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Fertilizer-prescription equations for targeted yield in radish under integrated nutrient management system

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ABSTRACT

Soil test crop response correlation studies under integrated plant nutrient system were carried out in Inceptisol of West Bengal during 2008 – 2010, with radish as a test crop following Ramamoorthy's 'inductive-cum-targeted yield model'. Four fertilizer (NPK) and three farmyard manure (FYM) levels were randomized in three well-established fertility gradients, each comprising 21 plots. Soil and plant analysis data were interpreted to formulate fertilizer adjustment equations, with or without FYM, at varying yield targets. It was computed that 1.40, 0.17 and 2.8 kg N, P and K, respectively, were required for producing 100 kg of radish. Contribution of fertilizer-source to the total NPK uptake in radish was far higher than that obtained from FYM and soil available sources. A ready-reckoner developed from soil-test based fertilizer adjustment equations showed that FYM application at 10 t ha^{-1}, along with NPK fertilizer, resulted in a net saving of 15, 1.8 and 5.0kg ha^{-1} of N, P and K, respectively, for cultivating radish.

Key words: Fertility gradient, fertilizer-prescription equation, Inceptisol, radish, ready-reckoner, yield target

INTRODUCTION

Increase in the rate of population growth in India (1.3% in 2012, Economic Survey, 2012-13). has necessitates production of additional food from a shrinking land area, without deterioration of soil health. This needs extensive research to help develop a scientific model for enhancing and sustaining food production and soil productivity, entailing minimal environment degradation. To attain this, it is essential that nutrients removed from the soil are replaced through judicious use of fertilizers and manures. Intensive cropping and imbalanced fertilizer application are major causes for depletion of macronutrients like N, P and K from soil. Indian agriculture is running at a 'net negative nutrient balance' of a staggering 8-10 million tonnes per year (Tandon, 2004), a figure set to reach around 15 million tonnes by 2025. Application of fertilizers by farmers without information on soil-fertility status and crop nutrient requirement affects both the soil and the crop adversely (Ray *et al*, 2000). Soil testing is an ideal scientific means for a quick and reliable estimation of soil-fertility status. Soil test crop response studies in field provide soil-test calibration between level of soil nutrients determined in the laboratory, and crop response to fertilizers observed in the field, for predicting fertilizer requirement of a crop. It is well-documented through various experiments across the country that the actual on-farm yield is lower than potential yield of a crop (Aggarwal *et al*, 2000; Ladha *et al*, 2003). These yield gaps provide ample scope for improving yield levels using techniques that prescribe fertilizer nutrients based on soil-test values and yield-targets desired. Fertilizer recommendations based on soil test crop response correlation (STCRC) are more quantitative, precise and meaningful, because, a combined use of soil and plant analysis is involved. This presents a balance between nutrients applied and available nutrients (nutrients already present) in the soil. Besides, it takes into account the farmer's ability to invest in a crop. STCR treatments are also known to record positive responses in terms of biomass yield and net returns more so when integrated sources of nutrients are used (Santhi *et al*, 2002). So far, STCRC-IPNS studies have not been made in vegetable crops in West Bengal. As radish (*Raphanus sativus* L.) is an important vegetable crop grown extensively in India, the present study was made with an objective of developing fertilizer prescription equations for targeted yield in this crop using organic manure (FYM) and chemical fertilizers combined.

MATERIAL AND METHODS

Experimental site

To develop a scientific basis for prescribing fertilizer recommendations in radish, field experiments were carried out during 2008 - 2010 at Central Research Farm, Bidhan Chandra Krishi Viswavidyalaya, Gayeshpur, Nadia, India (22°58¹ N latitude and 88°29¹ E longitude), with fodder maize (cv. Prakash) as the gradient, and radish (cv. Red culpin) as the test crop. Soil at the experimental site was Inceptisol, sandy loam in texture, at pH 6.9 and with organic carbon content of 0.6%. Initial, available N, P and K level in the soil was 308, 24 and 155 kg ha^{-1}, respectively.

