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Soil Test Crop Response based Fertilizer Equations for Bt Cotton under Rainfed Situation in Vertisol

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A B S T R A C T

Field experiments were conducted on a Typic Haplustert of Tamil Nadu by adopting the inductive cum targeted yield model developed for Bt cotton under rainfed situation. The basic parameters viz., NR, Cs, Cf and contribution of nutrients from FYM were computed from the field experimental data developed in the previous cropping season. Using these basic parameters, fertilizer prescription equations were developed under the Integrated Plant Nutrition System (IPNS) and nomograms were formulated for the desired yield target of Bt cotton for a range of soil test values. The quantity of nutrients that could be contributed by FYM at 12.5 t ha^{-1} was evaluated as 25, 20 and 26 kg N, P_2O_5 and potassium oxide K_2O respectively, when applied along with the NPK fertilizers as per soil test and desired yield target. The fertilizer prescription equations developed for Bt cotton proved their validity under six numbers of farmer's holdings under rainfed situation.

Introduction

In the era of precision agriculture, application of fertilizers based on soil testing is an essential tool to prescribe nutrient doses for crops besides assessing soil health. Further, the escalation in fertilizer prices has caused a serious set back for balanced fertilization. At present, an annual net negative balance of about 8-10 million tons of nutrients per annum is reported in India. This distortion in soil fertility and deterioration in soil health is due to indiscriminate and imbalanced use of fertilizers and it can be corrected only with proper manure – fertilizer schedule based on soil fertility evaluation.

Concomitant with the steep increase in adoption of private sector Bt cotton hybrids from the year 2002 onwards and also improved cotton production technologies besides good public sector hybrids, the

average productivity has increased from 308 kg ha $^{-1}$ to 550 kg ha^{-1} in India. Perambalur is the leading District in Bt cotton cultivation and is cultivated in an area of 22,000 ha. At this juncture, the unique inductive cum targeted yield model of *Ramamoorthy et al.*, (1967) is quite appropriate for determining a precise fertilizer prescription for Bt cotton under rainfed situation. Hence present study has been undertaken on black calcareous soils (Typic Haplustert) of TamilNadu.

Materials and Methods

A field experiment was conducted with Bt cotton *var*. Brahma BG (II) during 2011-2012 on Typic Haplustert at gotton research station farm, veppanthattai, Tamil Nadu Agricultural University, Coimbatore. The surface soil of the experimental field is black calcareous, very deep, moderately drained, clay loam in texture with pH 8.45, electrical conductivity (EC) 0.47 dSm^{-1}, and cation exchange capacity of 27.7 cmol (p+) kg$^{-1.}$ The initial soil available alkaline potassium permanganate (KMnO4) nitrogen (N), organic carbon, Olsen phosphorus (P), and ammonium acetate (NH_4OAc) K were 146kg ha^{-1}, 0.42%, 11 kg ha^{-1} and 124 kg ha^{-1} respectively. The P and K- fixing capacities of the soil were 345 and 96 kg ha^{-1} respectively. The available iron (Fe), manganese (Mn), zinc (Zn) and copper (Cu) were in the sufficiency ranges. Variation in soil fertility was created by adopting the inductive methodology developed by Ramamoorthy *et al.*, (1967). The experiment was laid out in a fractional design comprising twenty- four treatments with four level of N (0,30,60 and 90 kg ha^{-1}), four levels of P_2O_5 (0,15,30 and 45 kg ha^{-1}), four levels of K_2O (0,30,60 and 90 kg ha^{-1}), and three levels of FYM (0,6.25, and 12.5t ha^{-1}). The IPNS treatments (NPK alone, NPK+ FYM at 6.25 t ha^{-1}, and NPK+ FYM 12.5 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 on either direction. The treatment structure is given in table 1. Making use of the data on nutrient uptake, seed cotton yield, pre-sowing soil available N,P and K nutrients, and applied fertilizer doses, the basic parameters [viz., nutrient requirement (NR), contributions of nutrient from soil (Cs) and fertilizers (Cf)] were calculated as outlined by Ramamoorthy *et al.*, (1967) and those from FYM (C_{fym}) were estimated as described by Santhi *et al.*, (1999).

