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Integrated Fertilizer Recommendations for Lentil through Targeted Yield Model on Mollisol

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In order to develop the relationship between soil test and response of lentil to applied fertilizers under Integrated Plant Nutrition System (STCR-IPNS), a field experiment was conducted on *Aquic Hapludoll* of Uttarakhand during *Rabi* 2009-10 following Ramamoorthy's targeted yield model. Using the data on grain yield, initial soil test values on available NPK, doses of fertilizers and farm yard manure (FYM) applied and NPK uptake, the basic parameters *viz.,* nutrient requirement, contribution from soil, fertilizers and FYM were computed. It was found that 5.24, 0.72 and 3.58 kg of N, P and K respectively were required for producing one quintal of grain. The percent contribution of nutrients from soil, fertilizer and FYM were 32.01, 43.02 and 11.02 for N; 30.0, 32.03 and 8.04 for P; 31.06, 42.01 and 9.00 for K respectively. Making use of these basic parameters, fertilizer prescription equations were developed for lentil (*var*. PL-5) and an estimate of fertilizer doses were formulated for a range of soil test values and desired yield targets under NPK alone and IPNS (NPK plus FYM). Coefficient of determination (R^2) was significant (0.805 **) between yield and soil test values. Verification trial was also conducted to test the validity of fertilizer prescription equations in next season i.e. *Rabi* 2010-11. The variation in yield obtained from targeted yield ranged from -5.0 to +1.9 %.The farmer's practice of fertilizer application was least efficient to produce grain yield of lentil in comparison to other treatments. Highest response ratio was found with farm yard manure 10 t ha^{-1}+ yield target 16 q ha^{-1}.

Key words: Fertilizer prescription equations, integrated plant nutrition system, Lentil, Soil test crop response, yield target, Mollisol.

Lentil (*Lens culinaris* Medikus) is one of the important pulse crops in India which is cultivated in ~1.48 million hectares with a total production of 1.03 million tonnes (Anonymous, 2011) . 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 crop is well adapted to very poor and marginal uplands, where other *Rabi* crops cannot be grown successfully. The existing state blanket recommendation for lentil in Uttarakhand 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). Balanced fertilization is a function of soil type, crop or cropping pattern, inputs, residue effects, available soil nutrients, yield targets, economics of fertilizer use and time (Ghosh *et al*., 2004). 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. They showed linear relationship between grain yield and nutrient uptake. 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 behavior of crops through native and fertilizer nutrients. Hence, an effort was made to study the relationship between the nutrient supplied by the soil and added fertilizers, their uptake and yield of lentil and to develop appropriate balanced fertilizer schedules for Mollisol under integrated nutrient management system.

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Materials and Methods

A field experiment with lentil was conducted during 2009-10 on *Aquic Hapludoll* (Deshpande *et* *al*., 1971) at N.E.Borlaug Crop Research Centre of G.B. Pant University of Agriculture & Technology, Pantnagar, Uttarakhand). The surface soil of the experimental field was sandy loam in texture with pH 7.27 and electrical conductivity (EC) 0.32 dSm$_{-1.}$ The initial soil available alkaline potassium permanganate ($KMnO_4$) nitrogen (N), Olsen's phosphorus (P) and ammonium acetate (NH_4OAC) potassium (K) were 255 kg ha$_{-1}$, 26.4 kg ha$_{-1}$ and 181 kg ha$_{-1}$ respectively. By adopting the technique of inductive methodology developed by Ramamoorthy *et al*., (1967),variation in soil fertility was created by dividing the experimental field into three equal stripes, which were fertilized with $N_0P_0K_0$ (stripe I), $N_1P_1K_1$ (stripe II) and $N_2P_2K_2$ (stripe III) levels and a crop of sorghum variety (UTFS-46) was grown. After the harvest of sorghum crop, each strip was divided into 24 plots and pre sowing soil samples were collected from each plot and analyzed for alkaline $KMnO_4$-N (Subbiah and Asija, 1956), Olsen-P (Olsen *et al*., 1954) and NH_4OAc-K (Hanwey and Heidal, 1952). The experiment was laid out in a fractional factorial design comprising twenty four treatments with four levels of N (0, 15, 30, 45 kg ha$_{-}$^{1}), four levels of P_2O_5 (0, 25, 50 and 75 kg ha^{-1}), four levels of K_2O (0, 20, 40 and 60 kg ha$_{-1}$) and three levels of FYM (0, 5 and 10 t ha$_{-1}$). The IPNS treatments *viz.,* NPK alone, NPK+ FYM @ 5 t ha$_{-1}$ and NPK+ FYM @10 t ha$_{-1}$ were superimposed across the strips. The 21 fertilizer treatments and three controls were randomized in such a way that all the 24 treatments were present in all the three strips in either direction. The treatment structure is given in Table 1. Fertilizer used was urea, single super phosphate and muriate of potash and applied as a basal. The crop was grown in unirrigated condition to maturity and the grain and straw yields were recorded. From each plot, plant and grain samples were collected, processed and analyzed for total N, P and K contents and total uptake of each nutrient was calculated.

