Biological Forum – An International Journal **15(5a): 345-352(2023)**

ISSN No. (Print): 0975-1130
ISSN No. (Online): 2249-3239

Effect of Bio-fertilizers and Plant Growth Regulators on Growth, Yield, Quality and Economics of Strawberry (*Fragaria × ananassa* Duch.) Cv. Camarosa

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(Received: 03 April 2023; Revised: 28 April 2023; Accepted: 01 May 2023; Published: 15 May 2023)
(Published by Research Trend)

ABSTRACT: A Research was carried out at Agriculture Research Farm, Mata Gujri College, Fatehgarh Sahib (Punjab), India throughout the year 2021-22 to ascertain the impact of Biofertilizers and Plant growth Regulators on various parameters of strawberry Cv. Camarosa. Trial was conducted in randomised block design (RBD), replicated thrice with 10 various treatments. Findings of the research depicted that among all the different treatments, T_5 (*Azotobacter* 2g/plant + GA_3 5ppm) followed by T_6 (*Azotobacter* 2g/plant + NAA 5ppm), demonstrated significant effectiveness across various parameters of crop 's growth, flowering, yield, quality and economics. One of the main challenges in studying the effect of bio-fertilizers and plant growth regulators on strawberries is the complexity of interactions between these factors and environmental conditions, such as soil type, climate, and pest pressure, to draw meaningful conclusions about their impact on growth, yield, quality, and economic viability of strawberry cultivation. Measurements during initial growth stage of plants was maximum in T_5 (*Azotobacter* 2g/plant + GA_3 5ppm) compared to other treatments. T_6 *Azotobacter* 2g/plant + NAA 5ppm) followed closely behind T_5 in terms of crop growth (eg; plant height, number of leaves, stem girth, plant spreading etc.) parameters. Beside this, the flowering and yield parameters was also higher in T_5 (*Azotobacter* 2g/plant + GA_3 5ppm). The dose concluded combined *Azotobacter* 2g/plant + GA_3 @5ppm depicts significant results under Punjab region of India with respect to Strawberry Cv. Camarosa.

Keywords: Strawberry, Camarosa, *Azotobacter*, GA_3, Growth, Yield, Economics.

INTRODUCTION

Strawberry (*Fragaria × ananassa* Duch.) is one of the delicious and nutritious soft fruits of the world enriched with vitamins and minerals. These days, this fruit is becoming a globally favourite and cultivated worldwide. It is an octoploid species (2n= 8×=56) belonging to the genus *Fragaria* of the family Rosaceae is one of the most delicious and nutritious among soft fruits of the world. Its successful cultivation requires an optimum day temperature of 22-23° C and night temperature of 7-13° C in India (Kumar *et al.*, 2015). According to data related to Food and Agriculture Organization of the United Nations (FAOSTAT) it confirms China is the absolute leader by all means in production of strawberry with probably 3,336,690 tons during year 2020 and USA with 1,055,963 tons of strawberry production (FAOSTAT, 2020). In recent years, breeding of new varieties suitable for subtropical climate and accordingly the development of agro-techniques has resulted in boosting the strawberry cultivation even in non-traditional areas (Vishal *et al.*, 2016). It is the true fruit and is referred as aggregate/etaerio of achenes. The aromatic compound includes ethyl hexanoate and ethyl butanoate. There colour pigment is due to anthocyanin (Sharma, 2002 and Chadha, 2001). Strawberry fruit is a good source of vitamin-C (40-120 mg/100 g of fruit), protein and minerals like potassium, phosphorus, calcium and iron. The Strawberry fruits contain fair amounts of iron and hence fruits are beneficial to anemic patients. Strawberry is also a fair source of vitamin A (60 IU/100 g of edible portion). Strawberry is a short-day plant and has certain seasonal fruiting varieties which produce single crop in summer. The main objective of the strawberry growers is to produce a fruit with appealing appearance (size, colour and shape) not necessary accompanied by the same appealing tasteful characteristics (Kumar *et al.*, 2012). Bio-fertilizers are naturally occurring products with living micro-organisms which have no ill effects on plants, soil health and environment (Pal *et al.*, 2015). Biofertilizers are gaining increased attention to improve soil fertility and quality production of horticultural crops, due to hike in prices of chemical fertilizers and to minimize environmental pollution (Sindhu *et al.*, 2010).

