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Inductive Cum Target Yield Model Based Fertilizer Prescription for Chickpea Cultivation in North Western Mollisol

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Authors' contributions

This work was carried out in collaboration among all authors. Author AS designed the study, provided all necessary facilities required for the experiment. Author RB did supervision of field and all observation during crop duration has been collected. Author AS managed the analyses of the study, literature searches and wrote the first draft of the manuscript. All authors read and approved the final manuscript.

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ABSTRACT

A field experiment was conducted in an Aquic hapludoll at D_7 block of Norman E. Borlaug Crop Research Centre, G.B. Pant University of Agriculture and Technology, Pantnagar (29° N Latitude and 79°29' E Longitude), as the per technical program of All India Coordinated Research Project on Soil Test Crop Response Correlation to study the effect of soil and applied nutrients on chickpea to ensure balanced fertilization. Response to selected combinations of three levels of FYM (0, 5 and

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10 t ha^{-1}), four levels of nitrogen (0, 10, 20 and 30 kg ha^{-1}), four levels of phosphorus (0, 20, 40 and 60 kg P_2O_5 ha^{-1}) and four levels of potassium (0, 10, 20 and 30 kg K_2O ha^{-1}) at different fertility levels of chickpea was studied. Basic data for fertilizer prescription was computed on the basis of soil analysis, nutrient uptake and grain yield. Nutrient requirement for production of one quintal of grain yield of chickpea was found to be 4.41 kg nitrogen, 0.62 kg phosphorus and 2.53 kg potassium. Percent contribution of nitrogen, phosphorus and potassium was 37.05, 72.16 and 35.61, from soil, whereas from other sources as FYM was 68.31, 16.15 and 37.20 percent; chemical fertilizer 160.01, 16.79 and 93.51 and conjoint joint use of chemical fertilizer with FYM 64, 15.57 and 95.22 in terms of N, P and K respectively. Fertilizer prescription equations were generated by these basic data. These fertilizer prescription equations are valuable for efficient and judicious use of costly fertilizers to improve farmer’s economic conditions.

Keywords: Soil test crop response; chickpea; soil test values; fertilizer prescription equation; target yield and Mollisol.

1. INTRODUCTION

“Chickpea (*Cicer arietinum* L.) is also referred to as gram or bengal gram. Chickpea occupies around 35% of the land under pulses and contributes approximately 50% of India's total pulse production. The production of chickpea declined from 2.07 thousand metric tonnes in 1990 to 0.66 thousand metric tonnes in 2007 in Uttarakhand. Total chickpea growing area, production and productivity was respectively, 720 ha, 574 MT and 7.97 q ha^{-1} in 2019-20 in Uttarakhand. Due to unawareness and imbalance use of fertilizer and faulty combination of fertilizer used by farmer, the yield and productivity of agriculture land has been decreased. In Uttarakhand, rainfall is uncertain or uneven due to this some soil become acidic. Legumes are more sensitive to soil acidity as compared to cereals and other non legumes crops” [1,2]. Several methodologies have been used to recommend fertilizers based on chemical soil tests in order to maximize yield per unit of fertilizer consumption. Among the various approaches, the inductive cum target yield approach, [3] suggested balanced fertilization based on available nutrients in the soil and crop needs, has been found to be helpful. However, “applying N, P, and K fertilizer based on soil test target yield may achieve productivity but has a detrimental impact on soil health; thus, integrated plant nutrient system i.e. a combination of inorganic and organics, helps to improve crop productivity while maintaining soil health” [4]. Utilizing organic manures and chemical fertilizers wisely has enhanced the nutrients that are readily available in the soil. By ensuring a balanced fertilizer application, the STCR technique not only reduces fertilizer usage but also helps to improve soil health. Taking into account the aforementioned point, the current study was conducted with the aim of recommending judicious and economical fertilizer application for chickpea crop for specific growing season and agro climatic zone using soil test crop response approach.

2. MATERIALS AND METHODS

2.1 Experimental Site

The field experiment was carried out in 2019–20 at the N.E. Borlaug Crop Research Centre, G.B. Pant University of Agriculture and Technology, Pantnagar to study the soil response of soil and applied nutrients for balanced fertilization for chickpea. The experimental field is located at 29° N latitude, 79° 29' E longitude, and 243.84 m above mean sea level in the Shivalik range of the Himalayas. The trial site's soil was classified as Aquic Hapludoll [5]. Before the experiment began, soil samples from the experiment site were taken, evaluated for soil properties and the results are shown in Table 1.

