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Influence of Slow Release Fertilizers on Soil Nutrient Availability Under Turmeric (*Curcuma longa* L.)

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Abstract: The present investigation was carried out to study the influence of multi-nutrients (NPK) slow release fertilizers on the soil fertility status of turmeric at different growth status. Slow release NPK fertilizers are newly formulated and in the form of tablets, mixtures and coated which contains all the three major nutrients in them. These five slow release NPK fertilizer sources were tested in comparison with straight fertilizers at three NPK levels (75, 100 and 125% of recommended dose) in a randomized block design. The results of the present study clearly establish that the wet rhizome yield increased significantly up to 125% of NPK level applied and when applied in the form of tablets. Soil available major nutrients tested at 90 Days After Sowing (DAS), 180 DAS and at harvest stage of crop significantly increased with increasing levels of NPK and when applied in the form of tablets. The nutrient availability in soil, which is estimated as various availability indices are useful in comparing the efficacy of different fertilizer sources in maintaining an available pool of nutrients in soil during various stages of crop growth.

Key words: Nutrient tablets, fertilizer placement, slow release fertilizers

INTRODUCTION

Nutrient availability in the soil-plant system is dictated by complex interactions between plant roots, soil microorganisms, chemical reactions and pathways of losses. The concentration dependents of most of the processes is influenced by transformations induced by microbes (N_2 fixation, nitrification, denitrification and immobilization), chemical reactions (exchange, fixation, precipitation and hydrolysis) and physical processes (leaching, runoff and volatilization). The extent by which the added nutrients removed from soil solution by these processes, which compete with plant uptake, can thus affect both nutrient use efficiency and the environment.

The use efficiency of applied nutrients enhanced if soil fertility levels maintained to match with crops' demand and in proper proportions. In order to sustain the production system, it is essential that the nutrient demand of a crop to produce a target yield and the amount removed from the soil be perfectly matched.

Most of the organic-N based fertilizers are considered to be mainly slow releasing, involving many factors affecting their release. Urea formaldehyde, for example, releases available nitrogen as a result of the degradation of oligometric chains. The release depends strongly on chain length, soil properties (biological activity, clay content and pH) and external conditions such as soil moisture, wetting and drying and temperature. Release curve of these fertilizers are typically characterized by a too-high initial release (burst) and a too-slow release of about the last quarter to third of the nitrogen (tailing effect) (Shaviv, 1999). This pattern of release significantly differs from the sigmoidal form of nutrient uptake by plants (Raban *et al*., 1997).

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Gypsum coating on urea reduces the ammonia volatilization loss by about 40% as compared to uncoated prills and this continued use of gypsum coated urea can supplement the soil with sulphur (Jayalakshmi, 1989). Urea coated with 0.5, 1.0 and 2.0 ppm concentrations of neem extract was mineralized in 2, 6 and 8 weeks of incubation, respectively (Khandelwal *et al*., 1977).

Using mixtures of Mono-Ammonium Phosphate (MAP) and Triple Super Phosphate (TSP) as P sources with urea combinations could reduce urea-TSP reactions and improve fertilizer physical properties without significantly reducing the effect of added P on NH_3 volatilization (Fan *et al*., 1996).

Intensively grown cash crops with high yields consume large amounts of nutrients. Turmeric, an important commercial as well as spice crop, grown mainly for curcumin (a chemical principal which has medicinal and cosmetic value) occupies about 1.6 lakh ha with a production of 6.54 lakh ton and sharing 15.06% of total spices export of the country. Turmeric being a long duration and high yielding crop, it consumes greater amount of nutrients from the soil as well as from applied fertilizers for a prolonged period.

Though, earlier studies review the types of slow release fertilizers and its effect on various crops and soil, fertilization effects on turmeric yield and soil nutrient status has not been studied. For such high fertilizer responsive turmeric slow release fertilizers will be of immense use in increasing the yield and quality. With these background knowledge, the study was carried out to evaluate the effect of multi-nutrient slow release fertilizers on turmeric yield and soil nutrient status.

