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Optimization of Fertiliser Doses through Inductive cum Targeted Yield Model for Transgenic Cotton Under Drip Fertigation on an Inceptisol

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Studies on Soil Test Crop Response based Integrated Plant Nutrition System (STCR - IPNS) were conducted during 2011-12 adopting the Inductive cum Targeted yield model, on a Vertic Ustropept soil of Tamil Nadu, South India in order to develop fertilizer prescriptions for the desired yield targets of transgenic cotton through drip fertigation. The basis for making the fertilizer prescriptions *viz.* nutrient requirement (NR), contribution of nutrients from soil (Cs), fertilizer (Cf) and farmyard manure (Cfym) were computed using the field experimental data. Making use of these basic parameters, the fertilizer prescription equations were developed under NPK alone and IPNS, and nomograms (ready reckoner of fertilizer doses) were formulated for the desired yield targets of cotton for a range of soil test values. When applied along with the NPK fertilizers as per soil test and desired yield target, the quantity of nutrients that could be contributed by the application of farmyard manure (FYM) @ 12.5 t ha^{-1} (with 32% moisture, 0.64, 0.31 and 0.61 per cent of N, P and K respectively) for cotton was assessed as 40, 20 and 34 kg fertilizer N, P2O5 and K_2O respectively, The per cent reduction in fertilizer N, P_2O_5 and K_2O requirement under IPNS increased with increasing soil available NPK status.

Key words: Inceptisol, Transgenic cotton, Fertilizer prescription equations and STCR-IPNS

Cotton is an important commercial crop playing a key role in economical and social status of the world. Popularly known as 'White Gold', it is a premier cash crop of most of the SAARC countries with an enormous potential of sustainable employment generation both in rural and urban sector. India has the largest area under cotton production, 121.78 lakh ha. However, it stands second in production, 353.00 lakh bales (Supriya Pal, 2010) next only to China. This shows that the potential productivity of the crop is not fully exploited. There arises the need for important technological interventions for increasing the productivity of cotton.

The total cotton area in India was 12.1 million hectares in 2011, and the transgenic cotton occupied 88% of this area with a rapid increase from 50,000 hectares in 2002 to 10.6 million hectares in 2011. This has made India, the country with the largest area of transgenic cotton in the world (Clive James, 2012). A long-term study on the economic impacts of transgenic cotton in India, showed that it has increased yields, profits, and living standards of farmers (Policepatil, 2007).

In the prevailing regime of widespread negative nutrient balances, it is difficult to expect depleted soils to support bumper crops or yield with high growth rates, even in a superior hybrid or a genetically modified crop. Negative nutrient balances in most Indian soils not only mirror poor soil health, but also represent severe on-going depletion of the soil's nutrient capital, degradation of the environment, and vulnerability of the crop production system in terms of its ability to sustain high yields (Tandon, 2007). Insufficient nutrient additions compared to nutrient uptake leads to a decline in soil fertility. Cotton is a heavy feeder and the nutrient management in cotton is a complex phenomenon due to the production of vegetative and reproductive structures during the active growth phase. Though insufficient nutrient addition is a major impediment in realizing potential cotton yields, it forms just one side of the coin whose other side shows injudicious dumping of fertilizers at an inappropriate proportion leading to mere wastage of inputs instead of good remuneration.

Soil testing is a scientific tool to evaluate soil fertility by predicting the probability of getting a profitable crop response to recommended fertilizer application under specific soil-crop condition. Instead of blanket recommendation, soil test based nutrient management practices should be adopted for better productivity, profitability, sustainability and environmental safety (Venugopalan *et al.,* 2011). Also, soil testing is the first entry point to the farmers' field for extending agro-technology transfer to the

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farming community, including long-term soil fertility management (Velayutham, 2011).

At this juncture, the prescription procedure outlined by Truog (1960) and modified by Ramamoorthy *et al.* (1967) as "Inductive cum Targeted yield model" provides a scientific basis for balanced fertilization and balance between applied nutrients and soil available nutrients. Soil test based fertilizer recommendation plays a vital role in ensuring balanced nutrition to crops and also in preventing wasteful expenditure on the use of costly mineral fertilizers. Khosa *et al.* (2012) also reported the superiority of the target yield concept over other practices for different crops as it gave higher yields and optimal economic returns.

Having fertilizer recommendations in hand, the next important step is its proper application. At this juncture, fertigation facilitates and optimization of nutrient supply adjusted to the specific requirements of the crop in different phenological stages of growth and development becomes important. On account of the above facts, the present investigation was contemplated adopting the Inductive cum Targeted Yield model so as to derive a basis for recommending balanced nutrition through STCR- IPNS for transgenic cotton under drip fertigation on an Inceptisol.

