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Soil test based integrated fertilizer prescription for targeted green pod yield of cowpea

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ABSTRACT

Soil test crop response correlation studies were carried out following Ramamoorthy's 'inductive-cum-targeted yield' model on an Inceptisol for the development of integrated fertilizer prescription for targeted yield of green cowpea pod. The computed basic parameters *viz.*, nutrient requirement (NR) and per cent contributions of nutrients from soil (C_S), fertilizer (C_F), and farm yard manure (C_{FYM}) were used for the formulation of N, P and K fertilizer prescription equations. The per cent contribution of N, P and K from soil, fertilizer and farm yard manure (FYM) were 69.2, 145.2 and 17.3 for nitrogen; 63.6, 24.4 and 9.7 for phosphorus and 56.1, 79.5 and 22.1 for potassium, respectively. These parameters were used to prepare the ready reckoners of fertilizer prescription for the range of soil test values of N, P and K for desired yield target (± 5 to ± 10% of potential yield of the variety) of green cowpea pod.

Key words: *Vigna unguiculata,* inceptisol nutrient requirements, targeted yield.

INTRODUCTION

Cowpea (*Vigna unguiculata* [L.] Walp.) is the one of the most important food legume grown world over in humid tropical and sub-tropical agro-climatic-edaphic zones for consumption as staple food, leafy vegetable, green pod, fresh seed, dry grain and animal fodder. It has substantial adaptation to drought-prone and low soil fertility conditions where soils are sandy, water holding capacity is low, and rainfall is scanty. Worldwide total production of cowpea is estimated at 5.5 million tonnes of dry grain from 14.5 million ha of cultivated area with average productivity of 0.38 t ha^{-1}. In India, cowpea is grown on about 0.5 million ha with an average productivity of 0.60 to 0.75 t ha^{-1} which is quite low than the potential productivity of the cowpea varieties achieved at experimental farms and demonstration plots at farmer's field.

The high positive effect of the application of inorganic fertilizers especially of phosphorus on cowpea yield improvement has been reported (Mandal *et al*., 6). Cowpea responds to application of small starter N though it symbiotically fixes nitrogen, plant may suffer from temporary N deficiency during the seedling growth once the cotyledonary reserves have been exhausted (Eaglesham *et al*., 3). Differential response of cowpea genotypes to fertilizer application which has significant practical implications for field production has been reported by Abayomi *et al*. (1). Mostly, a general recommendation of 20:60:60 kg N, P, and K ha^{-1}, respectively, is being followed without considering soil nutrient level, fertilizer and manure nutrient efficiency, and crop nutrient requirement. However, Mandal *et al*. (6) obtained the highest cowpea grain yield when N, P and K were applied at rated 25% higher than the soil test-base optimum rate. In another study Swaroop *et al*. (17) have found the highest green pod yield of cowpea on application of 20 kg N, 80 kg P and 60 kg K ha^{-1}. It showed that fertilizer recommendations and response for optimum yield of cowpea has not been uniform and varied with initial soil fertility level. For efficient fertilization of the crop the existing soil fertility, use efficiency of available soil nutrients, fertilizer and manures nutrients, and crop requirements should be taken in to account. Information on above aspects is not available for the production of cowpea green pod. In view of the above the present investigation was undertaken to know nutrient requirement of the crop and contribution of nutrients from different sources viz. soil, fertilizer and organic manure (FYM) to total uptake for the development of N, P and K prescription equation and ready reckoner to prescribe fertilizer with and without organic manure for the targeted yield of cowpea green pod using Inductive cum targeted yield concept (Ramamoorthy *et al.*, 10).

