Calibration of potassium requirement for maximum and economic yields of turmeric (*Curcuma longa* L.) in a Mollisol of Uttarakhand

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ABSTRACT : Turmeric has a high demand for plant nutrients and generally responds to applied nutrients for yield & quality. Soil test values were calibrated for potassium requirements for maximum and economic yields of turmeric in an Aquic Hapludoll of Mollisol of Uttarakhand. The R^2 value of 0.687* was obtained to be significant when multiple regression of turmeric with soil test values, fertilizer doses and interaction, between soil and fertilizer doses. Adjustment equations of potassium doses for maximum and economic yields of turmeric under varying soil test value and price ratios (of nutrient input and turmeric yield) with desired return had been worked out. From the results, it was clearly demonstrated that turmeric responded to addition of potassium even under high levels of initial soil test values. Potassium dose decreased with increasing price ratio and marginal return for economic yield of turmeric.

Key words: Economic yield, Mollisol, Potassium, STCR, turmeric

India is called as the "Spice bowl of the world" as it produces variety of spices with quality. Though India leads in production of turmeric, but average productivity is very low due to imbalanced and suboptimal dose of chemical fertilizers, organic manure, bio-fertilizers and micronutrients (Kandiannan and Chandragiri, 2008). For economic optimum, environmentally safe and sustainable productivity, it is highly desirable that the fertilizer should be used as dictated by soil tests and requirements of crop. Multiple regression analysis and fertility gradient approach provided the basis for quantitative nutrient adjustment, based on soil test for maximum yield per hectare, maximum profit per hectare and maximum return per rupee spent on nutrient (Ramamoorthy, 1971). Such type of correlation for turmeric is lacking for turmeric grown in Mollisols of Uttarakhand. Therefore, a field experiment was conducted to formulate fertilizer prediction equations for maximum and economic yields of turmeric based on soil tests by studying the yield response pattern to simultaneous variations in soil fertility levels and fertilizer doses.

MATERIALS AND METHODS

Field experiments were conducted at the experimental station of G.B. Pant University of Agriculture & Technology, Pantnagar in 2012-13 and 2013-14. The experiment was conducted in two phase. In the first phase, i.e.in the preparatory trial (2012-13) in which whole experimental area was divided into three equal strips where fertility gradient created by applying graded levels of N, P and K and growing forage Oat (var. UPO-212) as exhaust crop.

In the second phase (2013-14), experiment on turmeric (var. Pant peetabh) was conducted by dividing each strip into 24 plots which 21 plots received fertilizer treatments consisted of selected combination of four levels of N (0, 50, 100 and 150 kg ha^{-1}), four levels of P_2O_5 (0, 50, 100 and 150 kg ha^{-1}), four levels of K_2O (0, 50, 100 and 150 kg ha^{-1}) and three levels of FYM (0, 10 and 20 t ha^{-1}), 3 plots considered as control. Before applying fertilizers, soil samples from each plot at 0-15 cm depth were collected, dried and analyzed for available nitrogen by the Alkaline $KMnO_4$ method (Subbiah and Asija, 1956), for available phosphorus by olsen's method (Olsen *et al.* 1952) and for available potassium by the ammonium acetate method (Hanway and Hiedal, 1952). Standard agronomic practices were adopted and during digging of rhizome, total yield, rhizome yield and haulm yield of the individual plots were recorded. Multiple regression equations were worked out for various functions viz., SPSS and Bio stat with the help of a computer.

RESULTS AND DISCUSSION

After harvest of the gradient stabilizing crop, the experiment plot had a range of 0.58-1.05 percent organic carbon, 112.90 to 263.42 kg N ha^{-1} Alkaline $KMnO_4$-N, 16.97 to 29.27 kg ha^{-1} Olsen's P and 58.24 to 189.28 kg ha^{-1} ammonium acetate-K. Thus sufficient variation in soil fertility was present which is prerequisite for sound soil test crop response correlation (Velayutham *et al.,* 1985). The rhizome yield ranged from 113.33 to 354.17 q ha^{-1}. The multiple regression equation represent a relationship between rhizome yield as dependent variable and the soil test values, fertilizer doses, nutrient uptake, interaction between soil test values, fertilizer doses and among fertilizer nutrients as independent variables was established through a multiple regression equation of quadratic model.

The following regression equations have been worked out by using quadratic equation as given below:

YIELD = 290.9058*- 0.5586 SN - 5.6318 SP* + 0.5941 SK - 0.6164 FN - 4.4757 FP* + 1.5466 FK* - 0.0016 FN^2 + 0.0035 FP^2 - 0.0026 FK^2 + 0.0085 FNSN + 0.2007 FPSP* - 0.0065 FKSK (R^2= 0.687)

Where,

Y = Rhizome yield (q ha^{-1})

FN, FP and FK = Nitrogen, Phosphorus and Potassium through fertilizer (kg ha^{-1})

SN, SP and SK = Soil test value for Nitrogen, Phosphorus and Potassium (kg ha^{-1})

* Significant at 5 % level.

The value of coefficient of predictability (R^2) obtained in multiple regression equation is 0.687** is highly significant and model fit to the data according to STCR norms, indicating 68.7 per cent variation in yield can be predicted by complete set of available soil N, P, & K and applied fertilizer doses of N, P & K and their interaction. Generally, the R^2 values above 0.66 are taken as indication of good fit, 0.45 to 0.65 as moderate fit, and below 0.45 as poor fit of the equation (ICAR, 1974).

