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Integrated Nutrient Management and Formulation of Targeted Yield Equations for Cowpea [*Vigna unguiculata* (L.) Walp.]

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Abstract A field experiment was conducted to study the effect of graded doses of fertilizers on yield of cowpea and to formulate the targeted yield equation for cowpea. Three fertility gradient stripes were createdin *Inceptisols* of Odisha by applying no fertilizer, recommended dose of fertilizer (RDF) and double the RDF and paddy was grown during *kharif* season of 2012-13. These three stripes were sub-divided into 24 sub plots and cowpea was grown with different graded doses of fertilizers and manure during *rabi*. Initial and post harvest soil nutrient status, nutrient uptake, nutrient requirement, soil efficiency, fertilizer efficiency and yield data were observed. The highest yield (51.5 q ha^{-1}) was achieved with 40:60:40 ($N:P_2O_5:K_2O$). Based on the data targeted yield equations were formulated for targeted yield of cowpea. The equations are very much useful for traget based yield achievement.

Keywords Cowpea *Inceptisols*, Targeted yield, Targeted yield equations.

Introduction

Cowpea [*Vigna unguiculata* (L.) Walp.], a true diploid (2n = 2x = 22) species, belongs to the family Leguminosae, tribe Phaseoleae, genus *Vigna*, and section Catiang [1]. It is a global legume whose cultivation is believed to have begun form Africa more than 5000 years ago [2, 3]. Cowpea is considered as one of the most inportant food and forage legumes in the semi-arid tropics that include parts of Asia, Africa, Southern Europe, Southern United States, and Central and South America [4, 5]. The West African sub-region contributes to about 95% of global cowpea production [6]. Of the 12.5 million tons of cowpea grains produced worldwide, over 64% takes place on low-input, subsistence farms in West and Central Africa [7]. It is a multipurpose drought hardy cropused as a source of food, fodder, feed, green manuring [8]. It also protects the soil from moisture loss and ero-

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Table 1. The chemical properties of a typifying pedon of the experimental site.

Depth (cm)	Organic carbon (g kg^{-1})	pH (1:2)	EC (dSm^{-1})	Exchangeable cations [c mol (p$^+$) kg^{-1}] in soil Ca	Mg	Na	K	Sum	Exchange acidity [c mol (p$^+$) kg^{-1} soil]	CEC [c mol (p$^+$)] kg^{-1} soil	Base staturation (%0
0–16	03.7	5.39	0.21	1.78	0.94	0.11	0.10	2.93	1.32	4.50	65.11
16–35	02.9	6.31	0.23	1.70	0.90	0.08	0.10	2.78	1.32	4.28	64.95
35–57	01.8	6.91	0.20	8.78	2.80	0.12	0.42	12.12	2.26	12.48	83.70
57–130	0.9	7.58	0.51	12.14	4.20	0.22	0.97	17.53	2.31	20.10	87.21

sion by water or wind. The crop is consumed in many forms. Young leaves, green pods, green leaves and dried leaves are used as vegetables whereas dry seeds and roots are used in a variety of food preparations [9]. Cowpea leaves are also known to contain a high amount of protein and minerals, such as calcium, phosphorus and vitamin B [10]. Protein concentrations of 29 to 43% have been reported for cowpea leaves but only from 21 to 33% in seed [9, 11]. Additionally, leaves contain considerably larger amounts of the essential amino acids, methionine and cysteine and they are a significant source of β-carotene, a vitamin A precursor [9]. The seed is reported to contain 24% crude protein, 53% carbohydrates, and 2% fat [12]. Cowpea grows well in poor soils that have more than 85% sand, less than 0.2% organic matter and low levels of phosphorus [13]. Furthermore, many cowpea cultivars can with stand drought and have short growing periods, making them very attractive to farmers in marginal, drought-prone areas that have low rainfall and poorly developed irrigation systems [14].

Soil test based fertilizer recommendation is widely accepted as an important basis for higher yield with optimum use of resources. Soil test as a gimmick unless it gives a correct appraisal of fertility status and predicts fertilizer required for maximum return or a definite yield goals [15]. Targeted yield approach is the most appropriate method for balance fertilization. This approach provides the basis of optimum resources utilization and balance crop nutrient management. Soil test based fertilizer application is a useful tool and presumed that fertilizer prescription equation is a unique technology to optimize need based fertilizer application. The concept of fertilizer prescription equation for desired yield target was first given by the earlier worker [16]. Later, theoretical basis and experimental techniques were established to suit it in Indian condition showing the linear relationship between yield and nutrient uptake [17]. For a given quantity of yield of any crop fertilizer requirement can be estimated considering efficiency of soil and fertilizer nutrients. Though fertilizer prescription equations have been developed for field crops like groundnut [18], sesamum [19], rice [20], mustard [21] and vegetables like pumpkin [22], lady's finger [23] and tomato [24] but no such equation has been developed for Cowpea for *Inceptisols*. Keeping in view on the above information the present study was carried out to formulate the targeted yield equations for cowpea in various soil fertility status in *Inceptisols*.