Yield targeted equations

From the above parameters the yield targeted equations were as given below:

(a) Under NPK alone

$$(i)FN = \frac{NR}{Cf/100} T - \frac{Cs}{Cf} SN$$

(b)Under IPNS

$$a)(i)FN = \frac{NR}{Cf/100} T - \frac{Cs}{Cf} SN - \frac{Cfym}{Cf} ON$$

$$\text{b)(i) } F\ P_2O_5 = \frac{NR}{Cf/100} \times T - \frac{Cs}{Cf} \times 2.29 \times SP$$

$$\text{a)(ii) } F\ P_2O_5 = \frac{NR}{Cf/100} \times T - \frac{Cs}{Cf} \times 2.29 \times SP - \frac{Cfym}{Cf} \times 2.29 \times OP$$

$$\text{a)(iii) } F\ K_2O = \frac{NR}{Cf/100} \times T - \frac{Cs}{Cf} \times 1.21 \times SK$$

$$\text{b)(iii). } F\ K_2O = \frac{NR}{Cf/100} \times T - \frac{Cs}{Cf} \times 1.21 \times SK - \frac{Cfym}{Cf} \times 1.21 \times OK$$

Where,
FN=Fertilizer N in kg ha^{-1}
F P_2O_5 =Fertilizer P_2O_5 in kg ha^{-1}
F K_2O =Fertilizer K_2O in kg ha^{-1}
T = yield target in q ha^{-1}
NR=Nutrient requirement N or P_2O_5 or K_2O kg q^{-1}
Cs=Per cent contribution of nutrients from soil
Cf=Per cent contribution of nutrients from fertilizer
Cfym= Per cent contribution of nutrients from FYM
SN=Soil test value for available N in (kg ha^{-1})
SP=Soil test value for available P in (kg ha^{-1})
SK=Soil test value for available K in (kg ha^{-1})
ON,OP and OK are the quantities of N,P and K supplied through FYM in kg ha^{-1}

These equations serve as a basis for predicting fertilizer doses for specific yield targets (T) for varied soil available nutrient levels.

Confirmatory test verification trials were conducted at various blocks of Perambalur district representing Pilamedu soil series *viz.*, Palayur, CRS farm, Nerkunam, Esanai, Perambalur and Venbavour villages, to confirm the validity of fertilizer prescription equations developed for Bt cotton under rainfed situation. The treatments followed were

i) Control
ii) Blanket recommendation
iii) STCR 28 q ha^{-1}
iv) STCR 32 q ha^{-1}
v) STCR - IPNS 28 q ha^{-1}
vi) STCR - IPNS 32 q ha^{-1}
vii) Farmer's practice.

The Bt cotton, BRAHMA BG II was sown during September 2012 and harvested on March -2013. The fertilizer doses applied, seed cotton yield, per cent achievement and response ratio of targeted yield are discussed below.

Results and Discussion

Seed cotton yield and soil available nutrients

The mean seed cotton yields of rainfed Bt cotton were 1354, 1902 and 2739 kg ha^{-1} in strip I, II and III respectively. The N uptake ranged from 14.08 to 83.49 kg ha^{-1}; P uptake ranged from 1.03 to 15.15 kg ha^{-1} and The K uptake ranged from 10.33 to 80.22 kg ha^{-1} in strip I - III respectively. The data on initial

soil test values revealed that mean $KMnO_4$ –N values were 146 kg ha^{-1} in strip I, 176 kg ha^{-1}in strip II and 194 kg ha^{-1} in strip III. The mean Olsen –P values were 10.34, 20.75 and 29.27 kg ha^{-1} in strip I, II and III respectively. The mean NH_4OAc –K values were 123, 174 and 214 kg ha^{-1} in strip I, II and III respectively.

The existence of operational range of soil test values for soil available N, P and K status in the present investigation was clearly depicted from the initial soil available nutrient status and the variation in the seed cotton yield and NPK uptake, which is a pre requisite for calculating the basic parameters and fertilizer prescription equations for calibrating the fertilizer doses for specific yield target. *Santhi et al.,* (2011) reported similar existence of operational ranges of available N, P and K for beetroot on Alfisol.

