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# Fertilizer Requirement of Lentil Based on Soil Test Crop Response Correlation Approach in an Inceptisol

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An experiment on nutrient requirement of lentil crop based on soil test crop response (STCR) correlation studies was conducted in an Inceptisol at Agricultural Research Farm, Banaras Hindu University, Varanasi during *rabi* 2017-18. Soil test data, lentil grain yield and NPK uptake by lentil crop were used for obtaining four important basic parameters, *viz*., nutrients required to produce one quintal of lentil grain (NR), contribution of nutrients from fertilizers (%CF), contribution of nutrients from soil (%CS) and contribution of nutrients from organic matter (%C-OM). It was found that 4.99, 0.90 and 2.16 kg of N, $P_2O_5$ and $K_2O$, respectively were required for producing one quintal lentil grain. The per cent contribution of nutrients from soil, fertilizer and FYM were 29.1, 105.1 and 7.3 for N; 65.3, 38.7 and 2.4 for $P_2O_5$; and 14.1, 58.5 and 4.3 for $K_2O$, respectively. Making use of these basic parameters, fertilizer prescription equations were developed for lentil (var. HUL-57TL) and an estimate of fertilizer doses formulated for a range of soil test values and desired yield targets for NPK alone and NPK plus FYM.

**Key words:** Lentil, STCR, nutrient requirement, basic parameters, FYM and Inceptisol

Lentil (*Lens culinaris* Medikus) is one of the important pulse crops in India which is cultivated in~1.48 million hectares (Mha) with a total production of 1.03 million tonnes (Mt). It is used as rich source of protein in vegetarian diet. In recent years, the area under lentil has expanded considerably because of its popularity in different cropping systems. The existing state blanket recommendation for lentil in Utter Pradesh does not ensure efficient and economic use of fertilizers, as it does not take into account the fertility variations resulting in imbalanced use of fertilizer nutrients. Dumping of fertilizers by the farmers in the fields without knowledge of soil fertility status and nutrient requirement by crop causes adverse effects on soil and crop regarding both nutrient toxicity and deficiency either by over or inadequate use (Ray *et al*. 2000). The fertilizer application by the farmers in the field without knowledge of soil fertility status and nutrient requirement of different crops usually leads to adverse effect on soil as well as crops by way of nutrient deficiency or toxicity due to over use or inadequate use of fertilizers. In this regard, targeted yield approach has been found to be beneficial which recommends balanced fertilization considering available nutrient status in the soil and the crop needs. Ramamoorthy *et al*. (1967) established theoretical basis and experimental technique to suit it to Indian conditions. For obtaining a given yield, needed fertilizer can be estimated considering efficiency of soil and fertilizer nutrient. The targeted yield approach circumvents the effect of soil heterogeneity, management practices and climatic conditions on the response behaviour of crops through native and fertilizer nutrients.

The objective of this study was to evolve the sound basis of fertilizer prescriptions for lentil 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 fertilizer for desired yield target of lentil by using STCR model.

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## Materials and Methods

A field experiment was conducted taking lentil as test crop during *rabi* 2017-18 on alluvial soil (Inceptisol) at Agricultural Research Farm, Banaras Hindu University, Varanasi to develop targeted yield equations following the procedure of Ramamoorthy *et al.* (1967). In 2017, selected site of 1269.6 $m^2$ 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 sorgham (var. M.P. chari) was grown as an exhaust crop during *kharif* 2017 for stabilizing fertility gradient. The crop was harvested at maturity. In the succeeding season, lentil (var. HUL-57TL) was grown as test crop during *rabi* 2017-18 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 0.5 *M* $NaHCO_3$ method (Olsen *et al.* 1954) and available K, by ammonium acetate method (Hanway and Heidel 1952) as described by Jackson (1973). Lentil was sown in lines at 50 cm apart; having 6 lines in a plot and recommended package of practices were followed. Lentil 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 a ton of lentil grain), %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 | - |

*Method of developing the basic data*

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

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

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 (%CF) without FYM

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

4. Per cent contribution of nutrients from fertilizer with FYM (%CFFYM)

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

5. Per cent contribution of nutrients from FYM (%CFYM)

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

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

## Results and Discussion

*Soil available nutrients and grain yield*

The range and mean values of soil available nutrients and grain yield of lentil in treated and control plots are furnished in table 2. In the NPK treated