Materials and Methods

Site description and soil characteristics

The field experiments were conducted at the Eastern block of TNAU farm, Coimbatore on an Inceptisol (Vertic Ustropept). The farm is located in the Western agro climatic zone of Tamil Nadu at 11°12' North latitude and 77° 03' East longitude at an altitude of 426.74 m above MSL. The field experiments were conducted during 2011 and 2012. The weather conditions during the crop growth showed mean maximum and minimum temperatures of 31.69°C and 20.97°C, respectively. The relative humidity ranged from 83 to 91 per cent and the amount of rainfall received was 641.2 mm distributed over 27 rainy days.

The soil was clay loam in texture, moderately alkaline in reaction (pH 8.4) and non - saline (EC 0.17 dS m^{-1}). The initial soil fertility status showed low available N (225 kg ha^{-1}, medium available P (19.9 kg ha^{-1}) and high available K (570 kg ha^{-1}). The available Zn, Cu and Mn were in the sufficient range (1.29, 1.94 and 14.66 mg kg^{-1} respectively) while available Fe was in the deficient range (3.34 mg kg^{-1}).The P and K fixing capacities of the soil were 100 kg ha^{-1} each.

Soil and plant analysis

The approved treatment structure and lay out design as followed in the All India Coordinated Research Project for Investigations on Soil Test Crop Response Correlation based on "Inductive cum Targeted yield model" (Ramamoorthy *et al.*,1967) was adopted in the present investigation. There were two phases of field experimentation *viz.*, gradient and test crop experiment. In the gradient experiment, operational range of variation in soil fertility was created deliberately. For this purpose, the experimental field was divided into three equal strips, the first strip received no fertilizer ($N_0P_0K_0$), the second and third strips received one (N_1P_1 K_1) and two ($N_2P_2K_2$) times the standard dose of N, P_2O_5 and K_2O, respectively and a gradient crop of fodder maize (var.CO 1) was grown. Eight pre-sowing and post-harvest soil samples were collected from each fertility strip and analyzed for alkaline $KMnO_4$-N, Olsen -P and NH_4 OAc-K. At harvest, plant samples were collected, processed and analyzed for N, P and K contents and NPK uptake was computed.

After confirming the establishment of fertility gradients in the experimental field, in the second phase of the field experiment, each strip was divided into 24 plots, and initial soil samples were collected from each plot and analysed for alkaline $KMnO_4$ -N (Subbiah and Asija, 1956), Olsen-P (Olsen *et al*.,1954) and NH_4OAc-K (Stanford and English, 1949). The experiment was laid out in a fractional factorial design comprising twenty four treatments, and the test crop experiment with transgenic cotton was conducted with four levels each of N (0, 60, 120 and 180 kg ha^{-1}), P_2O_5(0, 30, 60 and 90 kg ha^{-1}) and K_2O (0, 40, 80 and 120 kg ha^{-1}) and three levels of FYM (0, 6.25 and 12.5 t ha^{-1}). The experiment was conducted as per the approved guidelines of AICRP-STCR and fertilizer prescriptions were developed.

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

1. $N_0P_0K_0$	5. $N_1P_1K_1$	9. $N_2P_1K_1$	18. $N_3P_1K_1$
2. $N_0P_0K_0$	6. $N_1P_1K_2$	10. $N_2P_0K_2$	19. $N_3P_2K_1$
3. $N_0P_0K_0$	7. $N_1P_2K_1$	11. $N_2P_1K_2$	20. $N_3P_2K_2$
4. $N_0P_2K_2$	8. $N_1P_2K_2$	12. $N_2P_2K_0$	21. $N_2P_3K_1$
		13. $N_2P_2K_1$	22. $N_3P_3K_2$
		14. $N_2P_2K_2$	23. $N_3P_2K_3$
		15. $N_2P_2K_3$	24. $N_3P_3K_3$
		16. $N_2P_3K_2$	
		17. $N_2P_3K_3$	

The IPNS treatments *viz.*, NPK alone, NPK+ FYM @ 6.25 t ha^{-1} and NPK+FYM @ 12.5 t ha^{-1} were superimposed across the strips. There were 21 fertilizer treatments along with three controls which were randomized in each strip in such a way that all the treatments occurred in both the directions. The treatment structure is furnished in Table 1 and the layout in Figure 1. The test crop cotton was sown with a spacing of 120 cm x 90 cm. FYM was applied basally and fertilizer doses were imposed as per the treatments and the fertigation done at weekly intervals as per the schedule finalized by Jayaprakash (2008) for cotton on Inceptisol. The sources of nutrients used for fertigation were urea, single super phosphate and muriate of potash. Improved agronomic practices were followed periodically. The crop was grown to maturity, harvested and plot wise seed cotton, and stalk yield were recorded. The seed cotton, plant and post-harvest soil samples were collected from each plot. The plant samples were processed and analyzed for N (Humphries, 1956), P and K contents (Jackson, 1973), and NPK uptake by cotton was computed using the dry matter yield.

