Effect of Bio-fertilizers and Plant Growth Regulators on Growth, Flowering, Fruit Ion Content, Yield and Fruit Quality of Strawberry

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ABSTRACT
A study was undertaken to monitor the interactive effects of bio-fertilizers and plant growth regulators on performance of strawberry grown in open field condition at the Research Farm of Department of Agriculture, Mata Gujri Collage, kharora, Punjab during year 2016-17. Three different bio-fertilizers viz. Azotobacter (10 kg/ha), PSB (6 kg/ha) and VAM (12 kg/ha) and three plant growth regulators viz. GA₃ (100 ppm), Triacontanol (5 ppm) and NAA (50 ppm) were tested individually and in combinations in a randomized block design. The treatment PSB (6 kg/ha) + GA₃ (100 ppm) registered an improved plant growth with least time to produce first flower (57 days) compared to control treatment. The highest fruit length (40.7 mm), fruit width (27.2 mm), fruit weight (14.2 g) and number of fruits per plant (13) were observed in the plants treated with PSB (6 kg/ha) + Triacontanol (5 ppm). The nitrate, ammonium, magnesium, calcium and sulphate content of strawberry fruit were found maximum in the plants treated with Azotobacter (10 kg/ha) + GA₃ (100 ppm). While, the maximum phosphate and potassium contents were obtained from PSB (6 kg/ha) + Triacontanol (5 ppm) treated plants. The plants treated with PSB (6 kg/ha) + Triacontanol (5 ppm) confirmed the highest fruit yield (13.48 t/ha), TSS (11.4 ºB), ascorbic acid (63.67 mg/100g), total sugar (7.7%), reducing sugar (4.9%) and anthocyanin content (1.9). Thus, it can be concluded that an appropriate combination of bio-fertilizers and plant growth regulators may significantly improve the overall plant growth, fruit yield and quality.

Highlights
- The combined application of bio-fertilizers and growth regulators (i.e. PSB@6 kg/ha + GA₃@100 ppm) helped to improve the plant growth with least time to produce first flower.
- The physical characteristics, anion and cation content of strawberry fruit were positively affected by treating the plants with PSB@6 kg/ha + Triacontanol@5 ppm.
- The plants treated with PSB (6 kg/ha) + Triacontanol (5 ppm) registered a 33.0% higher yield compared to control treatment.
- An appropriate combination of bio-fertilizers and plant growth regulators (e.g. PSB@ 6 kg/ha) + Triacontanol@ 5 ppm) significantly improved the fruit yield and quality of strawberry.

Keywords: Strawberry, bio-fertilizers, plant growth regulators, fruit ion content, yield, quality
cherished in home gardens and commercial fields for its nutritious fruits containing a tantalizing aroma (Kumar et al. 2012). Among the fruit crops, it gives quick returns in shortest possible time with very high returns per unit area on the capital investment. Nutritionally, strawberry is a low calorie carbohydrate fruit but a rich source of vitamin A (60 IU/100g of edible portion), vitamin C (30-120 mg/100g of edible portion), fiber and also has high pectin content (0.55%) available in the form of calcium pectate. Water is a major constituent (90%) of strawberry fruit. Ellagic acid is a naturally occurring plant phenol which has been found to inhibit the cancer disease and asthma through regular consumption (Kumar et al. 2015). In India, Maharashtra is a leading state in production of strawberry fruit. It is also commercially grown in Haryana, Punjab, Uttar Pradesh, Jammu and Kashmir, Uttrakhand and lower hill of Himachal Pradesh (Singh and Saravanan 2012).

Bio-fertilizers are naturally occurring products with living micro-organisms which have no ill effects on plants, soil health and environment (Kumar et al. 2015; Pal et al. 2015). These micro-organisms are either freely living in soil or symbiotic with plant and contribute directly or indirectly towards nitrogen and phosphorous nutrition of plants. Bio-fertilizers are effective in boosting the growth and production of horticultural crops. It has been reported that the use of bio-fertilizers increases the crop yield from 15 to 30% (Singh et al. 2015). Bio-fertilizers also produce hormones, vitamins and other growth factors required for growth and development of plant (Mishra and Tripathi 2011). Apart from several agronomic practices followed in strawberry cultivation, the application of plant growth regulators play an important role in improving both vegetative and reproductive growth (Vishal et al. 2016).

