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# Impact of drip-bio-fertigation on plant growth, yield and fruit quality of strawberry cultivated in central Indian Punjab

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**Abstract**
A study was carried out to monitor the impact of drip-bio-fertigation on growth, yield and fruit quality of strawberry (cv. Chandler) during year 2017-18. For this purpose, Arka Microbial Consortium (AMC) was procured from Indian Institute of Horticultural Research (IIHR), Bengaluru. The experiment was conducted in a randomized block design with 10 treatments in three replications. Treatments included 100% RDF as control ($T_1$), 100% RDF + PSB @ 7 l/ha ($T_2$), 100% RDF + *Azotobacter* @ 7 Kg/ha ($T_3$), 100% RDF + AMC @ 5 l/ha ($T_4$), 100% RDF + AMC @ 7.5 l/ha ($T_5$), 75% RDF + PSB @ 7 l/ha ($T_6$), 75% RDF + *Azotobacter* @ 7 Kg/ha ($T_7$), 75% RDF + *Azotobacter* @ 7 Kg/ha + PSB @ 7 l/ha ($T_8$), 75% RDF + AMC @ 5 l/ha ($T_9$), 75% RDF + AMC @ 7.5 l/ha ($T_{10}$). The plant growth parameters *viz*. height (22.66 cm), spread (32.66 cm), number of leaves (30/plant), leaf area (135 $cm^2$), LAI (4.52), leaf fresh weight (55.66 g) and leaf dry weight (11.46 g) were recorded to be highest under T3 among all the treatments. However, The physical and chemical characteristics of strawberry fruit *viz*. length (43.4 mm), breadth (30.69 mm), weight (16.1 g), TSS (12.9 $^0$Brix), ascorbic acid (59.21 mg/100g), total sugar (6.41 %), reducing sugar (3.26 %) and non-reducing sugar (3.15 %) were recorded to be maximum under $T_5$ among all treatments. The benefit-cost ratio were computed to be in the range of 2.38-2.96 with highest value under the combination, 100% RDF + AMC @ 7.5 l/ha. The application of *Azotobacter* @ 7 kg/ha + 100 % RDF and 100% RDF + AMC @ 7.5 l/ha helped to improve the plant growth and fruit yield respectively.

**Keywords:** Strawberry, AMC, growth, and quality

## Introduction

Strawberry (*Fragaria* x *ananassa* Duch.) belonging to Rosaceae family has gained the status of being one of the most important soft fruit of the world. The strawberry cultivation in India is gaining momentum and the area under it is increasing promptly for the sake of achieving higher returns (Kachwaya and Chandel 2015) [11]. It is herbaceous crop with prostate growth habit, which behaves as an annual in sub-tropical region and perennial in temperature region. Strawberry is used as fresh fruit being rich in vitamin C and ellagic acid, which has anti cancerous property. Fruits are attractive with distinct pleasant aroma and flavour, consumed as dessert and also have a demand for the preparation of jams, ice cream, syrups etc. (Singh *et al.* 2015) [19]. Strawberry fruit has high levels of antioxidant properties that aids in slow ageing, prevent urinary tract infection and has ability to reduce blood sugar (Villagran 2001) [22]. It is amongst the few crops, which gives quick and very high returns per unit area on the capital investment, as the crop comes ready for harvest within six months of planting under open field conditions. USA is the leading producer of strawberry in the world. In India, it is generally grown in hilly and cool climatic zones of the country (Changotra *et al*. 2017) [4]. In India it is being cultivated in the states of Punjab, Haryana, Maharashtra, Himachal Pradesh, Jammu and Kashmir including some hilly regions of Uttar Pradesh with Maharashtra as a leading state in its production (Baba *et al*. 2018) [3].

