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Influence of manures, biofertilizers along with graded levels of inorganic nitrogen and phosphorous on growth, yield and quality of turmeric (*Curcuma longa* L.)

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ABSTRACT

The investigation was carried out during 2012-14 at HRS, Mondouri, BCKV, Nadia, West Bengal to find out the effect of bio-fertilizers with different levels of inorganics and type of manures. The experiment as laid out in RBD with three replications. Two organic manures (compost and vermicompost), two biofertilizers (Azospirillum lipoferum and Glomus fasiculatum) and three levels (100%, 75% and 50%) of NP were included in this experiment along with recommended dose of NPK (150:60:150 kg ha^{-1}). The uniform dose of potash was applied to all treatments. Among different treatments, maximum tiller number (3.40), leaf number (18.49), clump weight (378.38 g), projected yield (34.85 t ha^{-1}) and dry recovery (23.45%) were noticed in vermicompost + NP (75%)+ Azospirillum+ AMF. The same treatment also recorded maximum root colonization (55.24%, 73.50% and 79.68%) and maximum bacterial population (118.67× 10^{6} , 106.03 × 10^{6}, 97.41× 10^{6} CFU/g of soil) at 120, 180 DAP and after harvest respectively. Application of vermicompost + NP (100%) + Azospirillum + AMF recorded maximum oleoresin (11.31%). The plants raised with compost+ NP (100%)+ Azospirillum+ AMF recorded maximum curcumin (6.69%). Application of recommended dose of inorganic NPK recorded yield of 27.63 t ha^{-1} .

Keywords: Arbuscular mycorrhizal fungi, *Azospirillum*, turmeric and vermicompost

Turmeric (*Curcuma longa* L.) is one of the major spice and condiment crop of India. It is widely used as culinary item as well as in religious ceremonies. Consistent and indiscriminate use of chemical fertilizers has caused serious damage to the soil and ecology. In the present day agriculture, supplementary and complementary role of organics is being increasingly felt for sustainable productivity and keeping the soil health in order. Turmeric is a nutrient exhausting crop and responds well to organic manures and fertilizers. The present investigation was designed with the objective to supplement the use of ever increasing costly chemical fertilizers with the incorporation of biofertilizers that could ensure ecofriendly environment and economically sustainable cropping.

MATERIALS AND METHODS

The experiment was carried out at Horticultural Research Station, Mondouri, Bidhan Chandra Krishi Viswavidyalaya, Nadia, West Bengal during last week of April, 2012 to January, 2014. The soil at the experimental plot was sandy clay loam with pH 6.8 and 0.58% organic carbon. Available N, P and K in soil were 223.45 kg ha^{-1}, 18.07 kg ha^{-1}and 194.49 kg ha^{-1}, respectively. The experiment was laid out in RBD with three replications. Raised beds of 3.0×1.0 m and 15 cm high were prepared. Turmeric cv. Suguna was planted in a spacing of 20 ×25 cm. The organic inputs namely compost and vermicompost were applied basally during final land preparation @ 20.0 t and 5.0 t ha^{-1} respectively. Among biofertilizers, arbuscular mycorrhizal fungi (*Glomus fasiculatum*) was applied @ 65 kg ha^{-1} directly to the soil along with compost or vermicompost. *Azospirillum lipoferum* was incorporated through seed rhizome treatment @ 5g kg^{-1} seed material. The biofertilizers along with *Tricoderma viridae* @ 5 g kg^{-1} seed rhizome and Acacia gum (1 tablespoon) as sticker were taken in water in a plastic tray and mixed thoroughly. Healthy seed rhizome (30-35 g) were soaked in biofertilizer mixtures and stirred thoroughly 4-5 times. Recommended dose of inorganic fertilizers was 150:60:150 kg NPK ha^{-1}. The total amount of fertilizers was applied in three split doses. 1/3rd of N and full dose of P was applied after 15 days of planting whereas each split of 1/3rd N and ½ K will be applied after 45 and 90 days after planting. Urea, SSP and MOP were used as inorganic source of N, P and K respectively. Treated rhizomes of turmeric were planted to a depth of 3-4 cm, in the last week of April for both the years. The beds were mulched with paddy straw at the rate of 10 t ha^{-1} immediately after planting and 5t ha^{-1} at 45 and 90 days after planting. Earthing up was done before second and third mulching. 3-4 hand weedings were done. Irrigation was given as per requirement. The crop was harvested 8 months after planting, observations on different growth (at 60, 120 and 180 days after planting) and yield attributing parameters were recorded from five randomly selected plants per replication. Rhizome yield was taken