The basic parameters *viz*., nutrient requirement (NR), contribution of nutrients from soil (Cs) and fertilizers (Cf) were calculated by Ramamoorthy *et al*., (1967) and FYM (Cfym) was estimated as described by Santhi *et al*., (2002) from the data on nutrient uptake, crop yield, initial soil available nutrients and fertilizer/FYM doses applied. The basic parameters *viz*., nutrient requirement (NR), contribution of nutrients from soil (Cs) and fertilizers (Cf) were calculated by Ramamoorthy *et al*., (1967). These parameters were then transferred to workable equations as follows:

With NPK Alone $FD = \frac{NR}{Cf} \times 100 \times T - \frac{Cs}{Cf} \times STV$

With NPK + FYM $FD = \frac{NR}{Cf} \times 100 \times T - \frac{Cs}{Cf} \times STV - \frac{Cfym}{Cf} \times M$

Where, FD = Fertilizer dose of nutrient (kg ha$_{-1}$); T= Yield target (q ha$_{-1}$); STV= Soil Test Value for available N, P, K (kg ha$_{-1}$); M = Quantities of N/P/K supplied through farmyard manure (kg ha$_{-1}$).

Multiple regression equation to various functions connecting the grain yield of lentil with fertilizer doses ,soil test values and interaction between them were also fitted as $Y = \pm A \pm b_1 SN \pm b_2 SN^2 \pm b_3 SP \pm b_4 SP^2 \pm b_5 SK \pm b_6 SK^2 \pm b_7 FN \pm b_8 FN^2 \pm b_9 FP \pm b_{10} FP^2 \pm b_{11} FK \pm b_{12} FK^2 \pm b_{13} FNSN \pm b_{14} FPSP \pm b_{15} FKSK$; Where, Y= Crop yield (kg ha$_{-1}$); A = Intercept (kg ha$_{-1}$); bi = regression coefficients (kg ha$_{-1}$); SN, SP, SK = Available soil nitrogen, phosphorus and potassium (kg ha$_{-1}$) respectively; FN, FP, FK = fertilizer nitrogen, phosphorus and potassium (kg ha$_{-1}$) respectively.

To test the validity of these fertilizer prescription equations for lentil crop, verification trial was conducted during *Rabi* 2010-11 on the same soil type with Six treatments *viz.* T_1= Farmer's practice (FP), T_2= FYM @ 10 t ha^{-1} (FYM), T_4= General recommended dose (GRD), T_5= Yield target 16 q ha^{-1}(STCR YT_1) and T_6= Yield target 18 q ha^{-1} (STCR YT_2), T_7= T_5 + FYM was applied @ 10 tones ha^{-1} (STCR YT_1+ FYM) and T_8= T_6 + FYM was applied @ 10 t ha$_{-1}$(STCR YT_2+ FYM) and three replications in randomized block design. Using the data on grain yield, fertilizer doses applied, cost of fertilizer input and lentil grain, the parameters *viz*; yield deviation, response ratio and net benefit were computed.