2.2 Experimental Design and Layout

The field experiment was carried out in two phases *i.e.* fertility gradient stabilizing experiment (preparatory trial) and test crop experiment (main trial). At first, fertility gradient across the width of field was created by keeping the first strip unfertilized (control), adding 100 kg N, 100 kg P_2O_5 and 100 kg K_2O ha-1 in the second strip and 200 kg N, 200 kg P_2O_5 and 200 kg K_2O ha-1 in the third strip, respectively and grown Sorghum (var. Pant chari-1) as exhaust crop, for successful conduct soil test crop response correlation study and to minimize the interference of other soil and management factors affecting crop yield.

At the second phase a test crop, chickpea (var. Pusa 262) was sown on the site of fertility gradient experiment. Each strip (made in the fertility gradient stabilizing experiment in the previous season) was divided into twenty four plots (23 treated and one control) resulting in total seventy two (24×3) plots (4 m × 3 m size) plots. These treatments comprised of various selected combinations of nitrogen, phosphorus, potassium and farm yard manure (Table 2) were given randomized in each of the three strips.

Recommended agronomic practices like fertilizer application, irrigation, weeding was followed. The sources of nutrient used were urea for N, which was applied in two split doses, half as basal dose at the time of sowing and remaining half as top dressing; full basal dose for P and K were applied during transplanting in the form of single superphosphate (SSP) and muriate of potash (MOP), respectively. Farmyard manure (FYM) (40% moisture, 0.6% N, 0.3% P_2O_5 and 0.57% of K_2O) was applied as basal prior to transplanting.

2.3 Soil and Plant Analysis

Soil samples were collected at 0-15 cm depth from 72 plots before sowing of chickpea and analyzed for alkaline $KMnO_4$-N [10], Olsen-P [11] and ammonium acetate extractable-K [12]. Plant and grain samples were also collected at maturity, dried, then processed and analyzed for total N, P and K content. The data obtained from soil and plant analyses were used to calculate the basic data *viz.,* nutrient requirement (NR), per cent contribution from soil (CS), fertilizer (Cf), FYM (Cfym) and fertilizer and FYM (Cf*).

2.4 Basic Data Calculation

With the help of basic data fertilizer prescription equations were developed as follows:

2.4.1 Nutrient requirement for production of one quintal of economic produce

$$\text{Nutrient requirement (NR)} = \frac{\text{Total nutrient uptake (kg)}}{\text{Economical yield (q)}}$$

The values were reported as kg of N, P_2O_5 and K_2O required for producing one quintal of chickpea. Nutrient requirements were calculated separately for individual plot and then averages were taken for nutrient in question.

Table 1. Physico-chemical properties of the soil of experimental site

S. no.	Property	Values obtained	Methods employed
1.	Textural analysis		Bouycos Hydrometer
	Sand (%)	54.12	[6]
	Silt (%)	32.88	
	Clay (%)	13.00	
	Textural class	Sandy loam	USDA textural triangle
2.	pH (1:2 soil water suspension)	6.91	Glass electrode pH meter [7]
3.	Electrical conductivity (dSm^{-1})	0.32	EC meter [8]
4.	Organic carbon (%)	0.61	Wet digestion [9]
5.	Available nitrogen (kg ha^{-1})	163.07	Alkaline KMnO4 method [10]
6.	Available phosphorus (kg ha^{-1})	19.93	Olsen's extraction method [11]
7.	Available potassium (kg ha^{-1})	157.92	Neutral 1 N NH4OAc extraction method [12]

Table 2. Levels of N, P_2O_5 and K_2O applied in test crop experiment

Levels	FYM (t ha^{-})	N (kg ha^{-1})	P_2O_5 (kg ha^{-1})	K_2O (kg ha^{-1})
0	0	0	0	0
1	5	10	20	10
2	10	20	40	20
3	-	30	60	30