Making use of data on the yield of cotton, total uptake of N, P and K, initial soil test values for available N, P and K and doses of fertilizer N, P_2O_5 and K_2O applied, the basic parameters *viz*., nutrient requirement (NR), contribution of nutrients from soil (Cs), fertilizer (Cf) and farmyard manure (Cfym) were calculated as outlined by Ramamoorthy *et al*. (1967).

STRIP I	STRIP I		STRIP II		STRIP III		
OUTS	N0P0K0	N2P3K2	N0P0K0	N3P2K3	N0P0K0	N2P2K1	NPK alone B I
	N2P2K0 (A)	N2P1K1	N3P3K1 (B)	N2P2K3	N3P1K1 (C)	N1P1K1	
	N3P2K1	N1P1K2	N2P0K2	N1P2K1	N0P2K2	N2P3K3	
	N1P2K2	N3P3K2	N2P2K2	N3P3K3	N3P2K2	N2P1K2	
	N0P0K0	N3P2K3	N0P0K0	N2P2K1	N0P0K0	N2P3K2	NPK+ 6.25 t ha^{-1} FYM B II
	N3P3K1 (B)	N2P2K3	N3P1K1 (C)	N1P1K1	N2P2K0 (A)	N2P1K1	
	N2P0K2	N1P2K1	N0P2K2	N2P3K3	N3P2K1	N1P1K2	
	N2P2K2	N3P3K3	N3P2K2	N2P1K2	N1P2K2	N3P3K2	
	N0P0K0	N2P2K1	N0P0K0	N2P3K2	N0P0K0	N3P2K3	NPK+ 12.5 t ha^{-1} FYM B III
	N3P1K1 (C)	N1P1K1	N2P2K0 (A)	N2P1K1	N3P3K1 (B)	N2P2K3	
	N0P2K2	N2P3K3	N3P2K1	N1P1K2	N2P0K2	N1P2K1	
	N3P2K2	N2P1K2	N1P2K2	N3P3K2	N2P2K2	N3P3K3	

Spacing : 120 cm x 90 cm
Plot size : 6 m x 4.5 m = 27.0 m^2
No. of plots: 72

Fig.1. Layout plan of STCR –IPNS Experiment with transgenic cotton under drip fertigation (Fd.No.76, Eastern block, TNAU, Coimbatore)

i. Nutrient requirement (NR) kg q^{-1}

$$\text{Kg N/ } P_2O_5\text{/ } K_2O \text{ required per quintal of seed cotton production} = \frac{\text{Total uptake of N/ } P_2O_5\text{/ } K_2O\ (\text{kg ha}^{-1})}{\text{Seed cotton yield (q ha}^{-1})}$$

ii. Per cent contribution of nutrients from soil to total nutrient uptake (Cs)

$$\text{Per cent contribution of N/ } P_2O_5\text{/ } K_2O \text{ from soil} = \frac{\text{Total uptake of N/ } P_2O_5\text{/ } K_2O \text{ in control plot (kg ha-1)}}{\text{Soil test value for available N/ } P_2O_5\text{/ } K_2O \text{ in control plot (kg ha}^{-1})} \times 100$$

iii. Per cent contribution of nutrients from fertilizer to total uptake (Cf)

$$\text{Per cent contribution of N/ } P_2O_5/K_2O \text{ from fertiliser} = \frac{\text{Total uptake of N/ } P_2O_5\text{/ } K_2O \text{ in treated plot (kg ha}^{-1}) - \text{Soil test value for available N/} P_2O_5\text{/ } K_2O \text{ in treated plot (kg ha}^{-1}) \times \text{Average Cs}}{\text{Fertiliser N/ } P_2O_5\text{/ } K_2O \text{ applied (kg ha}^{-1})} \times 100$$

iv. Percent contribution of nutrients from organic manure to total uptake (Co)

Percent contribution from FYM (Cfym)

$$\text{Per cent contribution of N/P/K from FYM} = \frac{\text{Total uptake of N/P/K in FYM treated plot (kg ha}^{-1}) - \text{Soil test value for available N/P/K in FYM treated plot (kg ha}^{-1}) \times \text{Average Cs}}{\text{Nutrient N/P/K added through FYM (kg ha}^{-1})} \times 100$$

These parameters were used for developing fertilizer prescription equations for deriving fertilizers doses, and the soil test based fertilizer recommendations were prescribed in the form of a ready reckoner for desired yield target of cotton under NPK alone and under IPNS.

