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Effect of Zn enriched organic manures and zinc solubilizer application on the yield, curcumin content and nutrient status of soil under turmeric cultivation

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Abstract

A field experiment was conducted to study the effect of Zn enriched organic manures and Zn solubilizers on the yield, curcumin content of turmeric and nutrient status of the soil. The treatment with FYM + zinc solubilizing bacteria showed higher turmeric rhizome yield increase of 21.6 per cent than the FYM alone treatment (9.1 per cent) than no manure (control). The dry rhizome yield, reflected the promising effect of Zn and Fe enriched coirpith or FYM, and Zn enriched coirpith or FYM at M_1 (no manure) while at M_2 (NPK + FYM) and M_3 (NPK + FYM + Zn solubilizing bacteria), the foliar spray of Zn + Fe + MOP excelled the remaining treatments. Incorporation of farmyard manure at 12.5 t ha^{-1} along with Zn solubilizing bacteria stood superior by registering highest values for available of N, P and K content in the soil. The Zn solubilizing organism (*Bacillus* sp.) identified interestingly proved to have favorable effect on the availability of N, P and K. The effect of micronutrient treatments comprising of soil application of *per se* $ZnSO_4$, $FeSO_4$ and fortified FYM with Zn and Fe and foliar spray of these two nutrients resulted in synergistic effect on the enhanced availability of not only micronutrients but also K. The DTPA - Zn content of the soil though evidenced significant variation for the different treatments of FYM, FYM + ZSB (Zn solubilising bacteria) and micronutrients on an overall basis did not exceed the deficiency level. Addition of Fe with Zn either as such or fortified with FYM / with coirpith showed synergistic effect on Zn availability in the soil. The available B content of the soil showed an upheaval trend for manuring and Zn and Fe applications. During different stages of crop growth and at harvest stage, DTPA – Fe content in none of the treatments exceeded the threshold level. However, enhancement for treatments with organic manures and micronutrients were statistically perceptible. The availability of Cu and Mn in the soil, brought out the positive effect of Zn and Fe added as such or as fortified either alone or along with FYM and FYM + ZSB. Both content as well as uptake of all the major nutrients in the turmeric plant right from the early phase of crop growth to harvest were positively altered by FYM, FYM + ZSB and soil and foliar application of Zn and Fe.

Key words: Zn enriched manure, Zn solubilizers, yield, curcumin content, soil nutrients, turmeric

Introduction

Zinc deficiency has been reported to be the most widespread micro-nutritional disorder of the food crops in India as well as the world over. Though marked response of crops to Zn application has been noticed, Zn deficiency is a major nutritional constraint for successful crop production in Tamil Nadu (Ramadass *et al.*, 1995). The available Zn content of Indian soils varied from traces to 22 mg kg^{-1} (Nagarajan *et al.*, 1981; Katyal and Sharma, 1991) and 47 per cent of Indian soils were found to be deficient in Zn (Katyal and Sharma, 1991). The application of Zn enriched organics improved the soil nutrient status, availability and crop yield (Deverajan, 1987; Gupta, 1988; Singh and Rakipov, 1990; Thennarasu, 1994) Substantial buildup of available Zn in soil has been observed with the use of organic manures and residual effect of Zn application.

Materials and Methods

Field experiments on turmeric were conducted at the Poongar Block of Agricultural Research Station farm, Bhavanisagar. The field is situated at 11°29'North latitude and 77°08' longitude at an elevation of 256 m above mean sea level. The experiment was conducted in a split plot design with three replications. The crop was planted in June and harvested in April with duration of 290 days.

