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RESEARCH ARTICLE

EFFECT OF GA_3 AND PLANT GROWTH PROMOTING RHIZOBACTERIA (PGPR) ON GROWTH, YIELD AND FRUIT QUALITY OF STRAWBERRY, *FRAGARIA X ANANASSA* DUCH CV CHANDLER

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Abstract

The effects of plant growth promoting rhizobacteria (*Bacillus licheniformis* CKA 1, *Bacillus subtilis* CB 8 A, *Bacillus sp.* RG1, *Bacillus sp.* S_1 and *Bacillus sp.* S_2) and GA_3 (25, 50 & 75 ppm) on growth, yield and fruit quality of strawberry cultivar 'Chandler' were studied at Model Farm of Directorate of Research, Dr Y S Parmar University of Horticulture and Forestry, Nauni, Solan (HP), India during 2012-13. Study has shown that the plant growth promoting rhizobacteria (PGPR) + GA_3 @ 75 ppm gave best results in terms of plant growth, yield and fruit quality. The maximum plant height and spread were recorded in T_{15} whereas, the leaf area and the number of runners per plant were maximum in T_{18}. In comparison to other treatments, the number of crowns, number of fruits and yield per plant were highest in T_9. The maximum fruit weight and ascorbic acid were recorded in T_6 while the fruit length was maximum in T_9 while fruit diameter in T_{12}. The maximum fruit total soluble solids (TSS) and TSS: acid ratio were observed in T_{10} whereas acidity was maximum in T_{12} and minimum in T_{19}. Sugars were highest with the application of plant growth promoting rhizobacteria + GA_3 @75 ppm.

INTRODUCTION

Strawberry (*Fragaria* × *ananassa* Duch.) is a soft fruited, perennial, herbaceous plant of Rosaceae family which occupies a significant place in fruit growing in world. It gives high return within shortest time than other berry fruits. In Himachal Pradesh, it is being grown on limited scale in Kullu, Kangra, Sirmour, Solan and Shimla districts and occupies an area of 55 ha with annual production of 354 MT (Anonymous, 2014). The modern strawberry cultivation requires extensive use of chemical fertilizers for high yield and quality which are costly and create environmental problems. Thus, the improved management practices including use of plant growth regulators and plant growth promoting rhizobacteria have been becoming a resurgence of interest in sustainable and organic cultural practices (Esitken *et al.*, 2005). Plant growth regulators are known to improve growth, fruiting and quality of fruit crops through various physiological and metabolic processes. So, the plant growth regulators have been much used for improving growth and yield as well as runner production in strawberry. Beside these, plant growth promoting rhizobacteria may improve plant growth and yield by means of producing plant growth regulators (auxin, gibberellins, cytokinins etc.), solublizing of organic phosphate or mineralizing organic phosphate or other nutrients, fixing atmospheric nitrogen, facilitating the uptake of nutrients and preventing deleterious effects on soil as produced by chemical fertilizers. Various research workers found that plant growth promoting rhizobacteria could stimulate growth and increase yield in apple, sweet cherry, citrus, raspberry, high bush blueberry, mulberry and apricot (Pirlak and Kose, 2009).

Thus, the objective of present investigation is to study the effect of GA_3 and plant growth promoting rhizobacteria on plant growth, yield and quality of fruits of strawberry cultivar 'Chandler'.

MATERIAL AND METHODS

Present investigation was carried out at Model Farm of Directorate of Extension Education, Dr Y S Parmar University of Horticulture and Forestry, Nauni, Solan, (HP), India during 2012-13 as Randomized Block Design (RBD) with nineteen treatments, each with three replications consisting 57 beds (2x2 m) in which strawberry cultivar 'Chandler' runners were planted at a spacing of 50 x 25 cm during October, 2012. Three doses of GA_3 (25, 50 and 75 ppm) alone and in combination with five plant growth promoting rhizobacteria (S_1: *Bacillus licheniformis* CKA 1 (10^9 cfu/ml), S_2: *Bacillus subtilis* CB 8 A (10^9 cfu/ml), S_3: *Bacillus sp.* RG1 (10^9 cfu/ml), S_4: *Bacillus sp.* S_1 (10^9 cfu/ml) and S_5: *Bacillus sp* S_2 (10^9 cfu/ml)) were given as foliar application 20 days before expected flowering viz., T_1: GA_3 @ 25 ppm, T_2: GA_3 @ 50 ppm, T_3: GA_3 @ 75 ppm, T_4: S_1 + GA_3 @ 25 ppm, T_5 : S_1 + GA_3 @ 50 ppm, T_6 : S_1 + GA_3 @ 75 ppm, T_7: S_2+ GA_3 @ 25 ppm, T_8: S_2+ GA_3 @ 50 ppm , T_9 : S_2 + GA_3 @ 75 ppm, T_{10} : S_3 + GA_3 @ 25 ppm, T_{11} : S_3+ GA_3 @ 50 ppm, T_{12} : S_3 + GA_3 @ 75 ppm, T_{13} : S_4+ GA_3 @ 25 ppm, T_{14} : S_4+ GA_3 @ 50 ppm, T_{15} : S_4 + GA_3 @ 75 ppm, T_{16} : S_5 + GA_3 @ 25 ppm, T_{17} : S_5+ GA_3 @ 50 ppm, T_{18} : S_5 + GA_3 @ 75 ppm, T_{19} : Control.