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Materials and Methods

Site characteristics

The experimental site is characterized by medium land, sandy loam in texture both in surface and subsurface layers. Soil was moderately acidic (pH 5.39) in reaction and low in organic carbon (3.7 g kg^{-1}). CEC of the surface soil was 4.5 cmol (p$^+$) kg^{-1} with 65.1% base saturation. The experimental site is low in soil avail-

Table 2. Range and average yield of cowpea (cv *Utkal Manika*), soil test values and N, P and K uptake in different fertility gradient strips.

Particulars		B-I	B-II	B-III
Grain yield (q ha^{-1})	Range	13.4–42.4	14.9–47.5	16.0–51.5
	Average	29.9	33.5	36.3
Available N (kg ha^{-1})	Range	113.6–174.0	123.2–186.0	136.8–194.2
	Average	164.2	176.0	185.9
Available P_2O_5 (kg ha^{-1})	Range	30.6–38.8	39.6–48.8	44.6–57.3
	Average	34.8	44.7	53.1
Available K_2O (kg ha^{-1})	Range	99.2–115.4	114.8–128.2	120.6–148.4
	Average	107.0	121.3	135.3
N uptake (kg ha^{-1})	Range	22.30–70.4	26.0–82.8	46.8–88.6
	Average	51.0	59.0	79.8
P_2O_5 uptake (kg ha^{-1})	Range	9.2–28.8	11.0–35.2	11.8–39.6
	Average	20.4	24.5	26.6
K_2O uptake (kg ha^{-1})	Range	17.8–56.2	22.0–71.7	23.9–77.1
	Average	39.6	50.2	54.1

able N, medium in available P and low in available K. Micronutrients content in initial soil sample were found 50. 76, 1.83, 2.22 and 0.52 mg kg^{-1} for Fe, Mn, Cu, Zn and B respectively. The soil was classified as *fine, mixed, hyperthermic* family of *Vertic Haplustepts*. The chemical properties of a typifying pedon of the experimental site are presented in Table 1.

Experimental setup

The experimental site (0.3 ha) was divided into three equal blocks during *kharif* 2012-13 to create fertility gradient strips. Rice (cv *Lalat*) was grown in three fertility gradient stripes viz. without application of N, P, K in Block-I, N_{80} P_{40} K_{40} (recommended dose) in Block-II and N_{160} P_{80} K_{80} (double the recommended dose) in Block-III; thus, three fertility gradient stripes B-I, B-II and B-III were created. During *rabi* these three blocks were ploughed and each block was divided into 24 subplots (5.5 × 4.0 meter each). Initial soil samples were collected from each plot for initial nutrient status. Available soil N was analyzed by Alkaline Permanganate method, available P_2O_5 by Bray's No–1 method and soil available K_2O by Neutral Normal Ammonium Acetate method as described by Jackson [25]. In each strip, out of 24 subplots, 21 plots were super imposed with different graded doses of N, P, K; two plots were given FYM at 5 t and 10 t ha^{-1} respectively and one plot was kept absolute control. Cowpea (cv *Utkal Manika*) was grown during *rabi*. The N levels were kept 20, 30 and 40; P levels were 45, 60 and 75 & K levels were 20, 30 and 40 kg ha^{-1} each. Post harvest soil sample, stover and grain samplesm yield data were recorded to study the nutrients uptake followed by formulation of fertilizer prescription equation.

The required parameters for formulating fertilizer prescription equations for targeted yield were experimentally obtained for a given soil type-crop-agroclimatic condition. Nutrient requrement (NR), Soil efficiency (Cs) and Fertilizer efficiency (Cf) were found out as the procedure given by the earlier workers [17]. The available soil nutrient content is taken into consideration while estimating soil efficiency and fertilizer efficiency.

Therefore,

$$\text{NR (Nutrient requirement; kg q}^{-1}\text{)} = \frac{\text{Uptake of nutrient by Cowpea (kg/ha)}}{\text{Yield of cowpea (q/ha)}}$$

$$\text{Cs (Soil efficiency)} = \frac{\text{Uptake of nutrient in absolute control plot (kg/ha)}}{\text{Initial soil test value of that particular nutrient in control plot (kg ha)}}$$

Table 3. Targeted yield equation developed by AICRP on STCR, Bhubaneswar for cowpea. Where, FN, F P_2O_5 and F K_2O = kg fertilizer N, P_2O_5 and K_2O required; T=specific yield target in (q); S N, S P_2O_5 and K_2O=kg Soil available N, P_2O_5 and K_2O respectively; ON, O P_2O_5 and O K_2O=kg N, P_2O_5 and K_2O added through FYM.

