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Study on comparative efficacy of bio-organic nutrients on plant growth, leaf nutrient contents and fruit quality attributes of kiwi fruit

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Abstract: The comparative efficacy of bio-organic nutrients on cropping behavior and fruit quality of kiwifruit was analyzed using farm yard manure (FYM), vermicompost (VC), biofertilizers (BF), green manure (GM), and vermiwash (VW). Among various treatments the combination of FYM at 15 kg/vine, GM, VC at 15kg/vine, BFat50-g/ vine and VW at 2kg/vine significantly improved cropping behavior. This superior combination also resulted in considerably greater amounts of leaf macro-and micronutrients: N (2.49%), P (0.26%), K (1.48%), iron (Fe: 208.0 mg/kg), copper (Cu: 17.8 mg/kg), zinc (Zn: 36.2 mg/kg), and manganese (Mn: 88.3 mg/kg),which might be responsible for better cropping behavior, productivity and nutrient profile for sustainable kiwi fruit production. It can be concluded that with use of various sources of bio-organic materials under organic farming regime, there will be sufficient improvement in fruit quality and plant nutrient contents.

Keywords: Biofertilizer, Bio-organic nutrients, FYM, Green manure, Kiwi fruit, Vermiwash

INTRODUCTION

Organic fruit production methods are determined to a significant extent by the certification standards. Thus, the organic grower's toolbox is greatly restricted relative to what a conventional grower has. Organic production technology has gained momentum in recent years both in an increase consumer demand and a genuine desire of many fruit orchardists to sustain crop production and soil health. Moreover, organic produce commands and fetch a higher price than traditional commodity and thereby prompting producers to grow fruit crops organically (Schader, 2009). Natural soil fertility and nutrient sources such as manures, organic amendments, and mineral powders can change fertility management strategies. The alternative crop management systems are being promoted on the basis that they are more environmentally benign and specifically enhance soil and water quality relative to conventional practices. Soil nutrient cycling changes as organic fertility sources are used and hence, organic matter content increases. Thus, fertilization strategies will need to change over time as the soil changes. This can be in the form of farm yard manures, vermicompost, vermiwash, green manures, and other organic by-products, besides supplementing a large portion of the nutrient inputs. A number of recent reviews have been published on the effects of organic production systems on produce quality (Singh *et al.,* 2010; Bhardwaj *et al.,* 2011; Sharma *et al.,* 2011c). Most of the fruit orchardists of the Shiwalik hill range of north-western Himalayan region of India are being used integrated farming practices due to favorable economics, improved nutrient management options and the potential loss of pesticides. Exploring the potential and beneficial effects of organic nutrient sources on soil physico-chemical and biological properties has paved in turn to maintain or increase soil organic matter for better drainage and infiltration, and also well documented in the literature. Tillage practices, crop rotations, and use of green manures, biofertilizers and inputs of organic residues, farmyard manure, vermicompost and vermiwash affected organic matter content and physico-chemical and biological properties of soil (Yadav *et al.,* 2013).
Kiwifruit (*Actinidia deliciosa* Liang Ferguson.) or Chinese gooseberry, belongs to family Actinidiaceae, is the most recent among the fruit crops brought under domestication world-wide, and is perhaps the best known nutritious fruit amongst the other soft fruits. Undoubtedly, kiwifruit is a crop of the 20th century, as is evident from world production statistics covering 88,012 hectare of area

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with a start of only 2,000 MT world production in 1970 and now has reached the level of 13, 77,233 MT (FAO, 2009). Fruit growers in the north-western Himalayan region of India particularly in the State of Himachal Pradesh are increasingly taking to commercial cultivation of the exotic kiwi fruit towards crop diversification because of fetching a good returns and its market among high-end consumers. The cultivation has become a profitable venture for farming community to uplift the economic status of mid and foothills farmers for assured crop (Rana, 2014). The focus of this paper is on organic nutrient sources used in organic fruit production, but these sources can also be a component of conventional production.