MATERIALS AND METHODS

Field experiment was conducted on cowpea during summer - 2012 at research farm of Indian Agricultural Research Institute, New Delhi (250

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meters above the mean sea level, latitude 28.4°N, longitude 77.1°E) to develop soil test based fertilizer adjustment equations for targeted yield of cowpea green pod following the procedure described by Ramamoorthy *et al.* (10). The climate of Delhi is semi-arid and subtropical characterized by dry summers and cold winters. The soil of the experimental site was non-calcareous, well drained, sandy loam in texture and taxonomically categorized under the great group Typic Haplustept (old alluvium). During 2012 the average annual precipitation was 500 mm and mean minimum and maximum temperatures were 31.5 °C and 17.5 °C, respectively. The initial soil was analysed by following the standard procedures (Jackson, 4; Singh *et al*., 14) before the development of fertility gradient had $pH_{(1:2)}$ 8.1, $EC_{(1:2)}$ 0.2 dS m^{-1}, cation exchange capacity (CEC) 10.7 cmol kg^{-1}, organic carbon content 0.48 g kg^{-1}, alkaline permanganate oxidizable N 176.6 kg ha^{-1}, 0.5 *N* sodium bicarbonate-extractable P 14.3 kg ha^{-1}, neutral *N* ammonium acetate K 178 kg ha^{-1} and 0.15 % $CaCl_2$ extractable-S 21.7 kg ha^{-1}. DTPA-extractable Zn, Cu, Fe and Mn content were 0.86, 0.63, 8.5 and 14.20 mg kg $^{-1}$, respectively.

Fertility Gradient Experiment

Appreciable artificial fertility gradient viz. low (strip-I), medium (strip-II) and high (strip-III) was created with respect to N, P and K in half acre land during summer – 2011 prior to conducting main experiment on cowpea during summer - 2012 in aerobic rice – cabbage - cowpea sequence using the technique of inductive methodology developed by Ramamoorthy *et al.* (10). For this purpose the field was divided into three equal rectangular strips and graded doses of nitrogen (N), phosphorus (P) and potassium (K) fertilizers were applied viz. $N_0P_0K_0$, $N_{1/2}P_{1/2}K_{1/2}$ and $N_1P_1K_1$ where $N_1P_1K_1$ represents 400, 300, 300 kg ha^{-1} of N, P and K, respectively. Soil fertility gradient with respect to farmyard manure (FYM) was developed by applying FYM @ 0, 5 and 10 tonnes ha^{-1} in each of the three strips across the fertility gradient dividing each strip in three FYM gradient (Mahajan *et al*., 5). By this way nine distinctly different fertility blocks (three in each of three strips) were obtained. Then during summer - 2011 exhaust crop fodder maize (var. African tall) was grown so that fertilizer could interact with soil, plant rhizosphere and microbes and thus become a part of soil system. After the harvest of the cabbage crop in the sequence twenty-four soil samples (0 - 0.15 m) from each strip were collected and were analyzed for alkaline $KMnO_4$, $NHCO_3$ extractable P and neutral *N* ammonium acetate K (Singh *et al.*, 14) which showed that appreciable fertility gradient was developed with respect to N, P and K by the application of graded levels of fertilizer and farm yard manure. The contents of alkaline $KMnO_4$–N, $NaHCO_3$-extratable P and ammonium acetate extract- K ranged from 145.3 to 233.7, 11.4 to 39.2 and 143.0 to 261.0 kg ha^{-1} with mean values of 191.1, 22.6 and 193.2 kg ha^{-1}, respectively.

Test Crop Experiment

The experiment was laid out in fractional factorial randomized block design. Each fertility gradient strip was divided into 24 plots to accommodate 24 treatments (21 treatments + 3 controls) making a total of 72 (24×3) plots in the three strips. Over all three blocks comprising of 8 treatments were made within each strip randomized with three farmyard manure levels. The treatments comprised of various selected combinations of four levels of nitrogen (0, 10, 20 and 30 kg N ha^{-1}), phosphorus (0, 30, 60 and 90 kg ha^{-1}) and potassium (0, 30, 60 and 90 kg ha^{-1}) and three levels of farmyard manure (0, 5, 10 tonnes farmyard manure ha^{-1}) which were randomized in each of the three strips in such a way that all 24 treatments were present in all the three strips in either direction (Table 2). The sources of nutrients were fertilizer urea, diammonium phosphate and muriate of potash. Full doses of all the fertilizers were applied basally at the time of sowing. The test crop cowpea 'Pusa Sukomal' was grown in lines 0.5 m apart during summer – 2012 following all the standard agronomic practices.