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

| Parameters | NPK treated plots | | Control plots | |
|---|---|---|---|---|
| | Range | Mean ± SEm | Range | Mean ± SEm |
| $KMnO_4$-N (kg $ha^{-1}$) | 222.9-267.5 | 237.6 ± 2.4 | 200.0-234.1 | 217.11 ± 5.1 |
| Olsen-P (kg $ha^{-1}$) | 15.3-24.2 | 20.7 ± 4.0 | 10.9-21.9 | 16.44 ± 1.6 |
| $NH_4OAc$-K (kg $ha^{-1}$) | 186.9-231.1 | 209.0 ± 2.8 | 174.4-221.4 | 197.95 ± 7.7 |
| Yield (q $ha^{-1}$) | 18.1-21.9 | 20.0 ± 0.32 | 11.8-16.3 | 14.0 ± 0.46 |

plots (plots that received NPK alone or NPK plus FYM), $KMnO_4$-N increased from 222.9 kg $ha^{-1}$ in strip I to 267.5 kg $ha^{-1}$ in strip III with a mean value of 237.6 kg $ha^{-1}$. The Olsen-P ranged from 15.3 kg $ha^{-1}$ in strip I to 24.2 kg $ha^{-1}$ in strip III with a mean value of 20.7 kg $ha^{-1}$, while the $NH_4OAc$-K status varied from 186.9 kg $ha^{-1}$ in strip I to 231.1 kg $ha^{-1}$ in strip III with a mean value of 209.0 kg $ha^{-1}$.

In the NPK treated plots that received NPK alone or NPK plus FYM, the yield of lentil ranged from 18.1 to 21.9 q $ha^{-1}$ with a mean value 20.0 q $ha^{-1}$. In the overall control plots, the yield ranged from 11.8 to 16.3 q $ha^{-1}$ with a mean value of 14.0 q $ha^{-1}$. In the overall control plot of three fertility gradients (Table 2), the $KMnO_4$-N ranged from 200.0 to 234.1 kg $ha^{-1}$ with a mean of 217.1 kg $ha^{-1}$, Olsen-P status ranged from 10.9 to 21.9 kg $ha^{-1}$ with a mean value of 16.4 kg $ha^{-1}$, and the $NH_4OAc$-K status varied from 174.4 to 221.4 kg $ha^{-1}$ with a mean value of 197.9 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 Dwivedi *et al.* (2009) and Singh and Singh (2014) 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 prerequisite for calculating the basic parameters and fertilizer prescription equations for calibrating the fertilizer doses for specific yield targets. The equations are:

*NPK Alone*

$FN = 4.67\ T - 0.28\ SN$

$FP_2O_5 = 2.32\ T - 1.69\ SP$

$FK_2O = 3.70\ T - 0.24\ SK$

*NPK + FYM*

$FN = 4.67\ T - 0.28\ SN - 0.07\ ON$

$FP_2O_5 = 2.32\ T - 1.69\ SP - 0.06\ OP$

$FK_2O = 3.70\ T - 0.24\ SK - 0.07\ OK$

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

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

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

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

where, SN, SP and SK, 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 and OK 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 yield of lentil, 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 4.99, 0.90 and 2.16 kg $q^{-1}$ of grain, respectively. The %CS and %CF were found to be 29.1 and 105.1 for N, 65.3 and 38.7 for $P_2O_5$ and 14.1 and 58.5 for $K_2O$. Similarly, the per cent contribution of N, $P_2O_5$ and $K_2O$ from FYM was 7.3, 2.4 and 4.3, respectively. It was noted that contribution of K from fertilizer for lentil 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 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 and for chickpea by Mishra *et al*. (2015).

