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Improvement in yield and fruit quality of mango (*Mangifera indica*) with organic amendments

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ABSTRACT

A field experiment was laid out to observe response of various organic amendments on soil, plant nutrient status, soil microbial properties, yields and fruit quality parameters of mango (*Mangifera indica* L.) cv. Mallika. Application of biodynamic compost (30 kg/tree), cow pat pit (100 g), BD- 500 and BD- 501 as soil and foliar spray for two years (2015-16) improved the soil organic carbon (1.20%) at 0-15 cm and (1.19%) at 15-30 cm soil depth, available N (168.93 ppm), P (27.67 ppm), Zn (3.78 ppm), Cu (14.78 ppm) and Mn (2.54 ppm) at 0-15 cm and organic carbon (0.98%), available N (151.20 ppm), K (200.85 ppm), Cu (9.46 ppm) and Mn (2.13 ppm) at 15-30 cm soil depth.Leaf N (2.35%), Zn (39 ppm), Cu (41.00 ppm), Mn (72.67 ppm) and Fe (256.0 ppm), total soil bacterial population (69.17 $\times 10^8$) at 0-15 cm and (23.57 $\times 10^8$) at 15-30 cm soil depth, actinomycetes (60.91 $\times 10^6$) at 0-15 cm depth and (38.94 $\times 10^6$) at 15-30 cm soil depth were also improved.Dehydrogenase activity, fluorescein diacetate activity, alkaline and acid phosphatase activity, in 0-15 cm and 15-30 cm soil depth were 4.57 and 4.09 µg TPF/g soil/h; 944.33 and 798 mg fluorescein/g/h; 136.37 and 86.56 µg PNP/g/hr and 70.01 and 80.26 µg PNP /g/h, respectively. Improvement in the yield (134.64 kg/tree), total soluble solids contents in fruit (24.93 ^{0}Brix), total carotenoids content (5.95 mg/100g), FRAP (60.03 micromole/liters) and DPPH (anti-oxidant) per cent inhibition (71.90%) was also recorded.

Key words: Actinomycetes, Cow pat pit, Mango cv. Mallika, Organic amendments

High cost agrochemicals based crop production system is not sustainable because of multi-nutrient deficiencies in soil, surface and ground water pollution, shortages of non-renewable resources and low-farm income from high production costs. Mango production strategy is to be focused on reduced external inputs use and higher output without any adverse effect on environment (Ram and Verma 2015). The situation is more serious in production of large number of fruits, vegetables and spices (Pathak and Ram 2003). Emphasis should be given to protect the environment from overuse of agrochemicals (Ayala and Rao 2002). It is also important to mention that horticultural crops are grown for their nutritive/therapeutic/aesthetic values and many of them are consumed as fresh, hence, their organic production is more relevant than most of the field crops. Organic agriculture aims at sustainable production system based on natural processes and relies primarily on local, renewable resources. In horticultural crops, there is ample scope of organic farming to obtain superior quality produce to ascertain nutritional security for better human health (Ram *et al*. (2017). On farm produced quality organic inputs from locally available bio-resources form an integral component of organic agriculture (Ram and Pathak 2019). Therefore, keeping these facts in mind, an experiment was conducted to study the efficacy of different organic amendments and on-farm produced inputs on soil health, yield and fruit quality of mango cv. Mallika.

MATERIALS AND METHODS

The field experiment was laid out in randomized block design with 3 replications on 35 years old trees of mango cv. Mallika during 2015-16 at research farm of ICAR, Lucknow. The treatments comprised FYM (Farmyard manure) (40 kg/tree +*Azotobacter* + *Azospirillum* + PSB (phosphorus solubilizing bacteria) (10^8cfu/g) + Mycorrhiza (inoculum) (T1), Biodynamic compost (30 kg/tree) +bio-enhancers cow pat pit (CPP)- 100 g, BD- 500 and BD- 501 as soil and foliar spray) (T2), Neem cake + farmyard manure (20 kg/ tree) +*Azotobacter* + *Azospirillum* + PSB (10^8 cfu/g) (T3), vermi compost (30 kg/tree +*Azotobacter* + *Azospirillum*+ PSB (10^8 cfu/g) (T4), farmyard manure (40 kg/tree) + bio-enhancer (Amritpani 5% soil application) (T5), FYM (40 kg/tree) + green manuring (sunhemp) + *Azotobacter*+ *Azospirillum*+ PSB (10^8 cfu/g) (T6) and 1000g N P K / tree (T7). Fruit quality analysis, total soluble solids were recorded by refractometer and acidity was determined by standard procedure of AOAC, 1975. Total carotenoids, FRAP and DPPH were analyzed in ripen fruits (Benzie 1966, Litchenthaler 1987 and Williams *et al.* 1995). Soil and leaf