Plot wise soil samples (0 – 0.15 m) were collected before sowing and analyzed for alkaline-$KMnO_4$-N, bicarbonate-extractable P and neutral *N* ammonium acetate K. Treatment wise green cowpea pods were harvested regularly and fresh and dry weight was recorded. Similarly the weight of cowpea straw was recorded at maturity. For the analysis of total content of N, P and K (Singh *et al.*, 14) in cowpea green pod and straw, the collected representative samples were properly washed and then oven dried at 60 ± 2°C till a constant weight is attained. Oven dried samples were wet digested in di-acid mixture (HNO_3 : $HClO_4$ in 9 : 4, v/v) for the chemical analysis phosphorus and potassium (Jackson, 4). The total phosphorus content in the digest was determined by vanado-molybdate phosphoric acid yellow colour method at 420 nm and total potassium by using a microprocessor-based flame photometer (Flame Photometer-128, Systronics India, Ahemdabad, India) according to Jackson (4). Total nitrogen content in pod and straw was analysed by using modified micro-Kjeldahls' method (Jackson, 4).

Total uptake of N, P and K were computed using green cowpea pod and straw yield (on dry weight basis) and total nutrient contents in the cowpea pod and straw. The different required basic parameters *viz.* nutrient requirement (NR), and per cent contribution of nutrients from soil (% C_S), fertilizer (% C_F) and FYM (% C_{FYM}) were calculated by using the data on green pod yield, soil test value, fertilizer dose, FYM dose and nutrient uptake as described by Ramamoorthy *et al.* (10) and Subba Rao *et al.* (16).

The fertilizer prescription equations can be utilized for the calculation of fertilizer nutrient doses for desired target yield of cowpea pod based on soil test values of N, P and K and availability of on farm FYM and compost (Mahajan *et al.*, 5).

RESULTS AND DISCUSSION

Adequate variability with respect to available soil nutrients is a pre-requisite for calculating basic parameters and fertilizer prescription equations to compute the fertilizer doses for desired yield targets (Sharma and Singh, 13). Mahajan *et al*. (5) also obtained similar magnitude of operational ranges of alkaline $KMnO_4$ -N and $NHCO_3$ extractable P using preparatory crop fodder maize (var. African tall) in similar soil and climatic conditions.

The highest mean pod yield was obtained in strip III being the highest fertility gradient strip followed by in strip II and the lowest in low fertility strip I (Table 1). In general pod yield increased with the increase in doses of fertilizer N, P and K and with the application of farmyard manure in all the strips. Mean pod yields averaged over a particular fertility gradient were 5.98, 6.63 and 7.12 t ha^{-1} in strip I, strip II and strip III, respectively. The overall mean yield irrespective of fertility gradient and fertilizer and manure level was 6.58 t ha^{-1}. The highest pod yield of 9.71t ha^{-1} was observed in the second strip on application of 30, 60 and 60 kg ha^{-1} of N, P and K in conjunction with 10 t ha^{-1} of farmyard manure. Significant increase in cowpea grain yield with increase in levels of nitrogen upto 30 kg ha^{-1} has been reported by Mandal *et al*. (6). Swaroop *et al*. (17) reported that green pods yield increase with increase in levels of phosphorus and potash up to 80 kg ha^{-1} in a clay loam soil having medium level of available P and K.

The mean N, P and K uptake widely varied in accordance to soil available nutrient content, level of fertilizer and manure applied and green pod yield obtained. The maximum NPK uptake was in the highest fertility (strip III) followed by in medium (strip II) and low (strip I) fertility strips (Table 1). The total N uptake varied from 141.6 to 162.3 kg ha^{-1}; P from 17.3 to 20.3 kg ha^{-1} and K from 122.9 to 131.6 kg ha^{-1} in strip I to strip III. Similar magnitude of nutrient removal by cowpea has been reported by Mandal *et al*. (6). The correlation between pod yield and nutrient uptake was significant suggesting that for higher pod yield sufficient level of nutrient supply is required.

The basic data such as NPK required (NR) for producing one tonne green pod, per cent contribution

Table 1. Cowpea green pod yield and nutrient uptake under different fertility gradient.