Biofertilizers are organic products containing living cells of different type of microorganisms, which have the capability to convert nutritionally important elements from unavailable to available form through biological processes. *Azotobacter* fixes atmospheric nitrogen, surge the fertility of soil, spread biological activities and enhances the production of fruit. Use of *Azotobacter* increases the yield of plants and also increases soil fertility through nitrogen fixation (Kumar *et al.,* 2015). It plays dominant role in nutrient cycling and increase nutrient availability. PSB solubilize phosphorus to surge the fertility of soil and spread biological activities (Kumar *et al.,* 2015). Use of PSB meliorate the leaf content, increase P uptake by plants, encourage growth of plant and raise fruit yield. PSB also improve the plant growth ability in organic and mineral phosphate solubilisation (Hazarika *et al.,* 2015) Plant growth regulators or phytohormones are organic substances produced naturally in higher plants, controlling growth or other physiological functions at a site remote from its place of production and active in minute amounts. The growth and quality of fruits depends on different attributes which are closely associated with nutrient uptake by the plant and also with PGR'S's. The use of plant growth regulators has resulted in some outstanding achievements in several fruit crops with respect to growth, yield and quality (Suman *et al*., 2017). 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 is reported to increase leaf size, petiole length, whereas the application of auxins is also known to impart similar effects (Vishal *et al*., 2016). Gibberellic acid help in early flowering, cell elongation, increased time of flowering and yield. It expands quality, yield and fruit set of strawberry. NAA is a rooting agent and used for the vegetative propagation of plants from stem and leaf cuttings. Use of NAA increases the size of fruit, time of flowering, yield and grade of fruit. The application of NAA was delayed ripening and Anthocyanin accumulation of strawberry fruits (Kumar *et al.,* 2020).

The research gap in the field of biofertilizers lies in the need to explore and understand the diverse microbial communities present in these fertilizers and their interactions with plant systems. Further investigations are necessary to elucidate the mechanisms by which biofertilizers enhance nutrient uptake, soil health, and overall plant growth. Additionally, there is a lack of comprehensive studies comparing the effectiveness of different biofertilizers and their specific applications for various crops and environmental conditions. As for plant growth regulators, there is a dearth of research focusing on their long-term effects on plant physiology, gene expression, and ecosystem dynamics. A deeper understanding of the signaling pathways and molecular interactions involved in plant growth regulation is essential for maximizing their potential benefits in sustainable agriculture (Sharma *et al.*, 2014).

MATERIALS AND METHODOLOGY

The present investigation entitled "Effect of Bio-fertilizers and plant growth regulators on growth, yield and fruit quality of strawberry (*Fragaria* × *ananassa* Duch.) cv. Camarosa" was carried out at the Agriculture Research Farm, Department of Agriculture, Mata Gujri College, Fatehgarh Sahib, Punjab during the year 2021-22. The research farm is situated between 30° 56′11.90″N latitudes and 76° 18′13.18″E longitudes and at a mean height of 279 meter above sea level. The climatic condition of Fatehgarh Sahib is sub-tropical with three distinct seasons i.e. winter, summer and rainy. During the winter month (December-January), temperature fall 5-8°C. The research was laid out with 9 treatments which replicated thrice under factorial randomized block design. The treatments were T_1 (No biofertilizers + No plant growth regulators), T_2 (No biofertilizers + GA_3 5ppm), T_3 (No biofertilizers + NAA 5ppm), T_4 (*Azotobacter* 2g/plant + No plant growth regulators), T_5 (*Azotobacter* 2g/plant + GA_3 5ppm), T_6 (*Azotobacter* 2g/plant + NAA 5ppm), T_7 (PSB 2g/plant + No plant growth regulators), T_8 (PSB 2g/plant + GA_3 5ppm) and T_9 (PSB 2g/plant + NAA 5ppm). The runners of strawberry were planted at a spacing of 40 × 30 cm. The observations were recorded on various parameters like plant height, plant spread, number of leaves, leaf area, leaf area index, days taken to first flower, number of flowers/plant, berry length, berry weight, berry breadth, TSS, Titrable acidity, anthocyanin, total sugar, reducing sugar, non reducing sugar, total number of fruit per plant, fruit yield per plant, fruit yield per hectare.

