil application.

Bachchhav (1995) reported that fertigation with soluble fertilizer treatment increased the yield level per vine by 25.60 per cent compared to the soil application in grapes.

Raghupathi *et al.* (2002) investigated on the effect of N and K fertigation at different rates viz., 50, 100, 150 and 200 g plant⁻¹. The results of their studies revealed that fertigation at 200 g plant⁻¹ N and K gave maximum yield in Banana.

Alva *et al.* (2003) studied the effect of nitrogen and irrigation management practices of citrus in 27 orchard and they found that fruit yield of Valencia orange trees on Rough lemon rootstock was greater with application of 180 kg N/ha/year as fertigation compared to the trees which received a similar rate of N as three broadcast applications of granular product.

Thakur and Singh (2004) recorded highest number of fruits and total yield per plant with the application of 75 per cent of recommended dose of N, P and K through fertigation in mango cv. Amrapali.

Martinsson *et al.* (2006) reported the impact of fertilizer application on yield and quality of strawberries and they found that fertigation with full nutrient package increased yield ($186.60 \text{ g plant}^{-1}$) as compared to common practice ($113.80 \text{ g plant}^{-1}$).

Chauhan and Chandel (2008) studied the effect of fertigation on growth, yield, fruit quality and fertilizer use efficiency of kiwi fruit recorded significantly higher vine growth in fertigated treatment as compared to soil fertilization. The maximum shoot growth (155.24 and 168.50 cm) and trunk girth (2.26 and 2.31 cm) was recorded in fertigation with recommended dose of NPK fertilizers respectively.

Singh *et al.* (2009) studied the response of fertigation and plastic mulch on growth characteristic of young Dashehari mango and recorded significantly higher leaf area (80.00 cm^2) under drip irrigation at 0.8 'V' level with mulch +100 per cent dose of fertilizers through fertigation and lowest (56.16 cm^2) under surface irrigation at 'V' level +75 per cent dose of fertilizers.

Dhakar *et al.* (2010) conducted an experiment on one year old pomegranate plants comprising four fertigation levels (75%, 100%, 125% and 150% recommended dose of fertilizers). Fertigation level at 100 per cent recommended dose of fertilizers at alternate day showed significantly higher vegetative growth and physico-chemical characteristics. The maximum yield ($14.89 \text{ kg plant}^{-1}$) recorded in treatment with 100 per cent of recommended dose through fertigation.

Jeyakumar *et al.* (2010) noticed significant increase in number of fruits (94.73) under fertigation in comparison to soil application of fertilizers (76.40) in papaya.

Jhakar (2010) observed significant effect of 100 per cent recommended dose of fertilizers through fertigation on relative growth rate of shoots, plant spread and height in pomegranate.

Increase in fruit length, fruit diameter, fruit weight and TSS of Papaya under fertigation at 100 per cent recommended dose of N and K through drip irrigation was recorded by Sadarunnisa *et al.* (2010).

Banyal and Sharma (2011) studied the effect of fertigation and rootstocks on yield and quality of apple under high density plantation and recorded maximum fruit yield (12.19 and $12.62 \text{ kg plant}^{-1}$) with full dose of N, P and K through drip and minimum (11.11 and $10.47 \text{ kg plant}^{-1}$) fruit yield with full dose of N, P and K as soil fertilization

Raina *et al.* (2011), studied on drip fertigation in apricot and found that drip fertigation significantly influenced the fruit yield. Fertigation with 100 and 75 per cent recommended dose of conventional fertilizer on an average increased the fruit yield by 16.40 and 13.70 per cent over soil fertilization.

Ramniwas *et al.* (2012) observed the effect of irrigation and fertigation scheduling on growth and yield of guava under meadow orcharding and recorded significantly higher fruit weight (182.17 g) in fertigated treatment.

2.1.2 Effect of liquid plant growth promoting rhizomicrobial consortia on growth and yield.

Jeeva *et al.* (1988) obtained *Azospirillum* inoculation plus the highest N rate (100 %) enhanced the height and girth of the pseudostem, leaf production and leaf area, and increased bunch weight by 8.2 per cent compared with the non inoculated control receiving 100 per cent nitrogen in banana cv. Poovan.

Dibut-Alvarez *et al.* (1996) also observed in banana the treatments combining 80 per cent N with bacterial (*A.chroococcum*) inoculation showed no significant differences when compared with the controls (100% N) for the growth variables measured. Most yield components were also increased with bacterial inoculation at each level of N. Bacterial inoculation favoured fruit development, increasing the fruit/rachis ratio, particularly when N-fertilizer was kept between 80 and 100 per cent. They concluded that bacterial inoculation could compensate for 20 percent of the N-fertilizer without changing the yield corresponding to 30 g N/plantlet.

Wang (1996) reported that application of *Azospirillum* with 150 kg N/ha increased the yield by 54 per cent as compared with the application of 150 kg N alone in strawberry cv. Seascape.

Balakrishnan *et al.* (2001) studied the effect of three different biofertilizers (*Azotobacter*, VAM and *Azospirillum*) on fruit yield, fruit weight and pulp weight of custard apple. One hundred and fifty grams of biofertilizers was mixed with 10 kg sieved FYM per tree. *Azospirillum* inoculated plant gave maximum fruit yield 13.1 kg per tree, fruit weight 165.2 g, pulp weight 102.6 g. *Azotobacter* inoculated plant gave 12.5 kg per tree fruit yield, 160.3 g fruit weight, 95.1 g pulp weight.

Ahmad *et al.* (2003) studied the effects of N fertilizer and *Azotobacter chroococcum* on the performance of mango cv. Amrapali. Two strains of *A. chroococcum* (M-4 and CBD-15) were applied at 15 g per plant in combination with various levels of N fertilizer (standard rate of 145 g per tree, 96 g per tree, and 48 g per tree). Treatment with 145 g N per plant and *A. chroococcum* CBD-15 given greatest increase in shoot length (25.52 %), fruit weight (136.13 g). The highest yield was recorded with the application of 145 g N and 96 g N per plant with *A. chroococcum* CBD-15 i.e. 23.89 and 23.74 kg per plant respectively. The results suggested that 96 g N per plant in combination with *A. chroococcum* CBD-15 was optimum for the improvement of the yield of mango under high density planting.

El Moniem and Radwan (2003) reported that the standard treatment (100 % NPK) increased the length and diameter of pseudostem, number of green leaves per plant and leaf area in William banana. The plants receiving 25 or 50 per cent NPK plus biofertilizer (containing phosphate solubilizing bacteria, *Azotobacter* spp., *Azospirillum* spp. and *Pseudomonas* spp.) showed a slight increase in the vegetative growth parameters. However, 75 per cent NPK plus biofertilizer was superior to the other treatments. Application of 75 per cent NPK plus biofertilizer significantly increased the leaf macronutrient contents compared with either 25 or 50 per cent NPK plus biofertilizer or the recommended dose of NPK alone. Williams banana plants receiving biofertilizers showed an increase in length and weight of bunch, number of fingers per bunch and number of hands per bunch. The yield and yield components increased by increasing the NPK levels from 25 to 100 per cent. The yield significantly increased as a result of receiving 75 per cent NPK plus biofertilizer compared with the other treatments.

El-Shah *et al.* (2003) revealed that application of 150-105-144 kg NPK fed-1 (75% of the recommended NPK level) combined with Halex-2 biofertilizer was appeared to be the most economical and efficient treatment combination, with a balanced vegetative growth (leaf area, number of crowns, and fresh and dry masses plant⁻¹) and a higher yield potential (early yield plant⁻¹ and per m², marketable yield/m², non-marketable yield/m², total yield plant⁻¹, and per m² and average fruit weight) with a good fruit quality in strawberry.

Rana and Chandel (2003) recorded maximum plant height (25.48 cm), number of leaves per plant (29.00), leaf area (102.50 cm²), number of runners per plant (21.09), fruit yield (79.19 q ha⁻¹), fruit size (length- 37.32 cm and breadth- 23.65 cm) and fruit weight (10.02 g) when the plants were inoculated with *Azotobacter* along with 60 kg N ha⁻¹ in strawberry.

Gogoi *et al.* (2004) reported that in banana cv. Barjahaji (Musa AAA, Cavendish subgroup). 50% RD of N + 100% RD of P and K + *Azospirillum* + PSB, followed by 50% RD of N + 100% RD of P and K + *Azotobacter* + PSB, recorded the highest values for all yield parameters studied, i.e. number of hands per bunch, number of fingers per hand, weight of second hand, bunch weight, yield and harvest index.

Patel *et al.* (2005) conducted an experiment on mango cv. Amrapali using FYM at 50 and 100kg/plant, Vermicompost at 165 and 33 kg/ plant, *Azotobacter*, *Azospirillum*, Mixed strain of Arbuscular Mycorrhizal fungi and phosphate solubilising bacteria (PSB). All the biofertilizers were applied at 10 g/plant, while the Arbuscular Mycorrhizal fungi at 20 g/plant. The highest number of fruits (195.2), fruit weight (170.5 g/fruit), total soluble solids (20.18 %) and ascorbic acid 36 mg / 100 g

were recorded with FYM (50 kg) + vermicompost (16.5 kg) + *Azotobacter* (10 gm) and Phosphate solubilizing bacteria 10 g plant⁻¹

Esitken *et al.* (2006) recorded maximum shoot length (19.05 cm), maximum yield per trunk cross-sectional area (0.112 kg/ cm²) and fruit weight (7.35 g) in sweet cherry plants which were applied with the combination of plant growth promoting rhizobacteria *Pseudomonas* BA-8 + *Bacillus* OSU-142.

Nazir *et al.* (2006) noticed that the treatment combination of poultry manure + *Azotobacter* + wood ash + phosphate solubilizing bacteria + oil cake recorded maximum plant height (23.39 cm), plant spread (24.21 cm) number of runners per plant (13.03) and early blooming (10.33 days) highest fruit yield (238.95 g/plant) in strawberry cv. Senga sengana.

Orhan *et al.* (2006) observed that the inoculation of plant roots and rhizosphere with two *Bacillus* strains OSU-142 + M3 significantly increased yield (724.4 g / plant), cane length (136.1 cm), cane diameter (11.95 mm), number of cluster per cane (15.7) and number of berries per cane (10.51) compared to the control in raspberry.

Marathe and Bharambe (2007) reported that maximum fruit yield coupled with an adequate tree volume of sweet orange is attainable through combined use of organic plus inorganic or biofertilizers like *Azotobacter* and PSB biofertilizers.

Ram and Pathak (2007) reported maximum number of fruits and yield (92 & 13.69 kg tree⁻¹ and 283 & 40.11 kg tree⁻¹) were consistently recorded for 2 years from the trees applied with 20 kg FYM inoculated with *Azotobacter* in comparison to 21.37 kg tree⁻¹ fruit with recommended doses of fertilizer application in guava.

Kumar (2008) reported that treatment having *Azotobacter* (250 g tree⁻¹) with half of the recommended dose of chemical fertilizer and 50 kg of FYM proved to be the most dynamic substrate to record maximum fruit yield (96.66 kg tree⁻¹) categorizing maximum percentage of quality fruits under superior grade *i.e.* extra class (42.75 %). This treatment also recorded better canopy spread, fruit weight and bearing (fruits/panicle) of heavier fruits though found at par with control *i.e.* the treatment having only chemical fertilizer which recorded fruit yield of 94.50 kg tree⁻¹ categorizing less percentage of quality fruits under superior grade *i.e.* extra class (32.10 %) suggesting a possibility of reducing N, P and K fertilizer dose to the tune of 50 per cent and making quality litchi production economically more viable. Physicochemical characteristics as recorded in different treatments showed higher values in the substrate having biofertilizer in particular.

Zargar *et al.* (2008) reported that combined application of nitrogen (225 kg / ha), phosphorus (150 kg/ha) and biofertilizer (*Azotobacter*) showed highest

plant height (40.66 cm). The flowering parameters like number of primary flowers (8.0), number of secondary flowers (10.00) and total number of flowers per plant (18.00) were maximum in the treatment combination of nitrogen (225 kg / ha), phosphorus (150 kg / ha) and biofertilizer (PSB) in strawberry.

Gunes *et al.* (2009) noticed that the yield increased with P addition reaching a maximum of 94 g/plant at 200 kg P/ha in the absence of P solubilizing microorganisms. At this yield level, *Bacillus* FS-3 and *Aspergillus* FS-9 inoculation resulted in P fertilizer savings of 149 kg P / ha and 102 kg P / ha respectively and yield increased from 94 to 161 g / plant in strawberry.

Singh and Singh (2009) noticed the maximum growth in terms of plant height (27.63 cm), total biomass (42.02 g / plant) and chlorophyll content (2.63 mg / 100g) in the treatment consisting of *Azotobacter* + *Azospirillum* + 50 per cent N of the recommended dose + 100 ppm GA₃. Maximum fruit set (84.28 %), fruit length (45.36 mm), fruit weight (16.75 g), yield (94.26 q / ha). Maximum number of leaves (26.92), leaf area (123.29 cm²) and number of crowns per plant (5.87) were recorded with the application of *Azotobacter* + *Azospirillum* + 75 per cent N of the recommended dose + 100 ppm BA in strawberry cv. Sweet Charlie.

Umar *et al.* (2009) reported that maximum plant height (21.24 cm), plant spread (28.16 cm), and leaf area (74.95 cm²), maximum fruit size (37.62 × 28.01 mm), fruit weight (15.87 g), in the fruits obtained from the plants supplied with 25 per cent nitrogen through FYM + 75 per cent nitrogen through urea + *Azotobacter*. Maximum yield (372.89 g / plant) was obtained with the application of cent per cent nitrogen in the form of urea along with *Azotobacter* in strawberry cv. Chandler.

Esitken *et al.* (2010) recorded the highest number of fruits per plant (91.73) and fruit yield (642.1 g / plant) in the treatment combination of bacterial strains *Bacillus* M3 + *Pseudomonas* BA-8. Highest vitamin C content (71.58 mg / 100 g) was recorded in control.

Yadav *et al.* (2010) revealed that, the fruit characteristics like number of berries (22.27 / plant) and fruit yield (101.99 q / ha) the growth parameters like number of crown (4.33 / plant), number of runners (11.33 / plant), length of runners (45.67 cm) and number of flowers (29.60 / plant) recorded maximum in *Azotobacter* inoculated treatment with 50 per cent N substitution by vermicompost and remaining 50 per cent through inorganic fertilizer in strawberry.

Mishra and Tripathi (2011) showed that combined application of *Azotobacter* and PSB (each at 6 kg / ha) significantly increased the height of plant (19.29 cm), number of leaves (64.31), crowns (7.17), runners (5.26), number of flowers (67.27) and fruits set (37.88) per plant in strawberry. Maximum duration of harvesting (70.90 days) and minimum number of days taken to produce first flower (56.69 days)

and fruit set (6.12 days) with significantly more yield (322.17 g / plant) were also observed in *Azotobacter* and PSB (each at 6 kg / ha) fertilized plants. So far as the quality characters of berries are concerned, plants fertilized with *Azotobacter* and PSB (each at 6 Kg/ha) also produced berries with maximum length (4.63 cm), width (2.64 cm), weight (8.48 g) and volume (6.14 cc).

Varsha *et al.* (2011) revealed that, the fruit yield in terms of fruits harvested per plant (205.00) and fruit yield (39.45 kg / plant) were found to be maximum in the plants which were treated with 487.5 + 243.75 + 281.25 g NPK + 50 kg FYM + 250 g *Azotobacter* + 250 g PSB / plant. Same treatment also showed the superior fruit quality traits evaluated in terms of fruit weight (289.40 g), fruit size (length 8.84 cm, breadth 8.89 cm) and fruit volume (257.53 cm³) in guava.

Ahmad and Mohammad (2012) reported that, the nutrient combination consisting of manure + *Azotobacter* + wood ash + phosphorus solubilizing bacteria + oil cake had significantly increased the fruit diameter (3.11 cm), fruit length (3.95 cm), fruit volume (20.397 cm³) and fruit weight (11.11 g).

Erturk *et al.* (2012) noticed that, the bacterial root inoculations (PGPR) significantly increased yield per plant (20.85 %), average fruit weight (19.26 %) compared to control in strawberry cv. Fern.

Khalil (2012) noticed the maximum shoot length (170.60 cm) and leaf area (179 cm² maximum grape yield (13.89 kg/plant), cluster weight (397.17 g), berry weight (264.4 g/100 berries) and TSS (17.50 %) under the treatment where the vines were microbial inoculated and received 100 per cent of recommended doses of mineral fertilizers.

Singh and Saravanan (2012) found that, the combined application of VAM at 12 kg / ha + *Azotobacter* at 10 kg / ha has recorded highest number of fruits/plant (29.13), fruit yield / plant (417.73 g), fruit length (3.94 cm) and fruit diameter (3.12 cm) in strawberry over other treatments.

Akash *et al.* (2013) reported that guava plants applied with *Azotobacter* + 25 per cent of N tree⁻¹ through FYM + 75 per cent of N tree⁻¹ through inorganic fertilizer showed highest fruit yield (41.14 kg plant⁻¹), maximum fruit length (8.39 cm), breadth (7.94 cm), weight (244.24 g) and pectin (0.81 %).

Patil and Shinde (2013) reported maximum plant height (190.84 cm), plant girth (81.34 cm), leaves per plant (32.30) leaf area (17.93 m²) maximum bunch weight (19.31 kg) and yield per hectare (85.80 t / ha) in the banana plants which were applied with 50 per cent RDF + FYM + *Azotobacter* (50 g/plant) + PSB (50 g / plant) + VAM *Glomus fasciculatum* (250 g / plant), while the same treatment has recorded

minimum number of days (211.03) for shooting after planting and number of days for harvesting after shooting (117.46).

Pesakovic *et al.* (2013) found that strawberry plants treated with PGPR 1 (pure culture of Gram-negative diazotrophic nitrogen fixing bacteria *Klebsiella planticola*) gave the maximum fruit weight (10.87 g), length (27.88 mm), breadth (30.75 mm) and yield (0.52 kg / plant).

Rubee *et al.* (2013) reported the maximum growth in terms of plant height (19.25 cm), number of leaves per plant (18.80), leaf area (30.45 cm²), length of leaves (8.80 cm) and width of leaves (10.94 cm) in the treatment (T₁₂) *Azotobacter* (2.5 kg / ha) + *Azospirillum* (2.5 kg/ha) + NPK (50 %) + FYM in strawberry cv. Chandler.

Verma and Rao (2013) reported that, strawberry plants receiving *Azotobacter* + PSB + vermicompost + 50 per cent recommended dose of NPK recorded highest plant height (23.65 cm), plant spread (35.20 cm) and leaf area (34.80 cm²). The same treatment registered earliest in flowering (91 days), highest number of flowers per plant (16.10), flowering duration (124.33 days) also recorded highest fruit weight (7.30 g), number of fruits per plant (14.90), yield per plant (181.84 g), marketable yield per plant (145.47 g) and yield per hectare (101.02 q).

