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Influence of bio-inoculants and inorganic fertilizers on yield, nutrient balance, microbial dynamics and quality of strawberry (*Fragariax ananassa*) under rainfed conditions of Kashmir valley

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ABSTRACT

A field experiment was conducted during 2006–08 at Wadura, Sopore, Kashmir to evaluate the effect of bio-inoculants and inorganic fertilizers on the performance of strawberry (*Fragariax ananassa* Duch) under rainfed conditions. The treatments consisted of control (no culture), *Azotobacter chroococcum*, *Azospirillum brasilense*, *Pseudomonas striata*, Arbuscular mycorrhizal fungi, *Azotobacter+Azospirillum*, *Azotobacter+Azospirillum+Pseudomonas striata*, *Azotobacter+Azospirillum+*(*Arbuscular mycorrhizal* fungi) and recommended dose of fertilizers. The results indicated that application of recommended dose of fertilizers recorded significantly higher berry yield (6.02 tonne/ha), highest net returns (Rs 53 448/ha) and available nutrient (271.4 kg N and 18.62 kg P/ha) over rest of the treatments. Application of recommended dose of fertilizers increased available-soil N and P to the tune of 7.23, 8.38, 7.44 and 10.0% more over triple inoculation with *Azotobacter+Azospirillum+Pseudomonas striata* (253.1 N and 17.18 P kg/ha) and *Azotobacter+Azospirillum+*(*Arbuscular mycorrhizal* fungi) (252.6 N and 16.92 P kg/ha), respectively. Whereas multi-inoculation of *Azotobacter+Azospirillum*+PSB and *Azotobacter+Azospirillum+*(*Arbuscular mycorrhizal* fungi) increased available soil N and P by 1.81, 16.9, 1.60 and 15.1% over their initial levels, respectively. Multi-inoculation of *Azotobacter+ Azospirillum*+PSB, being at par with *Azotobacter+Azospirillum+Arbuscular mycorrhizal* fungi recorded significantly higher viable count of *Azotobacter chroococcum*, *Azospirillum brasilense* and *Pseudomonas striata* over rest of the treatments. However, application of recommended dose of fertilizers significantly reduced the microbial population over control. Significant improvement in root infection (60.8%) and its spore density (271.6 spores/50 g soil) were observed with co-inoculation of *Azotobacter+Azospirillum+Arbuscular mycorrhizal* fungi over sole inoculation with arbuscular mycorrhizal fungi (53.5% and 222.7 spores/50 g soil). The maximum TSS (8.81°B), TSS/acidity ratio (12.77), total sugars (7.40%) and ascorbic acid (50.69 mg/100 g) were recorded under co-inoculation with *Azotobacter+Azospirillum+Pseudomonus striata* being at par with *Azotobacter+Azospirillum+Arbuscular mycorrhizal* fungi but significantly higher over application of recommended dose of fertilizers. However, maximum titratable acidity was recorded with control (0.82%) which was significantly higher over all the treatments.

Key words: Bio-inoculants, Colonization, Microbial population, Nutrient balance, Strawberry, Yield

Strawberry (*Fragaria* × *ananassa* Duch) is a widely relished fruit owing to its flavour, delicacy and softness. It is in great demand as fresh fruit as well as in the processing industries, particularly for flavouring purposes. In India, Maharastra, Punjab, Haryana, Himachal Pradesh and Uttrakhand are the major states for its cultivation. In Jammu and Kashmir, the crop has assumed economic importance mainly due to high returns per unit area and production of berries within a few months of planting (Zargar *et al*. 2008). In Kashmir valley, 'Senga Sengana' is the most popular and superior variety of strawberry due to fleshy and softness of fruit growing in largest area under rainfed conditions. The enhancement of soil fertility assumes importance not only for sustainable agricultural productivity but also for nutritional status of strawberry in rainfed conditions. The extensive use of chemical fertilizers which affect the soil health, results in decreased soil productivity and have adverse affect on fruit quality (Macit *et al.* 2007). The use of biofertilizers is being sought to maintain and improve soil

