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Effect of slow release multi-nutrient fertilizers on the yield and nutrient uptake in turmeric (*Curcuma longa* L.)

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Abstract

To evaluate the efficacy of slow release NPK fertilizers in turmeric, two field experiments were conducted on a sandy clay loam soil. These slow release NPK fertilizers are new products in the form of tablets, mixtures and coated formulations, which contains all the three major nutrients in them. Five slow release NPK fertilizer sources were tested in comparison with straight fertilizers at three NPK levels *viz.,* 75, 100 and 125 % of recommended dose in a randomized block design. The results clearly indicated that the wet rhizome yield significantly increased with increasing levels of NPK and when applied in the form of tablets. The N, P and K uptake both in shoot as well as rhizome of turmeric increased significantly up to 125 % of NPK level applied. The uptake was significantly higher in plots which received tablet form of slow release fertilizers than other fertilizer sources.

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

Introduction

Crop productivity measured in terms of response to fertilizers can only be sustained if soil fertility levels are maintained to match with crops' need and in proper proportions. 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. In this context nutrient recovery from applied fertilizers is primarily important which varies according to crop species, management practices, soil properties and environmental conditions and above all nutrient sources. The nitrogen use efficiency in cereal crops in developed and developing nations are 42 and 29 %, respectively (Raun and Johnson, 1999). Despite placement of phosphatic fertilizers near the seed or plant hill, the amount of phosphate present in the soil solution is very low in comparison with adsorbed P (by the reaction of complexation and fixation). Results of the Long Term Fertilizer Experiments in India revealed a declining trend in total K with the progress in the number of crops at a particular site as a result of the removal of K by the crops far exceeded the quantum of K fertilizer input. This situation demands for evolving strategies and policies to boost NPK supplies in a timely manner in adequate quantities and to increase fertilizer use efficiency.

One such strategy is the use of multi-nutrient slow release fertilizers (SRFs). Fertilizer and Chemicals Travancore Limited (FACT), Cochin, India has evolved such a strategy by bringing slow release NPK fertilizers, which are new formulations containing all the three major nutrients in a single source. Number of slow release-N formulations have been tested *viz.*, isobutylidene diurea and sulphur-coated urea on potatoes (Elkashif *et al.*, 1983), sulphur-coated urea on onion (Brown *et al.*, 1988). Slow release NPK fertilizers were tested on rice (Maheswari, 1997), sugarcane (Mathywathany, 1998) and slow release N sources on maize (Pal, 1996) and tomato (Senthilvalavan, 2000).

Intensively grown cash crops with high yields consume large amounts of nutrients. Turmeric, an important commercial as well as spice crop occupies about 1.6 lakh ha with a production of 6.54 lakh tonnes 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. Singh *et al.* (1992) reported that increasing rate of nitrogen and potassium application increased the accumulation of N, P and K in turmeric rhizome. Sadanandan and Hamza (1998) obtained positive effects of NPK fertilization on the nutrient uptake and yield of turmeric.

Though the above studies review the fertilization effects on turmeric growth and nutrient uptake, use of slow release fertilizers on this important spice crop has not been attempted so far. For such high fertilizer responsive crop, slow release fertilizers will be of immense use in increasing the yield and quality. With these background knowledge the present attempt was made to evaluate the effect of multi-nutrient slow release fertilizers on turmeric.

Materials and methods

Two field experiments were conducted in a farmer's field on a sandy clay loam soil (fine mixed calcareous isohyperthermic Udic Haplustalf) with turmeric (cv. Erode local) as test crop in a consecutive year. The pH of the experimental soil was 8.2 and electrical conductivity was 0.32 dS m^{-1} in 1: 2.5, soil water suspension. Organic carbon content was 0.963 %, $KMnO_4$-N was 235 kg ha^{-1}, Olsen-P was 24.2 kg ha^{-1} and NH_4OAc-K was 384 kg ha^{-1}.