Fertility gradient experiment

Fertility-gradient experiment was conducted prior to the test-crop experiment as per inductive methodology proposed by Ramamoorthy *et al* (1967), during summer 2008-09, by dividing the experimental field into three rectangular strips along the breadth. Fertility gradients were created by applying graded doses of fertilizer N, P and K on the strips as shown in Table 1. Fodder maize was grown exhaustively to help the fertilizers undergo transformation in soil by the plant and microbes.

Test-crop experiment

After harvesting the exhaustive crop, each strip was divided into three sub-strips to impose three levels of FYM (0, 5 and 10 t ha^{-1}). Each sub-strip was further divided into seven sub-sub-strips, or plots, of 5m x 5m size. Thus, 21 plots constituted each strip. The test-crop experiment was conducted during *rabi* season (2008-09 and 2009-10) with radish (var. Red culpin) by superimposing 21 treatment combinations consisting of four levels of N (0, 40, 60 and 80 kg ha^{-1}), four levels of P (0, 9, 13 and 18 kg ha^{-1}) and four levels of K (0, 25, 33 and 50 kg ha^{-1}). In the 21 plots, all the 18 selected treatment-combinations, along with three Controls, were superimposed in each gradient strip, as per Fractional Factorial Randomized Block Design (or incomplete split-plot randomized block design) following the technical programme of All India Coordinated Research Project on Soil Test Crop Response Correlation (AICRP on STCRC) Studies. Half the N, along with full amount of P and K, was applied as a basal dose at the final land-preparation stage, and the rest half of N was top-dressed at 30 days after sowing.

Table 1. Graded dose of fertilizer applied to a gradient crop, maize

Strip	Level of fertilizer			Fertilizer dose (kg ha^{-1})		
				N	P	K
I	N_0	P_0	K_0	0	0	0
II	N_1*	P_1*	K_1*	100	22	83
III	N_2	P_2	K_2	200	44	166

* Recommended dose for fodder maize

Biometric observation

Total biomass yield in radish, comprising root and leaf, was recorded plot-wise after crop harvest under each treatment, under all the three fertility strips.

Soil analysis

Soil samples (0-0.2m depth) were collected before crop-sowing, prior to FYM and fertilizer application, and, after the harvest of both the gradient (maize) and the test (radish) crops. Soil samples were analyzed for available N, P and K as per standard methods (Jackson, 1973).

Plant analysis

At harvest, representative plant samples were collected from the test crop, washed thoroughly in tap water, followed by a wash in double distilled water. The plant samples were then dried at 60°C to a constant weight, ground and ashed at 550°C for 2 h in a muffle furnace. The ash was dissolved in 2N HCl for determining P and K content as per Chapman and Pratt (1961). Nitrogen content in the dried samples was estimated separately by digesting plant samples with sulphuric acid in the presence of digestion mixture ($CuSO_4$+K_2SO_4+ Se powder) (Micro-Kjeldahl digestion method), and, subsequently distilled and titrated (Jackson, 1973). Nutrient uptake was computed by multiplying the total dry-matter yield with nutrient concentration.

Data computation

From data on soil-test values, crop dry-matter yield and nutrient uptake, basic parameters like nutrient requirement (NR), soil efficiency (CS), fertilizer efficiency (CF) and organic efficiency (CO) were calculated, using the following formulae (developed as per Ramamoorthy *et al*, 1967):

$$\text{Nutrient requirement (NR) (kg of nutrient per 100kg of produce)} = \frac{\text{Total uptake of nutrient (kg ha}^{-1}\text{)}}{\text{Total biomass yield (100kg ha}^{-1}\text{)}}$$

$$\text{Soil efficiency or \% contribution from soil (CS)} = \frac{\text{Total uptake in Control plot (kg ha}^{-1}\text{)}}{\text{Soil-test value (STV) of nutrient in Control plot (kg ha}^{-1}\text{)}} \times 100$$