Results and Discussion

***Soil available nutrients and grain yield*:** The range and mean values of grain yield of lentil and soil available nutrients of treated and control plots are furnished in Table 2. In the NPK treated plots (plots that received NPK alone or NPK plus FYM),

Table 1. Treatment structure

Plot No.	Treatment combinations			Levels of nutrients (kg ha$_{-1}$)		
	N	P	K		NP_2O_5	K_2O
1	0	0	0	0	0	0
2	0	0	0	0	0	0
3	0	0	0	0	0	0
4	0	2	2	0	50	40
5	1	1	1	15	25	20
6	1	2	1	15	50	20
7	1	1	2	15	25	40
8	1	2	2	15	50	40
9	2	1	1	30	25	20
10	2	0	2	30	0	40
11	2	1	2	30	25	40
12	2	2	2	30	50	40
13	2	2	0	30	50	0
14	2	2	1	30	50	20
15	2	2	3	30	50	60
16	2	3	2	30	75	40
17	2	3	3	30	75	60
18	3	1	1	45	25	20
19	3	2	1	45	50	20
20	3	2	2	45	50	40
21	3	3	1	45	75	20
22	3	3	2	45	75	40
23	3	2	3	45	50	60
24	3	3	3	45	75	60

$KMnO_4$-N increased from 213 kg ha^{-1}in stripe I to 339 kg ha^{-1}in stripe III with a mean value of 276 kg ha^{-1}. The Olsen-P ranged from 21.9 kg ha^{-1} in stripe I to 38.2 kg ha^{-1} in stripe III with a mean value of 30.1 kg ha^{-1}, while the NH_4OAc-K status varied from 168 kg ha^{-1} in stripe I to 195 kg ha^{-1} in stripe III with a mean value of 181 kg ha^{-1}.In the overall control plot of three fertility gradients (Table 2), the $KMnO_4$-N ranged from 226 to 289 kg ha^{-1}with a mean of 257 kg ha^{-1}, Olsen-P status ranged from 24.2 to 35.3 kg ha^{-1}with a mean value of 29.8 kg ha^{-1}, and the NH_4OAc-K status varied from 171 to 185 kg ha^{-1} with a mean value of 178 kg ha^{-1}.

Table 2. Effect of treatments on available nutrients in pre sowing surface soil and grain yield of lentil.

Parameter	NPK treated plots		Control plots	
	Range	Mean	Range	Mean
$KMnO_4$-N (kg ha^{-1})	213–339	276	226–289	257
Olsen's-P (kg ha^{-1})	21.9–38.2	30.1	24.2–35.3	29.8
NH_4OAc-K (kg ha^{-1})	168–195	181	171–185	178
Grain yield (q ha^{-1})	14.8–23.3	19.1	13.7–16.8	15.3

In NPK treated plots (plots that received NPK alone or NPK plus FYM), the grain yield of wheat ranged from 14.8 to 23.3 q ha^{-1} with a mean value of 19.1 q ha^{-1}.In the overall control plots, the yield ranged from 13.7 to 16.8 q ha^{-1} with a mean value of 15.3 q ha^{-1}. The above data clearly indicate the existence of operational range of soil test values for available N, P and K status and grain 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.

Table 3. Nutrient requirement, percent contribution of nutrients from soil, fertilizer and FYM for lentil.

Particulars	N	P	K
NR (Kg q^{-1})	5.24	0.72	3.58
C_s* (%)	32.01	30.00	31.06
C_f (%)	43.02	32.03	42.01
C_{fym} (%)	11.02	8.04	9.00

Basic parameters: The basic data *viz*., nutrient requirement for producing one quintal grain yield of lentil, percent contribution of nutrients from soil (C_s), fertilizer (C_f) and FYM (C_{fym}) have been calculated and furnished in Table 3.These basic parameters were used for developing the fertilizer prescription equations under NPK alone and IPNS (Table 4). The nutrient requirement of N, P and K was 5.24, 0.72 and 3.58 kg q^{-1} of grain respectively. The percent

