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Effect of organic manures and microbial inoculants on yield, root colonization and total bacterial population in turmeric (*Curcuma longa* L.) intercropped in arecanut (*Areca catechu* L.) garden

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Abstract

The effect of combination of organic manures namely, compost, vermicompost, phosphocompost and mustard cake and microbial inoculants namely, *Azospirillum brasilense* and arbuscular mycorrhiza (*Glomus fasciculatum*) were evaluated for the organic production of turmeric (*Curcuma longa*) (cv. Suguna) grown as intercrop in arecanut (*Areca catechu*) (cv. Mohitnagar) plantation at Mondouri (Nadia, West Bengal) A significant difference in rhizome yield was noticed when organic manure-microbial inoculant combination was applied when compared with recommended dose of fertilizers (inorganic). Among different treatment combinations tried, the most effective treatment was vermicompost + *Azospirillum* sp. + *Glomus* sp. (28.94 t ha^{-1}), followed by compost + *Azospirillum* sp. + *Glomus* sp. (26.93 t ha^{-1}), as compared to recommended inorganic NPK (24.11 t ha^{-1}). Maximum root colonisation (74%) with microbial inoculants at 180 days after planting was observed with vermicompost + *Azospirillum* sp. + *Glomus* sp. Maximum bacterial population (105.25 x 10^5 CFU g^{-1} soil) at harvest was noticed in compost + *Azospirillum* sp. + *Glomus* sp., as compared to lowest population with recommended NPK (56.35 x 10^5 CFU g^{-1} of soil).

Keywords: arecanut, *Areca catechu, Curcuma longa*, intercropping, microbial inoculant, organic manure, turmeric.

Introduction

Organic manures and biofertilizers offer an alternative to chemical inputs and are being increasingly used in spice crop production including turmeric (*Curcuma longa* L.) (Srinivasan *et al*. 2000). Intercropping turmeric in arecanut (*Areca catechu* L.) plantation is known to be profitable without hampering the performance of the main crop (Roy *et al*. 2000). The experiment was undertaken to study the effect of organic manures and biofertilizers on yield, root colonisation and microbial population of turmeric under arecanut-turmeric inter-cropping system.

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Materials and methods

The experiment was carried out in a 6 year old arecanut (cv. Mohitnagar) plantation at Horticultural Research Station, Mondouri (Bidhan Chandra Krishi Viswavidyalaya) during April 2005 to December 2006. The experiment was laid out in randomised block design with three replications. Raised beds of 1.5 m x 1.5 m size and 15 cm height were prepared in the interspaces of four areca palms leaving 75 cm radius from the base of each palm.

Two biofertilizers 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 were altogether 13 treatments including 100% recommended inorganic NPK. The organic inputs, compost, vermicompost, phosphocompost and mustard cake were applied basally during final land preparation @ 20 t, 5 t, 10 t and 3 t ha^{-1}, respectively. The mean nutrient content (N, P and K) of different manures were: 0.75%, 0.20% and 0.50% in vermicompost, 1.36%, 1.80% and 1.20% in phosphocompost, 5.20%, 3.00% and 0.65% in mustard cake and 5.20%, 1.00% and 1.40% in neem cake, respectively (Reddy & Reddi 2002; Joshi & Setty 2005). *G. fasciculatum* was applied @ 65 kg ha^{-1} directly to the soil and *A. brasilense* was incorporated through seed treatment @ 5 g kg^{-1} seed rhizome. The biofertilizers were collected from Nodule Research Laboratory, BCKV, Mohanpur. Healthy seed rhizomes (30-35 g) were treated with *Trichoderma viride* @ 5 g kg^{-1} seed rhizome and *Acacia* gum was used as sticker. Seed rhizomes were soaked in biofertilizer mixture for 30 min and stirred thoroughly; after soaking, rhizome bits were dried under shade. For inorganic treatment, turmeric was fertilized @ 150:60:150 kg NPK ha^{-1} in three splits. Full P and 1/3rd N were applied as basal. 1/3rd N and ½ K were applied at 45 and 90 days after planting (DAP). Urea, 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 mid April during 2005 and 2006. The crops were mulched with paddy straw @ of 10 t ha^{-1} immediately after planting and 5 t ha^{-1} at 45 and 90 DAP. Earthing up was done before second and third mulching. Three to four hand weedings were done. Irrigation was given as per requirement. As the experiment was under complete bio-organic management, the recommended dose of compost, 25 kg $palm^{-1}$ $year^{-1}$ along with neem cake @ 3 kg $palm^{-1}$ $year^{-1}$ were applied during pre-monsoon (June) and post-monsoon (September), respectively.

The crop was harvested 8 months after planting. Observations on growth (at 180 DAP) 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.