$$\text{Fertilizer efficiency or \% contribution from fertilizer (CF)} = \frac{\text{Total uptake in fertilized plot (kg ha}^{-1}\text{)} - \text{(STV of nutrient in fertilizer treated plot X CS)}}{\text{Fertilizer dose (kg ha}^{-1}\text{)}} \times 100$$

$$\text{Organic efficiency or \% contribution from organic component (CO)} = \frac{\text{Total uptake in organic plot (kg ha}^{-1}) - (\text{STV of nutrient in organic-treated plot X CS})}{\text{Organic fertilizer dose (kg ha}^{-1})} \times 100$$

From these basic parameters, fertilizer prescription equations were developed for radish using targeted yield calculator (TYC) software of AICRP on STCR, developed by Indian Institute of Soil Science, Bhopal. Based on the equations, fertilizer recommendation was prescribed as a ready-reckoner for arriving at desired yield-target in radish.

RESULTS AND DISCUSSION

Creation of fertility gradient at the experimental site

In the present investigation, all the variation needed in soil fertility level was created deliberately in the same field. The gradient crop developed variability in soil fertility in the three experimental strips in a differential manner. Available-nitrogen after harvest increased to 90.4 and 99.1 kg ha^{-1} in medium (Strip-II) and high (Strip-III) fertility-gradient strip, respectively, from that in the low fertility Strip-I (Table 2). On the other hand, available phosphorus content increased to 37.9 and 44.5 kg ha^{-1}, while, available potassium content increased to 35.2 and 81.4kg ha^{-1} in medium- and high-fertility gradient strips from the low fertility ones, respectively. Increased availability of N, P and K in soil was due to fertilizer application in graded doses, thus creating a fertility gradient in the same field. The gradient developed with regard to K was stiffer and uniform (Fig. 1), while, the same for N and P was rather non-uniform. Occurrence of non-uniform gradients for N and P is not uncommon (AICRP Bi-annual Report, STCR, 2007-08). This was due to loss of N through different mechanisms and by locking of P by soil components. Maize has been found to develop fertility gradients for the three major nutrients in the experimental strips, because, maize is an exhaustive crop causing overmining of plant nutrients, thus leaving relatively stable nutrient sinks in the soil that result in creating the fertility gradient.

Table 2. Soil chemical properties at completion of the gradient crop

Strip	pH_w	Organic C (%)	Available nutrient		
			N	P	K
			kg ha^{-1}		
I	7.21	0.50	267.4	20.2	130.7
II	7.04	0.65	357.8	58.1	165.9
III	7.01	0.62	366.5	64.7	212.1

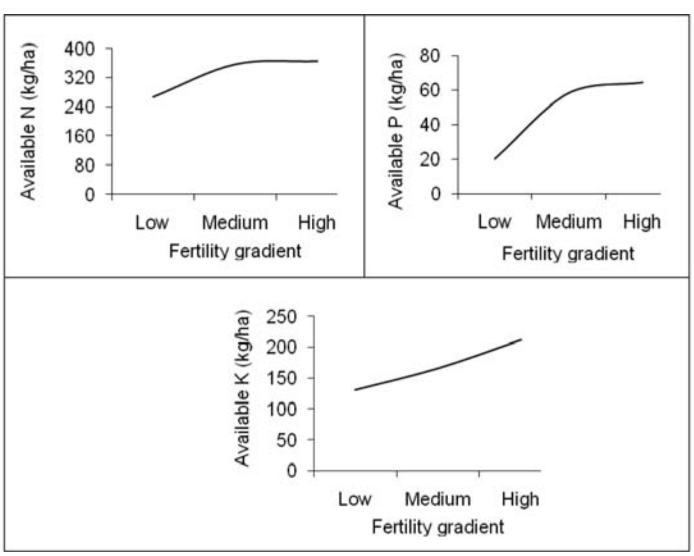

Fig. 1. Fertility gradient of the experimental field with reference to available N, P and K in soil