MATERIALS AND METHODS

The study was carried out during 2010-2011on kiwifruit cv. Allison in the Department of Fruit Science and Experimental Research Farm of the Dr. Y.S. Parmar University of Horticulture and Forestry, located in Solan, Himachal Pradesh, India. The orchard is situated at an elevation of 1260 m above mean sea level (30° 60 50'45"N; 77° 08'30"E longitude). Trees of uniform age (25 years old), planted at 6x6 m apart were selected for the studies. The climate is sub-temperate with an annual rainfall in the range between 60 and 100 cm. The experimental soils were classified as sandy loam (Sand: 40.2%, Silt: 30.4%, Clay: 29.7 %) with 6.9 pH, 0.25 dS/m electrical conductivity (EC) and 0.85% organic carbon (OC). The initial available nitrogen (N), phosphorus (P) and potassium (K) contents in the soil were 302.00, 65.00 and 266.00 kg/ha, respectively. Di ethylene triamine penta acetic acid (DTPA) extractable micronutrients namely, iron (Fe), copper (Cu), zinc (Zn) and manganese (Mn) were 57.2, 2.3, 1.8 and 45.6mg/kg, respectively. The experimental soil also contained an initial viable microbial population of *Pseudomonas* spp. (3.50×10^6colony forming units (cfu)/g soil)*, Azotobacter chroococcum* (4.10×10^6cfu/gsoil), 550 spores of AM fungi/kg soil, actinobacteria count (4×10^6cfu/g soil), and total soil fungal count (1×10^6cfu/g soil).

The experiment was designed considering five different bio-organic nutrient sources viz., farm yard manure (FYM), vermicompost (VC), biofertilizer (BF), green manure (GM) and vermiwash (VW), applied to determine the optimum and best combination in comparison with the traditional farming practice. The treatments were replicated thrice in a randomized block design (Cochran and Cox, 1963). Different inputs of bio-organic sources with different levels in different combinations namely, FYM: 30, 60 kg/vine (FYM_{30}, FYM_{60}), green manure, GM (Sun hemp, *Crotolaria juncea* L.); vermicompost: 15, 30 kg/vine (VC_{15}, VC_{30}); biofertilizer: 50, 100 g/ vine (BF_{50}, BF_{100}); vermiwash @ 2% in water v/v (VW_2) at 15 days interval were applied. Different bio-organic treatment combinations wereT_1: control (recommended dose of NPK fertilizers along with 20 kg of FYM vine^{-1});T_2: FYM_{60};T_3: GM;T_4: VC_{30};T_5: BF_{100};T_6: VW_2;T_7: FYM_{30}+VC_{15};T_8: FYM_{30}+BF_{50};T_9: FYM_{30}+VW_2;T_{10}: VC_{15}+BF_{50};T_{11}: VC_{15}+VW_2;T_{12}: BF_{50}+VW_2; T_{13}: FYM_{15}+GM+VC_{15}+BF_{50}+VW_2.