Root samples for mycorrhizal study were randomly collected from the secondary and tertiary branches as juvenile healthy roots of turmeric at 60, 120 and 180 DAP. The roots were fixed in forma-acetic alcohol solution and were processed and stained according to modified Phillips & Hayman (1970) method. Roots were segmented in 1 cm length and autoclaved in 10% KOH solution at 15 lbs psi steam pressure for 1-2 min, and then if necessary were treated with 10% ammoniacal hydrogen peroxide to clear pigmentation. After thorough washing with water, the root pieces were treated with 0.5 N HCl for 10 min, then stained in 0.1% Trypan Blue in lactophenol solution for 15-20 min. Stained root segments of 1 cm length were suspended in lactophenol to remove excess stain and were placed on slide for microscopic observation. The slide micrometer method (Kormanik & Mc Graw 1982) was followed to assess root infection intensity in experimental plants. A minimum of 10 and maximum of 25 root segments were examined for each replication. Per cent root infected was measured by examining presence or absence of

mycorrhizal hyphae and other structures (vesicles and arbuscules) per unit length of root pieces as observed with the help of ocular micrometer. The enumeration of the microbial population was done on agar plates containing Thornton's agar media following serial dilution technique and pour plate method; plates were incubated at 30^0C. The counts were taken at 5^{th} day of incubation. The result was reported as number of cells g^{-1} of soil.

Results and discussion

Yield

Considering the projected yield per hectare, the most effective treatment was vermicompost + *Azospirillum* sp. + *Glomus* sp. (28.94 t ha^{-1}), that was on par with compost + *Azospirillum* sp. + *Glomus* sp. (26.93 t ha^{-1}) (Table 1).

Vermicompost application enhances the activity of beneficial microbes like N_2 fixers and colonization by mycorrhizal fungi and hence plays a significant role in N_2 fixation and phosphate mobilization leading to better uptake by the plant. Thus the increased availability of nutrients and uptake by the plants would have resulted in better growth and yield in plots treated with vermicompost. Application of organic manures enhanced nutrient availability, improved physical conditions of the soil, and increased the yield of ginger (Rajan & Singh 1973; Sadanandan & Hamza 1998). Thomas (1965) obtained higher rhizome yield with application of 10 t of organic manure and 5 t of green leaf as mulch, without any fertilizer application in ginger.

Root colonization

Root colonization of microbial inoculants varied significantly with different combinations of organic manures and bio-fertilizers. At 60 DAP, application of compost + *Azospirillum* sp. + *Glomus* sp. resulted in 57.2% of plants being colonised that was on par with vermicompost + *Azospirillum* sp. + *Glomus* sp. Minimum root infection was found in plants raised with recommended NPK (23.5%) (Table 1).

At 120 DAP, significantly higher root infection was noticed in vermicompost + *Azospirillum* sp. + *Glomus* sp. combination (81.9%) and minimum infection was found with recommended NPK (28.7%).

At 180 DAP also significantly higher root colonization with vermicompost + *Azospirillum* sp. + *Glomus* sp. (74.1%) was observed, whereas minimum root colonization was found with application of recommended NPK (21.3%).

Root colonization steadily increased up to 120 DAP and decreased thereafter irrespective of treatments. This declining trend might be due to decay of older roots as well as due to depletion of organic matter in course of time. The higher rate of root colonization was associated with the combined application of *Azospirillum* sp. and *Glomus* sp., indicating a synergistic relation between the two microbes.

Total bacterial population

There was an increasing trend regarding total bacterial population with age till crop maturity and decreased thereafter, irrespective of treatment combinations (Table 2). At 60 DAP, significantly higher population (92.39 x 10^5 CFU g^{-1} of soil) was found with compost + *Azospirillum* sp. + *Glomus* sp. that was on par with vermicompost + *Azospirillum* + *Glomus* sp. (91.88 x 10^5 CFU g^{-1} of soil). At 120 DAP, application of vermicompost + *Azospirillum* + *Glomus* sp. recorded significantly higher population (122.72 x 10^5 CFU g^{-1} of soil) that was on par with compost + *Azospirillum* (120.46 x 10^5 CFU g^{-1} of soil). At 180 DAP, compost + *Azospirillum* sp. + *Glomus* sp. contained significantly higher population (117.94 x 10^5 CFU g^{-1} of soil), when compared to other treatments. After harvest also significantly higher population (105.25 x 10^5 CFU g^{-1} of soil) was noticed in plots receiving compost + *Azospirillum* + *Glomus* sp.

The study indicated that turmeric responds well to application of organics and biofertilizers and higher yields could be obtained by application of vermicompost + *Azospirillum* sp. + *Glomus* sp. and maximum root colonization was also observed in this treatment.