Singh *et al.* (2015) reported that application of vermicompost + *Azotobacter* + PSB + AM produced maximum plant height (20.26 cm), plant spread (25.64 cm), number of leaves (54.30) and leaf area (97.87 cm²) plant⁻¹, number of flowers (64.23) and number of fruit set/plant (50.63) and maximum yield of 311.26 g per plant in strawberry.

Rueda *et al.* (2016) revealed that, the combination of *Azospirillum* spp. and *Azotobacter* spp. with 100 ppm of N showed better results on growth parameters: increase in plant height (18.57cm), chlorophyll content (48.57 Soil Plant Analysis Development -SPAD), fresh root weight (25.82 g) dry root weight of 5.93 g in strawberry.

Yadav *et al.* (2016) reported that inoculation of *Azotobacter* along with half of the dose of N supplied through vermicompost and the remaining half of N supplied through inorganic chemical fertilizers in two equal splits each at the establishment and before flowering stage (T₁₂) significantly improved cropping behavior, physical-chemical and biological properties in the rhizosphere soil which in turn favoured for improved yield and quality attributes of strawberry fruits and maintained soil health and productivity on long-term basis for sustainable fruit production.

Jain *et al.* (2017) reported that the maximum fruit weight (12.86 g), number of fruits plant⁻¹ (11.78) and yield (112.63 g plant⁻¹) was recorded in plants treated with T₁₅ (vermicompost + Poultry manure + *Azotobacter* + PSB) in strawberry.

2.2 Effect of fertigation and liquid plant growth promoting rhizomicrobial consortia on fruit quality

2.2.1 Effect of fertigation on fruit quality

Peterson (1998) reported the effect of fertigation on strawberry and found that the fruit size and fruit quality of fertigated plants was considerably better as compared to that of the non-fertigated plants.

Neilson *et al.* (2000) studied the response of N fertigation at different rates (12, 24, 48 g N/tree) on Gala apple and found that flesh firmness and titratable acidity decreased, while total soluble solids and starch content increased in response to higher level of N applied through fertigation.

The highest bunch weight, hands per bunch, fingers per bunch and finger weight with 100 per cent of recommended dose of NPK fertilizers applied through fertigation (Kavino *et al.*, 2002)

Park *et al.* (2004) studied the effect of fertigation on fruit quality of apple and documented that liquid fertilizers increase the average fruit weight, soluble solids and hardness of fruits. Fruit colouring in fertigation was much brighter than in control.

Taghavi *et al.* (2006) studied the effect of nitrate ammonium fertigation ratio on fruit quality of strawberry cultivar Selva. They recorded highest pH and vitamin C in fruits receiving nutrient solution containing more ammonium. However, the soluble solids content and fruit titratable acidity decreased as the amount of ammonium increased in the nutrient solution. Fertigation has been reported to increase vitamin C and anthocyanin content of strawberry.

Vitamin C (57.39 mg 100 g⁻¹ fresh weight) and acidity (0.98%) were comparatively higher in strawberry fruit harvested from (80 kg N ha⁻¹ year⁻¹) fertigated treatment than those harvested from low level of fertigation treatment (Wold and Opstad, 2007).

Maldonado and Pritts (2008) reported that starch (41.80 mg), glucose (42.30 mg), sucrose (54.20 mg) and total non-structural carbohydrate (138.30 mg) were comparatively higher in strawberry fruits harvested from fertigation treatment than those harvested from soil fertilization plots.

Rodas *et al.* (2013) studied the effect of chemical properties and rates of external colour of strawberry fruits grown using nitrogen and potassium fertigation and observed that analysis of variance values for the content of total soluble solids, titratable acidity, the relationship between total soluble solids and titratable acidity revealed that these characteristics were significantly influenced by both nitrogen and potassium doses as well as interaction between the two factors. The maximum TSS of

fruits was achieved with the application of 200 and 400 kg ha⁻¹ of nitrogen, maximum titratable acidity (0.80 %) and sugar to acid ratio of 9.52 obtained with the application of 200 kg ha⁻¹ of nitrogen and 344.50 kg ha⁻¹ of K₂O.

2.2.2 Effect of liquid plant growth promoting rhizomicrobial consortia on fruit quality

Zabetakis, (1997) reported that enhancement in the biosynthesis of furanone which is the flavour compound in strawberry (*Fragaria x ananassa*) was observed on inoculation with PSB *Bacillus subtilis*.

Ahmad *et al.* (2003) studied the effects of N fertilizer and *Azotobacter chroococcum* on the performance of mango cv. Amrapali. Two strains of *A. chroococcum* (M-4 and CBD-15) were applied at 15 g per plant in combination with various levels of N fertilizer (standard rate of 145 g per tree, 96 g per tree, and 48 g per tree). Treatment with 145 g N per plant and *A. chroococcum* CBD-15 gave the greatest increase in beta-carotene content (18.67 mg/100 g pulp). The highest TSS (23.64 %) and ascorbic acid (45.53 mg/100 g pulp) contents were obtained with 96 g N per plant + *A. chroococcum* CBD-15.

El Moniem and Radwan (2003) reported that the values of fruit physical properties were increased by the application of the biofertilizer (containing phosphate solubilizing bacteria, *Azotobacter spp.*, *Azospirillum spp.* and *Pseudomonas spp.*) plus 25, 50 or 75 per cent NPK. The treatment with biofertilizer plus 75 per cent NPK gave the highest values of fruit quality (the contents of pulp from total soluble solids, total sugars, acidity and starch) followed by 50 per cent NPK plus biofertilizer and 100 per cent NPK alone.

Rana and Chandel (2003) reported the maximum TSS content (8.78⁰ Brix) with *Azotobacter* inoculation along with 80 kg N ha⁻¹ in strawberry cv. Chandler.

Ustad *et al.* (2004) studied the effects of *Glomus fasciculatum* inoculation, in combination with 2 sets of bioinoculants (Set I: *Azotobacter chroococcum*, *Azospirillum brasiliense*, *Pseudomonas striata* and *Trichoderma harzianum* and Set II: 15 local isolates of bacteria, fungi and actinomycetes in cow dung powder) and 50 or 75 recommended fertilizer rates (RFR) on the yield and postharvest quality of banana cv. Rajapuri. Inoculation of plants with *G. fasciculatum* resulted in lesser number of days before fruit ripening (3.82) and higher reducing sugar (18.20 %), total sugar (19.94 %), total soluble solid (TSS 24.55 degrees Brix), acidity (0.09 %) and TSS:acid ratio (274.3) compared to uninoculated plants. Plants treated with Set I recorded higher reducing sugar content and TSS, whereas plants treated with Set II recorded higher non reducing sugar and TSS: acid ratio.

EL Hamd (2006) investigated the effect of bio-fertilizers phosphorein (phosphate solubilizing bacteria) at 250g. /feddan, nitrobein (N fixing bacteria) at 400g/ feddan and rhizobactrein (N fixing bacteria) at 20g/feddan + 0, 25, 50 and

75% of the recommended doses of P or N, on chemical (anthocyanin, total soluble solids , total sugars, ascorbic acid and juice ph) characteristics of strawberry cv Chandler. The bio-fertilizer treatments enhanced the earliness, anthocyanin, T.S.S. and ascorbic acid content. The other characteristics studied in this investigation didn't significantly influence by the treatments.

Yadav *et al.* (2008) studied the effect of integrated nutrient management on physico-chemical characters of phalsa fruits (*Grewia subinaequalis*). Maximum fruit size, average weight, juice percentage, total soluble solids and ascorbic acid were recorded with the use of 110 g urea + 125 g SSP + 26 g MOP + 10 kg FYM + *Azotobacter* + PSB followed by 55 urea + 63 g SSP + 13 g MOP + 15 g FYM + *Azotobacter* + PSB). Maximum sugars and pulp/stone ratio were recorded with the use of 55 g urea + 63 g SSP + 13 g MOP + 15 kg FYM + *Azotobacter* + PSB , followed by 110 g urea + 125 g SSP + 26 g MOP + 10 kg FYM + *Azotobacter* + PSB.

Mahendra *et al.* (2009) recorded maximum TSS (14⁰ Brix), ascorbic acid (76.35 mg/100 g), reducing sugar (4.95 %), non reducing sugar (4.95 %) and minimum acidity (0.17 %) with the soil application of FYM + 100 per cent NPK + *Azotobacter* + PSB closely followed by FYM + 75 per cent NPK + *Azotobacter* + PSB during the year of experimentation in Ber.

Singh and Singh (2009) reported that the treatment combination of *Azotobacter* + *Azospirillum* + 50 per cent N of the recommended dose + 100 ppm GA₃ has produced maximum TSS (8.96⁰ Brix), total sugars (8.55%) and ascorbic acid content (59.22 mg/100g) in strawberry

Umar *et al.* (2009) reported the maximum TSS (6.81⁰ Brix), total sugars (4.73 %), ascorbic acid (73.71 mg / 100 g) and anthocyanin content (0.191 OD) in the fruits obtained from the plants supplied with 25 per cent nitrogen through FYM + 75 per cent nitrogen through urea + *Azotobacter*.

Singh *et al.* (2010) reported that the application of recommended dose of fertilizers recorded the maximum TSS (8.81⁰ Brix), TSS/acidity ratio (12.77), total sugars (7.40 %) and ascorbic acid content (50.69 mg/100 g) were recorded under co-inoculation with *Azotobacter* + *Azospirillum* + *Pseudomonas striata* in strawberry cv. Chandler.

Mishra and Tripathi (2011) showed that combined application of *Azotobacter* and PSB (each at 6 kg/ha) significantly increased TSS (10.30⁰Brix), total sugars (9.54 %), ascorbic acid (57.55 mg / 100g edible material) with minimum titratable acidity (0.548 %) contents in comparison to untreated plants in strawberry.

Ahmad and Mohammad (2012) reported that, the nutrient combination consisting of manure + *Azotobacter* + wood ash + phosphorus solubilizing bacteria +

oil cake, had significantly increased the total sugars (7.95 %), TSS (9.01⁰ Brix), acidity (0.857 %), TSS: acidity ratio (11.12) and yield (238.95 g / plant) in strawberry cv. Kurdistan.

Singh and Saravanan (2012) found that, the combined application of VAM @ 12 kg / ha + *Azotobacter* @ 10kg / ha has recorded highest specific gravity (1.380), TSS (7.36⁰ Brix), juice content (92.34 %) and vitamin C (59.12 mg / 100g) over other treatments in strawberry.

Akash *et al.* (2013) reported that guava plants applied with *Azotobacter* + 50 per cent of N tree⁻¹ through FYM + 50 per cent of N tree⁻¹ through inorganic fertilizer showed highest TSS (12.95 ⁰Brix), total sugars (8.61 %) and minimum physiological loss in weight (14.29 %) after ten days under ambient conditions.

Pesakovic *et al.* (2013) reported that in strawberry the application of PGPR 2 (combination of nitrogen fixing and phosphor-mineralizing bacteria) gave the maximum TSS (10.18 ⁰Brix), total sugars (7.51 %), reducing sugars (6.60 %) and titrable acidity (1.09 % of malic acid).

Tomic *et al.* (2015) revealed the applied biofertilizers - Biofertilizer 1 (inoculum of the mixture of liquid bacteria cultures of the genera *Azotobacter*, *Derxia*, and *Bacillus*) and Biofertilizer 2 (inoculums of liquid culture of diazotrophic bacteria belonging to the genus *Klebsiella*). made significant impact on quality traits (soluble solids content, titratable acidity, vitamin C, total anthocyanins, total phenolic content, and total antioxidant capacity in the fruits of Clery, Joly and Dely strawberry plants.

Jain *et al.* (2017) reported that the maximum shelf life (5.69 days), TSS (7.05 °B), ascorbic acid (53.44 mg / 100 g of pulp), acidity (0.64 %), and pH (2.66) was found best in T₁₅ (vermicompost + Poultry manure + *Azotobacter* + PSB) in strawberry.

2.3 Effect of fertigation and liquid plant growth promoting rhizomicrobial consortia on benefit cost ratio of strawberry

Yadav *et al.* (2010) revealed that *Azotobacter* inoculated treatment with 50 per cent N substitution by FYM and remaining 50 per cent through inorganic fertilizer in two equal splits at establishment and before flowering stage gave highest benefit: cost ratio (4.97) in strawberry.

Kumar and Dey (2011) conducted an experiment to know the B: C ratio of cv. Chandler and reported benefit cost ratio of Chandler was 2.26.

Singh and Saravanan (2012) recorded maximum net return (5,18,007 Rs/ha) and cost benefit ratio (1:3.21) in the treatment VAM @ 12 kg/ha + *Azotobacter* @ 10 kg/ha in strawberry.

Pervin *et al* (2014) conducted an experiment to know the B: C ratio of strawberry and this study revealed that the net return (₹/ha) from the FA-016 variety cultivation with alternate day irrigation and low fertilizer doses ($N_{70}K_{70}P_{40}S_{25}$) was ₹ 5177643.75. The BCR (9.79) was also highest in the variety of FA-016. The farmer can earn about ₹ 1402463.75 per/ha a net return by cultivating BARI Stb-1 with the application of same irrigation water and fertilizer doses.

Mahesh gowda (2016) conducted an experiment to know the B: C ratio of different genotypes of strawberry, among the genotypes, Sabrina accounted net income of ₹.303225.00 per 1032m² resulted benefit cost ratio of 1: 1.88.

Jain *et al.* (2017) reported that the application of Vermicompost + Poultry manure + *Azotobacter* + PSB (T₁₅) has resulted in maximum net returns per hectare (Rs.11, 91, 599) followed by (Rs. 11, 60, 349) T₁₇ (Vermicompost + FYM + *Azotobacter* + PSB) respectively with a cost: benefit ratio of 1: 3.62 (T₁₅) and 1: 3.64 (T₁₇) per hectare.

Material and Methods

III MATERIAL AND METHODS

The present investigation on “Influence of liquid plant growth promoting rhizomicrobial consortium on growth, yield and quality of strawberry (*Fragaria x ananassa* Duch.) under naturally ventilated polyhouse condition” was carried out in polyhouse of the Department of Fruit Science, College of Horticulture, Mudigere during 2017-2018.

The details of material used and methodology adopted during the course of investigation are described in this chapter under the following headings.

3.1 Geographical location of the experimental site

The experiment was carried out in a low cost polyhouse of the Department of Fruit Science, College of Horticulture, Mudigere situated in the Western Ghats and represents the typical hilly zone (Zone-9 and Region-V) of Karnataka. It is located at 13° 25' North latitude and 75° 25' East longitude with an altitude of 982 m above mean sea level.

3.2 Weather conditions of the experimental site

Mudigere is one of the areas which receives heavy rainfall. The average rainfall received during the year was 1639.60 mm, distributed over a period of eight months (May - December) with the peak period in July. The mean maximum temperature of the experimental site was 30° C and the average minimum temperature was 20.2° C. The meteorological data for the period of experimentation was obtained from the meteorological observatory of Zonal Agricultural and Horticultural Research Station, Mudigere and the same is presented in Appendix-II.

3.3 Experimental details

3.3.1 Design and experimental layout

Location	: College of Horticulture, Mudigere, Karnataka.
Number of treatments	: 11
Number of replications	: 03
Design	: Completely Randomized Design (CRD)
Variety	: Sabrina
Plot size	: 2.0 m × 0.9 m
Spacing	: 30 cm × 30 cm
Number of plants per plot	: 12 (6 plants of 2 rows)
Planting method	: Double row system with raised bed

Planting time : November 2017

3.3.2 Treatment details

The treatment details are described as below.

T₁ - 75% RDF through fertigation

T₂ - 100% RDF through fertigation

T₃ - 100% RDF through soil application

T₄ - 75% RDF through soil application

T₅ - 75% RDF through fertigation + *Azotobacter*

T₆ - 75% RDF through fertigation + PSB

T₇ - 75% RDF through fertigation + KSB

T₈ - 75% recommended fertilizers through fertigation

T₉ - 75% RDF through fertigation + *Azotobacter* + PSB

T₁₀ - 75% RDF through fertigation + *Azotobacter* + KSB

T₁₁ - 75% RDF through fertigation + *Azotobacter* + PSB + KSB

Note:

The recommended dose of NPK for strawberry is 150:100:120 kg ha⁻¹ applied on 15, 30, 45, 60, 75 and 90th day after planting.

Recommended FYM at 20 t ha⁻¹ applied commonly to all the treatments.

Azotobacter (*Azotobacter chroococcum*) - 250 ml acre⁻¹

PSB (*Bacillus megaterium*) - 250 ml acre⁻¹

KSB (*Bacillus mucilaginosus*) - 250 ml acre⁻¹

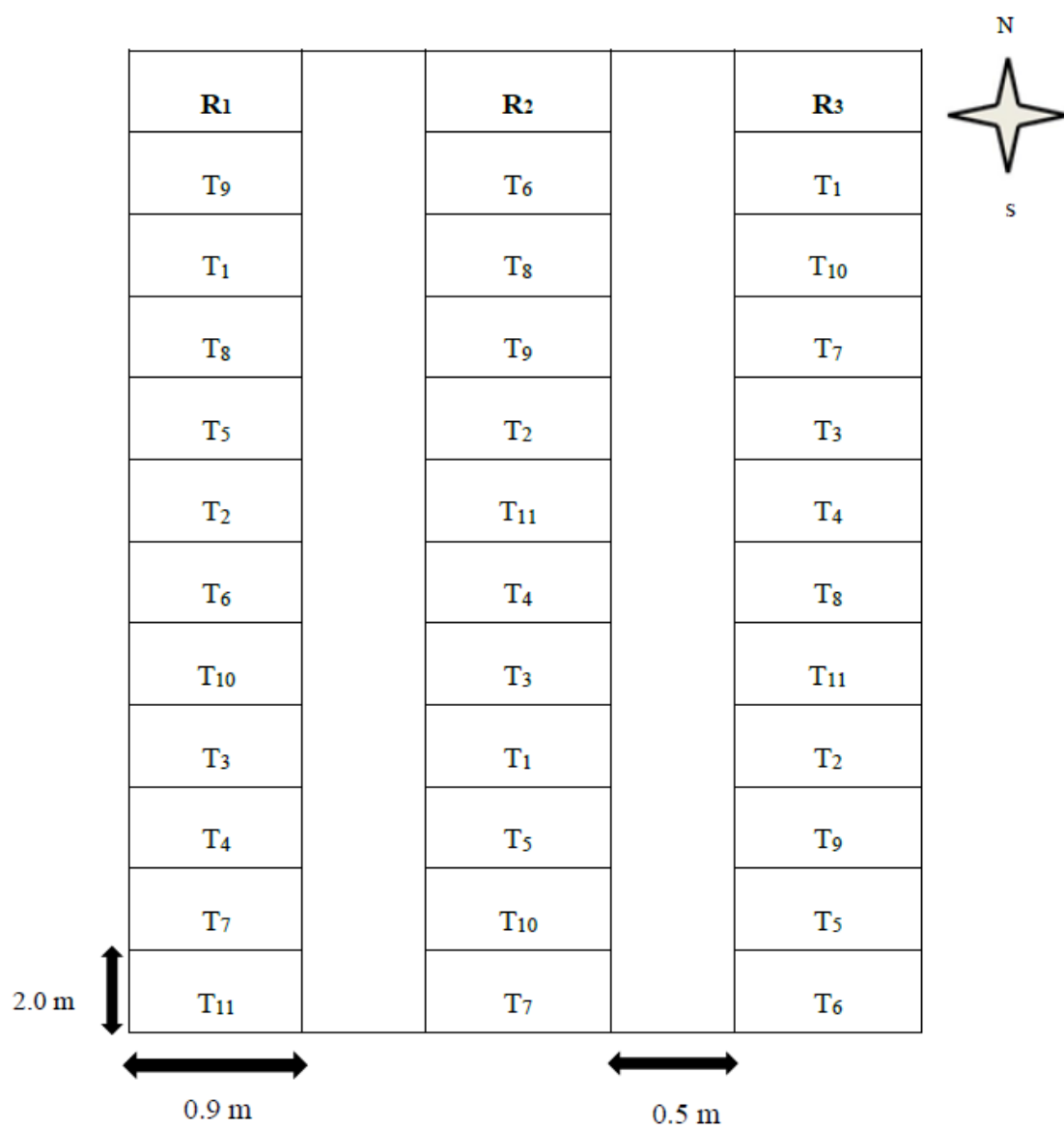


Fig. 1. Plan and Layout of the experiment

3.4 Source of planting material

Tissue culture plants procured from KF Bio Planter Private Limited, Kumar capital -Haveli, Pune (Maharashtra) was used for the study.