Basic parameters

In the targeted yield model, making use of the data on yield of Bt cotton, uptake of NPK, initial soil test values, and the doses of fertiliser N, P_2O_5, and K_2O applied, the basic parameters were computed. The basic parameters for developing fertilizer prescription equations for Bt cotton are (i) nutrient requirement in kg per quintal of seed cotton yield (NR) and percentage contribution of nutrients from soil (Cs), fertilisers (Cf), and farm yard manure (Co).

Nutrient Requirement (NR)

The results of the present investigation revealed that Bt cotton under rainfed situation requires 2.48 kg of N, 0.78 kg of P_2O_5, and 3.12 kg of K_20 for producing one quintal of seed cotton (Table 3). Among the three nutrients, the requirement of K_2O is relatively higher; followed by N and P_2O_5. Similar trends of nutrient requirement for N, P_2O_5 and K_20 were reported by *Smitha John* (2004) for cabbage and *Santhi et al.,* (2011) for beet root (Table 2).

Percentage Contribution of nutrients from soil (Cs), Fertilizers (Cf), and Farm yard manure (Cfym) to Total Uptake

The percentage contribution of nutrients from soil (Cs) to the total uptake was computed from the absolute control. In the present study, it was found that the soil has contributed 11.08% of available N, 18.60% of available P, and 8.66 % of available K respectively toward the total N, P, and K uptake by beetroot. Among the three nutrients, the percentage contribution from soil was relatively higher for P followed by N and K.

With regard to fertilizer nutrients (Cf), the contribution was computed from NPK-applied plots, and the values were 46.34 %, 21.35 %, and 81.40 %, respectively for N, P_2O_5, and K_2O in which the contribution from applied fertilizer followed the order of K_2O > N> P_2O_5. The estimated Cf clearly revealed that the magnitude of contribution by fertilizer K_2O was 4.14 times greater than P_2O_5 and 2.12 times that of N. With regard to N, P_2O_5, and K_2O, comparatively greater contribution was recorded from fertilizers than from the soil. With regard to K_2O, comparatively less Cs was recorded, which might be due to the preferential nature of Bt cotton toward the applied K_2O than the native K_2O.

The percentage contribution of nutrients from farm yard manure (C_{fym}) to the total uptake was computed from the farm yard manure applied plots. It was found that farm yard manure has contributed 24.58 % of N, 7.81 % of P_2O_5 and 36.87 % of K_2O respectively toward the total N, P, and K uptake by rainfed Bt cotton following the order N > K_2O >

P_2O_5. Similar trends for Cs, Cf, and Co for N, P_2O_5, and K_20 were reported by *Vijayalakshmi* (2008) for radish on Typic Haplustalf.

Fertilizer prescription equations

Soil test based fertilizer prescription equations for desired yield target of Bt cotton under rainfed situation were formulated using the above said basic parameters

NPK alone

FN = 5.35 T – 0.24 SN
FP_2O_5 = 3.67 T - 1.99 SP
FK_2O = 3.83 T – 0.13 SK

NPK with farm yard manure

FN = 5.35 T – 0.24 SN – 0.53 ON
FP_2O_5 = 3.67 T - 1.99 SP – 0.84 OP
FK_2O = 3.83 T – 0.13 SK - 0.55 OK

where, FN, FP_2O_5 and FK_2O respectively are fertilizer N, P_20_5 and K_20 in kg ha^{-1}; T is the yield target in q ha^{-1} and SN, SP and SK respectively are alkaline $KMnO_4$–N, Olsen and NH_4OAc–K in kg $ha^{-1.}$ ON, OP and OK are quantities of N, P and K supplied through FYM in kg $ha^{-1.}$ *Santhi et al.*, (2012) documented the formulation of fertilizer prescription equations for expand various agriculture and horticulture crops of TamilNadu.