The microbial inoculants include the consortia of *A. chroococcum*, *Pseudomonas* spp. and AM fungi namely, *Glomus fasciculatum*(Thaxtersensu Gerdemann), and were applied in equal proportions as band application at 15 cm depth in the basin of each vine tree being followed by a light irrigation for proliferation of the cultures. The microbial consortium of *A. chroococcum* strain A_{41}, *Pseudomonas* spp. and AM fungi were procured from the Department of Microbiology, Indian Agriculture Research Institute, New Delhi, India. The doses of bio-organic sources in different treatments were based on the nutrient composition of FYM, biofertilizers (bio-inoculants), vermicompost, vermiwash and green manure to compensate the full recommended NPK chemical fertilizers to the trees. Full dose of FYM, vermicompost and biofertilizers were applied in the first week of March in basin of each tree. The nutrient composition of FYM included 0.47% N, 0.23% P, 0.39% K, 0.005% Zn, 0.0005% Cu, 0.005% Mn, and 0.47% Fe. Vermicompost derived using mature green waste windrowed compost as feedstock to the worm reactors that were manufactured from timber surrounded and steel mesh as the base. Vermicompost used in the experiment contained 1.75% N, 0.87% P_2O_5, 1.25% K_2O, 170.7 mg/kg Fe, 5.69 mg/kg Cu, 23.48 mg/kg Zn and 94.78 mg/kg Mn Liquid formulation namely, vermiwash obtained during vermicomposting process from *Eisenia foetida* used as a foliar spray after 15 to 30 days of fruit set at 15 days interval up to fruit harvest during the late evening hours. The chemical composition of vermiwash contained 7.36 pH, 0.24 dS/ m EC, 0.006% OC, 0.03% N, 1.72% P, 22.00 mg/kg K, 0.04 mg/kg Fe, 0.02 mg/kgCu, 0.03 mg/kg- Zn, and 0.55 mg/kgMn. Sun hemp (*Crotolaria juncea* L.) as green manure crop was grown in the plant basin during the last week of June and was incorporated into the soil after 45 days at the time of flowering. NPK fertilizers used were Urea (46% N), single super phosphate (16% P_2O_5) and muriate of potash (60% K_2O). Nitrogen was applied in two splits by broadcasting method at30 cm away from the tree trunk in the basin i.e. first half during the first week of March (3 weeks before flowering) and second half 30 days after fruit set. Phosphatic and potassic fertilizers were applied along with FYM/ vermicompost during the month of December.

A representative sample size of uniform and healthy shoots from current season's growth was selected randomly under each replication for measuring annual extension growth of vines. The quantity of fruit harvested was calculated for total yield on the basis of weight, the harvested fruits were classified into three grades viz., A (>70 g), B (50-70 g) and C (<50 g). The yield of different grades was expressed in kilogram per vine (kg/vine). The harvested fruits were also utilized for analyzing physical-biochemical characteristics using standard procedures. The leaf samples (leaf blade along with petiole) were collected from four directions of vine and washed to remove dust and followed the standard procedures (Kenworthy, 1964). The leaves were finely ground and homogenized, and the sample material was digested with concentrated HNO_3 and H_2O_2 in heating block digester at 120 ^{0}C for 2 hours. Total leaf N was estimated using Nitrogen autoanalyzer -Kjeltech Foss Tecator model-2300 and P by vanadomolybdophosphoric acid method (Jackson, 1973). Potassium (K) and micronutrients (Cu, Zn, Fe and Mn) in the samples were determined using Atomic absorption spectrophotometer model 4141.

Statistical analysis of data was carried out using analysis of variance (ANOVA) to compare the efficacy of nutrient sources applied. The significance of variation among the treatments was observed by the least significant differences (LSD) to compare the means at 5% level of significance.

RESULTS AND DISCUSSION

Plant growth measurements: Among the different bio-organic combinations, treatment T_{13} resulted in maximum (151cm) annual vine extension growth followed by T_4, T_7, T_{10}, T_{11} with corresponding values of 141, 139, 137 and 135 cm, respectively (Table 1). The application of bio-organics resulted in the increase in the growth of vine ascribed to increased N uptake and increased release of growth factors (auxins, gibberellins and cytokinins) in the root zone (Singh *et al.,* 2010). Organic manures serve as substrate and source of energy for microorganisms and thus, incorporation of crop residue increased the organic matter and in turns the microbial biomass in the rhizosphere. Besides, the incorporation of green manure into the soil as a possible nutrient source especially nitrogen, which is the chief promoter of growth, and have influenced on improved and better growth (Bair *et al.,* 2008). The importance of vermicompost in improving growth of fruit crops such as Mango, Sapota, Guava and Banana is well documented by many workers (Athani *et al.,* 2009) and attributed to release of higher amount of nutrients as well as growth stimulating substances excreted by earthworms in their casts.

