Research Findings

Turmeric field in Tamil Nadu, India. Photo by P.K. Karthikeyan.

Response of Turmeric (*Curcuma longa*) to Potassium Fertilization on K Deficient Soil in Northern Bangladesh

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Abstract

Field experiments were carried out over two growing seasons (2010/11 and 2011/12) to study the effect of potassium (K) fertilization on turmeric (*Curcuma longa*) on a light textured K deficient soil (Terrace Soil if the Level Barind Tract, AEZ 25) at Shibganj, Bogra, at the Bangladesh Agricultural Research Institute's (BARI) Spices Research Center (SRC) (Latitude 24°51'0 N, longitude 89°22'0 E, and elevation 23 m). The work was carried out to establish the optimum application rate of K to maximize yield and nutrient uptake of turmeric (var. BARI Holud-3) and to draw up a K balance sheet for K utilization by the crop. Five treatments were compared including a control without K application: T_1=K_0 control, T_2=K_{40}, T_3=K_{80}, T_4=K_{120} and T_5=K_{160} kg ha^{-1}. Potassium chloride (muriate of potash, MOP) was used as the source of K. The plots were laid out in a randomized complete block design (RCBD), each treatment with three replicates. A blanket dose of $N_{133}P_{18}S_{13}Zn_2$ kg ha^{-1} was given to all plots.

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Application of K significantly increased (R^2>0.9) rhizome yield up to 37.2 and 26.3 t ha^{-1} in 2010/11 and 2011/12 respectively, both with the application of 160 kg K ha^{-1}. Yield attributes of turmeric also improved with increased K application. K application increased yield by 39 and 52 percent (in 2010/11 and 2011/12 respectively). The amount of K taken up by turmeric increased in response to raised levels of K application up to 160 kg K ha^{-1} ranging from 68-180 kg K ha^{-1}. An apparent K balance was estimated on the basis of K added through fertilizer and K uptake by the turmeric. This K balance was found to be negative in all the treatments in the study area. Among the K levels used, 160 kg K ha^{-1} was found to be economically most profitable, contributing an additional income of approx. USD 2,200 to 2,600 per hectare. Considering the linear response of yield to applied K along with the economic returns, the application of K at 160 kg ha^{-1}, along with a blanket dose of $N_{133}P_{18}S_{13}Zn_2$ kg ha^{-1}, appears to be the best-suited dose for maximizing the yield of turmeric in K deficient terrace soil in the Level Barind Tract (AEZ 25) soil. However, the observed negative K balance, even when other nutrient supply is balanced, as well as the findings of linear response in yield, high agronomic efficiency (AE) for applied K, and the insensitivity to K cost, all suggest that there is scope to increase K and possibly nitrogen (N) and phosphorus (P) application levels to achieve even higher yields and profitability.

Introduction

Fertile soil is an important natural resource for any country. It is important therefore that Bangladeshi farmers try to obtain higher yields while managing soil fertility through judicious use of fertilizers to achieve sustainable crop yields. In Bangladesh, however, soils are being exhausted due to the increase in cropping intensity and the introduction of high yielding varieties and new technologies. Available data indicate that the fertility of most Bangladeshi soils has deteriorated (Ali *et al.,* 1997 and Islam, 2008) which is responsible for the stagnation and in some cases, decline, of crop yields. The use of chemical fertilizers mainly to supply Nitrogen (N), Phosphorus (P), Potassium (K) and Sulphur (S) has been increasing steadily but these fertilizers have not been applied in balanced proportions which has led to a depletion of constituent nutrients. Annual rates of depletion of N, P, K and S in areas under intensive cultivation range between 180 and 250 kg ha^{-1} yr^{-1}. Potassium is the third major plant nutrient following N and P. Analysis of nutrient use ratio shows that K use is low and it is for this reason that K deficiency is identified as deficient in most soils in Bangladesh (Noor *et al*., 1998).

