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Effect of biofertilizer and photosynthetic bacteria on growth, yield and quality of Strawberry (*Fragaria* × *ananassa* Duch.) cv. winter dawn

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Abstract
The present investigation "Effect of Biofertilizer and Photosynthetic Bacteria on growth, yield and quality of Strawberry (*Fragaria* × *ananassa* Duch.) cv. Winter Dawn" was laid out on the experimental site of Department of Horticulture, Sam Higginbottom University of Agriculture Technology & Sciences, Naini, Prayagraj (UP), during 2023. The present investigation was carried out in randomized block design with 17 treatment which were replicated thrice. The treatments were T_0 (Control), T_1 (RDF + *Azotobacter* 2g/Plant), T_2 (RDF+ *Azotobacter* 3 g/Plant), T_3 (RDF + *Azospirillum* 2g/Plant), T_4 (RDF + *Azospirillum* 3 g/Plant), T_5 (RDF + Photosynthetic bacteria 20 ml/L), T_6 (RDF + Photosynthetic bacteria 30 ml/L), T_7 (RDF + *Azotobacter* 2g/Plant + *Azospirillum* 2g/Plant), T_8 (RDF + *Azotobacter* 3 g/plant + *Azospirillum* 3 g/plant), T_9 (RDF + *Azotobacter* 2 g/plant + PSB 20 ml), T_{10} (RDF + *Azotobacter* 2 g/plant + PSB 30 ml), T_{11} (RDF + *Azotobacter* 3 g/plant + PSB 20 ml), T_{12} (RDF + *Azotobacter* 3 g/plant + PSB 30 ml), T_{13} (RDF + *Azospirillum* 2 g/plant + PSB 20 ml), T_{14} (RDF + *Azospirillum* 2 g/plant + PSB 30 ml), T_{15} (RDF + *Azospirillum* 3 g/plant + PSB 20 ml), T_{16} (RDF + *Azospirillum* 3 g/plant + PSB 30 ml). On the basis of our experimental findings it can be concluded that the treatment T_{16} (RDF + *Azospirillum* 3 g/plant + PSB 30 ml) was found best in terms of growth, yield and quality parameters of Strawberry plants cv. winter dawn.

Keywords: *Azospirillum*, *Azotobacter*, photosynthetic bacteria, yield, quality, RDF

Introduction
Strawberry (*Fragaria* × *ananassa* Duch.), an aggregate fruit of Rosaceae family, occupies a significant place in fruit industry, since it is cultivated both in plains as well as in hills. It is an herbaceous crop with prostate growth habit, which behaves as an annual in sub-tropical region and perennial in temperature region and has gained the status of being one of the most important soft fruits of the world after grape. Being rich in vitamin A (60 IU/100 g), vitamin C (30-120 mg/100 g), fiber, iron, pectin (0.55%) and ellagic acid, strawberry is mainly consumed as fresh fruit. However, it also contains very good amount of phenols, flavonoids, dietary glutathionine that too exhibit a high level of antioxidant capacity against free radicals. Due to very high return per unit area and production of berries within few months of planting, the crop has gained economic importance throughout the world Zargar *et al.* [24] which ultimately increases the area and production of the crop to many folds over the past decades. However, due to shallow root system, large number of fruit production per unit area and sensitivity of the plants to nutritional balance Albregts *et al.*, [2] strawberry needs extensive use of mineral fertilizers as these mineral fertilizers play the fundamental role in determining growth, yield and quality of the fruit. But the inorganic forms of fertilizer are short in supply and very expensive too which ultimately increases the production cost up to 30% Hamlet *et al.* [10] In addition, even though chemical fertilizers are beneficial in increasing the crop yield but at the same time their regular, excessive and imbalance use may lead to health and ecological hazards, depletion of physico-chemical properties of the soil water. Moreover, the production of these chemical fertilizers is an energy intensive process, require energy resources. Further, import of these fertilizers creates pressure on foreign exchange reserves to a great extent. Hence, there is an urgent need to think about the use of alternative source of safe fertilizers which may enhance sustainably of crop yield without