The field lay out and the randomization of treatments were carried out as per the statistical methods given by Panse and Sukhatme (1967). The treatment details are furnished hereunder. In the Main plots: M_0 - NPK control, M_1 - NPK + FYM and M_2 - NPK + FYM + Zn solubilizer and the sub plots were F_1 – Control, F_2 - $ZnSO_4$ @ 50 kg ha^{-1}, F_3 - $ZnSO_4$ enriched FYM (1 t FYM ha^{-1}), F_4 - $ZnSO_4$ @ 50 kg ha^{-1} + $FeSO_4$ @ 100 kg ha^{-1}, F_5 - $ZnSO_4$+ $FeSO_4$ enriched FYM (1 t ha^{-1}), F_6 - 0.5 % $ZnSO_4$ + 1.0% $FeSO_4$ foliar spray, F_7 - Multimicronutrient spray (1% DAP + 1% MOP + 0.5% $ZnSO_4$ + 1% $FeSO_4$) foliar spray, F_8 - $ZnSO_4$ enriched coir pith (1 t ha^{-1}) and F_9 - $ZnSO_4$+ $FeSO$-$_4$ enriched coirpith (1 t ha^{-1}). Where $ZnSO_4$ was applied @ 50 kg ha^{-1} and $FeSO_4$ @ 100 kg ha^{-1} for soil application and foliar application of micronutrients were done at 4th, 5th and 6th month after planting. The foliar spray was done at 90th, 120th and 150th days after planting. At maturity rhizomes were harvested in 296 days after planting with the help of spade and then clumps were separated carefully. Fresh harvested rhizome were cleaned, weighed and used for recording data. Dry weight of the plant parts was recorded. Soil samples were collected at

90^{th} (St_1), 120^{th} (St_2), 150^{th} (St_3) day after sowing and at harvest (St_4). Several random samples were collected from each plot, mixed and representative samples were drawn. The collected samples were dried in shade, gently powdered with a wooden mallot and sieved through 2 mm sieve and analyzed for pH (1:2 soil: water), EC, organic carbon, free $CaCO_3$, available N, P and K, exchangeable Ca, Mg and Na, available S, hot water soluble B, DTPA extractable Zn, Cu, Fe and Mn. Turmeric leaf samples were collected on 90^{th}, 120^{th}, 150^{th} day after sowing and at harvest and dry matter determination was made before the lower leaves were lost at 140 days after planting as suggested by Pal *et al.*(1993). The mature rhizome samples were collected at the time of harvest (280^{th} day after planting).

Results and discussion

Dry matter yield and curcumin content: Among the manurial treatments, M_3 recorded the highest leaf dry matter (760 kg ha^{-1}) than M_2 (713 kg ha^{-1}) and M_1 (639 kg ha^{-1}) (Table 1). In the case of micronutrient treatments the highest leaf dry matter production was observed in F_6 (781 kg ha^{-1}) and was significantly superior to all other treatments and the control (551 kg ha^{-1}). The leaf dry matter yield increased from St_1 (284 kg ha^{-1}) to St_3 (1056 kg ha^{-1}) and later decreased during the harvest stage (712 kg ha^{-1}). Among the manure and treatment interactions, at M_1, F_5 and F_9 recorded the highest values than all other treatments and were on par with each other, whereas in M_2 and M_3, the foliar spray treatment (F_6) stood apart and was significantly superior to all other treatments and control. In the case of stages and treatments interaction, Zn + Fe enriched coirpith was found to be superior in St_1 and harvest stage whereas in St_2 and St_3, F_6 (foliar spray of Zn and Fe) recorded higher leaf dry matter production.

For stem dry matter yield, the main effect of manure, treatments and stages and the interaction effect of stages with treatments followed similar trend as those of the leaves dry matter yield (Table 1). Among the treatments and manure interaction, at F_7 and F_9, M_3 and M_2 remained comparable among them, but for all other treatments M_3 was found to be superior to M_2 and M_1.

In rhizome dry matter yield, among the manurial treatments M_3 (2430 kg ha^{-1}) recorded the highest value than M_2 (2183 kg ha^{-1}) and M_1 (1844 kg ha^{-1}). In the case of treatments, F_7 (2544 kg ha^{-1}) was found to be significantly higher than all other treatments and control (1338 kg ha^{-1}). The rhizomes dry matter yield increased with the advancement in growth from St_1 (308 kg ha^{-1}) to St_4 (5924 kg ha^{-1}). Among the interaction of treatments with manures at F_1, M_2 and M_3 remained comparable. At M_1, F_9 recorded the highest rhizome dry matter yield, whereas at M_2 and M_3, F_7 was found to be significantly superior to all other treatments. In the interaction of stages and treatments, at St_1 all the micronutrient treatments were comparable among themselves but superior to control whereas at remaining stages, F_7 was found to be superior to all other treatments.