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samples were drawn and analysed before the imposition of treatments and at the end of experiment. Organic carbon was estimated by the chromic acid oxidation method (Walkley and Black 1934).

Available phosphorus was extracted by Olsen's method (Olsen *et al.* 1954) and P in the extract was estimated colorimetrically by ascorbic acid blue colour method (Watanabe and Olsen 1965). Available K was estimated by flame photometer in 1N neutral ammonium acetate soil extract. The micronutrients (Fe, Mn, Zn and Cu) were extracted by DTPA method (Lindsay and Norvell 1978) and their content in the extract was estimated by atomic absorption spectrophotometer Chemito Model-203D. Nitrogen in leaf and manure samples was analysed by micro Kjeldahl method (Jackson 1967). For the analysis of P, K, Ca, Mg, Fe, Mn, Zn and Cu, the leaf and manure, samples were digested in tri-acid mixture of nitric acid: sulphuric acid: perchloric acid (10:1:4). Phosphorus and potassium in the extract was analysed colourimetrically by vanadate-molybdate yellow colour method and flame photometrically, respectively, Ca and Mg by versene titration method and micronutrients by atomic absorption spectrophotometer (Jackson 1967). Experimental soil had 7.5 pH and electrical conductivity ranging from 0.11 to 0.17 dS/m with 0.759% organic carbon, 30.7 ppm P, 235 ppm K, 6.7 ppm Zn, 10.9 ppm Cu, 6.0 ppm Mn and 11.0 ppm Fe (Tandon 1993). Enumeration of beneficial free-living N_2-fixing bacteria *Azotobacter* sp. and *Azospirillum* sp. was carried out by dilution plate count method using specific media, viz. Jenson's media for *Azotobacter* (Jenson 1954) and N-free malate medium for *Azospirillum* (Okon *et al.* 1977) in different rhizospheric soils. Soil biological properties in terms of enzymatic activity, viz. dehydrogenase activity was estimated using 2, 3, 5 triphenyal tetrazolium chloride using 1 gram air-dried soil (<2 mm) and expressed as µg of triphenylformazan (TPF) formed per gram of oven dried soil per hour (Casida *et al.* 1964). General microbial activity was measured by hydrolysis of fluorescein diacetate (FDA) using the procedure of Adam and Duncan (2001) using 3, 6- diacetyl fluorescein as substrate and measuring the absorbance of released fluorescein at 490 nm. The microbial biomass C (MBC) was determined by the fumigation-extraction method according to Vance *et al.* (1987) using a correction factor (kc) of 0.33 (Sparling and West 1988). The microbial biomass N (MBN) was determined by the method of Brookes *et al.* (1985) using a 0.54 conversion factor (Brookes *et al.* 1985). The microbial biomass P (MBP) was determined by fumigation-extraction according to method of Brookes *et al* (1982) and McLaughlin and Alston (1986) using a 0.40 conversion factor (Brookes *et al.* 1982). Soil Urease, alkaline and acid phosphatase activity was measured by the methods described by Tabatabai (1994). Experimental data were statistically analysed following the analysis of variance method (Panse and Sukhatme 1978).

