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SOIL SCIENCE

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

Manish Kumar Sood, Dilip Singh Kachawaya and Mahesh Chand Singh*

Department of agriculture, Mata Gujri College, Fatehgarh Sahib-140406, Punjab, India

*Corresponding author: mahesh_25_pau@yahoo.co.in (**ORCID ID:** 0000-0002-2937-8475)

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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. GA_3 (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) + GA_3 (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) + GA_3 (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 + GA_3@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

Strawberry (*Fragaria* × *ananassa* Duch.) is one of the most delicious and nutritious soft fruits of the world (Singh *et al.* 2007). It is herbaceous perennial and short day plant cultivated in more than 75 countries. The juicy flesh of strawberry is used in production of alcoholic beverages and fruit wines. A change in chemical and physical properties of strawberry fruits and products is chiefly related to the processing operations (Hendawi *et al*. 2013). The modern cultivated strawberry is a hybrid crop evolved by crossing two species, *Fragaria chilonensis* and *Fragaria virginiana.* Strawberry is a member of Rosaceae family with an octaploid chromosome number of 2n= 56 (Vishal *et al*. 2016). Strawberry is 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 (GA_3) 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).

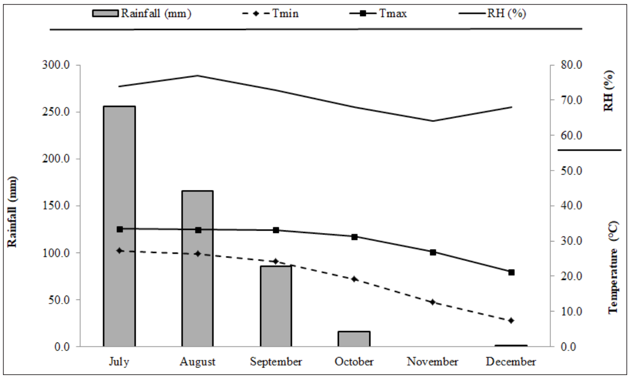

Fig. 1: Climate of study area

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

Table 1: Soil physical, chemical and biological properties

Particulars	Value obtained	Method employed
Bulk density (mg/m^{-3})	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 (× 10^6 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

(a)

(b)

Fig. 2a, b: A view of drip irrigated strawberry crop grown on beds

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 Triacontanal (5 ppm) was prepared (w/w) by dissolving 100 mg of GA_3, 50 mg NAA, 5 ml of Triacontanal 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 Triacontanal. 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 Triacontanal 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.

Fig. 3: Drip irrigated and mulched strawberry crop

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 theses 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 and 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

Table 2: Effect of bio-fertilizer and plant growth regulator on growth and flowering of strawberry

Treatment	Plant height (cm)	Plant spread (cm)	Number of leave per plant	Leaf area (cm^2)	Days taken to produce first flower	Number of flowers per plant
Control (without bio-fertilizer and growth regulator)	21.10	17.04	33.86	81.93	68.92	13.85
Azotobacter (10 Kg/ha)	25.72	22.8	36.34	88.05	62.05	16.82
PSB (6Kg/ha)	25.85	22.00	40.48	89.47	59.96	15.21
VAM (12 kg/ha)	25.80	21.84	39.41	88.23	60.10	16.91
GA_3(100 ppm)	26.11	24.89	48.80	97.96	58.88	16.79
Triacontanal (5 ppm)	25.81	21.56	36.46	91.81	60.16	16.78
NAA (50 ppm)	25.69	22.50	45.33	89.78	60.16	16.79
Azotobacter (10 kg/ha) + GA_3 (100 ppm)	26.91	26.05	50.85	95.05	58.03	16.72
PSB (6 kg/ha) + GA_3 (100 ppm)	27.17	27.47	52.48	98.39	57.05	17.39
VAM (12 kg/ha)+ GA_3 (100 ppm)	25.95	21.66	43.47	90.38	60.18	16.77
Azotobacter (10 kg/ha) + Triacontanal (5 ppm)	23.10	22.06	36.82	88.95	61.04	16.85
PSB (6 kg/ha) + Triacontanal (5 ppm)	24.62	24.29	50.36	95.66	60.28	17.83
VAM (12 kg/ha) + Triacontanal (5 ppm)	23.78	21.92	39.31	93.73	60.51	16.51
Azotobacter (10 kg/ha) + NAA (50 ppm)	24.94	23.40	37.26	90.73	60.46	17.48
PSB (6 kg/ha) + NAA (50 ppm)	25.36	22.39	36.76	92.21	60.73	18.18
VAM (12 kg/ha) + NAA (50 ppm)	25.35	21.45	42.76	90.15	59.91	17.01
Standard error of mean	0.40	0.57	0.72	0.37	0.49	0.40
CD (0.05)	**1.17**	**1.65**	**1.96**	**1.09**	**1.42**	**1.16**