The total dry matter yield of turmeric revealed similar trend of rhizome dry matter yield in the case of manure, stages and treatment effects, whereas in the case of interaction of manures with treatments, except F_5, in which M_2 and M_1 remained comparable with all other treatments exhibited the similar trend of the main effect of the manures. In case of stages and treatments interaction, Zn + Fe enriched coirpith (F_9) was found to be superior in St_1 and harvest stage but remained comparable with F_6, F_8, F_5 and F_1 at St_1 and with F_7 at harvest, whereas in St_2 and St_3, F_7 (foliar spray of Zn and Fe along with MOP and urea) recorded higher total dry matter yield. The curcumin content was highest with M_3 (4.53 %) and superior to M_2 and M_1 whereas M_2 (4.41 %) remained on par with no manure control (4.38 %). Among the micronutrient treatments, F_9 recorded the highest curcumin content of 4.76 %, which was superior to all other treatments and the control (3.77 %). The increase in the yield of leaf, stem and rhizome and whole plant dry matter and curcumin content of turmeric on FYM + ZSB and FYM addition alone as well as with Zn and Fe might be due to the enhanced supply of nutrient favoured by complexation and chelation reaction resulting in increase of availability of native soil nutrients, besides the applied Zn and Fe. This can be confirmed by the significant positive correlation seen between yield and hot water - B (0.73** at St_1, 0.67** at St_2, 0.70** at St_3, 0.64** at harvest), DTPA - Zn (0.80** at St_1, 0.78** at St_2, 0.85** at St_3, 0.68** at harvest). The treatment that received FYM + zinc solubilizing bacteria showed higher turmeric rhizome yield with increase of 21.6 % than the FYM alone treatment (9.1 %) than no manure control. The marked effect of FYM + ZSB on turmeric rhizome yield might have been attributed to the direct role played by zinc solubilizer on enhancing the availability of not only Zn but also K to a greater extent and N, P and Fe to a certain extent which was reflected on the total uptake of nutrients at the maturity stage. The per cent increase in the total uptake of nutrients at harvest M_2 and M_3 over M_1 for N (27.2 and 40.5 %); P (43.8 and 53.8 %); K (33.5 and 53.5 %), Zn (23 and 56 %) and Fe (44.4 and 70.0 %) also tend to support for the above reasoning. Even here, one could readily refer the more influential nature of zinc solubilizer on Zn and Fe followed by K, N and P in the given sequence. This again suggests the involvement of this specific organism on the transformations of all nutrients apart from Zn for which further studies are warranted.

Rhizome yield: As regards the dry rhizome yield among the different treatments, the values associated for various combinations of M x F very clearly reflected the promising effect of Zn and Fe enriched coirpith or FYM, at M_1 (no manure) while at M_2 and M_3, the foliar spray Zn, + Fe + MOP excelled the remaining treatments (Table 1). From this trend it could be inferred that Zn / Fe fortified organic manures might be more effective on soil having low organic matter status or where bulky organic manure are not applied. This might be attributed to the potential effect of enriched coirpith in improving physical properties, microbial, physicochemical and properties of soil nutrient availability in the soil, which is consequently reflected on plant growth and yield. The better performance of foliar spray treatments as compared to soil application could be ascribed to marginally higher pH (7.9) of the soil, which is found to be conducive for the formation of unavailable ionic compounds of Zn and Fe and particularly the later. The Zn and Fe application facilitated and accelerated the uptake of all the nutrients, thereby increasing the yield. It is confirmed by the significant positive correlations of yield with DTPA - Zn content in soil (0.80** at St_1, 0.78** at St_2, 0.85** at St_3 and 0.68** at harvest), leaves (0.69** at St_1, 0.84** at St_2, 0.84** at St_3 and 0.79** at harvest) and rhizomes (0.88** at St_1, 0.85** at St_2, 0.84** at St_3 and 0.80** at harvest) and also a significant positive relationship of

Table 1. Effect of Zn and Fe on the dry matter production of turmeric (kg ha^{-1})