Five slow release (SR) NPK sources tested for their efficacy in the present study were tablet 1 (contains urea formaldehyde, ammonium sulphate, amophos, rock phosphate, muriate of 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) and coated FAP (coated amophos, urea and muriate of potash). In the first field experiment these five SR NPK sources were tested in comparison with straight NPK fertilizers *viz.*, urea, single super phosphate and muriate of potash. These six fertilizer sources were applied at three NPK levels *viz.*, 75, 100 and 125 % of recommended dose (150: 60: 108 kg N, P_2O_5 and K_2O ha^{-1}, respectively). In the second experiment only four SR NPK sources were tested and the tablet 1 was excluded (because of high production cost and problem in handling as expressed by the manufacturer). Thus, there were totally eighteen treatments (six NPK sources each at three levels) in the first experiment and fifteen treatments (five NPK sources each at three levels) in the second experiment, which were replicated three times in a randomized block design.

Sowing of well matured, disease free turmeric rhizome (cv. Erode local, 10 months duration) was done by following a spacing of 45 x 15 cm. These slow release fertilizers were applied to their respective plots in two splits, one at 30th day after sowing (DAS) and another at 120th DAS. The required quantity of N, P_2O_5 and K_2O as per the levels *viz.*, 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. 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 (Anonymous, 2004).

Plant sampling was done by destructive method at different growth stages of turmeric crop *viz.,* 90th DAS, 180th DAS and at harvest. Five numbers of turmeric plants were uprooted from the sampling row of each experimental plot and the uprooted plants were cleaned, separated into shoot and rhizome and dried in a shade followed by drying in hot air oven at 60° C, ground using Wiley mill and stored in butter paper covers. The dry weight was recorded and the respective dry matter production was computed. 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. The rhizomes were harvested by manual digging and the wet rhizome yield was recorded.

The shoot and rhizome samples were analyzed for total N by microkjeldahl method (Humphries, 1956). In di-acid (nitric and perchloric in 9: 4 ratio) digest, total P was estimated by vanadomolybdo phosphoric yellow method (Jackson, 1973) and total K by flame photometry (Jackson, 1973). Using the data on nutrient concentration the respective nutrient uptake were computed. The data were statistically analysed as per the method described by Panse and Sukhatme (1967).

Results and discussion

Rhizome yield: Influence of different NPK sources and their levels on the wet rhizome yield is presented in Table 1. Wet rhizome yield in field experiment 1 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. In field experiment 2 the highest wet rhizome yield was obtained with tablet 2 at 125 % NPK which is significantly superior to other sources and levels. The lowest yield (27.33 t ha^{-1}) was with mixture 1 at 75 % NPK level. 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 other sources, *viz.*, mixture 1 & 2 and coated FAP were all on par with straight fertilizers in influencing the rhizome yield. 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 must 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 *viz.*, tablet 1 and tablet 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 per cent of NPK input for this important commercial crop. The saving of 25 per cent NPK with the use of SR NPK fertilizers has already been realized in rice (Maheswari, 1997) and sugar cane (Mathywathany, 1998). Shankaraiah and Reddy (1988) have recorded similar yield increases for NPK fertilization in turmeric.

Nutrient uptake

The uptake of nutrients *viz.,* nitrogen, phosphorus and potassium were computed for both field experiments. Since there is no significant variation in the uptake pattern between two field

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

Field Experiment I

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				
SE (d)	0.62	0.88	1.52				
CD (*P*=0.05)	1.26	1.79	3.10				

Field Experiment II

Level (L)	Tablet 2	Mixture 1	Mixture 2	Coated FAP	Standard Fertilizer	Mean
75 % NPK	34.33	27.33	29.33	30.50	27.50	29.80
100 % NPK	40.33	33.17	35.00	34.00	32.33	34.97
125 % NPK	43.67	37.83	38.17	38.00	37.33	39.00
Mean	39.44	32.78	34.17	34.17	32.39	34.59
	L	S	L× S			
SE (d)	0.62	0.80	1.38			
CD (*P*=0.05)	1.27	1.64	NS			

Table 2. Nitrogen uptake (kg ha^{-1}) in turmeric shoots with different NPK sources (S)