It was commonly believed that adequate amounts of K were present in Bangladeshi soil to meet crop demand. While this might have been true for local crop varieties with low yield potentials, major crop intensification that has occurred in recent years has placed a higher demand on K supply, rendering crops more susceptible to K deficiency. Despite the growing consciousness of farmers of the beneficial effect of applying K together with N and P, there is widespread K deficiency which has been reported on a variety of crops. These include potato, sweet potato and other root crops, sugarcane, fruit, onion, garlic, fiber crops and high-yielding variety (HYV) cereals (Islam *et al*., 1985; Kundu *et al*., 1998; Noor *et al*., 1993; Miah *et al*., 2008). In terms of unit nutrient requirement, K is almost equal to that of N (Sadanandan *et. al*., 1998). In most plant species the K requirement in leaves, fruits and tubers is about 20-50 kg^{-1}g. Potassium, although not itself a constituent of any metabolite, plays a key role in functions of plant

Photos 1. Turmeric rhizome (BARI Holud-3) is a popular spice in Bangladesh. Photos by S. Akhter.

physiology and metabolism (Marschner, 2012). These functions relate directly to the beneficial effects of K on both crop yield and quality. Potassium activates numerous enzymes, is required in high concentrations for protein synthesis and is needed in both the light and dark reactions of photosynthesis. Additionally it plays a major role in osmoregulation and is thus directly involved in growth in cell extension. Its control of the turgor changes of guard cells in the stomata means that K regulates water loss from plants via transpiration. Potassium is highly mobile in plants and readily moves from older to younger leaves so that, like N deficiency, symptoms of K deficiency appear first in the older leaves. Potassium also increases resistance of plants against both biotic and abiotic stresses which is of high importance in crop production.

Spice crops like turmeric (*Curcuma longa*) and ginger are highly sensitive to a lack of K and require a large amount of available soil K which must be maintained because much of the K taken up by the roots is removed by the harvested crop. Crop response studies to K fertilization in different spice crops showed that among the three major nutrients, K is required in greatest amounts (Sadanandan *et al*., 2002). Application of K has also been shown to increase yield, size of fingers in ginger and turmeric, oleoresin in ginger, and curcumin recovery in turmeric. Potassium also indirectly improves utilization of N and protein formation, in terms of size, weight, color etc. (Sadanandan *et al*., 2002). In turmeric plants K deficiency manifests itself as chlorotic lesions and drying of leaf tips. Sadanandan (1993) reported that in black pepper (*Piper nigrum* L), K from older leaves is re-distributed to the younger growing tissues, resulting in deficiency symptoms in older leaves, leading to a drastic reduction in crop growth. The importance of K in plant nutrition and agricultural crop production has been well recognized and reviewed by many workers (Bidari and Hebsur, 2011). In general, adequate K nutrition has been shown to enhance yields and disease resistance of roots and tubers (Jansson, 1978). It also favors the establishment of root crops in the field (Rabindran and Nirmal, 2005).

Turmeric is a spice commonly used in cooking Asian food and is an excellent source of K. This rhizomatous spice crop which has been cultivated in Bangladesh since ancient times is one of the country`s major spices (Siddique and Azad, 2010). Turmeric is obtained by grinding the rhizomes to obtain the yellow colored powder curcumin. This powder is the main spice in Asian cuisines and curry powder. Most turmeric produced is used as a condiment but is also used as a coloring agent by food industries. A small quantity is taken by the cosmetics industry in Bangladesh. The medicinal value of turmeric is also well recognized in Bangladesh. Turmeric has a high demand for plant nutrients and generally responds to increased soil fertility by increasing yield. The quantity of fertilizers (inorganic or organic) required by the crop depend on the variety selected as well as the soil, and

Photo 2. Potassium fertilized turmeric crop. Photo by S. Akhter.

weather conditions prevailing during crop growth (Karthikeyan *et al*., 2009). Among the spices, turmeric removes the most K (see Photo 2), followed by ginger and pepper (Sadanandan *et al*., 2002).

In Bangladesh, the recovery and diversification of spice exports to international markets is a real possibility but this may be restricted by a lack of K supply (Akhter *et al*., 2013). Akhter *et al*. (2013) reported very good adaptation of spices in northern Bangladesh, although the sandy soils of this region are highly leached and the consequent lack of K can become a constraint to spice production. Spice crops like turmeric and ginger are highly sensitive to a lack of K and require a large amount of available soil K. In the case of turmeric in particular, there is a growing understanding by farmers of the importance of using K, balanced by the use of N and P fertilizers to improve rhizome yields. This has contributed greatly to the economic viability of the crop and led to an increase in demand for K fertilizers. There is, however, a need for a quantitative investigation as to how much K is required by turmeric and how efficiently this nutrient is utilized.