At present, strawberry occupies an area of 500 hectare in India with a production of 3800 MT (Anonymous 2017) [2].
Bio-fertigation can precisely deliver the bio inoculants in the root zone of plant (Gomathy *et al*. 2008) [7] thereby resulting in improved water and fertilizer use efficiency. Liquid formulations of microbial inoculants have benefits such as zero contamination, longer shelf life and higher efficiency (Singleton *et al.* 2002) [20]. These liquid formulations of microbial resources could be a potential organic input for precision farming, which can be easily delivered through fertigation system for effective colonization of root zone of plants. Liquid bio-fertilizers are the microbial preparations containing specific beneficial microorganisms which are capable of fixing or solubilizing or mobilizing plant nutrients by their biological activities. Effective microorganisms can also be applied in the field along with inorganic materials (Hussain *et al.* 1999) [9].
Arka Microbial Consortium (AMC) contains N-fixing, P and Zn solubilizing, and plant growth promoting microbes as a single formulation. The novelty of this technology is that there is no need to apply N-fixing, phosphorous solubilizing and growth promoting bacterial inoculants individually. Phosphorus solubilizing bacteria and fungi play a vital role in persuading the insoluble phosphatic compounds such as rock phosphate, bone meal and basic slag and particularly the chemically fixed soil phosphorus into available form. *Azotobacter* belongs to the genus diazotrophic bacteria which is a free-living organism whose resting stage is a cyst. It is abundantly found in neutral to alkaline soils, in aquatic environments, and on some plants. *Azotobacter* is capable of performing several metabolic activities, including atmospheric nitrogen fixation by conversion to ammonia. *Azotobacter* spp. has the highest metabolic rate of any organisms. (Pindi and Satyanarayana 2012) [16].
Bio-fertilizers are naturally occurring products with living microorganisms which are resulted from the roots or cultivated soil and do not have any ill effect on plants, soil health and environment. Besides, their role in fixing atmospheric nitrogen and phosphorous solubilisation, is also helpful in stimulating the plant growth hormones. Bio-fertilizer *viz*. *Azotobacter* and PSB fix atmospheric nitrogen and solubilize phosphorus to increase fertility of soil and increases number of biological activities. Bio-fertilizers are the derived product of living microorganism that are capable to fixing atmospheric nitrogen and also convert insoluble phosphorus to soluble phosphorus for uptake of plants (Kumar *et al*. 2015) [12]. While studying the performance of strawberry grown in open field conditions in relation to differential irrigation scheduling, Kachwaya *et al* (2018) [10] recorded the highest fruit weight of strawberry of 12.2 g and 13.2g for year 2010 and 2011 respectively under drip irrigation at 120% $ET_c$ reporting a total fruit yield of 15.2 t/ha and 17.3 t/ha for two respective years. However, in 2016-17, Sood *et al* (2018) [21] studied the effect of bio-fertilizers and plant growth regulators on growth, flowering, fruit ion content, yield and fruit quality of Strawberry at the same experimental site and reported the height fruit weight of 14.2 g and total yield of 13.5 t/ha under PSB (6 kg/ha) + Triacontanal (5 ppm) treatment. The present study was thus undertaken to study the impact of drip-bio-fertigation on plant growth, yield and fruit quality of strawberry grown in open field condition.