Level (L)	Tablet 1	Tablet 2	Mixture 1	Mixture 2	Coated FAP	Straight Fertilizer	Mean
				90 DAS			
75 % NPK	18.0	20.9	11.6	13.8	19.3	13.5	16.2
100 % NPK	17.6	21.0	15.4	18.4	18.6	16.8	18.0
125 % NPK	23.6	22.7	17.4	16.0	18.8	19.1	19.6
Mean	19.8	21.5	14.8	16.1	18.9	16.5	17.9
	L	S	L×S				
SE (d)	0.8	1.2	2.0				
CD (*P*=0.05)	1.7	2.4	NS				
				180 DAS			
75 % NPK	30.3	32.3	25.7	27.5	32.9	31.5	30.0
100 % NPK	51.2	45.2	30.5	37.1	35.7	33.5	38.9
125 % NPK	51.9	53.9	34.4	34.2	38.7	36.2	41.6
Mean	44.5	43.8	30.2	32.9	35.8	33.7	36.8
	L	S	L×S				
SE (d)	0.9	1.2	2.1				
CD (*P*=0.05)	1.7	2.4	4.2				
				At Harvest			
75 % NPK	10.4	10.8	7.6	8.5	9.9	7.5	9.1
100 % NPK	11.4	10.2	8.4	10.0	11.8	8.5	10.3
125 % NPK	15.1	13.6	8.2	10.3	10.0	9.8	11.2
Mean	12.3	11.5	8.6	9.6	10.6	8.6	10.2
	L	S	L×S				
SE (d)	0.2	0.2	0.4				
CD (*P*=0.05)	0.3	0.5	0.8				

Table 3. Nitrogen uptake (kg ha^{-1}) in turmeric rhizome with different NPK sources (S)

Level (L)	Tablet 1	Tablet 2	Mixture 1	Mixture 2	Coated FAP	Straight Fertilizer	Mean
				90 DAS			
75 % NPK	8.7	9.5	5.6	7.0	9.9	6.9	7.9
100 % NPK	8.5	9.8	7.3	9.3	9.4	9.2	9.0
125 % NPK	12.3	11.9	8.4	8.3	10.7	9.4	10.1
Mean	9.8	10.4	7.1	8.2	10.0	8.5	9.0
	L	S	L×S				
SE (d)	0.4	0.5	0.9				
CD (*P*=0.05)	0.7	1.1	1.8				
				180 DAS			
75 % NPK	36.0	41.1	23.0	29.5	35.9	31.2	32.8
100 % NPK	53.2	54.1	32.8	35.8	41.6	38.5	42.7
125 % NPK	58.2	62.1	41.9	46.6	45.1	41.9	49.3
Mean	49.1	52.4	32.6	37.3	40.9	37.2	41.6
	L	S	L×S				
SE (d)	1.0	1.4	2.4				
CD (*P*=0.05)	1.9	2.8	4.8				
				At Harvest			
75 % NPK	69.0	63.0	46.6	53.6	47.7	56.5	56.1
100 % NPK	84.6	77.0	59.8	74.4	72.8	54.1	70.4
125 % NPK	85.2	90.2	72.0	72.2	68.2	63.1	75.2
Mean	79.6	76.7	59.5	66.7	62.9	57.9	67.2
	L	S	L×S				
SE (d)	1.3	1.8	3.2				
CD (*P*=0.05)	2.6	3.7	6.5				

experiments, the results of field experiment 1 are only presented and discussed hereunder.

Nitrogen uptake: Nitrogen (N) uptake in turmeric shoot at different growth stages increased significantly with increasing levels of NPK (Table 2). The highest N uptake was recorded at 180th DAS with tablet 2 (53.9 kg ha^{-1}) at 125 % NPK level and this was on par with tablet 1. The N uptake at harvest stage was low, however, there was significant influence by the sources and levels. N uptake in turmeric rhizome was significantly influenced by SR NPK sources at all levels and stages (Table 3). Highest N uptake was observed with tablet 2 (11.9, 62.1 and 90.2 kg ha^{-1} at 90th DAS, 180th DAS and harvest stage, respectively) at 125 % NPK level. This was followed by coated FAP and mixture 2. The lowest N uptake was recorded with mixture 1 at 75% NPK level. Unlike in shoots the N uptake in rhizome at harvest stage was higher and significant than the previous stages.