Parameters	NR (kg q^{-1})	Cs (%)	Cf (%)	Co (%)	Fertilizer Prescription Equation
N	0.75	14.9	45	28	FN=1.67 T – 0.0.33 SN-0.62ON
P_2O_5	0.71	27.0	22	25	F P_2O_5 = 1.22 T – 1.13 S P_2O_5 - 1.13 O P_2O_5
K_2O	1.43	18.6	95	21	F K_2O = 1.5 T- 0.19 S K_2O – 0.22 O K_2O

$$\text{Cf (Fertilizer efficiency)} = \frac{\text{Uptake of nutrient in fertilizer treated plot (kg/ha)} - \text{initial soil test value (kg ha)} \times \text{Cs}}{\text{Amount of fertilizer nutrient applied (kg ha)}}$$

$$\text{Co (Organic matter efficiency)} = \frac{\text{Total nutrient uptake in OM treated plot} - \text{Soil test value} \times \text{Soil efficiency}}{\text{Nutrient applied through OM}}$$

T– Targeted yield (q ha^{-1}) of cowpea desired to be obtained within its varietal limitation

SN– Initial soil available N (kg ha^{-1}) analyzed by Alkaline permanganate method

SP_2O_5–Initial soil available P_2O_5 (kg ha^{-1}) analyzed by Bray's No. 1 method

K_2O– Initial soil available K_2O (kg ha^{-1}) analyzed by Ammonium acetate method

Co– Efficiency of organic matter.

Soils were analyzed as per the methodologies laid down by Jackson [25].

These parameters are then transferred to a workable equation (targeted yield equation) as follows:

$$FD = \frac{(NR \times 100 \times T)}{Cf} - \frac{(Cs \times STV)}{Cf} - \frac{(Co \times Org)}{Cf}$$

Where FD=fertilizer dose (kg ha^{-1}); T=yield target (q ha^{-1}) and STV=soil test value.

Results and Discussion

Among three fertility gradient stripes maximum available soil nutrient found in B-III strip as it received double of the recommended doses during *kharif*. The mean value of soil available N, P and K increases with increase in fertility gradient strip from B-I to B-III. Mean available soil N was found 164.2, 176.0 and 185.9 kg ha^{-1}; that of P_2O_5 was found 34.8, 44.7 and 53.1 kg ha^{-1} and mean available K_2O was found 107.0, 121.3 and 135.3 kg ha^{-1} in B-I, B-II and B-III stripes respectively. As B-III strip received more amount of applied fertilizer (double of the recommended dose in rice) during *kharif* therefore much higher soil fertility status, nutrient uptake and yield were observed. In contrast, the lowest uptake and yield were found in the B-I as no fertilizer was added in rice during *kharif*. The range and average of initial soil test values, uptake of nutrients and yield of Cowpea are presented in Table 2.

Uptake of N, P and K shows an increasing trend with increasing fertility gradient strips from B-I to B-II as it was found in case of initial soil nutrients status. The mean uptake of N was found 51.0, 59.0 and 79.8 kg ha^{-1}; that of P_2O_5 was found 20.4, 24.5 and 26.6 kg ha^{-1} and mean K_2O uptake was found 39.6, 50.2 and 54.1 kg ha^{-1} in B-I, B-II and B-III stripes respectively.

The uptake of nutrient co-relates well with grain yield of cowpea. Result shows that higher the N, P, K uptake higher is the yield of grains. The average pod yield ranges from 29.9 q ha^{-1} in the lowest fertility gradient strip (B-I) to 36.3 q ha^{-1} in the highest fertility gradient strip (B-III).

Based on the basic parameters nutrient requirement (NR) soil efficiency (Cs) and fertilizer efficiency (Cf) calculated as given and computing them into

Table 4. Ready reckoner for fertilizer recommendations for specific yield targets of cowpea (cv *Utkal Manika*) under different soil fertility status.

Available soil nutrient (kg ha^{-1})			Fertilizer nutrient required (kg ha^{-1}) Targeted yield (60 q ha^{-1})			Targeted yield (70 q ha^{-1})			Targeted yield (80 q ha^{-1})		
N	P_2O_5	K_2O	N	P_2O_5	K_2O	N	P_2O_5	K_2O	N	P_2O_5	K_2O
100	10	80	67	62	60	74	74	75	101	86	90
120	15	90	61	56	56	67	68	71	94	81	86
140	20	100	54	51	52	61	63	67	87	75	82
160	25	110	47	45	48	54	57	63	81	69	78
180	30	120	41	39	44	48	52	59	74	64	74
200	35	130	34	34	41	41	46	56	68	58	71
220	40	140	28	28	37	34	40	52	61	52	67
240	45	150	21	22	33	28	35	48	54	47	63
260	50	160	14	17	29	21	29	44	48	41	59

workable equations. The fertilizer requirement for targeted yield of cowpea was formulated which is given in Table 3. In the equations, the target (T) has to be fixed by the extension scientists/farmers concerned and the SN, SP_2O_5 and SK_2O values have to be put for available soil nitrogen, soil phosphorus and soil potassium of that particular field which has to be precisely determined in the laboratory by analyzing the soil samples of that field.

A ready reckoner of fertilizer doses has been prepared taking into consideration different yield targets at different fertility status of the soils and presented in Table 4 which will be useful for extension officers, scientists and farmers alike in balanced fertilization of crop for targeted yield. These equations will be useful in red, laterite and yellow soils (*Inceptisols* and *Alfisols*) which constitute 84% of the total geographical area of Odisha, India.

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