Plant growth regulators are plant hormone enhancers or disrupters which are man-made or naturally derived (Kumar et al. 2012). There is a lot of information that show how plant bio-regulators encourage the biochemical changes in plants, which in turn induce vegetative and reproductive responses. According to one study, Gibberellic acid induces stem and internodes elongation, seed germination, enzyme production during germination and fruit setting and growth (Kumar et al. 2012). The application of gibberellic acid (GA₃) is reported to increase leaf size, petiole length, whereas the application of auxins is also known to impart similar effects (Vishal et al. 2016). The plants treated with Triacontanol may increase the number of roots which in turn can help the plants to take up more nutrients from soil and increase production per plants. Saima et al. (2014) reported the highest number of leaves per plant and leaf area with triacontanol and anthocyanin treated with CCC. According to Jamali et al. (2011) the application salicylic acid (SA) and nickel (Ni) in appropriate proportion may significant increase number of fruits per plant, inflorescences, leaf area per plant and yield. On the other hand, Abdollahi et al. (2012) reported an increased yield, inflorescence and number of fruits per plant when Zinc sulphate (100 mg/l) without Paclobutrazol (PP333) and Boron (H3BO3) application.

Thus, it becomes imperative to study the effect of plant bio-regulators on various physiological processes with the advantage to increase strawberry production (Saima et al. 2014). The present study was thus undertaken to evaluate the most suitable combination of bio-fertilizers and plant growth regulators enhancing the yield and fruit quality of strawberry.

MATERIALS AND METHODS

Study site

The present study was carried out at the Research Farm of Department of Agriculture, Mata Gujri Collage, Kharora, Punjab during year 2016-17 to monitor the interactive effects of bio-fertilizers and plant growth regulators on growth, flowering, fruit ion content, yield and quality of strawberry (Cv. Chandler) grown in open field condition. The study site is situated 13 kilometers away from Sri Fatehgarh Sahib between latitude of 30°56’ N and longitude of 76°40’ E respectively at an altitude of 255 m above mean sea level.

Climate

The climatic condition of study area is sub-tropical with three distinct seasons i.e. winter, summer and rainy. During the winter season (December-January), temperature ranges from 5 to 8°C, while in summer season (May-June) it ranges from 42 to
45°C. Most of rainfall is received from mid of July to end of September after which the intensity of rainfall decreases. The mean annual rainfall of the study area is 670 mm.

The mean monthly maximum temperature was recorded in the range of 21.3-33.5°C with minimum and maximum values in the months of December and July respectively (Fig. 1).

![Fig. 1: Climate of study area](image)

Similar was the trend for mean monthly minimum temperature (7.4-27.2°C). The mean monthly relative humidity RH) at the study area was recorded in the range of 72.8-77.0% with minimum and maximum values for the month of September and August respectively (Fig. 1). The seasonal rainfall was recorded to be 525.2 mm with July being the wettest month (256.1 mm) followed by August (165.6 mm) and month of December contributed to minimum rainfall (1.7 mm). However, no rainfall was contributed by the month of November.

**Field preparation and planting**

Organic manure (FYM) was applied one fortnight before planting the runners and mixed uniformly during field preparation. The field was well prepared by repeated ploughing followed by fine planking to obtain a fine tilth. The soil physical, chemical and biological properties are reported in Table 1. The one year old runners of uniform age and size procured from a strawberry grower from Nauni, Solan (HP) were planted. Before planting, the strawberry runners having cut 2/3rd portion of leaves and roots were treated with 1.0 g Bavistin per litre of water to protect the plant from fungal infection. Raised beds of 15 cm height were prepared for planting the strawberry runners. The runners were planted on raised beds each having a spacing of 1 m × 0.80 m at 40 cm × 20 cm during mid of October 2016. Hand weeding, one at 25-30 days after transplanting (DAT) and second at 50 DAT was done.