RESULT AND DISCUSSION

A. Effect of PGR's and Biofertilizer on Vegetative Growth of Strawberry

The Effect of PGR'S And Biofertilizer recorded highest in treatment *Azotobacter* and GA_3. The combined effect of *Azotobacter* and GA_3 were observed highest in plant height, plant spread, maximum number of leaves per plant, leaf area, leaf area index.

The maximum plant height (25.24cm) was recorded in T_5 (*Azotobacter* 2g/plant + GA_3 5ppm) although minimum plant height (21.70cm) was recorded in T_1 (Control). The maximum plant spread (34.32cm) was recorded in T_5 (*Azotobacter* 2g/plant + GA_3 5ppm) and minimum plant spread (27.42cm) was recorded in T_1 (Control). The maximum number of leaves per plant (30.65) was recorded in T_5 (*Azotobacter* 2g/plant + GA_3 5ppm) as compared to minimum number of leaves per plant (22.79) was recorded in T_1 (Control). The maximum leaf area (87.08cm^2) was recorded in T_5 (*Azotobacter* 2g/plant + GA_3 5ppm) and minimum leaf area (81.83cm^2) was recorded in T_1 (Control). The maximum leaf area index (4.46) was recorded in T_5 (*Azotobacter* 2g/plant + GA_3 5ppm) although minimum leaf area index (3.99) was recorded in T_1 (Control). The increase in vegetative growth with *Azotobacter* is due to the inoculation of plants with nitrogen fixing bacteria resulted in production of more chlorophyll which leads to growth. Vegetative growth also increased due to the spray of plant growth regulators. The use of GA_3 with combination of biofertilizers like *Azotobacter* might have caused the increase in plant height and plant spread together with stronger evolution of root system (Kumar *et al.,* 2012).

Table 1: Effect of Bio-fertilizers and plant growth regulators on growth parameters of strawberry (*Fragaria × ananassa* Duch.) cv. Camarosa.

Treatments	Plant Height (cm)	Plant Spread (cm)	Number of leaves	Leaf Area (cm^2)	Leaf Area Index
T_1 B_0P_0 No biofertilizers + No plant growth regulators	21.70	27.42	22.79	81.83	3.99
T_2 B_0P_1 No biofertilizers + GA_3 (5ppm)	24.38	31.59	26.54	86.85	4.32
T_3 B_0P_2 No biofertilizers + NAA (5ppm)	23.36	31.86	27.47	84.08	4.23
T_4 SB_1P_0 *Azotobacter* (2g/plant) + No plant growth regulators	23.61	30.99	25.58	84.76	4.13
T_5 B_1 P_1 *Azotobacter* (2g/plant) + GA_3 (5ppm)	25.24	34.32	30.65	87.08	4.46
T_6 B_1P_2 *Azotobacter* (2g/plant) + NAA (5ppm)	25.16	32.14	29.20	85.70	4.28
T_7 B_2P_0 PSB (2g/plant) + No plant growth regulators	22.91	29.17	25.34	83.92	4.01
T_8 B_2P_1 PSB (2g/plant) + GA_3 (5ppm)	24.54	32.21	29.31	84.16	4.03
T_9 B_2P_2 PSB (2g/plant) + NAA (5ppm)	23.64	30.95	26.88	84.59	4.12
SE(m)±	0.41	0.79	0.84	0.76	0.10
CD (0.05)	1.23	2.38	2.51	2.29	0.31