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quality and productivity levels at low input cost. Through better conservation of C, N and P, use of sole or co-inoculation of bio-inoculants, viz *Azotobacter*, *Azospirillum* and *Pseudomonas striata* and arbuscular mycorrhizal fungi which are the components of organic farming regulate steady supply of nitrogen and phosphorus during plant growth (Singh and Singh 2006). Biofertilizers are known to exert indirect effects on soil microbiological activities which in turn help the plant to grow better, besides direct effect on nitrogen fixation and P mobilization (Rana and Chandel 2003). Although, the effects of bio-inoculants in legumes, cereals and oilseed crops have been well established, however, no much information is available on strawberry. Keeping this in view, the present investigation was undertaken to study the effect of bio-inoculants and inorganic fertilizers on yield, nutrient balance and microbial dynamics in the rhizosphere soil of strawberry under rainfed conditions of Kashmir valley.

MATERIALS AND METHODS

A field experiment was conducted at Regional Research Station, SKUAST-K, Wadura, Sopore, Kashmir under ranifed temperate conditions during 2006–08. The soil was silty-clay loam, neutral in reaction (*p*H 7.07) having organic C 10.02 g/kg, available N 248.6 kg/ha, available P 14.7 kg/ha and available K 250.3 kg/ha. The treatments consisted of control (no culture), *Azotobacter chroococcum*, *Azospirillum brasilense*, *Pseudomonas striata* (PSB), Arbuscular mycorrhizal fungi (AMF), *Azotobacter*+*Azospirillum*, *Azotobacter*+*Azospirillum*+PSB, *Azotobacter*+*Azospirillum*+ AMF and recommended dose of fertilizers (RDF) (80:17.6:33.2 kg/ha NPK, respectively) were laid out in a random block design with 3 replications. Each plot received 20 tonnes/ha farmyard manure prior to the planting. Recommended dose of nitrogen @ 80 kg/ha (½ as basal and ½ as top-dressing before blossoming) was supplied through urea after adjusting the quantity of N already supplied through di-ammonium phosphate. Phosphorus and potassium were applied as basal dose @ 17.6 and 33.2 kg/ha each in the form of DAP and muriate of potash, respectively. Application of NPK was done only in the plots where recommended dose of fertilizers (100% RDF) was allotted, whereas remaining plots were only inoculated with sole or combined biofertilizers as per treatments without using chemical fertilizers.