The field study reported in this paper on turmeric was carried out on a K deficient sandy soil in north Bangladesh to investigate the influence of increasing rates of K supply under conditions of adequate supply of all other nutrients. The aims of the experiment were as follows: (i) to establish the optimum application rate of K to obtain maximum yield and to consider the associated yield components; (ii) to determine the uptake of K by the crop; and (iii) to draw up a K balance sheet of K uptake and loss in this particular soil.

Materials and methods

The experiment was established at the Bangladesh Agricultural Research Institute's (BARI) Spices Research Center (SRC) experimental farms at Shibganj, Bogra (lat 24°51'0 N, long 89°22'0 E, 23 m elev.). The site is within agro-ecological zone (AEZ) 25 (terrace soil of the Level Barind Tract), which is flood free, highland with light-textured (sandy loam) K deficient and high-permeability soil. The variety of turmeric tested over two seasons (2010-2011 and 2011-2012) was BARI Holud-3. In both years, the unit plot size was 2 m x 1.5 m. There were five treatments comprising, viz. T_1=K_0, T_2=K_{40}, T_3=K_{80}, T_4=K_{120} and T_5=K_{160} kg ha^{-1} with three replications. The experiment was laid out in a Randomized Complete Block Design (RCBD). All treatments received a blanket dose application of $N_{133}P_{18}S_{13}Zn_2$ kg ha^{-1}. Urea, triple super phosphate, MOP, gypsum and zinc sulphate were used as the sources of N, P, K, S and zinc (Zn), respectively. This treatment provided a balanced nutrient supply to accompany the various rates of K supply. The total amounts of P, S and Zn were applied at the time of final land preparation. Nitrogen and K were applied as a top dressing in three equal splits at 80, 120 and 180 days after planting. Two rhizomes of turmeric were sown in May in both years in each pit and on emergence the plants were thinned to one plant per hill. Rhizomes were planted maintaining a spacing of 50 cm x 25 cm between and within the rows.

The seed rhizomes/fingers were planted at a depth of 8 cm. Weeding was done periodically whenever necessary. The crops were harvested when all the plants started drying in February 2011 and 2012. Data on various parameters including yield and K concentration of 10 randomly selected plants from each treatment were recorded. Collected data were analyzed statistically with the help of a statistical package, MSTAT-C, and Duncan's Multiple Range Test (DMRT) was used to determine the significant differences between treatments (Steel and Torrie, 1960). Plant samples were also collected from each plot for chemical analysis.

Soil chemical analysis

Prior to fertilizer application, initial soil samples in the study area were collected from 0-15 cm soil depth, and were analyzed for all important soil parameters using standard procedures (Table 1). The soil was found to be slightly acidic, intensively leached, and deficient in soil available K, as well as S and boron (B).

The following chemical determinations were made: pH by use of a combined glass calomel electrode (Jackson, 1958); organic carbon by the wet oxidation method (Walkley and Black, 1934); total N by a modified Kjeldahl method; calcium (Ca) and magnesium (Mg) by atomic absorption spectrophotometric (AAS); and K by flame photometry following soil extraction with NH_4OAc. Manganese (Mn) and Zn were also determined by AAS after DTPA (diethylenetriaminepentaacetic acid) soil extraction. Available P was estimated by the Bray and Kurtz method and B by the $CaCl_2$ extraction method. Sulphur was determined using the turbidimetric method with $BaCl_2$.

Plant chemical analysis

At harvest, the collected plant samples from each plot were dried at 65°C in an electric oven for 72 h, then ground to pass through a 20 mesh sieve and analyzed following standard procedures. Plant samples were digested with HNO_3-$HClO_4$ (3:1) for K determination using a flame photometer. Nutrient uptake was calculated by multiplying the concentration of K in the plant samples (see Photo 3) with the corresponding plant dry weights. Potassium balance was calculated by subtracting outputs (K removed or taken up by turmeric rhizome and straw) from the inputs (K added as fertilizer) (Panaullah *et al.*, 2000).

