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Effect of organic manures and microbial inoculants on soil nutrient availability and yield of turmeric intercropped in arecanut gardens

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ABSTRACT

The combination of organic manures and microbial inoculants viz. Azospirillum brasinese and AM (Glomus fasciculatum) were tried for the organic production of turmeric grown as intercrop in arecanut plantation of six years old. The experiment was laid out in RBD with three replication for consecutive two years (2005-2006) at Horticultural Research Station, Mondouri, BCKV, Nadia, West Bengal. A significant difference in the rhizome yield was noticed when organic manure-microbial inoculants combination was compared with recommended dose of fertilizers (inorganic). Among different treatment combinations tried, the most effective treatment was vermicompost + Azospirillum + AM (28.94 t ha^{-1}), followed by compost + Azospirillum + AM (26.93 t ha^{-1}), as compared to recommended inorganic NPK (24.11 t ha^{-1}). The soil under vermicompost + Azospirillum + AM showed maximum organic carbon content (0.71%) and available potassium (209.09 kg ha-1) after harvest; whereas maximum available nitrogen (253.05 kg ha^{-1}) and phosphorous (29.44 kg ha^{-1}) were noticed in mustard cake + Azospirillum and phosphocompost + Azospirillum + AM respectively. In general a higher build up of soil nutrients was observed after the experimentation for organic manure-microbial inoculants combinations compared to inorganic management.

Key words: Microbial inoculants, organic manure, soil nutrient

Turmeric (*Curcuma longa* L.) is one of the important spice crops in India. It is widely used as culinary item as well as in religious ceremonies. The demand for turmeric is increasing due to its wide utility as a spice, dye in textile industry, cosmetics and also by the drug industries particularly for the preparation of anti-cancer medicines. India accounts for 80% of the world production and enjoys monopoly in the export of this crop.

The indiscriminate use of inorganic fertilizers and chemical pesticides has resulted in ecological imbalance with consequent ill effect to the soil and crops. However in recent years, microbial inoculants in the form of bio fertilizers have emerged as promising component of plant nutrient supply system. The micro-organisms involved contribute much towards improving the fertility status of the soil besides augmenting higher yield. Moreover, intercropping turmeric in arecanut plantation is profitable without hampering the performance of the main crop (Roy *et al*, 2000). Hence, the experiment was designed with the objective to supplement chemical fertilizers with the incorporation of biofertilizers for organic turmeric and ensure eco-friendly environment.

MATERIALS AND METHODS

The experiment was carried out in six years old arecanut (cv. Mohitnagar) plantation at Horticultural Research Station, Mondouri, BCKV for two consecutive years from April, 2005 to December, 2006. The soil of the experimental plot was sandy clay loam with pH 6.8 and 0.50% organic carbon. Available N, P and K in soil were 231.66 kg ha-1, 17.09 kg ha-1 and 204.49 kg ha^{-1} respectively. Raised beds of 1.5 m x 1.5 m and 15 cm height were prepared in the interspaces of four areca palms leaving 75.0 cm radius from the base of each palm. Two bio fertilizers namely *Azospirillum brasilense* and arbuscular mycorrhiza (*Glomus fasciculatum*) and four organic manures (compost, vermicompost, phosphocompost and mustard cake) were included as bio-organic inputs. The biofertilizers were applied singly and in combination with organic manures. There are altogether 13 treatments including 100% recommended inorganic NPK. The experiment was laid out in RBD with 3 replications. The organic inputs namely compost, vermicompost, phosphocompost and mustard cake were applied basally during final land preparation @ 20, 5, 10 and 3 t ha^{-1}, respectively. AM was applied @ 65 kg ha^{-1} directly to the soil and *Azospirillum* was incorporated through seed treatment @ 5 g kg^{-1} seed rhizome. Healthy seed rhizomes (30-35 g) were treated with *Trichoderma viride* @ 5 g kg^{-1} and *Acacia* gum was used as sticker. Seed rhizomes were soaked in biofertilizer mixture for 30 minutes and stirred thoroughly 4-5 times to confirm uniform soaking. After soaking, rhizome bits were dried under shade in airy place. For inorganic treatment, turmeric was fertilized @ 150:60:150 kg NPK per hectare in 3 splits. First, 1/3rd N, full P and ½ K were applied during planting and thereafter 1/3rd N and ½ K were applied at 45 and 90 days after planting (DAP). Urea,