The plant growth promoting effects of GA_3 and bacterial treatments were observed by determining plant height (cm), plant spread (cm), leaf area (cm^2), number of crowns, number of runners and plant biomass on dry weight basis (g) while effects on yield were evaluated by determining number of fruits, yield per plant (g). The effects on physico-chemical properties of fruits were determined by analyzing fruit weight, fruit size, TSS, TSS: acid ratio, ascorbic acid and sugars etc.

The plant height (cm), spread (cm), number of crowns per plant, number of runners per plant, number of fruits per plant and yield per plant (g) were recorded as per standard practices. The leaf area was measured by leaf area meter (Licor-Model 3100) and expressed in square centimeter (cm^2). Fruit weight (g) was recorded by weighing the ten fruits on a top pan electronic balance and the average weight per fruit was calculated. Fruit size (mm) (length and width) was recorded with the help of Vernier calipers. Chemical characteristics like total soluble solid (TSS ^{0}Brix) was determined by Erma hand refractometer (0-32^{0}Brix range) and acidity with the help of titration method (0.1 N NaOH using phenolphthalein indicator). Total sugars, reducing sugars and non-reducing sugars were recorded as per A.O.A.C. method (1980), while ascorbic acid was calculated as per procedure given by Rangana (2010). Statistical analysis of the data was carried out by the method of analysis of variance as outlined by Gomez and Gomez (1983).

Result and Discussion

Effect on plant growth and yield:

The best results regarding plant height, fruiting and physico-chemical characteristics were recorded with GA_3 application at 75 ppm in combination with PGPR. As compared to control (T-1), the maximum plant height (30.63 cm) and plant spread (31.23 cm) were recorded in T_{15}, whereas the maximum leaf area (137.68 cm^2) and the number of runners per plant (38.38) in T_{18}. In comparison to other treatments, the number of crowns, the number of fruits and yield per plant were maximum in T_9 (4.95, 19.73 and 260.93 g, respectively) and minimum in T_{19} (control).

The results of promoting plant growth and yield through GA_3 and plant growth promoting rhizobacteria in strawberry were similar to the reports of Singh and Singh (2009), Seo *et al.* (2009), Pirlak and Kose (2009), Perez *et al*. (2009) and Paroussi *et al.* (2002). Many plant growth promoting bacteria have the ability to produce the plant growth regulators like IAA, GA_3 and cytokinin which may play the most important role in plant growth promotion (Patten and Glick, 2002 and Khalid *et al.*, 2004). Yield enhancement effect of

T-1: Effect of plant growth promoting rhizobacteria and GA_3 on plant growth and yield of strawberry cultivar chandler

Treatment	Plant height (cm)	Plant spread (cm)	Leaf area (cm^2)	Number of crowns/ plant	Number of runners/ plant	Number of fruits/ plant	Yield per plant (g)
T_1	22.18	24.06	105.37	3.22	23.75	14.97	183.67
T_2	23.08	24.65	107.07	3.63	25.21	15.13	192.00
T_3	24.29	26.14	109.88	3.91	28.42	16.20	210.04
T_4	23.27	25.54	108.68	3.55	29.86	17.17	217.67

T_5	25.01	28.81	111.40	3.88	30.75	17.40	229.67
T_6	28.43	29.45	116.09	4.24	36.38	17.73	254.20
T_7	25.08	26.27	107.28	3.44	24.04	18.20	229.67
T_8	25.23	26.95	112.07	4.13	32.08	18.47	240.41
T_9	26.05	28.36	120.00	4.95	35.18	19.73	260.93
T_{10}	22.94	24.45	105.95	3.29	26.74	15.40	193.19
T_{11}	25.37	25.20	108.10	3.66	28.09	16.03	209.46
T_{12}	26.48	27.88	112.04	3.98	28.83	16.27	217.68
T_{13}	24.64	24.36	121.62	3.28	30.54	16.10	195.61
T_{14}	29.28	30.20	126.72	3.71	32.09	16.93	208.89
T_{15}	30.63	31.23	129.34	4.33	32.25	17.40	216.83
T_{16}	24.47	25.10	114.92	3.50	25.57	16.00	181.24
T_{17}	26.04	27.20	118.13	4.06	30.31	16.53	203.17
T_{18}	28.48	30.22	137.68	4.13	38.38	17.47	238.61
T_{19}	21.05	23.70	103.61	3.15	23.00	13.62	151.73
$CD_{0.05}$	1.58	1.95	2.39	0.71	1.50	1.74	1.83

plant growth promoting rhizobacteria could be explained with the nitrogen fixing, phosphate solubillizing and siderophore producing capacity of bacteria. It has also been reported that *Bacillus* is important on N_2 fixation on tomatoes, pepper and apricot (Sahin *et al.,* 2000 and Esitken *et al.,* 2003) and P solubilizing (Aslantas *et al.,* 2007) which are most important nutrient elements for strawberry growing. GA_3 has also been reported to increase plant height, spread, leaf area and yield in strawberry as reported by Sharma and Singh, (2009).