Fertilizer prescription under IPNS for desired yield target of Bt cotton under Rainfed situation

A ready reokoner was prepared based on these equations for a range of soil test values and for yield target of 32 q ha^{-1}(Table 3). The data clearly revealed the fact that fertilizer N, P_2O_5 and K_2O requirements decreased with increase in soil test values. For a yield target of 32 q $ha^{-1}$of seed cotton yield with soil test values of 275: 24: 400 kg ha^{-1} of $KMnO_4$ –N, Olsen-P and NH_4OAc–K, the fertilizer N, P_2O_5 and K_2O doses were 106, 70 and 71 kg ha^{-1} respectively. When FYM (26 % moisture, 0.51 %, 0.25 % and 0.50 % N, P and K) at 12.5 t ha^{-1} was applied along with NPK, the required fertilizer N, P_2O_5 and K_20 doses were 81, 50 and 44 kg ha^{-1} respectively. Under IPNS, the savings of fertilizer N, P_2O_5 and K_2O were 93, 60 and 51 kg ha^{-1} respectively for NPK plus FYM @ 6.25 t ha^{-1} and 25, 20 and 26 kg ha^{-1} for NPK plus FYM @ 12.5 t ha^{-1} respectively. These quantities of nutrients can be reduced from the recommended doses of fertilizers for a particular soil test value and yield target.

Results of confirmatory test verification trials

The per cent achievement of the targeted yield was within +/- 10 per cent variation in all the locations for both the yield targets under NPK alone and IPNS proving the validity of the equations. Among the different treatments followed, STCR-IPNS - 32 q ha^{-1} has recorded the highest yield of 32.58, 32.85, 32.38 and 32.85 q ha^{-1} at Nerkunam, Esanai, Venbavour and Perambalur trials respectively (Tables 1 and 4). The highest response ratio of 4.57, 4.14, 4.43 and 4.92 kg kg^{-1} were also recorded in the STCR-IPNS-32 q ha^{-1} treatments at Nerkunam, Esanai, Venbavour and Perambalur trials respectively. Farmer's practice recorded relatively lower yield (20.75 q ha^{-1}) and response ratio (1.56 kg kg^{-1}) as compared to blanket and STCR treatments. While the STCR - IPNS treatments recorded the highest per cent achievement and response ratio among all the treatments. Though the blanket fertiliser recommendation recorded relatively higher yield and response ratio over farmer's practice, it was lower when compared to STCR treatments. STCR-IPNS for 32 q ha^{-1} has recorded a yield increase of

46.7 per cent over blanket and 57.5 per cent over farmer's practice (Table 4). The mean data of the four locations revealed that STCR-IPNS based fertilizer recommendations for an yield target of 32 q ha^{-1} has recorded the highest mean seed cotton yield of 32.67 q ha^{-1}, response ratio of 4.52 kg seed cotton yield kg^{-1} fertilizer applied, per cent achievement of 102.0 Sherene *et al.,* (2006) (Table 3).

Table.1 Treatment structure for test crop experiment on Bt cotton

S. No	Treatment Combinations			Level of Nutrients kg ha^{-1}		
	N	P	K	N	P_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	30	**60**
5.	1	1	1	30	15	**30**
6.	1	1	2	30	15	**60**
7.	1	2	1	30	30	**30**
8.	1	2	2	30	30	**60**
9.	2	1	1	60	15	**30**
10.	2	0	2	60	0	**60**
11.	2	1	2	60	15	**60**
12.	2	2	0	60	30	**0**
13.	2	2	1	60	30	**30**
14.	2	2	2	60	30	**60**
15.	2	2	3	60	30	**90**
16.	2	3	2	60	45	**60**
17.	2	3	3	60	45	**90**
18.	3	1	1	90	15	**30**
19.	3	2	1	90	30	**30**
20.	3	2	2	90	30	**60**
21.	3	3	1	90	45	**30**
22.	3	3	2	90	45	**60**
23.	3	2	3	90	30	**90**
24.	**3**	**3**	**3**	**90**	**45**	**90**

Table.2 Nutrient requirement, percent contribution of nutrients from soil and fertilizer for rainfed Bt cotton

Parameters	**Basic data**		
	N	P_2O_5	**K_2O**
Nutrient requirement (kg /q)	2.48	0.78	**3.12**
Percent contribution from soil (Cs)	11.08	18.60	**8.66**
Percent contribution from fertilizers (Cf)	46.34	21.35	**81.40**
Percent contribution from FYM (Cfym)	**24.58**	**7.81**	**36.87**

