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Impact of biofertilizers, vermicompost and *Trichoderma* on growth and yield in strawberry (*Fragaria* × *ananassa*) cv. Sweet Charlie

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ABSTRACT

Strawberry (*Fragaria* × *ananassa* Duch.), a popular fruit which is widely cultivated in temperate as well as subtropical climate. It has a unique place among cultivated berry fruits. The present investigation was carried out at the experimental field of Department of Horticulture, Sam Higginbottom University of Agriculture, Technology and Sciences (SHUATS), Prayagraj, India. Growth and yield parameters were recorded in experiment and it was found that maximum plant height, plant spread, number of leaves and leaf area were observed with T_{11} (5 kg ha^{-1} *Trichoderma* + 2.5 t ha^{-1} Vermicompost + 7 kg ha^{-1} *Azotobacter* + 6 kg ha^{-1} PSB + 20 kg ha^{-1} VAM) followed by T_5 (5 kg ha^{-1} *Trichoderma* + 2.5 t ha^{-1} Vermicompost + 7 kg ha^{-1} *Azotobacter*), whereas minimum was reported in control (T_0). Plant height ranged from 12.15 cm and 16.68 cm while plant spread ranged from 12.15 cm to 16.68 cm. Number of leaves per plant ranged from 11.58 to 15.76. The leaf area varied from 64.56 cm^2 to 74.64 cm^2. Maximum yield per plant was recorded in plants treated with T_{11} (5 kg ha^{-1} *Trichoderma* + 2.5 t ha^{-1} Vermicompost +7 kg ha^{-1} *Azotobacter* + 6 kg ha^{-1} PSB + 12 kg ha^{-1} VAM). Fruit yield per plant varied from 53.00 g to 111.08 g in different treatment combinations.

Key words: Biofertilizer, Productivity, Strawberry, *Trichoderma*

Strawberry (*Fragaria* × *ananassa* Duch.) is an attractive and nutritious fruit crop with a pleasant aroma and delicate flavour which belongs to the family Rosaceae. It is a popular soft fruit which can be cultivated in temperate climate and subtropical climate, where irrigation facilities exist. Botanically strawberry fruit are termed as aggregate fruit called etario of achenes. The edible portion of strawberry is succulent thalamus. Strawberry flowers are bisexual and are mostly self-pollinated. The presence of ellagic acid, which prevents cancer and occurrence of heart diseases and abundance of anthocyanins have made it a more valuable fruit (Nazir *et al.* 2012). Organic farming improves soil quality in terms of various parameters, viz. physical, chemical and biological properties, indicating an enhanced soil health and sustainability of crop production (Ramesh *et al* 2010). Amongst the free living nitrogen fixing bacteria, *Azotobacter* is the most intensively investigated genera. Apart from its ability to fix atmospheric nitrogen, *Azotobacter* is also known to synthesis biologically active growth promoting substance such as Indol Acetic Acid (IAA), Gibrellic Acid (GA) and Vitamin-B in culture media. *Azotobacter* fixes atmospheric nitrogen and enhances the production of various fruit crops.

The use of Phosphate Solubilizing Bacteria (PSB) as inoculant simultaneously increases phosphorus uptake by the plant and hence improves the crop yield. Strains belonging to genera Pseudomonas, Bacillus and Rhizobium are amongst most powerful phosphate solubilizers. The principal mechanism for mineral phosphate solubilization is the production of organic acids, and acid phosphates which plays a major role in the mineralization of organic phosphorus in soil. Vesicular Arbuscular Mycorrhizae plays a vital role in establishment, growth and productivity of strawberry plants. VAM fungi can supply phosphorus which effects floral differentiation and growth. Dual inoculation of such fungi with a Rhizobium and other bacterium on plant enhanced the growth and other beneficial effect (Sadhana 2014).

Vermicompost when applied to soil improves the soil physical properties, soil pH, water holding capacity and add micro and macro nutrients to the soil thus increase the nutrient availability and ultimately its absorption by plants. *Trichoderma* is prevalent in almost all types of soil and all types of crop production but naturally their population is too

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low that they cannot be effective. There are two important species of *Trichoderma* which are *Trichoderma harzanium* and *Trichoderma viride*, which are to be known as bio-control agent. *Trichoderma* is very effective in controlling the diseases and hence increases the yield of fruit crops.