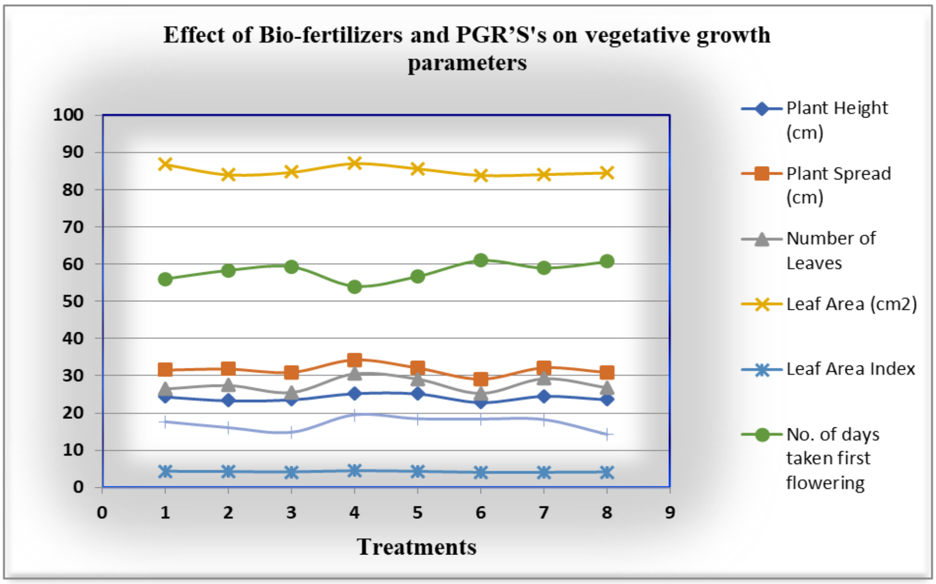

Fig. 1. Effect of Bio-fertilizers and plant growth regulators on growth parameters of strawberry (*Fragaria × ananassa* Duch.) cv. Camarosa.

B. Effect of PGR's and Biofertilizer on Flowering and Yield of Strawberry

PGR's (GA_3) and Biofertilizer (*Azotobacter*) shown positive impact on flowering and yield. The minimum number of days taken for first flowering and maximum number of flowers per plant was observed in plant which were treated with combination of Biofertilizer and PGR'S (*Azotobacter* and GA_3). The combined effect of PGR'S and Biofertilizer in Treatment T_5 recorded maximum number of berries per plant, maximum yield per plant and maximum yield per hectare. The minimum days taken to first flowering (54.00 days) was recorded in T_5 (*Azotobacter* 2g/plant + GA_3 5ppm) whereas, the maximum days taken to first flowering (67.67 days) was recorded in T_1 (Control). The maximum number of flowers per plant (19.43) was recorded in the treatment T_5 (*Azotobacter* 2g/plant + GA_3 5ppm) whereas, the minimum number of flowers per plant (13.70) was recorded in the T_1 (Control). The maximum number of berries per plant (12.00) was recorded in the treatment T_5 (*Azotobacter* 2g/plant + GA_3 5ppm) and, the minimum fruit number (8.33) of fruits was recorded in T_1 (Control). The maximum yield per plant (240.47g) was recorded in the treatment T_5 (*Azotobacter* 2g/plant + GA_3 5ppm) however, the minimum yield per plant (132.83g) was observed in T_1 (Control). The maximum yield per hectare (9.62 t/ha) was recorded in the treatment T_5 (*Azotobacter* 2g/plant + GA_3 5ppm) whereas, the minimum yield per hectare (5.31 t/ha) was observed in T_1 (Control). The earliness of first flowering may be due to an optimum supply of nutrients and growth hormones in right amount during the entire crop period which induces the vegetative development of plant and ultimately more photosynthesis (Beer *et al.*, 2017). The *Aztobacter* and PSB application accelerated the development of inflorescence, leaf number in autumn which are positively correlated with the number of flowers in spring. The increased fruit set per plant, berry length and berry width as well as berry weight may also be due to the nitrogen fixers and phosphorus solubilizer not only increased the availability of nitrogen and phosphorus to the plants but also increases the translocation of minerals from root to flower through plant foliage (Singh *et al.*, 2009).

Table 2: Effect of Bio-fertilizers and plant growth regulators on Flowering and Yield parameters of strawberry (*Fragaria* × *ananassa* Duch.) cv. Camarosa.

Treatments	Number of days taken first Flowering	Number of Flowers per Plant	Number of Berries per Plant	Yield per Plant (g)	Yield per ha (t/ha)
T_1 No biofertilizers + No plant growth regulators	67.67	13.70	8.33	132.83	5.31
T_2 No biofertilizers + GA_3 (5ppm)	56.00	17.55	9.00	151.70	6.07
T_3 No biofertilizers + NAA (5ppm)	58.33	15.97	9.67	163.44	6.54
T_4 *Azotobacter* (2g/plant) + No plant growth regulators	59.33	14.72	10.33	181.76	7.27
T_5 *Azotobacter* (2g/plant) + GA_3 (5ppm)	54.00	19.43	12.00	240.47	9.62
T_6 *Azotobacter* (2g/plant) + NAA (5ppm)	56.67	18.35	11.67	218.71	8.74
T_7 PSB (2g/plant) + No plant growth regulators	61.00	18.28	9.67	169.83	6.79
T_8 PSB (2g/plant) + GA_3 (5ppm)	59.00	18.13	11.00	210.04	8.40
T_9 PSB (2g/plant) + NAA (5ppm)	60.67	14.13	10.00	184.88	7.39
SE(m)±	1.05	0.62	0.60	13.10	0.52
CD (0.05)	3.14	1.85	1.79	39.26	1.57