Yield response in radish

Results showed that yield in radish was significantly influenced by soil fertility gradient and level of FYM and NPK. On an average, irrespective of the dose of organic or NPK fertilizers, highest yield (48.8 t ha^{-1}) was recorded in medium-fertility strip, followed by high (41.6 t ha^{-1}) and low (38.7 t ha^{-1}) fertility strips (Table 3). Profuse growth of leaves in the high-fertility strip may have failed to translocate photosynthates to the roots, resulting in relatively low yield. Application of FYM at 5 t ha^{-1} produced the highest yield (45.1 t ha^{-1}), followed by 'no FYM' and FYM at 10 t ha^{-1}, irrespective of the gradient and dose of mineral NPK applied.

Across fertility gradients and FYM levels, yield in radish was significantly influenced by level of N imposed. Maximum yield (45.6 t ha^{-1}) was obtained with application of the highest level of N (80kg ha^{-1}). However, this yield was statistically at par with that obtained with 40 or 60kg N ha^{-1}. This indicates that the optimum dose of N for radish could be 40kg ha^{-1}. With increasing application of N, only vegetative growth increased. Yield increased significantly with increasing levels of P and K, and maximum yields were obtained with 13 and 33 kg ha^{-1} of P and K, respectively; thereafter, it dropped significantly with further increase in levels of both these nutrients. Thus, optimum levels of P and K for growing radish would be 13 and 33 kg ha^{-1}, respectively.

Nutrient uptake

Irrespective of the levels of FYM or NPK, no significant difference was seen in N uptake by the crop due to different fertility gradients, but the uptake of P and K was significantly influenced (Table 3). However, in all other cases too, the same trend was seen as in yield. Again,

Table 3. Effect of fertility gradient, FYM and NPK level on yield and NPK uptake in radish (mean of two years' data)

Gradient	Yield (t ha^{-1})	Nutrient uptake (kg ha^{-1})		
		N	P	K
Low	38.7^{b}	45.1	11.6^{b}	102.6^{b}
Medium	48.8^{a}	49.9	14.7^{a}	126.8^{a}
High	41.6^{b}	48.3	13.7^{a}	111.1^{b}
		NS		
FYM level (t ha^{-1})				
0	41.8	47.2	11.0^{c}	111.1
5	45.1	49.9	13.8^{b}	116.1
10	42.2	46.3	15.2^{a}	113.3
	ns	ns		ns
N level (kg ha^{-1})				
0	28.5^{b}	22.2^{c}	6.5^{c}	52.6^{b}
40	45.6^{a}	56.1^{a}	15.9^{a}	125.5^{a}
60	45.2^{a}	48.9^{b}	13.0^{b}	119.0^{a}
80	45.6^{a}	58.6^{a}	14.0^{b}	132.9^{a}
P level (kg ha^{-1})				
0	28.5^{c}	22.2^{b}	6.5^{c}	52.6^{c}
9	44.2^{ab}	47.0^{a}	12.6^{b}	110.5^{b}
13	48.4^{a}	54.1^{a}	15.3^{a}	132.8^{a}
18	42.1^{b}	53.9^{a}	15.1^{a}	122.2^{ab}
K dose (kg ha^{-1})				
0	28.5^{c}	22.2^{c}	6.5^{b}	52.6^{b}
25	46.1^{a}	49.8^{ab}	14.4^{a}	123.1^{a}
33	47.3^{a}	56.1^{a}	14.7^{a}	127.6^{a}
50	41.0^{b}	48.9^{b}	14.2^{a}	117.7^{a}

Values of mean followed by a different letter were significantly different at $p \leq 0.05$ using Duncan's Multiple Range Test (DMRT); NS indicates non-significant

irrespective of the gradient and NPK levels, FYM application had no significant effect on uptake of either N or K by radish. However, significant variation was observed in P uptake by the crop. Maximum uptake (15.2 kg ha^{-1}) resulted from application of 10 t FYM ha^{-1}, while, the minimum was with zero level of FYM.