In modern day intensive cultivation of crops results in huge application of chemical fertilizers which are not only in short supply and expensive but also pollute the environment, soil and water. Although the chemical fertilizers contribute a lot in fulfilling the nutrient requirement but their regular, excessive and unbalanced use may lead to the health and ecological hazards, depletion of physico-chemical properties of the soil and ultimately poor crop yield. Hence, there is need of alternate source of safe fertilizers which may enhance crop yield without having adverse effects on soil properties.

MATERIALS AND METHODS

The present research work was conducted at Department of Horticulture, Sam Higginbottom University of Agriculture, Technology and Sciences (SHUATS), Prayagraj, India. The experiment was laid out in randomized block design (RBD) with 12 treatments replicated thrice. During the experiment there were three biofertilizers were used, i.e. *Azotobacter* (7 kg ha^{-1}), PSB-phosphate solubilising bacteria (6 kg ha^{-1}) and VAM- vesicular arbuscular mycorrhiza (12 kg ha^{-1}) and vermicompost was applied 2.5 tonnes ha^{-1}. There were 12 treatment combinations and each treatment was replicated thrice. T_0 (Control), T_1 (*Trichoderma* + Vermicompost), T_2 (*Trichoderma* + *Azotobacter*), T_3 (*Trichoderma* + PSB), T_4 (*Trichoderma* + VAM), T_5 (*Trichoderma* + Vermicompost + *Azotobacter*), T_6 (*Trichoderma* + Vermicompost + PSB), T_7 (*Trichoderma* + Vermicompost + VAM), T_8 (*Trichoderma* +Vermicompost + *Azotobacter* + PSB), T_9 (*Trichoderma* + Vermicompost + *Azotobacter* + VAM), T_{10} (*Trichoderma* + Vermicompost + PSB+ VAM), T_{11} (*Trichoderma* + Vermicompost + *Azotobacter* + PSB + VAM). Plant height, plant spread, number of leaves per plant, leaf area per plant and fruit yield per plant were recorded during the investigation.

Method of Application: The runners were treated prior to planting in field. In this method, runners were inoculated using 100 g of bio-fertilizers and 20 g of *Trichoderma*. In a bucket adequate quantity of water mixed properly adding the bio-fertilizes and *Trichoderma* and put in a cool place. Roots of runner were then dipped in this mixture for 3-5 minutes so as to roots get inoculums and then dried for 30 minutes under shade before planting. One year old healthy runner plants of 'Sweet Charlie' cultivar were brought out from Dr. Y.S. Parmar University of Horticulture and Forestry, Nauni, Solan (Himachal Pradesh) were planted on 60 x 60 cm size beds at 30 x 30 cm distance. Among the insect pests, termites were found in soil. Recommended dose of Neem oil was sprayed twice to control the termites in the field. The harvesting of fruits was done when the fruits attained more than 75% colour. The composite sample drawn from experimental field, 10-15 cm depth prior to application of manorial treatments was subjected to mechanical, physical and chemical analysis.

Soil Analysis: The analysis of soil was conducted in soil testing laboratory of Department of Horticulture, Naini Agriculture Institute, SHUATS, Prayagraj U P. Physical analysis of soil components (sand, silt and clay) was done by Boyounce Hydrometer (Piper 1966). Soil pH was recorded by potentimetery (Jackson 1973), organic matter (%) by Walkely (1947), Ec (dS m^{-1} at 25^{0}C) by Ec meter, available N (kg ha^{-1}) by alkaline permagnate method (Subbiah & Asija 1956), available P (kg/ha) by Bray's method (Jackson 1973) and available K (kg/ha) by ammonium acetate method (Jackson 1973).

Statistical analysis: The data recorded during the course of investigation was subjected to statistical analysis described by Panse and Sukhatme (1985). The significance and non-significance of treatment effect was judged with the help of 'F' (variance ratio) table. The significance differences between the mean were tested against the critical difference at 5% probability level.