Table 4. Fertilizer prescription equations for targeted yield of lentil

(kg ha^{-1})	NPK + FYM	NPK alone
FN	= 12.2 T – 0.74 SN –0.25 ON	= 12.2 T – 0.74 SN
FP	= 2.25 T - 0.94 SP - 0.25 OP	=2.25T- 0.94 SP
FK	= 8.52 T - 0.74 SK - 0.21 OK	=8.52T- 0.74 SK

Where, FN, FP and FK = Doses (kg ha^{-1}) of N, P and K through fertilizer, T = Yield target (q ha^{-1}); SN, SP and SK = Soil test values for $KMnO_4$-N, Olsen's-P and NH_4 OAC -K in kg ha^{-1} respectively, ON, OP and OK = quantities of N, P and K supplied through FYM in kg ha^{-1}.

contribution of nutrients from soil and fertilizers were found to be 32.01 and 43.02 for N, 30.0 and 32.03 for P and 31.06 and 42.01 for K. Similarly the percent contribution of N, P and K from FYM was 11.02, 8.04 and 9.0 respectively. The results indicated that the percent contribution of nutrients from fertilizer sources was more than that from the soil source. These findings are closely accorded with those reported by Gayathri *et al*., (2009) and Chatterjee *et al*., (2010) for potato.

An estimate of fertilizer doses for nitrogen, phosphorus and potassium was prepared from the basic data based on these equations for a range of soil test values and for the different yield target of lentil grain without farmyard manure and with 10 tonnes farmyard manure (Table 5). The data clearly

Table 5. Soil test based fertilizer recommendation (kg ha^{-1}) under IPNS for different yield targets of lentil

STV (kg ha^{-1})	Yield target 16 q ha^{-1} NPK alone	NPK + FYM@ 10 t ha^{-1}	Per cent reduction over NPK alone	Yield target 18 q ha^{-1} NPK alone	NPK + FYM@ 10 t ha^{-1}	Per cent reduction over NPK alone
SN	FN	FN		FN	FN	
150	84.2	76.7	8.9	108.6	101.1	6.9
170	69.4	61.9	10.8	93.8	86.3	8.0
190	54.6	47.1	13.7	79.0	71.5	9.5
210	39.8	32.3	18.8	64.2	56.7	11.7
230	25.0	17.5	30.0	49.4	41.9	15.2
SP	FP	FP		FP	FP	
10	26.2	21.7	17.2	31.3	26.8	14.4
15	21.9	17.4	20.6	26.4	21.9	17.1
20	17.2	12.7	26.2	21.7	17.2	20.7
25	12.5	8.0	36.0	17.0	12.5	26.5
30	7.8	3.3	57.7	12.3	7.8	36.6
SK	FK	FK		FK	FK	
100	62.3	54.1	13.2	79.4	71.2	10.3
120	47.5	39.3	17.3	64.6	56.4	12.7
140	32.7	24.5	25.1	49.8	41.6	16.5
160	17.9	9.7	45.8	35.0	26.8	23.4
180	3.1	-	-	20.2	12.0	40.6

revealed that fertilizer rates decreased with increase in soil test values for the different yield targets. The results are in conformity with the results observed by Saxena *et al*., (2008) for onion; Gayathri *et al*., (2009) and Chatterjee *et al*., (2010) for potato, Pant and Gautam,(2012) for scented rice and Gogoi,(2012) for pumpkin. It is obvious from findings that there was net savings of fertilizers for each target.

Regression analysis: Relationship between grain yield as dependent variable and the soil test values, fertilizer doses, interactions between soil test values and fertilizer doses as independent variables was also established through a multiple regression equation of quadratic model. $Y = 15.354 + 0.0031SN + 0.0861\,SP - 0.0190\,SK + 0.0829\,FN - 0.00064\,FN^{2*} + 0.166\,FP - 0.00053\,FP^{2*} - 0.192\,FK + 0.00012\,FK^2 - 0.0000060\,FNSN - 0.00274\,FPSP - 0.00115\,FKSK$ ($R^2 = 0.805^{**}$). From R^2 value, it can be observed that variation up to 80.5 % in lentil grain yield can be explained by the variation in soil test values and fertilizer doses. In a quadratic model, the response type (+ - -) observed for the nutrients nitrogen and phosphorus followed law of

Table 6. Fertilizer doses applied, yield and response ratio as influenced by various fertilization approaches in the verification trial on lentil.