## Material and Methods

The present study was conducted at the Agriculture Research Farm, Department of Agriculture, Mata Gujri College, Fatehgarh Sahib, Punjab. 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. The experimental plot was well prepared by repeated ploughing followed by planking to obtain a fine tilth. Beds each having height of 25 cm was prepared for planting the runners. The strawberry runners having cut the 2/3rd portion of leaves were planted on raised bed of 3 m × 0.80 m size at 40 × 30 cm distance with the help of khurpi on the last week of October and a black polythene sheet of 25 micron is used as mulch.
The field was divided into 30 plots each having dimensions of 3 m × 0.80 m. The experiment was laid out in a randomized block design with ten treatments and three replications. $T_1$ (100% RDF as control), $T_2$ (100% RDF + PSB @ 7 l/ha), $T_3$ (100% RDF + *Azotobacter* @ 7 Kg/ha), $T_4$ (100% RDF + AMC @ 5 l/ha), $T_5$ (100% RDF + AMC @ 7.5 l/ha), $T_6$ (75% RDF + PSB @ 7 l/ha), $T_7$ (75% RDF + *Azotobacter* @ 7 Kg/ha), $T_8$ (75% RDF + *Azotobacter* @ 7 Kg/ha + PSB @ 7 l/ha), $T_9$ (75% RDF + AMC @ 5 l/ha), $T_{10}$ (75% RDF + AMC @ 7.5 l/ha). Water soluble fertilizers, N:P:K (19:19:19), (0:0:50) and Urea were used to fulfill the recommended dose of fertilizers in strawberry crop. The recommended dose of fertilizers (RDF) i.e. 150:100:120 kg/ha was followed. The water soluble bio-fertilizers were applied 40 days after planting in single dose according to various treatment combinations. A known quantity of different water soluble bio-fertilizers was diluted with water in separate container before its application through venturi in drip system.
Observations were recorded on plant height (cm), plant spread (cm), number of leaves, leaf area ($cm^2$), leaf area index, leaf dry weight per plants (g) and leaf fresh weight per plant (g). For determination of physical characteristics of fruit, ten randomly selected fruits from each treatment were analyzed for fruit length (mm), fruit breadth (mm) using digital vernier caliper. Total soluble solids ($^0$Brix) were recorded using hand refractometer. Total sugars, reducing sugar and non-reducing sugar were expressed as percent on fresh fruit weight basis as given in (AOAC 1980) [1]. Anthocyanin content (at OD 530) of berry was determined by the method given in Harborne (1973) [8]. Economic analysis was done on the basis of current market prices of inputs. To analyze treatmental effect, control treatment was considered as a check while calculating the economics of strawberry production. The statistical analysis was done as suggested in Panse and Sukhatme (1985) [15].

## Results and Discussion

### Growth attributes

Different combinations of bio-fertilizer exhibit significant influence on the growth characters in strawberry plants (Table 1). The maximum plant height (22.66 cm), plant spread (32.66 cm), number of leaves per plant (29.66), leaf area (135 $cm^2$), leaf area index (4.52), leaf fresh weight (55.66 g) and leaf dry weight (11.46 g) were recorded with the application of $T_3$ (100% RDF + *Azotobacter* @ 7 Kg/ha). However, minimum plant height (18 cm), plant spread (26.83 cm), number of leaves per plant (23.66), leaf area (126 $cm^2$), leaf area index (4.01), leaf fresh weight (46.66 g) and leaf dry weight (8.33 g) were recorded with the application of $T_6$ (75%

RDF + PSB @ 7 l/ha). Rana and Chandel (2003) [17] reported that the nitrogen integration using combination of inorganic N and *Azotobacter* inoculation produce maximum plant height and number of leaves in strawberry. The addition of bio-fertilizer (*Azotobacter*) might be helpful in nitrogen fixation and quicker source for plant absorption. Higher number of leaves and leaf area might be due to higher cell division caused by cytokinins and also due to higher supply of assimilates mediated by BA application (Dwivedi *et al*. 1999) [15]. The fruiting stage of the crop is demonstrated in Fig. 1.

**Fig 1:** Strawberry at fruiting stage

**Table 1:** Effect of bio-fertigation on Vegetative growth of strawberry

| Treatments | Plant height (cm) | Plant Spread (cm) | No. of leaves/plant | Leaf area ($cm^2$) | LAI | Leaf fresh weight/plant (g) | Leaf dry weight/plant (g) |
|---|---|---|---|---|---|---|---|
| $T_1$ | 18.33 | 27 | 25 | 128 | 4.20 | 47.66 | 8.83 |
| $T_2$ | 19.66 | 28.33 | 27 | 130 | 4.44 | 52 | 9.96 |
| $T_3$ | 22.66 | 32.66 | 29.66 | 135 | 4.52 | 55.66 | 11.46 |
| $T_4$ | 21 | 30.75 | 27.66 | 132 | 4.27 | 51 | 10.66 |
| $T_5$ | 22 | 31.81 | 28.33 | 134 | 4.50 | 53 | 11.33 |
| $T_6$ | 18 | 26.83 | 23.66 | 126 | 4.01 | 46.66 | 8.33 |
| $T_7$ | 19.66 | 27.66 | 24 | 128.33 | 4.20 | 48.66 | 8.76 |
| $T_8$ | 19.66 | 28.18 | 25.66 | 129.66 | 4.23 | 49.66 | 9 |
| $T_9$ | 18.66 | 27.37 | 24 | 127.5 | 4.06 | 47 | 8.83 |
| $T_{10}$ | 19 | 27.44 | 24.33 | 128.33 | 4.23 | 47.66 | 9.06 |
| SE (mean) | ±0.71 | ±0.57 | ±0.77 | ±1.21 | ±0.06 | ±1.18 | ±0.48 |
| CD (0.05) | 2.12 | 1.69 | 2.31 | 3.60 | 0.18 | 3.51 | 1.44 |