3.5 Cultural operations

3.5.1 Sterilization of polyhouse

Polyhouse was subjected to sterilization by drenching with 4 per cent formaldehyde solution and covered with polythene sheets for a period of 10 days to induce the effect of fumigation followed by proper ventilation for 3 days and watered sufficiently for leaching the chemical residue.

3.5.2 Preparation of experimental plot

The experimental plot was ploughed two times with the help of tractor-drawn implement followed by two harrowing and a planking to give final tilth. The beds were raised to a height of 45 cm from ground level and micro plots were prepared as per the plan with the width of each bed at 90 cm. A spacing of 50 cm between two beds was maintained to facilitate easy intercultural operations.

3.5.3 Drip irrigation installation and water management

To facilitate proper treatment imposition, drip irrigation system was installed in the experimental unit. Sub mains were laid perpendicular to the replication of the experiment. The inline laterals at the spacing of 30 cm were established in such a way that water was made to discharge from those laterals. Irrigation was given to the crop once in two days interval.

3.5.4 Application of manures and fertilizers

Well decomposed farm yard manure was applied at the time of bed preparation. Liquid plant growth promoting rhizomicrobial consortia was procured from Department of Microbiology, University of Agricultural and Horticultural Sciences, Shivamogga. Microbial consortium is mixed with FYM and then applied to the soil 15 days before planting. Fertilizers were applied through drip irrigation method by using the ventury system. The source of nutrients used to meet the demand of N, P and K were urea, di ammonium phosphate, muriate of potash, potassium nitrate and 19:19:19. At different intervals, fertilizer solution was prepared by mixing the required quantity of fertilizers and water in the plastic container which was connected with suction device of the ventury system. Fertigation schedule was started from 15 days after planting and was continued up to 90 days at 15 days interval.

3.5.5 Mulching

Before transplanting, the raised beds were completely mulched with a 50-micron thickness black polythene sheet. Holes of appropriate sizes were made on the mulching sheet for planting. The mulching helps to protect the fruit from rotting, controlling the weed growth and also helps to conserve soil moisture.

3.5.6 Transplanting

Tissue culture plants were transplanted into each hole of polythene mulch on 24th November 2017 in the evening hours to facilitate the good establishment of plants. The plantlets were placed along with a ball of earth followed by irrigation for better establishment.

3.5.7 Aftercare operations

Gap filling was done where ever required after transplanting due to mortality of few seedlings. The flower clusters appearing at the early stages were removed in order to promote vegetative growth.

3.5.8 Intercultural operations

The experimental area was kept clean by hand weeding. Irrigation was given through drip system at an interval of once in two days during crop growth period.

3.6 Observations recorded

Five competitive plants were selected randomly and tagged in each treatment for the purpose of recording observations on growth, flowering, fruit yield and quality parameters. The observations were recorded at monthly interval.

3.6.1 Morphological parameters

Observations like plant height, number of trifoliate leaves, plant spread and number of runners per plant were taken at 30 days interval after planting. While plant dry weight was recorded at harvest.

3.6.1.1 Plant height

The plant height was measured from the ground level to the first node at the tip of the plant at 30, 60, 90 and 120 days after transplanting and expressed in centimetre.

3.6.1.2 Number of trifoliate leaves per plant

The total number of fully opened leaves produced in each tagged plant at 30, 60, 90 and 120 days after transplanting was counted manually and the average per plant was worked out and represented.



Plate 1. General view of experimental plot

3.6.1.3 Plant spread

The maximum horizontal spread of plant in north-south and east-west direction was measured and represented in centimetre.

3.6.1.4 Number of crowns per plant

The total numbers of crowns produced from each plant at 60, 90 and 120 days was counted manually and the average was worked out.

3.6.1.5 Number of runners per plant

The total number of runners produced from the crown of each plant at the end of the crop growing season was counted manually and the average was worked out.

3.6.1.6 Leaf area

Leaf area was computed by using digital leaf area meter (LAM 211) and expressed in cm².

3.6.1.7 Leaf area index

Leaf area index was computed by using formula suggested by Watson (1952)

$$LAI = \frac{A}{P}$$

Where, A=Leaf area

P= Ground area

3.6.1.8 Plant dry weight at harvest

Three plants from each treatment were uprooted and dried in hot air oven at 65° C for 48 hours till plants reached a constant weight and recorded weight is expressed in gram per plant.

3.6.2 Flowering parameters

3.6.2.1 Days taken from flower bud initiation to berry maturity

The total number of days taken from the date of flower bud initiation to berry maturity was recorded.

3.6.2.2 Number of flowers per plant

Number of flowers from tagged plants were counted till it reached final harvest and the average number of flowers per plant was worked out.

3.6.2.3 Duration of flowering

The total duration from the first flower to last flower emergence in that particular season was recorded as duration of flowering.

3.6.3 Yield parameters

3.6.3.1 Fruit volume

The volume of the fruits was recorded by water displacement method and expressed in Cubic Centimetre per fruit.

3.6.3.2 Fruit weight

The matured fruits were harvested from the tagged plants and the weight of fruit was recorded in digital analytical balance, then the average value of individual fruit was worked out and expressed in grams.

3.6.3.3 Fruit length

The length from the stalk end and floral end of the fruit was measured with the help of digital vernier calipers and expressed in centimetre.

3.6.3.4 Fruit diameter

Fruit diameter was measured with the help of digital vernier calipers at the area of maximum width and it was expressed in centimetre.

3.6.3.5 Number of fruits per plant

The number of fruits per plant was counted manually from randomly selected five plants and then the average value was worked out and presented as number of fruits per plant.

3.6.3.6 Yield per plant

The fruits were harvested when three fourth of skin developed a red colour. The harvesting operation was done in early morning hours to reduce the transpirational losses. The observations on fruit weight and yield were recorded from each treatment after every harvest. The total yield was calculated by adding the values obtained in the different flush of harvest and expressed as grams per plant.

3.6.4 Quality and Biochemical parameters

3.6.4.1 Chlorophyll estimation

Chlorophyll content of leaf was analysed by collecting the healthy matured second leaf from the centre of the plant at peak vegetative stage. Fresh and fully matured leaves from the plant were placed in ice box covered by polyethene bag to avoid desiccation which was brought to the laboratory from the research field and were cut into small pieces. A known weight of the sample (100 mg) was immersed in 7.0 ml of dimethyl sulfoxide (DMSO) and stored in dark condition for 24 hours to facilitate dispersion of chlorophyll into dimethyl sulfoxide (DMSO). After an incubation period, the supernatant liquid was collected by decanting and leaf tissue was discarded. The final volume of the supernatant solution was made up to 10 ml



Flower bud stage



Fully opened flower



Petal fall stage



I stage of receptacle growth



Light green stage



Pink tinge stage



Pink stage



Red stage

Plate 2. Different stages of flower and fruit development

using DMSO. Chlorophyll-a, chlorophyll b and total chlorophyll content of leaf tissue was determined by using dimethyl sulfoxide (DMSO) method as suggested by Shaof and Lium (1976).

The absorbance of the extract was recorded at 645 and 663 nm in the spectrophotometer using Dimethyl sulfoxide as blank. The Chlorophyll-a, Chlorophyll-b and total chlorophyll contents were calculated by using the formulae given below.

$$\text{Total chlorophyll} = [20.2(A_{645}) + 8.02(A_{663})] \frac{V}{1000 \times W \times a} \times (\text{mg/g fresh wt.})$$

$$\text{Chlorophyll - a} = [12.7(A_{663}) - 2.69(A_{645})] \frac{V}{1000 \times W \times a} \times (\text{mg/g fresh wt.})$$

$$\text{Chlorophyll - b} = [22.9(A_{645}) - 2.69(A_{663})] \frac{V}{1000 \times W \times a} \times (\text{mg/g fresh wt.})$$

Where,

A - Absorbance at a specific wavelength (645nm & 663 nm)

V - Final volume of the Chlorophyll extract (10 ml)

W - Fresh weight of the sample (100 mg)

a - Path length of light in cuvette (1 cm)

3.6.4.2 Total Soluble Solids

The total soluble solid of the juice was determined with the digital refractometer at room temperature by putting a few drops of juice on the prism and expressed as degree brix (°Brix). The refractometer was calibrated with distilled water before use.

3.6.4.3 Titratable acidity

Twenty-five grams of fruit pulp was thoroughly homogenized in an electric blender and volume was made to 250 ml. The mixture was filtered through Whatman No. 1 filter paper. 50 ml of sample was then titrated against N/10 NaOH solution using phenolphthalein as an indicator till it gave pink coloured endpoint. The total titratable acidity was calculated in terms of citric acid on the basis of 1 ml of N/10 NaOH equivalent to 0.0067 gram of anhydrous citric or per cent citric acid in juice (Ranganna, 1995). The total titratable acidity was expressed in terms of citric acid percentage on fresh fruit weight basis.

$$\text{Titratable acidity (\%)} = \frac{\text{Titrate} \times \text{Normality of Alkali} \times \text{Volume made up} \times \text{Equivalent wt. of acid}}{\text{Vol. of sample taken} \times \text{Vol. of aliquot taken} \times 1000} \times 100$$

3.6.4.4 Reducing sugar

The reducing sugar content of the fruit was estimated by Anthrone method and is expressed in percentage. The reducing sugar content of the fruit was estimated by pipetting out 1 ml of sample aliquot and different concentrations (0, 0.2, 0.4, 0.6, 0.8 and 1.0 ml) of glucose standard solution in different test tubes were taken and the volume was made up to 2.5 ml each with distilled water to form the standard glucose graph. All the tubes were kept in an ice bath and added 5 ml of anthrone reagent to the test tube slowly. The contents were gently stirred with a glass rod. Then the contents of test tubes were heated on boiling water bath for exactly 7.5 minutes and were cooled immediately in ice bath. After cooling, the absorbance of the solutions was measured at 630 nm against the blank. The sugar content was calculated through standard glucose curve.

$$\text{Reducing sugars (\%)} = \frac{\text{Glucose (mg) in sample from standard curve}}{\text{Aliquot taken for test (ml)}} \times \frac{\text{Vol. made (ml) after alcohol evaporation}}{\text{Vol. taken for alcohol evaporation (ml)}} \times \frac{\text{Vol. made (ml) after sample extraction}}{\text{Sample taken for extraction (mg)}} \times 100$$

3.6.4.5 Non-reducing sugar

The percentage of non-reducing sugars was obtained by subtracting the percentage of reducing sugars from the total sugars and expressed in percentage.

$$\text{Non-reducing sugar (\%)} = \text{Total sugar} - \text{Reducing sugar}$$

3.6.4.6 Total sugar

The total sugar content of the fruit was estimated by following the method of Ranganna (1977) and expressed in percentage.

The total sugar content of the fruit can be calculated by using the formula

$$\text{Total sugars (\%)} = \frac{\text{Glucose (mg) in sample from standard curve}}{\text{Aliquot taken for test (ml)}} \times \frac{\text{Vol. made (ml) after hydrolysis (ml)}}{\text{Vol. taken for alcohol hydrolysis (ml)}} \times \frac{\text{Vol. made after alcohol evaporation (ml)}}{\text{volume taken for evaporation (mg)}} \times \frac{\text{Vol. made (ml) after sample extraction (ml)}}{\text{Sample taken for extraction (mg)}} \times 100$$

3.6.4.7 Ascorbic acid

Ascorbic acid was estimated by using 2, 6-dichlorophenol indophenol titration method. The sample was extracted in 4 per cent of oxalic acid, filtered using Whatman No.4 paper and made up to a known volume (50 ml). The known volume of filtrate (5 ml) was pipetted out in a conical flask and 5 ml of oxalic acid was added and titrated against 2, 6-Dichlorophenol-indophenol dye. The titration was carried out until an appearance of light pink colour. The dye was prepared using 50 mg of sodium salt of 2, 6- Dichlorophenol-indophenol dye in approximately 200 ml of double distilled water containing 4.2 mg of sodium bicarbonate. It was used for titration and standardizing ascorbic acid (Ranganna, 1986) and expressed in milligram per hundred grams of edible pulp.

$$\text{Ascorbic acid (mg / 100g)} = \frac{\text{Titre value} \times \text{dye factor} \times \text{vol. made up}}{\text{Aliquot taken for estimation} \times \text{vol. of sample taken}} \times 100$$

Where, dye factor =0.5

3.6.4.8 Sugar to acid ratio

The sugar to acid ratio was calculated by dividing the total sugar content by the titrable acidity.

3.6.4.9 Shelf life

Shelf life of fruits was decided based on the appearance and marketability of the fruits. When the fruits crossed edible ripe stage, those fruits were considered to have reached the end of their shelf life (Turner, 1997) and is expressed in days.

3.6.5 Soil characteristics of the experimental site

The soil of the experimental site was medium sandy loam. Before and after the experimentation the soil samples were collected from the depth of 0-30 cm in randomly selected spots. Soil sample was air dried, powdered and passed through 2 mm sieve and analysed for chemical properties.

3.6.5.1 Available macro-nutrient element

Available N was estimated by alkaline potassium permanganate method (Subbiah and Asija, 1956) and P extracted by Olsen's method (Olsen *et al.*, 1954) which was determined by stannous chloride reduced ammonium molybdate method in HCl system (Jackson, 1973). K was extracted by neutral normal ammonium acetate (Merwin and Peach, 1957) and was analysed on the flame photometer.

3.6.5.2 Microbial analysis

The microbial population in respect of total bacteria, fungi, actinomycetes, *Azotobacter*, PSB and KSB were assessed at 0, 45, 90 and at harvest by serial dilution technique.

Soil samples collected from the rhizosphere of the plant were placed in a polyethylene bag and brought to the laboratory and stored in a refrigerator at 5^o C until used for analysis.

3.6.5.2.1 Enumeration of soil microorganisms

Soil microbial populations were enumerated from the soil samples collected from the planting media. The soil samples collected were mixed thoroughly and were subjected to serial dilution using 1 gram of soil in 10 ml of distilled water. The enumeration of microorganisms was done after culturing these organisms using different media by standard dilution plate technique, and numbers of colonies were counted. Specific media used for enumeration of soil microorganisms such as Nutrient Agar (NA) for bacteria, Martin's Rose Bengal Agar (MRBA) for fungi and Kuster's Agar (KA) for actinomycetes.

3.6.6 Economics of cultivation

3.6.6.1 Cost of cultivation

The cost of all the inputs prevailed at the time of their use and the labour cost was considered to work out the cost of cultivation for the standard polyhouse area of 1032 m².

3.6.6.2 Gross income

The gross income was worked out based on the prevailing market price of strawberry fruits for the standard polyhouse area of 1032 m².

3.6.6.3 Net income

The net income per standard polyhouse area of 1032 m² was calculated by using the following formula.

$$NI = \text{Gross income} - \text{Cost of cultivation}$$

3.6.6.4 Benefit-cost ratio

The benefit-cost ratio for different treatments was worked out based on the price of inputs used for cultivation and price of marketable produce in the local market by using following formula and it is expressed in ratio.

$$\text{Benefit : cost ratio} = \frac{\text{Net income (₹ / ha)}}{\text{Cost of cultivation (₹ / ha)}}$$

3.7 Statistical analysis of experimental data

The collected data on various aspects such as growth, yield and quality parameters were tabulated and subjected to statistical analysis. Analysis of variance (ANOVA) given by Fisher and Yates (1963) was used for analysis of data. Whenever 'F' test was found significant for comparing the means of two treatments, critical differences at 5 per cent were worked out.

Experimental Results

IV EXPERIMENTAL RESULTS

The present investigation on “Influence of liquid plant growth promoting rhizomicrobial consortia on growth, yield and quality of strawberry (*Fragaria × ananassa* Duch.) under naturally ventilated polyhouse” was conducted during 2017-18 in the experimental plot of Department of Fruit Science, College of Horticulture, Mudigere. The results obtained during the course of investigation have been presented under the following headings.

4.1 Effect of fertigation and liquid PGPR on morphological parameters of strawberry

The data on the effect of fertigation and liquid plant growth promoting rhizomicrobial consortia on morphological parameters of strawberry viz., height of the plant, number of leaves per plant, number of runners per plant and plant spread are presented below.

4.1.1 Plant height

The data pertaining to plant height of strawberry for different fertigation and liquid microbial consortia treatments was recorded at different stages of crop growth is presented in table 1. The plant height was found to be significantly differed among the treatments at 30, 60, 90 and 120 days after planting.

The plant height at 30 days after planting was found maximum (13.83 cm) in T₁₁ (75 % RDF through fertigation + *Azotobacter* + PSB + KSB) and the minimum was observed in T₄ (10.10 cm). Whereas at 60 days after planting the maximum plant height of 17.97 cm was recorded in T₁₁ and the minimum plant height (13.93 cm) was recorded in T₄ (75% RDF through soil application). At 90 days after planting, the plants provided with 75% RDF through fertigation + *Azotobacter* + PSB + KSB (T₁₁) exhibited maximum plant height of 28.17 cm and the minimum plant height of 22.17 cm was observed in T₄. While at 120 days after planting the maximum plant height (34.00 cm) was recorded in T₁₁ and the minimum plant height (25.03 cm) was found in T₄ (75% RDF through soil application).