MATERIALS AND METHODS

Field experiment was conducted in a farmer's field near Coimbatore, South India on a sandy clay loam soil (fine mixed calcareous isohyperthermic Udic Haplustalf) with turmeric (cv. Erode local) as test crop during 2002 to 2003. Physical and chemical properties of representative sample of surface (0-15 cm) soil collected from the experimental field before the start of the experiment are presented in Table 1.

The Slow Release (SR) NPK sources which were tested for their efficacy in the present study are tablet 1 (contains urea formaldehyde, ammonium sulphate, amophos, rock phosphate, muriate of

Table 1: Physical and chemical properties of soil of field experiment

Properties	Content
Coarse sand (%) (0.2 to 2.0 mm)	18.80
Fine sand (%) (0.02 to 0.2 mm)	32.00
Silt (%) (0.002 to 0.02 mm)	16.27
Clay (%) (<0.002 mm)	32.40
Texture-Sandy clay loam	
pH (1:2.5 soil water suspension)	8.20
Electrical conductivity (1:2.5 soil water suspension) (dSm^{-1})	0.32
Cation exchange capacity (cmol (p^+) kg^{-1})	22.50
Organic carbon (g kg^{-1})	9.63
Total N (g kg^{-1})	0.28
Total P (g kg^{-1})	0.14
Total K (g kg^{-1})	9.80
Free $CaCO_3$ (g kg^{-1})	40.00
Available N (kg $KMnO_4$-N ha^{-1})	235.00
Available P (kg Olsen-P ha^{-1})	24.20
Available K (kg NH_4OAc-K ha^{-1})	384.00
Available S (mg $CaCl_2$-S kg^{-1})	11.50
Exchangeable-Ca (cmol (p^+) kg^{-1})	4.80
Exchangeable-Mg (cmol (p^+) kg^{-1})	2.30
DTPA-Fe (mg kg^{-1})	3.10
DTPA-Mn (mg kg^{-1})	4.92
DTPA-Zn (mg kg^{-1})	1.57
DTPA-Cu (mg kg^{-1})	3.40

potash and clay), tablet 2 (contains phosphogypsum-urea, ammonium sulphate, amophos, rock phosphate, muriate of potash, clay and gypsum), mixture 1 (mixture of contents of tablet 2), mixture 2 (mixture of contents of tablet 2 + neem cake), coated FAP (coated amophos, urea and muriate of potash). These five SR NPK sources were tested in comparison with urea, single super phosphate and muriate of potash (straight NPK fertilizers) and applied at three NPK levels (75, 100 and 125% of recommended dose, 150:60:108 kg N, P_2O_5 and K_2O ha^{-1}, respectively). Thus, there were totally eighteen treatments (six NPK sources each at three levels) which were replicated three times in a randomized block design. The experimental field was ploughed, leveled and divided into 54 plots of each 40 m^2 (8×5 m) size. Sowing of well matured, disease free turmeric rhizome (cv. Erode local, 10 months duration) was done by following a spacing of 45×5 cm.

The required quantity of N, P_2O_5 and K_2O as per the levels (75, 100 and 125% of recommended dose) for each plant was satisfied with 4 tablets (in the case of tablets) and its equivalent quantity in the case of mixtures. The tablets are placed at a depth of 5 cm by making a hole near the crop, where as other sources were applied on the surface. In the case of straight fertilizers single super phosphate was applied basally on 30th DAS whereas urea and muriate of potash were applied in five equal splits at monthly interval starting from first month after sowing. All other routine cultural operations until the harvest of the crop were followed as per the recommendations made in the Crop Production Techniques of Horticultural Crops (Anonymous, 2004).

Soil samples (0-15 cm depth) drawn from each experimental plot at 90th, 180th Days After Sowing (DAS) and at harvest of the crop. The soil samples dried in shade, ground with a wooden mallet, passed through a 2 mm sieve and stored in clean polythene bags for the estimation of available nutrients. The samples were anlysed for $KMnO_4$-N (Subbiah and Asija, 1956), Olsen-P (Olsen *et al.*, 1954) and NH_4OAc-K (Standford and English, 1949). At maturity the dried above ground portion (shoot) was removed 10 days before harvest leaving below ground portions so as to allow the rhizomes to mature and the below ground rhizomes were harvested by manual digging. The data were statistically scrutinized as per the method described by Panse and Sukhatme (1967).