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Single super phosphate and Muriate of potash were used as inorganic source of N, P and K respectively. Rhizomes of turmeric were planted to a depth of 3-4 cm, in the middle of April during both the years 2005 and 2006. Crops were mulched immediately with paddy straw at the rate of 10 t ha^{-1} immediately after planting and 5 t ha^{-1} at 45 and 90 days after planting. Earthing up was done before second and third mulching. Three to four hand weedings were done. Irrigation was given as per requirement.

Table 1: Nutrient content of the bio-organic inputs

Inputs	Nutrient content (%)		
	N	P_2O_5	K_2O
Compost	0.75	0.20	0.50
Vermicompost	3.00	1.00	1.50
Phosphocompost	1.36	1.80	1.20
Mustard cake	5.20	3.00	0.65
Neem cake	5.20	1.00	1.40

Source: Reddy and Reddi (2002) and Joshi and Prabhakarasetty (2005)

The experiment under complete bio-organic management, the scheduled nutrient management practices could not be followed in arecanut. Recommended dose of compost *i.e.* 25 kg palm^{-1} year^{-1} along with neem cake @ 3.0 kg palm^{-1} year^{-1} were applied during pre-monsoon and post-monsoon respectively. The crop was harvested eight months after planting. Observations on different growth (at 180 days after planting) and yield attributing parameters were recorded from five randomly selected plants per replication. Rhizome yield was taken on net plot basis at harvest and the projected yield was calculated on the basis of yield per plot, considering the 60% area occupied by intercrop in the present investigation.

The soil samples were collected randomly by auger core from interspaces at 0-25 cm depth at 60, 120, 180 days after planting and after harvest and analyzed for organic carbon (Walkley and Black method), available nitrogen (Modified Kjeldhal method), available phosphorous (Modified Olsen method) and available potassium by neutral ammonium acetate extraction followed by Flame photometry (Jackson, 1973).

RESULTS AND DISCUSSION

The pooled data reveals that available NPK and organic matter content of the soil were influenced by different treatment combinations (Table 2 and 3).

Organic carbon

The increasing trend of organic carbon content was noticed up to 120 DAP and thereafter there was a decreasing trend with the progress of crop growth, irrespective of treatments. However, at 60 DAP, maximum organic carbon (0.70%) was noticed in compost + *Azospirillum* + AM applied plots, followed by vermicompost + *Azospirillum* + AM (0.69%), as compared to minimum organic carbon content (0.64%) with recommended dose of NPK. At 120 and 180 DAP, maximum organic carbon content was found with compost + *Azospirillum* + AM (0.82 and 0.77% respectively), followed by vermicompost + *Azospirillum* + AM (0.81 and 0.75%).

Table 2: Effect of treatments on organic carbon and available nitrogen content in soil (pooled)