**Water and Fertilizer application**

The crop was irrigated through drip system with

| Particulars                                      | Value obtained | Method employed                                      |
|-------------------------------------------------|----------------|------------------------------------------------------|
| Bulk density (mg/m³)                            | 1.48           | Weighing bottle method                               |
| Soil porosity (%)                               | 38.00          | Using the value of bulk density and particles density |
| pH                                              | 6.96           | 1:2 soil suspension method (Jackson, 1973) Digital pH meter |
| EC (dSm⁻¹)                                      | 0.398          | 1:2 soil suspension method (Jackson, 1973) Digital electrical conductivity meter |
| Organic carbon                                  | 0.55           | Walkey and Black rapid titration method (1934)       |
| Available N                                     | 35.596 ppm     | Ion chromatography                                   |
| Available P                                     | 6.794 ppm      | Ion chromatography                                   |
| Available K                                     | 38.123 ppm     | Ion chromatography                                   |
| Available ca                                    | 1198.223 ppm   | Ion chromatography                                   |
| Available Mg                                    | 135.123 ppm    | Ion chromatography                                   |
| Available S                                     | 3.101 ppm      | Ion chromatography                                   |

| Total bacterial count on nutrient agar (× 10⁶ cfu/of soil) | 110 | Serial dilution method |
| Total bacterial count on nutrient agar (× 10⁷ cfu/of soil) | 53  | Serial dilution method |
| Total bacterial count on nutrient agar (× 10⁸ cfu/of soil) | 3   | Serial dilution method |
inline drippers (Fig 2a, b). The water for irrigating the crop was taken from a tube well installed at the experimental site. For the first week of planting the runners, light irrigation was given on daily basis and optimum soil moisture level was maintained in the field as desired. Fertilizers like Urea, DAP (di-ammonium phosphate) and MOP (murate of potash) were used in experimental field to fulfill the recommended dose of fertilizers in strawberry crop. Fertilizers were applied through basal application and split application. The recommended dose of nitrogen and entire quantity of phosphatic and potassic fertilizers were applied as basal. The calculated amount of N:P:K (100:120:80 kg/ha) was applied in two splits i.e. half dose of nitrogen after one month of transplanting and remaining half dose of nitrogen was applied after two months of transplanting.

**Experimental treatments**

The experimental trial was carried out in randomized block design in three replicates with sixteen treatments viz. control (without bio-fertilizer and growth regulator), Azotobacter (10 kg/ha), PSB (6 kg/ha), VAM (12 kg/ha), GA$_3$ (100 ppm), Triacontanol (5 ppm), NAA (50 ppm), Azotobacter (10 kg/ha) + GA$_3$ (100 ppm), PSB (60 kg/ha) + GA$_3$ (100 ppm), VAM (12 kg/ha) + GA$_3$ (100 ppm), Azotobacter (10 kg/ha) + Triacontanol (5 ppm), PSB (6 kg/ha) + Triacontanol (5 ppm), VAM (12 kg/ha) + Triacontanol (5 ppm), Azotobacter (10 kg/ha) + NAA (50 ppm), PSB (60 kg/ha) + NAA 50 ppm), VAM (12 kg/ha) + NAA (50 ppm). The bio-fertilizers and growth regulators were procured from the market.
Preparation and application of stock solution

The stock solution of GA$_3$ (100 ppm), NAA (50 ppm) and Triacortanal (5 ppm) was prepared (w/w) by dissolving 100 mg of GA$_3$, 50 mg NAA, 5 ml of Triacortanal in absolute alcohol. The final volume of one liter was prepared by adding distilled water in a volumetric flask. The randomly selected plants were sprayed with GA$_3$, NAA and Triacortanal. The sprays were applied with the baby - sprayer which was washed thoroughly with water and rinsed with solution before every use. The first application of stock solution was started at 40 DAT of the runners. The second application of GA$_3$ was done at 20 days interval, NAA at the time of flowering (December) and Triacortanal was applied to strawberry plants at the time of fruiting.

Plant protection

Termites were the major pest in the experiment field. The symptoms could be characterized by wilting and drying of whole plant in 45 DAT and that could be seen near the root zone. To control the termites, chloropyriphos 20 EC along with irrigation water was applied and carboryl @ 0.15% was sprayed to control strawberry caterpillars. Blitox @ 0.25% and Bavistin @ 0.2% were sprayed alternatively at the initial stage of growth to protect the plant from fungal attack. Straw mulching (Fig. 3) was done and low tunnels were also used to protect the crop from frost at desired time.