Pure culture of *Azotobacter chroococcum*, *Azospirillum brasilense* and *Pseudomonas striata* isolated from the roots and rhizosphere soils, identified and were screened on the basis of certain biochemical tests such as Gram's reactions, catalase, ammonification, indole acetic acid, pigmentation, gelatin hydrolysis, N_2 fixation, P-solubilization etc. in the present study. These cultures were grown on Jenson's, N-free malate and Pikovaskyas medium, respectively for 4 days. The cells were centrifuged, washed twice in sterile distilled water and suspended in 0.15% phosphate buffer at *p*H 7.0. Arbuscular mycorrhizal fungi isolated from the rhizosphere soil of legume (beans, soybean and peas) and cereal plants (maize, oat and wheat) were maintained on wheat roots under sterilized conditions (1:1 ratio of soil and sand). About 20 g arbuscular mycorrhizae fungal culture including root segments, infected hyphae and 10–13 viable arbuscular mycorrhizal fungal spores/gram inoculum were used/plant rhizosphere of strawberry. The seedlings of 'Senga Sengana' strawberry were inoculated with *Azotobacter chroococcum*, *Azospirillum brasilense* and *Pseudomonas striata* by root dipping for 15 min in the respective microbial suspensions @ 1 litre broth/1 000 runners (containing 10^8_10^9 cfu/ml broth) and immediately planted on raised flat bed (4 m × 4 m) which have 110 plants/plot at the spacing of 40 m × 40 cm in first week of November which is the best time of planting of 'Senga Sengana' in Kashmir valley to avoid cold injury of buds and crown. After planting of strawberry runners, plots were covered with rice straw to protect the plants from cold temperature as well as to keep the fruits away from soil contact and to conserve soil moisture. When the fruits reached commercial maturity as per the intensity of colour development, strawberry fruits were picked during mid to last week of May (4–5 pickings). At the time of berry picking, 5 fruits/plant (20 plants/plot) were collected for measurement of fruit length, diameter and weight. Fruit TSS was measured with Ermma hand refractrometer, titratable acidity and total sugars were measured by the methods of Rangana (1986) and AOAC (1980), respectively. Ascorbic acid was determined by the 2, 6–dichloroindophenol titrimetric method (Lundergan and Moore 1975). Rhizosphere soil and root samples were collected from each treatment after harvesting of the crop for further analysis. Standard methods were used for determination of root colonization, mycorrhizal spores and viable count of *Azotobacter chroococcum*, *Azospirillum brasilense* and *Pseudomonas striata*. The soil samples were collected, processed and analyzed for available N and P as per standard methods. Economics analysis was done on the basis of prevailing market price of inputs used and the output obtained from the each treatment. To analyze treatment effect, control treatment was considered as a check while calculating the economics of strawberry production. The additional production in each treatment was calculated after subtracting the yield of control plot from the yield of each treatment. The increase in yield over control obtained from each treatment was multiplied by the prevailing market price (kg/ha) of strawberry fruit and was considered as additional produce (A). Additional cost of input involved in each treatment as per prevailing market price over control (Rs/ha) was also worked out as per the extra cost incurred in each treatment (B). The additional net income over control (A-B) was calculated after subtracting the additional cost of each treatment (B) from additional produce value over control (A).

RESULTS AND DISCUSSION

Yield attributes, berry yield and economics

Inoculation of strawberry seedlings either with sole or co-inoculation with biofertilizers and application of recommended dose of fertilizers significantly increased the growth, berry attributes and berry yield over control (Table 1). The maximum plant height (21.14 cm), fruit diameter (29.0 mm), fruit/plant (11.99 g), fruit weight (10.73) and dry matter (2.69 tonnes/ha) was recorded with recommended dose of fertilizers, followed by multi-inoculation of biofertilizers. However, no clear trend was observed in respect of runner production. The highest runner production were recorded with *Azotobacter*+ *Azospirillum* (11.32/plant), followed by *Azotobacter* alone (11.13/plant). The increased vegetative growth and berry attributes by biofertilizers inoculation might be due to the fact that fixation of N_2 and solubilization of sparingly soluble phosphorus by nitrogen-fixing bacteria and P-solubilizing/mobilizing micro-organisms, respectively, that played important role in the assimilation of numerous amino acids which helped in increasing the photosynthesis efficiency (Rana and Chandel 2003). The increased runner production under *Azotobacter* treated plots might be due to secretion of growth-promoting substances, especially cytokinin by *Azotobacter* which increased the runner production (Nazir *et al.* 2006).