**Fruit yield and quality attributes**

The maximum berry length (43.4 mm), berry breadth (30.69 mm), berry weight (16.1 g) were recorded in treatment $T_5$ (100% RDF + AMC @ 7.5 l/ha) however, minimum berry breadth (26.03 mm), berry weight (13.21 g) were recorded in treatment $T_9$ (75% RDF + AMC @ 5 l/ha). However, the minimum values were recorded in treatment $T_1$ (100% RDF as control). The increase may be due to balanced availability of macro and micronutrients and growth promoting hormones produced by different bio-fertilizers applied in different treatment combinations. This may be attributed to better filling of fruits due to more balanced uptake of nutrients which may have lead to better metabolic activities in the plant ultimately leading to high protein and carbohydrate synthesis (Nazir *et al*. 2015) [14].

Total soluble solid (12.9 $^0$Brix), ascorbic acid (59.21 mg/100g), total sugar (6.41 %), reducing sugar (3.26 %), non-reducing sugar (3.15 %) and anthocyanin content (0.216 OD at 530 nm) were recorded to be maximum with the application of $T_5$ (100% RDF + AMC @ 7.5 l/ha). However, the minimum total soluble solid (9.1 $^0$Brix), ascorbic acid (46.66 mg/100g), non-reducing sugar (2.25 %) and anthocyanin content (0.170 OD at 530 nm) were reported with the application of $T_1$ (100% RDF as control). Moreoiver, the minimum total sugar (4.76 %) and reducing sugar (2.12 %) were obtained with the application of $T_6$ (75% RDF + PSB @ 7 l/ha). The increase in TSS and total sugar contents with combination of *Azotobacter* and PSB may be attributed to the quick metabolic transformation of starch and pectin into soluble compounds and rapid translocation of sugars from leaves to the developing fruits (Mishra and Tripathi 2011) [13]. The minimum (0.67 %) and maximum (0.80%) tritratable acidity were recorded with the application of $T_5$ (100% RDF + AMC @ 7.5 l/ha) and $T_1$ (100% RDF as control) respectively. The reduction in titratable acidity may be attributed to conversion of organic acids and photosynthates into sugar during fruit ripening through application of bio-fertilizers (Esitken *et al.* 2010) [6].

The maximum (8.63 t/ha) and minimum (7.11 t/ha) yields were recorded under $T_5$ (100% RDF + AMC @ 7.5 l/ha) and $T_6$ (75% RDF + PSB @ 7 l/ha) respectively. The increase in yield might be due to increased fruit set per plant, increased berry size and weight. The increased yield 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 (Singh and Singh 2009) [18].