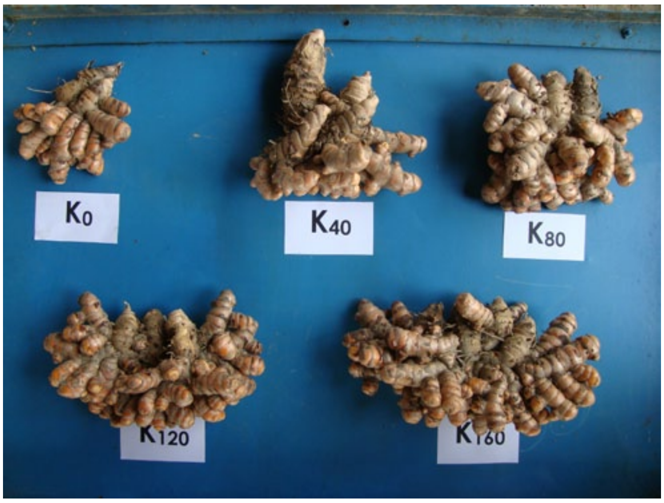

Photo 3. Effect of K on turmeric rhizome. Photo by S. Akhter.

Results and discussion

Yield and yield contributing factors

The results for yield and yield contributing characters of turmeric over two seasons (2010/11 and 2011/12) are presented in Table 2 and Fig. 1. Turmeric responded significantly to K fertilization in Terrace soil of the Level Barind Tract (AEZ 25) at Shibgonj, Bogra, in both years. The positive response of turmeric to increased K fertilization expressed itself through yield contributing characteristics much more in the 2011/12 season than the previous

Table 1. Fertility status of the soil at SRC.

Soil parameters	pH	OM	Ca	Mg	K	Total N	P	S	B	Mn	Zn
		%	-----*meq 100 g^{-1}*-----			%	----------------*µg g^{-1}*----------------				
2010-2011	5.6	0.98	4.2	0.8	0.11	0.08	14	9	0.17	8.3	1.30
2011-2012	6.1	1.20	4.6	1.8	0.11	0.09	18	20	0.25	9.7	0.65
Critical level	-	-	2.0	0.5	0.12	-	7	10	0.20	1.0	0.60

Table 2. Yield contributing characters of turmeric as influenced by different rates of K application (average of 10 plants).

Treatment	Plant height		Tillers/plant		Leaves/plant	
	2010/11	2011/12	2010/11	2011/12	2010/11	2011/12
	-------------*cm*------------		------------------------------*No.*------------------------------			
T_1 (K_0)	163.80	103.0 c	3.2 c	2.3 d	20.5 d	8.5 d
T_2 (K_{40})	171.80	112.1 b	3.4 bc	2.9 cd	22.0 cd	12.1 c
T_3 (K_{80})	173.93	114.4 b	3.6 ab	3.1 bc	22.4 bc	13.9 c
T_4 (K_{120})	163.80	122.2 a	3.7 ab	3.7 ab	23.8 ab	18.1 b
T_5 (K_{160})	165.40	124.7 a	3.9 a	4.1 a	24.9 a	21.4 a
CV (%)	5.8	3.2	5.2	11.9	3.9	8.9

Note: Figures in a column having same letter(s) do not differ significantly at 5% level by DMRT.
All treatments received a blanket dose application of $N_{133}P_{18}S_{13}Zn_2$ kg ha^{-1}.