C. Effect of PGR's and Biofertilizer on Fruit Quality of Strawberry

The treatment of PGR'S and Biofertilizer on strawberry plants shown best effect of PSB and GA_3 on TSS, Acidity, Anthocyanin, Total Sugar, Reducing Sugar, Non-Reducing Sugar.

The effect of PGR'S and Biofertilizer recorded maximum in combined effect of *Azotobacter* and GA_3 on Berry length, Berry weight, berry breadth. The maximum berry length (38.35mm) was recorded in the treatment T_5 (*Azotobacter* 2g/plant + GA_3 5ppm) whereas, the minimum (31.32mm) berry length was recorded in T_1 (Control). The maximum berry breadth (37.85mm) was recorded in the treatment T_5 (*Azotobacter* 2g/plant + GA_3 5ppm) whereas, the minimum (30.14mm) berry breadth was recorded in T_1 (Control). The maximum berry weight (20.00g) was recorded in the treatment T_5 (*Azotobacter* 2g/plant + GA_3 5ppm) whereas, the minimum (15.91g) berry weight was recorded in T_1 (Control). The maximum TSS (10.14 ^{0}Brix) was recorded in the T_8 (PSB 2g/plant + GA_3 5 ppm) whereas, the minimum TSS (9.21 ^{0}Brix) was recorded in T_1 (Control). The lower acidity was recorded (0.64%) in fruits harvested from T_8 (PSB 2g/plant + GA_3 5ppm) however, higher acidity in fruits (0.76%) was recorded under treatment T_1 (Control). The maximum (0.95 OD at 530 nm) in T_8 (PSB 2g/plant + GA_3 5ppm), while minimum anthocyanin content (0.42 OD at 530 nm) recorded in T_1 (Control). The maximum total sugar (6.31%) was recorded in the treatment T_8 (PSB 2g/plant + GA_3 5ppm) whereas, minimum total sugar content (4.82%) recorded in T_1 (Control). The maximum reducing sugars (4.10%) was recorded in the treatment T8 (PSB 2g/plant + GA_3 5ppm) whereas, minimum reducing sugar content (3.03%) was observed in T_1 (Control). The maximum non-reducing sugars (2.11%) was recorded in the treatment T8 (PSB 2g/plant + GA_3 5ppm) whereas, minimum non-reducing sugar content was (1.71%) noted under treatment T_1 (Control). GA_3 significantly increases TSS and sugar as well as it reduces the titrable acidity. Anthocyanin content enhanced with the application of GA_3 (Roussos *et al.*, 2009). The increase in total sugar could be attributed due to quick metabolic transformation of soluble compounds and more conversion of organic acid into sugar and also increase sugar content might be due to degradation of polysaccharides into monosaccharides (Hazarika *et al.*, 2015).

Table 3: Effect of Bio-fertilizers and plant growth regulators on quality parameters of strawberry (*Fragaria* × *ananassa* Duch.) cv. Camarosa.