Type of responses identified in the present investigation was (+ - -) for potassium. Potassium showed the response type '+ - -' is characterized by positive and decreasing response of applied fertilizer nutrients. There is negative correlation between soil and fertilizer nutrients. The law diminishing return is said to be operate in this case. Therefore, it is the ideal response type (+ - -) for linear, quadratic and interaction term. By examine the signs of linear, quadratic and interaction terms of fertilizer potassium in above equation. The ideal equation for the partial function of potassium nutrient is following type:

$$Y = a + bx - cx^2 - dxz$$

Where,

a = constant independent of x and z

b & c = regression coefficient of linear and quadratic terms of x

z = soil test values of nutrient in question

x = fertilizer doses (kg ha^{-1})

On differentiating the above equation, the following mathematical expression emerged.

$$\frac{dy}{dx} = b - 2xc - dz$$

Since $\frac{dy}{dx}$ = 0 under condition of maximum yield

$$X_{(max)} = \frac{b - dz}{2c} \qquad \ldots (1)$$

Where,

$X_{(max)}$ = dose of fertilizer for maximum yield at soil test values z

Substituting the values b, c and d in above regression equation, where response type '+ – –' was obtained on the need of fertilizer for maximum yield was calculated. For economic dose, the consequences of 'law of diminishing return' have to be taken care of under such conditions where marginal return just equals the last rupee invested on fertilizer nutrient, that is output/input ratio become unity.

Mathematically, it may be expressed as :

$p\Delta Y = q\Delta X$

or

where,

p = Price of 1 kg of turmeric rhizome in rupees

q = Price of 1 kg of nutrient in rupees

y = Yield in q ha^{-1}

From above equations it can be inferred as:

$b - 2cx - dz = q/p$

$$\text{Or } X_{(eco)} = \frac{b - (q/p) - dz}{2c} \qquad \ldots (2)$$

Putting the value of b, c and d from above regression equation (+ – –) response type economic rider while deciding nutrient dose, that as 'desired marginal return'. This becomes especially important when limited money could be put for different alternative purposes return per last rupee of investment becomes the only, criteria, guiding the investment policy, under such conditions.

$p \times y = DR\ X\ qx$

where,

DR =desired marginal return on investment in fertilizer and therefore,

$$\frac{dy}{dx} = DR\ \frac{q}{p}$$

From the above equations it could be deduced to

$b - 2cx - dx = DR\ X\ q/p$

$$X_{(eco)}\ DR = \frac{b - (DR\ Xq/p) - dz}{2c}$$

By putting the values of b, c and d the economic doses can be calculated at a particular level of desired marginal return (DR), ratio (q/p) and soil test value (z)

Since + - - type of response only observed in case of potassium, therefore, fertilizer doses of maximum and economic yield can be calculated with the help of above equation .

$FK_{(max)}$=279.42 - 1.25 SK

$FK_{(econ)}$ = 279.42-1.25 SK - 26.60 x R x DR

Where,

SK = Soil test value of potassium (kg ha^{-1})

FK = Fertilizer potassium (kg ha^{-1})

PR (Price ratio) = q/p = price of 1 kg nutrient in question/price of 1 kg dry matter of turmeric.

The response type, obtained for potassium for turmeric can be seen from the regression equation (R^2=0.687) was signified by sign '+ - -'. The positive response will decrease with increasing soil test values for given fertilizer dose.

Thus, fertilizer doses of potassium for maximum and economic yields can be calculated by taking fertilizer cost and yield of dry rhizome at current price index with the help of above equations. The ready reckoner for fertilizer recommendation at various soil test values. Price ratio and desired marginal returns of 1, 2 and 3 rupee per last rupee invested in fertilizer are given in Table 1.

The data given in Table 1 clearly indicate that fertilizer potassium doses decreased with increasing price ratio (price of 1 kg potassium fertilizer per price of dry turmeric) and desired return, at any particular soil test value. Similarly, with increasing soil test value at particular price ratio and desired return, the economic fertilizer doses decreased. Similar results also found by Singh *et al.,* (1996), Singh *et al.,* (1997), Yanthan *et al.,* (2010) and Ahirwar *et al.,* (2015).

CONCLUSION

Therefore, it may be concluded that quadratic type multiple regression equation developed by connecting rhizome yield of turmeric as a dependent variable and soil test value, applied fertilizer doses and their interaction as independent variables are suitable for calculating fertilizer dose of potassium for maximum and economic yield of turmeric. From R^2 (0.687**) value, it can be observed that 68.7 per cent variation in turmeric yield can be predicted. Calibration of fertilizer dose of Potassium for maximum and economic yield with price ratio and marginal return invested in fertilizer by farmers recommended for turmeric in a Mollisol of Uttarakhand.

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Table 1: Potassium requirement of turmeric for maximum and economic yield

Soil test value (NH_4OAc-K)	**Max. yield**	**For economic yield**								
		Price ratio (R) = Price of one kg K_2O / Price of one kg dry turmeric								
		1			**2**			**3**		
		Desired return (DR)			**Desired return (DR)**			**Desired return (DR)**		
		1	**2**	**3**	**1**	**2**	**3**	**1**	**2**	**3**
75	203.67	177.07	150.47	123.87	150.47	97.27	44.07	123.87	44.07	-
100	172.42	145.82	119.22	92.62	119.22	66.02	12.82	92.62	12.82	-
125	141.17	114.57	87.97	61.37	87.97	34.77	-	61.37	-	-
150	109.92	83.32	56.72	30.12	56.72	3.52	-	30.12	-	-
175	78.67	52.07	25.47	-	25.47	-	-	-	-	-
200	47.42	20.82	-	-	-	-	-	-	-	-
225	16.17	-	-	-	-	-	-	-	-	-

$FK_{(max)}$ =279.42 - 1.25 SK

$FK_{(econ)}$ = 279.42-1.25 SK - 26.60 x R x DR

Price of one kg dry turmeric = Rs. 200.00, Price of one kg potassium fertilizer = Rs. 27.67

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