Fruit grade and yield: A perusal of data presented revealed that all of the different treatments of bio-organic nutrient sources exhibited a significant (0.05%) influence on 'A' grade fruits. The vines under T_1 treatment produced maximum yield of 'A' grade fruits at 16 kg/vine, whereas, the minimum (4 kg/vine) yield was obtained from treatment combination of T_3 (GM) which was statistically similar to T_6 and T_{12} produced 4.2 and 4.5 kg/vine of 'A' grade fruits, respectively. The treatment T_{13} recorded higher yield of 'B' grade fruits (34.2 kg/ vine) which was statistically similar to T_4 (33 kg/vine). The minimum yield of 'C' grade fruits (13 kg/vine) was recorded in T_{13} which was statistically at par with T_1 and T_7 recording 14 and 14.5 kg/vine, respectively. Maximum yield of 'C' grade fruits (22 kg/vine) was harvested from T_5 which was statistically similar to T_{12}, T_6 and T_3 treatments. Overall, maximum fruit yield (69.3 kg/vine) was recorded in T_1 followed by T_{13}, while minimum (38.1 kg/vine) was recorded in T_3 and was statistically similar toT_5 and T_{12}. The organic treatments showed lower response with respect to fruit yield compared to conventional inorganic practices because the organic manure released nutrients slowly during the first year of application and the increase of microbial population also trended supports this hypothesis. Immediate availability of nutrients through inorganic fertilizers, along with organic manures ascribed to conducive physical environment that lead to higher nutrient absorption from the native as well as applied sources. This favored highest nutrient uptake and ultimately resulted in higher yield, whereas, reverse is true with organic manures.

The nitrogen containing organic compounds in organic manures especially in FYM are more resistant to decomposition and only about one third of the nitrogen is easily released. The remaining amount of nitrogen persisted in the soil for a long period. Bair *et al.* (2008) in their study put forth that higher residual effect of green manuring might have increased the soil organic matter content and available nutrients, which in turn, favorably affected growth and yield attributes and ultimately the fruit yield in the subsequent year. Higher yields obtained with combined use of vermcompost and green manure was possibly due to supply of balanced nutrition, congenial physical and biological soil environment (Deshpande and Senapathy, 2010).

Fruit quality attributes: Among different bio-organic treatment combinations, the total soluble solids (TSS) ranged between 13.06 and 15.20°Brix (°B). Maximum TSS (15.20 °B) was recorded in T_{13} followed by T_4, T_7, T_1, T_{11}, T_{10}, T_2, T_8 and T_9 with corresponding values of 15.18, 15.12, 15.11, 15.07, 15.05, 15.03, 14.98 and14.96 °B, respectively (Table 1). It is evident from the data shown that the fruit acid content was significantly decreased with the application of different organic sources. Maximum TSS: acid ratio (14.2) was recorded in T_{13} which was statistically similar to T_4 and T_7 treatment. Similarly, the highest reducing sugar content of 6.99 percent was recorded in T_{13} ,whereas, maximum non-reducing sugars (2.93%) was recorded in T_{13} and T_4 being statistically at par with T_7, T_5 and T_{12} treatments. The data on the effect of different organic treatment combinations on ascorbic acid content revealed that maximum ascorbic acid (85.1 mg/100g) content was recorded in $T_{13,}$ whereas, treatment T_3 recorded minimum (60.3 mg/100g) ascorbic acid content. These results are in line with the findings of Amarante *et al.* (2008) who reported that apple fruit samples of cv. Royal Gala taken from the organic orchard had lower titratable acidity and high TSS content than conventional orchard. Similar results were reported by Peck *et al.* (2009) who inferred that fruit from organic production system had higher TSS and TSS: acid ratio than fruit from integrated fruit

Table 1. Effect of bio-organic nutrient sources on growth, fruit yield, grade and biochemical attributes of kiwifruit.