Treatments	Berry Length (mm	Berry Breadth (mm)	Berry Weight (g)	TSS °brix	Acidity (%)	Anthocyanin	Total Sugar (%)	Reducing Sugar (%)	Non reducing sugar (%)
T_1 B_0 P_0 No biofertilizers + No plant growth regulators	31.32	30.14	15.91	9.21	0.76	0.42	4.82	3.03	1.71
T_2 B_0P_1 No biofertilizers + GA_3 (5ppm)	33.17	33.76	16.88	9.98	0.69	0.58	5.14	3.14	1.89
T_3 B_0P_2 No biofertilizers + NAA (5ppm)	33.27	31.67	16.94	9.80	0.70	0.84	4.91	3.16	1.66
T_4 B_1P_0 *Azotobacter* (2g/plant) + No plant growth regulators	32.37	34.54	17.56	9.38	0.73	0.66	4.88	3.30	1.50
T_5 B_1 P_1 *Azotobacter* (2g/plant) + GA_3 (5ppm)	38.35	37.85	20.00	10.03	0.67	0.82	5.22	4.00	1.16
T_6 B_1P_2 *Azotobacter* (2g/plant) + NAA (5ppm)	35.09	35.79	18.94	9.79	0.68	0.72	5.20	3.57	1.55
T_7 B_2P_0 PSB (2g/plant) + No plant growth regulators	33.68	34.46	17.53	9.83	0.71	0.60	5.39	3.59	1.71
T_8 B_2P_1 PSB (2g/plant) + GA_3 (5ppm)	37.28	36.09	19.05	10.14	0.64	0.95	6.31	4.10	2.11
T_9 B_2P_2 PSB (2g/plant) + NAA (5ppm)	33.77	34.85	18.44	10.06	0.66	0.89	6.06	4.03	1.93
SE(m)±	0.38	0.71	0.76	0.09	0.02	0.03	0.12	0.05	0.12
CD (0.05)	1.14	2.13	2.27	0.26	0.05	0.08	0.35	0.16	0.37

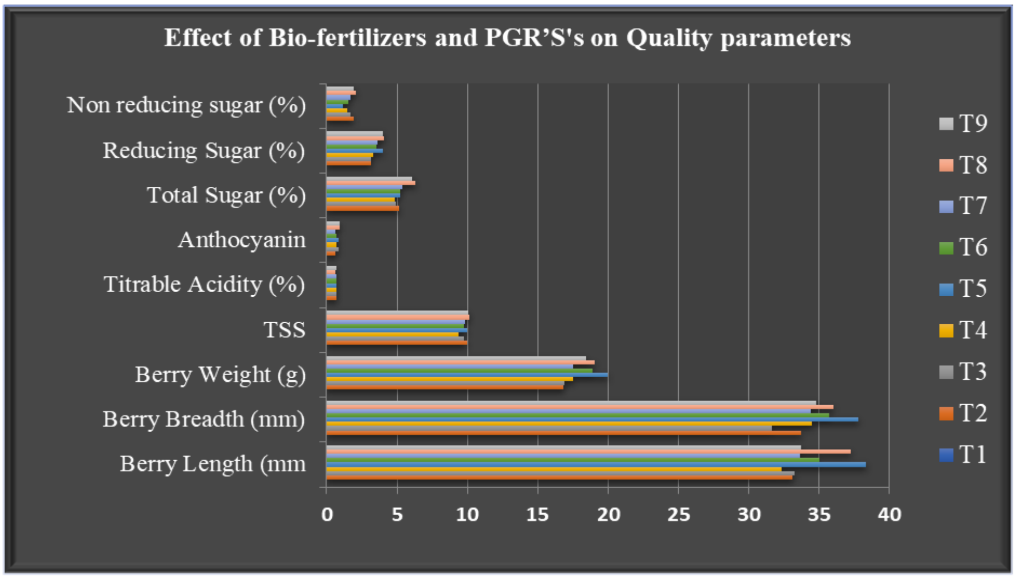

Fig. 2. Effect of Bio-fertilizers and plant growth regulators on quality parameters of strawberry (*Fragaria* × *ananassa* Duch.) cv. Camarosa.

D. Effect of PGR's and Biofertilizer on Economics of Strawberry

Higher cost of cultivation (Rs.5,36,932.15) was recorded in T_5 (*Azotobacter* 2g/plant + GA_3 5 ppm). However, minimum cost of cultivation (Rs. 5,32,332.15) was recorded in T_1 (Control). The maximum gross income (Rs. 19,24,000) was recorded in T_5 (*Azotobacter* 2g/plant + GA_3 5 ppm) and minimum Gross income (Rs. 10,62,000) was recorded in treatment T_1 (Control). The maximum net return (Rs. 13,87,067.85) was recorded in T_5 (*Azotobacter* 2g/plant + GA_3 5 ppm) whereas, net return (Rs. 5,29,667.85) was recorded in treatment T_1 (Control). The maximum B:C (2.58:1) was recorded in treatment T_5 (*Azotobacter* 2g/plant + GA_3 5ppm) although, B: C (0.99:1) was recorded in treatment T_1 (Control). The implementation of bio-fertilizers and plant growth regulators can lead to reduced input costs for farmers, as these alternatives often offer a more cost-effective solution compared to conventional chemical inputs. Additionally, improved strawberry yield and quality resulting from the use of these products can potentially lead to higher market prices, providing farmers with better economic returns on their produce. Economics of strawberry crop influenced by different combination of biofertilizers and plant growth regulators (Singh *et al.*, 2010).