having any adverse effect on soil properties and environmental hazards and also to reduce cost of cultivation. Biofertilizers are considered as economically attractive and ecologically sound route for reducing external inputs augmenting nutrient supply and to improve the quality and quantity of internal resources with maximum outputs. These biofertilizers act as carriers containing beneficial micro-organisms in a viable state, intended for seed or soil application, designed to improve soil fertility status and also helps in plant growth by increasing the number and biological activity of desired microorganisms in root environment Gabr *et al.* [9] Further, they are able to fix atmospheric nitrogen in the range of 20-200 kg N/ha/year; solubilize P in the range of 30-50 kg P2O5/ha/year; mobilize P, Zn, Fe, Mo to varying extent. So far considerable number of bacterial species mostly associated with the plant rhizosphere has been tested and found to be beneficial for plant growth, yield and fruit quality. These includes *Azospirillum*, *Azotobacter*, Pseudomonas Esitken *et al.* [7, 8] etc. De Silva *et al.*, [6] Sudhakar *et al.*, [21] Aslantas *et al.*, [3] Karlıdag *et al*., [7] Kumar *et al.* [22] also reported that these bacteria colonize in the root of the plant and stimulate the growth and increase the yield of different fruit crops such as apple, apricot, blueberry, citrus, cherry, peach, mulberry, strawberry. Hence, the possible solution to lower the risk of accumulation of inorganic source of fertilizer is to combine chemical fertilizers with biofertilizers Adesemoyea *et al.* However, there is scanty information available regarding the potentially of biofertilizer to substitute the amount of inorganic fertilizers for improving the growth, yield and quality of strawberry. Keeping these views in mind, the present investigation was carried out to study the effect of bio-fertilizer and photosynthetic bacteria on growth, yield and quality of strawberry (*Fragaria* × *ananassa* Duch.) cv. Winter dawn.

Materials and Methods

Studies on effect of bio-fertilizers & photosynthetic bacteria on growth, yield and quality of strawberry was carried out on cv. Winter dawn during 2023-24 at Horticulture Research Field of Naini Agricultural Institute, SHUATS, Prayagraj, (Uttar Pradesh). The experiment was laid out in RBD viz. Treatments at 17 levels viz. T_0: control, T_1: RDF + *Azotobacter* (2g/Plant), T_2: RDF+ *Azotobacter* (3 g/Plant), T_3: RDF + *Azospirillum* (2g/Plant), T_4: RDF + *Azospirillum* (3 g/Plant), T_5: RDF + Photosynthetic bacteria (20 ml/L), T_6: RDF + Photosynthetic bacteria (30 ml/L), T_7: RDF + *Azotobacter* (2g/Plant) + *Azospirillum* (2g/Plant), T_8: RDF + *Azotobacter* (3 g/plant) + *Azospirillum* (3 g/plant), T_9: RDF + *Azotobacter* (2 g/plant + PSB 20 ml, T_{10}: RDF + *Azotobacter* (2 g/plant)+ PSB 30 ml, T_{11}: RDF + *Azotobacter* (3 g/plant + PSB 20 ml, T_{12}: RDF + *Azotobacter* (3 g/plant)+ PSB 30 ml, T_{13}: RDF + *Azospirillum* (2 g/plant) + PSB 20 ml, T_{14}: RDF + *Azospirillum* 2 g/plant + PSB 30 ml, T_{15}: RDF + *Azospirillum* 3 g/plant + PSB 20 ml, T_{16}: RDF + *Azospirillum* 3 g/plant + PSB 30 ml. The transplanting was done on 28/10/2023 in field condition. The treatments were applied three times in form of foliar application with the help of knapsack sprayer provided by the department on monthly intervals. Data was analyzed using STAR.