RESULTS AND DISCUSSION

Pooled data from Table 1 shows the maximum plant height 16.68 cm was observed with T_{11} at 110 DAT followed by 15.58 cm with T_5 and 15.53 cm with T_9, 15.37 with T_7 and 15.22 with T_6 which were at par to each other. However, the minimum plant height 12.15 cm was observed with T_0 (RDF). Bio-fertilizers, vermicompost and *Trichoderma* had articulated impact on growth characters of strawberry crop. The expansion in vegetative growth parameters may be because of the generation of more chlorophyll content with inoculation of nitrogen fixers. The other logical explanation behind increased vegetative growth might be the creation of plant growth regulators by microorganism in rhizosphere, which are absorbed by the roots. *Trichoderma* might have an indirect effect on plant growth parameters of strawberry

Table 1 Effect of bio-fertilizers, vermicompost and *Trichoderma* on plant height (cm) of strawberry (*Fragaria* × *ananassa*) cv. Sweet charlie

Treatment	T_0	T_1	T_2	T_3	T_4	T_5	T_6	T_7	T_8	T_9	T_{10}	T_{11}	SE.m (±)	CD (5%)
30 Days	3.50	3.49	3.22	3.25	3.44	3.35	3.38	3.10	3.69	3.96	3.72	4.85	0.09	0.27
60 Days	4.74	4.75	4.97	5.22	4.61	5.25	5.48	4.98	5.00	5.32	4.19	6.11	0.32	0.90
90 Days	7.62	8.19	8.13	8.40	8.44	9.83	8.81	9.56	9.37	10.08	8.27	11.27	0.23	0.67
110 Days	12.15	13.64	13.97	12.8	13.18	15.58	15.22	15.37	14.7	15.53	14.8	16.68	0.37	1.05

Table 2 Effect of bio-fertilizers, vermicompost and *Trichoderma* on plant spread (cm^2) of strawberry (*Fragaria* × *ananassa*) cv. Sweet charlie

Treatment	T_0	T_1	T_2	T_3	T_4	T_5	T_6	T_7	T_8	T_9	T_{10}	T_{11}	SEm (±)	CD (5%)
30 Days	7.89	9.14	8.69	8.46	10.18	9.84	9.58	8.85	8.67	8.69	9.09	9.35	0.22	0.90
60 Days	9.96	10.32	11.31	11.36	11.23	11.47	11.09	11.40	10.60	11.07	10.63	13.85	0.39	1.11
90 Days	15.60	15.88	17.83	17.32	18.17	19.60	18.88	19.28	18.09	18.42	19.18	20.82	0.54	1.54
110 Days	20.44	22.74	21.44	22.46	22.74	24.00	22.85	23.07	23.64	22.24	21.73	25.20	0.70	1.99

plant because it causes increase in nutrient availability in soil which favors better growth and development of plants. This increase in plant height with the application bio-fertilizer, vermicompost and *Trichoderma* over the span of investigation get the support of Singh *et al.* (2015)**,** in strawberry.

Data presented in Table 2 shows that plant spread recorded maximum 25.20 cm in treatment (T_{11}) at 110 DAT followed by 24.00 cm in treatment (T_5) and 23.64 cm in treatment (T_8) which were at par. While, the minimum plant spread 20.44 cm was observed in treatment T_0 (RDF). Application of vemicompost is considered as a rich source of available plant nutrients, growth regulators, enzymes, antifungal and antibacterial compound (Arancon *et al.* 2004). *Azotobacter* is one of the most intensively investigated free living nitrogen fixing bacteria and apart from having ability to fix atmospheric nitrogen it is also known to synthesize biologically active PGRs such as IAA, GA etc. (Yadav *et al.* 2010a), that might be the reason for the plant spread. The similar finding was also reported by Singh *et al.* (2015) in strawberry and Verma and Rao (2013) in banana.