2.4.2 Contribution of nitrogen, phosphorus and potassium from soil (Cs)

Efficiency of soil nutrients was calculated from soil test values of unfertilized plots (control plots).

$$\text{Percent contribution of available nutrient from soil (Cs)} = \frac{\text{Total uptake of nutrient in control plot}}{\text{Soil test value of that nutrient in control plot}} \times 100$$

2.4.3 Contribution of concerned nutrient from fertilizer without FYM (Cf)

Efficiency of fertilizer was calculated from the plots treated without FYM.

$$\text{Percent contribution of available nutrient from fertilizer (Cf)} = \frac{\begin{array}{c}\text{(Total uptake of nutrient in fertilizer and FYM treated plots)} - \\ \text{(Soil test value of nutrient in fertilizer and FYM treated plots} \times \text{Cs} \div 100) - \\ \text{(Nutrient added through FYM} \times \text{Cfym} \div 100)\end{array}}{\text{Fertilizer dose applied}} \times 100$$

2.4.4 Contribution of nitrogen, phosphorus and potassium from FYM (Cfym)

Efficiency of FYM for any nutrient was calculated from those plots treated with FYM (6 plots).

$$\text{Percent contribution of nutrient from FYM} = \frac{\text{(Total uptake of nutrients in only FYM treated plots)} - \text{(Soil test value of nutrient in only FYM treated plots} \times \text{Cs} \div 100}{\text{Nutrient dose applied by FYM (NPK)}} \times 100$$

2.4.5. Contribution of concerned nutrient from fertilizer with FYM (Cf*)

Fertilizer efficiency of nutrient with FYM was calculated from plots treated with both organic and inorganic sources of nutrient.

$$\text{Contribution of concerned nutrient from fertilizer with FYM (Cf}*) = \frac{\text{(Total uptake of nutrient in fertilizer and FYM treated plots)} - \text{(Soil test value of nutrient in fertilizer and FYM treated plots} \times \text{Cs} \div 100)}{\text{Fertilizer dose (NPK) applied}} \times 100$$

2.5 Fertilizer Requirements for Targeted Yield

Fertilizer requirements of N, P_2O_5 and K_2O for targeted yields were worked out as follows:

2.5.1 Fertilizer requirement equations for nutrients through use of chemical fertilizer (without FYM)

FN = (NR/Cf) ×100 T - (Cs/Cf) ×SN
FP2O5 = (NR/Cf) ×100 T - (Cs/Cf) × 2.29 × SP
FK2O = (NR/Cf) ×100 T – (Cs/Cf) × 1.21 SK

2.5.2 Fertilizer requirement equations for nutrients through conjoint use of chemical fertilizer and FYM (with FYM)

FN = (NR/Cf*) ×100 T – (CS/Cf*) × SN – (Cfym/Cf*) × M
FP2O5 = (NR/Cf*) × 100 T – (CS/Cf*) × 2.29 × SP – (Cfym/Cf*) × 2.29 × M
FK2O = (NR/Cf*) × 100 T – (CS/Cf*) × 1.21 SK – (Cfym/Cf*) × 1.21 M

Where, FN = Fertilizer N (kg N ha^{-1}); FP_2O_5 = Fertilizer P (kg P_2O_5 ha^{-1}); FK_2O = Fertilizer K (kg K_2O ha^{-1}); NR = Nutrient requirement of N, P and K; Cf = Percent contribution of concerned nutrient from fertilizer without FYM; Cf* = Percent contribution of concerned nutrient from fertilizer with FYM; CS = Percent contribution of concerned nutrient from soil; Cfym = Percent contribution of concerned nutrient from FYM; T = Targeted yield (q ha^{-1}); SN = Soil test value for available N (kg ha^{-1}); SP = Soil test value for available P (kg ha^{-1}); SK = Soil test value for available K (kg ha^{-1}); and M = Concerned nutrient content in organic.

2.6 Statistical Analysis

Analysis of the data obtained in STCR test crop experiments were done as outlined by AICRP on Soil Test Crop Response project of ICAR. Statistical analysis of test crop experiments will be carried out by the method of simple correlation and multiple regressions [13].