Treatments	Organic C (%)				Available N (kg ha^{-1})			
	60 DAP	120 DAP	180 DAP	After harvest	60 DAP	120 DAP	180 DAP	After harvest
Compost + *Azospirillum*	0.66	0.78	0.73	0.66	243.48	257.54	251.98	242.25
Compost + AM	0.67	0.79	0.74	0.66	231.76	244.81	240.25	230.46
Compost + *Azospirillum* + AM	0.70	0.82	0.77	0.67	240.87	262.03	258.28	248.08
Vermicompost + *Azospirillum*	0.66	0.77	0.73	0.69	242.24	261.73	256.15	247.27
Vermicompost + AM	0.67	0.78	0.74	0.70	236.94	253.86	251.11	242.33
Vermicompost +*Azospirillum* + AM	0.69	0.81	0.75	0.71	246.11	259.29	256.79	245.00
Phosphocompost + *Azospirillum*	0.65	0.76	0.71	0.63	233.86	250.34	245.45	231.27
Phosphocompost + AM	0.66	0.77	0.71	0.64	231.20	243.81	239.72	236.81
Phosphocompost + *Azospirillum* + AM	0.67	0.78	0.74	0.65	234.78	250.20	245.11	236.13
Mustard Cake + *Azospirillum*	0.66	0.73	0.71	0.64	247.46	264.02	261.63	253.05
Mustard Cake + AM	0.65	0.75	0.72	0.65	244.19	262.33	259.81	250.48
Mustard Cake + *Azospirillum* + AM	0.66	0.77	0.74	0.69	248.85	266.60	263.03	254.19
Recommended NPK	0.64	0.75	0.69	0.62	250.30	264.16	259.84	240.22
SEm (±)	**0.02**	**0.02**	**0.004**	**0.004**	**0.91**	**1.21**	**1.10**	**1.09**
LSD (0.05)	**NS**	**NS**	**0.01**	**0.01**	**2.56**	**3.42**	**3.10**	**3.09**

Note: Initial soil nutrient status: Organic carbon content = 0.51%, available N= 231.66 kg ha^{-1}

After harvest, the soil of the plots showed positive organic carbon balance as compared to initial organic carbon status *i.e.,* before laying out the experiment. The soil of the plots under vermicompost + *Azospirillum* + AM treatment showed maximum organic carbon content (0.71%) after harvest followed by vermicompost + AM (0.70%) application. The lowest organic carbon content was recorded with recommended NPK (0.62%). The build up of organic carbon content of the plots treated with organic manures and biofertilizers inoculants was due to additive effect of carbonaceous compounds of the organic manures and also the microbial biomass.

Table 3: Effect of treatments on available phosphorous and potassium content in soil (pooled)

Treatments	Available P (kg ha^{-1})				Available K (kg ha^{-1})			
	60 DAP	120 DAP	180 DAP	After harvest	60 DAP	120 DAP	180 DAP	After harvest
Compost + *Azospirillum*	18.20	19.29	17.92	15.53	213.31	222.45	214.31	207.49
Compost + AM	20.41	22.40	20.77	17.17	214.57	226.32	214.86	208.63
Compost + *Azospirillum* + AM	20.95	23.04	21.60	17.60	220.55	230.72	221.22	211.75
Vermicompost + *Azospirillum*	20.53	20.83	19.75	17.15	205.54	219.73	205.15	203.41
Vermicompost + AM	20.11	21.73	20.91	18.00	210.15	222.98	213.27	207.28
Vermicompost +*Azospirillum* + AM	21.12	23.33	21.42	18.91	218.89	226.96	218.55	209.09
Phosphocompost + *Azospirillum*	25.70	28.00	26.98	25.47	205.06	216.27	207.75	203.12
Phosphocompost + AM	28.49	30.57	29.66	26.65	211.15	219.78	215.16	204.00
Phosphocompost + *Azospirillum* + AM	30.47	32.11	30.35	29.44	209.14	220.28	213.71	205.33
Mustard Cake + *Azospirillum*	21.58	21.35	20.58	18.73	206.54	219.18	210.36	206.40
Mustard Cake + AM	22.56	23.49	21.14	19.01	213.04	222.45	215.22	207.67
Mustard Cake + *Azospirillum* + AM	23.06	30.18	26.22	17.33	213.46	220.29	212.18	208.25
Recommended NPK	31.49	30.74	22.45	16.52	221.06	228.85	214.93	200.11
SEm (±)	**0.73**	**1.28**	**0.76**	**0.48**	**0.65**	**1.14**	**1.12**	**0.96**
LSD (0.05)	**2.08**	**3.62**	**2.16**	**1.35**	**1.85**	**3.22**	**3.19**	**2.73**