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 GA_3 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 GA_3 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) + GA_3 (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

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	25.35	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
GA_3(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) + GA_3 (100 ppm)	35.89	26.91	12.35	12.06
PSB (6 kg/ha) + GA_3 (100 ppm)	39.26	26.69	14.09	13.00
VAM (12 kg/ha)+ GA_3 (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)	38.64	25.35	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

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) followed by PSB (6 kg/ha) + GA_3 (100 ppm) treated plants. The fruit width recorded maximum under PSB (6 kg/ha) + Triacontanal (5 ppm) followed by Azotobacter (10 kg/ha) + GA_3 (100 ppm) and PSB (6 k/ha) + GA_3 (100 ppm) treated plants which themselves were statistically at par. Similarly, number of fruits per plant was recorded maximum under (6 kg/ha) + Triacontanal (5 ppm) followed by PSB 6 (kg/ha) + NAA (50 ppm) and PSB (6 kg/ha) + GA_3 (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.

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) + GA_3 (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) + GA_3 (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
GA_3(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) + GA_3 (100 ppm)	29.29	44.59	287.55	1777.92	549.03	3665.22	113.62
PSB (6 kg/ha) + GA_3 (100 ppm)	26.15	41.74	291.88	1781.99	544.05	3421.59	105.70
VAM (12 kg/ha)+ GA_3 (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
Standard error of mean	0.34	0.23	0.46	1.06	0.23	1.45	0.42
CD (0.05)	0.98	0.68	1.33	3.08	0.68	4.21	1.24

Table 5: Effect of bio-fertilizer and plant growth regulator yield fruit quality of strawberry

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
GA_3(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) + GA_3 (100 ppm)	10.24	0.77	59.95	7.35	4.59	2.75	0.90	13.13
PSB (6 kg/ha) + GA_3 (100 ppm)	10.91	0.70	62.44	7.64	4.80	2.87	0.87	13.25
VAM (12 kg/ha)+ GA_3 (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
Standard error of mean	0.07	0.01	0.44	0.01	0.01	0.01	0.01	0.03
CD (0.05)	0.20	0.04	1.28	0.02	0.05	0.04	0.04	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 the maximum fruit yield from PSB + Triacontanol treated plants and minimum in control. The fruit yield was recorded more in Triacontanol treated plant mainly due to more number of roots absorbing water and nutrients resulting in faster growth (Hochmuth *et al.* 2001; Diengngan *et al*. 2016).

The increase in fruit yield might be due to increased fruit set per plant, increased fruit size and weight which may also be due to the fact that nitrogen fixers and phosphorous solubulizers not only increased the availability of nitrogen and phosphorous to the plants but also increased their translocation from root to flower through plant foliage. These results were also in line with findings of Singh and Singh (2009).

Effect of bio-fertilizers and growth regulators on fruit quality of strawberry

The maximum TSS (11.42 °B), minimum titratable acidity (0.61 %) and maximum ascorbic acid (63.68%) values were recorded in PSB (6 kg/ha) + Triacontanol (5 ppm) treated plants. Similarly, the total sugar (7.76 %) and reducing sugar (4.88%) content were obtained maximum in PSB (6 kg/ha) + Triacontanol (5 ppm) treated plants (Table 5). The results were found in good agreement with 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).

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 control treatment. Thus, it can be concluded that an appropriate combination of bio-fertilizers and plant growth regulators may significantly improve the overall plant growth, flowering, fruit ion content, fruit yield and quality.

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