RESULTS

Rhizome Yield

Wet rhizome yield varied from 28.10 t ha^{-1} with mixture 1 at 75% NPK level to 41.21 t ha^{-1} with tablet 2 at 125% NPK level. Yield increase with each successive level of NPK fertilizers was significant over its previous level (Table 2). The effect of tablet 1 and 2 in influencing rhizome yield was similar but significantly superior over other SR NPK sources as well as straight fertilizers. The mixture 1 and 2 and coated FAP were all on par with straight fertilizers in influencing the rhizome yield.

Nitrogen Availability

With increasing levels of nutrients, nitrogen availability increased significantly. Among the sources, tablet 1 and 2 were found to be superior to others in enhancing nitrogen availability at 90 and 180th DAS. Whereas, at harvest stage $KMnO_4$-N was maximum with mixture 1 and 2 (Table 3).

At 90th DAS nitrogen availability ranged from 227 kg ha^{-1} with mixture 1 at 75% NPK level to 283 kg ha^{-1} with tablet 2 at 125% NPK level. However, tablet 2 was on par with tablet 1 at all the three NPK levels and significantly superior to mixture 2, coated FAP and straight fertilizer in enhancing soil nitrogen availability. At 180th DAS higher nitrogen availability was recorded with tablets and mixtures at all NPK levels. The availability ranged from 240 kg ha^{-1} with straight fertilizers at 75% NPK level to 355 kg ha^{-1} with tablet 1 at 125% NPK level. The availability with tablet 1 was on par with tablet 2 and significantly higher than those of other NPK sources. At harvest stage, maximum

Table 2: Yield of wet rhizome (t ha^{-1}) in turmeric with different NPK sources

	NPK source (S)						
Level (L)	Tablet 1	Tablet 2	Mixture 1	Mixture 2	Coated FAP	Straight fertilizer	Mean
75% NPK	31.67	32.62	28.10	28.81	29.05	28.81	29.84
100% NPK	37.62	39.05	33.49	33.81	33.04	34.54	35.26
125% NPK	39.64	41.21	36.67	36.19	36.43	37.62	37.96
Mean	36.31	37.62	32.75	32.94	32.84	33.66	34.35
	L	S	L×S				
SED	0.62	0.88	1.52				
CD (p = 0.05)	1.26	1.79	3.10				

Table 3: Nitrogen availability (kg $KMnO_4$-N ha^{-1}) in soil at different growth stages of turmeric with different NPK sources

	NPK source (S)						
Level (L)	Tablet 1	Tablet 2	Mixture 1	Mixture 2	Coated FAP	Straight fertilizer	Mean
90 DAS							
75% NPK	260	262	227	246	252	245	249
100% NPK	263	269	232	253	248	246	252
125% NPK	276	283	266	273	264	261	271
Mean	267	271	242	258	255	251	257
	L	S	L×S				
SED	3	4	7				
CD (p = 0.05)	6	8	NS				
180 DAS							
75% NPK	275	273	240	258	245	240	255
100% NPK	314	334	250	293	251	245	281
125% NPK	355	353	261	299	251	250	295
Mean	315	320	250	283	249	245	277
	L	S	L×S				
SED	4	6	10				
CD (p = 0.05)	8	11	20				
Harvest stage							
75% NPK	204	213	228	233	209	205	215
100% NPK	260	252	265	278	256	251	259
125% NPK	283	274	277	277	270	259	274
Mean	250	249	255	263	243	236	249
	L	S	L×S				
SED	2	3	5				
CD (p = 0.05)	4	6	10				

nitrogen availability was observed with mixture 1 and 2 and the successive increase in NPK levels significantly increased the nitrogen availability. Maximum availability of 283 kg N ha^{-1} was observed with tablet 1 at 125% NPK level and the lowest with (204 kg ha^{-1}) at 75 % NPK level.