Table.3 Soil test based fertilizer prescriptions under IPNS for 32 q ha^{-1} target seed cotton yield of Bt cotton under rainfed situation (kg ha^{-1})

	IPNS				
	NPK alone kg /ha	**NPK plus FYM @6.25 t /ha (kg /ha)**	**Percent reduction over NPK alone**	**NPK +FYM @12.5 t /ha**	**Percent reduction over NPK alone**
$KMnO_4$ –N (kg ha^{-1})					
100	147.2	134.61	8.55	122.0	**17.09**
125	141.2	128.61	8.92	116.0	**17.82**
150	135.2	122.61	9.31	110.0	**18.61**
175	129.2	116.61	9.74	104.0	**19.48**
200	123.2	110.61	10.22	98.03	**20.43**
225	117.2	104.61	10.74	92.03	**21.47**
250	111.2	98.61	11.32	86.03	**22.63**
275	105.2	92.61	11.97	80.03	**23.93**
Olsen P (kg ha^{-1})					
10	97.54	87.56	10.23	77.59	**20.45**
12	93.56	83.58	10.66	73.61	**21.32**
14	89.58	79.60	11.14	69.63	**22.27**
16	85.6	75.62	11.65	65.65	**23.30**
18	81.62	71.64	12.22	61.67	**24.44**
20	77.64	67.66	12.85	57.69	**25.69**
22	73.66	63.68	13.54	53.71	**27.08**
24	69.68	59.70	14.32	49.73	**28.63**
NH_4OAc -K (kg ha^{-1})					
100	109.5	96.4	11.96	83.43	**23.80**
150	103.0	89.9	12.71	76.93	**25.31**
200	96.56	83.46	13.56	70.43	**27.06**
250	90.06	76.96	14.54	63.93	**29.01**
300	83.56	70.46	15.67	57.43	**31.27**
350	77.06	63.96	16.99	50.93	**33.90**
400	70.56	57.46	18.56	44.43	**37.03**
450	**64.06**	**50.96**	**20.44**	**37.93**	**40.78**

Table.4 Results of four confirmatory trials on rainfed Bt cotton

S.No.	**Treatments**	**Nutrients added (kg ha^{-1})**			**Mean Seed cotton yield (q ha^{-1})**	**Mean Achievement (%)**	**Mean RR**
		N	**P_2O_5**	**K_2O**			
1.	Control	0	0	0	18.92	-	**-**
2.	Blanket	60	30	60	22.28	-	
3.	STCR –NPK alone 28 q ha^{-1}	96-113	60	51-85	26.67	95.23	**2.16**
4.	STCR –NPK alone 32 q ha^{-1}	118-135	60	66-100	30.61	95.64	**3.83**
5.	STCR -IPNS 28 q ha^{-1}	71-88	60	25-59	28.49	101.74	**3.77**
6.	**STCR -IPNS 32 q ha^{-1}**	**93-109**	**59 -96**	**40-75**	**32.67**	**102.1**	**4.52**
7.	**Farmer's practice**	**49**	**25**	**37**	**20.75**	**-**	**1.56**

Fertilizer Prescription Equations

FN = 5.35 T – 0.24 SN – 0.53 ON

FP_2O_5 = 3.67 T - 1.99 SP – 0.84 OP

FK_2O = 3.83 T – 0.13 SK - 0.55 OK

STCR-IPNS based fertilizer recommendations for a yield target of 32 q ha^{-1} has recorded the highest yield, response ratio and per cent achievement. Therefore, the fertilizer prescription equations developed for Bt cotton under IPNS can be recommended for black calcareous soils with an yield target of 32 q ha^{-1} under rainfed situation

In conclusion, soil test based fertilizer prescription for Bt cotton under rainfed situation was developed on Typic Haplustert soil of Tamil Nadu taking into account the nutrient requirement and contributions of NPK from the nutrient sources (soil, fertilizer and FYM). This allows the balanced supply of nutrients through IPNS.

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