Table 4: Effect of Bio-fertilizers and plant growth regulators on economics of strawberry (*Fragaria* × *ananassa* Duch.) cv. Camarosa.

Sr. No.	Treatments	Total cost of cultivation (Rs./ha)	Gross income (Rs./ha)	Net return (Rs./ha)	B:C ratio
T_1	B_0P_0	5,32,332.15	10,62,000	5,29,667.85	0.99:1
T_2	B_0P_1	5,34,832.15	12,14,000	6,79,167.85	1.26:1
T_3	B_0P_2	5,33,332.15	13,08,000	7,74,667.85	1.45:1
T_4	B_1P_0	5,34,334.15	14,54,000	9,19,665.85	1.72:1
T_5	B_1P_1	5,36,932.15	19,24,000	13,87,067.85	2.58:1
T_6	B_1P_2	5,35,432.15	17,48,000	12,12,567.85	2.26:1
T_7	B_2P_0	5,34,152.15	13,58,000	8,23,847.85	1.54:1
T_8	B_2P_1	5,36,652.15	16,80,000	11,43,347.85	2.13:1
T_9	B_2P_2	5,35,152.15	14,78,000	9,42,847.85	1.76:1

DISCUSSION

There were considerably seen variation in vegetative growth of strawberry plants in the process of using different biofertilizers and plant growth regulators treatment combinations. On the basis of present investigation, it is evident that the maximum plant height, plant spread, number of leaves per plant, leaf area and leaf area index were obtained when plants were treated in treatment combination of treatment T_5 (*Azotobacter* 2g/plant + GA_3 5ppm). Plant height, plant spread, number of leaves per plant, leaf area and leaf area index also increased due to the spraying of GA_3 which induced the growth by cell division, and cell elongation. The ability to increased plant spread after GA_3 treatment may be due to the increased length of certain internodes which were either in the process of elongation at the time of treatment or were differentiated soon thereafter (Lolaei *et al.*, 2013). More number of leaves in GA_3 treated plants facilitates the synthesis of maximum number of crowns and runners (Rathod *et al.*, 2021). These results are in conformity with Mishra and Tripathi (2011); Kumar *et al.* (2012); Prasad *et al.* (2012); Nazir *et al.* (2015); Vishal *et al.* (2016); Palei *et al.* (2016); Saima *et al.* (2014) who were reported that application of biofertilizers and plant growth regulators during growth period increases plant height, plant spread, leaf area and number of leaves per plant and also these findings were similar to Rajbhar *et al.* (2015); Kumar *et al.* (2015) in strawberry. A study was also admit by Singh *et al.*, (2015); Mishra and Tripathi (2011). The increase in number of fruits per plant might be due to the vigorous growth of plants treated with gibberellins which accumulates higher starch, carbohydrates and photosynthates which leads to setting of higher number of berries. These findings are in conformity with the findings of Ahire *et al.* (2018); Saima *et al.* (2014); Rustam *et al.* (2017); Vishal *et al.* (2017). This increase in yield might be due to number of roots which causes plants to take up more nutrients from the soil. The increased fruit set per plant, berry length and berry width as well as berry weight may also be due to the nitrogen fixers and phosphorus solubilizer not only increased the availability of nitrogen and phosphorus to the plants but also increases the translocation of minerals from root to flower through plant foliage (Singh and Singh, 2009). These results were in accordance to that of Kumar *et al.* (2012); Mishra and Tripathi (2011); Nazir *et al.* (2015); Rustam *et al.* (2017); Ahire *et al.* (2018) who reported maximum yield per plant and yield per hectare. The increase in physical characters of plants is due to application of both biofertilizer and plant growth regulator in combination which increase the number of roots. These roots help the plants to consume more nutrients from soil, promoted growth of plant and improve the quality of fruit. Gibberellic-acid plays a regulatory role in the mobilization of metabolites from source to sink (developing fruits) and able to produce more metabolites through the activity of photosynthesis which ultimately sank in the developing fruits and resulting berries with maximum weight (Iqbal *et al.*, 2011). The maximum TSS, total sugar, reducing sugar, non-reducing sugar and anthocyanin content were attained maximum with treatment combination in treatment T_7 (PSB 2g/plant and GA_3 5 ppm). Higher sugar content under the influence of growth regulators could be attributed to increased leaf area, plant spread and consequently more synthesis of carbohydrates and other metabolites and their translocation to the fruit tissue Thakur *et al.* (2017). The upsurge in TSS and total sugar contents with *Azotobacter* and PSB application may be due to the rapid metabolic transformation of starch and pectin into soluble compounds and rapid translocation of sugars from leaves to the developing fruits (Mishra and Tripathi 2011). These results are finding in the conformity of Singh and Singh (2006); Mishra and Tripathi (2011); Khunte *et al.* (2014); Saima *et al.* (2014); Kumar *et al.* (2015); Thakur *et al.* (2015); Matsuane *et al*. (2016); Thakur *et al.* (2017). The cost of cultivation, Gross income, Net return and B:C ratio of strawberry cv. Camarosa treatment wise calculated for season for an area of one hectare in open field condition. The highest cost of cultivation, gross income, net return and B:C ratio in treatment T_5 (*Azotobacter* 2g/plant + GA_3 5 ppm). Similar observations were also reported by Singh *et al.* (2010); Jain *et al.* (2017); Kushwah *et al.* (2018).