Quality analysis

The biometrical observations were recorded on five randomly selected plants of each treatment. The quality analysis of fruits at harvesting was done using ion chromatography. The quality analysis of fruits at harvesting was done using standard procedure as reported in AOAC (2002).

Statistical analysis

The statistical analysis was done as per design of the experiment as suggested by Panse and Sukhatme (1987) and Ranganna (1995). The interpretation of results is based on ‘F’ test. The critical difference (CD) was worked out for significant treatments.

RESULTS AND DISCUSSION

Effect of bio-fertilizers and growth regulators on growth and flowering of strawberry

The plant growth of strawberry was significantly affected by combined application of bio-fertilizers and growth regulators. The plant growth parameters viz. plant height, plant spread, number of leaves per plant, leaf area were registered maximum and minimum under treatments PSB (6 kg/ha) + GA$_3$ (100 ppm) and control respectively. The maximum plant height, plant spread, number of leaves per plant and leaf area were obtained as 27.2 cm, 27.5 cm, 53 and 98.4 cm$^2$ respectively (Table 2). However, the minimum values of these growth parameters were obtained as 21.1 cm, 17.0 cm, 34 and 81.9 cm$^2$ respectively (Table 2). The least number of days taken to produce first flower (57 days) was recorded under PSB (6 kg/ha) + GA$_3$ (100 ppm) followed by Azotobacter 10 (kg/ha) + GA$_3$ (100 ppm). However, the maximum number of days to produce first flower (69 days) was recorded under control treatment. The increase in plant height, plant spread, number of leaves per plant, days taken to produce first flower and leaf area in relation to application bio-fertilizers and plant growth regulators during the growth period received the support from Sharma and Singh (2009), Mishra and Tripathi (2011), Prasad et al. (2011), Kumar et al. (2012), Nishad et al. (2014), Kumar et al. (2015), Nazir et al. (2015), Rajbhar et al. (2015), Singh et al. (2015), Vishal et al. (2016), Palei et al. (2016). The increase in plant height, plant spread, number of leaves per plant and leaf area of strawberry plant and decrease in days taken to produce first flower may be due the growth regulated by gibberellins by causing cell elongation in mature petiole of strawberry plant system. This could be the fact that gibberellins increased cell division, cell elongation.
and cell length due to increase in epidermal and parenchyma cell. The increase in vegetative growth by PSB was helpful in cell elongation and cell division in meristmatic region of plant due to the production of plant growth substances (NAA and GA). Application of bio-fertilizers such PSB helped to increase the biological nitrogen fixation and availability of phosphorous which is required for strong vegetative growth (Kumar et al. 2015).

The results were also found in conformity with Saravanan et al. (2013) and El-Shabasi et al. (2009), Rajbhar et al. (2015) who reported that GA₃ application increases petiole length and reduces the days required to produce first flower. The increase in vegetative growth and other parameters might be due to the production of more chlorophyll content with inoculation which is due to more leaf area. Better development of root system is possibly due to plant growth hormones like NAA and GA₃ which directly influence the increase in plant growth parameters.

The maximum number of flowers per plant (18) was recorded in PSB (6 kg/ha) + NAA (50 ppm) followed by PSB (6 kg/ha) + Triacontanal (5 ppm), Azotobacter (10 kg/ha) + NAA (50 ppm) and PSB (6 kg/ha) + GA₃ (100 ppm) treated plants which themselves were statistically at par. The result were found in agreement with the finding of Palei et al. (2016) who reported maximum number of flowers from NAA 100 ppm treated plants. The numbers of flowers per plant were obtained more in NAA treated plants due to more number of flowering stocks arisen from those plants as the stimulus (florigen) convert vegetative bud to fruiting bud with the help of exogenously applied NAA.

