Efficacy of *Azotobacter* and vermicompost alone and in combination on vegetative growth, flowering and yield of strawberry (*Fragaria* x *ananassa* Duch.) Cv. Chandler

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ABSTRACT

An experiment was carried out in the Department of Horticulture, Chandra Shekhar Azad University of Agriculture and Technology, Kanpur (U.P.), India, during 2009-10 and 2010-11 to study the efficacy of *Azotobacter,* vermicompost alone and in combination on vegetative growth, flowering, yield and quality of strawberry cv. Chandler. For this one year old runners of strawberry cv. Chandler were planted at a spacing of 30 x 30 cm on 8-10 cm raised beds of 60 x 60 cm dimension accommodating four plants per bed. There were nine treatments comprising two levels each of *Azotobacter* (6 and 7 kg/ha) and vermicompost (20 and 30 tonnes/ha) and their combinations along with one control, replicated thrice in randomized block design. Five kg of FYM was applied as a basal dose in all the treatments including control. All the doses of *Azotobactor* and vermicompost were applied at the time of planting in the field. The data of both the years of experiment were analyzed which clearly shows that combined application of *Azotobacter* at 7 kg/ha + vermicompost at 30 tonnes/ha significantly increased the height of plant (19.45 and 17.65 cm, respectively), number of leaves (63.60 and 59.60, respectively), number of crowns (7.28 and 6.27, respectively), number of runners (5.34 and 4.32, respectively) per plant, whereas maximum number of flowers (67.48 and 64.51, respectively) and fruits set (39.21 and 36.19, respectively) per plant with increased duration of harvesting (71.04 and 69.02 days, respectively) and minimum number of days taken to produce first flower (56.15 and 54.15days, respectively) and fruit set (6.44 and 5.94days, respectively) with significantly more yield (324.38 and 320.39 g/plant, respectively) were also observed in *Azotobacter* at 6 kg/ha + vermicompost at 30 tonnes/ha applied plants. So far as the quality characters of berries are concerned, combined application of *Azotobacter* at 7 kg/ha + vermicompost at 30 tonnes/ha also produced berries with maximum length (5.01 and 4.51cm, respectively), width (2.64 and 2.34 cm, respectively), weight (9.02 and 8.49 g, respectively), volume (6.12 and 5.82 cc, respectively), TSS (10.31 and 9.29 ^{0}Brix, respectively), total sugars (9.73 and 8.74%, respectively), ascorbic acid (56.52 and 54.53 mg/100g edible pulp, respectively) with minimum titratable acidity (0.52 and 0.47%, respectively) contents in comparison to untreated plants under plains of central Uttar Pradesh (India).

KEY WORDS: Strawberry, *Azotobacter,* Vermicompost, Vegetative growth, Flowering, Yield, Quality.

INTRODUCTION

Strawberry (*Fragaria* x *ananassa* Duch.) is an octaploid in nature with 2n=8x=56 chromosome number, is a herbaceous and perennial plant of family rosaceae, which gives the high return within shortest time than other berry fruits. Its fruits are very nutritious with distinct pleasant aroma and flavour and are consumed as dessert or processed as jam, syrup, ice-cream and for quick freezing and canning *etc*. Modern day intensive crop cultivation results with the huge application of chemical fertilizers which are not only in short supply but also expensive and pollute the environment, soil and water too. Nitrogen fixing bacteria, phosphate solubulizers and vermicompost are the main bio-fertilizers for horticultural crops. These bio-fertilizers having micro-organisms which are either free living in soil or symbiotic with plants and contribute directly or indirectly towards nitrogen and phosphorus nutrition of plants.

MATERIALS AND METHODS

Twelve month old runners of strawberry cv. Chandler were planted on 8-10 cm raised beds of 60 cm x 60 cm dimension at the spacing of at 30 x 30 cm in Department of Horticulture, C.S. Azad University of Agriculture and Technology, Kanpur-208 002 (U.P.), India during the years 2009-10 and 2010-11. There were nine treatments comprising two levels each of *Azotobacter* (6 and 7 kg/ha) and vermicompost (20 and 30 tonnes/ha) and their combinations along with one control, replicated thrice in randomized block design. Five kg of FYM was applied as a basal dose in all the treatments including control. All the doses of *Azotobactor* and vermicompost were applied at the time of planting in the field. The data recorded on different parameters during both the years of experimentation were analyzed and were presented separately.