Maximum number of leaves per plant 15.76 cm was observed in treatment (T_{11}) at 110 DAT followed by 15.53 in treatment (T_{10}) and 15.27 in T_7 which were at par to each other (Table 3). While, minimum number of leaves per plant 11.58 was observed with T_0 (RDF). Increase in number of leaves per plant might be due to Azotobacter as it influences the nitrogen, which is the chief constituent of protein that is required for the formation of protoplasm that enhances the cell division as well as cell enlargement. The mechanism by which PSB augments plant growth is by dissolution of phosphate (Nowsheen *et al*. 2006) and through biosynthesis of auxins (Sattar and Gaur 1987) and Indole Acetic Acid

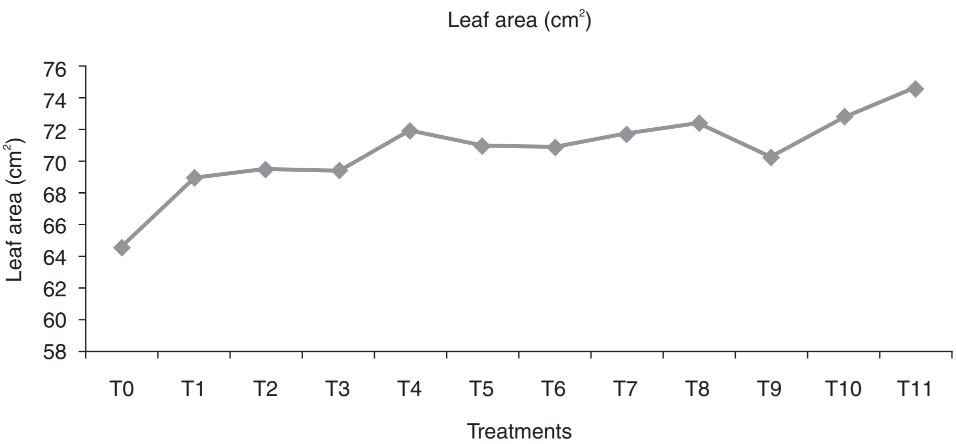

Fig 1 Leaf area (cm^2).

Table 3 Effect of biofertilizers, vermicompost and *Trichoderma* on number of leaves of strawberry (*Fragaria* × *ananassa*) cv. Sweet Charlie

Treatment	T_0	T_1	T_2	T_3	T_4	T_5	T_6	T_7	T_8	T_9	T_{10}	T_{11}	SEm (±)	CD (5%)
30 Days	2.73	3.09	3.41	3.67	3.36	4.05	4.39	3.58	3.62	3.26	3.77	4.61	0.17	0.47
60 Days	4.54	4.78	4.97	5.38	5.54	6.06	6.62	6.52	6.44	6.85	6.91	7.2	0.43	1.22
90 Days	5.67	6.61	6.49	6.97	7.44	7.48	9.65	8.03	7.34	9.83	10.18	10.63	0.53	1.03
110Days	10.61	11.79	12.72	13.15	14.00	15.43	15.54	16.04	13.89	15.63	15.78	16.65	0.5	1.03

Table 4 Effect of biofertilizers, vermicompost and *Trichoderma* on leaf area (cm^2) of strawberry (*Fragaria* × *ananassa*) cv. Sweet charlie

Treatment	T_0	T_1	T_2	T_3	T_4	T_5	T_6	T_7	T_8	T_9	T_{10}	T_{11}	SEm (±)	CD (0.5%)
Leaf area (cm^2)	64.56	68.92	69.52	69.40	71.94	71.00	70.95	71.75	72.41	70.29	72.79	74.64	1.63	4.64

Table 5 Effect of biofertilizers, vermicompost and *Trichoderma* on fruit yield per plant (g) of strawberry (*Fragaria* × *ananassa*) cv. Sweet charlie

Treatment	T_0	T_1	T_2	T_3	T_4	T_5	T_6	T_7	T_8	T_9	T_{10}	T_{11}	SEm (±)	CD 5%
Fruit yield per plant	53.00	66.18	71.44	74.81	71.50	89.79	94.22	103.71	101.45	103.32	104.62	111.08	2.68	7.62