Similar increases in N uptake in turmeric due to NPK fertilization was reported by Sadanandan and Hamza (1998) and Selvakumari

Table 4. Phosphorus uptake (kg ha^{-1}) in turmeric shoots with different NPK sources (S)

Level (L)	Tablet 1	Tablet 2	Mixture 1	Mixture 2	Coated FAP	Straight Fertilizer	Mean
				90 DAS			
75 % NPK	2.3	2.3	1.4	1.8	2.3	1.8	2.0
100 % NPK	2.4	2.6	1.9	2.3	2.3	2.2	2.3
125 % NPK	3.0	3.2	1.9	2.4	2.6	2.4	2.6
Mean	2.5	2.7	1.7	2.2	2.4	2.2	2.3
	L	S	L×S				
SE (d)	0.11	0.12	0.23				
CD (*P*=0.05)	0.22	0.30	NS				
				180 DAS			
75 % NPK	2.9	3.0	2.6	2.6	2.7	2.5	2.7
100 % NPK	5.1	5.1	3.5	3.7	3.9	3.4	4.1
125 % NPK	4.9	5.0	3.5	3.9	4.4	3.5	4.2
Mean	4.3	4.4	3.2	3.4	3.7	3.1	3.7
	L	S	L×S				
SE (d)	0.08	0.11	0.19				
CD (*P*=0.05)	0.16	0.22	0.38				
				At Harvest			
75 % NPK	0.62	0.64	0.46	0.54	0.60	0.53	0.57
100 % NPK	0.63	0.74	0.52	0.65	0.64	0.59	0.63
125 % NPK	0.77	0.82	0.60	0.64	0.65	0.69	0.70
Mean	0.67	0.73	0.53	0.61	0.63	0.60	0.63
	L	S	L×S				
SE (d)	0.02	0.02	0.04				
CD (*P*=0.05)	0.03	0.05	NS				

Table 5. Phosphorus uptake (kg ha^{-1}) in turmeric rhizome with different NPK sources (S)

Level (L)	Tablet 1	Tablet 2	Mixture 1	Mixture 2	Coated FAP	Straight Fertilizer	Mean
				90 DAS			
75 % NPK	1.40	1.57	0.97	1.09	1.80	1.35	1.36
100 % NPK	1.41	1.62	1.27	1.45	1.57	1.52	1.48
125 % NPK	1.90	1.99	1.49	1.49	1.72	1.55	1.69
Mean	1.57	1.73	1.24	1.34	1.70	1.47	1.51
	L	S	L×S				
SE (d)	0.06	0.08	0.14				
CD (*P*=0.05)	0.12	0.17	NS				
				180 DAS			
75 % NPK	8.4	9.5	6.1	6.9	8.4	7.8	7.9
100 % NPK	13.4	15.3	8.5	9.5	12.1	11.5	11.7
125 % NPK	15.4	15.9	9.8	10.2	10.7	10.2	12.0
Mean	12.4	13.6	8.1	8.9	10.4	9.8	10.5
	L	S	L×S				
SE (d)	0.25	0.36	0.62				
CD (*P*=0.05)	0.51	0.72	1.25				
				At Harvest			
75 % NPK	17.4	18.5	14.7	16.1	14.9	16.3	16.3
100 % NPK	22.6	23.0	17.6	17.7	19.4	20.6	20.1
125 % NPK	25.0	25.2	20.7	22.1	21.5	21.3	22.6
Mean	21.7	22.2	17.6	18.6	18.6	19.4	19.7
	L	S	L×S				
SE (d)	0.37	0.53	0.90				
CD (*P*=0.05)	0.76	1.07	NS				

and Basker (1998). N uptake in turmeric shoot and rhizome generally increased with advancement of turmeric growth from 90th DAS and up to 180th DAS. At harvest stage, however, N uptake in turmeric shoot declined whereas in rhizome increased.

