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Fertilizer Recommendations Developed through Soil Test Crop Response Studies with Integrated Plant Nutrient Management System for Field Pea in an Inceptisol

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A field experiment was conducted on Inceptisol at Agricultural Research Farm, Banaras Hindu University, Varanasi during *rabi* 2016 using integrated plant nutrient management system on the basis of STCR approach through which we are able to develop fertilizers recommendation equation for field pea. Soil test data, pea grain yield and NPK uptake by pea crop were used for achieving four important basic parameters *viz*., nutrients required to produce one quintal of pea grain (NR), contribution of nutrients from fertilizers (%CF), contribution of nutrients from soil (%CS) and contribution of nutrients from organic matter-FYM (%C-OM). It was found that 5.56, 0.79 and 3.08 kg of N, P_2O_5 and K_2O, respectively were required for producing one quintal pea grain yield. The per cent contribution of nutrients from soil, fertilizer and FYM were 36.2, 133.7 and 12.6 for N; 51.7, 24.8 and 3.04 for P_2O_5 and 23.0, 71.4 and 10.0 for K_2O, respectively. By using these basic parameters, ready reckoner of fertilizer doses was equipped for varying soil test values and desired yield targets of pea grain yield for NPK alone and NPK + FYM.

Key words: Pea, nutrient, grain yield, STCR, fertilizer, basic parameters, FYM

Field pea (*Pisum sativum* L.) belongs to leguminoceae family and is a native of Central or South-east Asia (Warren *et al.* 1956). It is also known as 'Dry Pea' and commonly known as 'Matar' in India. Field pea is one of the widespread pulse crop in the world as well as in India. Field pea generally comes in two colours, *i.e.* green and yellow. Pea is commonly used in human diet throughout the world and it is rich in protein (21-25%), carbohydrates, vitamin A, vitamin C, calcium (Ca), phosphorus (P) and has high levels of amino acids, lysine and tryptophan (Bhat *et al.* 2013). Peas are distributed in Asia, Africa, Europe, North America, Australia, China, Russia, Ukraine, India, Ethiopia, France, Canada and USA. India is the second largest producer of pea in the world after Russia (Negi *et al.* 2004). In India, field pea is grown over an area of 11.5 lakh ha with a production of about 10.36 lakh tonnes during XII Plan period (2012-15). Uttar Pradesh is the major field pea growing state with 4.59 lakh tonnes of production in 3.07 lakh ha areas (2012-13). It alone produces about 49% of pea produced in India. Besides Uttar Pradesh, Madhya Pradesh, Bihar and Maharashtra are the major pea producing states (Anonymous 2015).

One of the reasons for lower production is imbalanced use of fertilizers by the farmers without knowing soil fertility status and nutrient requirement of crop causes adverse effects on soil and crop both in terms of nutrient toxicity and deficiency (Ray *et al*. 2000). Farmers are using excess chemical fertilizers to achieve higher yield but the decision on fertilizer use requires knowledge of the expected crop yield and response to nutrient application. It is a function of crop nutrient needs, supply of nutrients from indigenous sources and the short-term and long-term fate of the applied fertilizer nutrients (Dobermann *et al*. 2003). Hence, there is a scope to increase the production of pea by soil test crop response (STCR) correlation method, the fertilizer doses are recommended based on fertilizer adjustment equations which are developed after establishing significant relationship between soil test values and the added fertilizers. Fertilizers recommendation based on STCR correlation concept are more quantitative, precise and

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meaningful because combined use of soil and plant analysis are involved in it. It gives a real balance between applied nutrients and the available nutrients already present in the soil. Keeping the above facts in view and non-availability of STCR-IPNS data for pea in eastern Uttar Pradesh this study was conducted.

The objective of this study was to evolve the sound basis of fertilizer prescriptions for field pea in alluvial soil (Inceptisol) at different soil fertility levels under the conditions of fertilizer scarcity and to ensure maximum fertilizer use efficiency. The study also intended to find the relationship between the nutrients supplied by the soil and added through organic and inorganic sources, their uptake and to develop a guideline for judicious application of fertilizers for desired yield target of field pea by using STCR model.