4.1.2 Number of trifoliate leaves per plant

It is apparent from the data presented in table 2 depicted that there was significant differences among the treatments with respect to number of trifoliate leaves per plant at different crop growth stages as influenced by fertigation and liquid plant growth promoting rhizomicrobial consortia.

Table 1. Effect of fertigation and liquid plant growth promoting rhizomicrobial consortia (PGPR) on plant height of strawberry

Treatments	Plant height (cm)			
	30 DAP	60 DAP	90 DAP	120 DAP
T ₁ - 75% RDF through fertigation	10.88	15.03	23.77	27.53
T ₂ - 100% RDF through fertigation	11.03	15.10	23.93	28.03
T ₃ - 100% RDF through soil application	10.37	14.52	23.10	26.67
T ₄ - 75 % RDF through soil application	10.10	13.93	22.17	25.03
T ₅ - 75% RDF through fertigation + <i>Azotobacter</i>	11.70	16.03	25.27	31.00
T ₆ - 75% RDF through fertigation + PSB	11.61	15.87	24.57	29.33
T ₇ - 75% RDF through fertigation + KSB	11.47	15.53	24.53	29.17
T ₈ - 75% RDF through fertigation + <i>Azotobacter</i> + PSB	13.20	17.23	27.07	32.33
T ₉ - 75% RDF through fertigation + <i>Azotobacter</i> + KSB	12.63	16.83	26.17	32.03
T ₁₀ - 75% RDF through fertigation+ PSB + KSB	12.28	16.50	25.83	31.50
T ₁₁ - 75% RDF through fertigation + <i>Azotobacter</i> + PSB + KSB	13.83	17.97	28.17	34.00
S. Em ±	0.11	0.12	0.16	0.33
C. D. (P = 0.05)	0.33	0.36	0.48	0.97

DAP- Days after planting

Table 2. Effect of fertigation and liquid PGPR on number of trifoliolate leaves of strawberry

Treatments	Number of trifoliolate leaves			
	30 DAP	60 DAP	90 DAP	120 DAP
T ₁ - 75% RDF through fertigation	6.68	10.77	17.52	23.03
T ₂ - 100% RDF through fertigation	6.82	11.00	18.00	23.67
T ₃ - 100% RDF through soil application	6.25	10.07	16.67	22.17
T ₄ - 75 % RDF through soil application	6.04	9.17	14.83	20.43
T ₅ - 75% RDF through fertigation + <i>Azotobacter</i>	7.40	12.33	19.33	26.83
T ₆ - 75% RDF through fertigation + PSB	7.22	11.78	18.17	25.90
T ₇ - 75% RDF through fertigation + KSB	7.23	11.50	18.03	25.47
T ₈ - 75% RDF through fertigation + <i>Azotobacter</i> + PSB	8.33	14.23	22.83	32.63
T ₉ - 75% RDF through fertigation + <i>Azotobacter</i> + KSB	7.97	13.58	21.83	30.17
T ₁₀ - 75% RDF through fertigation+ PSB + KSB	7.83	13.20	21.83	28.83
T ₁₁ - 75% RDF through fertigation + <i>Azotobacter</i> + PSB + KSB	8.40	15.17	24.04	34.03
S. Em ±	0.06	0.15	0.13	0.24
C. D. (P = 0.05)	0.17	0.45	0.39	0.70

DAP- Days after planting

At 30 days after planting the maximum number of leaves (8.40) was recorded in T₁₁ (75 % RDF through fertigation + *Azotobacter* + PSB + KSB) treatment, which was statistically at par with T₈ (75 % RDF through fertigation + *Azotobacter* + PSB) treatment (8.33) whereas the minimum number of leaves (6.04) was observed in T₄ (75 % RDF through soil application). The maximum number of leaves was recorded in the treatment T₁₁ at 60 days (15.17), at 90 days (24.04) and at 120 days (34.03) after planting. The minimum number of leaves was recorded in the T₄ at 60 days (9.17), at 90 days (14.83) and at 120 days (20.43) after planting.

4.1.3 Plant spread

The plant spread at 30, 60, 90 and 120 days after planting differ significantly among the treatments (Table 3).

The plant spread in north - south direction was found maximum in T₁₁ (75 % RDF through fertigation + *Azotobacter* + PSB + KSB) that is 15.50 cm, 25.40 cm, 34.00 cm and 44.67 cm at 30, 60, 90 and 120 days after planting respectively, the maximum plant spread in east-west direction was recorded in the same treatment T₁₁ (75% RDF through fertigation + *Azotobacter* + PSB + KSB) that is 14.90 cm, 24.33 cm, 32.23 cm and 43.33 cm at 30, 60, 90 and 120 days after planting respectively, the minimum plant spread at 30 days was recorded in T₄ (75 % RDF through soil application) in north - south direction and east west direction that is (11.08 cm) and (10.97 cm) respectively. T₄ (75 % RDF through soil application) shown minimum plant spread in both directions that is 19.80 cm and 19.47 cm at 60 days, 25.33 cm and 23.83 cm at 90 days, 31.83 and 31.00 cm at 120 days respectively.

4.1.4 Number of crowns per plant

The number of crowns at 60, 90 and 120 days after planting differ significantly among the treatments (Table 4).

The number of crowns was found maximum in T₁₁ (75 % RDF through fertigation + *Azotobacter* + PSB + KSB) 2.70, 3.83 and 4.93 at 60, 90 and 120 days after planting respectively, which was followed by treatment at T₈ (75 % RDF through fertigation + *Azotobacter* + PSB) 2.49, 3.38 and 4.30 at 60, 90 and 120 days after planting respectively. The minimum number of crowns per plant was recorded at 60 days (1.10), at 90 days (1.86) and at 120 days (2.20) after planting in T₄ (75 % RDF soil application).

Table 3. Effect of fertigation and liquid PGPR on plant spread of strawberry

Treatments	Plant spread (cm)							
	30 DAP		60 DAP		90 DAP		120 DAP	
	North-south	East- west	North-south	East- west	North-south	East- west	North-south	East- west
T ₁	12.11	12.13	20.67	20.69	26.90	25.90	34.37	33.33
T ₂	12.45	12.52	21.12	21.07	27.00	26.33	34.83	34.50
T ₃	11.61	11.45	20.40	20.10	26.20	24.10	33.10	32.33
T ₄	11.08	10.97	19.80	19.47	25.33	23.83	31.83	31.00
T ₅	13.79	13.03	22.60	22.00	29.33	28.35	39.33	37.83
T ₆	13.10	12.67	21.80	21.83	28.25	27.83	38.50	37.07
T ₇	12.95	12.53	21.73	21.72	27.67	27.68	37.33	36.67
T ₈	14.77	14.23	24.17	23.60	32.17	32.32	43.10	42.17
T ₉	14.62	13.80	23.68	23.17	31.60	31.73	42.03	41.00
T ₁₀	14.40	13.67	23.25	22.50	30.87	31.28	39.83	39.17
T ₁₁	15.50	14.90	25.40	24.33	34.00	33.23	44.67	43.33
S. Em ±	0.14	0.10	0.15	0.14	0.16	0.11	0.32	0.22
C. D. (P = 0.05)	0.42	0.30	0.44	0.41	0.47	0.33	0.94	0.65

DAP- Days after planting

Table 4. Effect of fertigation and liquid PGPR on number of crowns of strawberry

Treatments	Number of crowns		
	60 DAP	90 DAP	120 DAP
T ₁ - 75% RDF through fertigation	1.37	2.45	3.17
T ₂ - 100% RDF through fertigation	1.50	2.58	3.26
T ₃ - 100% RDF through soil application	1.18	2.20	2.73
T ₄ - 75 % RDF through soil application	1.10	1.86	2.20
T ₅ - 75% RDF through fertigation + <i>Azotobacter</i>	2.02	2.83	3.71
T ₆ - 75% RDF through fertigation + PSB	1.82	2.70	3.63
T ₇ - 75% RDF through fertigation + KSB	1.65	2.67	3.61
T ₈ - 75% RDF through fertigation + <i>Azotobacter</i> + PSB	2.49	3.38	4.30
T ₉ - 75% RDF through fertigation + <i>Azotobacter</i> + KSB	2.30	3.10	4.03
T ₁₀ - 75% RDF through fertigation + PSB + KSB	2.21	2.85	3.97
T ₁₁ - 75% RDF through fertigation + <i>Azotobacter</i> + PSB + KSB	2.70	3.83	4.93
S. Em ±	0.03	0.07	0.09
C. D. (P = 0.05)	0.09	0.21	0.26

DAP- Days after planting

4.1.5 Number of runners per plant

The data on the effect of fertigation and liquid PGPR treatments on strawberry cv. Sabrina exerted a significant influence on number of runners per plant was recorded at the end of growing season and is presented in table 5.

The maximum number of runners per plant (2.37) was recorded in T₁₁ (75 % RDF through fertigation + *Azotobacter* + PSB + KSB) while the minimum number of runners per plant (1.15) was recorded in T₄ (75 % RDF through soil application).

4.2 Effect of fertigation and liquid PGPR on growth parameters of strawberry

4.2.1 Leaf area

The data on the effect of fertigation and liquid PGPR treatments on leaf area showed significant results which is enumerated in table 6 and it was recorded at 30, 60, 90 and 120 days after planting.

The maximum leaf area (73.83 cm², 95.63 cm², 118.93 cm² and 140.17 cm² at 30, 60, 90 and 120 days after planting, respectively) was noticed in the plants provided T₁₁ (75% RDF through fertigation + *Azotobacter* + PSB + KSB) which was followed by T₈ (73.00 cm², 92.67 cm², 117.20 cm² and 138.17 cm² at 30, 60, 90 and 120 days after planting, respectively) which received 75% RDF through fertigation + *Azotobacter* + PSB. The minimum leaf area (61.17 cm², 80.67 cm², 103.83 cm² and 122.70 cm² at 30, 60, 90 and 120 days after planting, respectively) was recorded in T₄ which received 75% RDF through soil application.

4.2.2 Leaf area index

The data on the effect of fertigation and liquid PGPR treatments on leaf area index of strawberry cv. Sabrina exerted a significant influence on leaf area index recorded at 30, 60, 90 and 120 days after planting and is presented in table 7.

The maximum leaf area index of 0.65, 0.90, 1.20, 1.46 at 30, 60, 90 and 120 days after planting, respectively was noticed in the plants provided with 75% RDF through fertigation + *Azotobacter* + PSB + KSB. The minimum leaf area of 0.39, 0.55, 0.75 and 0.95 at 30, 60, 90 and 120 days after planting, respectively was recorded in T₄ (75 % RDF through soil application).

4.2.3 Plant dry weight at harvest

The data pertaining to plant dry weight recorded at harvesting stage of strawberry cv. Sabrina showed a significant difference among the treatments as influenced by fertigation and liquid PGPR is presented in table 5.

Table 5. Effect of fertigation and liquid PGPR on total number of runners per plant and plant dry weight at harvesting stage of strawberry

Treatments	Number of runners plant ⁻¹	Plant dry weight (g plant ⁻¹)
T ₁ - 75% RDF through fertigation	1.45	24.33
T ₂ - 100% RDF through fertigation	1.57	25.17
T ₃ - 100% RDF through soil application	1.33	22.67
T ₄ - 75 % RDF through soil application	1.15	21.33
T ₅ - 75% RDF through fertigation + <i>Azotobacter</i>	1.68	27.60
T ₆ - 75% RDF through fertigation + PSB	1.78	27.83
T ₇ - 75% RDF through fertigation + KSB	1.60	26.17
T ₈ - 75% RDF through fertigation + <i>Azotobacter</i> + PSB	2.17	33.00
T ₉ - 75% RDF through fertigation + <i>Azotobacter</i> + KSB	2.03	30.67
T ₁₀ - 75% RDF through fertigation + PSB + KSB	1.97	29.50
T ₁₁ - 75% RDF through fertigation + <i>Azotobacter</i> + PSB + KSB	2.37	33.63
S. Em ±	0.04	0.25
C. D. (P = 0.05)	0.12	0.74

Table 6. Effect of fertigation and liquid PGPR on leaf area of strawberry

Treatments	Leaf area (cm ²)			
	30 DAP	60 DAP	90 DAP	120 DAP
T ₁ - 75% RDF through fertigation	66.33	83.33	107.20	128.33
T ₂ - 100% RDF through fertigation	69.63	84.70	108.20	130.73
T ₃ - 100% RDF through soil application	64.33	81.83	106.67	125.30
T ₄ - 75 % RDF through soil application	61.67	80.67	103.83	122.70
T ₅ - 75% RDF through fertigation + <i>Azotobacter</i>	67.83	89.00	112.40	135.50
T ₆ - 75% RDF through fertigation + PSB	67.50	87.93	109.33	134.00
T ₇ - 75% RDF through fertigation + KSB	66.77	86.17	109.10	132.57
T ₈ - 75% RDF through fertigation + <i>Azotobacter</i> + PSB	73.47	92.67	117.20	138.17
T ₉ - 75% RDF through fertigation + <i>Azotobacter</i> + KSB	72.33	91.50	116.27	136.90
T ₁₀ - 75% RDF through fertigation+ PSB + KSB	73.00	91.27	114.87	136.03
T ₁₁ - 75% RDF through fertigation + <i>Azotobacter</i> + PSB + KSB	73.83	95.63	118.93	140.17
S. Em ±	0.33	0.33	0.36	0.38
C. D. (P = 0.05)	0.97	0.96	1.03	1.11

Table 7. Effect of fertigation and liquid PGPR on leaf area index of strawberry

Treatments	Leaf area index			
	30 DAP	60 DAP	90 DAP	120 DAP
T ₁ - 75% RDF through fertigation	0.44	0.68	0.84	1.13
T ₂ - 100% RDF through fertigation	0.45	0.70	0.85	1.23
T ₃ - 100% RDF through soil application	0.42	0.65	0.77	1.10
T ₄ - 75 % RDF through soil application	0.39	0.55	0.75	0.95
T ₅ - 75% RDF through fertigation + <i>Azotobacter</i>	0.52	0.75	0.95	1.26
T ₆ - 75% RDF through fertigation + PSB	0.50	0.74	0.93	1.23
T ₇ - 75% RDF through fertigation + KSB	0.49	0.73	0.92	1.21
T ₈ - 75% RDF through fertigation + <i>Azotobacter</i> + PSB	0.62	0.85	1.14	1.36
T ₉ - 75% RDF through fertigation + <i>Azotobacter</i> + KSB	0.55	0.83	1.10	1.32
T ₁₀ - 75% RDF through fertigation+ PSB + KSB	0.51	0.82	1.07	1.30
T ₁₁ - 75% RDF through fertigation + <i>Azotobacter</i> + PSB + KSB	0.65	0.90	1.20	1.46
S. Em ±	0.02	0.02	0.02	0.03
C. D. (P = 0.05)	0.06	0.06	0.06	0.10

The maximum plant dry weight (33.63 g plant⁻¹) was recorded in T₁₁ (75% RDF through fertigation + *Azotobacter* + PSB + KSB) which was on par with T₈ (33.00 g plant⁻¹) which received 75 % RDF through fertigation + *Azotobacter* + PSB while the minimum plant dry weight (21.33 g plant⁻¹) was recorded in T₄ (75 % RDF through soil application).

4.3 Effect of fertigation and liquid PGPR on biochemical parameters of strawberry

4.3.1 Chlorophyll content in leaf

The chlorophyll content of leaves varied significantly with respect to fertigation and liquid PGPR treatments which are furnished in the table 8.

4.3.1.1 Chlorophyll - a

The chlorophyll-a content in leaf varied significantly among fertigation and liquid PGPR treatments. The maximum chlorophyll-a content (1.78 mg/g of fresh weight) was recorded in T₁₁ (75% RDF through fertigation + *Azotobacter* + PSB + KSB) which was on par with T₈ (1.72 mg / g of fresh weight) which received 75 % RDF through fertigation + *Azotobacter* + PSB and the minimum chlorophyll- a content (1.27 mg / g of fresh weight) was recorded in T₄ (75 % RDF through soil application).

4.3.1.2 Chlorophyll - b

The chlorophyll- b content in leaf varied significantly among the fertigation and liquid PGPR treatments. The maximum chlorophyll -b content (0.58 mg g of fresh weight) was recorded in T₁₁ (75 % RDF through fertigation + *Azotobacter* + PSB + KSB) which was followed by 0.54 mg / g of fresh weight in T₈ (75% RDF through fertigation + *Azotobacter* + PSB) and the minimum chlorophyll -b content (0.32 mg / g of fresh weight) in leaf was recorded in T₄ (75 % RDF through soil application).

4.3.1.3 Total leaf Chlorophyll content

The total leaf chlorophyll content varied significantly among different fertigation and liquid PGPR treatments. The maximum total chlorophyll (2.36 mg / g of fresh weight) content was recorded in T₁₁ (75 % RDF through fertigation + *Azotobacter* + PSB) which was on par with T₈ (2.26 mg / g of fresh weight) which received 75 % RDF through fertigation + *Azotobacter* + PSB and the minimum total chlorophyll (1.59 mg / g of fresh weight) was recorded in T₄ (75 % RDF through soil application).

Table 8. Effect of fertigation and liquid PGPR on chlorophyll content of strawberry

Treatments	Chlorophyll content of leaves (mg g ⁻¹ of fresh weight)		
	Chlorophyll a	Chlorophyll b	Total chlorophyll
T ₁ - 75% RDF through fertigation	1.38	0.41	1.79
T ₂ - 100% RDF through fertigation	1.41	0.43	1.84
T ₃ - 100% RDF through soil application	1.33	0.36	1.70
T ₄ - 75 % RDF through soil application	1.27	0.32	1.59
T ₅ - 75% RDF through fertigation + <i>Azotobacter</i>	1.59	0.47	2.06
T ₆ - 75% RDF through fertigation + PSB	1.56	0.46	2.02
T ₇ - 75% RDF through fertigation + KSB	1.52	0.45	1.97
T ₈ - 75% RDF through fertigation + <i>Azotobacter</i> + PSB	1.72	0.54	2.26
T ₉ - 75% RDF through fertigation + <i>Azotobacter</i> + KSB	1.66	0.52	2.18
T ₁₀ - 75% RDF through fertigation + PSB + KSB	1.63	0.51	2.14
T ₁₁ - 75% RDF through fertigation + <i>Azotobacter</i> + PSB + KSB	1.78	0.58	2.36
S. Em ±	0.04	0.01	0.04
C. D. (P = 0.05)	0.12	0.03	0.11

4.4 Effect of fertigation and liquid PGPR on flowering parameters of strawberry

4.4.1 Days taken from flower bud initiation to berry maturity

The data presented in table 9 clearly indicated the significant difference with respect to days taken from flower bud initiation to berry maturity of strawberry in response to fertigation and liquid plant growth promoting rhizomicrobial consortia.