Note: Initial soil nutrient status : Available P = 17.09 kg ha^{-1}, Available K= 204.49 kg ha^{-1}

Table 4: Effect of treatments on yield of turmeric

Treatments	Yield $plot^{-1}$ (kg 2.25 sq m^{-1})			Projected yield (t ha^{-1})			+/- of yield over control (t ha^{-1})
	2005	2006	Mean	2005	2006	Mean	
Compost + *Azospirillum*	8.32	9.28	8.80	22.19	24.75	22.06	-2.05
Compost + AM	7.52	8.53	8.03	20.05	22.75	20.12	-3.99
Compost + *Azospirillum* + AM	10.12	10.85	10.49	26.99	28.93	26.93	+2.82
Vermicompost + *Azospirillum*	8.82	7.75	8.29	23.52	20.67	23.59	-0.52
Vermicompost + AM	9.26	9.87	9.57	24.69	26.32	24.75	+0.64
Vermicompost +*Azospirillum* + AM	10.86	12.15	11.51	28.96	32.40	28.94	+4.83
Phosphocompost + *Azospirillum*	8.90	7.84	8.37	23.73	20.91	24.01	-0.1
Phosphocompost + AM	8.45	7.35	7.90	22.53	19.60	22.66	-1.45
Phosphocompost + *Azospirillum* + AM	9.28	8.62	8.95	24.75	22.99	24.56	+0.45
Mustard Cake + *Azospirillum*	6.45	7.15	6.80	17.20	19.07	17.10	-7.01
Mustard Cake + AM	7.49	7.70	7.60	19.97	20.53	20.00	-4.11
Mustard Cake + *Azospirillum* + AM	8.65	8.24	8.45	23.07	21.97	23.28	-0.83
Recommended NPK	9.06	9.82	9.44	24.16	26.19	24.11	--
SEm (±)	**0.30**	**0.87**	**0.37**	**0.63**	**1.82**	**1.07**	--
LSD (0.05)	**0.93**	**2.68**	**1.05**	**1.95**	**5.63**	**3.03**	--

Note: + =increase, -= decrease

Available nitrogen, available phosphorus and available potassium

There was an initial increasing trend in amount of mineralizable nitrogen upto 120 days of crop growth irrespective of treatments, but significant variations within the treatments also noticed. The soil of recommended NPK plots exhibited maximum available nitrogen (250.30 kg ha^{-1}) at 60 DAP but during 120 and 180 DAP the combination of mustard cake + *Azospirillum* + AM recorded maximum available nitrogen of 266.60 and 263.03 kg ha^{-1} respectively. The minimum values of these three stages of crop growth were 231.20, 243.81 and 239.72 kg ha^{-1} with phosphocompost + AM. In general the available nitrogen content was more or less higher where mustard cake was applied as organic source of nutrients. After harvest the maximum (253.05 kg ha^{-1}) and minimum (230.46 kg ha^{-1}) availability of nitrogen were associated with mustard cake + *Azospirillum* and compost + AM respectively. The available nitrogen status of the soil was enhanced by all treatment combinations. The higher level of available nitrogen in fertilizer treated plots during early stages of crop growth was obviously due to the presence of mineral nitrogen of the fertilizers which later on decreased due to plant uptake, losses of nitrogen by micro-organisms. Higher level of available nitrogen in plots receiving mustard cake in combination with *Azospirillum* and AM was due to mineralization of organic nitrogen from mustard cake in addition to nitrogen fixation by *Azospirillum* (in presence of available organic carbon), while lowest amount of available nitrogen in phosphocompost plus AM treated plots indicated immobilization of mineral nitrogen by AM and other microbial population in presence of organic carbon in phosphocompost.