Across fertility-gradients and FYM levels, application of different levels of N caused significant changes in uptake of N, P and K by radish. Maximum uptake of N and K was associated with the highest level of N application (80kg ha^{-1}), while, minimum values were obtained with no N input (Table 3). However, magnitude of NPK uptake due to application of different levels of P and K followed the same trend as that for yield. Uptake increased with increasing levels of P and K and, maximum NPK uptake was seen with application of optimum levels of P and K, as mentioned earlier, i.e., 13 and 33 kg ha^{-1}, respectively.

Developing targeted-yield equations in radish:

Basic parameters

Pre-sowing soil-test values, and, data on dry matter yield and nutrient uptake by radish, were used for calculating basic parameters, viz., nutrient requirement (NR) in kg for producing one quintal of radish, per cent contribution from soil (CS), fertilizer (CF) and organic source (CO). Average nutrient requirement for producing 100kg dry matter yield in radish was 1.40, 0.17 and 2.8 kg of N, P and K, respectively (Table 4). This is in close conformity with results of Bera *et al* (2006) and Thilagam and Natesan (2009). Contribution of N, P and K as estimated from soil, FYM and fertilizer sources was 6.8, 7.1 and 26.4; 17.6, 4.9 and 29.8, and 47.3, 27.4 and 186.7%, respectively. These results indicate that nutrient contribution from fertilizer sources is greater than that from soil or organic sources. These findings are in agreement with Ray *et al* (2000), Meena *et al* (2001), Shrinivas *et al* (2001) and Bera *et al* (2006). Interestingly, it was observed that contribution of K from fertilizer was more than 100% (186.7%). This high value of K could be due to an interaction effect of higher doses of N and P, and the primary effect of starter K dose, in treated plots leading to release of soil K, and consequent higher uptake from native soil sources by the crop (Ray *et al*, 2000). Similarly, high efficiency of potassic fertilizer was reported for rice by Ahmed *et al* (2002) and Bera *et al* (2006) in alluvial soil, and for maize (Reddy *et al*, 2000) and jute (Ray *et al*, 2000) in Inceptisol.

Table 4. Basic parameters of targeted yield equation for radish

Parameter	Basic data		
	N	P	K
Nutrient requirement (kg nutrient per 100kg dry matter yield)	1.40	0.17	2.8
Contribution from soil (soil efficiency, %)	6.8	7.1	26.4
Contribution from fertilizer (fertilizer efficiency, %)	47.3	27.4	186.7
Contribution from organics (organic efficiency, %)	17.6	4.9	29.8

Fertilizer-prescription equations, developed using basic parameters estimated by the whole-field method, are presented below:

Prescription equations for fertilizer NPK alone

$$\begin{cases} F_N = 2.95\,T - 0.14\,S_N \\ F_P = 0.62\,T - 0.26\,S_P \\ F_K = 1.47\,T - 0.14\,S_K \end{cases}$$

Prescription equations for fertilizer NPK plus organics (FYM)

$$\begin{cases} F_N = 2.95\,T - 0.14\,S_N - 0.37\,O_N \\ F_P = 0.62\,T - 0.26\,S_P - 0.18\,O_P \\ F_K = 1.47\,T - 0.14\,S_K - 0.16\,O_K \end{cases}$$

where,

F_N, F_P and F_K=fertilizer N, P and K required (kg ha^{-1}); T=yield target [(100 kg) ha^{-1}]; S_N, S_P and S_K=soil available N, P and K (kg ha^{-1}), and O_N, O_P and O_K=quantity of N, P and K added as FYM (FYM contains 0.46% N, 0.09% P and 0.37% K).