The minimum number of days taken for berry maturity (25.00 days) was recorded in T₁₁ (75% RDF through fertigation + *Azotobacter* + PSB) which was followed by the treatment T₈ (25.89 days) supplied with 75% RDF through fertigation + *Azotobacter* + PSB. The maximum number of days taken for berry maturity (29.33 days) was recorded in T₄ (75 % RDF through soil application).

4.4.2 Duration of flowering

There was a significant difference among fertigation and liquid PGPR treatments on strawberry with respect to the duration of flowering which is presented in table 9. The maximum duration of flowering (71.67 days) was recorded in T₁₁ (75 % RDF through fertigation + *Azotobacter* + PSB + KSB) while, the minimum duration of flowering (56.33 days) was recorded in T₄ (75% RDF through soil application).

4.4.3 Number of flowers per plant

The data in table 10 indicates that fertigation and liquid PGPR treatments exerted a significant influence on the number of flowers per plant. T₁₁ (75 % RDF through fertigation + *Azotobacter* + PSB + KSB) recorded maximum number of flowers per plant (24.21) which is on par with T₈ (23.74) supplied with 75 % RDF through fertigation + *Azotobacter* + PSB whereas the minimum number of flowers per plant (17.83) was observed in T₄ (75 % RDF through soil application).

4.5 Effect of fertigation and liquid PGPR on yield attributes of strawberry

4.5.1 Number of berries per plant

Fertigation and liquid PGPR treatments showed significant difference with respect to number of berries per plant which is presented in table 10. The maximum number of berries per plant (21.00) was recorded in T₁₁ (75% RDF through fertigation + *Azotobacter* + PSB + KSB) followed by T₈ (20.17) which received 75% RDF through fertigation + *Azotobacter* + PSB Whereas T₄ (75% RDF through soil application) given minimum number of fruits per plant (15.03).

Table 9. Effect of fertigation and liquid PGPR on flowering parameters of strawberry

Treatments	Days taken from flower bud initiation to berry maturity	Duration of flowering (days)
T ₁ - 75% RDF through fertigation	28.00	60.50
T ₂ - 100% RDF through fertigation	27.83	61.00
T ₃ - 100% RDF through soil application	29.00	28.33
T ₄ - 75 % RDF through soil application	29.33	56.33
T ₅ - 75% RDF through fertigation + <i>Azotobacter</i>	27.33	64.50
T ₆ - 75% RDF through fertigation + PSB	27.17	63.67
T ₇ - 75% RDF through fertigation + KSB	27.67	62.50
T ₈ - 75% RDF through fertigation + <i>Azotobacter</i> + PSB	25.89	68.33
T ₉ - 75% RDF through fertigation + <i>Azotobacter</i> + KSB	26.50	65.67
T ₁₀ - 75% RDF through fertigation + PSB + KSB	26.16	66.33
T ₁₁ - 75% RDF through fertigation + <i>Azotobacter</i> + PSB + KSB	25.00	71.67
S. Em ±	0.17	0.25
C. D. (P = 0.05)	0.51	0.73

Table 10. Effect of fertigation and liquid PGPR on yield attributes of strawberry

Treatments	Number of flowers plant ⁻¹	Number of berries per plant ⁻¹	Berry weight (g)	Yield plot ⁻¹ (kg)
T ₁ - 75% RDF through fertigation	20.17	16.45	16.67	3.07
T ₂ - 100% RDF through fertigation	21.50	16.87	17.08	3.13
T ₃ - 100% RDF through soil application	19.33	16.03	15.33	2.84
T ₄ - 75 % RDF through soil application	17.83	15.03	14.80	2.60
T ₅ - 75% RDF through fertigation + <i>Azotobacter</i>	22.00	18.07	18.43	3.57
T ₆ - 75% RDF through fertigation + PSB	21.83	17.97	18.17	3.33
T ₇ - 75% RDF through fertigation + KSB	21.73	17.75	17.83	3.23
T ₈ - 75% RDF through fertigation + <i>Azotobacter</i> + PSB	23.74	20.17	20.13	4.23
T ₉ - 75% RDF through fertigation + <i>Azotobacter</i> + KSB	22.60	19.33	19.55	4.00
T ₁₀ - 75% RDF through fertigation + PSB + KSB	22.75	18.83	19.17	3.87
T ₁₁ - 75% RDF through fertigation + <i>Azotobacter</i> + PSB + KSB	24.21	21.00	20.90	4.73
S. Em ±	0.19	0.15	0.22	0.07
C. D. (P = 0.05)	0.56	0.44	0.65	0.21

4.5.2 Berry weight

The weight of berry has differed significantly among various fertigation and liquid PGPR treatments of strawberry and the data on the mean weight of berry is presented in Table-10. The maximum berry weight (20.90 g) was recorded in T₁₁ (75 % RDF through fertigation + *Azotobacter* + PSB + KSB). The minimum berry weight (14.80 g) was recorded in T₄ (75 % RDF through soil application).

4.5.3 Yield per plant

Fertigation and liquid PGPR treatments resulted in significant difference with respect to yield per plant of strawberry cv. Sabrina presented in (Fig.2)

The T₁₁ which received 75 % RDF through fertigation + *Azotobacter* + PSB + KSB maximum fruit yield per plant (387.67 g) which was followed by T₈ (75 % RDF through fertigation + *Azotobacter* + PSB) which gave the yield of 370.33g per plant. The minimum fruit yield per plant (209.33 g) was recorded in T₄ which received 75 per cent RDF through soil application.

4.5.4 Yield per plot

It is obvious from the result that yield per plot (consisting of 12 plants per plot) of strawberry fruits was significantly altered due to the different fertigation and liquid PGPR treatments (Table 10). T₁₁ which received 75 % RDF through fertigation + *Azotobacter* + PSB + KSB recorded maximum fruit yield per plot (4.73 kg) which was followed by T₈ (4.23 kg) which received 75% RDF through fertigation + *Azotobacter* + PSB. While minimum yield per plot was recorded in T₄ (2.60 kg) which received 75 per cent RDF through soil application.

4.5.5 Fruit length

The data pertaining to the fruit length of Strawberry in response to fertigation and liquid PGPR treatments have shown significant results and it is furnished in Table-11. The maximum fruit length (4.78 cm) was recorded in T₁₁ (75 % RDF through fertigation + *Azotobacter* + PSB + KSB) which was statistically on par with T₈ (4.56 cm) which received 75 per cent RDF through fertigation + *Azotobacter* + PSB. The minimum fruit length (3.45 cm) was recorded in T₄ (75 % RDF through soil application).

Table 11. Effect of fertigation and liquid PGPR on fruit length, diameter and volume of strawberry

Treatments	Length (cm)	Diameter (cm)	Volume (cc)
T ₁ - 75% RDF through fertigation	3.93	3.15	17.87
T ₂ - 100% RDF through fertigation	3.98	3.20	18.03
T ₃ - 100% RDF through soil application	3.70	2.73	16.50
T ₄ - 75 % RDF through soil application	3.45	2.57	15.97
T ₅ - 75% RDF through fertigation + <i>Azotobacter</i>	4.23	3.27	19.81
T ₆ - 75% RDF through fertigation + PSB	4.12	3.23	19.30
T ₇ - 75% RDF through fertigation + KSB	4.08	3.15	19.17
T ₈ - 75% RDF through fertigation + <i>Azotobacter</i> + PSB	4.56	3.73	21.23
T ₉ - 75% RDF through fertigation + <i>Azotobacter</i> + KSB	4.42	3.70	21.17
T ₁₀ - 75% RDF through fertigation + PSB + KSB	4.30	3.52	20.75
T ₁₁ - 75% RDF through fertigation + <i>Azotobacter</i> + PSB + KSB	4.78	3.90	21.67
S. Em ±	0.11	0.07	0.17
C. D. (P = 0.05)	0.31	0.21	0.51

4.5.6 Fruit diameter

The data in table 11 indicates that fertigation and liquid PGPR treatments exerted a significant influence on fruit diameter. The maximum fruit diameter (3.90 cm) was recorded in T₁₁ (75 % RDF through fertigation + *Azotobacter* + PSB + KSB) which was on par with T₈ (3.73 cm) which received 75 per cent RDF through fertigation + *Azotobacter* + PSB and T₉ (3.70 cm) which received 75 % RDF through fertigation + *Azotobacter* + KSB. The treatment T₄ (75 % RDF through soil application) recorded minimum fruit diameter (2.57 cm).

4.5.7 Fruit volume

The significant difference was observed in fruit volume of strawberry with respect to different fertigation and liquid PGPR treatments which is presented in table 11. The maximum fruit volume (21.67 cc) was observed in T₁₁ (75 % RDF through fertigation + *Azotobacter* + PSB + KSB) which was on par with T₈ (21.17 cc) and T₉ (21.17) while, minimum fruit volume (15.97 cc) was observed in T₄ (75 % RDF through soil application).

4.6 Effect of fertigation and liquid PGPR on fruit quality parameters of strawberry

4.6.1 Total soluble solids

It is apparent from the data presented in the table 12 that there were significant differences observed in the total soluble solids of fruits with respect to fertigation and liquid PGPR treatments. Among all the treatments the plants which received 75 % RDF through fertigation + *Azotobacter* + PSB + KSB (T₁₁) recorded maximum TSS (12.20 °B), which was followed by T₉ (11.73 °B) which received 75% RDF through fertigation + *Azotobacter* + KSB. The minimum TSS (8.33 °B) was recorded in T₄ (75% RDF through soil application).

4.6.2 Ascorbic acid

The influence of fertigation treatments on the ascorbic acid content of strawberry fruits was found to be significant in pooled analysis and the data is furnished in the table 12. The highest ascorbic acid content (68.83 mg / 100 g) was recorded in 75 % RDF through fertigation + *Azotobacter* + PSB + KSB (T₁₁) while the minimum was recorded in T₄ (54.17 mg / 100 g).

Table 12. Effect of fertigation and liquid PGPR on fruit quality of strawberry

Treatments	Total soluble solids (⁰ B)	Ascorbic acid (mg 100g ⁻¹)	Sugars: acid ratio	Shelf life
T ₁ - 75% RDF through fertigation	9.13	60.83	8.35	2.43
T ₂ - 100% RDF through fertigation	9.27	63.03	8.51	2.47
T ₃ - 100% RDF through soil application	8.69	56.00	7.26	2.03
T ₄ - 75 % RDF through soil application	8.33	54.17	6.68	1.90
T ₅ - 75% RDF through fertigation + <i>Azotobacter</i>	10.67	64.67	9.23	2.27
T ₆ - 75% RDF through fertigation + PSB	10.80	63.67	8.84	2.33
T ₇ - 75% RDF through fertigation + KSB	10.86	62.33	9.1	2.47
T ₈ - 75% RDF through fertigation + <i>Azotobacter</i> + PSB	11.63	66.83	9.77	2.63
T ₉ - 75% RDF through fertigation + <i>Azotobacter</i> + KSB	11.73	67.70	10.86	2.77
T ₁₀ - 75% RDF through fertigation + PSB + KSB	11.33	66.30	10.18	2.75
T ₁₁ - 75% RDF through fertigation + <i>Azotobacter</i> + PSB + KSB	12.20	68.83	12.00	2.81
S. Em ±	0.13	0.31	0.10	0.05
C. D. (P = 0.05)	0.39	0.91	0.30	0.14

4.6.3 Reducing sugar

It is obvious from the result that reducing sugar of strawberry fruits was significantly altered due to the treatments of fertigation and liquid PGPR (Fig.3) The maximum reducing sugar content (6.19 %) was recorded in T₁₁ (75 % RDF through fertigation + *Azotobacter* + PSB + KSB) which was followed by T₉ (5.97 %) which received 75 per cent RDF through fertigation + *Azotobacter* + KSB. The minimum reducing sugar content (4.77 %) was recorded in T₄ (75% RDF through soil application).

4.6.4 Non reducing sugar

The data clearly indicated that fertigation and liquid PGPR treatments have shown significant results with respect to non-reducing sugar content of strawberry fruits (Fig.3). The maximum non reducing sugar content (2.01%) was recorded in T₁₁ (75% RDF through fertigation + *Azotobacter* + PSB + KSB) which was on par with T₉ (1.97 %) which received 75 per cent RDF through fertigation + *Azotobacter* + KSB, T₁₀ (1.92 %) which received 75 per cent RDF through fertigation + PSB + KSB and T₈ (1.91 %) which received 75 per cent RDF through fertigation + *Azotobacter* + PSB. The minimum non reducing sugar content (1.33 %) was recorded in T₄ (75% RDF through soil application).

4.6.5 Total sugar

Data pertaining to total sugar content reveals that the effect of different fertigation and liquid PGPR treatments was found significant in strawberry fruits (Fig.3). The maximum total sugar content (8.20 %) was recorded in T₁₁ (75% RDF through fertigation + *Azotobacter* + PSB + KSB) which was followed by T₉ (7.93 %) which received 75 per cent RDF through fertigation + *Azotobacter* + KSB. The minimum total sugar content (6.10%) was recorded in T₄ (75% RDF through soil application).

4.6.6 Titratable acidity

It is evident from the data that titratable acidity content was significantly influenced by various fertigation and liquid PGPR treatments on strawberry fruits shown in (Fig.4). The maximum titratable acidity (0.91 %) was recorded in T₄ (75 % RDF through soil application) which was on par with T₃ (0.88 %) which received 100 per cent RDF through soil application, while the minimum titratable acidity (0.68 %) was recorded in T₁₁ which received 75 per cent RDF through soil application + *Azotobacter* + PSB + KSB.

4.6.7 Sugars to acid ratio

The data pertaining to the effect of different fertigation and liquid PGPR treatments on sugars to acid ratio of the fruits differed significantly and it is presented in table 12. The maximum sugars to acid ratio (12.00) was recorded in T₁₁ (75% RDF through fertigation + *Azotobacter* + PSB + KSB), which was followed T₉ (10.86) which received 75 per cent RDF through fertigation + *Azotobacter* + KSB. The minimum sugars to acid ratio (6.68) was recorded in T₄ (75% RDF through soil application).

4.6.8 Shelf life

In this study there was no significant difference, among different fertigation and liquid PGPR treatments with respect to shelf life (Table 12). The maximum shelf life (2.81 days) was recorded in T₁₁ (75% RDF through fertigation + *Azotobacter* + PSB + KSB) and the minimum (1.90 days) was observed in T₄ (75% RDF through soil application).

4.7 Soil analysis

4.7.1 pH and Electrical conductivity (EC)

It is evident from the data that pH and EC of soil at last picking shown significant differences with respect to different treatments which is presented in table 13. Maximum pH (6.70) was found in the soil of T₁₁ (75% RDF through fertigation + *Azotobacter* + PSB + KSB) Whereas the maximum EC (0.14 dS m⁻¹) was recorded in T₅ and T₉ which received 75% RDF through fertigation + *Azotobacter* and 75% RDF through fertigation + *Azotobacter* + KSB which is on par with T₃, T₄, T₆, T₇, T₈, T₁₀ and T₁₁. The minimum (0.10 dS m⁻¹) was observed in the soils of T₁ and T₂.

4.7.2 Organic carbon

Treatment effect on organic carbon content at last picking was determined and reported in Table-13. Organic carbon content varied significantly due to different treatments under study. Organic carbon content was found maximum (1.45 g/kg) in treatment supplied with 75% RDF through fertigation + PSB + KSB (T₁₀). Whereas minimum (1.20 g/kg) was found in T₄ which received 75% RDF through soil application.

4.7.3 Nitrogen (N)

The data on available nitrogen as influenced by different fertigation and liquid plant growth promoting rhizomicrobial consortia are presented in Table-13. It was observed that the treatments exerted a significant influence on available nitrogen.

Table 13. Effect of fertigation and liquid PGPR on pH, EC, OC and available N, P₂O₅, K₂O of strawberry field soil

Treatments	pH	Electrical conductivity dS m ⁻¹	Organic carbon g kg ⁻¹	Avail. N	Avail. P ₂ O ₅	Avail. K ₂ O
Initial soil	6.50	0.10	1.35	160.21	45.23	346.20
T ₁ - 75% RDF through fertigation	6.52	0.10	1.22	180.33	60.67	485.00
T ₂ - 100% RDF through fertigation	6.60	0.10	1.21	183.33	66.00	501.67
T ₃ - 100% RDF through soil application	6.61	0.11	1.20	177.33	57.00	473.33
T ₄ - 75 % RDF through soil application	6.55	0.13	1.29	168.33	52.17	450.00
T ₅ - 75% RDF through fertigation + <i>Azotobacter</i>	6.67	0.14	1.25	219.67	69.67	490.00
T ₆ - 75% RDF through fertigation + PSB	6.48	0.12	1.37	186.33	95.67	478.67
T ₇ - 75% RDF through fertigation + KSB	6.58	0.12	1.27	185.33	68.33	546.67
T ₈ - 75% RDF through fertigation + <i>Azotobacter</i> + PSB	6.55	0.11	1.35	224.67	99.67	495.00
T ₉ - 75% RDF through fertigation + <i>Azotobacter</i> + KSB	6.61	0.14	1.37	221.83	75.00	570.00
T ₁₀ - 75% RDF through fertigation + PSB + KSB	6.62	0.11	1.45	190.00	96.33	588.00
T ₁₁ - 75% RDF through fertigation + <i>Azotobacter</i> + PSB + KSB	6.70	0.11	1.38	229.67	106.67	595.00
S. Em ±	0.04	0.01	0.03	1.24	0.61	1.33
C. D. (P = 0.05)	0.12	0.03	0.09	3.62	1.78	3.86

The highest available N (229.67 kg/ha) was recorded in T₁₁ (75% RDF through fertigation + *Azotobacter* + PSB + KSB) treatment which was followed by T₈ (224.67 kg/ha) lowest available N (168.33 kg/ha) was recorded in T₄ (75% RDF through soil application).

4.7.4 Phosphorus (P)

The data pertaining to effect of different fertigation and liquid PGPR treatments on available phosphorus content are presented in Table-13. It is evident from the data that available P was significantly affected by different fertigation and liquid PGPR treatments. The highest available P (106.67 kg / ha) was recorded in T₁₁ (75 % RDF through fertigation + *Azotobacter* + PSB + KSB). Whereas, the lowest available P (52.17 kg/ha) was recorded in T₄ (75 % RDF through soil application).

4.7.5 Potassium (K)

The perusal of data presented in Table-13 reveals that different fertigation and liquid PGPR treatments exerted a significant variation in the available soil K content during this study. The highest available K (595.00 kg / ha) content was recorded in T₁₁ (75 % RDF through fertigation + *Azotobacter* + PSB + KSB) treatment and the lowest (450.00 kg / ha) was recorded in the treatment (T₄) supplied with 75 per cent RDF through soil application.