Treatments	Leaves (kg ha^{-1})	Stem (kg ha^{-1})	Rhizome (kg ha^{-1})	Total DMP (kg ha^{-1})	Rhizome yield (t ha^{-1})	Increase over control	Curcumin content (%)
F_1	551	387	1338	2276	22.9	-	3.77
F_2	619	439	1999	3057	24.4	6.4	4.16
F_3	712	502	2166	3380	26.4	15.2	4.46
F_4	677	477	2037	3191	25.7	12.3	4.29
F_5	741	522	2230	3493	26.4	15.3	4.63
F_6	781	551	2321	3653	25.5	11.2	4.48
F_7	750	527	2544	3821	26.2	14.1	4.51
F_8	733	518	2257	3508	27.5	19.8	4.61
F_9	770	543	2478	3791	28.0	22.1	4.76
LSD(p=0.05)	10**	7**	47**	60**	1.3**	-	0.11**
M_1	639	451	1844	2932	23.5	-	4.04
M_2	714	504	2183	3401	25.6	9.1	4.38
M_3	760	535	2430	3724	28.6	21.6	4.53
LSD(p=0.05)	6**	4**	27**	35**	0.8**	-	0.06**
St_1	284	190	308	782	-	-	-
St_2	763	477	898	2138	-	-	-
St_3	1056	684	1478	3218	-	-	-
St_4	712	635	5924	7271	-	-	-
LSD(p=0.05)	7**	5**	32**	40**	-	-	-
F x M	17**	12**	82**	104**	NS		NS
F x St	20**	14**	95**	120**	-	-	-
M x St	12**	8**	55**	69**	-	-	-
F x M x St	NS	NS	NS	NS	-	-	-

Table 2. Soil characteristics of turmeric experimental field

Particulars	Location Bhavanisagar
Mechanical Analysis	
Clay (per cent)	29.7
Silt (per cent)	7.2
Sand (per cent)	63.1
Moisture (per cent)	5.18
Textural class	Sandy clay loam
Physico-Chemical properties	
pH (1:2 soil :water)	7.9
E.C. (dS m^{-1})	0.41
Free $CaCO_3$ (per cent)	2.0
Chemical Analysis	
Organic carbon (per cent)	0.44
CEC (me 100 g^{-1})	14.2
Total Zn (mg kg^{-1})	70
Total Cu (mg kg^{-1})	11
Total Fe (mg kg^{-1})	38000
Total Mn (mg kg^{-1})	82
$KMnO_4$ - N (kg ha^{-1})	253
Olsen - P (kg ha^{-1})	15.3
NH_4OAc - K (kg ha^{-1})	255
NH_4OAc - Ca (mg kg^{-1})	444
NH_4OAc - Mg (mg kg^{-1})	131
NH_4OAc - Na (mg kg^{-1})	88.3
$CaCl_2$ - S (mg kg^{-1})	14.2
Hot water - B (mg kg^{-1})	0.50
DTPA - Zn (mg kg^{-1})	0.91
DTPA - Cu (mg kg^{-1})	2.63
DTPA - Fe (mg kg^{-1})	6.2
DTPA - Mn (mg kg^{-1})	5.9

Table 3. Effect of zinc and iron on the soil nutrient status of turmeric

	N	P	K	B	Zn	Cu	Fe	Mn
	(kg ha^{-1})			(mg kg^{-1})				
F_1	246	14.7	243	0.48	0.894	2.44	5.25	6.43
F_2	259	15.5	260	0.49	0.964	2.50	5.39	6.60
F_3	277	16.8	268	0.52	0.909	2.69	4.84	7.09
F_4	268	15.8	261	0.50	0.970	2.53	5.47	6.70
F_5	279	16.6	272	0.53	0.893	2.70	5.02	7.14
F_6	263	15.6	260	0.49	0.905	2.49	5.37	6.58
F_7	263	15.8	265	0.49	0.931	2.52	5.46	6.68
F_8	270	16.3	270	0.51	0.948	2.60	4.69	6.87
F_9	275	16.5	273	0.51	0.905	2.64	4.76	7.00
LSD (5%)	5.5**	0.30**	4.94**	0.010**	0.042**	0.059**	0.10**	0.133**
M_1	250	13.9	246.8	0.466	0.78	2.38	5.35	5.83
M_2	272	17.1	264.8	0.509	0.94	2.60	4.84	7.07
M_3	277	16.8	279.0	0.529	1.06	2.72	5.23	7.46
LSD (5%)	3.16**	0.18**	2.85**	0.006**	0.024**	0.034**	0.06**	0.077**
St_1	316	17.9	296	0.595	1.102	3.05	6.1	8.08
St_2	274	16.3	278	0.527	0.972	2.70	5.4	7.14
St_3	253	15.2	257	0.458	0.843	2.34	4.7	6.20
St_4	223	14.4	222	0.423	0.78	2.17	4.3	5.73
LSD (5%)	3.7**	0.20**	3.29**	0.006**	0.028**	0.039**	0.07**	0.089**
F x M	NS	NS	NS	NS	NS	NS	0.17**	NS
F x St	11.0**	NS	9.88*	NS	NS	NS	NS	NS
M x St	NS	NS	NS	NS	NS	NS	NS	0.15**
F x M x St	NS	NS	NS	NS	NS	NS	NS	NS