Materials and Methods

A field experiment was conducted taking pea as test crop during *rabi* 2016-17 on alluvial soil (Inceptisol) of Agricultural Research Farm, Institute of Agricultural Sciences, Banaras Hindu University, Varanasi to develop targeted yield equations following the procedure of Ramamoorthy *et al.* (1967). In 2015, selected site of 1245.6 m^2 dimension was divided into three strips of equal size and in each strip, different fertilizer doses, low (0, 0, 0), medium (120, 60, 60) and high (240, 120, 120) kg ha^{-1} of N, P_2O_5 and K_2O, respectively were applied to develop a fertility gradient, and rice variety Malviya-234 was grown as an exhaust crop during *kharif* 2016 for stabilizing fertility gradient. The crop was harvested at maturity in the succeeding season; field pea variety Malviya Pea-15 was grown as test crop during *rabi* 2016-17 in the same field in which the fertility gradient stabilizing experiment was conducted. Each strip (made in the fertility gradient stabilizing experiment in the previous season) was divided into 24 (21 treated and 3 control plots) equal sized (4 m × 3 m) plots resulting in total of 72 (24 × 3) plots. Three blocks (A, B and C) comprising of 8 treatments were made within each strip randomized with farmyard manure (FYM) levels. Treatments of N, P_2O_5, K_2O and FYM were used as shown in table 1. The fertilizers used were urea, single superphosphate and muriate of potash. Full doses of P_2O_5 and K_2O were applied as basal, while N was applied in two equal splits, half as basal and remaining half at 30 days after sowing. Plot-wise nutrient levels were tested before applying FYM and NPK. Soil samples (0-20 cm) from all the 72 plots were collected and analyzed for available N, by the alkaline permanganate method (Subbiah and Asija 1956); available P, by Olsen *et al*. (1954) and available K, by ammonium acetate method (Hanway and Heidel 1952). Pea crop was sown in lines at 30 cm apart; having 10 lines in a plot and recommended package of practices were followed. Pea grain and straw yields were recorded separately, and plant samples were taken for estimation of N, P and K contents for working out uptake by the crop. Plot-wise soil test data, fertilizers doses, yield and uptake were used for obtaining NR (nutrient required to produce one quintal pea grain yield), %CS (per cent contribution of nutrients from soil), %CF (per cent contribution of nutrients from fertilizers) and %C-OM (per cent contribution of nutrients from organic matter), as per method described by Ramamoorthy *et al.* (1967).

Table 1. Levels of nitrogen, phosphorus, potassium and FYM used in experiment

N (kg ha^{-1})	P_2O_5 (kg ha^{-1})	K_2O (kg ha^{-1})	FYM (t ha^{-1})
0	0	0	0
10	20	15	5
20	40	30	10
30	60	45	-

1. Nutrient requirement in kg q^{-1} of grain (NR)

$$= \frac{\text{Total uptake of the nutrient (kg ha}^{-1}\text{)}}{\text{Grain yield (q ha}^{-1}\text{) in plot}}$$

2. Per cent contribution of nutrients from soil (% CS)

$$= \frac{\text{Total uptake of nutrient in the control plot (kg ha}^{-1}\text{)}}{\text{Soil test values of nutrient in control plot (kg ha}^{-1}\text{)}} \times 100$$

3. Per cent contribution of nutrients from fertilizer without FYM (% CF)

$$= \frac{\left(\begin{array}{c}\text{Total uptake of}\\ \text{nutrient (kg ha}^{-1}\text{) in}\\ \text{fertilizer treated}\\ \text{plot}\end{array}\right) - \left(\begin{array}{c}\text{Soil test values}\\ \text{(kg ha}^{-1}\text{) of nutrient}\\ \text{in fertilizer treated}\\ \text{plot} \times \text{\%CS/100}\end{array}\right)}{\text{Nutrient dose applied through fertilizer (kg ha}^{-1}\text{)}} \times 100$$

4. Per cent contribution of nutrients from organic manure (%CFYM)

$$= \frac{\left(\begin{array}{c}\text{Total uptake of}\\ \text{nutrient (kg ha}^{-1}\text{) in}\\ \text{organic manure}\\ \text{treated plot}\end{array}\right) - \left(\begin{array}{c}\text{Soil test values}\\ \text{(kg ha}^{-1}\text{) of nutrient}\\ \text{in organic plot}\\ \times \text{\%CS/100}\end{array}\right)}{\text{Dose of nutrient added through FYM (kg ha}^{-1}\text{)}} \times 100$$

These parameters were used to develop equations for soil test based fertilizer recommendations for desired yield targets of field pea under NPK alone as well as NPK plus FYM.

Table 2. Available nutrients in pre-sowing surface soil and yield of pea crop

Parameters	NPK treated plots		Control plots	
	Range	Mean ± SEm	Range	Mean ± SEm
$KMnO_4$-N (kg ha^{-1})	218-271	244.5 ± 1.14	209-237	223 ± 3.18
Olsen-P (kg ha^{-1})	21-34	27.5 ± 0.42	19-25	22 ± 0.61
NH_4OAc-K (kg ha^{-1})	195-240	217.5 ± 1.35	184-216	200 ± 3.90
Yield (q ha^{-1})	15.8-26.4	21.1 ± 0.33	12.1-17.1	14.6 ± 0.55

Results and Discussion

Soil available nutrients and grain yield

The range and mean values of soil available nutrients and grain yield of field pea in treated and control plots are presented in table 2. In the NPK treated plots (plots that received NPK alone or NPK plus FYM), $KMnO_4$-N increased from 218 kg ha^{-1} in strip I to 271 kg ha^{-1} in strip III with a mean value of 244 kg ha^{-1}. The Olsen-P ranged from 21 kg ha^{-1} in strip I to 34 kg ha^{-1} in strip III with a mean value of 27 kg ha^{-1}, while the NH_4OAc-K status varied from 195 kg ha^{-1} in strip I to 240 kg ha^{-1} in strip III with a mean value of 217 kg ha^{-1}.