Pod yield/ Nutrient uptake	Strip I		Strip II		Strip III	
	Range	Mean ± SD[a] (CV)[b]	Range	Mean ± SD[a] (CV)[b]	Range	Mean ± SD[a] (CV)[b]
Pod yield (t ha^{-1})	3.98 - 7.90	5.98±1.01 (17.0)	5.11 - 9.12	6.63±1.05 (15.9)	5.12 - 9.71	7.12±1.22 (17.2)
N uptake (kg ha^{-1})	90.0 - 192.8	141.6±25.4 (17.9)	110.6 -198.5	154.2±25.2 (16.3)	115.7 - 220.7	162.3±33.7 (20.7)
P uptake (kg ha^{-1})	9.4 - 26.6	17.3±4.7 (27.0)	9.6 - 29.5	17.5±4.8 (27.4)	11.0 - 29.8	20.3±4.9 (24.0)
K uptake (kg ha^{-1})	73.0 - 181.5	122.9±30.3 (24.6)	77.5 - 225.3	125.9±36.7 (29.2)	82.7 - 225.8	131.6±39.5 (30.0)

[a]Standard Deviation
[b]Coefficient of Variance ((Standard Deviation/Mean) x 100)

Table 2. Nutrient requirement of cowpea and contribution of nutrient from soil, fertilizer and farm yard manure.

Parameters	Nutrients		
	N	P	K
Nutrients requirement of green pod yield (kg t^{-1})	23.2	2.8	19.2
Per cent contribution from available soil nutrient (%CS)	69.2	63.6	56.1
Per cent contribution from fertilizer nutrient (%CF)	145.2	24.4	79.5
Per cent contribution from farm yard manure (% CFYM)	17.3	9.7	22.1

of nutrients from soil (% CS), per cent contribution of nutrients from fertilizer (% CF) and percent contribution of nutrients from FYM (% CFYM) have been calculated (Ramamoorthy *et al.,* 10) and presented in Table 2. These basic parameters were used for the development of fertilizer adjustment equations for NPK alone and in integration with FYM. The requirement of N, P and K were 23.2, 2.8 and 19.2 kg t^{-1} of green pod yield of cowpea, respectively. Cowpea required more N as compared to P and K for per unit pod yield because of high protein content of the crop and involvement of N in protein synthesis (Sebetha *et al*., 12). The per cent contribution of nutrients from soil, fertilizers and FYM were found to be 69.2, 145.2 and 17.3% for nitrogen, 63.6, 24.4 and 9.7% for P and 56.1, 79.5 and 22.1% for K, respectively (Table 2). The contribution of nitrogen and potassium from fertilizer were higher compare to soil and FYM. Unlike for K, the percent contribution of P from soil was higher than that from fertilizer which indicated the importance of labile soil P fraction in cowpea nutrition (Samadi, 11). The lower contribution of P from fertilizer source than N and K and contribution of all the nutrients from FYM is in agreement with Mahajan *et al*. (5) for wheat and rice crop. Cowpea being leguminous crop has a strong ability to fix atmospheric nitrogen through symbiosis with nodulating bacteria (Martin *et al*., 7) and contributed exceptionally high towards fertilizer N efficiency.

The essential basic information derived (Table 2) from soil test crop response correlation field experiment was used for formulating N, P and K fertilizer prescription equations with (integrated equation) and without organic manure (FYM) for the targeted yield of cowpea (Table 3). By using fertilizer prescription equations ready reckoner were prepared for range of soil test values of N, P and K for 8.0 t ha^{-1} green pod yield of cowpea (Table 4). Fertilizer N, P and K requirements decreased by 0.48, 2.6 and 0.71 kg ha^{-1}, respectively, with unit (kg ha^{-1}) increment in the soil test values of the nutrients. Several workers have reported decrease in fertilizer doses with increase in the soil test values of the N, P K and S in number of crops *viz*. wheat (Mahajan *et al*., 5), maize (Singh *et al*., 15), and toria and soybean (Paul *et al*., 8) with varying magnitude depending on soil types, nutrient use efficiency of the crop from different sources, management practices and climatic conditions. Fertilizer requirement will decrease at lower yield target and increase with increase in the yield target. Because of high cost and environmental risk involved use of chemical fertilizers alone cannot meet the high requirements of P and K by cowpea especially in low fertility soil. Therefore, integrated equation of soil test crop response involving organic manure (FYM) was developed which resulted in reduced requirement of N, P and K fertilizer by about 4.0, 8.0 and 11 kg ha^{-1}, respectively, on conjoint use of chemical fertilizers with 10 t ha^{-1} FYM having 0.3% N, 0.2% P and 0.4% K. Almost similar findings have been reported by several workers in cowpea and other vegetable crops grown in diversified agro-climatic-edaphic regions (Beena *et al*., 2; Polara *et al*., 9).