Table 1. Effect of organic manures and biofertilizers on yield and root colonization of turmeric

Treatment	Projected yield (t ha^{-1})			Per cent root infection								
				60 days after planting			120 days after planting			180 days after planting		
	2005	2006	Pooled	2005	2006	Pooled	2005	2006	Pooled	2005	2006	Pooled
Compost + *Azospirillum* sp.	22.19	24.75	22.06	39.2	42.8	41.0	48.1	51.3	49.7	40.5	44.5	42.5
Compost + *Glomus* sp.	20.05	22.75	20.12	53.5	55.9	54.7	64.9	71.9	68.4	58.4	63.2	60.8
Compost + *Azospirillum* sp. + *Glomus* sp.	26.99	28.93	26.93	57.5	59.1	58.3	77.8	80.2	79.0	70.2	73.4	71.8
Vermicompost + *Azospirillum* sp.	23.52	20.67	23.59	40.1	39.1	39.6	42.1	49.5	45.8	38.3	40.9	39.6
Vermicompost + *Glomus* sp.	24.69	26.32	24.75	48.7	53.5	51.1	70.0	74.6	72.3	62.7	67.3	65.0
Vermicompost + *Azospirillum* sp. + *Glomus* sp.	28.96	32.40	28.94	54.9	59.5	57.2	79.3	84.5	81.9	72.1	76.1	74.1
Phosphocompost + *Azospirillum* sp.	23.73	20.91	24.01	36.5	31.3	33.9	44.0	39.8	41.9	36.0	35.4	35.7
Phosphocompost + *Glomus* sp.	22.53	19.60	22.66	44.0	48.6	46.3	63.7	69.3	66.5	57.8	60.6	59.2
Phosphocompost + *Azospirillum* sp. + *Glomus* sp.	24.75	22.99	24.56	51.4	49.4	50.4	72.6	67.8	70.2	61.6	64.2	62.9
Mustard cake + *Azospirillum* sp.	17.20	19.07	17.10	30.5	35.7	33.1	42.5	39.1	40.8	35.7	33.5	34.6
Mustard cake + *Glomus* sp.	19.97	20.53	20.00	45.7	43.1	44.4	60.8	58.6	59.7	50.3	55.3	52.8
Mustard cake + *Azospirillum* sp. + *Glomus* sp.	23.07	21.97	23.28	44.6	48.0	46.3	61.5	68.7	65.1	56.7	60.1	58.4
Recommended NPK (Inorganic)	24.16	26.19	24.11	22.9	24.1	23.5	24.3	29.1	28.7	19.0	23.6	21.3
SEm(±)	0.632	1.826	1.070	0.530	1.265	0.563	3.061	0.768	1.250	0.765	1.476	0.655
CD (P=0.05)	1.948	5.628	3.028	1.547	3.692	1.602	8.934	2.243	3.537	2.233	4.308	1.855

Table 2. Effect of organic manures and biofertilizers on total bacterial population in soil

Treatment	Total bacteria (x 10^5 CFU g^{-1} of soil)											
	60 days after planting			120 days after planting			180 days after planting			After harvest		
	2005	2006	Pooled	2005	2006	Pooled	2005	2006	Pooled	2005	2006	Pooled
Compost + *Azospirillum* sp.	75.63	95.30	85.47	112.66	128.25	120.46	100.52	120.70	110.61	88.41	100.25	94.33
Compost + *Glomus* sp.	72.45	90.52	81.49	95.34	110.36	102.85	90.33	108.34	99.34	81.61	93.50	87.56
Compost + *Azospirillum* sp. + *Glomus* sp.	85.28	99.50	92.39	122.57	115.47	119.02	105.75	130.12	117.94	95.40	115.09	105.25
Vermicompost + *Azospirillum* sp.	79.06	98.33	88.70	110.07	125.56	117.82	102.73	110.51	106.62	87.11	98.00	92.56
Vermicompost + *Glomus* sp.	75.10	85.45	80.28	95.75	115.15	105.45	98.18	105.66	101.92	79.15	95.66	87.41
Vermicompost + *Azospirillum* sp. + *Glomus* sp.	91.66	92.10	91.88	115.10	130.33	122.72	98.91	118.75	108.83	87.49	105.72	96.61
Phosphocompost + *Azospirillum* sp.	65.43	78.37	71.90	95.53	127.50	111.52	89.12	105.47	97.30	82.33	97.30	89.82
Phosphocompost + *Glomus* sp.	78.50	56.76	67.63	101.23	92.47	96.85	100.37	90.81	95.59	73.36	90.17	81.77
Phosphocompost + *Azospirillum* sp. + *Glomus* sp.	72.10	86.74	79.42	102.46	132.50	117.48	95.21	125.93	110.57	80.75	100.37	90.56
Mustard cake + *Azospirillum* sp.	80.25	84.60	82.43	92.71	116.19	104.45	91.50	112.50	102.00	80.83	95.43	88.13
Mustard cake + *Glomus* sp.	72.36	80.33	76.35	90.33	106.21	98.27	105.00	100.14	102.57	79.00	95.25	87.13
Mustard cake + *Azospirillum* sp. + *Glomus* sp.	69.40	92.25	80.83	85.25	128.25	106.75	95.08	115.15	105.12	85.12	98.10	91.61
Recommended NPK (Inorganic)	60.81	77.67	69.24	65.90	79.61	72.76	55.29	68.31	61.80	50.37	62.33	56.35
SEm(±)	2.148	1.301	1.255	2.352	1.219	1.324	2.224	1.482	1.336	1.276	1.532	0.997
CD (P=0.05)	6.270	3.798	3.571	6.865	3.559	3.766	6.492	4.325	3.799	3.725	4.472	2.835

Initial population of total bacteria: 45.33 x 10^5 CFU g^{-1} of soil

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