RESULTS AND DISCUSSION

The composite soil samples were collected at 0-15 and 15-30 cm soil depth from the basins of experimental trees before the application of treatments. Soil collected at 0-15 cm depth contained 1.0% organic carbon, 140 ppm available P, 180 ppm available K, 2.10 ppm Zn, 9.11 ppm Cu, 1.09 ppm Mn and 3.98 ppm Fe and at 15-30cm soil depth,contained 0.95% organic carbon, 135ppm available P, 24ppm available K, 24ppm Zn, 175 ppm Cu, 1.78 ppmMnand 3.87 ppm Fe. Soil samples were collected after two years of experimentation at same soil depth levels. Maximum increase in soil organic carbon (1.20%) at 0-15cm and (1.19%) at 15-30 cm soil depth was recorded with (T2). Maximum available N (168.93 ppm), P (27.67 ppm), Zn (3.78 ppm), Cu (14.78ppm) and Mn (2.54 ppm) in soil were also recorded with same treatments at 0-15 cm soil depth. Improvement in nutrients levels and organic carbon in rhizospheric soil were also recorded at the 15-30 cm soil depth. Maximum available N (151.20 ppm), K (200.85 ppm), Cu (9.46 ppm) and Mn (2.13 ppm) were recorded with (T2) and P (33.10 ppm) with (T5) (Table 1). Application of organic amendments improved soil organic carbon, soil microbial biomass carbon which leads to nutrient accumulation (Joergensen *et al.* 2010, Wang *et al.* 2010). Ram *et al.* (2014) have also reported improvement in soil

Table 1 Improvementin soil organic carbon and nutrients levels in rhizospheric soil of experimental trees (0-15 and 15-30 cm soil depth) with application of treatments

Treatment	0-15 cm soil depth								15-30 cm soil depth							
	OC (%)	Available N (ppm)	P (ppm)	K (ppm)	Zn (ppm)	Cu (ppm)	Mn (ppm)	Fe (ppm)	OC (%)	Available N (ppm)	P (ppm)	K (ppm)	Zn (ppm)	Cu (ppm)	Mn (ppm)	Fe (ppm)
T1	1.02	155.867	23.267	191.35	2.127	9.533	2.10	4.587	0..98	146.07	29.43	175.46	1.94	7.67	2.55	4.90
T2	1.20	168.933	27.667	201.517	3.78	14.78	2.547	4.953	1.19	151.20	29.46	200.85	2.41	9.46	2.13	4.94
T3	1.09	140.00	21.367	193.23	3.05	12.44	1.780	4.627	1.07	126.0	27.53	192.85	2.13	7.95	2.03	5.26
T4	1.02	135.86	26.967	182.85	2.687	12.447	2.073	5.587	1.02	130.933	32.26	200.28	2.19	5.93	1.920	5.33
T5	1.11	135.60	26.267	200.38	3.447	13.747	1.94	4.287	0.92	130.0	33.10	174.30	2.09	8.32	1.93	4.14
T6	1.16	137.467	24.60	190.15	2.68	8.053	2.16	5.313	1.09	126.867	32.86	183.43	2.18	7.31	2.23	4.86
T7	0.92	121.467	23.467	187.83	2.047	7.493	1.573	4.133	0.85	110.533	28.53	165.05	1.67	5.59	1.55	4.61
CD (P=0.0)	NS	22.85	2.081	NS	0.686	2.431	0.321	0.426	NS	15.725	3.129	24.13	NS	2.01	0.491	NS

and leaf nutrient status in guava cv. Allahabad Safeda.