Among the SR NPK sources, tablet 1 and 2 recorded significantly higher level of N uptake in turmeric shoot and rhizome as compared to other sources. These tablets were applied by placement at a depth of 5 cm near the rhizosphere. Slow release of N coupled with reduced losses due to NH_3 volatilization and leaching have evidently enhanced N uptake from the tablets. Whereas in the case of mixtures and straight fertilizers, N uptake was of low magnitude which might be due to increased losses of N through NH_3 volatilization and leaching on their application with larger volume of soil on surface as compared to the tablets.

Phosphorus uptake: Phosphorus (P) uptake in turmeric shoot at 90th DAS ranged from 1.4 kg ha^{-1} with mixture 1 at 75 % NPK level to 3.2 kg ha^{-1} with tablet 2 at 125 % NPK (Table 4). P uptake at 180th DAS was maximum (5.1 kg ha^{-1}) with tablet 1 & 2 at 100

Table 6. Potassium uptake (kg ha^{-1}) in turmeric shoots with different NPK sources (S)

Level (L)	Tablet 1	Tablet 2	Mixture 1	Mixture 2	Coated FAP	Straight Fertilizer	Mean
				90 DAS			
75 % NPK	52.3	55.3	36.3	41.4	51.6	42.7	46.6
100 % NPK	52.7	56.7	43.5	47.3	56.8	51.0	51.3
125 % NPK	69.6	69.4	51.8	52.1	57.4	60.7	60.2
Mean	58.2	60.5	43.9	46.9	55.3	51.5	52.7
	L	S	L×S				
SE (d)	2.3	3.3	5.6				
CD (*P*=0.05)	4.7	6.6	NS				
				180 DAS			
75 % NPK	78.1	84.8	77.3	76.6	79.2	81.1	79.5
100 % NPK	136.9	125.7	93.0	91.4	93.4	93.7	105.7
125 % NPK	136.0	139.1	102.1	93.4	111.9	105.7	114.7
Mean	117.0	116.5	90.8	87.2	94.9	93.5	100.0
	L	S	L×S				
SE (d)	2.0	2.9	5.0				
CD (*P*=0.05)	4.1	5.8	10.1				
				At Harvest			
75 % NPK	35.4	36.0	30.9	32.3	33.6	28.7	32.8
100 % NPK	38.8	45.4	27.2	32.0	34.2	34.2	35.3
125 % NPK	44.3	45.7	35.0	35.2	39.5	38.0	39.6
Mean	39.5	42.4	31.0	33.1	35.7	33.6	35.9
	L	S	L×S				
SE (d)	0.43	0.60	1.05				
CD (*P*=0.05)	0.87	1.23	2.13				

Table 7. Potassium uptake (kg ha^{-1}) in turmeric rhizome with different NPK sources (S)

Level (L)	Tablet 1	Tablet 2	Mixture 1	Mixture 2	Coated FAP	Straight Fertilizer	Mean
				90 DAS			
75 % NPK	27.2	30.5	19.0	22.2	30.3	22.9	25.4
100 % NPK	28.4	32.3	25.4	28.0	30.7	30.2	29.2
125 % NPK	38.1	38.0	27.8	28.2	33.3	33.9	33.2
Mean	31.2	33.6	24.1	26.2	31.5	29.0	29.2
	L	S	L×S				
SE (d)	1.1	1.6	2.7				
CD (*P*=0.05)	2.3	3.2	NS				
				180 DAS			
75 % NPK	78.6	83.6	58.1	66.5	73.0	62.7	70.4
100 % NPK	129.1	132.0	73.1	82.3	82.0	94.1	98.8
125 % NPK	140.1	144.8	86.2	92.3	92.0	87.8	107.2
Mean	115.9	120.1	72.4	80.3	82.3	81.6	92.1
	L	S	L×S				
SE (d)	2.2	3.1	5.3				
CD (*P*=0.05)	4.4	6.3	10.8				
				At Harvest			
75 % NPK	133.9	131.1	107.6	127.4	117.8	123.2	123.5
100 % NPK	160.0	179.0	149.5	133.2	148.3	149.2	153.2
125 % NPK	197.6	200.2	179.5	169.8	177.2	171.1	182.6
Mean	163.9	170.1	145.5	143.5	147.8	147.8	153.1
	L	S	L×S				
SE (d)	2.9	4.2	7.1				
CD (*P*=0.05)	5.9	8.4	14.6				