Phosphorus Availability

Addition of successive levels of NPK significantly increased phosphorus availability in soil at 180th DAS. However, at 90th DAS as well as at harvest stage phosphorus availability at 100 and 125% NPK levels were similar (Table 4). Though SR NPK sources significantly influenced phosphorus availability, at 90th DAS there were no clearly established variations among the sources. The availability ranged from 19.7 kg ha^{-1} with mixture 1 at 75% NPK level to 36.3 kg ha^{-1} with tablet 2 at 125% NPK level. At 180th DAS the tablet 1 and 2 recorded significantly higher phosphorus availability than mixture 1 and 2, coated FAP and straight fertilizer. At harvest stage, increasing levels of NPK did not significantly influence phosphorus availability in soil. Phosphorus availability due to the addition of tablets significantly enhanced and were on par with mixture 2 however, other sources (mixture1, coated FAP and straight fertilizers) remained on par with each other in influencing the P stats of the soil.

Table 4: Phosphorus availability (kg Olsen-P ha^{-1}) in soil at different growth stages of turmeric with different NPK sources

	NPK source (S)						
Level (L)	Tablet 1	Tablet 2	Mixture 1	Mixture 2	Coated FAP	Straight fertilizer	Mean
90 DAS							
75% NPK	21.30	22.30	19.70	20.0	22.7	22.3	21.4
100% NPK	34.70	35.70	32.70	35.3	36.0	29.3	33.9
125% NPK	36.00	36.30	32.30	36.0	34.7	34.3	34.9
Mean	30.70	31.40	28.20	30.4	31.1	28.7	30.1
	L	S	L×S				
SED	0.77	1.09	1.90				
CD (p = 0.05)	1.57	2.23	3.85				
180 DAS							
75% NPK	37.30	35.00	31.70	31.3	35.0	33.0	33.9
100% NPK	45.30	42.70	35.70	41.0	33.7	35.0	38.9
125% NPK	45.70	46.70	43.30	45.0	44.3	39.3	44.1
Mean	42.80	41.40	36.90	39.1	37.7	35.8	38.9
	L	S	L×S				
SED	0.78	1.11	1.92				
CD (p = 0.05)	1.59	2.25	3.90				
Harvest stage							
75% NPK	34.30	37.00	34.70	36.0	36.3	36.0	35.7
100% NPK	42.30	43.30	39.00	40.3	38.3	37.7	40.2
125% NPK	42.70	42.30	41.30	42.3	39.3	38.0	41.0
Mean	39.80	40.90	38.30	39.6	38.0	37.2	39.0
	L	S	L×S				
SED	0.57	0.81	1.400				
CD (p = 0.05)	1.16	1.65	2.850				

Table 5: Potassium availability (kg NH_4OAc-K ha^{-1}) in soil at different growth stages of turmeric with different NPK sources

	NPK source (S)						
Level (L)	Tablet 1	Tablet 2	Mixture 1	Mixture 2	Coated FAP	Straight fertilizer	Mean
90 DAS							
75% NPK	441	473	408	428	464	428	440
100% NPK	460	496	444	460	480	447	465
125% NPK	516	551	473	467	477	457	490
Mean	472	507	442	452	473	444	465
	L	S	L×S				
SED	7	10	17				
CD (p = 0.05)	14	20	35				
180 DAS							
75% NPK	415	399	418	441	415	379	411
100% NPK	496	490	483	486	486	470	485
125% NPK	499	490	509	496	479	476	491
Mean	470	459	470	474	460	441	462
	L	S	L×S				
SED	8	11	16				
CD (p = 0.05)	16	NS	32				
Harvest stage							
75% NPK	392	399	405	412	405	376	398
100% NPK	425	441	438	451	405	402	427
125% NPK	454	470	447	454	447	425	450
Mean	424	437	430	439	419	401	425
	L	S	L×S				
SED	6	9	15				
CD (p = 0.05)	13	18	NS				

Potassium Availability

At 90th DAS, K availability ranged from 408 kg ha^{-1} with mixture 1 at 75% NPK level to 551 kg ha^{-1} with tablet 2 at 125% NPK level. Potassium availability with tablet 2 was significantly higher than those of other sources followed by tablet 1 and coated FAP, which were on par. However, at 180th DAS there is no significant variation was observed among sources (Table 5).