Composite leaf sampling was done before the application of various treatments. Leaf contained 1.65% N, 0.10% P, 1.61% K, 23.75 ppm Zn, 13.50 ppm Cu and 371.25 ppm Fe. Improvement in leaf nutrient contents was recorded after the application of different treatments. Maximum N (2.347%), Zn (39 ppm), Cu (41.00 ppm), Mn (72.67 ppm) and Fe (256.0 ppm) was recorded with T2 and maximum K (1.10%) with T7 (Fig 1). Collective soil samples were taken from experimental field at 0-15 cm and 15-30 cm soil depth before the treatments application. Total bacterial population (4×10^9 cfu/g), fungi (8.74×10^5 cfu/g) and actinomycetes (1.10×10^7cfu/g) were recorded at 0-15cm soil depth, while it was (3.2×10^9 cfu/g), (4.10×10^5 cfu/g) and (0.027×10^7 cfu/g) at 15-30cm depth. Soil samples collected after two years of treatments application showed increase in total bacterial population (69.17×10^8 cfu/g) at 0-15 cm soil depth and (23.57×10^8 cfu/g) at 15-30 cm depth with T2 while maximum total fungi population (32.12×10^8 cfu/g) was recorded at 0-15 cm with T4. Maximum actinomycetes population (60.91×10^6 cfu/g) at 0-15 cm depth and (38.94×10^6 cfu/g) at 15-30 cm soil depth was recorded with T2 (Table 2). Fox and MacDonald (2003) reported that improvement in soil fertility affects the diversity and population of microbial community in various ways. Dehydrogenase and hydrolysis of fluorescein diacetate (FDA) was also observed in rhizospheric soil of experimental trees at different soil depth. Highest dehydrogenase activity (4.57 µg TPF/g soil/hr) was recorded at 0-15 cm depth and 4.09 µg TPF/g soil/h with T2. Hydrolysis of fluorescein diacetate was also measured in soil applied with different organic amendments as it is widely used as enzymatic method for measuring overall soil microbial activity (Schnurer and Rosswall 1982) recorded maximum (944.33 mg fluorescein/g/h) at 0-15 cm and (798 mg fluorescein/g/h) at 15-30 cm soil depth with T2 (Table 2). Debnath *et al.* (2015) reported that soil enzymatic activities were decreased down towards depths irrespective of the facts that the perennial fruit tree crops had deeper roots. Initial microbial biomass carbon (179.36 mg C /kg soil) at 0-15 cm, (121.99 mg C/kg soil) at 15-30 cm soil depth, microbial biomass nitrogen (93.32 mg N/kg soil) at 0-15 cm soil depth, 46.66 mg N/kg soil at 15-30 cm soil depth, microbial biomass phosphorus (2.82 mg P/kg soil) at 0-15 cm soil depth, 0.78 mg P/kg soil at 15-30 cm soil depth were recorded (Table 2). After two years of experimentation, maximum microbial biomass carbon (750.27 mg C/kg soil) was recorded at 0-15 cm soil depth with T2. Microbial biomass nitrogen was also varied significantly with application of different treatments and 188.87 mg N/kg soil was recorded highest with T6 at 0-15 cm depth while it was maximum (136.67 mg N/kg soil) with T2 Maximum microbial biomass phosphorus (4.58 mg P/kg soil) and 2.18 mg P/kg soil was recorded with T2 at 15-30 cm depth. This might be due to the supply of additional mineralizable and readily hydrolysable carbon as a result of organic matter application resulting

Table 2 Improvement in microbial populations, dehydrogenase activity and FDA, microbial biomass carbon, nitrogen and phosphorus and urease, alkaline phosphatase and acid phosphatase activities in rhizospheric soil after application of various treatments

Treatment	Bacterial population at different soil depth ($\times 10_8$ cfu/g)		Fungal population at different soil depth ($\times 10_4$cfu/g)		Actinomycetes population at different soil depth ($\times 10_6$cfu/g)		Dehydrogenase activity (µg TPF/g/hr)		FDA (mg fluorescein/g/hr)		Microbial biomass carbon (mg/kgsoil)		Microbial biomass nitrogen (mg/kg soil)		Microbial biomass phosphorus (mg/kg)		Urease activity (mg/kg soil)		Alkaline phosphate activity (µg PNP/g/hr)		Acid phosphate activity (µg PNP/g/hr)	
	0-15 cm	15-30 cm	0-15 cm	15-30 cm	0-15 cm	15-30 cm	0-15 cm	15-30 cm	0-15 cm	15-30 cm	0-15 cm	15-30 cm	0-15 cm	15-30 cm	0-15 cm	15-30 cm	0-15 cm	15-30 cm	0-15 cm	15-30 cm	0-15 cm	15-30 cm
T1	44.37	11.10	8.72	0.53	12.63	2.38	2.39	2.94	516.33	345.67	148.67	182.03	133.23	47.67	0.78	0.58	1.45	1.24	88.33	62.93	55.09	56.90
T2	69.14	18.21	13.44	5.42	30.64	38.94	4.57	4.09	944.33	798.33	750.27	192.50	181.43	136.67	4.58	2.18	1.55	1.52	136.37	86.56	70.01	80.26
T3	52.24	4.88	20.82	5.06	37.47	20.88	3.25	2.93	595.00	593.83	237.40	148.97	154.77	80.33	1.47	1.52	1.43	1.43	88.03	61.91	59.05	67.72
T4	47.67	23.57	32.13	5.50	60.91	6.18	3.16	3.41	539.67	481.83	287.13	142.97	140.70	71.37	1.97	0.87	1.23	1.12	88.97	79.58	59.29	62.75
T5	26.58	14.83	4.80	2.23	42.82	6.87	2.81	3.00	525.0	606.33	311.63	169.43	133.60	106.20	1.12	1.09	1.20	1.25	69.33	60.83	58.34	43.89
T6	34.33	9.50	4.73	3.77	6.86	4.55	4.08	3.66	832.0	762.83	438.27	195.03	188.87	119.60	2.80	1.74	1.12	1.30	116.93	85.48	64.47	74.15
T7	4.23	3.70	4.10	0.43	2.40	7.23	2.73	1.98	403.50	304.83	274.33	33.27	112.57	31.67	0.36	0.43	0.99	1.12	85.10	47.58	54.98	43.05
C D (P=0.05)	9.34	10.79	11.49	NS	22.75	13.25	1.31	1.15	236.74	236.48	186.01	NS	41.16	29.99	1.09	1.13	NS	NS	32.95	13.74	NS	15.23