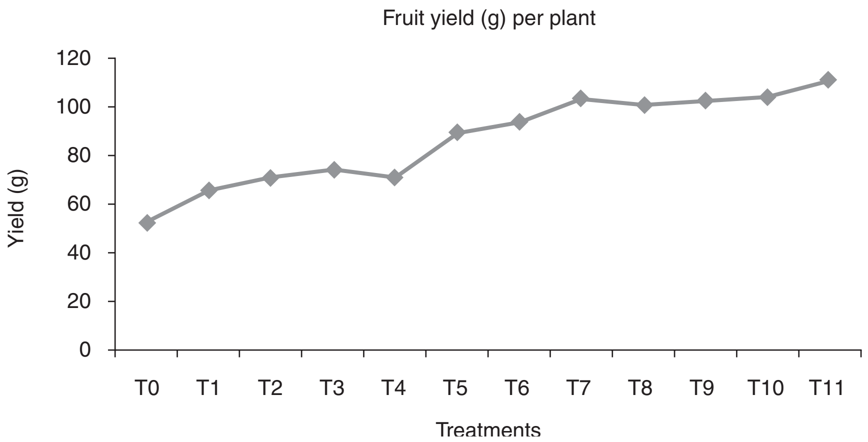

Fig 2 Fruit yield (g) per plant.

(Bareae *et al*. 1976). This increase in number of leaves per plant with the application biofertilizer, vermicompost and *Trichoderma* over the span of investigation gets the backing of Tripathi and Babu (2008) and Singh *et al.* (2015) in strawberry.

Data presented in Table 4 and Fig 1, it is clearly evident that during the year 2013-14, the maximum leaf area was observed 74.64 cm^2 was recorded with T_{11} at 110 DAT followed by 72.79 cm^2 with T_{10} and 72.41 cm^2 with T_8, respectively. The minimum leaf area 64.56 cm^2 was recorded with T_0 (RDF). The leaf area varied from 64.56 cm^2 to 74.64 cm^2. Leaf area was increased significantly with the utilization of biofertilizers, vermicompost and *Trichoderma* at various treatment combinations. Increase in leaf area might be due to increased growth of plant in the form of height and number of leaves, which accumulated more photosynthates and thereby causing increase in leaf area. These results get the backing of Yadav *et al.(* 2010b) and Singh *et al.* (2015) in strawberry.

It was observed that biofertilizers and Vermicompost and *Trichoderma* had remarkable effect on fruit yield of strawberry. Maximum yield per plant was recorded in plants treated with T_{11} (5 kg ha^{-1} *Trichoderma* + 2.5 t ha^{-1} Vermicompost +7 kg ha^{-1} *Azotobacter* + 6 kg ha^{-1} PSB + 12 kg ha^{-1} VAM) Table 5 and Fig 2. Increase in fruit yield may be as a result of increase in the number of leaves which is an efficient photosynthesis structure and help in producing higher amount of carbohydrates in the plants. Beneficial effects of *Azotobacter* might be due to the fixation of atmospheric nitrogen resulting in improvement in growth and flowering characters. Moreover, increase in number of flowers, which also ultimately resulted in higher fruit yield due to capability of vermicompost in producing growth hormone, enzymes, antifungal and antibacterial compounds, which in turn increased the fruit yield. These findings are in line with Singh *et al*. (2015) and Hipparagi *et al*. (2011) in strawberry.

Conclusion

From the results obtained during the present investigation with different treatment combinations of Biofertilizers, Vermicompost and *Trichoderma* on growth and yield in strawberry cv. Sweet Charlie. The maximum plant height, plant spread, number of leaves and leaf area were observed with T_{11} followed by T_5, whereas minimum was reported in untreated plants, i.e. control (T_0). Maximum yield per plant was recorded in treatment T_{11} and fruit yield per plant varied from 53.00 g to 111.08 g in different treatment combinations. On the basis of above findings it may be concluded that for getting substantial higher yield of quality berries with more propagating materials, the plants of strawberry should be treated with Biofertilizers, Vermicompost and *Trichoderma*.

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