At harvest stage each successive NPK level left significantly high K residue in soil than the preceding one. It ranges from 376 kg ha^{-1} with straight fertilizer at 75% NPK level to 470 kg ha^{-1} with tablet 2 at 125% NPK level. In general, the SR NPK fertilizers left similar amounts of NH_4OAc-K in the soil.

DISCUSSION

Turmeric being a long duration crop it is essential that the fertilizers must be applied in optimal amounts and the release of nutrients from them has to be steadily prolonged to match the nutrient needs of the crop over its growth period. The point, which deserves mention, is the comparable performance of SR NPK sources (tablet 1 and 2) at 75% NPK level to that of straight fertilizer at 100% NPK level. This trend would be a boon for the development of a fertilizer nutrient conservation package leading to a saving of 25% of NPK input for this important commercial crop. The saving of 25 percent NPK with the use of SR NPK fertilizers has already been realized in rice (Maheswari, 1997) and sugarcane (Mathywathany, 1998). Shankaraiah and Reddy (1998) have recorded similar yield increases for NPK fertilization in turmeric.

Nitrogen availability in soil maintained at a higher level by the tablet 1 and 2 as compared to other SR NPK sources and straight fertilizer. The tablet form of SR NPK fertilizers applied by placement at a depth of 5 cm nearer to the rhizosphere. Slow release of nitrogen coupled with reduced losses due to NH_3 volatilization and leaching had evidently maintained nitrogen status as well as nitrogen uptake from the tablets. The low efficiency of mixture form of SR NPK sources attributed to the very slow release of nutrients during early stages of turmeric growth and its subsequent release during later stages, which resulted in mismatch with crop nutrient demand. Placement of tablets near the rhizosphere soil ensured a higher concentration of phosphorus in unit volume of soil solution in the immediate vicinity of turmeric roots. Thus, a higher concentration gradient was set up for the phosphorus from the tablets to diffuse faster to the turmeric roots as compared to the phosphorus from other sources. Similar beneficial effects of phosphorus placement were discussed by Prummel (1957), Reith (1959) and Ryan (1962). In the case of mixtures, coated FAP and standard fertilizers, the volume of the experimental soil, with which these fertilizer materials were in contact on application was large, evidently P reversion reactions had occurred at a faster rate resulting in the fixation of applied P in amounts of higher magnitude as compared to those from tablet form of SR NPK sources.

Potassium (muriate of potash) is normally applied by broadcast and very rarely by banded application in soils of low potassium availability or with high potassium fixing capacity. Welch *et al*. (1966) have found as much as four times increase in crop response to banded application over broadcast application of potassium. In the present study, potassium placed in the form of tablets enhanced potassium availability significantly over the uptake from other SR NPK sources. With the high cation exchange capacity of the experimental soils, potassium loss due to leaching under the experimental situation of garden land condition would never be as significant to merit a consideration. Thus, the slow and steady release of potassium from tablets near the rhizosphere matched the crop uptake, whereas, other forms of SR NPK sources maintained high available potassium at harvest because of it's mismatch with crop's demand. Thus, the tablet form of NPK sources was an appropriate source to maintain a desirable level of NPK availability at various stages of turmeric growth.

CONCLUSIONS

Thus, the results of the present study clearly established that the wet rhizome yield increased significantly up to 125% of NPK level. This implied that the presently followed recommendation of 150 kg N, 60 kg P_2O_5 and 108 kg K_2O per ha is sub-optimal and there exist a scope to redefine the fertilizer optima for turmeric. Though nutrient availability in soil, which is estimated as various availability indices are ephemeral in nature, still they are useful in comparing the efficacy of different fertilizer sources in maintaining an available pool of nutrients in soil during various stages of crop growth.

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