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on net plot basis at harvest and projected yield was calculated on the basis of yield per plot, considering the 75 per cent area occupied by the crop (Anon., 1995). For determination of dry recovery the composite sample were kept at 70^{0}C till constant weight. The curcumin and oleoresin content were estimated using air condenser and chromatographic column respectively. Study on root colonisation and total bacterial population: 1.Estimation of per cent root infection - Soil adhering to the roots was washed carefully under tap water and the roots were fixed in Forma acetic alcohol solution. The roots were then processed and stained according to modified Phillips and Hayman (1970) method. 2. Count of total number of viable bacteria- Soil samples taken from the rhizosphere were used for microbial count of *Azospirillum lipoferum,* Serial dilution plating method was followed for microbial population count (Vincent, 1970). Isolation of *Azospirillum* was done by serial dilution upto 10^6 of soil samples with sterilized distilled water and then plated in nitrogen free Bromothymol blue (NFB) media and incubated at 28^{0}C ± 2^{0}C for 3 days and observations were taken by counting the colonies and expressed in colony forming units (CFU) per g of soil. The statistical analysis for microbial population and root colonization was made through one way ANOVA. The standard error of mean and the value of least significant difference (LSD) to compare the difference between means are provided in the tables of the results. Angular and square root transformation were utilized for statistical analysis as per requirement.

RESULTS AND DISCUSSION

Data presented in the table 1 to 3, revealed a number of interesting features on growth, yield and quality parameters of turmeric.

Growth parameters

At 60 DAP, the plants under treatment vermicompost + NP (100%) recorded the maximum plant height (91.12 cm) and minimum plant height (75.66 cm) under vermicompost+ NP (50%) + *Azospirillum* + AMF (Table 1). The plant height under recommended NPK (inorganic) was 82.47 cm. At 120 DAP, maximum plant height was observed with compost + NP (100%) + *Azospirillum* + AMF (140.47 cm) followed by compost + NP (100%) [140.24 cm] as compared to minimum plant height under vermicompost + NP @ 50% (123.65 cm). At 180 DAP, application of compost + NP (75%) + *Azospirillum* + AMF recorded maximum plant height (171.52 cm) as compared to minimum plant height (150.63 cm) under NPK (100%) inorganic only. The response of bio-inoculants in the early stage of growth was not pronounced which was indicated in the late stage. The favourable effects of organic manures were noticed through comparing the plant height as compared to NPK (100%) only. Irrespective of kind of organics, the efficacy of *Azospirillum* + AMF was also observed particularly at NP (100%) and NP (75%) levels. Generally, in all root and tuber crops, as the underground storage organ increase in size, there will be a gradual decrease in the growth of above ground parts (Kawakami, 1978). Turmeric responds to heavy dressing of organic matter and many experimental evidences are available on the beneficial effects of organic matter either alone or in combination with inorganic fertilizers on the growth and productivity of turmeric (Rethinam *et al.,* 1994).