CONCLUSIONS

Based on the current research study conducted in 2021-22, It can be concluded consecutively that treatments T_5 (*Azotobacter* 2g/plant + GA_3 5ppm) followed by T_6 (*Azotobacter* 2g/plant + NAA 5ppm) was found bests in termss of growth, quality, yield and economics parameters of the Strawberry Cv. Camarosa under Punjab Region of India. To be concluded, it can be asserted that when *Azotobacter* 2g/plant is used along with + GA_3 5ppm depicts significant results in strawberry Cv. Camarosa.

FUTURE SCOPE

As global concerns about environmental sustainability grow, bio-fertilizers and plant growth regulators offer eco-friendly alternatives to traditional chemical-based approaches, reducing environmental impact and promoting sustainable farming practices. Continued research in this area could lead to the development of more effective bio-fertilizers and growth regulators, ultimately enhancing strawberry yield and meeting the rising demand for food in a world with an ever-increasing population. Understanding the precise impact of bio-fertilizers and plant growth regulators on the biochemical composition of strawberries could lead to the production of higher-quality fruits with enhanced nutritional value and better taste. Exploring the potential of bio-fertilizers and growth regulators to boost the plant's natural defenses can help reduce reliance on chemical pesticides and foster healthier strawberry crops. Evaluating the economics of adopting bio-fertilizers and growth regulators can reveal potential cost savings for farmers, making strawberry cultivation more financially viable in the long run. With the increasing demand for organic produce, studying the role of bio-fertilizers and plant growth regulators could facilitate the transition towards organic strawberry farming methods. Research in this area may uncover strategies to make strawberries more resilient to climate change-related challenges, such as extreme weather events and shifting growing seasons. The interdisciplinary nature of this topic encourages collaboration between agronomists, biologists, economists, and environmental scientists, fostering a holistic approach to agricultural research. Tailoring the use of bio-fertilizers and growth regulators to specific soil types, climates, and strawberry varieties can optimize their effectiveness and ensure tailored solutions for different regions and farming systems. By improving strawberry crop yield, quality, and economics, the findings from this research can contribute to global food security efforts, ensuring a stable supply of nutritious fruits for an increasingly populated world.

Acknowledgement. We greatly acknowledge Mata Gujri College, Fatehgarh Sahib, for providing their facilities to conduct this research experiments.
Conflict of Interest. None.

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How to cite this article: Himansh Marwaha, Lakhwinder Singh and Dilip Singh Kachawaya (2023). Effect of Bio-fertilizers and Plant Growth Regulators on Growth, Yield, Quality and Economics of Strawberry (*Fragaria × ananassa* Duch.) Cv. Camarosa. *Biological Forum – An International Journal, 15*(5a): 345-352.