3. RESULTS AND DISCUSSION

3.1 Fertility Gradient Experiment

Table 3 indicated that there was proper creation of fertility gradient and it was significant with respect to N, P and K levels. "These results validate that experimental field was suitable for soil test crop response studies for the next season test crop. The findings are closely accorded with those reported by [14], [15] in Mollisol of Uttarakhand". The trend in results obtained in yield and soil test value were found in order, strip III > strip II > strip I. Strip III showed high fertility status and high yield, where maximum doses of nutrient were applied followed by Strip II and Strip I.

3.2 Test Crop Experiment

3.2.1 Yield response and nutrient uptake

Table 4. indicated yield and nutrient uptake of chickpea in three separate strips supplied with graded doses of fertilizers revealed that the strip III had the highest mean yield (22.11 q ha^{-1}) followed by the strip II (22.02 q ha^{-1}) and the strip I (20.61 q ha^{-1}). Strip III had the highest nutrient uptake (101.58, 13.12 and 57.81 kg ha^{-1} of N, P, and K respectively), followed by Strip II (94.64, 13.12 and 49.73 kg ha^{-1} of N, P and K respectively), and Strip I had the lowest (87.40, 13.18 and 52.60 kg ha^{-1} of N, P, and K, respectively). The highest response of chickpea in terms of nutrient uptake and yield in strip III can be attributed by the addition of high NPK doses in strip third, which has been reflected in chickpea due to residual effect. This was caused by the combined effect of residual and additional nutrients, which led to increased nutrient uptake and yield of chickpea. [16] indicated that "the increase in production and uptake by chickpea was due to an increase in growth parameters, a larger number of pods gained through the application of nutrients from various organic and inorganic sources". Because of a increase in yield attributing charecters, there was an increase in the uptake of nutrients with an increase in nutrient levels [17].

3.2.2 Soil available nutrients

The present study shows that there was well-established variation in the fertility gradient, which is further supported by the nutrient status in three separate strips. Strip III had the largest percentage of organic carbon (1.10%) while Strip I had the lowest (0.84%). Maximum (169.95, 18.80, and 177.62 kg ha^{-1} of N, P, and K, respectively) soil available nutrient status was found in strip III, followed by strip II (166.92, 17.50, and 141.31 kg ha^{-1} of N, P, and K, respectively), and lowest (152.59, 14.80, and 118.84 kg ha^{-1} of N, P, and K, respectively) in strip I (Table 4). The aforementioned results clearly show that there was considerable variation in the soil test value and chickpea grain yield, which is a requirement for calculating the basic data and fertilizer adjustment equations for calibrating fertilizer doses for specific yield targets.

3.2.3 Basic parameters to develop fertilizer prescription equations

The basic data required for formulating the fertilizer prescription equations are given in Table 5.

The nutrient requirement for production of one quintal of chickpea was 4.41 kg for N, 0.62 kg for P and 2.53 kg for K in sandy loam soils of Pantnagar with humid and subtropical climate. The per cent contribution through soil was 37.05, 72.16 and 35.61 of N, P and K, respectively. The contribution of applied fertilizer alone was 160.01, 16.79 and 93.51 per cent of N, P and K, respectively. The per cent contribution of nutrient through fertilizer along with FYM was 35.1, 33.9 and 36.7 for N, P and K, respectively. The applied FYM contributed 68.31 per cent of N, 16.15 per cent of P and 37.20 per cent of K. In the case of P, the data showed that the percentage contribution from soil was more than the percentage contribution from fertilizer, whereas in the case of N and K, the percentage contribution from fertilizer was higher than the percentage contribution from soil. The above findings are consistent with [15] findings on urd bean, in which the contribution of nutrients from fertilizer was 66.94% for N, 41.21% for P, and 51.64% for K. The nutrient contribution from fertilizer was higher than that from soil and followed the pattern N > K > P. FYM contributed 68.31, 16.15, and 37.20% of the nutrients N, P, and K, respectively.