The maximum number of leaves clump^{-1} (5.48) was noticed under vermicompost + NP (75%) + *Azospirillum* + AMF against the minimum number (4.34) under recommended NPK (inorganic). At 120 DAP, application of vermicompost + NP (75%) + *Azospirillum* + AMF occupied the first position for production maximum number of leaves (12.43) as compared to minimum leaf number of 10.75 under vermicompost + NP (50%) combination (Table 1). At 180 DAP, application of vermicompost + NP (75%) + *Azospirillum* + AMF occupied the first position for production of highest number of leaves (18.49) as compared to lowest leaf number (15.62) in recommended NPK (inorganic). The above findings indicated that effect of organic manures and microbial inoculants on leaf number was more prominent to vermicompost + bio-inoculants at NP (75%) and NP (100%) levels. This may be due to the increase in soil-fertility level in the in the soil which is evidenced by the higher available NPK in the soil.

The plants grown under vermicompost + NP (100%) + *Azospirillum* + AMF recorded maximum tiller (1.32) as compared to minimum tiller (0.33) under compost + NP (50%) + at 60 DAP. At 120 DAP, the similar trend was also noticed like 60 DAP (Table 1). The maximum tiller (2.25) was produced under the same treatment against the minimum tiller (1.07) under recommended NPK (inorganic). At 180 DAP, the plants given with treatment combination vermicompost + NP (75%) + *Azospirillum* + AMF recorded maximum tiller (3.42) as compared to minimum tiller (1.94) under vermicompost + NP (75%). Role of organic manures in maintaining soil health and their influence on growth and development of crop has been well documented (Sultan, 1995; Singh *et al.*, 1997). Besides influencing the physicochemical properties of soil, vermicompost is also known to contain growth promoting substances, enhance microbial activity and prevent nitrogen loss (Shinde *et al.*, 1992). Compared to the availability of nutrients from most of the bulky organic manures, the release of nutrients from the added vermicompost is more and could be the reason for higher number of leaves and tillers. The result of the present investigation is in agreement

Table 1: Influence of organic and inorganic nutrition on height, tiller and leaf number of turmeric

Treatments	Plant height (cm)			No. of tillers clump^{-1}			No. of leaves clump^{-1}		
	60 DAP	120 DAP	180 DAP	60 DAP	120 DAP	180 DAP	60 DAP	120 DAP	180 DAP
C+ NP 100% + *Azospirillum* + AMF	81.68	140.47	165.84	0.78	0.78	3.23	5.23	11.23	16.98
C + NP 75% + *Azospirillum* + AMF	90.27	137.07	171.52	1.16	1.16	2.75	4.96	11.78	17.40
C + NP 50% + *Azospirillum* + AMF	77.09	132.65	160.32	0.68	0.68	2.46	4.84	11.33	16.93
VC + NP 100% + *Azospirillum* + AMF	85.42	137.77	169.63	1.32	1.32	2.87	4.48	11.64	17.57
VC + NP 75% + *Azospirillum* + AMF	78.33	136.10	166.53	0.74	0.74	3.42	5.48	12.43	18.49
VC + NP 50% + *Azospirilllum* + AMF	75.66	131.45	164.16	0.72	0.72	2.48	5.16	11.27	17.13
C + NP 100%	89.55	140.24	160.44	0.82	0.82	2.60	5.24	11.34	16.40
C + NP 75%	83.33	137.64	168.44	0.58	0.58	2.76	4.98	11.23	16.03
C + NP 50%	84.62	130.00	163.83	0.33	0.33	2.28	5.24	10.92	15.92
VC + NP 100%	91.12	138.89	166.51	1.16	1.16	2.36	4.62	11.42	16.68
VC + NP 75%	87.76	133.45	157.58	0.72	0.72	1.94	5.12	11.02	16.75
VC + NP 50%	83.34	123.65	155.55	0.53	0.53	2.15	4.76	10.57	15.68
Recommended NPK (inorganic)	82.47	130.36	150.63	0.66	0.66	2.42	4.34	11.10	15.62
SEm (±)	**1.63**	**1.93**	**2.15**	**0.21**	**0.21**	**0.12**	**0.26**	**0.11**	**0.14**
LSD (0.05)	**4.65**	**5.49**	**6.10**	**NS**	**NS**	**0.34**	**NS**	**0.32**	**0.38**