yield with Fe content in leaves (0.71** at St_1, 0.36** at St_2 and 0.31* at St_3) and rhizomes (0.39* at St_1, 0.31* at St_2, 0.31* at St_3 and 0.31* at harvest). The application of manures significantly increased yield of fresh rhizomes from 23.5 (M_1) to 28.6 t ha^{-1} (M_3) with the tune of increase of 21.7 per cent over the control (Table 1). Among the treatments, F_9 (30.8 t ha^{-1}) recorded the highest rhizome yield and was comparable with F_8. All the micronutrient treatments were significantly superior to the control (22.9 t ha^{-1}). The interaction M x F was non significant.

Characteristics of initial soils: The initial soil sample collected from the field experiment was assessed for the physico-chemical properties. Mechanical analysis of the soil revealed that the soil is an Alfisol (*Typic Hapustalf*) with sandy clay loam texture consisting of 63.1 % sand fractions and 36.9 % of finer fractions (Clay + Silt) (Table 2). The soil was alkaline in reaction (pH 7.9) and EC 0.41 dSm^{-1}. The available N, P and K status was low, medium and medium, respectively. Among the micronutrients, DTPA- Zn recorded deficient status of 0.91 mg kg^{-1} and marginally deficient in DTPA – Fe status.

Nutrient status of soil

Major nutrients: The availability of all the three major nutrients has conspicuously improved for the different treatments (Table 3). Incorporation of farmyard manure @12.5 t ha^{-1} along with Zn solubilizing bacteria stood superior to FYM alone and control treatment by registering the highest values for availability of N, P and K content in the soil. As compared to control, *per se* addition of FYM also exerted positive effect on the major nutrients availability, which was quite natural since it has been well established that bulky organic manures play a vital role in improving the major nutrient availability by direct contribution as well as indirectly by influencing chemical transformation reactions and microbial activity. The Zn solubilizing organism (*Bacillus* sp.) proved to have a favourable effect on the availability of N, P and K, thereby indicating the vital role of these organisms in the transformation reaction of these three nutrients in the soil. Although the interaction of FYM and FYM + Zn solubilizer with micronutrient did not have significant effect on the major nutrient availability, the effect of micronutrient treatments comprising of enriched soil application of *per se* $ZnSO_4$, $FeSO_4$ and fortified FYM / coirpith with Zn and Fe and foliar spray of these two nutrients resulted in synergistic effect. Optimal level of Zn (50 kg $ZnSO_4$ ha^{-1}) and Fe (100 kg $FeSO_4$ ha^{-1}) led to enhanced availability of not only micronutrients but also K. The indirect effect of increasing the availability of major nutrients by the addition of micronutrient fertilizer derives support from the significant positive relationship of $KMnO_4$ - N with DTPA – Zn (0.83** at 90 DAS, 0.79** at 120 DAS, 0.84** at 150 DAS and 0.81** at harvest).