### Effect of bio-fertilizers and growth regulators on physical characteristics of strawberry fruit

The physical characteristics of strawberry fruit viz. fruit length, fruit width, fruit weight and number of fruits per plant were recorded maximum and minimum under treatments viz. PSB (6 kg/ha) + Triacontanal (5 ppm) and control respectively. The maximum fruit length, width, weight and number of fruits per plant were recorded as 40.7 cm, 27.2 cm, 14.2 g and 13 respectively (Table 3). However, the minimum fruit length, width, weight and number of fruits per plant were obtained as 31.6 cm, 21.1 cm, 9.6 g and 9 respectively. This indicates the beneficial effect of bio-fertilizers and growth regulators on the physical characteristics of strawberry fruit.
cm, 10.5 g and 10 respectively (Table 3). The fruit length and fruit weight were maximum under PSB (6 kg/ha) + Triacontanal (5 ppm) treated plants. The fruit width recorded maximum under PSB (6 kg/ha) + Triacontanal (5 ppm) followed by Azotobacter (10 kg/ha) + GA₃ (100 ppm) treated plants which themselves were statistically at par. Similarly, number of fruits per plant was recorded maximum under PSB (6 kg/ha) + Triacontanal (5 ppm) followed by Azotobacter (10 kg/ha) + GA₃ (100 ppm) treated plants. From the present study it is reported that the fruit length, fruit width and weight were increased significantly with the use of bio-fertilizers and plant growth regulators. The results obtained were in agreement with the findings of Mishra and Tripathi (2011), Kumar et al. (2012), Khunte et al. (2014) and Nazir et al. (2015) who reported maximum fruit length, fruit width, fruit weight and number of fruits per plant from PSB and Triacontanol treated plants due to increase in the number of roots which in turn helped the plants to take up more nutrients from the soil and increase the yield.

**Table 3: Effect of bio-fertilizers and PGRs on physical characteristics of fruit**

| Treatment | Berry length (mm) | Berry breadth (mm) | Berry weight (g) | Total number of fruit per plant |
|-----------|-------------------|--------------------|-----------------|-------------------------------|
| Control (without bio-fertilizer and growth regulator) | 31.60 | 21.10 | 10.47 | 10.01 |
| Azotobacter (10 Kg/ha) | 36.69 | 23.55 | 11.35 | 12.10 |
| PSB (6Kg/ha) | 33.72 | 25.51 | 12.32 | 10.80 |
| VAM (12 kg/ha) | 37.14 | 25.35 | 11.58 | 12.41 |
| GA₃ (100 ppm) | 38.93 | 25.75 | 13.40 | 12.06 |
| Triacontanal (5 ppm) | 36.68 | 24.81 | 12.49 | 10.88 |
| NAA (50 ppm) | 39.00 | 23.95 | 13.37 | 10.76 |
| Azotobacter (10 kg/ha) + GA₃ (100 ppm) | 35.89 | 26.91 | 12.35 | 12.06 |
| PSB (6 kg/ha) + GA₃ (100 ppm) | 39.26 | 26.69 | 14.09 | 13.00 |
| VAM (12 kg/ha) + GA₃ (100 ppm) | 35.72 | 25.62 | 11.66 | 12.05 |
| Azotobacter (10 kg/ha) + Triacontanal (5 ppm) | 34.20 | 23.10 | 11.65 | 11.59 |
| PSB (6 kg/ha) + Triacontanal (5 ppm) | 40.71 | 27.17 | 14.18 | 13.31 |
| VAM (12 kg/ha) + Triacontanal (5 ppm) | 36.73 | 23.78 | 12.20 | 11.10 |
| Azotobacter (10 kg/ha) + NAA (50 ppm) | 39.00 | 24.94 | 12.00 | 12.09 |
| PSB (6 kg/ha) + NAA (50 ppm) | 38.76 | 25.36 | 12.12 | 13.14 |
| VAM (12 kg/ha) + NAA (50 ppm) | 36.84 | 23.56 | 12.24 | 12.03 |
| Standard error of mean | 0.54 | 0.48 | 0.24 | 0.11 |
| CD (0.05) | 1.57 | 1.41 | 0.70 | 0.32 |

Effect of bio-fertilizers and growth regulators on anion and cation concentration of strawberry fruit