3.2.4 Fertilizer requirement

Using the basic parameters, soil test-based fertiliser prescription equations for target yield of chickpea were developed. The fertiliser doses without FYM and with FYM was computed using a fertiliser prescription equation (Table 6) having the range of soil test values and chickpea yield targets 15, 20, and 25 q ha-1. The results showed that fertiliser doses increased with an increase in chickpea target yield and decreased with an increase in soil test value. In the current study, fertiliser equivalence of FYM was calculated by comparing the fertilizer requirements of the nutrient in question with and without FYM at a specific soil test value and target yield. The average saving of fertilizer by 5.0 tonnes FYM were 9.24 kg ha^{-1} N, 3.68 kg ha^{-1} P and 3.35 kg ha^{-1} K along with the experimental soil test value and yield targets. . The above investigation clearly illustrated that there was net saving of fertilizer as well ensuring the proper application of fertilizer in accordance to soil test values. The findings are in conformity with study of [15, 18].

Table 3. Significance, R square and mean of soil test values of whole plots

Dependent variable	P level	R Square	Mean (kg ha^{-1})
SN	<0.01**	0.740	163.15
SP	<0.01**	0.813	17.04
SK	<0.01**	0.831	145.92

Table 4. Range and mean of the soil test values, yield and plant uptake under different strips

Sr. no.	Particulars	Strip I	Strip II	Strip III	Whole field
1.	Organic carbon (%)	0.31-1.33 (0.84)	0.42-1.34 (0.96)	0.51-1.63 (1.10)	0.31-1.63 (0.97)
2.	Alkaline $KMnO_4$-N (kg ha^{-1})	87.81-188.16 (152.59)	100.35-263.42 (166.92)	125.44-225.79 (169.95)	87.81-225.42 (163.15)
3.	Olsen-P (kg ha^{-1})	12.10-19.45 (14.80)	15.40-19.89 (17.50)	15.13-24.64 (18.80)	12.10-24.64 (17.04)
4.	NH4OAc-K (kg ha^{-1})	76.16 -161.28 (118.84)	92.96-198.24 (141.31)	144.48-247.52 (177.62)	76.16-247.52 (145.92)
5.	Grain yield (q ha^{-1})	12.77-29.43 (20.61)	12.77-29.43 (22.02)	13.24-30.27 (22.11)	12.77-30.27 (21.58)
6.	Nitrogen uptake (kg ha^{-1})	44.96-139.76 (87.40)	61.50-128.83 (94.64)	55.00-140.46 (101.58)	44.96-140.46 (94.54)
7.	Phosphorus uptake (kg ha^{-1})	9.22-17.77 (13.18)	7.72-18.15 (13.12)	8.50-17.08 (13.41)	7.72-18.15 (13.24)
8.	Potassium uptake (kg ha^{-1})	35.45-72.40 (52.60)	28.76-78.48 (49.73)	42.59-82.92 (57.81)	28.76-82.92 (53.38)

Table 5. Basic data for calculating fertilizer dose with and without FYM for targeted yield of chickpea

Sr. No	Particulars	Without FYM			With FYM		
		N	P	K	N	P	K
1.	Nutrient required (kg q^{-1})	4.41	0.62	2.53	4.41	0.62	2.53
2.	Percent contribution From applied soil (%)	37.05	72.16	35.61	37.05	72.16	35.61
3.	Percent contribution from applied fertilizer (%)	160.01	16.79	93.51	197.64	15.57	95.22
4.	Contribution from applied FYM nutrients (%)	--	--	--	68.31	16.15	37.20

Table 6. Soil test based fertilizer adjustment equations for targeted yield of chickpea

Fertilizer dose (kg ha-1)	Equation with FYM (kg ha-1)	Equation without FYM (kg ha-1)
Nitrogen	FN = 2.23 T – 0.19 SN – 0.35 ON	FN = 2.76 T – 0.23 SN
Phosphorus	FP = 3.98 T – 4.63 SP – 1.04 OP	FP = 3.69 T – 4.30 SP
Potassium	FK = 2.66 T – 0.37 SK – 0.39 OK	FK = 2.71 T – 0.38 SK

4. CONCLUSION

From the results of the research, it can be concluded that fertiliser prescription based on inductive cum target yield approach not only aided in resource efficiency but also ensured attaining desired yield targets in accordance with farmer economic interests for applying fertilizer. The efficient use of nutrients was increased by integrating their application, which also resulted in fertiliser savings. It is necessary to validate these equations through follow up trial so that farmers and soil testing facilities may use them to recommend chickpea fertilizer doses.

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COMPETING INTERESTS

Authors have declared that no competing interests exist.

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