Observations on plant height, number of leaves, crown and runners per plant were recorded at the end of fruiting season, whereas days taken to produce first flower, fruit set and duration of harvesting were recorded as suggested by Kidmos *et al.* (1996). Number of flowers and fruits per plant were counted at five days interval during entire cropping season. At each picking, data on berry weight and yield per plant were recorded. The length and width of ten berries were measured with vernier caliper. These berries were also used for measuring volume by water displacement method. The TSS of berries was recorded with the help of hand refractometer. The titratable acidity, total sugars and ascorbic acid contents were determined by the methods as suggested by A.O.A.C. (1980).

RESULTS AND DISCUSSION

Height of plants and Number of leaves

Data presented in Table-1, clearly revealed that the height of plants and number of leaves per plant were increased significantly with the use of *Azotobacter* and vermicompost alone and in combination at different levels. The maximum height of plants (19.45 and 17.65 cm, respectively) and number of leaves (63.60 and 59.60, respectively) per plant were obtained with the application of *Azotobacter 7* kg/ha + vermicompost 30 tonnes/ ha. The height of plants and number of leaves per plant get reduced with the reduction in doses of *Azotobacter,* vermicompost and their combinations and they were minimum under control (13.93 & 12.4 cm, and 36.48 and 32.48, respectively) during both years of experimentation. The increase in plant height and number of leaves might be due to the production of more chlorophyll content with inoculation of nitrogen fixers. The other reason for increased vegetative growth may be the production of plant growth regulators by bacteria in rhizosphere, which are absorbed by the roots. Better development of root system and the possibly synthesis of plant growth hormones like IAA, GA and cytokinins and direct influence of bio-fertilizers might have caused increase in plant growth parameters.The increase in height of plants and number of leaves per plant with the application of *Azotobacter* + vermicompost has also been reported by Hammam (2003) in banana, Marathe and Bharambe (2005) in sweet orange and Nazir *et al.* (2006) and Tripathi *et al.* (2010) in strawberry.

Crowns and runners

During the entire course of investigation the number of crowns and runners per plant were significantly increased with the application of *Azotobacter* and vermicompost at different levels (Table-1). The maximum number of crowns (7.28 and 6.27, respectively) and runners (5.34 and 4.32, respectively) per plant were produced in the plants applied with *Azotobacter* at *7* kg/ha + vermicompost at 30 tonnes/ha, whereas the minimum number of crowns (3.09 and 3.02, respectively) and runners (2.32 and 1.72, respectively) per plant were recorded under control. These findings are in complete agreement with that of Nazir *et al.* (2006), who narrated highest runners per plant in strawberry with poultry manure + *Azotobacter* + wood ash + vermicompost + oil cake application. Increase number of crown and runners per plant might be due to increased growth of plant in the form of height and number of leaves, which accumulated more photosynthates and thereby increased crowns and runners per plant.

Number of days taken to produce first flower and fruit set

During both years of investigation *i.e.* 2009-10 and 2010-11, the minimum number of days taken to produce first flower (56.15 and 54.15 days, respectively) was recorded in the plants which were fertilized with *Azotobacter* 6 kg/ha + vermicompost 30 tonnes/ha (Table-1). However, maximum number of days (76.37 and 74.34 days, respectively) taken to produce first flower was recorded under control. This phenomenon may be on account of prolonged growth of plant in the presence of *Azotobacter* and vermicompost bio-fertilizers. These results have got the support of the findings of Shukla *et al.* (2009), who also recorded earliest flowering with NPK + PSB and NPK + *Azotobacter* treatments in tomato.

The minimum number of days taken to fruit set (6.44 and 5.94 days, respectively) were recorded in plants supplied with *Azotobacter* 6 kg/ha + vermicompost 30 tonnes/ha, whereas, unfertilized (control) plants took maximum days (8.76 and 8.26 days, respectively) for fruit setting during both years of investigation (Table-1). Research reports are lacking in this aspects and thus warrant further studies.

Number of flowers and fruits set

Further it was also observed that during both years of investigation, the maximum number of flowers per plant (67.48 and 64.51, respectively) were recorded in *Azotobacter 6* kg/ha + vermicompost 30 tonnes/ha applied plants, whereas, the minimum number (29.91 and 26.95, respectively) were observed in the untreated (control) plants (Table-1). This increase in number of flowers per plant may possibly be due to the fact that *Azotobacter* and vermicompost application accelerated the development of inflorescence, leaf number in autumn, which are positively correlated with the number of flowers and fruits in the following spring. Increased number of flowers might have also resulted because of increase in number of crowns per plant. Similar observations were also reported by Tripathi *et al.* (2010) in strawberry, who found that higher dose of *Azotobacter* and PSB (7 kg/ha) increased the number of flowers per plant.