A ready-reckoner for fertilizer recommendation in radish

Based on generated equations, a ready-reckoner was prepared for different soil-test values for yield target of 35 and 45 t ha^{-1}, under NPK alone and under NPK+FYM. Results showed that for producing 35 t ha^{-1} of radish at average soil nutrient status of 300, 30 and 200 kg N, P and K ha^{-1}, respectively, fertilizer nutrient required was 39, 4.4 and 10.8 kg ha^{-1} N, P and K, respectively (Table 5); But, the requirement was reduced to 24, 2.6 and 5.8 kg ha^{-1} N, P and K, respectively, when the fertilizer was applied together with 10 t ha^{-1} FYM. This resulted in a saving of 15, 1.8 and 5.0 kg ha^{-1} N, P and K, respectively. Again, for producing 45 t ha^{-1} of radish at the same soil-available-nutrient levels, fertilizer nutrient requirement was 63, 6.6 and 20.8 kg ha^{-1} N, P and K, respectively (Table 6); But, the requirement was reduced to 48, 4.8 and 15.8 kg ha^{-1} N, P and K, respectively, when used with FYM. This resulted in similar magnitude of nutrient savings, i.e., 15, 1.8 and 5.0 kg ha^{-1} N, P and K, respectively. Thilagam and Natesan (2009) also reported that application of FYM at 15 t ha^{-1} together with chemical fertilizer resulted in a saving of 35, 10.9 and 23.3 kg ha^{-1} N, P and K, respectively, in cauliflower.

Table 5. A ready reckoner for fertilizer dose at varying soil-test values for a yield target of 35 t ha^{-1}

Soil-test value (kg ha^{-1})			Fertilizer nutrient required (kg ha^{-1}) for yield target of 35 t ha^{-1}					
			Inorganic			Inorganic+ FYM (10 t ha^{-1})		
N	P	K	N	P	K	N	P	K
250	5	100	47	7.0	22.5	32	5.7	17.5
275	10	125	43	6.6	20.0	28	4.8	14.2
300	15	150	39	6.1	16.7	24	4.4	11.7
325	20	175	36	5.2	13.3	21	3.9	8.3
350	25	200	32	4.8	10.8	17	3.1	5.8
375	30	225	29	4.4	7.5	15	2.6	2.5
400	35	250	25	3.5	5.0	10	2.2	0.0

Table 6. A ready reckoner for fertilizer dose at varying soil-test values for a yield target of 45tha^{-1}

Soil-test value (kg ha^{-1})			Fertilizer nutrient required (kg ha^{-1}) for yield target of 45 t ha^{-1}					
			Inorganic			Inorganic+ FYM (10 t ha^{-1})		
N	P	K	N	P	K	N	P	K
250	5	100	70	9.2	32.5	55	7.4	26.7
275	10	125	67	8.7	29.2	52	7.0	24.2
300	15	150	63	8.3	26.7	48	6.6	20.8
325	20	175	60	7.4	23.3	45	6.1	18.3
350	25	200	56	7.0	20.8	41	5.2	15.8
375	30	225	52	6.6	17.5	37	4.8	12.5
400	35	250	49	5.7	15.0	34	4.4	9.2

CONCLUSION

Irrespective of fertility gradient or FYM level, optimum dose of N, P and K for cultivating radish was 40, 13 and 33 kg ha^{-1}, respectively. This also corresponded to a higher removal of N, P and K by biomass of the harvested crop. Contribution of N, P and K from the soil-available pool was 6.8, 7.1 and 26.4% to total N, P and K uptake by the crop, respectively, while, such contribution from applied fertilizer was 47.3, 27.4 and 186.7%, and, that from applied FYM was 17.6, 4.9 and 29.8%, respectively. A ready-reckoner developed using soil-test based fertilizer adjustment equations in radish showed that application of FYM at10 t ha^{-1} along with chemical fertilizer resulted in a net saving of 15, 1.8 and 5.0 kg ha^{-1} of N, P and K, respectively, for cultivating radish at average soil-nutrient status of 300, 30 and 200 kg ha^{-1} N, P and K, respectively. This indicates the usefulness of STCRC-IPNS technology for achieving higher-crop production and a more rational use of fertilizer nutrients.

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