Results and Discussion

Maximum plant height was recorded 22.23 cm with treatment T_{16} (RDF + *Azospirillum* 3 g/plant + PSB 30 ml) and it was followed by 21.89 cm in T_8 (RDF + *Azotobacter* (3 g/plant) + *Azospirillum* (3 g/plant). The minimum plant height of 17.96 cm is recorded under T_0 (control). This increase in height of plant with the application biofertilizers and Photosynthetic bacteria during the course of investigation get the support of Ingle *et al.* (2008) [11] in okra, Poniker *et al.* (2006) [17] in turmeric, Marathe and Bharambe (2005) in sweet orange, Nowsheen *et al.* (2006) [16] and Tripathi *et al.* (2010) [22] in strawberry.

Maximum plant spread was recorded 34.52 cm with treatment T_{16} (RDF + *Azospirillum* 3 g/plant + PSB 30 ml) and it was followed by 33.66cm in T_8 (RDF + *Azotobacter* (3 g/plant) + *Azospirillum* (3 g/plant). The minimum plant spread of 19.51 cm are recorded under T_0 (control). Plant spread is significantly increased in Photosynthetic bacteria and biofertilizers treated plant. These findings are in complete agreement with Nowsheen *et al.* (2006) [16] in strawberry.

Maximum Number of leaves per plant was found in T_{16} (RDF + *Azospirillum* 3 g/plant + PSB 30 ml) (19.45) treated plants, whereas the minimum leaf area recorded under the control (12.01). These findings are in complete agreement with that of Moniem and Rudwan (2003) [15] who reported highest number of leaves in strawberry. The increase leaf number might be increased nitrogen availability which were affected by higher percentage of nitrogen through nitrogen fixing culture which has been documented by Bambal *et al.* (1998) [5] whereas production of growth regulators by the *Azotobacter* in the root zone which gets absorbed by the plant roots that results the increasing in number of leaves which has been reported by Rana and Chandel (2003) [18]. Maximum yield per plant (g) was recorded in the T_{16} (RDF + *Azospirillum* 3 g/plant + PSB 30 ml) (782.50 g) whereas the minimum yield per plant was recorded from the untreated plants (control) (230.44 g). These findings are in line with the Poniker *et al.* (2006) [17] in turmeric, Wange *et al.* (1998) [23] in strawberry, Kadlag *et al.* (2007) [13] in tomato and Tripathi *et al.* (2010) [22] in strawberry, who recorded higher yield with *Azotobacter* application. The increase in yield might be due to increased fruit set per plant, berry length and berry width as well as berry weight and may be due to the fact that nitrogen fixers.

Maximum fruit weight (g) (36.11 g) was recorded in treatment T_{16} (RDF + *Azospirillum* 3 g/plant + PSB 30 ml) followed by (35.98g) in T_8 (RDF + *Azotobacter* (3 g/plant) + *Azospirillum* (3 g/plant) as compared to other and the minimum was observed in T_0 (Water spray) i.e (18.68 g). This increase in fruit size and weight might be due to the increased photosynthetic ability of plants fertilized with photosynthetic bacteria+ *Azotobacter*, which in turn might have favored and increased accumulation of dry matter. Fruit size, weight and Berry volume are highly correlated with dry matter content and balance level of hormone and nitrogen fixers are known for accumulation of dry matter and their translocation Kachot *et al.*, (2001) [12] as well as synthesis of different growth regulators.

Maximum TSS (11.88 °Brix) were produced from the plants treated with treatment T_{16} (RDF + *Azospirillum* 3 g/plant + PSB 30 ml) followed by treatment T_8 (RDF + *Azotobacter* (3 g/plant) + *Azospirillum* (3 g/plant) having TSS of (11.280Brix) The minimum in T_0 (control) with TSS (6.230Brix). These findings are in agreement with the result of Singh *et al.* (2009) [20] in ber, Baksh *et al.* (2008) [4] in guava, Rathi and Bist (2004) [19] in pear.