Sole inoculation of strawberry seedlings with *Azotobacter*, *Azospirillum*, *Pseudomonas striata* and arbuscular mycorrhizal fungi significantly increased berry yield, being 10.7, 9.0, 8.0 and 7.1% more over control, respectively. Combined inoculation of *Azotobacter*+ *Azospirillum*+ *Pseudomonas striata* being at par with *Azotobacter*+ *Azospirillum*+*Arbuscular mycorrhizal* fungi, recorded maximum berry yield which was significantly higher over sole inoculation of biofertilizers and increased by 22.0 and 20.5% higher over control. Better strawberry yield with multi-inoculation might be due to increased availability of N and P through enhanced biological N_2-fixation in strawberry and P availability through *Pseudomonas striata* and arbuscular mycorrhizal fungi (Rana and Chandel 2003). Synergism among *Azotobacter*, *Azospirillum* and *Pseudomonas striata* might have resulted in better berry yield with their combined inoculation as against single inoculation. The highest berry yield (6.02 tonnes/ha) was recorded with the application of recommended dose of fertilizers being 46.8% more over control. This might be due to easy availability of N, P and K from inorganic sources resulted in higher yield of berry. These observations are in conformity with those from Sonsteby *et al.* (2004) who reported increased number of fruits with higher weight due to application of N, P and K. Application of recommended dose of fertilizers recorded highest fruit yield which fetched additional income by 1.98 and 2.13 fold over inoculation with *Azotobacter*+*Azospirillum*+PSB and *Azotobacter*+ *Azospirillum*+*Arbuscular mycorrhizal* fungi, respectively. Application of recommended dose of fertilizers recorded maximum additional berry yield (1.13 tonnes/ha) and net income (Rs 26 508/ha) over multi-inoculation with *Azotobacter*+*Azospirillum*+*Pseudomonas striata*.

Nutrient balance in soil

The N content (an indicator of available N pool) of the soil after final picking of strawberry significantly increased over control in all the treatments except under PSB and

Table 1 Effect of biofertilizers and inorganic fertilizers on fruit attributes and fruit yield of strawberry (pooled data of 2 years)

Treatment	Plant height (cm)	Fruit length (mm)	Fruit diameter (mm)	Fruits/ plant	Fruit weight (g)	Runners/ plant	Dry matter (tonnes/ ha)	Berry yield (tonnes/ ha)	Increase in yield over control (tonnes/ha)	Economic viability		
										A	B	A–B
Control (no culture)	15.66	23.42	20.95	8.04	7.19	8.37	1.69	4.10				
Azotobacter	18.02	27.42	25.92	9.15	8.45	11.13	1.93	4.54	0.44	13 200	20	13 180
Azospirillum	17.58	27.02	24.95	9.10	8.15	8.77	1.86	4.47	0.37	11 100	20	11 080
PSB	17.70	26.10	24.42	8.65	7.94	7.80	1.78	4.43	0.33	9 900	20	9 880
AMF	17.30	25.58	23.95	8.53	7.74	8.89	1.75	4.39	0.29	8 700	80	8 620
Azotobacter+*Azospirillum*	18.94	28.17	26.87	10.14	9.07	11.32	2.18	4.77	0.67	20 100	40	20 060
Azotobacter+*Azospirillum*+PSB	20.05	29.27	28.27	11.00	9.61	10.10	2.50	5.00	0.90	27 000	60	26 940
Azotobacter+*Azospirillum*+AMF	19.64	28.82	27.87	10.74	9.44	10.97	2.42	4.94	0.84	25 200	120	25 080
RDF (80+17.6+33.2 kg NPK/ha)	21.14	28.75	29.00	11.99	10.73	9.11	2.69	6.02	1.92	57 600	4 152	53 448
SEm±	0.41	0.47	0.48	0.25	0.18	0.43	0.04	0.05				
CD (*P*=0.05)	1.24	1.41	1.45	0.79	0.54	1.44	0.11	0.16				

A, Additional produce cost over control (Rs/ha); B, additional cost of input over control (Rs/ha); A-B, additional net income over control (Rs/ha)

Sale price of strawberry fruit was @ Rs 30/kg

Table 2 Effect of sole and co-inoculation of biofertilizers and inorganic fertilizers on balance of N and P in soil after strawberry harvest (pooled data of 2 years)