The maximum number of fruit set per plant (39.21 and 36.19, respectively) was observed when the plants were applied with *Azotobacter 6* kg/ha + vermicompost 30 tonnes/ha, followed by *Azotobacter* 7 kg/ha + vermicompost 20 tonnes/ha (32.02 and 29.06, respectively), whereas the least number of fruit set per plant was produced from unfertilized (contol) plants (17.83 and 14.85, respectively) during both years of investigation (Table-1). These results are in conformity with the finding of Gajbhiye *et al.* (2003), who noted that increase in *Azotobacter* and PSB concentration resulted in higher fruit set in tomato. *Azotobacter* is expected to hasten plant development; hence an increase in fruit set in the present studies is due to the cumulative effect of *Azotobacter* and vermicompost application.

Duration of harvesting

During the present investigation the duration of harvesting was significantly increased with the application of *Azotobacter* and vermicompost alone and in combined application. The maximum duration of harvesting (71.04 and 69.02 days, respectively) was observed when the plants were fertilized with *Azotobacter* 6 kg/ha + vermicompost 30 tonnes/ha (Table-1). Similar results were also recorded by Tripathi *et al.* (2010), Singh and Singh (2009) in strawberry, who got advanced duration of harvesting (earliness) by approximately one month which obviously extended the period of harvesting.

Yield

Data presented in Table-2 clearly revealed that *Azotobacter* and vermicompost has given remarkable increase in the yield of strawberry fruits during both years of investigation *i.e.*

Table 1: Influence of different levels of *Azotobacter* and vermicompost alone and in combination on vegetative growth and flowering of strawberry cv. Chandler

Treatments	Height of plant (cm)		Number of leaves per plant		Number of crowns per plant		Number of runners per plant		Days taken to produce first flower		Number of flowers per plant		Days taken to fruit set		Number of fruits set per plant		Duration of harvesting (days)	
	2009-10	2010-11	2009-10	2010-11	2009-10	2010-11	2009-10	2010-11	2009-10	2010-11	2009-10	2010-11	2009-10	2010-11	2009-10	2010-11	2009-10	2010-11
Vermicompost 20 tonnes/ha	14.69	13.19	45.07	41.04	5.28	4.28	4.15	3.13	67.90	65.88	40.23	37.22	8.26	7.76	22.23	19.25	61.45	59.47
Vermicompost 30 tonnes/ha	16.15	14.65	49.77	45.77	5.68	4.68	4.49	3.47	64.86	62.85	44.64	41.65	7.58	7.08	24.73	21.71	63.87	61.85
Azotobacter 6 kg/ha	17.14	15.64	50.62	48.62	5.50	4.49	4.37	3.39	64.45	62.47	47.83	44.83	7.73	7.23	20.21	17.24	65.01	63.02
Azotobacter 7kg/ha	17.19	15.69	52.62	48.62	6.09	5.10	4.40	3.41	62.22	60.23	49.21	46.19	7.29	6.79	24.04	21.02	65.97	63.98
Azotobacter 6 kg/ha +Vermicompost 20 tonnes/ha	18.14	16.64	53.63	49.63	6.19	5.18	4.46	3.48	62.37	60.37	52.07	49.05	7.21	6.71	24.97	21.95	66.42	64.39
Azotobacter 7 kg/ha + Vermicompost 20 tonnes/ha	18.54	17.04	56.16	52.16	6.38	5.34	4.56	3.53	61.83	59.81	60.27	57.29	6.97	6.49	32.02	29.06	68.36	66.38
Azotobacter 6 kg/ha + Vermicompost 30 tonnes/ha	18.67	17.17	61.08	57.08	6.55	5.61	4.50	3.47	56.15	54.19	67.48	64.51	6.44	5.94	39.21	36.19	71.04	69.02
Azotobacter 7 kg/ha +Vermicompost 30 tonnes/ha	19.45	17.95	63.60	59.60	7.28	6.27	5.34	4.32	59.09	57.06	58.21	55.17	7.08	6.58	27.36	24.38	67.82	65.79
Control (untreated)	13.93	12.43	36.48	32.48	3.09	3.02	2.32	1.27	76.37	74.34	29.91	26.95	8.76	8.26	17.83	14.85	53.47	51.52
S.E.±	0.94	1.00	2.18	1.83	0.39	0.20	0.17	0.10	0.82	0.87	1.89	1.40	0.59	0.28	1.14	1.32	1.57	0.88
CD at 5%	2.16	2.30	5.05	3.76	0.91	0.47	0.39	0.24	1.89	2.02	4.37	3.23	1.37	0.66	2.63	2.60	3.62	2.03