In the NPK treated plots that received NPK alone or NPK plus FYM, the yield of pea ranged from 15.8-26.4 q ha^{-1} with a mean value 21.1 q ha^{-1}. In the overall control plots, the yield ranged from 12.1-17.1 q ha^{-1} with a mean value of 14.6 q ha^{-1}. In the overall control plot of three fertility gradients (Table 2), the $KMnO_4$-N ranged from 209 to 237 kg ha^{-1} with a mean of 223 kg ha^{-1}, Olsen-P status ranged from 19 to 25 kg ha^{-1} with a mean value of 22 kg ha^{-1}, and the NH_4OAc-K status varied from 184 to 216 kg ha^{-1} with a mean value of 200 kg ha^{-1}. Though these soils are considered as fertile, they are low in N and humus and medium in P and K. Almost similar results were found by Bera *et al.* (2006) and Dwivedi *et al.* (2009) for on-farm evaluation of soil test based site specific nutrient management in pearl millet-based cropping systems on alluvial soils.

The above data clearly indicate the existence of operational range of soil test values for available N, P and K status and yield of treated and control plots, which is a pre-requisite for calculating the basic parameters and fertilizer prescription equations for calibrating the fertilizer doses for specific yield targets. The equations are:

NPK Alone

$FN = 4.15\ T – 0.27\ SN$

$FP_2O_5 = 3.18\ T – 2.08\ SP_2O_5$

$FK_2O = 4.31\ T –0.32\ SK_2O$

NPK + FYM

$FN = 4.15\ T – 0.27\ SN – 0.09\ ON$

$FP_2O_5 = 3.18\ T – 2.08\ SP_2O_5 – 0.12\ OP_2O_5$

$FK_2O = 4.31\ T – 0.32\ SK_2O – 0.14\ OK_2O$

FN = Fertilizer N (kg ha^{-1})

FP_2O_5 = Fertilizer P_2O_5 (kg ha^{-1})

FK_2O = Fertilizer K_2O (kg ha^{-1})

T = Yield target (q ha^{-1})

where, SN, SP_2O_5 and SK_2O, respectively are alkaline $KMnO_4$-N, Olsen-P as P_2O_5 and NH_4OAc-K as K_2O in kg ha^{-1} and ON, OP_2O_5 and OK_2O are the quantities of N, P_2O_5 and K_2O in kg ha^{-1} supplied through FYM, respectively.

Basic parameters

The basic data *viz*., nutrient requirement for producing one quintal grain of pea, per cent contribution of nutrients from soil (%CS), fertilizer (%CF) and FYM (%CFYM) have been calculated (Table 3). These basic parameters were used for developing the fertilizer prescription equations under NPK alone and NPK plus FYM. The nutrient requirement of N, P_2O_5 and K_2O were 5.56, 0.79 and 3.08 kg q^{-1} of grain, respectively. The %CS and %CF were found to be 36.2 and 133.7 for N, 51.7 and 24.8 for P_2O_5 and 23.0 and 71.4 for K_2O. Similarly, the per cent contribution of N, P_2O_5 and K_2O from FYM was 12.6, 3.08 and 10.0, respectively. It was noted that contribution of K from fertilizer for pea was higher in comparison to soil. This high value of K could be due to the interaction effect of higher doses of N, P coupled with priming effect of starter K doses in the treated plots, which might have caused the release of soil K, resulting in the higher uptake from the native

Table 3. Basic data and fertilizer adjustment equations of field pea (*var.* Malviya Pea-15) in inceptisol

Basic Data	N	P_2O_5	K_2O
Nutrient requirement (kg q^{-1})	5.56	0.79	3.08
Soil efficiency (%) or %CS	36.2	51.7	23.0
Fertilizer efficiency (%) or %CF	133.7	24.8	71.4
Organic efficiency (%) or %CFYM	12.6	3.04	10.0

Table 4. Estimation of soil test based fertilizer recommendation for 25 q ha^{-1} grain yield target of pea crop

Soil test values ($kg\ ha^{-1}$)			Fertilizer doses ($kg\ ha^{-1}$) under NPK alone			Fertilizer dose ($kg\ ha^{-1}$) under NPK+ FYM @ 10 t ha^{-1}		
SN	SP	SK	FN	FP_2O_5	FK_2O	FN	FP_2O_5	FK_2O
180	10	140	55.1	58.7	62.9	50.6	55.1	57.3
200	15	160	49.7	47.4	56.5	45.2	44.7	50.9
220	20	180	44.3	37.0	50.1	39.8	34.3	44.5
240	25	200	38.9	26.6	43.7	34.4	23.9	38.1
260	30	220	33.5	16.2	37.3	29.0	13.5	31.7

SP = Soil available P as P_2O_5, and SK = Soil available K as K_2O.