Treatment	Nutrient balance after crop harvest (kg/ha)					
	Available N	Loss (–) or gain (+) of N over control	Loss (–) or gain (+) of N over initial	Available P	Loss (–) or gain (+) of P over control	Loss (–) or gain (+) of P over initial
Control (no culture)	231.3		–17.3	13.02		–1.68
Azotobacter	240.4	+9.1	–8.2	14.00	+0.98	–0.70
Azospirillum	236.8	+5.5	–11.8	13.72	+0.70	–0.98
PSB	233.7	+2.4	–14.9	16.03	+3.01	+1.33
AMF	232.6	+1.3	–16.0	15.60	+2.58	+0.90
Azotobacter+Azospirillum	249.8	+18.5	+1.20	14.73	+1.71	+0.03
Azotobacter+Azospirillum+PSB	253.1	+21.8	+4.50	17.18	+4.16	+2.48
Azotobacter+Azospirillum+AMF	252.6	+21.3	+4.0	16.92	+3.90	+2.22
RDF (80+17.6+33.2 kg NPK/ha)	271.4	+40.1	+22.8	18.62	+5.60	+3.92
SEm±	1.87			0.22		
CD (*P*=0.05)	5.62			0.67		
Initial value	248.6			14.7		

arbuscular mycorrhizal fungi-treated plots (Table 2). However, *Azotobacter* alone enhanced available N significantly over control. The maximum build-up of available N (271.4 kg/ha) was recorded with the application of recommended dose of fertilizers. This could be attributed to increase in root and shoot dry matter of strawberry when incorporated into the soil might have enhanced the multiplication of micro-organisms which might have converted organically bound N into inorganic form. The favourable soil conditions after fruit picking might have helped in the mineralization of soil N leading to the build-up of available N in soil (Sonsteby *et al.* 2004). As regards to combined inoculation of biofertilizers, triple inoculation with *Azotobacter+Azospirillum +Pseudomonas striata* (253.1 kg/ha) was at par with *Azotobacter+Azospirillum*+AMF (252.6 kg/ha) recorded highest available N over single and combined inoculation with *Azotobacter+Azospirillum* (249.8 kg/ha). Synergism among *Azotobacter+Azospirillum+Pseudomonas striata* might have resulted in better N_2–fixation. Further, the presence of P-solubilizing microorganisms, that increases the availability of P, might have facilitated the supply of ATP energy which would have been used by free-living bacteria for enhancing the biological N_2-fixation (Johansson *et al.* 2004).

Available P in soil was significantly higher over control in all the treatments (Table 2). Maximum available P (18.62 kg/ha) was recorded with the application of recommended dose of fertilizers, followed by *Azotobacter+Azospirillum+Pseudomonas striata* (17.18 kg/ha) and *Azotobacter+Azospirillum+Arbuscular mycorrhizal* fungi (16.92 kg/ha) treatment. Application of recommended dose of fertilizers increased available-soil P by 8.38 and 10.4% over multi-inoculation with *Azotobacter+Azospirillum+Pseudomonas striata* and *Azotobacter+Azospirillum+Arbuscular mycorrhizal* fungi, respectively. Whereas, multi-inoculation of *Azotobacter+Azospirillum*+PSB and *Azotobacter+Azospirillum*+AMF improved available-soil P by 16.9 and 15.1% over initial levels of P, respectively. Similarly, sole inoculation with *Pseudomonas striata* recorded highest available P over single inoculation with *Azotobacter*, *Azospirillum* and dual inoculation with *Azotobacter+Azospirillum* but was at par with arbuscular mycorrhizal fungi inoculation. The loss or gain of N and P under various treatments over control indicates the maximum gain of N and P with recommended dose of fertilizers (40.1 and 5.60 kg/ha), followed by triple inoculation with *Azotobacter+Azospirillum*+PSB (21.8 and 4.16 kg/ha) and *Azotobacter+Azospirillum+Arbuscular mycorrhizal* fungi (21.3 and 3.90 kg/ha). Similarly, maximum gain of N and P over initial status was observed in recommended dose of fertilizers treatment (22.8 and 3.92 kg/ha), followed by triple inoculation with *Azotobacter +Azospirillum+Pseudomonas striata* (4.50 and 2.48 kg/ha) and *Azotobacter+Azospirillum+ Arbuscular mycorrhizal* fungi (4.0 and 2.22 kg/ha). These results are in conformity with those of Seshadri *et al*. (2000) and Zargar *et al*. (2008).