Table 2: Influence of different levels of *Azotobacter* and vermicompost alone and in combination on yield and quality of strawberry cv. Chandler

Treatments	Yield per plant (g)		Average berry length (cm)		Average berry width (cm)		Average berry weight (g)		Average berry volume (cc)		T.S.S. (ºBrix)		Titratable acidity (%)		Total sugars (%)		Ascorbic acid (mg/100/pulp)	
	2009-10	2010-11	2009-10	2010-11	2009-10	2010-11	2009-10	2010-11	2009-10	2010-11	2009-10	2010-11	2009-10	2010-11	2009-10	2010-11	2009-10	2010-11
Vermicompost 20 tonnes/ha	126.04	121.05	2.94	2.44	1.93	1.63	6.27	5.74	4.66	4.36	7.94	6.95	0.67	0.62	6.87	5.86	52.21	50.19
Vermicompost 30 tonnes/ha	168.23	163.19	3.21	2.71	2.09	1.79	6.82	6.29	5.12	4.82	8.36	7.34	0.65	0.60	6.98	5.95	52.88	50.91
Azotobacter 6 kg/ha	158.21	153.23	3.59	3.09	2.18	1.88	6.88	6.35	5.14	4.84	8.46	7.49	0.65	0.60	7.53	6.51	53.02	51.03
Azotobacter 7kg/ha	172.97	167.94	3.73	3.23	2.23	1.93	7.52	6.99	5.21	4.91	8.58	7.60	0.64	0.59	7.84	6.86	53.78	51.70
Azotobacter 6 kg/ha + Vermicompost 20 tonnes/ha	187.23	183.26	4.12	3.64	2.27	1.97	7.81	7.28	5.34	5.04	8.84	7.81	0.62	0.57	8.03	7.06	54.03	52.06
Azotobacter 7 kg/ha + Vermicompost 20 tonnes/ha	236.07	231.05	4.46	3.96	2.55	2.25	8.92	8.39	5.72	5.42	9.67	8.71	0.58	0.53	9.38	8.42	55.73	53.71
Azotobacter 6 kg/ha + Vermicompost 30 tonnes/ha	324.38	320.39	5.01	4.51	2.64	2.34	9.02	8.49	6.12	5.82	10.31	9.29	0.52	0.47	9.73	8.74	56.52	54.53
Azotobacter 7 kg/ha + Vermicompost 30 tonnes/ha	213.62	208.59	4.27	3.77	2.40	2.10	6.61	6.08	5.59	5.29	9.41	8.43	0.59	0.54	8.34	7.37	54.83	52.88
Control (untreated)	91.56	86.61	2.42	1.92	1.44	1.14	4.68	4.15	3.98	3.68	7.05	6.03	0.70	0.65	6.65	5.68	46.93	44.90
S.E.$\pm$	7.08	5.14	0.06	0.04	0.04	0.03	0.30	0.04	0.15	0.09	0.10	0.06	0.005	0.003	0.11	0.05	0.55	0.53
CD at 5%	16.33	11.66	0.15	0.11	0.11	0.06	0.70	0.10	0.34	0.21	0.24	0.14	0.012	0.008	0.26	0.11	1.27	1.23

2009-10 and 2010-11. The maximum yield per plant (324.38 and 320.39 g/plant, respectively) was recorded in the plant applied with Azotobacter 6 kg/ha + vermicompost 30 tonnes/ha followed by 236.07 and 231.05 g/plant, respectively, from the application of *Azotobacter* 7 kg/ha + vermicompost 20 tonnes/ha, whereas the minimum yield per plant (91.56 and 86.61 g/plant, respectively) was recorded from the untreated control plants during both years of investigation *i.e.* 2009-10 and 2010-11. These findings are in accordance with the findings of Wange *et al.* (1998) and Tripathi *et al.* (2010) 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 width as well as berry weight. Moreover, it may also be due to the fact that nitrogen fixers and vermicompost not only increased the availability of nitrogen to the plants but also increased their translocation from root to flower through plant foliage (Singh and Singh, 2009).