The anion and cation concentration in strawberry fruit was significantly affected by the interactive application of bio-fertilizers and growth regulators. The nitrate content in strawberry fruits was recorded maximum (29.3 ppm) in plants treated with Azotobacter (10 kg/ha) + GA₃ (100 ppm) followed by Azotobacter (10 kg/ha) + Triacontanol (5 ppm), Azotobacter (10 kg/ha) + NAA (50 ppm) and Azotobacter (10 kg/ha) + NAA (50 ppm) treated plants (Table 4). Similarly, the ammonium content (44.59 ppm), magnesium content (549.03 ppm), calcium content (3665.22 ppm) and sulphate content (113.62 ppm) were recorded maximum in the fruits produced from the plants treated with Azotobacter (10 kg/ha) + GA₃ (100 ppm). However, the phosphate (295.07 ppm) and potassium content (1783.09 ppm) were recorded maximum under PSB (6 kg/ha) + Triacontanal (5 ppm) treated plants.
Table 4: Effect of bio-fertilizers and PGRs on anion and cation content of fruit

| Treatment                          | Nitrate content (ppm) | Ammonium content (ppm) | Phosphate content (ppm) | Potassium content (ppm) | Magnesium content (ppm) | Calcium content (ppm) | Sulphate content (ppm) |
|------------------------------------|-----------------------|------------------------|-------------------------|-------------------------|-------------------------|------------------------|------------------------|
| Control (without bio-fertilizer and growth regulator) | 21.33 | 38.97 | 284.72 | 1743.67 | 539.40 | 3283.05 | 103.52 |
| Azotobacter (10 Kg/ha)             | 25.32 | 43.02 | 287.11 | 1775.63 | 544.93 | 3358.62 | 106.37 |
| PSB (6kg/ha)                       | 22.86 | 40.72 | 289.78 | 1778.03 | 541.78 | 3343.44 | 105.03 |
| VAM (12 kg/ha)                     | 23.07 | 41.92 | 287.66 | 1767.80 | 542.11 | 3344.00 | 105.73 |
| GA₃ (100 ppm)                      | 22.88 | 40.59 | 286.63 | 1746.90 | 540.59 | 3299.19 | 104.92 |
| Triacontanal (5 ppm)               | 22.62 | 40.63 | 286.84 | 1754.51 | 540.81 | 3310.22 | 104.88 |
| NAA (50 ppm)                       | 22.35 | 40.89 | 286.88 | 1756.37 | 540.76 | 3304.21 | 104.87 |
| Azotobacter (10 kg/ha) + GA₃ (100 ppm) | 29.29 | 44.59 | 287.55 | 1777.92 | 549.03 | 3665.22 | 113.62 |
| PSB (6 kg/ha) + GA₃ (100 ppm)      | 26.15 | 41.74 | 291.88 | 1781.99 | 544.05 | 3421.59 | 105.70 |
| VAM (12 kg/ha) + GA₃ (100 ppm)     | 27.63 | 42.36 | 287.29 | 1768.89 | 546.47 | 3467.30 | 107.73 |
| Azotobacter (10 kg/ha) + Triacontanal (5 ppm) | 28.99 | 43.48 | 288.70 | 1769.73 | 545.70 | 3450.88 | 109.19 |
| PSB (6 kg/ha) + Triacontanal (5 ppm) | 27.62 | 42.20 | 295.07 | 1783.09 | 543.41 | 3500.29 | 107.57 |
| VAM (12 kg/ha) + Triacontanal (5 ppm) | 27.91 | 42.86 | 287.63 | 1768.95 | 543.63 | 3437.19 | 107.52 |
| Azotobacter (10 kg/ha) + NAA (50 ppm) | 28.91 | 43.48 | 287.73 | 1769.81 | 544.59 | 3451.37 | 108.66 |
| PSB (6 kg/ha) + NAA (50 ppm)       | 27.91 | 41.50 | 288.43 | 1773.58 | 543.86 | 3417.37 | 106.17 |
| VAM (12 kg/ha) + NAA (50 ppm)      | 28.70 | 41.60 | 287.48 | 1767.96 | 544.56 | 3436.44 | 107.81 |