**Table 2:** Effect of bio-fertigation on physical and chemical characteristics of fruit

| Treatments | Berry length (mm) | Berry breadth (mm) | Berry weight (g) | TSS ($^0$Brix) | Ascorbic acid (mg/ 100g) | Titratable acidity (%) | Anthocyanin (at OD 530 nm) | Total sugar (%) | Reducing sugar (%) | Non-reducing sugar (%) |
|---|---|---|---|---|---|---|---|---|---|---|
| $T_1$ | 36.98 | 26.9 | 13.72 | 9.1 | 46.66 | 0.80 | 0.170 | 4.82 | 2.57 | 2.25 |
| $T_2$ | 39.78 | 27.76 | 14.92 | 10.9 | 55.78 | 0.72 | 0.185 | 5.59 | 2.93 | 2.66 |
| $T_3$ | 41.81 | 28.61 | 15.24 | 12.1 | 56.31 | 0.69 | 0.210 | 5.91 | 3.11 | 2.8 |
| $T_4$ | 41.18 | 28.94 | 15.77 | 11.8 | 53.28 | 0.74 | 0.193 | 5.53 | 3.10 | 2.42 |
| $T_5$ | 43.4 | 30.69 | 16.1 | 12.9 | 59.21 | 0.67 | 0.216 | 6.41 | 3.26 | 3.15 |
| $T_6$ | 37.76 | 26.63 | 13.37 | 10 | 51.22 | 0.75 | 0.177 | 4.76 | 2.12 | 2.63 |
| $T_7$ | 38.46 | 26.78 | 13.93 | 11 | 52.19 | 0.74 | 0.180 | 5.51 | 2.9 | 2.61 |
| $T_8$ | 39.70 | 27.16 | 14.05 | 11.2 | 53.65 | 0.74 | 0.182 | 5.56 | 2.94 | 2.61 |
| $T_9$ | 37.75 | 26.03 | 13.21 | 9.7 | 48.95 | 0.77 | 0.178 | 4.97 | 2.62 | 2.34 |
| $T_{10}$ | 38.15 | 26.77 | 13.79 | 9.8 | 50.64 | 0.74 | 0.186 | 5.47 | 2.65 | 2.82 |
| SE (mean) | ±0.75 | ±0.62 | ±0.34 | ±0.48 | ±1.53 | ±0.01 | ±0.0032 | ±0.16 | ±0.09 | ±0.14 |
| CD (0.05) | 2.23 | 1.84 | 1.01 | 1.43 | 4.57 | 0.04 | 0.0096 | 0.50 | 0.29 | 0.43 |

## Economic analysis

The cost of cultivation was recorded to be highest (Rs. 4,36,440) under was recorded in treatment $T_2$ (Table 3). The minimum cost (Rs. 4,18,240) of cultivation was recorded in treatment $T_9$. $T_5$ recorded the highest gross income (Rs. 17,26,000), net return (Rs. 12,91,110) and benefit-cost ratio (B:C) of 2.96). However, the minimum gross income (Rs. 14,22,000), net return (Rs. 10,01,910) and B:C of 2.38 were recorded in treatment $T_6$.

**Table 3:** Effect of different treatment combinations on economics of strawberry crop

| Treatments | Total cost of cultivation (Rs./ha) | Yield/ha (t/ha) | Gross income (Rs./ha) | Net return (Rs./ha) | B:C ratio |
|---|---|---|---|---|---|
| $T_1$ | 433990 | 7.48 | 1496000 | 1062010 | 2.44 |
| $T_2$ | 436440 | 7.95 | 1590000 | 1153560 | 2.64 |
| $T_3$ | 434830 | 8.46 | 1692000 | 1257170 | 2.89 |
| $T_4$ | 434590 | 8.24 | 1648000 | 1213410 | 2.79 |
| $T_5$ | 434890 | 8.63 | 1726000 | 1291110 | 2.96 |
| $T_6$ | 420090 | 7.11 | 1422000 | 1001910 | 2.38 |
| $T_7$ | 418480 | 7.4 | 1480000 | 1061520 | 2.53 |
| $T_8$ | 420930 | 7.61 | 1522000 | 1101070 | 2.61 |
| $T_9$ | 418240 | 7.33 | 1466000 | 1047760 | 2.50 |
| $T_{10}$ | 418540 | 7.48 | 1496000 | 1077460 | 2.57 |

## Conclusion

The study reveals that the application of *Azotobacter* @ 7 kg/ha + 100 % RDF significantly affected the plant growth in terms of improved vegetative growth as compare to control treatment including others. Further, the combination, 100% RDF + AMC @ 7.5 l/ha helped to improve the fruit yield and quality in relation to yield and quality attributes with highest B:C ratio of 2.96.

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