Table 3. Soil test based fertilizer prescription equations involving IPNS for targeted yield of cowpea green pod.

Fertilization programme	Fertilizer prescription equation
NPS alone	FN = 1.59T – 0.47 SN
	FP = 1.13T – 2.61 SP
	FK = 2.41T – 0.71 SK
NPS + FYM	FN = 1.59T – 0.47 SN - 0.12FYM
	FP = 1.13T – 2.61 SP - 0.40FYM
	FK = 2.41T – 0.71 SK - 0.28 FYM

FN, FP and FK – fertilizer N, P and K in kg ha^{-1}, respectively; T-target yield in q ha^{-1}; SN, SP and SK– Alkaline $KMnO_4$ – N, sodium bicarbonate-extractable P and neutral *N* ammonium acetate K in kg ha^{-1}, respectively; FYM - farmyard manure (t ha^{-1}),

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Table 4. Ready reckoner of soil test based fertilizer recommendations of N, P and K for 8 t ha^{-1} of green cowpea yield with (integrated) without farm yard manure (FYM).

Alkaline $KMnO_4$-N (kg ha^{-1})	Fertilizer N (kg ha^{-1}) alone	Fertilizer N (kg ha^{-1}) + 10t FYM ha^{-1}	% N ferti. reduction over N alone	Olsen's P (kg ha^{-1})	Fertilizer P (kg ha^{-1}) alone	Fertilizer P (kg ha^{-1}) + 10t FYM ha^{-1}	% P ferti. reduction over P alone	Ammonium Acetate K (kg ha^{-1})	Fertilizer K (kg ha^{-1}) alone	Fertilizer K (kgha^{-1}) + 10t FYM ha^{-1}	% K ferti. reduction over K alone
100	80.3	76.1	5.2	5.0	77.5	69.5	10.3	100	122.2	111.1	9.1
110	75.5	71.4	5.4	7.5	71.0	63.0	11.3	110	115.2	104.0	9.7
120	70.7	66.7	5.7	10.0	64.5	56.5	12.4	120	108.1	97.0	10.3
130	66.0	61.9	6.2	12.5	58.0	50.0	13.7	130	101.1	89.9	11.0
140	61.2	57.2	6.5	15.0	51.5	43.5	15.5	140	94.0	82.9	11.8
150	56.4	52.5	6.9	17.5	44.9	37.0	17.7	150	86.9	75.8	12.8
160	51.7	47.7	7.7	20.0	38.4	30.5	20.6	160	79.9	68.8	13.9
170	46.9	43.0	8.3	22.5	31.9	23.9	25.1	170	72.8	61.7	15.3
180	42.2	38.3	9.2	25.0	25.4	17.4	31.5	180	65.8	54.7	16.8
190	37.4	33.6	10.2	27.5	18.9	10.9	42.3	190	58.7	47.6	18.9
200	32.6	28.8	11.7	30.0	12.4	4.4	64.4	200	51.7	40.5	21.6
210	27.9	24.1	13.6	32.5	5.9	0.0	100.0	210	44.6	33.5	24.9
220	23.1	19.4	16.0	35.0	0.0	0.0	0.0	220	37.6	26.4	29.7
230	18.3	14.6	20.2	37.5				230	30.5	19.4	36.4
240	13.6	9.9	27.2	40.0				240	23.4	12.3	47.5
250	8.8	5.2	40.9	42.5				250	16.4	5.3	67.6
260	4.0	0.4	90.0	45.0				260	9.3	0.0	100.0
270	0.0	0.0		47.5				270	2.3	0.0	100.0

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