4.8. Microbial analysis of the soil

Initial microbial population of the soil before planting of strawberry was analyzed. The bacterial biomass of about 40.13 *cfu* at 10⁻⁵ dilution was observed per gram of the soil. At 10⁻³ dilution, the fungal biomass was 8.30 *cfu* / g of soil. The actinomycetes population at 10⁻² dilution was 4.90 *cfu* / g of soil. However regarding *Azotobacter*, PSB and KSB population at 10⁻⁵ dilution it was 10.20, 5.40 and 5.90 *cfu*/g of soil respectively. The data pertaining to total population of bacteria, fungi, actinomycetes, *Azotobacter*, PSB and KSB with respect to various treatments is presented in table 14 a and 14 b.

4.8.1 Total bacteria

Treatments varied significantly with total bacterial population of soil (Table 14 a). The higher bacterial population of 97.00 *cfu* / g of soil, 124.47 *cfu* / g of soil, 140.20 *cfu* / g of soil and 152.67 *cfu* / g of soil was recorded in treatment T₁₁ (75% RDF through fertigation + *Azotobacter* + PSB + KSB) at 30, 60, 90 and 120 days after planting respectively at 10⁻⁵ dilution. The minimum bacterial count (44.30 *cfu* / g of soil, 60.28 *cfu* / g of soil, 70.37 *cfu* / g of soil and 80.57 *cfu* / g of soil) at 10⁻⁵ dilution was found in treatment (T₄) supplied with 75 per cent RDF through soil application at 30, 60, 90 and 120 days after planting respectively.

Table 14 a. Effect of fertigation and liquid PGPR on total microbial population

Treatments	Total bacteria (<i>cfu/g</i> of soil)				Total fungi (<i>cfu/g</i> of soil)				Total actinomycetes (<i>cfu/g</i> of soil)			
	0 th day	45 th day	90 th day	120 th day	0 th Day	45 th day	90 th day	120 th day	0 th day	45 th day	90 th day	120 th day
T ₁	49.17	67.49	75.47	85.63	11.47	15.17	21.77	34.70	5.53	9.20	13.00	21.67
T ₂	50.53	64.11	76.63	86.43	12.07	15.40	22.00	35.17	5.27	9.60	13.40	22.00
T ₃	45.23	68.26	71.90	81.30	11.83	14.50	22.53	35.70	5.72	10.10	13.45	22.53
T ₄	44.30	60.28	70.37	80.57	10.07	14.30	21.67	33.10	5.07	8.90	12.90	21.57
T ₅	70.10	85.25	98.27	107.77	10.50	15.80	23.20	33.43	5.60	11.31	16.47	23.20
T ₆	73.07	88.36	100.70	110.30	10.33	15.60	23.07	33.97	5.30	10.43	14.13	23.07
T ₇	68.83	84.15	106.21	116.63	11.43	15.73	23.00	35.27	5.17	10.80	14.50	23.00
T ₈	83.36	97.03	109.87	121.17	11.53	16.83	23.60	34.87	5.67	10.50	15.33	23.60
T ₉	83.33	96.17	108.17	120.10	11.37	15.93	23.47	34.63	5.33	10.70	15.40	23.47
T ₁₀	81.37	96.17	107.53	118.63	12.03	16.00	23.33	34.43	5.87	11.07	15.52	23.33
T ₁₁	97.00	124.47	140.20	152.67	12.47	17.50	25.23	37.80	6.33	11.42	17.33	25.23
S. Em ±	2.18	0.62	0.55	0.62	0.34	0.31	0.51	0.66	0.52	0.56	0.41	0.58
C. D. (P = 0.05)	6.34	1.81	1.60	1.81	0.99	0.91	1.49	1.93	1.51	1.62	0.19	1.70

Table 14 b. Effect of fertigation and liquid PGPR on total microbial population.

Treatments	Mean <i>Azotobacter</i> population (cfu/g of soil)					Mean PSB population (cfu/g of soil)					Mean KSB population (cfu/g of soil)				
	0 th day	45 th day	90 th day	120 th day		0 th Day	45 th day	90 th day	120 th day		0 th Day	45 th day	90 th day	120 th day	
T ₁	13.60	16.43	25.97	30.27		6.50	10.54	16.00	26.63		6.83	10.03	21.17	31.00	
T ₂	14.47	16.93	26.50	31.53		7.77	9.44	16.33	27.07		7.00	10.10	22.27	32.50	
T ₃	13.47	15.62	25.60	29.53		7.57	8.83	15.00	25.73		6.53	10.56	21.37	30.60	
T ₄	12.90	15.54	24.30	27.27		6.73	8.80	14.50	24.87		6.50	9.50	19.93	28.53	
T ₅	16.60	25.48	40.62	49.50		8.40	11.16	17.00	26.60		7.17	10.67	19.83	33.37	
T ₆	13.80	16.07	26.63	31.40		11.27	13.50	31.00	44.67		7.57	11.50	21.57	34.00	
T ₇	14.57	17.52	27.47	33.57		8.63	10.48	18.17	27.70		15.00	24.00	42.00	49.00	
T ₈	17.47	26.78	42.53	50.80		11.60	14.74	32.33	48.73		8.53	13.50	25.50	36.00	
T ₉	17.30	27.56	42.60	52.37		9.53	10.77	18.83	28.90		16.30	13.50	46.00	50.50	
T ₁₀	15.53	18.27	28.77	33.07		11.50	16.38	32.33	53.80		16.40	24.50	45.00	51.37	
T ₁₁	20.43	30.33	45.23	56.87		13.17	18.50	37.33	55.23		17.07	27.33	48.33	54.50	
S. Em ±	0.68	0.59	0.60	0.83		0.28	0.38	0.66	0.74		0.30	0.42	0.84	0.77	
C. D. (P = 0.05)	1.97	1.72	1.74	2.41		0.83	1.10	1.93	2.16		0.87	1.24	2.24	2.23	

4.8.2 Total fungi

Treatments varied significantly with total fungal population of soil (Table 14 a). The higher fungal population of 12.47 *cfu* / g of soil, 17.50 *cfu* / g of soil, 25.23 *cfu* / g of soil and 37.80 *cfu* / g of soil was recorded in treatment T₁₁ (75 % RDF through fertigation + *Azotobacter* + PSB + KSB) at 30, 60, 90 and 120 days after planting respectively at 10⁻³ dilution. The minimum fungal count (10.07 *cfu* / g of soil, 14.30 *cfu* / g of soil, 21.67 *cfu* / g of soil and 33.10 *cfu*/g of soil) at 10⁻³ dilution was found in treatment (T₄) supplied with 75 per cent RDF through soil application at 30, 60, 90 and 120 days after planting respectively.

4.8.3 Total actinomycetes

Treatments varied significantly with total fungal population of soil (Table 14 a). The higher actinomycetes population of 6.33 *cfu*/g of soil, 11.42 *cfu* / g of soil, 17.33 *cfu*/g of soil and 25.23 *cfu* / g of soil was recorded in treatment T₁₁ (75% RDF through fertigation + *Azotobacter* + PSB + KSB) at 30, 60, 90 and 120 days after planting respectively at 10⁻² dilution. The minimum actinomycetes count (5.07 *cfu*/g soil, 8.90 *cfu* / g soil, 12.90 *cfu* / g soil and 21.57 *cfu* / g soil) was found in treatment (T₄) supplied with 75 per cent RDF through soil application at 30, 60, 90 and 120 days after planting respectively.

4.8.4 Total *Azotobacter* population

Treatments varied significantly with total *Azotobacter* population of soil (Table 14 b). The higher *Azotobacter* population of 20.43 *cfu* / g of soil, 30.33 *cfu* / g of soil, 45.23 *cfu* / g of soil and 56.87 *cfu* / g of soil was recorded in treatment T₁₁ (75 % RDF through fertigation + *Azotobacter* + PSB + KSB) at 30, 60, 90 and 120 days after planting respectively at 10⁻⁵ dilution. The minimum *Azotobacter* count (12.90 *cfu* / g of soil, 15.54 *cfu* / g of soil, 24.30 *cfu* / g of soil and 27.27 *cfu* / g of soil) at 10⁻⁵ dilution was found in treatment (T₄) supplied with 75 per cent RDF through soil application at 30, 60, 90 and 120 days after planting respectively.

4.8.5 Total PSB (*Phosphorous solubilising bacteria*)

Treatments varied significantly with total PSB population of soil (Table 14 b). The higher PSB population of 13.17 *cfu* / g of soil, 18.50 *cfu* / g of soil, 37.33 *cfu* / g of soil and 55.23 *cfu* / g of soil was recorded in treatment T₁₁ (75 % RDF through fertigation + *Azotobacter* + PSB + KSB) at 30, 60, 90 and 120 days after planting respectively at 10⁻⁵ dilution. The minimum bacterial count (6.73 *cfu* / g of soil, 8.80 *cfu* / g of soil, 14.50 *cfu* / g of soil and 24.87 *cfu* / g of soil) at 10⁻⁵ dilution was found in treatment (T₄) supplied with 75 per cent RDF through soil application at 30, 60, 90 and 120 days after planting respectively.

4.8.6 Total KSB (*Potassium solubilising bacteria*)

Treatments varied significantly with total KSB population of soil (Table 14 b). The higher PSB population of 17.07 *cfu/g* soil, 27.33 *cfu / g* of soil, 48.33 *cfu / g* of soil and 54.50 *cfu / g* of soil was recorded in treatment T₁₁ (75 % RDF through fertigation + *Azotobacter* + PSB + KSB) at 30, 60, 90 and 120 days after planting respectively at 10⁻⁵ dilution. The minimum bacterial count (6.50 *cfu / g* of soil, 9.50 *cfu/g* of soil, 19.93 *cfu / g* of soil and 28.53 *cfu / g* soil) at 10⁻⁵ dilution was found in treatment (T₄) supplied with 75 per cent RDF through soil application at 30, 60, 90 and 120 days after planting respectively.

4.9 Benefit cost ratio

The benefit cost ratio of different fertigation and liquid PGPR treatments of strawberry differed significantly which is presented in the Table-15. T₁₁ (75 % RDF through fertigation + *Azotobacter* + PSB + KSB) accounted maximum net income (₹ 323114 for 1032 m² of poly house area) which was followed by T₈ (₹ 271021 for 1032 m² of poly house area) which received 75 per cent RDF through fertigation + *Azotobacter* + PSB and T₉ which received 75 per cent RDF through fertigation + *Azotobacter* + KSB (₹ 246941 for 1032 m² of poly house area) whereas T₄ supplied with 75 per cent RDF through soil application was found to be lowest (₹ 107551 for 1032 m² of poly house area). The maximum benefit cost ratio (2.90) was obtained from T₁₁ (75 % RDF through fertigation + *Azotobacter* + PSB + KSB) which was followed by T₈ (2.59) and T₉ (2.45), while the lowest benefit cost ratio (1.66) was observed in T₄.

Table 15. Economics of fertigation and liquid PGPR treatments on strawberry production (per 1032 m²)

Treatments	Total cost of cultivation (₹/1032m ²)	Yield in terms of kg per 1032 m ²	Returns from fruit yield (₹/1032 m ²)	Number of runners per 1032 m ²	Returns from runners (₹/1032 m ²)	Gross income (₹/1032m ²)	Net income (₹/1032m ²)	Benefit: Cost
T ₁	172917	1760	316800	877	3508	320308	147391	1: 1.85
T ₂	172917	1794	322920	900	3600	326520	153603	1: 1.89
T ₃	163285	1628	293040	785	3140	296180	132895	1: 1.81
T ₄	163285	1490	268200	659	2636	270836	107551	1: 1.66
T ₅	170428	2046	368280	1060	4240	372520	202092	1: 2.19
T ₆	170428	1909	343620	1014	4056	347676	177248	1: 2.04
T ₇	170428	1852	333360	1003	4012	337372	166944	1: 1.98
T ₈	170455	2425	436500	1244	4976	441476	271021	1: 2.59
T ₉	170455	2293	412740	1164	4656	417396	246941	1: 2.45
T ₁₀	170455	2218	399240	1129	4516	403756	233301	1: 2.37
T ₁₁	170482	2712	488160	1359	5436	493596	323114	1: 2.90

Note- Price of strawberry fruits/marketable price at 180 ₹ /kg.
Cost of strawberry runners/ marketable price at 4 ₹ / runner

Discussion

V DISCUSSION

Strawberry is one of the most popular and very much liked fruit for its cool and refreshing nature. The application of fertilizer plays an important role in the production of quality fruits and harnessing optimum yield. At present chemical fertilizers contribute a lot in fulfilling the nutrient requirement but their regular, excessive and unbalanced use may lead to health and ecological hazards, depletion of physico-chemical properties of the soil and ultimately the poor crop yield. Hence, there is a need to think use of alternate source of safe fertilizers which may enhance crop yield without having adverse effects on soil properties. Now it is inevitable to establish an alternate solution to minimize the usage of inorganic fertilizers without deterioration of soil productivity. Therefore, the use of bio-fertilizer (microbial consortia) seems to be a ray of hope in this direction when they are used in combination with inorganic fertilizers in a balanced proportion for increasing yield, quality and production of crop. Considering the importance of microbial consortia the present investigation was carried out on “Influence of liquid plant growth promoting rhizomicrobial consortia on growth, yield and quality of strawberry (*Fragaria × ananassa* Duch.) under naturally ventilated polyhouse” during 2017-2018 and the results obtained are discussed in this chapter.

5.1 Effect of fertigation and liquid PGPR on morphological parameters of strawberry

5.1.1 Plant height and number of trifoliolate leaves per plant

Plant height and the number of leaves increased significantly with respect to the application of recommended dose of fertilizers through fertigation and liquid plant growth promoting rhizomicrobial consortium. The plants supplied with 75 % RDF through fertigation + *Azotobacter* + PSB + KSB (T₁₁) recorded maximum plant height of 13.83, 17.97, 28.17, 34.00 cm and at 30, 60, 90 and 120 days after planting respectively whereas the minimum plant height of 10.10, 13.93, 22.17, 25.03 cm was recorded in T₄ (75 % RDF through soil application). The maximum number of trifoliolate leaves per plant of 8.40, 15.17, 24.20 and 34.03 cm was recorded in treatment T₁₁ (75 % RDF through fertigation + *Azotobacter* + PSB + KSB) at 30, 60, 90 and 120 days after planting respectively. The minimum number of trifoliolate leaves of 6.04, 9.17, 14.83, 20.43 was recorded in T₄ (75% RDF through soil application) at 30, 60, 90 and 120 days after planting respectively.

The well accomplished sustained vegetative growth in terms of plant height and number of leaves per plant might be due to sustained nutrient availability due to

fertigation schedule. The combined effect of inorganic fertilizers, nitrogen fixing biofertilizer i.e *Azotobacter*, phosphate solubilizing bacteria, potassium solubilizing bacteria enhances the macronutrient availability in the soil. This increased supply of nutrients might have led ultimately for better metabolic activities and high protein synthesis. The response of the crop might be due to these availability of nutrients that might have coincided with plant need. Further, protein synthesis from reserved carbohydrate leads to enhanced production of leaves. The production of more chlorophyll content with the inoculation of nitrogen fixers like *Azotobacter* might have also contributed to the production of more number of trifoliate leaves. Similar results were reported by Zargar *et al.* (2008), Rana and Chandel (2003), Rubee *et al.* (2013), Singh and Singh (2009) and Yadav *et al.* (2010) in strawberry.

5.1.2 Plant spread

Significant difference was observed among the treatments with respect to plant spread in both north-south and east-west direction. The plant spread in north-south direction was maximum in T₁₁ (75% RDF through fertigation + *Azotobacter* + PSB + KSB) i.e. 15.50 cm, 25.40 cm, 34.00 cm and 44.67 cm at 30, 60, 90 and 120 days after planting respectively. Treatment T₁₁ also recorded maximum plant spread of 14.90 cm, 24.33 cm, 33.23 cm and 43.33 cm at 30, 60, 90 and 120 days after planting respectively in east-west direction.

The maximum plant spread might be due to increased cell division, cell elongation and a corresponding increase in the length of petiole by the synthesis of plant hormones like IAA, GA₃ and cytokine in the said treatment. These results are in conformity with that of Verma and Rao (2013) and Singh *et al.* (2015) who observed increased plant spread in strawberry with the application of *Azotobacter* and Phosphate solubilizing bacteria.

5.1.3 Number of runners and crowns per plant

The results on number of runners per plant showed significant difference among different treatments. The maximum number of runners per plant (2.37) was recorded in treatment T₁₁ (75% RDF through fertigation + *Azotobacter* + PSB + KSB) while, the minimum number of runners per plant (1.15) was recorded in T₄ (75 % RDF through soil application). The maximum number of crowns per plant was recorded in T₁₁ (4.93) at 120 days after planting whereas the minimum number of crowns was recorded in T₄ (2.20).

Increased number of runners and crowns per plant might be due to the cumulative effect of inorganic fertilizers, FYM, nitrogen fixing bacteria, phosphate solubilizing bacteria and potassium solubilizing bacteria which enhanced the nitrogen, potassium and phosphate availability in the soil. Timely supply of macro nutrients from 75% RDF through fertigation and also secretion of growth promoting substances



T₁- 75% RDF through fertigation



T₂- 100% RDF through fertigation



T₃-100% RDF through soil application

Plate 3. Effect of fertigation and liquid PGPR on different treatments (T₁, T₂ and T₃) at fruiting stage of strawberry



T₄ -75% RDF through soil application



T₅ - 75% RDF through fertigation + *Azotobacter*



T₆ - 75% RDF through fertigation + PSB

Plate 4. Effect of fertigation and liquid PGPR on different treatments (T₄ T₅ and T₆) at fruiting stage of strawberry



T_7 - 75% RDF through fertigation + KSB



T_8 - 75% RDF through fertigation +
Azotobacter + PSB



T_9 -75% RDF through fertigation +
Azotobacter + KSB

Plate 5. Effect of fertigation and liquid PGPR on different treatments (T_7 , T_8 and T_9) at fruiting stage of strawberry



T_{10} -75% RDF through fertigation +
PSB + KSB



T_{11} -75% RDF through fertigation +
Azotobacter + PSB + KSB

Plate 6. Effect of fertigation and liquid PGPR on different treatments (T_{10} and T_{11}) at fruiting stage of strawberry

especially cytokinin by nitrogen fixing bacteria might have increased the number of runner per plant as cytokinin helps in branching and development of side buds (Waithaka and Dana, 1978). The increase in number of runners per plant might also be due to increased plant growth in the form of plant height, number of leaves and leaf area which accumulated more photosynthates and thereby increased runners per plant. The results are in conformity with the findings of Rana and Chandel (2003), Arancon *et al.* (2004), Rubee *et al.* (2013), Yadav *et al.* (2010) and Nazir *et al.* (2006) in strawberry.