Note: C= compost; N=Nitrogen; P= Phosphate;VC= vermicompost; AMF = Arbuscular mycorrhizal fungi; NS= Non significant

Table 2: Influence of organic and inorganic nutrition on root characters, clump weight, yield and quality of turmeric

Treatments	Weight of clump (g)	Root characters			Yield per plot (kg3.0m-^{2})	Projected yield (t ha^{-1})	Dry recovery (%)	Curcumin (%)	Oleoresin (%)
		Number clump^{-1}	Weight (g)	Length (cm)					
C + NP 100% + *Azospirillum* + AMF	345.20	24.17	12.81	15.58	12.33	30.82	23.28	6.69	11.30
C + NP 75% + *Azospirillum* + AMF	368.76	30.67	11.75	13.08	13.47	33.68	22.76	6.62	10.43
C + NP 50% + *Azospirillum* + AMF	264.23	25.17	10.31	14.24	9.34	23.35	21.92	6.06	10.22
VC + NP 100% + *Azospirillum* + AMF	358.71	25.92	13.29	13.79	13.08	32.71	22.84	6.11	11.31
VC + NP 75% + *Azospirillum* + AMF	378.38	28.67	15.82	13.37	13.94	34.85	23.45	6.19	11.26
VC + NP 50% + *Azospirilllum* + AMF	276.91	20.83	8.38	11.67	10.54	26.35	22.46	5.89	10.62
C+ NP 100%	317.38	26.58	11.93	13.87	11.37	28.43	21.84	6.07	10.24
C+ NP 75%	273.90	19.42	9.90	13.78	10.26	25.66	21.37	5.92	10.16
C + NP 50%	242.35	16.00	8.93	11.42	8.68	21.70	20.28	5.59	9.82
VC + NP 100%	324.82	26.52	11.25	14.50	11.75	29.38	22.16	6.55	10.84
VC + NP 75%	292.63	22.41	10.05	12.46	10.96	27.41	21.64	6.37	10.29
VC + NP 50%	248.65	22.25	10.02	11.23	9.13	22.83	20.43	5.89	10.35
Recommended NPK (inorganic)	296.52	17.58	8.65	12.64	11.05	27.63	20.67	5.39	9.92
SEm (±)	**5.22**	**1.86**	**1.49**	**0.61**	**0.48**	**0.95**	**0.47**	**0.13**	**0.15**
LSD (0.05)	**14.83**	**5.30**	**4.24**	**1.73**	**1.36**	**2.69**	**1.32**	**0.36**	**0.41**

Table 3: Influence of organic and inorganic nutrition on root colonization and total bacterial population in soil of turmeric

Treatments	Per cent root infection				Total bacteria (× 10^6 CFU g^{-1} of soil)			
	60 DAP	120 DAP	180 DAP	After harvest	60 DAP	120 DAP	180 DAP	After harvest
Compost + NP 100% + *Azospirillum* + AMF	24.39	44.39	66.56	70.89	71.51	80.87	76.57	73.36
Compost + NP 75% + *Azospirillum* + AMF	19.44	39.26	55.00	61.26	76.35	98.36	87.71	83.13
Compost + NP 50% + *Azospirillum* + AMF	16.72	34.95	61.84	64.52	67.05	81.28	73.78	65.66
Vermicompost + NP 100% + *Azospirillum* + AMF	21.81	47.78	69.23	73.00	87.44	107.76	99.66	83.85
Vermicompost + NP 75% + *Azospirillum* + AMF	29.10	55.24	73.50	79.68	92.58	118.67	106.03	97.41
Vermicompost + NP 50% + *Azospirilllum* + AMF	21.15	43.00	64.33	66.48	86.10	101.67	97.75	90.00
Compost + NP 100%	-	-	-	-	-	-	-	-
Compost + NP 75%	-	-	-	-	-	-	-	-
Compost + NP 50%	-	-	-	-	-	-	-	-
Vermicompost + NP 100%	-	-	-	-	-	-	-	-
Vermicompost + NP 75%	-	-	-	-	-	-	-	-
Vermicompost + NP 50%	-	-	-	-	-	-	-	-
Recommended NPK (inorganic)	-	-	-	-	-	-	-	-
SEm (±)	**0.83**	**1.27**	**2.39**	**2.66**	**3.50**	**5.80**	**5.15**	**1.11**
LSD (0.05)	**2.06**	**3.16**	**5.94**	**6.60**	**12.72**	**14.40**	**12.79**	**2.75**