Viable count of soil micro-organisms

The viable counts of *Azotobacter chroococcum*, *Azospirillum brasilense* and *Pseudomonas striata* in rhizosphere soil improved significantly in all the treatments over control except recommended doses of fertilizers (Table 3). Highest population of *Azotobacter, Azospirillum* and *Pseudomonas striata* was recorded under multi-inoculation of *Azotobacter+Azospirillum+Pseudomonas striata* (4.0, 9.08 and 3.47 × 10^6 cfu/g soil), being at par with *Azotobacter+Azospirillum+Arbuscular mycorrhizal* fungi (3.91 and 8.85 × 10^6 cfu/g soil) in respect of *Azotobacter* and *Azospirillum*

Table 3 Effect of sole and co-inoculation of biofertilizers and inorganic fertilizers on free-living N-fixers, P-solubilizing microbes (log transformed value), AM root colonization and spore density in rhizosphere soil of strawberry (square-root transformed value)

Treatment	*Azotobacter* ($\times 10^6$ cfu g/soil)	*Azospirillum* ($\times 10^6$ cfu g/soil)	*Pseudomonas striata* ($\times 10^6$ cfu g/soil)	Root colonization (%)	AM spores (per 50 g soil)
Control (no culture)	1.25 (1.41)	3.81(1.92)	2.03(1.61)	13.8(4.09)	92.70(9.78)
Azotobacter	2.79 (1.75)	5.05(2.08)	2.46(1.70)	19.3(4.70)	115.9(10.90)
Azospirillum	1.88 (1.58)	7.17(2.32)	2.36(1.66)	16.2(4.33)	98.1(10.05)
PSB	2.26 (1.66)	5.51(2.14)	2.91(1.78)	18.8(4.66)	123.3(11.23)
AMF	2.20 (1.65)	5.40(2.12)	2.32(1.68)	53.5(7.51)	222.7(15.01)
Azotobacter+Azospirillum	2.99 (1.79)	7.94(2.39)	2.54(1.71)	24.5(5.24)	140.6(11.98)
Azotobacter+Azospirillum+PSB	4.00 (1.94)	9.08(2.49)	3.47(1.87)	23.8(5.18)	153.0(12.49)
Azotobacter+Azospirillum+AMF	3.91 (1.93)	8.85(2.47)	2.62(1.73)	60.8(7.98)	271.6(16.56)
RDF (80+17.6+33.2 kg NPK/ha)	1.70 (1.55)	5.15(2.09)	2.16(1.64)	8.10(3.33)	72.8(8.70)
SEm±	0.15	0.32	0.06	1.53	4.16
CD (P=0.05)	0.46	0.96	0.19	4.58	12.48

*Figures in parentheses are the log and square root-transformed over pooled values of 2 years

population which were significantly higher over all the treatments. This might be due to synergistic effect of these beneficial micro-organisms, enhanced P-solubilization and plant growth-promoting substances around the plant rhizosphere which increased *Azotobacter, Azospirillum* and *Pseudomonas striata* population in the strawberry rhizosphere. Further, sole inoculation with *Azotobacter* recorded highest population of *Azotobacter* (2.79×10^6 cfu/g soil) over single inoculation with *Azospirillum*, PSB and arbuscular mycorrhizal fungi in the rhizosphere of strawberry which indicated that the inoculated strain could compete effectively with the native strains. This clearly shows that preferential stimulation of specific population due to varying composition of root exudates and micro-ecological variation lead to selective favouring of particular organisms or group of organisms over others (Biro *et al*. 2000).