% NPK level and minimum (2.5 kg ha^{-1}) with straight fertilizer. Similar trend was observed at harvest stage also. P uptake in turmeric rhizome ranged from 0.97 kg ha^{-1} with mixture 1 at 75 % NPK level to 1.99 kg/ha with tablet 2 at 125 % NPK level at 90th DAS (Table 5). However, the uptake with tablet 2 was on par with tablet 1 and coated FAP and significantly superior over mixtures and straight fertilizers. At harvest stage, the uptake at 125 % NPK level was significantly higher than 100 and 75 % NPK level.

Singh *et al.* (1992) have reported significant increase in P uptake in turmeric due to NPK application. Translocation of P from turmeric shoot to rhizome occurred in significant amounts with advancement of turmeric growth. Placement of tablet near the rhizosphere soil ensured a higher concentration of P in unit volume of soil solution in the immediate vicinity of turmeric roots. Thus, a higher concentration gradient was set up for the P from the tablets to diffuse faster to the turmeric roots as compared to the P from other sources. Similar beneficial effects of P placement were discussed by Prummel (1957), Reith (1959) and Ryan (1962). In the case of mixtures, coated FAP and straight fertilizers, the volume of the experimental soil, which is calcareous, with which these fertilizer materials were in contact on application was large which evidently enhanced P reversion reactions 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 uptake: Potassium (K) uptake in turmeric shoot at various growth stages is presented in Table 6. Maximum K uptake was observed at 180th DAS with tablet 1 at 125 % NPK level. The uptake at 90th DAS ranged from 36.3 kg ha^{-1} with mixture 1 at 75% NPK level to 69.6 kg ha^{-1} with tablet 1 at 125% NPK level. At 180th DAS, the K uptake was enhanced significantly by all the sources at 125% NPK level and the maximum was recorded with tablets 1 and 2. At harvest stage, K uptake in shoots varied from 27.2 kg ha^{-1} with mixture 1 at 100% NPK level to 45.7 kg ha^{-1} with tablet 2 at 125% NPK level. K uptake in turmeric rhizome was also significantly influenced by SR NPK sources in all the stages (Table 7). At harvest stage, K uptake ranged from 107.6 kg ha^{-1} with mixture 1 at 75% NPK level to 200.2 kg ha^{-1} with tablet 2 at 125% NPK level.

With enhanced level of NPK, uptake of K in turmeric shoot and rhizome increased. Such positive influence of K fertilizer application on K uptake in turmeric was reported by Balashanmugam and Subramanian (1991) and Sadanandan and Hamza (1998). There was a significant translocation of K from turmeric shoot to rhizome with advancement of growth. In all the SR NPK sources, muriate of potash is the common K source component, which is water soluble. Muriate of potash is normally applied by broadcast and very rarely by banded application in soils of low K availability or with high K fixing capacity. Welch *et al.* (1966) found as much as four times increase in crop response to banded application over broadcast application of K. In the present study, K placed in the form of tablets at a depth of 5 cm near the rhizosphere enhanced K uptake significantly over the uptake from other SR NPK sources. Thus, the slow and steady release of K from tablets near the rhizosphere matched the crop uptake sparing not as much K for fixation by soil clays as from other SR NPK sources resulting in enhanced K uptake from the tablets by turmeric. The larger soil volume with which K from the mixtures, coated FAP and straight fertilizers had come in contact on application enhanced K fixation and thus K uptake from these sources was low as compared to the tablets.