Note: AMF = Arbuscular mycorrhizal fungi; Initial population of total bacteria: 43.72×10^6 CFU g^{-1} of soil

with the findings of Nirmalatha (2009) and Shamrao *et al.* (2013). The above ground plant growth responses to biofertilizer like in the present investigation have been reported by Patil and Kundel (1988) and Balashanmugan (1994) in turmeric.

The maximum number of roots of 30.67 was noticed in compost + NP (75%) + *Azospirillum* + AMF (Table 2). The least root number (17.58) was associated with recommended NPK (inorganic). The weight of root was found maximum (15.82 g) in the treatment combination of vermicompost + NP (75%) + *Azospirillum* + AMF. The minimum weight of roots was observed in the treatment combination of vermicompost + NP (50%) + *Azospirillum* + AMF (8.38 g). The maximum length of 15.58 cm was observed with the treatment combination of compost + NP (100%) + *Azospirillum* + AMF and the minimum in vermicompost + NP (50%) [11.23 cm].

Yield parameters

The treatment combination of vermicompost + NP (75%) + *Azospirillum* + AMF was found superior for production of highest clump weight (378.38 g) as compared to lowest clump weight of 242.35 g with compost + NP @ 50% (Table 2). The highest yield (34.85 t ha^{-1}) was recorded with vermicompost + NP (75%) + *Azospirillum* + AMF .The lowest yield (21.70 t ha^{-1}) was observed in treatment combination compost + NP (50%). The plants grown under recommended NPK (inorganic) exhibited the projected yield of 27.63 t ha^{-1} only, indicating the favourable effect of bio-inoculants and organic manures in enhancing the production of turmeric over recommended dose of fertilizer.

Quality parameters

As per data (Table 2), maximum dry recovery (23.45%) was noticed in treatment combination of vermicompost + NP (75%) + *Azospirllum*+ AMF as compared to lowest dry recovery (20.28%) under compost + NP (50%). Maximum curcumin content (6.69%) was recorded with compost + NP (100%) + *Azospirillum* + AMF as compared to lowest curcumin content (5.39%) in recommended NPK. The plants raised under treatment combination vermicompost + NP (100%) + *Azospirillum* + AMF followed by compost + NP (100%) + *Azospirillum* + AMF (11.31%, 11.30% respectively) recorded highest oleoresin content as compared to lowest (9.92%) under recommended NPK (inorganic).

The findings in respect to the quality parameters are also in good agreement with Velmurugan *et al.* (2008) who recorded higher content of curcumin and oleoresin under the application of FYM + *Azospirillum* +

Phosphobacteria. Mohan *et al*. (2004) recorded a linear response of growth, yield and quality of turmeric with inoculation of *Azospirillum* in combination with N levels compared to that of *Azotobacter* under Karnataka condition. Gill *et al.* (1999) observed significant increase in rhizome yield and curcumin content with increased FYM (upto 60 t ha^{-1}) and wheat straw mulch level. The quality parameters of turmeric are found to be high under organic farming (IISR, 2005). The beneficial effect of biofertilizer treatment on rhizome quality might be due to better nourishment of the crop by increasing nutrient availability in the root zone through greater microbial activities (Bijaya and Ado, 2005).