Treatment		Annual vine extension growth (cm)	Fruit yield (kg vine^{-1})	Fruit grade			TSS (^{0}Brix)	Acidity (%)	TSS: acid ratio	Reducing sugars (%)	Non-reducing sugars (%)	Total sugars (%)	Ascorbic acid (mg/100g)
				'A' grade (kg vine^{-1})	'B' grade (kg vine^{-1})	'C' grade (kg vine^{-1})							
T_1	Control	149	69.3	16.0	39.3	14.0	15.11	1.26	11.99	6.91	2.84	9.90	84.3
T_2	FYM_{60}	131	51.0	7.0	27.0	17.0	15.03	1.16	12.96	6.66	2.74	9.55	81.1
T_3	GM	115	38.1	4.0	14.0	20.1	13.06	1.30	10.04	5.86	2.51	8.51	60.3
T_4	VC_{30}	141	58.0	11.0	33.0	14.0	15.18	1.08	14.19	6.96	2.93	10.05	84.1
T_5	BF_{100}	108	38.5	5.5	11.0	22.0	13.19	1.28	10.30	5.80	2.88	8.84	65.3
T_6	VW_2	105	38.7	4.2	13.7	20.8	13.08	1.29	10.14	5.82	2.75	8.72	62.0
T_7	FYM_{30}+ VC_{15}	139	55.5	11.0	30.0	14.5	15.12	1.11	13.62	6.92	2.90	9.98	84.0
T_8	FYM_{30}+ BF_{50}	128	49.0	10.0	23.0	16.0	14.98	1.18	12.69	6.51	2.63	9.28	80.0
T_9	FYM_{30}+ VW_2	125	48.2	10.0	22.2	16.0	14.96	1.19	12.57	6.45	2.66	9.25	77.2
T_{10}	VC_{15}+BF_{50}	137	53.0	9.0	27.0	17.0	15.05	1.16	12.97	6.89	2.76	9.80	82.1
T_{11}	VC_{15}+VW_2	135	52.2	9.0	26.0	17.0	15.07	1.17	12.88	6.79	2.78	9.72	82.9
T_{12}	BF_{50}+VW_2	109	39.2	4.5	13.5	21.2	13.28	1.27	10.45	5.89	2.86	8.91	76.2
T_{13}	FYM_{15}+GM+ VC_{15}+BF_{50}+VW_2	151	61.7	14.5	34.2	13.0	15.20	1.07	14.20	6.99	2.93	10.08	85.1
$LSD_{0.05}$		9.0	3.5	1.2	2.4	2.2	0.74	0.04	0.82	0.32	0.07	0.41	3.0

FYM_{60}, farmyard manure: 60 kg/vine, GM, green manure (*Crotolariajuncea* L.), VC_{30}, Vermicompost: 30 kg/vine. BF_{100}, Biofertilizer:100 g/vine, VW_2, vermiwash: 2% v/v, FYM @ 30 kg + vermicompost @ 15 kg/ vine, FYM @ 30 kg + biofertilizer @ 50 g/vine, FYM @ 30 kg/vine+ spray of vermiwash at 15 days interval @ 2% v/v, Vermicompost @ 15 kg vine^{-1} + biofertilizer @ 50 g/vine, Vermicompost @ 15 kg/vine+ spray of vermiwash at 15 days interval @ 2% v/v, Biofertilizer @ 50 g/vine+ spray of vermiwash at 15 days interval @ 2% v/v, FYM @ 15 kg/vine+ Green manure + vermicompost @ 15 kg/vine+ biofertilizer (mixed culture @ 50 g/vine) + vermiwash at 15 days interval @ 2% v/v; TSS, total soluble solids

Table 2. Effect of bio-organic nutrient sources on leaf nutrient contents of kiwifruit.