| Treatment                          | TSS (ºB) | Titratable acidity (%) | Ascorbic acid (mg/100g) | Total Sugar (%) | Reducing Sugar (%) | Non reducing Sugar (%) | Anthocyanin Content (at 530 nm) | Yield per hectare (t/ha) |
|------------------------------------|----------|------------------------|-------------------------|-----------------|-------------------|-----------------------|-------------------------------|-------------------------|
| Control (without bio-fertilizer and growth regulator) | 8.51 | 0.91 | 50.93 | 6.41 | 4.14 | 2.19 | 0.390 | 10.10 |
| Azotobacter (10 Kg/ha)             | 9.05     | 0.84 | 53.60 | 6.46 | 4.22 | 2.24 | 0.88  | 12.61 |
| PSB (6kg/ha)                       | 10.14    | 0.81 | 55.33 | 6.93 | 4.63 | 2.31 | 1.11  | 12.77 |
| VAM (12 kg/ha)                     | 10.04    | 0.85 | 54.01 | 7.01 | 4.66 | 2.36 | 0.64  | 12.71 |
| GA₃ (100 ppm)                      | 10.44    | 0.77 | 61.29 | 7.18 | 4.73 | 2.43 | 0.67  | 13.19 |
| Triacontanal (5 ppm)               | 9.74     | 0.66 | 59.77 | 7.21 | 4.72 | 2.50 | 1.11  | 13.16 |
| NAA (50 ppm)                       | 9.92     | 0.85 | 57.51 | 7.33 | 4.49 | 2.85 | 1.05  | 13.11 |
| Azotobacter (10 kg/ha) + GA₃ (100 ppm) | 10.24 | 0.77 | 59.95 | 7.35 | 4.59 | 2.75 | 0.90  | 13.13 |
| PSB (6 kg/ha) + GA₃ (100 ppm)      | 10.91    | 0.70 | 62.44 | 7.64 | 4.80 | 2.87 | 0.87  | 13.25 |
| VAM (12 kg/ha) + GA₃ (100 ppm)     | 10.31    | 0.73 | 57.10 | 7.63 | 4.58 | 3.03 | 1.32  | 12.92 |
| Azotobacter (10 kg/ha) + Triacontanal (5 ppm) | 10.09 | 0.75 | 52.86 | 7.58 | 4.50 | 3.01 | 0.89  | 12.84 |
| PSB (6 kg/ha) + Triacontanal (5 ppm) | 11.42 | 0.61 | 63.68 | 7.66 | 4.88 | 2.89 | 1.89  | 13.48 |
| VAM (12 kg/ha) + Triacontanal (5 ppm) | 10.17 | 0.75 | 59.84 | 6.73 | 4.44 | 2.30 | 0.48  | 12.71 |
| Azotobacter (10 kg/ha) + NAA (50 ppm) | 10.33 | 0.86 | 58.85 | 6.79 | 4.34 | 2.45 | 0.49  | 12.86 |
| PSB (6 kg/ha) + NAA (50 ppm)       | 9.45     | 0.71 | 57.79 | 7.21 | 4.29 | 2.93 | 0.45  | 13.05 |
| VAM (12 kg/ha) + NAA (50 ppm)      | 9.92     | 0.74 | 56.69 | 7.07 | 4.25 | 2.85 | 0.49  | 13.10 |

| Treatment                          | Standard error of mean | CD (0.05) |
|------------------------------------|------------------------|-----------|
| Control (without bio-fertilizer and growth regulator) | 0.07 | 0.20 |
| Azotobacter (10 Kg/ha)             | 0.01 | 0.04 |
| PSB (6kg/ha)                       | 0.01 | 0.12 |
| VAM (12 kg/ha)                     | 0.01 | 0.02 |
| GA₃ (100 ppm)                      | 0.01 | 0.05 |
| Triacontanal (5 ppm)               | 0.01 | 0.04 |
| NAA (50 ppm)                       | 0.03 | 0.03 |
| Azotobacter (10 kg/ha) + GA₃ (100 ppm) | 0.03 | 0.04 |
| PSB (6 kg/ha) + GA₃ (100 ppm)      | 0.04 | 0.04 |
| VAM (12 kg/ha) + GA₃ (100 ppm)     | 0.03 | 0.03 |
Effect of bio-fertilizers and growth regulators on fruit yield of strawberry