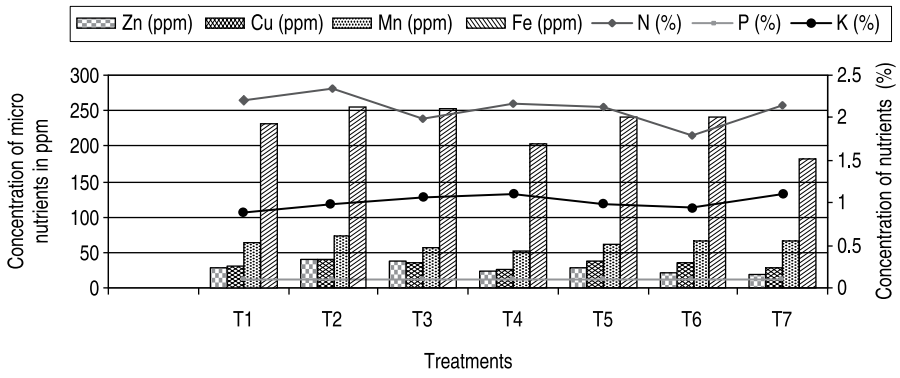

Fig 1 Leaf nutrients level after application of various treatments.

in higher microbial activity and in turn higher microbial biomass carbon (SMBC). The lowest SMBC was observed with the application of RDF alone. These results are in close conformity with those of Chandrashekhar (2012). Enzymatic activities in rhizospheric soil were also recorded before the application of different treatments and urease activity (1.17 mg urea g/soil/h) at 0-15 cm depth, 1.11 mg urea/ gsoil/h at 15-30 cm depth, acid phosphatase (47.6 µg PNP /g/h) at 0-15 cm, 57.85 µg PNP/g/h at 15-30 cm depth, alkaline phosphatase (95.04 µg PNP /g/h) at 0-15 cm depth, 59.43 µg PNP/g/h at 15-30 cm depth were recorded (Table 2). Alkaline phosphatase activity in rhizospheric soil was improved with application of different treatments and it was recorded maximum at 0-15 cm depth (136.37 µg PNP/g/h) and 15-30 cm (86.56 µg PNP/g/h) with T2 and minimum (69.33 µg PNP /g/h) with (T5) at 0-15 cm depth and 47.58 µg PNP/g/h at 15-30 cm with T7. Improvement in acid phosphatase activity was recorded after two years of treatments application and 70.01 µg PNP/g/h was recorded maximum at 0-15 cm soil depth and (80.26 µg PNP/g/h) at