Physical fruit characters

During both years of investigation *i.e.* 2009-10 and 2010-11, the berry size (length and width), weight and volume was significantly increased with the use of *Azotobacter* and vermicompost. The maximum berry length (5.01 and 4.51 cm, respectively), width (2.64 and 2.34 cm, respectively), weight (9.02 and 8.49 g, respectively) and volume (6.12 and 5.82 cc, respectively) were recorded in the plants supplied with *Azotobacter* 6 kg/ha + vermicompost 30 tonnes/ha, followed by *Azotobacter 7* kg/ha + vermicompost 20 tonnes/ha, whereas, the minimum berry length (2.42 and 1.92 cm, respectively), width (1.44 and 1.14 cm, respectively), weight (4.68 and 4.15 g, respectively) and volume (3.98 and 3.68 cc, respectively) were recorded under control (Table-2). Similar results were obtained by Gajbhiye *et al.* (2003) and Shukla *et al.* (2009) in tomato.

The increase in berry size (length and width), weight and volume during both years of investigation might be due to the increased photosynthetic ability of plants supplied with *Azotobacter* + vermicompost, which in turn might have favoured and increased the accumulation of dry matter. Fruit size, weight and volume are highly correlated with dry matter content and balanced level of hormone. Nitrogen fixers are known for accumulation of dry matter and their translocation as well as favours synthesis of different growth regulators (Awasthi *et al.,* 1998).

Chemical fruit characters

On the basis of both years investigation, it was observed that the TSS and total sugars content of berries were significantly increased by different level of *Azotobacter* and vermicompost applications (Table-2). The maximum TSS (10.31 and 9.29 ^{0}Brix, respectively) and total sugars (9.73 and 8.74%, respectively) contents were recorded in the berries produced from the plants applied with *Azotobacter* 6 kg/ha + vermicompost 30 tonnes/ha, followed by *Azotobacter 7* kg/ha + vermicompost 20 tonnes/ha (9.67 & 8.71 ^{0}Brix, respectively and 9.38 & 8.42%, respectively) and the minimum TSS (7.05 and 6.03 ^{0}Brix, respectively) and total sugars contents (6.65 and 5.68%, respectively) in unfertilized (control) plants. An increase in TSS and total sugars contents with *Azotobacter* and vermicompost application may be attributed due to the quick metabolic transformation of starch and pectin into soluble compounds and rapid translocation of sugars from leaves to the developing fruits. These findings are in agreement with the result of Singh *et al.* (2009) in ber, Rathi and Bist (2004) in pear and Baksh *et al.* (2008) in guava.

The maximum titratable acidity (0.70 and 0.65%, respectively) was recorded in the berries which were produced from the unfertilized (control) plants, whereas, the minimum acidity (0.52 and 0.47%, respectively) was recorded with *Azotobacter* 6 kg/ha + vermicompost 30 tonnes/ha supplied plants during both the years of experimentation (Table-2). The findings are in conformity with the observations of Singh *et al.* (2009) in ber, Rathi and Bist (2004) in pear and Baksh *et al.* (2008) in guava.

Further perusal of data presented in Table-2 clearly revealed that during both years of experimentation *i.e.*2009-10 and 2010-11, the maximum amount of ascorbic acid content was recorded in berries produced from the plants fertilized with *Azotobacter* 6 kg/ha + vermicompost 30 tonnes/ha (56.52 and 54.53 mg/100g edible pulp, respectively), closely followed by *Azotobacter 7* kg/ha + vermicompost 20 tonnes/ha (55.73 and 53.71 mg/100g edible pulp, respectively), whereas, the minimum ascorbic acid content was recorded in fruits produced from untreated (control) plants (46.93 and 44.90 mg/100g edible pulp, respectively). This result got the support with the findings of Singh *et al.* (2009) in ber and Tripathi *et al.* (2010), Yadav *et al.* (2010) in strawberry. The respective increase in ascorbic acid content might be due to the increased efficiency of microbial inoculants to fix atmospheric nitrogen, increase in availability of phosphorous and secretion of growth promoting substances which accelerates the physiological process like carbohydrates synthesis, etc.

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Received on 21 September, 2012 and accepted on 11 March, 2012