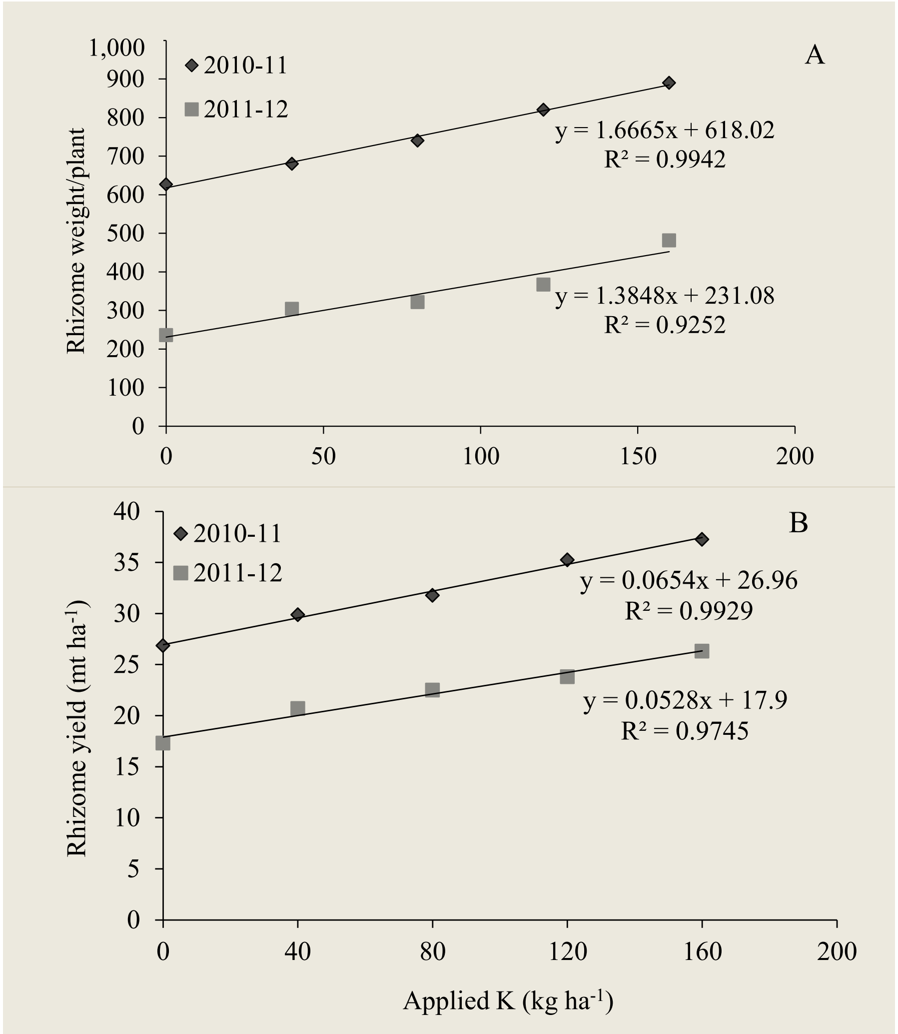

Fig. 1. Response of turmeric to K fertilization: (A) rhizome weight/plant and (B) rhizome yield in Bogra, 2010-11 and 2011-12.

one (Table 2). The weight of rhizome per plant (Fig. 1A) and rhizome yield (Fig. 1B) increased linearly (R^2>0.9) through the entire range of K application, from 0 to 160 kg K ha^{-1}, suggesting that additional K input may have further improved yield. In 2010/11, yield increased from 26.8 to 37.2 mt ha^{-1}, a 39 percent increase, while in 2011/12, yield increased from 17.3 to 26.3 mt ha^{-1}, a 52 percent increase (Fig. 1B). The increase in fresh rhizome yield might be attributed to the cumulative effect of all the yield contributing parameters of turmeric under study. Rathinavel (1983) reported significant increase in plant height, tiller production, number of leaves, number of mother, primary and secondary rhizomes and ultimately yield of turmeric due to K application. Singh *et al.* (1998) also showed that increasing rates of K application had a positive and significant effect on fresh rhizome yield. We explain the large difference in yield between 2010/11 and 2011/12 by heavy rainfall at the last stage of crop maturity. To conclude, during 2010/11 and 2011/12, application of 160 kg K ha^{-1} increased rhizome yields by 46 percent (as an average of the two years) over the control (K_0).

K uptake and balance

An apparent K balance was estimated on the basis of K supplied by fertilizer and removed by K uptake by the turmeric plants (Fig. 2). A well-defined pattern emerged in relation to K application. With increasing rate of K application, uptake of K increased and K balance also decreased correspondingly. Potassium uptake ranged from 68 to 180 kg K ha^{-1} as the rate of application increased. It is of interest that the K balance was found to be negative in all the treatments in the location under study, even though the crop had received balanced fertilization with other nutrients. The uptake of K by turmeric ranged between 68 to 180 kg K ha^{-1} for the varied rates of K application (Fig. 2). This finding is in agreement with the observation of Karthikeyan *et al.* (2009) and Sadanandan *et al.* (2002)