Treatment	Fertilizer doses (kg ha^{-1}) N:P_2O_5:K_2O:FYM (t ha^{-1})	Grain yield (kg ha^{-1})	Increase in yield over FP (kg ha^{-1})	Value of additional yield (Rs.) (A)	Cost of fertilizer (Rs.) (B)	Net Benefit (Rs.) (A-B)	Per cent yield deviation	RR (kg kg^{-1})
T_1:FP	0:0:0:0	1170	-	-	-	-	-	-
T_2 : FYM	0:0:0:10	1210	40	1680	500	1180	-	-
T_3: GRD	20:50:30:0	1510	340	14280	1511.4	12768.6	-	3.4
T_4: STCR YT_1	10.2 : 39.0 : 8.2 : 0	1520	350	14700	1004.2	13695.8	-5.0	6.1
T_5 : STCR YT_2	34.6 : 50.0 : 28.7 : 0	1750	580	24360	1685.1	22674.9	- 2.8	5.1
T_6 : STCR YT_1+FYM	2.7 : 29:0 : 10	1630	460	19320	1133.9	18186.1	+ 1.9	14.5
T_7 : STCR YT_2+FYM	27.1:39.0 : 18.8 : 10	1810	640	26880	1802.3	25077.7	+ 0.6	7.5

Rate: N: 12.9; P_2O_5: 20.6; K_2O:7.5; FYM: 0.5Rs.kg^{-1} and Lentil grain: 42 Rs.kg^{-1}

Initial STV (kg ha^{-1}) of the site: SN: 250, SP: 20and SK: 175

diminishing return which characterizes at a given soil test value, the yield increases up to a limit with increasing doses of fertilizer but above which, there will be no increase but decrease in yield. While the response type (- + +) observed for potassium, characterizes a positive correlation between soil and fertilizer nutrients. In this condition the response would be inconsistent as it decreases up to a certain level and increases beyond that level. Similar types of response were also observed with forage sorghum by Garg and Sachan (1985).

***Testing of validity of the fertilizer prescription equations*:** Verification trial on the same soil type showed fairly close similarity (within ±10% variation) between the yield target and those actually obtained (Table 6).Variation in yield obtained from the targeted yield ranged from -5.0 to +1.9 %. The lower deviation might be due to better response to the applied nutrients on STCR basis in presence of FYM indicating the importance of balanced nutrition of crops (Apoorva *et al*., 2010).The farmer's practice of fertilizer application was least efficient in producing grain yield of lentil. Mean yield, net benefit and response ratio was higher in treatments where fertilizer was applied on the basis STCR approach than the general recommended dose treatment.

Between the two targets tried targeting for 16 q ha^{-1} recorded higher response ratio than the 18 q ha^{-1} which might be due to the better use efficiency of applied NPK fertilizers at low levels of yield targets (Santhi *et al*., 2002). Highest grain yield (18.10 q ha^{-1}) was recorded with STCR YT_2+ FYM followed by STCR YT_2 (17.50 q ha^{-1}) and similar trend was noted for 16 q ha^{-1} yield target (Table 6). Also, the IPNS treatments recorded higher per cent achievement of targets and response ratio over other treatments. This may be due to the favourable complementary influence of organic and inorganic on chemical, physical and biological properties of soil under IPNS (Apoorva *et al*., 2010). Besides, conjoint use of FYM with fertilizer contributed the nutrient directly which not only led the reduction in the nutrient requirement but also allows the balanced supply of the nutrients. These results corroborate with the finding of Santhi *et al*., (2011).

Therefore, findings of the present study clearly revealed that in STCR-IPNS recommendations for lentil will not only show the excellence over the other approaches but will also steer the farmers for the efficient and economic use of fertilizers depending on their financial status. However some other soil parameters which affect the soil nutrient retention should also be considered.

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