**Table 3.** Basic data and fertilizer adjustment equations of hybrid lentil (var. HUL-57TL) in alluvial soils

| Basic data | N | $P_2O_5$ | $K_2O$ |
|---|---|---|---|
| Nutrient requirement (kg $q^{-1}$) | 4.99 | 0.90 | 2.16 |
| Soil efficiency (%) or %CS | 29.1 | 65.3 | 14.1 |
| Fertilizer efficiency (%) or %CF | 105.1 | 38.7 | 58.5 |
| Organic efficiency (%) or %CFYM | 7.34 | 2.49 | 4.34 |

**Table 4.** Estimation of soil test based fertilizer recommendation for 20 q ha$^{-1}$ grain yield target of lentil

| 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 | 10.0 | 160 | 43.0 | 29.5 | 35.6 | 39.5 | 27.7 | 32.8 |
| 200 | 15.0 | 180 | 37.4 | 21.0 | 30.8 | 33.9 | 19.2 | 28.0 |
| 220 | 20.0 | 200 | 31.8 | 12.6 | 26.0 | 28.3 | 10.8 | 23.2 |
| 240 | 25.0 | 220 | 26.2 | 4.1 | 21.2 | 22.7 | 2.3 | 18.4 |
| 260 | 30.0 | 240 | 20.6 | 0.0 | 16.4 | 17.1 | 0.0 | 13.6 |

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 lentil

| Nutrient | $R^2$ | Multiple regression equation |
|---|---|---|
| N | 0.91** | PHN = 56.06 + 1.542LY** + 0.68533SN** + 0.0079FN* |
| P | 0.82** | PHP = 4.51044 + 0.40946LY* + 0.35639SP** - 0.00693FP** |
| K | 0.74** | PHK = 110.5179 + 1.25269LY** + 0.44816SK** - 0.03117FK |

** Significant at 1% level: Here PHN, PHP and PHK stand for the post harvest soil test values of N, P and K (kg ha$^{-1}$); LY is the lentil yield (q ha$^{-1}$), SN, SP and SK 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$^{-1}$ applied.

Contribution of nutrients from FYM is low which might be due to lower mineralization rate of FYM (Singh *et al*. 2015). However, in the case of $P_2O_5$, the contribution was more from soil than from fertilizer.

An estimate of fertilizer doses was prepared based on these equations for a range of soil test values and for yield target of 20 q ha$^{-1}$ of lentil (Table 4). For achieving this target with soil test values of 180:10:160 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 43.0, 29.5 and 35.6 kg ha$^{-1}$, respectively. When FYM (0.5, 0.3 and 0.4% of N, P and K, respectively) was applied @ 10 t ha$^{-1}$ along with NPK, the required fertilizer N, $P_2O_5$ and $K_2O$ doses were 39.5, 27.7 and 32.8 kg ha$^{-1}$, respectively. Under STCR approach the required dose of fertilizer is low due to nutrient availability increased by FYM through mineralization. Singh *et al.* (2017) also reported that under integrated plant nutrient system, required dose of fertilizer to achieve desired yield target are reduced.

Fertilizer prescription equations were transformed into ready reckoner for requirements of fertilizer, say for yield target of 20 q ha$^{-1}$ of lentil on soils with varying soil test value for both NPK applied with and without FYM. These results clearly showed that the fertilizer requirements varied with the soil test values for the same level of crop production. Hence, balanced fertilization through soil testing becomes essential for increasing crop production. Similar results were found by Regar and Singh (2014) for 40 q ha$^{-1}$ yield of rice and Prakash and Singh (2013) for 45 q ha$^{-1}$ yield of wheat. It is obvious from these findings that there was net saving of fertilizers in each target.

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

The prediction equation for a post-harvest soil test value can be used to make a fertilizer recommendation for entire cropping system. This is very useful because the soil of farmers' fields under intensive cultivation cannot be tested for each crop for practical reasons. The relationships amongst the post-harvest soil test values, fertilizer applied doses, initial soil test values and grain yield from the treated plots for *rabi* lentil crop are presented in table 5.

Appreciably large $r^2$ values (significant at 1%) were obtained for these equations. This suggests that such regression equations can be used with confidence for the prediction of available N, P and K after lentil for making soil test based fertilizer recommendation for succeeding crops. Similar results were also found by Bera *et al.* (2006) and Singh *et al.* (2014) for the three major nutrients.

## Conclusions

These findings can successfully be used in the larger parts of Gangetic eastern plains of Uttar Pradesh as effective guide for efficient fertilizer management by reducing cost of cultivation, increasing fertilizer-use efficiency and keeping environment pollution free, maintaining soil quality and soil health with judicious use of chemical fertilizers. Therefore, soil test based fertilizer recommendation may be a useful tool for balanced fertilization of nutrients.

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