Root colonisation and total bacterial poulation

At 60 DAP, maximum root infection (29.10%) was noticed in vermicompost + NP (75%) + *Azospirillum* + AMF (Table 3). At 120, 180 and at harvest maximum root colonization was noticed in vermicompost + NP (75%) + *Azospirillum* + AMF (55.24%, 73.50% and 79.68%). The lowest root colonization at harvest was observed with compost + NP (75%) + *Azospirillum* + AMF (61.26%). Navale *et al*. (2004) observed that combined inoculation of *Glomus mosacea* + *Azospirillum lipoferum* recorded the maximum root colonization than individual inoculation. The present findings colloborate with earlier workers such as Kumar and Bagyaraj (1988) who shown that application of compost stimulated VAM colonization. It is logical to believe that increased microbial activity through the action of *Azospirillum* + AMF + compost or vermicompost might have supplied micronutrients and growth promoting substances and enzymes ultimately helped in the proliferation of VAM fungi and thus resulted in higher root colonization. The results were in conformity with earlier workers who reported that inoculated VAM fungi increased mycorrhizal colonization (Kalavathi *et al*., 2000).

There was an increasing trend regarding total bacterial population with ages upto 180 DAP and thereafter decreased, irrespective of the treatment combinations. This has probably been occurred due to depletion of organic matter during later stage of growth. At 60 DAP, maximum population (92.58 × 10^6 CFU g^{-1} of soil) was recorded with vermicompost + NP (75%) + *Azospirillum* + AMF as compared to lowest population (67.05 × 10^6 CFU g^{-1} of soil) with compost + NP (50%) + *Azospirillum* + AMF. The plants under vermicompost + NP (75%) + *Azospirillum* + AMF recorded maximum population at 120 DAP (118.67 × 106 CFU g^{-1} of soil), 180 DAP (106.03 × 106 CFU g^{-1} of soil) and after harvest (97.41 × 106 CFU g^{-1} of soil). Inoculation of beneficial micro-organism enhanced efficiency of native population of AMF which increased the root colonization in the rhizosphere.

The bio-organic combination performed better over recommended dose of fertilizers. Among different treatments, maximum number of tillers, leaf number, clump weight and projected yield was noticed in vermicompost + NP (75%) + *Azospirillum* + AMF (Chanchan *et al*., 2017).

The next best treatment was compost + NP (75%) + *Azospirillum* + AMF (33.68 t ha^{-1}) followed by vermicompost + NP (100%) + *Azospirillum* + AMF (32.71 t ha^{-1}). Application of recommended dose of inorganic NPK (100%) only recorded yield of 27.63 t ha^{-1} which is higher than the treatment combination of compost or vermicompost at 75% (NP) and 50% (NP) levels and compost/vermicompost + *Azospirillum* + AMF at NP (50%) but lower than compost or vermicompost + *Azospirillum* + AMF at NP (100%) or NP (75%) level which clearly indicates the favourable effect of compost/vermicompost and bio-inoculants over recommended dose of inorganic fertilizer and also there is a chance of reduction of inorganic nitrogen and phosphorus by 25 per cent. Kale *et al*. (1992) observed that vermicompost application enhanced the activity of beneficial microbes. Thus the increased availability of nutrients and uptake by the plants would have resulted in better growth and yield in plots treated with vermicompost. The improvement in growth and yield due to application of bio-inoculants incombination of organic manure has been reported by Mohan *et al.* (2004) in turmeric. The role of biofertilizers like *Azospirillum* and VAM in enhancing the availability of nitrogen and phosphorus has been well established by several workers (Selvarajan and Chezhiyan, 2001; Subramaniam *et al*., 2003; Reddy *et al*., 2003 and Mohan *et al*., 2004). The microorganism can build up organic matter of the soil which can increase the availability of other nutrients (Parthasarathy *et al.*, 2007) and synthesis of growth promoting substances like IAA and GA_3 (Jeon *et al.*, 2003).

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