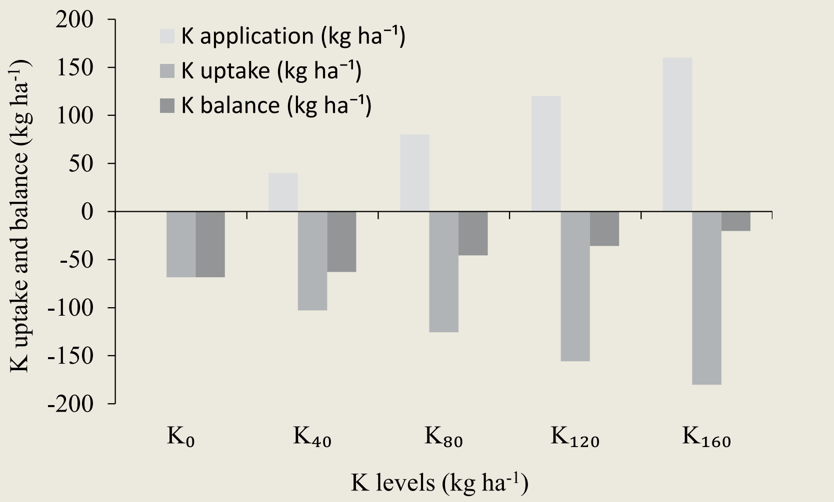

Fig. 2. Apparent K balance for turmeric in Bogra, 2010-2011.

who reported uptake of K to be highest, compared to other nutrients, by spice crops. These findings also reported an annual removal of 194 kg K ha^{-1} by turmeric through harvested produce which is in close agreement with our finding of 180 kg K ha^{-1} occurring at the highest rate of K application of 160 kg K ha^{-1}. Spice crops thus have a high demand for K which determines both yield and quality. This is especially important for turmeric which takes up large amounts of K from the soil which is removed at harvest in the rhizomes. Apart from this direct effect of K, the beneficial effect of K fertilization in increasing the uptake and utilization of other nutrients is an important aspect of K fertilization. Studies have also shown that K requirement of spices depends on the K status and dynamics in soil, the rooting pattern of different spices and varieties, and their productivity. There is thus an essential need for K to be supplied and maintained at optimum rates to augment production and improve quality (Sadanandan *et al.*, 2002; Sadanandan, 2000).

Economic performance

The economic performance of different levels of K is shown in Table 3. The highest gross additional returns in both years were with the highest K level applied. This resulted in additional income of approx. USD 2,200 to 2,600 per hectare, while the cost of K fertilizer applied was only USD 60 ha^{-1}. These findings also suggest that, with AE of over 50 kg kg^{-1} and relevant cost of input and harvested product, MOP application is not sensitive and should be applied sparingly.

Table 3. Economic performance of different levels of potassium on turmeric yield.

Treatment	Applied K	Agronomic efficiency K		Gross additional income		K cost
		2010/11	2011/12	2010/11	2011/12	
	kg ha^{-1}	-----------*kg kg^{-1}*-----------		----------*USD ha^{-1}*----------		*USD ha^{-1}*
T_1	0		-	-		-
T_2	40	76	85	755	850	15
T_3	80	62	65	1,233	1,300	30
T_4	120	70	54	2,100	1,625	45
T_5	160	65	56	2,600	2,250	60

Note: Input Price: kg K = Tk. 30; Output price: 1 kg turmeric = Tk. 20; 1 USD = 80 Tk.

Conclusion

The influence of K on growth, and yield parameters of turmeric (BARI Holud-3) was assessed through two field experiments on a Haplaquept light textured K deficient Terrace Soil of the Level Barind Tract (AEZ 25) in Bogra, the major turmeric growing region of Bangladesh. Turmeric was found to be highly responsive to K (AE achieved >50 kg kg^{-1}) which increased yields in the study area. Increasing the rate of application of K in the form of MOP enhanced growth, nutrient uptake and utilization, increasing yield of turmeric. Uptake of K by turmeric ranged between 68 and 180 kg K ha^{-1} and increased with increasing rate of K application. A negative K balance was observed even with balanced fertilization, implying the importance of K management in achieving sustainable yields and maintaining soil health. Economic analysis also showed very high profitability for potash application, exceeding USD 2,000 ha^{-1}.

Considering the economic returns, the linear response to K application and the negative K balance, the need for further investigation using higher levels of nutrient application should be considered. In the meantime, we strongly support that application of K at 160 kg ha^{-1}, along with a blanket dose of $N_{133}P_{18}S_{13}Zn_2$ kg ha^{-1}, be adopted as the best-suited dose for maximizing the yield of turmeric in K deficient Terrace Soil in the Level Barind Tract (AEZ 25).

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