Table 5: Effect of treatments on fertility build up (+) or depletion (-) in soil

Treatments	Fertility build up (+) / depletion (-) over 2005			
	Organic C (%)	Available N	Available P (kg ha^{-1})	Available K
Compost + *Azospirillum*	+ 0.14	+ 10.18	+ 2.44	+ 3.76
Compost + AM	+ 0.16	+ 10.62	+ 2.64	+ 5.08
Compost + *Azospirillum* + AM	+ 0.10	+ 10.88	+ 3.16	+ 5.04
Vermicompost + *Azospirillum*	+ 0.10	+ 11.88	+ 2.88	+ 8.00
Vermicompost + AM	+ 0.10	+ 10.92	+ 3.02	+ 7.26
Vermicompost +*Azospirillum* + AM	+ 0.12	+ 12.22	+ 4.08	+ 9.72
Phosphocompost + *Azospirillum*	+ 0.06	+ 11.54	+ 3.22	+ 7.28
Phosphocompost + AM	+ 0.10	+ 10.46	+ 3.84	+ 7.88
Phosphocompost + *Azospirillum* + AM	+ 0.08	+ 11.62	+ 4.98	+ 7.58
Mustard Cake + *Azospirillum*	+ 0.06	+ 12.10	+ 3.16	+ 7.36
Mustard Cake + AM	+ 0.06	+ 10.90	+ 3.38	+ 5.84
Mustard Cake + *Azospirillum* + AM	+ 0.10	+ 13.16	+ 3.94	+ 2.88
Recommended NPK	+ 0.04	+ 6.86	+ 2.12	+ 8.28

Like nitrogen the increasing trend of available P was noticed upto 120 DAP and thereafter decreasing trend was observed with the progress of crop growth stages, irrespective of treatments. However, the magnitude of such changes varied among different treatment combinations. The highest available phosphorus content at 60 DAP (31.49 kg ha^{-1}) was recorded with recommended NPK, followed by phosphocompost + *Azospirillum* + AM (30.47 kg ha^{-1}). But with the progress of crop growth *i.e.,* at 120 and 180 DAP the maximum available phosphorus content (32.11 and 30.35 kg ha^{-1}) was noticed with phosphocompost + *Azospirillum* + AM. After harvest, soil analysis showed the maximum available phosphorus (29.44 kg ha^{-1}) associated with phosphocompost + *Azospirillum* + AM, followed by phosphocompost + AM (26.65 kg ha^{-1}) and phosphocompost + *Azospirillum* (25.47 kg ha^{-1}). The minimum level of available phosphorus content was recorded with compost + *Azospirillum* throughout the period of experimentation *i.e.,* 18.20, 19.29, 17.92 and 15.53 kg ha^{-1} at 60, 120 and 180 DAP and after harvest respectively. Higher level of available phosphorus in inorganic fertilizer treated plot was due to the applied mineral phosphorus in the soil. Phosphocompost, *Azospirillum* and AM treated plots have the highest amount of available phosphorus due to release of phosphorus form mineralization of phosphorus from phosphocompost and phosphorus solubilizing action of AM. *Azospirillum* absorbed mineral phosphorus from the soil and phosphorus mineralized from compost that resulted in the lowest level of available phosphorus in the soil.

Available K increased up to 120 DAP, thereafter recorded a decline. After harvest, available K-balance was positive. However, the magnitude of changes differed among the treatments. At 60 DAP, maximum available potassium content (221.06 kg ha^{-1}) was recorded with application of recommended NPK, followed by compost + *Azospirillum* + AM (220.55 kg ha^{-1}), as compared to lowest available potassium content (205.54 kg ha^{-1}) with vermicompost + *Azospirillum.* At 120 and 180 DAP, the maximum available potassium content was found in the plots treated with compost +

Azospirillum + AM (230.72 and 221.22 kg ha^{-1} respectively). After harvest, the maximum (209.09 kg ha^{-1}) and minimum (200.11 kg ha^{-1}) available potassium content of soil were recorded in the plots having vermicompost + *Azospirillum* + AM and recommended NPK respectively. Higher level of available potassium in inorganic fertilizer treated plots was due to additive effect of inorganic potassium from the added fertilizer to the soil. Highest level of available potassium in compost + *Azospirillum* + AM treated soil indicates possibility of higher solubility of different potassium pools of soil due to accelerated activities of *Azospirillum* and AM in presence of compost as an easily available carbon source.