5.2 Effect of fertigation and liquid PGPR on growth parameters of strawberry.

5.2.1 Leaf area and leaf area index

Leaf area and leaf area index differed significantly at all stages of crop growth due to various treatments effect. The plants received 75 % RDF through fertigation + *Azotobacter* + PSB + KSB (T₁₁) recorded maximum leaf area and leaf area index of (73.83 cm² and 0.65), (95.63 cm² and 0.90) , (118.93 cm² and 1.20) and (140.17 cm² and 1.46) at 30, 60, 90 and 120 days after planting respectively.

The combined effect of microbial consortia and NPK application was found significant in obtaining increased leaf area due to nutrients involvement in metabolic processes of plant growth, photosynthetic efficiency, carbohydrate metabolism, etc. Microbial consortia (*Azotobacter*, PSB and KSB) also helped in synthesising hormones that fix major nutrients and helps to utilize in cell elongation which led to expansion of more leaf area. Microbial consortia releases certain growth hormones like IAA, GA₃ and cytokinin in the rhizosphere which could have caused greater cell division and cell expansion results in increased leaf area. The increase in leaf area and more number of leaves results in increased leaf area index. Similar result have been obtained by Rana and Chandel (2003), Nazir *et al.* (2006), Sahoo and Singh (2005) and Rubee *et al.* (2013) in strawberry.

5.2.2 Total dry weight

The maximum plant dry weight (33.63 g plant⁻¹) was recorded in T₁₁ (75 % RDF through fertigation + *Azotobacter* + PSB + KSB) which was on par with T₈ (33.00 g plant⁻¹) which received 75% RDF through fertigation + *Azotobacter* + PSB while, the minimum plant dry weight of 21.33 g plant⁻¹ was recorded in T₄ (75 % RDF through soil application). The increased total dry weight might be attributed due to the application of 75 % RDF through fertigation + *Azotobacter* + PSB + KSB resulted higher uptake and accumulation of greater amounts of photosynthates leading to increase in number of leaves, plant size and fresh biomass which in turn yields higher dry matter content. These result is in conformity with the findings of Wang and

Lin (2002), Singh *et al.* (2008), Preusch *et al.* (2004), Khalid *et al.* (2013) in strawberry.

5.3 Effect of fertigation and liquid PGPR on biochemical parameters of strawberry

5.3.1 Chlorophyll content in leaf

The different fertigation treatments on strawberry plants showed significant results with respect to chlorophyll content. The maximum total chlorophyll (2.36 mg/g of fresh weight) content was recorded in T₁₁ (75% RDF through fertigation + *Azotobacter* + PSB) which was on par with T₈ (2.26 mg / g of fresh weight) which received 75% RDF through fertigation + *Azotobacter* + PSB. Whereas the minimum total chlorophyll content of 1.59 mg/g of fresh weight was recorded in T₄ (75 % RDF through soil application). The increased chlorophyll content might be due to supply of optimum levels of N, P and K through fertigation. The role of nitrogen and potassium in the functioning of chlorophyll is well established. Nitrogen is the chief constituent of chlorophyll, proteins and amino acids, the synthesis of which is accelerated through increased supply of nitrogen (Kohli *et al.* 1980). The results are in confirmation with the observations of Singh and Singh (2009), Wang and Lin (2002), Subraya (2015) and Mounashree (2017) in strawberry,

5.4 Effect of fertigation and liquid PGPR on flowering parameters of strawberry

5.4.1 Days taken from flower bud initiation to berry maturity and duration of flowering

Significant results were obtained with respect to days taken from flower bud initiation to berry maturity and duration of flowering of strawberry in response to fertigation and liquid plant growth promoting rhizomicrobial consortia. The minimum number of days (25.00 days) taken for berry maturity was recorded in T₁₁ (75% RDF through fertigation + *Azotobacter* + PSB). Early flowering in T₁₁ might be due to supply of optimum levels of N, P and K which results in early achievement of required net assimilation rate and differentiation of flower bud. Adequate amount of nitrogen present in plant with satisfactory carbohydrate content could have led to early flowering. Early flowering in T₁₁ might also be due to the addition of FYM and liquid microbial consortium, resulted in early completion of vegetative stage leading to early onset of reproductive stage (Herenica *et al.*, 2011). The results are in line with the findings of Khalid *et al.* (2013), Nazir *et al.* (2006), Singh *et al.* (2008) and Ayesha *et al.* (2011) in strawberry, Prabburam and Sathiamoorthy (1993) in banana.

The maximum duration of flowering (71.67 days) was recorded in T₁₁ (75 % RDF through fertigation + *Azotobacter* + PSB + KSB) while, the minimum duration

of flowering (56.33 days) was recorded in T₄ (75% RDF through soil application). The extension of flowering duration in strawberry might be due to frequent irrigation and fertilization might have caused high C/N ratio which would have promoted extension of flowering period. These results of present investigation are in confirmation with the report of earlier workers Sonsteby *et al.* (2009) in strawberry and Valji (2011) in papaya. The extension of duration of flowering in strawberry with the application of 75 % RDF through fertigation + *Azotobacter* + PSB + KSB might also be due to the healthy and vigorous growth of plants at vegetative stage wherein they can store sufficient amounts of photosynthates for producing more number of flowers. The research result is in conformity with the findings of Macit *et al.* (2007) and Yadav *et al.* (2010) in strawberry.

5.4.2 Number of flowers per plant

The number of flowers per plant differed significantly among the treatments. The maximum number of flowers per plant (24.21) was recorded in plants applied with T₁₁ (75 % RDF through fertigation + *Azotobacter* + PSB + KSB) whereas, minimum number of flowers per plant (17.83) was observed in T₄ (75% RDF through soil application). The increased number of flowers might be due to supply of optimum level of nutrients as N, P and K nutrients and hormones provided by microbial consortium played a significant role in increasing Gibberlic acid in roots thus breaking bud dormancy and increased flowering buds and fruiting sites (Tagliavini *et al.* 2005). Increase in carbohydrate content with NPK and microbial consortium inoculation may be because of their influence on enzyme reaction, formation of metabolites for carbohydrates and proteins, utilization of sugar and starch. Hormones like Auxin, cytokines released by biofertilizers promote flower formation. Khalid *et al.* (2013), Rayees *et al.* (2015), Yadav *et al.* (2010), Arancon *et al.* (2004) and Wang and Lin (2002), Sahoo and Singh (2005) obtained similar results in strawberry.

5.5 Effect of fertigation and liquid PGPR on yield parameters of strawberry

5.5.1 Number of berries per plant

Berry number significantly increased with respect to fertigation treatments. The maximum number of berries per plant (21.00) was recorded in T₁₁ (75 % RDF through fertigation + *Azotobacter* + PSB + KSB) whereas T₄ (75 % RDF through soil application) produced minimum number of fruits per plant (15.03). The increase in per cent fruit set and number of fruits per plant with the application of 75% RDF through fertigation + *Azotobacter* + PSB + KSB (T₁₁) might be due to production of more photosynthates because of more number of trifoliate leaves and leaf area besides enhanced physiological traits further resulted in better transfer to the sink (Jeyakumar *et al.*, 2010). The increase in number of fruits per plant might also be due to the

application of recommended dose of fertilizer along with microbial consortium. The increased phosphorus availability through phosphorous solubilizing bacteria and IAA from *Azotobacter* might have increased various endogenous hormonal levels in plant tissue responsible for enhanced pollen germination and pollen tube formation which might have ultimately led to increased fruit set and number of fruits per plant. These results are in accordance with the earlier findings of Yadav *et al.* (2010), Macit *et al.* (2007), Khalid *et al.* (2013) in strawberry, Dheware and Waghmare, (2009) in sweet orange.

5.5.2 Berry weight

The berry weight was significantly differed with fertigation and liquid PGPR treatments of strawberry plants. The maximum berry weight (20.90 g) was recorded in T₁₁ (75 % RDF through fertigation + *Azotobacter* + PSB + KSB). The minimum berry weight (14.80 g) was recorded in T₄ (75% RDF through soil application). The combined application of NPK along with *Azotobacter*, PSB and KSB might have increased fruit weight due to cumulative effect of increased population of bacteria at balanced dose of NPK which in turn increased biological nitrogen fixation and production of growth regulators by *Azotobacter* in root zone. The applied N, P, K and microbial consortia was were utilized efficiently by the plant which resulted in producing maximum photosynthates in terms of high biomass and translocation of assimilates to the developing sink results in higher fruit weight (Patil and Shinde, 2013). These results are in line with the findings of Wange (1996), Rana and Chandel (2003), Sahoo and Singh (2005) in strawberry.

5.5.3 Length, diameter and volume of fruit

The results fruit length, fruit diameter and fruit volume showed significant difference among the different treatments. The maximum fruit length of 4.78 cm, diameter of 3.90 cm and volume of 21.67 cc was recorded in T₁₁ (75% RDF through fertigation + *Azotobacter* + PSB + KSB). The active source group is more as affected by optimum supply of macro elements. Once the source is developed, it need to be expressed in terms of sink. So maximum sink capacity in terms of fruit length, diameter and volume are the true character of that treatment. The increase in fruit length, width and volume might also attributed to better fillings of fruits due to balanced uptake of nutrients which resulted better metabolic activities in the plant ultimately led to high protein and carbohydrate synthesis. Besides, nitrogen filling abilities of the microbial inoculants, the capacity to release of phytohormones especially gibberellins which increases the fruit size (Ahmad and Mohammad, 2012). The interactional effect of N, P and K and liquid microbial consortium applied through treatment 75% RDF through fertigation + *Azotobacter* + PSB + KSB might



Plate 7a. Effect of fertigation and liquid PGPR treatments on strawberry



Plate 7b. Effect of fertigation and liquid PGPR treatments on strawberry

have improved cell elongation, cell thickening and fruit development (Ghaderi and Talaie, 2008). These results are in conformity with the findings of Yadav *et al.* (2010), Khalid *et al.* (2013), Nazir *et al.* (2006), Rana and Chandel, (2003) and Umar *et al.* (2009) in strawberry.

5.5.4 Yield per plant and yield per plot

The results of the present study revealed that significant variations for yield per plant was observed in plants subjected to different fertigation treatments. The treatment T₁₁ which received 75% RDF through fertigation + *Azotobacter* + PSB + KSB recorded maximum fruit yield per plant (387.67 g) which is presented in Fig. 2 and the minimum fruit yield per plant (209.33 g) was recorded in T₄ which received 75 per cent RDF through soil application. With respect to yield per plot, T₁₁ (75 % RDF through fertigation + *Azotobacter* + PSB + KSB) recorded maximum fruit yield per plot (4.73 kg) and the minimum fruit yield per plot was recorded in T₄ (2.60 kg) which received 75 per cent RDF through soil application.

The higher yield might be due to increased flowering, more fruit set, higher fruit weight, size and volume. The yield attributes or the sink capacity of crop is determined by its vegetative growth throughout the life cycle of the plant. Vigorous growth is associated with higher sink capacity of a crop and the increase in yield resulted from better root proliferation. In addition, increased nutrient elements in the soil enhanced uptake of nutrients and water caused to higher photosynthesis leading to an increase in assimilation rates (Lieten, 1996). The results are in accordance with the findings of Ahmad and Mohammad (2012), Nazir *et al.* (2006), Umar *et al.* (2009), Macit *et al.* (2007), Rana and Chandel (2003), Zargar *et al.* (2008), Panova *et al.* (1979), Erturk *et al.* (2012), (Sahoo and Singh 2005), Rathi and Bist (2004) and Ram *et al.* (2007) in strawberry, Kuttimani *et al.* (2013) in banana.

5.6 Effect of fertigation and liquid PGPR on fruit quality parameters of strawberry

5.6.1 TSS, Reducing sugars, Non-reducing sugars, Total sugars and Sugars to acid ratio

The data on different quality characteristic of fruits reveals that fertigation and liquid PGPR treatments significantly influenced the above mentioned parameters. The maximum reducing sugars (6.19 %), non-reducing sugars (2.01 %), total sugars (8.20 %) which is presented in Fig.3 and sugars to acid ratio (12.00), TSS content (12.20 °B), was recorded in T₁₁ (75% RDF through fertigation + *Azotobacter* + PSB + KSB).

The increase in TSS and total sugars may be attributed to combined effect of microbial consortium and optimum supply of NPK through fertigation. Absorption of nitrogen may have exerted regulatory role as an important constituent of endogenous factors in affecting the quality of fruit in which carbohydrate is important and during ripening of fruits the carbohydrate reserves of the roots and stem are drawn upon heavily by fruits which might have resulted into higher TSS and sugar contents in fruits (Antipchuk *et al.*, 1982). The increase in TSS and sugars may also be due to nitrogen from different sources that might have increased the vigour of strawberry plants including increased leaf area with higher synthesis of assimilates due to enhanced rate of photosynthesis. Such effects have been attributed to increased rate of translocation of photosynthetic products from source to developing fruits thereby increasing total sugars (Magge, 1963). Due to increase in total sugars sugar to acid ratio was found to be maximum. The current findings are in line with the findings of Ahmad and Mohammad (2012), Umar *et al.* (2009), Singh *et al.* (2010), Mohamed *et al.* (2011), Shehata *et al.* (2011), Pesakovic *et al.* (2013) and Rayees *et al.* (2015) in strawberry, Khalil (2012) in grapes.

5.6.2 Ascorbic acid

The highest ascorbic acid content (68.83 mg/100 g) was recorded in T₁₁ (75 % RDF through fertigation + *Azotobacter* + PSB + KSB) while the minimum was recorded in T₄ (54.17 mg / 100 g). Higher ascorbic acid content with the higher levels of nitrogen might be attributed to increase in synthesis and catalytic activity of several enzymes and co-enzymes which are instrumental in ascorbic acid synthesis (Boora and Singh, 2000). The higher ascorbic acid content may also be due to influence of liquid microbial consortia which might increase the rate of biosynthesis of ascorbic acid from its precursor glucose 6 phosphate which may enhance the ascorbic acid

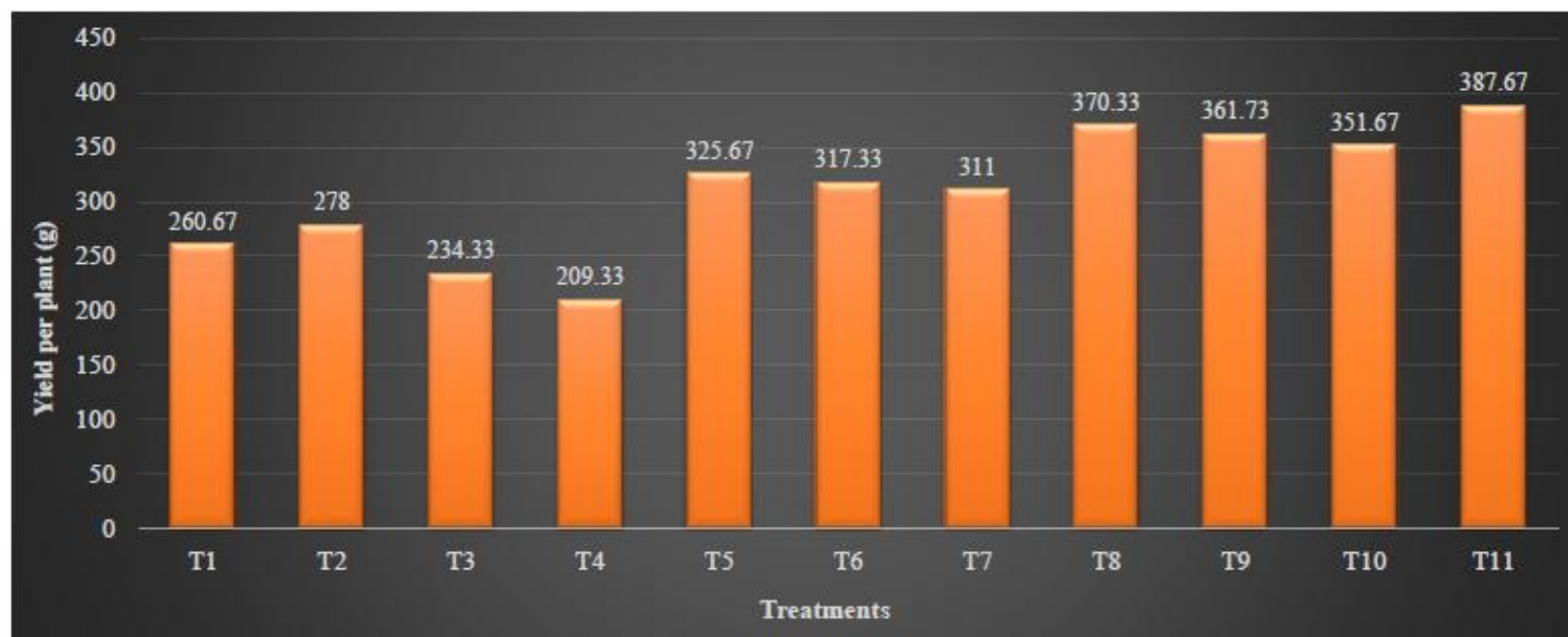


Fig. 2. Effect of fertigation and liquid PGPR on yield per plant (g) of strawberry

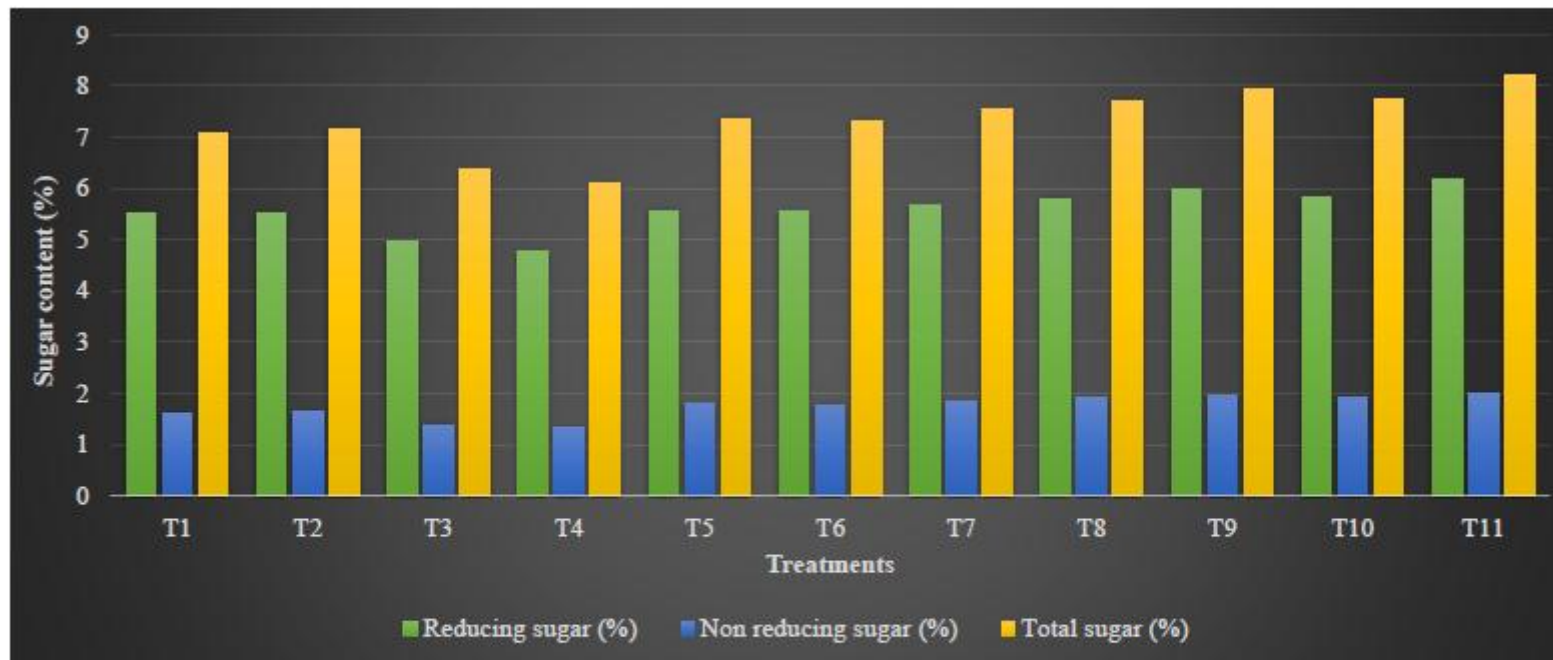


Fig. 3. Effect of fertigation and liquid PGPR on sugar content (%) of strawberry

content. The organic fertilizers are hydrophilic in nature and absorb moisture and nutrients which persist longer thus improving the soil structure and indirectly enhancing fruit quality and ascorbic acid contents (Ali *et al.* 2003). These results are in accordance with findings of Arancon *et al.* (2004) Wang and Lin, (2002), Singh *et al.* (2010) and Ayesha *et al.* (2011) in strawberry.