T- 2. Effect of plant growth promoting rhizobacteria and GA_3 on physico-chemical characteristics of strawberry fruits cultivar chandler

Treatment	Fruit weight (g)	Fruit size (mm)		TSS (^{0}Brix)	Titratable acidity (%)	TSS: Acid Ratio	Ascorbic acid (mg/100 g)	Total sugars (%)	Reducing sugars (%)	Non- reducing sugar (%)
		Fruit length	Fruit diameter							
T_1	15.09	34.05	24.20	9.53	1.24	7.73	42.33	6.03	4.15	1.79
T_2	15.71	34.59	25.12	9.14	1.45	6.39	45.47	6.17	4.39	1.69
T_3	16.14	35.71	25.97	8.76	1.57	5.64	46.83	6.65	4.54	2.00
T_4	16.13	34.98	24.85	10.04	1.16	8.66	43.42	6.31	4.34	1.87
T_5	16.64	35.69	25.20	9.72	1.29	7.54	51.50	7.15	4.65	2.38
T_6	17.61	38.28	26.12	9.40	1.50	6.70	58.20	7.21	4.78	2.31
T_7	16.02	36.30	25.38	10.12	1.43	7.16	41.57	6.27	4.31	1.86
T_8	16.42	37.85	25.82	9.28	1.48	6.30	43.33	6.72	4.44	2.16
T_9	16.68	40.21	26.90	9.20	1.61	5.76	54.20	6.84	4.58	2.14
T_{10}	15.95	34.84	25.59	10.97	1.19	9.22	48.20	6.14	4.29	1.76
T_{11}	16.42	35.48	25.70	10.83	1.34	8.09	50.20	7.24	4.43	2.67
T_{12}	16.32	40.16	27.48	9.69	1.70	5.93	58.05	7.98	4.83	3.00
T_{13}	15.64	36.35	24.59	10.45	1.21	8.96	43.03	6.08	4.61	1.40
T_{14}	15.72	37.06	25.76	9.92	1.35	7.34	46.67	7.01	4.84	2.06
T_{15}	16.59	37.37	26.29	8.99	1.54	5.99	57.72	7.10	5.34	1.68
T_{16}	14.72	33.77	25.06	10.41	1.14	9.10	45.58	6.34	4.73	1.54
T_{17}	15.62	34.97	25.23	9.85	1.21	8.15	55.42	6.67	4.78	1.79
T_{18}	16.99	36.89	26.03	9.61	1.43	6.72	57.95	6.77	5.05	1.63
T_{19}	14.52	33.02	23.71	9.57	1.09	8.74	41.00	5.95	4.02	1.84
$CD_{0.05}$	1.07	0.99	0.93	0.87	0.26	1.44	1.93	0.51	0.53	0.53

Effect on fruit quality:

The results (T-2) pertaining to fruit characteristics in the experiment shows that the maximum fruit weight (17.61 g) and ascorbic acid (58.20 mg) were recorded in T_6 followed by T_{18} (16.99 g and 57.95 mg/100 g respectively). The fruit length (40.21 mm) was maximum in T_9 while fruit diameter (27.48 mm) in T_{12}. The maximum fruit TSS (10.97 ^{0}Brix) and TSS: acid ratio (9.22) were observed in T_{10} whereas acidity was maximum in T_{12} (1.70 %) and minimum in T_{19} (1.09 %). The highest total (7.98 %) and non- reducing sugars (3.00 %) were recorded in T_{12} followed by T_{11} (7.24 and 2.67 % respectively). The highest reducing sugars (5.34 %) were found in T_{15} followed by T_{18} (5.05 %) as compared to control.

These results are in confirmation with the findings of Singh and Singh (2009), Pirlak and Kose (2009) and Lolaei *et al.* (2013). The GA_3 and plant growth promoting rhizobacteria has been reported to increase fruit quality of strawberry. The enlargement of the strawberry fruit is dependent on the auxin produced by the developing achenes. GA_3 might have affected auxin metabolism which might have indirectly helped in the fruit enlargement. GA_3 application increases the acid and ascorbic acid content but TSS decreased slightly. This is supported by Sharma and Singh (2009).

Thus the results of this study suggested that GA_3 and plant growth promoting rhizobacteria have a great potential to affect plant growth, yield and fruit quality of strawberry. Therefore, these can be utilized for sustainable and ecological fruit production and the use of chemical fertilizers can be reduced to a great extent.

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