The arbuscular mycorrhizal infection levels and its spore density in the rhizosphere of strawberry was significantly higher in plots where arbuscular mycorrhizal fungi was inoculated as single and multi-inoculation of beneficial micro-organism as compared to uninoculated plots (Table 3). Except with *Azospirillum*, all the beneficial micro-organisms upon inoculation had significantly improved arbuscular mycorrhizal spore density in the rhizosphere of strawberry. However, root colonization significantly improved with mono as well as co-inoculation of beneficial micro-organisms. Inoculation of beneficial micro-organisms enhanced efficiency of native population of arbuscular mycorrhizal fungi which increased the root colonization and its spore density in the strawberry rhizosphere. The maximum root infection (60.8%) and its spore density (271.6 spores/50 g soil) were observed with co-inoculation of *Azotobacter+Azospirillum+Arbuscular mycorrhizal* fungi which was significantly higher over sole inoculation of arbuscular mycorrhizal fungi (53.5% and 222.7 spores/50 g soil). The variation in root colonization and its spore density might be due to physiological state, susceptibility of the host plant to inoculum, nutritional status and the biotic factors (root exudates, change in hormonal production in the roots, state of photosynthesis *etc.*) related to plant phenology (Murphy *et al.* 2000). The results are in conformity with those of Vosatka *et al*. (2000) who had observed stimulation in root infection as well as spore density with bacterization and this might be due to synergistic effect caused by both organisms. Application of recommended dose of fertilizers significantly reduced root infection (8.10%) and its spore density (72.8 spores/50 g soil) over control in the strawberry rhizosphere. This might be due to high concentration of available soil P owing to application of inorganic fertilizers which could have suppressed the activity of native population of arbuscular mycorrhizal fungi. Similar findings have also been reported by Treseder and Allen (2002).

Fruit quality

The fruit quality parameters of strawberry were significantly influenced by the application of sole and co-inoculation of biofertilizers. The maximum TSS (8.81°Brix), TSS/acidity ratio (12.77), total sugars (7.40%) and ascorbic acid (50.69 mg/100 g) were recorded in treatment combination of *Azotobacter+Azospirillum+Pseudomonas striata*, being at par with *Azotobacter+Azospirillum+ Arbuscular mycorrhizal* fungi but significantly higher over recommended dose of fertilizers (Table 4). Increased TSS and total sugars in strawberry fruits due to inoculation of free-living nitrogen-fixing bacteria either sole or co-inoculation might be due to steady supply of nutrients by the bio-inoculants throughout the growth period. This increased the vigour of strawberry plants and increased leaf area with higher synthesis of assimilates due to enhanced rate of photosynthesis. Such effects might be attributed to increased rate of mobility of photosynthetic products from leaves to developing fruits, thereby increasing TSS and total sugars