The existence of mutual synergistic influence of Zn on Olsen – P was very well reflected by the relationship with DTPA – Zn (0.76** at 90 DAS, 0.74** at 120 DAS, 0.81** at 150 DAS and 077** at harvest). The negative correlation were obtained between DTPA – Fe content and Olsen – P (-0.69** at 90 DAS, -0.61** at 120 DAS, -0.53** at 150 DAS and –0.70** at harvest) and NH_4OAc – K (-0.53** at 90 DAS, -0.52** at 120 DAS, -0.46 at 150 DAS and –0.40** at harvest) content of the soil invariably at all the stages of crop growth inspite of the presence of optimal level of DTPA – Fe in the soil (3.8 to 6.85 mg kg^{-1}). It is to be recalled here, that inspite of the negative correlations between DTPA – Fe and Olsen – P and NH_4OAc – K content of the soil, invariably at all stages of crop growth NH_4OAc – K and Olsen - P for the Zn + Fe treatments, were significantly higher than control.

The application of Zn increased the content of available K which can derive support from the significant positive correlation that existed between NH_4OAc – K and DTPA – Zn (0.82** at 90 DAS, 0.86** at 120 DAS, 0.86** at 150 DAS and 0.81** at harvest).

Micronutrients: The DTPA - Zn content of the soil though evidenced significant variation for the application of FYM, FYM + ZSB, Zn + Fe on an overall basis the actual values did not exceed the deficiency level (Table 3). However at 90 DAS and 120 DAS the treatments receiving $ZnSO_4$ as such and also as Zn fortified FYM / coirpith reached the level of sufficiency. This trend is in consonance with the findings of Anand Swarup (1991) in field crops. The perusal of data pertaining to the total uptake of Zn by turmeric showed nearly 64 and 114 % increase for treatments with organic manures and Zn alone and Zn + Fe, respectively. This enhanced uptake might be the probable cause for keeping the DTPA –Zn in the deficiency level at advanced growth stages and maturity phase (Singh, 1988). Similar reasons can also be attributed for the on par performance of Zn and Zn + Fe enriched FYM / coirpith and *per se* addition of $ZnSO_4$ treatments, as the total uptake of Zn was significantly higher for the former than the later treatment. The reports available on the positive effect of Zn fertilization and Zn enriched FYM (Thennarasu, 1994 and Biju Joseph, 1998) and coirpith (Selvi and Augustine Selvaseelan, 1991) on Zn availability, add support to the above. Moreover, addition of Fe with Zn either as such or fortified FYM / coirpith showed synergistic effect on Zn availability in the soil.

The hot water B content of the soil showed upheaval trend for manuring as that of N and K. The Zn and Fe application increased the available B content in the soil. The significant positive correlation coefficient obtained between hot water – B and DTPA Zn (0.82** at 90 DAS, 0.75** at 120 DAS, 0.79** at 150 DAS and 0.80** at harvest) also confirmed the positive effect of Zn on B.

Based on the DTPA – Fe content of the initial soil, the field can be categorized as Fe deficient soil as the critical value proposed for DTPA – Fe for calcareous soils is < 6.4 mg kg^{-1} (Savithri *et al.,* 1996). During different stages of crop growth and harvest, DTPA – Fe content in none of the treatments exceeded the threshold level. However, differences are critical for treatments with organic manures and micronutrients are statistically perceptible. The significantly lower values associated with FYM and FYM + ZSB as compared to check could be attributed to enhanced uptake of Fe by turmeric rather than any other complex formation reactions. Treatments receiving 100 kg $FeSO_4$ ha^{-1} with 12.5 t FYM ha^{-1} and as Zn + Fe fortified FYM / coirpith at 1 t ha^{-1} failed to bring out any conspicuous increase in the DTPA – Fe content in the soil. This might probably be due to the formation of hydroxyoxides of Fe in the soil for which the higher pH (7.9) and arable conditions created during cultivation of turmeric are conducive.

With regard to the availability of Cu and Mn in the soil, the trend of results very clearly brought out the positive effect of Zn and Fe added as such or as fortified either alone or along with FYM and FYM + ZSB. Here too as that of P and K, the incidental effect of Zn solubilizing bacteria on increasing Cu and Mn availability was indicated as M_3 was associated with the highest value for DTPA – Cu and Mn content as compared to M_2 and M_1. As mentioned above the total uptake of Cu and Mn by the crop was also markedly higher for FYM, FYM + ZSB and micronutrient treatments.

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