Treatment		Macronutrients (%)			Micronutrients (mg/kg)			
		N	P	K	Fe	Cu	Zn	Mn
T_1	Control	2.53	0.29	1.51	210.0	18.3	38.0	89.3
T_2	FYM_{60}	2.31	0.21	1.40	185.0	14.4	31.6	79.0
T_3	GM	1.93	0.15	1.28	146.0	9.5	22.0	60.7
T_4	VC_{30}	2.48	0.24	1.47	207.0	17.7	36.0	87.5
T_5	BF_{100}	1.94	0.17	1.30	145.0	9.1	19	60.2
T_6	VW_2	1.99	0.16	1.31	147.0	10.0	20.0	61.5
T_7	FYM_{30}+ VC_{15}	2.47	0.23	1.45	202.0	17.6	34.8	87.2
T_8	FYM_{30}+ BF_{50}	2.25	0.19	1.39	173.0	13.8	30.5	72.0
T_9	FYM_{30}+ VW_2	2.28	0.20	1.39	181.0	14.1	30.1	75.3
T_{10}	VC_{15}+BF_{50}	2.33	0.22	1.43	194.0	15.0	31.5	83.3
T_{11}	VC_{15}+VW_2	2.35	0.23	1.44	197.0	16.1	32.6	85.0
T_{12}	BF_{50}+VW_2	2.06	0.19	1.35	147.7	10.1	23.0	64.0
T_{13}	FYM_{15}+GM+VC_{15}+ BF_{50}+VW_2	2.49	0.26	1.48	208.0	17.8	36.2	88.3
$LSD_{0.05}$		0.2	0.03	0.1	9.3	0.9	2.5	5.2

FYM_{60}, farmyard manure: 60 kg/vine, GM, green manure (*Crotolaria juncea* L.), VC_{30}, Vermicompost: 30 kg/vine. BF_{100}, Biofertilizer:100 g/vine, VW_2, vermiwash: 2% v/v, FYM @ 30 kg + vermicompost @ 15 kg/ vine, FYM @ 30 kg + biofertilizer @ 50 g/vine, FYM @ 30 kg/vine+ spray of vermiwash at 15 days interval @ 2% v/v, Vermicompost @ 15 kg $vine^{-1}$ + biofertilizer @ 50 g/vine, Vermicompost @ 15 kg/vine+ spray of vermiwash at 15 days interval @ 2% v/v, Biofertilizer @ 50 g/ vine+ spray of vermiwash at 15 days interval @ 2% v/v, FYM @ 15 kg/vine+ Green manure + vermicompost @ 15 kg/vine+ biofertilizer (mixed culture @ 50 g/vine) + vermiwash at 15 days interval @ 2% v/v

production system. The improved fruit quality attributes is due to the beneficial effects of organic treatments on the total leaf area which reflected in more accumulation of carbohydrates through photosynthesis process. Interestingly, the vines which received organic manures produced improved and better fruit quality attributes due to better growth of plants which favored the accumulation of higher sugars, ascorbic acid and less acid content. Moreover, the combined effect of FYM, vermicompost and biofertilizers on improving these attributes in pear ascribed to total leaf area, which reflected in more carbohydrates production through photosynthesis process (Fawzi *et al.,* 2010). Singh *et al.* (2010) recorded higher TSS and ascorbic acid content with lower acidity from strawberry fruits under organic amendment treatments. These results are in line with the findings of Umar *et al.* (2009) who also recorded that FYM augmented with *Azotobacter* inoculation had increased vitamin C content in strawberry. Osman and Abd El-rhman (2010) reported that organic and biological nitrogen fertilization have given the highest TSS, total sugars, reducing and non-reducing sugars content and lowest acidity. The higher values of total soluble solids, L-ascorbic acid and lowest values of acidity were recorded in fruit trees fertilized with AM fungi along with *Bacillus megaterium* as biofertilizer (Ibrahim *et al.,* 2010). Maheshwari *et al.* (2004) observed highest ascorbic acid content in chilly in treatment combination of vermiwash at 1:5 with basal and top dressing. In kiwifruit, fruit grade is also an important quality characteristic. Quality of fruits produced under treatment T_{13} was superior with more of 'B' grade size fruits, and attributed that the phytochemical were diluted in standard nutritional package and practice in treatment T_1 where higher yield was recorded.