Yield

With regards to yield per hectare, the most effective treatment was vermicompost + *Azospirillum* + AM (28.94 t ha^{-1}), followed by compost + *Azospirillum* + AM (26.93 t ha^{-1}) and vermicompost + AM (24.75 t ha^{-1}), as compared to lowest yield (17.10 t ha^{-1}) with mustard cake + *Azospirillum* combination. Application of recommended NPK produced yield of 24.11 t ha^{-1} which is lower than the treatments where organic manures were applied with both *Azospirillum* and AM except in mustard cake (Table 4). Biswas *et al.* (1971) reported that the application of organic manures improved the soil aggregates resulting in favourable pore geometry, which in turn increased the soil porosity thereby paving the way for good development of rhizomes under the soil. Application of organic manures incurred nutrient availability, improved physical conditions of the soil, and increased the yield (Rajan and Singh, 1973 and Sadanandan and Hamza, 1998). Thomas (1965) obtained higher rhizome yield with the application of 10 t of organic manure and 5 t of green leaf as mulch, without any fertilizer application. The results of the present investigation are also in good agreement with the findings of Reddy *et al.*, 2003.

Build up of soil fertility

The results showed the build up of soil fertility after two years of growing turmeric in arecanut plantation, irrespective of treatments (Table 5). However, the magnitude of such changes varied with different treatments. The build up range of organic carbon was 0.04% to 0.16%. The highest magnitude was recorded with compost + AM (+0.16%), followed by compost + *Azospirillum* (+0.14%) and vermicompost + *Azospirillum* (+0.12%). The build up of available N (range 6.86 to 13.16 kg ha^{-1}) was highest in mustard cake + *Azospirillum* + AM treated plots (+13.16 kg ha^{-1}), followed by vermicompost + *Azospirillum* + AM (+12.22 kg ha^{-1}). The least organic carbon (+0.04%) and nitrogen (+6.86 kg ha^{-1}) build up were noticed in recommended NPK. The build up of available P (range +2.12 to +4.98 kg ha^{-1}) showed maximum magnitude (+4.98 kg ha^{-1}) with phosphocompost + *Azospirillum* + AM, followed by vermicompost + *Azospirillum* + AM (+4.08 kg ha^{-1}) and mustard cake + *Azospirillum* + AM (+3.94 kg ha^{-1}). Combination of vermicompost + *Azospirillum* + AM was most effective in highest build up of available K (+9.72 kg ha^{-1}) in soil (range 2.88 to 9.72 kg ha^{-1}), followed by recommended NPK (+8.28 kg ha^{-1}) and vermicompost + *Azospirillum* (+8.00 kg ha^{-1}).

In terms of yield, the most effective treatment was vermicompost + *Azospirillum* + AM (28.94 t/ha), followed by compost + *Azospirillum* + AM (26.93 t/ha), as compared to recommended inorganic NPK (24.11 t/ha). The soil under vermicompost + *Azospirillum* + AM showed maximum organic carbon content (0.71%) and available potassium (209.09 kg ha-1) after harvest; whereas maximum available nitrogen (253.05 kg ha-1) and phosphorous (29.44 kg ha-1) were noticed in mustard cake + *Azospirillum* and phosphocompost + *Azospirillum* + AM respectively. In general a higher build up of soil nutrients was observed after the experimentation for organic manure-microbial inoculants combinations compared to inorganic management.

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