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. Until precise fertilizer optima is established through proper fertilizer optimization studies, the 125% of NPK level, *viz.*, 187.5 kg N, 75 kg P_2O_5 and 135 kg K_2O per ha may safely be used to harvest better yields than what is presently harvested. Also, the superiority of tablet form of SR NPK in influencing the yield and nutrient uptake in turmeric was clearly established in the present investigation.

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References

Anonymous, 2004. *Crop Production Technologies of Horticultural Crops*. Directorate of Horticulture and Plantation Crops, Government of Tamil Nadu, Chennai, India.

Balashanmugam, P.V. and K.S. Subramanian, 1991. Effect of split application of potassium on turmeric. *South Indian Horticulture,* 39(3): 139-142.

Brown,B.D., A.J. Hornbacher and D.V. Naylor, 1988. Sulfur-coated urea as a slow-release nitrogen source for onions. *J. Am. Soc. Hort. Sci.,* 113(6): 864-869.

Elkashif, M.E., S.J. Locascio and D.R. Hensel, 1983. Isobutylidene di-urea and sulfur-coated urea as N sources for potatoes. *J. Am. Soc. Hort. Sci.,* 108(4): 523-526.

Humphries, E.C. 1956. *Mineral components and ash analysis –modern methods of plant analysis*. Springer - Verleg, Berlin 1, 468-502.

Jackson, M.L., 1973. *Soil Chemical analysis*. Prentice Hall Private Ltd., New Delhi, India.

Maheswari, S.T. 1997. *Evaluation of slow release fertilizers on rice.* M.Sc.(Ag) thesis, Tamil Nadu Agricultural University, Coimbatore, India.

Mathywathany, G. 1998. *Evaluation of slow release fertilizers on sugarcane*. M.Sc.(Ag) thesis, Tamil Nadu Agricultural University, Coimbatore, India.

Pal, S.S. 1996. Effect of modified urea formulations on N use efficiency in maize. *J. Indian Soc. Soil Sci.,* 44(4): 732-736.

Panse, V.G. and P.V. Sukhatme, 1967. *Statistical methods for Agricultural Workers*. Indian Council of Agricultural Research, New Delhi, India.

Prummel, J. 1957. Fertilizer placement experiments. *Plant and Soil,* 8: 231-253.

Raun, W.R. and G.V. Johnson, 1999. Improving nitrogen use efficiency for cereal production. *Agronomy J*., 91: 357-363.

Reith, J.W.S. 1959. Fertilizer placement for swedes and turnips. *Empire. J. Experimental Agriculture,* 27: 300-312.

Ryan, P.F. 1962. Fertilizer placement for kale. *Irish J. Agricultural Research,* 1: 231-236.

Sadanandan, A.K. and S. Hamza, 1998. Effect of organic manures on nutrient uptake yield and quality of turmeric (*Curcuma longa* L.). In: *Developments in Plantation crops Research*. Eds. N.M. Mathew and C. Kuruvilla Jacob, Allied Publ. Ltd. New Delhi, India. p175-181.

Selvakumari, G. and M. Baskar, 1998. Integrated plant nutrition system for turmeric (*Curcuma longa* L.) on Inceptisol. *Bullettin Indian Soc. Soil Sci*., 2: 152-155.

Senthilvalavan, P.S. 2000. Relative efficiency of controlled release and water-soluble fertilizers on yield and quality of vegetable crops (Tomato, PKM-1; Chilli, PKM-1). M.Sc.(Ag) thesis, Tamil Nadu Agricultural University, Coimbatore, India.

Shankaraiah, V. and I.P. Reddy, 1988. Studies on effect of different manurial and spacing levels with local and high yielding turmeric varieties. *Indian Cocoa, Arecanut and Spices J***.,** 11(3): 94-95.

Singh, V.B., B. Swer and P.P. Singh, 1992. Influence of nitrogen and potassium on yield and quality of turmeric cv. Lakadong. *Indian Cocoa, Arecanut and Spices J.,* 15(4): 106-108.

Welch, L.F., P.E. Johnson, G.E. McKibben, L.V. Boone and I.W. Pendleton, 1966. Relative efficiency of broadcast versus banded potassium for corn. *Agronomy J*., 58: 618-621.