Leaf nutrient status: Leaf N content was significantly influenced by all the treatments (Table 2). Maximum leaf nitrogen content (2.53%) was recorded in treatment T_1 which was statistically at par with T_{13}, T_4, T_{11} and T_{10} recording 2.49, 2.48, 2.47, 2.35 and 2.33%, respectively. The data also revealed that all the bio-organic treatments resulted in variable levels of leaf P content. Maximum (0.29%) leaf P content was observed in T_1 followed by T_{13} (0.26%), whereas, minimum (0.15%) was recorded in T_3 which was statistically at par with T_6 and T_5 recording 0.16 and 0.17 per cent leaf P content, respectively. Similarly, leaf K content was also significantly influenced by different treatments. Maximum (1.51%) leaf K content was recorded in T_1 followed by T_{13}, T_4, T_{11} and T_{10} with corresponding values of 1.48, 1.47, 1.45, 1.44 and 1.43% respectively. Significant (0.05%) differences for leaf Zn content of vines were also observed (Table 3). Maximum leaf Zn (38.0 mg/kg) content was recorded in treatment T_1 followed byT_{13} and T_4 recording 36.2 and 36.0 ppm, respectively. Highest leaf Fe content (210.0 mg/kg) was recorded in treatment T_1 which was statistically similar to T_{13}, T_4 recording 208.0, 207 and 202 mg/kg respectively. Similarly, maximum 89.3 mg/ kg leaf Mn content was observed in T_1 followed by

T_{13}, T_4, T_7 and T_{11} recording 88.3, 87.5, 87.2 and 85.0 mg/kg, respectively. The data showed that maximum (18.3 mg/kg) leaf Cu content was recorded in T_1 which was statistically at par with T_{13}, T_4 and T_7 recording 17.8, 17.7 and 17.6 mg/kg leaf Cu content, respectively (Table 2). The increased availability of macro-and micronutrients in the leaves of kiwifruit vines with the addition of vermicompost, green manure and biofertilizers ascribed to the acceleration of microbial N-fixation, improved physical condition of soil, root development by mycellial network of mycorrhizal fungi, more moisture retention and thus increased absorption of water and nutrients. The increase in leaf nutrient content in different treatments receiving microbial fertilizers also suggests that these microbial fertilizers solubilize the available nutrient pool in the soil and improves the uptake of both macro and micronutrients. This attributed to the N-fixation ability of *A. chroococcum*, better P mobilization and enhanced uptake of micronutrients due to AM fungi application (Pilania *et al.,* 2010). The uptake of various nutrients (N, P, K, Ca, Mg, Fe, Cu, Mn and Zn) was significantly higher in pomegranate upon dual inoculation with AM fungi and *Azotobacter* (Aseri *et al.,* 2008) and in sweet orange with AM fungi + PSB (Shamseldin *et al.,* 2010) has also been reported. The higher uptake of N and P was apparently due to improved symbiotic N_2 fixation as well as due to improved phosphotase activity and thereby P mobilization and subsequent P uptake by mycorrhizal hyphae, whereas, the significantly higher amount of other nutrients viz. K, Ca, Mg, Cu, Fe, Zn and Mn might be due to the production of nutrient-solubilizing enzymes by microorganisms and ability of AM fungal hyphae towards uptake of immobile ions, besides increasing the surface area of roots thereby tapping larger soil volume.

Conclusion

The preliminary studies on organic kiwifruit production showed that T_{13} [FYM @15 kg vine-1 + green manure + vermicompost @ 15 kg vine-1+ biofertilizer (mixed culture @ 50 g vine-1) + vermiwash at 15 days interval @ 2% v/v] was found to be most effective to produce better fruit quality in terms of TSS, total sugars and ascorbic acid content. Therefore the bio-organic inputs may be used as an alternative to inorganic fertilizers which were found to be helpful in enhancing quality of produce.

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