Fig 1: Field visit of strawberry plants at horticulture research field, SHUATS, Prayagraj, by Dr. Vijay Bahadur (Head, Department of Horticulture) and Dr. Samir E. Topno (Advisor)

Table: Effect of Biofertilizer and Photosynthetic Bacteria on plant growth, plant spread, no. of leaves, fruit weight, TSS content.

Treatment symbol	Treatment Details	Plant Height (cm)	Plant Spread (cm)	No. of leaves	Yield/plant (g)	Fruit weight (g)	TSS (°Brix)
T_0	Control (water)	17.96	19.51	12.01	230.44	18.68	6.23
T_1	RDF + *Azotobacter* (2 g/Plant)	19.72	20.63	13.94	303.47	21.97	7.57
T_2	RDF+ *Azotobacter* (3 g/Plant)	19.81	22.09	15.05	337.95	22.19	8.19
T_3	RDF + *Azospirillum* (2 g/Plant)	19.98	22.7	15.49	369.49	22.86	8.57
T_4	RDF + *Azospirillum* (3 g/Plant)	20.42	24.76	16.39	376.96	23.25	8.68
T_5	RDF + Photosynthetic bacteria (20 ml/L)	19.64	25.64	16.92	457.65	26.49	8.72
T_6	RDF + Photosynthetic bacteria (30 ml/L)	19.49	25.82	17.20	522.36	29.68	8.87
T_7	RDF + *Azotobacter* (2 g/Plant) + *Azospirillum* (2 g/Plant)	20.57	31.15	18.92	679.18	33.12	10.85
T_8	RDF + *Azotobacter* (3 g/plant) + *Azospirillum* (3 g/plant)	21.89	33.66	19.35	771.43	35.98	11.28
T_9	RDF + *Azotobacter* (2 g/plant) + PSB 20 ml	20.17	27.42	17.49	591.05	30.98	8.99
T_{10}	RDF + *Azotobacter* (2 g/plant) + PSB 30 ml	20.19	30.15	18.22	625.81	31.13	9.97
T_{11}	RDF + *Azotobacter* (3 g/plant) + PSB 20 ml	21.21	28.44	17.62	606.09	32.65	9.26
T_{12}	RDF + *Azotobacter* (3 g/plant) + PSB 30 ml	20.42	31.57	19.01	740.63	34.93	11.06
T_{13}	RDF + *Azospirillum* (2 g/plant) + PSB 20 ml	21.35	28.74	17.70	610.67	31.95	9.67
T_{14}	RDF + *Azospirillum* 2 g/plant + PSB 30 ml	21.24	30.77	18.60	685.45	33.68	10.40
T_{15}	RDF + *Azospirillum* 3 g/plant + PSB 20 ml	21.68	29.37	18.09	664.06	34.18	9.73
T_{16}	RDF + *Azospirillum* 3 g/plant + PSB 30 ml	22.23	34.52	19.45	782.50	36.11	11.88
	F – Test	S	S	S	S	S	S
	S.Ed (±)	0.255	0.325	0.313	2.066	1.535	0.06
	C.D.@5%	0.521	0.666	0.64	4.227	3.07	0.123
	CV	1.523	1.451	2.235	0.46	5.982	0.783

Conclusion

With the investigation on current research on "Effect of Biofertilizer and Photosynthetic Bacteria on growth, yield and quality of Strawberry (*Fragaria* × *ananassa Duch.*) cv. Winter Dawn" it can be concluded that treatment T_{16} (RDF + *Azospirillum* 3 g/plant + PSB 30 ml) is found best in terms of plant height (22.23 cm), plant spread (34.52 cm), number of leaves (19.45), yield/plant (782.50 g), fruit weight (36.11 g) and T.S.S (11.88°brix). Thus, treatment T_{16} (RDF + *Azospirillum* 3 g/plant + PSB 30 ml) was found best in terms of growth, yield and quality of plants, followed by T_8 (RDF + *Azotobacter* (3 g/plant) + *Azospirillum* (3 g/plant).

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