Table 3 Response of various treatments on fruit yield and its attributes

Treatment	Number of fruit/tree			Av. fruit wt (kg)			Yield/tree (kg/tree)		
	2015	2016	Mean ± sd	2015	2016	Mean ± sd	2015	2016	Mean ± sd
T1	326	239.17	282.58±61.40	0.285	0.253	0.27±0.02	111.18	60.68	85.93±35.71
T2	484.33	403.83	444.08±56.92	0.349	0.261	0.30±0.06	160.3	108.98	134.64±36.29
T3	530	355.33	442.66±123.51	0.309	0.228	0.27±0.06	147.13	81.75	114.44±46.23
T4	405.33	253.17	329.25±107.59	0.311	0.229	0.27±0.06	131.37	61.56	96.46±49.36
T5	354.66	304.5	329.58±35.47	0.313	0.187	0.25±0.09	97.95	57.95	77.95±28.28
T6	393.33	323.33	358.33±49.50	0.305	0.247	0.28±0.04	123.89	82.18	103.03±29.49
T7	262.66	177.83	220.24±59.98	0.308	0.251	0.28±0.04	88.46	46.18	67.32±29.90
CD (P=0.05)	149.86	136.068		NS	0.031		42.33	27.20	

Table 4 Response of various treatments on quality parameters of fruit

Treatment	Total soluble solids (%)			Titrable acidity (%)			Total caretonoids (mg/100g)			FRAP (micromole/liter)			DPPH (Antioxidant) per cent inhibition		
	2015	2016	Mean ± sd	2015	2016	Mean ± sd	2015	2016	Mean ± sd	2015	2016	Mean ± sd	2015	2016	Mean ± sd
T1	22	22.93	22.46 ± 0.66	0.3	0.27	0.28 ± 0.02	4.24	5.4	4.82 ± 0.82	44.38	44.98	44.68 ± 0.42	59.17	51.04	55.10 ± 5.75
T2	23.5	26.36	24.93 ± 2.02	0.24	0.27	0.25 ± 0.02	5.5	6.4	5.95 ± 0.64	45.58	74.478	60.03 ± 20.43	66.98	76.82	71.90 ± 6.96
T3	21.83	23.33	22.58 ± 1.06	0.22	0.28	0.25 ± 0.04	4.41	5.1	4.75 ± 0.49	44.65	66.759	55.70 ± 15.63	55.59	43.79	49.69 ± 8.34
T4	21	22.66	21.83 ± 1.17	0.31	0.26	0.28 ± 0.04	5.06	4.7	4.88 ± 0.25	43.61	44.813	44.21 ± 0.85	65.64	52.9	59.27 ± 9.01
T5	21.53	23.4	22.46 ± 1.32	0.32	0.29	0.30 ± 0.02	3.73	5.83	4.78 ± 1.48	43.39	56.46	49.92 ± 9.24	55.76	58.58	57.17 ± 1.99
T6	22.33	24.16	23.24 ± 1.29	0.28	0.27	0.27 ± 0.01	3.38	5.5	4.44 ± 1.50	39.41	48.129	43.76 ± 6.17	66.47	67.82	67.14 ± 0.96
T7	20.5	22.36	21.43 ± 1.32	0.38	0.28	0.33 ± 0.07	4.98	6.09	5.53 ± 0.78	42.96	46.97	44.96 ± 2.84	55.39	51.03	53.21 ± 3.08
C D (P=0.05)	1.74	2.08		NS	NS		0.87	1.04		2.93	19.16		8.95	19.83	

15-3- cm soil depth with T2 while it was minimum (54.98 µg PNP) with T7 at 0-15 cm depth.

Maximum number of fruits 444.08 and average fruit weight (0.30kg) and average yield (134.64 kg/tree) was recorded with T2 while it was minimum (67.32 kg/tree) with T7 (Table 3). Maximum total soluble solids (24.93 ^{0}Brix), total carotenoids content (5.95 mg/100g) in fruits was recorded with T2. Ferric reducing-antioxidant power (FRAP) in fruit juice was also recorded maximum (60.03 micromole/liters) with T2 and minimum 43.76 micromole/ liters with T6. Observations on DPPH (anti-oxidant) per cent inhibition were varied significantly and highest abilities to scavenge DPPH radical (71.90%) was recorded with T2 (Table 4). Improvement in fruit quality, viz. total carotenoids,soluble solid may be due to balanced nutrition through organic sources which lead to improve DPPH and FRAP activity in fruit juice. Ram *et al.* (2017) have also reported improvement in fruit quality parameters with application of organic amendments. Uma *et al.* (2012) reported the higher flavonoids and anthocyanins are responsible for the increased DPPH and FRAP activity in many fruits and vegetables.

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