5.6.3 Shelf life and Titratable acidity

The results depicted that the higher shelf life was observed in T₁₁(2.81 days) which received 75% RDF through fertigation + *Azotobacter* + PSB + KSB which was on par with T₉ (2.77 days) and T₁₀ (2.75 days) which received 75 % RDF through fertigation + *Azotobacter* + KSB and 75 % RDF through fertigation + PSB + KSB respectively. The possible reason for reduction in weight loss and spoilage by microbial consortium might be due to some chemical changes by them within fruits, so that the fruits could retain more water against the force of evaporation and possibly they might have also altered some of the proteinaceous constituents. (Singh *et al.*, 1995).

Titrateable acid content of fruits (Fig. 4) revealed that the fruit acidity was higher (0.91 %) in fruits produced by plants supplied with 75 per cent RDF through soil application (T₄) and the minimum (0.68 %) was recorded in T₁₁ which received 75 % RDF through fertigation + *Azotobacter* + PSB + KSB. The reduction in titrateable acidity may be attributed to the conversion of the organic acids and photosynthates into sugar during fruit ripening by applying biofertilizers (Esitken *et al.*, 2010). The reduction in titrateable acidity may also be due to utilization of acids as a substrate for respiration during the ripening and neutralization of organic acids due to potassium in tissues (Tisdale and Nelson, 1996). The results are in confirmation with the findings of Singh and Singh (2009), Wang and Lin (2002), Khalid *et al.* (2013) and Umar *et al.* (2009) in strawberry.

5.7 Soil nutrients content

Available soil nutrients content were significantly affected by different treatments during this study. The fertigation with 75 per cent recommended dose of NPK through drip along with combined application of *Azotobacter*, phosphate solubilising bacteria and potassium solubilising bacteria improved the soil NPK status in the present study. The increase in soil available NPK might be due to increased number of applications through drip system which might reduce their losses and fixation of nutrients. Fertigation reduced the nutrient leaching below the root zone when compared to conventional method of fertilizer application. The lesser leaching losses occurred under drip system might have due to the fact that NPK fertilizers were applied in small doses through six split applications. These results are in conformity

with those of Weijun *et al.* (2011) who reported that fertigation treatments had higher soil available nutrient concentration than conventional soil fertilization in apricot. *Azotobacter* is a free living nitrogen bacteria, which fix the atmospheric nitrogen in soil, PSB have the ability to solubilize chemically fixed soil phosphorus and phosphatic fertilizer and potassium solubilizing bacteria has the ability to mobilize the elementary or mixture of potassium which can be easily absorbed by plant, it can also enrich the soil. The result and reasons are in agreement with the findings of Bora *et al.* (2002), Medhi *et al.* (2007) and Ram *et al.* (2007).

5.8 Total microbial population in the soil.

Total microbial population was significantly affected by different treatments during this study. The fertigation with 75 per cent recommended dose of NPK through drip along with combined application of *Azotobacter*, phosphate solubilising bacteria and potassium solubilizing bacteria improved the soil microbial count in the present study. The application of microbial consortium eventually increased the counts of bacteria, actinomycetes, and fungi in soil. The increase in bacterial biomass under this treatment might be due to increased microbial activity and multiplication as it was inoculated with microbial consortium. These data were in conformity with the findings of Fan *et al.* (2016) with respect to Kiwi fruit.

5.9 Benefit cost ratio

The benefit cost ratio of different fertigation and liquid PGPR treatments of strawberry differed significantly. The maximum benefit cost ratio (2.90) was obtained from T₁₁ (75% RDF through fertigation + *Azotobacter* + PSB + KSB) which was followed by T₈ (2.59) which received 75 per cent RDF through fertigation + *Azotobacter* + PSB and T₉ (2.45) which received 75 per cent RDF through fertigation+ *Azotobacter* + KSB while the lowest benefit cost ratio (1.66) was observed in T₄ (75 % RDF through soil application). It is clear that higher the yield, higher will be the returns. In addition, the total cost of cultivation and the market price of the produce plays important role with respect to net returns.

Conclusion

On the basis of results obtained from the present investigation it can be concluded that application of 75% RDF through fertigation along with *Azotobacter*, PSB and KSB in liquid form or else application of 75% RDF through fertigation along with *Azotobacter* and PSB showed promising results with respect to growth, yield and quality parameters there by it saved 25 per cent of fertilizers.

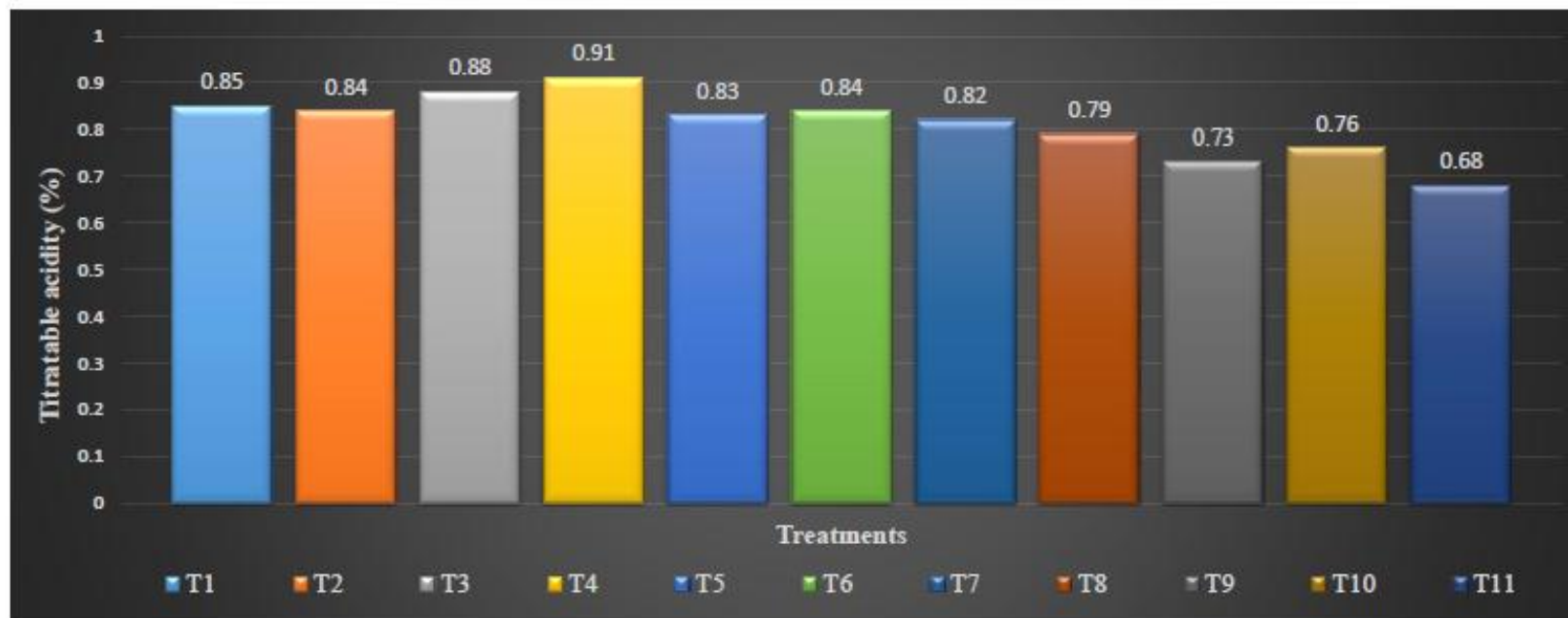


Fig. 4. Effect of fertigation and liquid PGPR on titratable acidity (%) of strawberry

Future line of work

There is enormous scope to conduct research on the following aspects in future,

1. Standardizing the supply of micro nutrients through drip irrigation.
2. Use of different source of manures for increased growth, yield and quality of strawberry.
3. Integrated nutrient management by using inorganic fertilizers through fertigation, organic manures along with biofertilizers needs to be studied.

Summary

VI SUMMARY

The present investigation entitled “Influence of liquid plant growth promoting rhizomicrobial consortia on growth, yield and quality of strawberry (*Fragaria × ananassa* Duch.) under naturally ventilated polyhouse” was carried out in the low cost polyhouse of the Department of Fruit Science, College of Horticulture, Mudigere during 2017-18. The Salient findings of the investigation have been summarized below.

The maximum plant height (34.00 cm), trifoliate leaves (34.03), number of crowns per plant (4.93), and the maximum plant spread in north-south (44.67 cm) and in east-west (43.33 cm) direction was recorded in T₁₁ (75% RDF through fertigation + *Azotobacter* + PSB + KSB) at 120 days after planting.

The plants which are supplied with 75% RDF through fertigation + *Azotobacter* + PSB + KSB (T₁₁) recorded maximum number of runners per plant (2.37). The maximum leaf area and leaf area index (140.17 cm² and 1.46) at 120 days after planting was observed in T₁₁ which was followed by T₈ (138.17cm² and 1.36) provided with 75% RDF through fertigation + *Azotobacter* + PSB.

The maximum plant dry weight of 33.63 g was recorded in T₁₁ which received 75% RDF through fertigation + *Azotobacter* + PSB + KSB which was on par with T₈ (33.00 g) which received 75 per cent RDF through fertigation + *Azotobacter* + PSB.

Treatments showed significant differences with respect to leaf chlorophyll content and the maximum chlorophyll-a content (1.78 mg/g of fresh weight), chlorophyll- b content (0.58 mg/g of fresh weight) and the total chlorophyll content (2.36 mg/g of fresh weight) was recorded in T₁₁ (75% RDF through fertigation + *Azotobacter* + PSB + KSB) which was followed by T₈ (75% RDF through fertigation + *Azotobacter* + PSB + KSB) recorded 1.72, 0.54, 2.26 mg/g of fresh weight of chlorophyll- a, chlorophyll- b and total chlorophyll content respectively.

Significantly minimum number of days (25.00 days) was taken from flower bud initiation to berry maturity in T₁₁ (75% RDF through fertigation + *Azotobacter* + PSB + KSB) which was followed by treatment T₈ (25.89 days) supplied with 75 per cent RDF through fertigation + *Azotobacter* + PSB. The maximum duration of flowering (71.67 days) was recorded in T₁₁ (75% RDF through fertigation + *Azotobacter* + PSB + KSB).

Highest number of flowers per plant (24.21) was recorded in T₁₁ (75% RDF through fertigation + *Azotobacter* + PSB + KSB). Maximum number of berries per plant (21.00), berry weight (20.17 g), fruit yield per plant (387.67 g) and fruit yield per plot (4.73 kg) was recorded in T₁₁ (75 % RDF through fertigation + *Azotobacter* +

PSB + KSB) which was followed by treatment provided with 75 per cent RDF through fertigation + *Azotobacter* + PSB recorded 20.17 berries per plant, 20.13 g of berry weight, 370.33 g of fruit yield per plant, 4.23 kg fruit yield per plot.

Maximum fruit length (4.78 cm), volume (21.67 cc) was recorded in T₁₁ (75 % RDF through fertigation + *Azotobacter* + PSB + KSB) which was on par with T₈ (4.56 cm & 21.23 cc respectively). The maximum fruit diameter of 3.90 cm was recorded in T₁₁, which was on par with T₈ (3.73 cm).

The quality parameters like TSS was found maximum (12.20 °B) in T₁₁ (75 % RDF through fertigation + *Azotobacter* + PSB + KSB) followed by T₉ (11.73 °B). The highest ascorbic acid content (68.83 mg/100 g) was recorded in T₁₁ which was followed by T₉ (67.70 mg/100 g). The minimum titratable acidity (0.68 %) was recorded in T₁₁ followed by T₉ (0.73 %). Whereas sugar to acid ratio was found maximum (12.00) in T₁₁ followed by T₉ (10.86).

The maximum reducing sugar content (6.19 %) was recorded in T₁₁ which is found to be on par with T₉ (5.97 %). With respect to non-reducing sugar content the highest (2.01 %) was observed in T₁₁ (75% RDF through fertigation + *Azotobacter* + PSB + KSB). The maximum total sugar content of 8.20 % was recorded in T₁₁ followed by T₉ (7.93 %).

The highest available N (229.67 kg/ha), P (106.67 kg/ha) and K (595.00 kg/ha) content of soil was recorded in T₁₁ which received 75% RDF through fertigation + *Azotobacter* + PSB + KSB.

The plants which are supplied with 75% RDF through fertigation + *Azotobacter* + PSB + KSB (T₁₁) recorded maximum mean bacterial population (152.67 cfu / g of soil), highest fungal population (37.80 cfu / g of soil), actinomycetes population (25.23 cfu / g of soil), *Azotobacter* population (56.87 cfu / g of soil), PSB (55.23 cfu/g of soil) and KSB population (54.50 cfu / g of soil) at 120 days after planting.

Treatment T₁₁ (75 % RDF through fertigation + *Azotobacter* + PSB + KSB) accounted maximum net income (₹ 323114 for 1032 m² of poly house area) which was followed by T₈ which received 75 per cent RDF through fertigation + *Azotobacter* + PSB (₹ 271021) or 1032 m² poly house area). The maximum benefit cost ratio (2.90) was obtained from T₁₁ which was followed by T₈ (2.59).

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Appendices

VIII APPENDICES

APPENDIX - I

Physical properties of soil from experimental site

Sl. No.	Particulars	Values (%)
a.	Coarse sand	32.43 %
b.	Fine sand	40.82 %
c.	Silt	16.25%
d.	Clay	10.50%

APPENDIX-II

**Monthly mean meteorological data recorded during the experimental year
2017 – 18 recorded at the ZAHRS, Mudigere**

Months	Rainfall (mm)	Relative Humidity (%)	Temperature (° C)	
			Maximum (°C)	Minimum (°C)
April	40.8	75.10	33.76	23.23
May	158.1	84.58	31.54	19.90
June	303.4	85.43	25.36	20.66
July	410.2	85.87	25.35	20.32
August	393.9	85.20	25.50	20.40
September	200	85.16	24.56	20.13
October	66.3	85.19	29.03	20.06
November	12.0	84.40	29.70	20.06
December	10.6	80.00	28.70	20.03
January	0.0	80.48	31.19	20.32
February	0.0	81.89	31.50	20.35
March	29.4	87.80	32.41	20.58

Total annual rainfall- 1624.7 mm

APPENDIX III

Economics of strawberry cultivation under naturally ventilated polyhouse (1032 m²)

Sl. No.	Particulars	Total cost (₹)	Depreciation cost (₹/7 months)
I.	Non-recurring contingency (NRC) (for a life span of 10 years)		
a)	Construction of polyhouse @ ₹ 800/m² Top : UV stabilized polyfilm Side : 70% Agro shade net	825600	48160
b)	Irrigation system and other Irrigation system including fertigation unit, 2 HP motor and electric charges Irrigation equipments and fertilizers storage	160000 30000	11333 1750
	Total of NRC	1015600	61243
II.	Recurring contingency (ORC) for a life span of one season (1032 m²).		
1.	Inputs		
a)	Planting materials (9166 plants/1032 m ² @ 9 ₹/plant)	82494	
b)	Fertilizers (RDF- 150:100:120 kg NPK/ha, FYM- 10t/ha)	120	
	Urea @ 6 ₹/kg	217	
	DAP @ 24 ₹/kg	134	
	MOP @ 16.88 ₹/kg	508	
	Potassium nitrate @ 113 ₹/kg	9810	
	19: 19: 19 @ 180 ₹/kg	27	
	Azotobacter 400 ₹/1000ml	27	
	PSB @ 400 ₹/1000ml	27	
	KSB @ 400 ₹/1000ml	800	
	FYM @ 800 ₹/ton		
c)	Soil sterilization	3000	
	Mulching sheet	10000	
	Plant protection chemicals	1000	
2.	Labour charges		
a)	Bed preparation and mulching (05 labours)	1000	
b)	Planting, weeding, harvesting and (10 labours)	3000	
	Transportation		
	Total	112164	
	Grand total (NRC + ORC)	173407	

Note- Price of strawberry fruits/marketable price at 180 ₹/kg.

Cost of strawberry runners/ marketable price at 4 ₹/ runner

APPENDIX-IV

List of symbols and abbreviations

Symbols	Abbreviations
%	Per cent
@	At
°C	Degree centigrade
C. D.	Critical difference
Cm	Centimetre
cm ²	Centimetre square
cv.	Cultivar
<i>et al.</i>	And others
G	Gram
<i>i.e.</i>	That is
Kg	Kilogram
Mg	Milligram
ml	Millilitre
S. Em ±	Standard Error of Mean
S. D	Standard deviation
<i>viz.</i>	As follows
TSS	Total soluble solids
DAP	Di ammonium phosphate
MOP	Muriate of potash
DAP	Days after planting
MAP	Mono ammonium phosphate
N	Nitrogen
P	Phosphorous
K	Potassium
RDF	Recommended dose of fertilizers
HA	Humic acid
KNO ₃	Potassium nitrate
19:19:19	Equal proportion of NPK