Table 5. Prediction equations for post-harvest soil test value for pea

Nutrient	R^2	Multiple regression equation
N	0.95**	PHN = 4.0235 + 0.5914PY** + 0.9658SN** + 0.0371FN*
P	0.98**	PHP = -3.3040 + 0.0519PY* + 1.2034SP** + 0.0259FP**
K	0.96**	PHK = -3.3323 - 0.0154PY** + 1.0409SK** - 0.0023FK

** Significant at 1 % level: Here PHN, PHP and PHK stand for the post-harvest soil test values of N, P and K (kg ha^{-1}); PY is the pea grain yield (q ha^{-1}), SN, SP_2O_5 and SK_2O represent the initial soil test values of N, P and K (kg ha^{-1}) and FN, FP and FK represent the fertilizer doses of N, P_2O_5 and K_2O kg ha^{-1} required.

soil sources by the crop (Ray *et al*. 2000). Similar type of higher efficiency of K-fertilizer was also reported for rice by Ahmed *et al*. (2002) in alluvial soils. Contribution of nutrients from FYM is low which might be due to lower mineralization rate of FYM (Sachan *et al*. 1981). However, in the case of P_2O_5, the contribution was more from soil than from fertilizer.

An assessment of fertilizer doses was made based on these equations for a range of soil test values and for yield target of 25 q ha^{-1} of pea (Table 4). For achieving this target with soil test values of 180:10:140 kg ha^{-1} of $KMnO_4$-N, Olsen-P and NH_4OAc-K, the fertilizer N, P_2O_5 and K_2O doses required were 46.1, 51.5 and 51.7 kg ha^{-1}, respectively. When FYM (0.5, 0.3 and 0.4% of N, P_2O_5 and K_2O, respectively) was applied @ 10 t ha^{-1} along with NPK, the required fertilizer N, P_2O_5 and K_2O doses were 50.6, 55.1 and 57.3 kg ha^{-1}, respectively. Under IPNS system the required dose of fertilizer is low due to increased nutrient availability by FYM through mineralization.

Fertilizer prescription equations were transformed into ready reckoner for requirements of fertilizer, say for yield target of 25 q ha^{-1} of pea on soils with varying soil test value for both NPK applied with and without FYM. From this findings it is obvious that with varying soil test values, the fertilizer recommendation varies for the same level of crop production. Hence, balanced fertilization through soil testing becomes essential for increasing crop production. Similar results were also found by Avtari *et al*. (2010) for 2 t ha^{-1} yield of yellow mustard, Prakash and Singh (2013) in wheat, Regar and Singh (2014) in rice, Mishra *et al.* (2015) in chickpea and Singh *et al.* (2015) in maize. It is obvious from these findings that there was net saving of fertilizers in each target and ultimately to reduce cost of cultivation.

Prediction of post-harvest soil available nutrients (N, P and K)

A post-harvest prediction equation of soil test value can be used to make a fertilizer recommendation for entire cropping scheme. This is very useful because the soil of farmers' field under intensive farming cannot be tested for each crop for practical reasons. The interactions among the post-harvest soil test values, fertilizer applied doses, initial soil test values and grain yield from the treated plots for pea crop are obtained in table 5.

Noticeably large R^2 values (significant at 1%) were obtained for these equations. This suggests that such regression equations can be applied with confidence for the prediction of available N, P and K after pea for making soil test based fertilizer recommendation for succeeding crops. Similar significances were also found by Verma and Singh (1991) and Bera *et al.* (2006) for the three major nutrients.

Conclusions

Use of integrated plant nutrient management system resulted in saving of fertilizer nutrients in pea crop. Target yield equations generated from STCR-IPNMS tools ensures not only sustainable crop production but also economize use of high cost fertilizer inputs which is desirable cost benefit ratio. Practice of fertilizing crops using fertilizer prescription equations needs to be popularized among farmers to achieve higher productivity, nutrient use efficiencies and profitability. It is also advocated that the trends observed in this study may hold true for broad generalization in the larger parts of the Gangetic eastern plains that would serve as potent guide for efficient fertilizer management sustainably.

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