On the basis of present investigation, it is reported that the fruit yield of strawberry was significantly affected with the use of bio-fertilizers and plant growth regulators under different treatment combinations. The maximum fruit yield (13.5 t/ha) was recorded in PSB (6 kg/ha) + Triacontanol (5 ppm) followed by PSB (6 kg/ha) + GA$_3$ (100 ppm) and the minimum value (10.1 t/ha) was obtained in control treatment (Table 5). Kachwaya et al. (2018) reported the highest yield of strawberry grown in open field conditions as 15.2 and 17.3 t/ha with drip irrigation at 120% of ET$_c$ during year 2010 and 2011 respectively. However, the difference in yield of strawberry obtained in the present study in comparison with Kachwaya et al. (2018) may be due to difference in climatic conditions of the study areas and difference in study objectives. The results of presented here were in good agreement with the findings of Mishra and Tripathi (2011), Kumar et al. (2012) and Nazir et al. (2015) who reported maximum TSS, ascorbic acid, total sugar and reducing sugar and minimum titratable acidity from PSB + Triacontanol treated plants. The TSS, ascorbic acid, total sugar and reducing sugar and minimum titratable acidity was more in Triacontanol treated plants mainly due to increased number of roots which causes plant to take up more nutrients from the soil and increase production. The results were in agreement with the findings of Singh et al. (2009) in ber, Baksh et al. (2008) in guava. The respective increase in ascorbic acid content might be due to increased efficiency of microbial inoculants to fix atmospheric nitrogen, increase in availability of phosphorous and secretion of growth promoting substances which accelerates the physiological process like carbohydrates synthesis etc. The maximum non-reducing sugar (3.03%) was recorded in VAM (12 kg/ha) + GA$_3$ (100 ppm) treated plants which was statistically at par with that obtained in Azotobacter (10 kg/ha) + Triacontanol (5 ppm) treated plants. However, minimum non reducing sugar was recorded in Control treatment and the results were found in a good agreement with the findings of Thakur et al. (2016) and Saima et al. (2014).

CONCLUSION

The combined application of bio-fertilizers and growth regulators (i.e. PSB@6 kg/ha + GA$_3$@100 ppm) helped in increasing the average plant height, plant spread, number of leaves and leaf area with least time to produce first flower compared to other treatments. The physical characteristics of strawberry fruit were significantly affected by treating the plants with PSB (6 kg/ha) + Triacontanol (5 ppm). The anion and cation content of strawberry fruit were also positively affected by application of bio-fertilizers and growth regulators. The plants treated with PSB (6 kg/ha) + Triacontanol (5 ppm) confirmed the highest fruit yield (13.5 t/ha), TSS (11.4 °B), ascorbic acid (63.67 mg/100g of fruit pulp), total sugar (7.7%), reducing sugar (4.9%) and anthocyanin content at 530 nm (1.9). The plants treated with PSB (6 kg/ha) + Triacontanol (5 ppm) registered a 33.0% higher yield compared to the findings of Mishra and Tripathi (2011), Khunte et al. (2014), Kumar et al. (2015) and Nazir et al. (2015) who reported maximum TSS, ascorbic acid, total sugar and reducing sugar and minimum titratable acidity from PSB + Triacontanol treated plants. The TSS, ascorbic acid, total sugar and reducing sugar and minimum titratable acidity was more in Triacontanol treated plants mainly due to increased number of roots which causes plant to take up more nutrients from the soil and increase production. The results were in agreement with the findings of Singh et al. (2009) in ber, Baksh et al. (2008) in guava. The respective increase in ascorbic acid content might be due to increased efficiency of microbial inoculants to fix atmospheric nitrogen, increase in availability of phosphorous and secretion of growth promoting substances which accelerates the physiological process like carbohydrates synthesis etc. The maximum non-reducing sugar (3.03%) was recorded in VAM (12 kg/ha) + GA$_3$ (100 ppm) treated plants which was statistically at par with that obtained in Azotobacter (10 kg/ha) + Triacontanol (5 ppm) treated plants. However, minimum non reducing sugar was recorded in Control treatment and the results were found in a good agreement with the findings of Thakur et al. (2016) and Saima et al. (2014).

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growth regulators may significantly improve the overall plant growth, flowering, fruit ion content, fruit yield and quality.

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