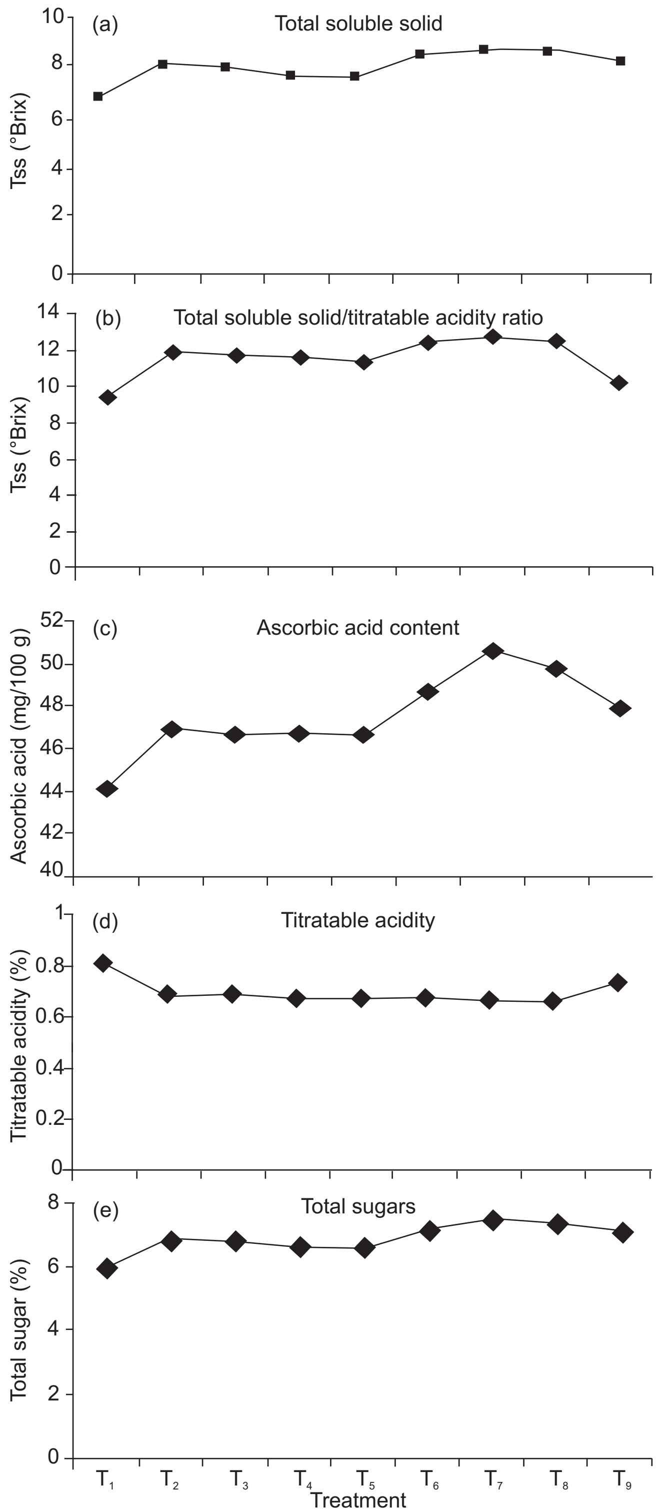

Fig 1 Influence of bio-inoculants and inorganic fertilizers on quality of strawberry
T_1-Control (no culture); T_2-*Azotobacter;* T_3-*Azospirillum;* T_4-PSB; T_5-AMF; T_6-*Azotobacter+Azospirillum;* T_7-*Azotobacter* + *Azospirillum* + PSB; T_8-*Azotobacter* + *Azospirillum* + AMF; T9-100% RDF (80:40:40 NPK kg/ha)

in berry fruit (Singh and Singh 2006). However, decline in TSS under recommended dose of fertilizers might be due to the fact that most of the metabolites were consumed by excessive vegetative growth, whereas a little amount were left for storage in the berries (Haynes and Goh 1987). Application of recommended dose of fertilizers reduced ascorbic acid content in strawberry, whereas multi-inoculation of biofertilizers increased the ascorbic content in strawberry fruit. Similar results were reported by Sahoo and Singh (2005). The maximum titratable acidity was recorded under control (0.82%) which was significantly higher over all the treatments (Table 4). Sole or combined inoculation of biofertilizers had no significant difference in titratable acidity. Application of recommended dose of fertilizers also recorded slightly higher titratable acidity (0.74%) as compared to sole and co-inoculation of biofertilizers. Applications of nitrogen and potassium had the most important effect on fruit quality, especially on titratable acidity as increased acidity in derived when these nutrients come from inorganic sources as compared to organic one. The increase in acidity might be due to synthesis of more organic acids as a result of improved foliage which might have kept the berry temperature lower by shading them and thus resulting in lower loss of acids in respiration. Similar results were also reported by Macit *et al.* (2007).

Results of the study indicated that multi-inoculation of bio-fertilizers improved the quality of fruits, soil fertility and microbial activity in the soil but could not achieve highest fruit yield and net returns. However, application of recommended dose of fertilizers obtained highest berry yield and net returns. Therefore, it is concluded that integration of inorganic fertilizers with bio-fertilizers may not only achieve highest strawberry yield and net returns but also improved quality of fruit and fertility of soil.

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