Fertiliser Prescription Equations

Making use of these parameters, the fertilizer prescription equations (FPEs) were developed for cotton as furnished below.

i) Fertilizer nitrogen (FN)

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

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

ii) Fertilizer phosphorus (FP_2O_5)

$$FP_2O_5 = \frac{NR}{Cf/100} T - \frac{Cs}{Cf} \times 2.29 \times SP$$

$$FP_2O_5 = \frac{NR}{Cf/100} T - \frac{Cs}{Cf} \times 2.29 \times SP - \frac{Cfym}{Cf} \times 2.29 \times OP$$

iii) Fertilizer potassium (FK_2O)

$$FK_2O = \frac{NR}{Cf/100} T - \frac{Cs}{Cf} \times 1.21 \times SK$$

$$FK_2O = \frac{NR}{Cf/100} T - \frac{Cs}{Cf} \times 1.21 \times SK - \frac{Cfym}{Cf} \times 1.21 \times OK$$

where, FN, FP_2O_5 and FK_2O are fertilizer N, P_2O_5 and K_2O in kg ha^{-1}, respectively; NR is nutrient requirement (N or P_2O_5 or and K_2O) in kg q^{-1}, Cs is per cent contribution of nutrients from soil, Cf is per cent contribution of nutrients from fertiliser, Cfym is percent contribution of nutrients from FYM, T is the yield target in q ha^{-1}; SN,SP and SK respectively are alkaline $KMnO_4$-N, Olsen-P and NH_4OAc-K in kg ha^{-1} and 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 fertiliser doses for specific yield targets (T)of transgenic cotton for varied soil available nutrient levels.

Results and Discussion

Seed cotton yield, Uptake and Initial available NPK status

The range and mean values (Table 2) indicated that the seed cotton yield ranged from 1082 kg ha^{-1} in absolute control to 3405 kg ha^{-1} in $N_{180}P_{90}K_{80}$ + FYM @ 12.5 t ha^{-1} of strip II with mean values of 2146, 2691 and 2803 kg ha^{-1}, respectively in strips I, II and III. The N uptake by cotton varied from 43.2 to 152.9 kg ha^{-1}; P uptake from 8.69 to 47.7 kg ha^{-1} and K uptake from 52.2 to 140.2 kg ha^{-1} in strips I, II and III, respectively.

Table 2. Initial soil available NPK, seed yield and NPK uptake by cotton (kg ha^{-1})

Parameters (kg ha^{-1})	Strip-I		Strip-II		Strip-III	
	Range	Mean	Range	Mean	Range	Mean
$KMnO_4$–N	207-216	213	232-241	238	252 - 260	255
Olsen–P	15-18	16.4	28 - 33	30.4	36 - 42	38.0
NH_4OAc-K	550-560	554	584-594	589	606 - 613	609
Seed cotton yield	1082-2618	2146	1275-3405	2691	1406-3401	2803
N uptake	43.2-117.1	94.0	57.8-152.9	118.0	63.83-152.6	124.5
P uptake	8.69-24.9	19.5	13.1-47.7	27.6	13.0 - 46.6	28.4
K uptake	52.2-103.4	84.2	62.2-140.2	109.9	69.9 - 139.7	114.8

The data on initial soil test values of cotton revealed that, the mean $KMnO_4$-N was 213, 238 and 255 kg ha$_{-1}$, respectively in strips I, II and III. The mean Olsen-P values were 16.4, 30.4 and 38.0 kg ha^{-1} respectively in strips I to III and the mean NH_4OAc-K values were 554, 589 and 609 kg ha^{-1} in strips I, II and III, respectively (Table 2).

The existence of operational range of soil test values for available N, P and K status in the present investigation was clearly depicted from the initial soil available nutrient status and variations in the seed cotton yield and NPK uptake, which is a prerequisite for calculating the basic parameters and developing fertiliser prescription equations for calibrating the fertiliser doses for specific yield target of cotton. In a similar study Andi (1998) reported existence of operational range of available N, P and K for sunflower on Inceptisol.

Response of transgenic cotton to fertiliser N, P_2O_5 and K_2O

The response of cotton to different levels of fertilizer N, P_2O_5 and K_2O were assessed in terms of response ratio (RR). There was a progressive increase in response for N upto the highest level i.e. 180 kg ha^{-1} and the highest RR recorded was 5.30 at N180. Similar trend was observed for phosphorus and potassium with the highest RR of 4.60 and 2.95 observed at P_{90} and K_{120} respectively (Table 3). Application of N, P and K had a significant effect on plant growth and yield and there was a progressive increase in response for N, P_2O_5 and K_2O levels from N60 to N_{180}, P_{30} to P_{90} and K_{40} to K_{120}, respectively.

Basic parameters

In the targeted yield model, The basic parameters for developing fertiliser prescription equations for cotton are (i) nutrient requirement (NR) in kg per quintal of seed cotton, per cent contribution of available NPK from soil (Cs), fertilizers (Cf) and farmyard manure (Cfym). Making use of data on the yield of cotton, total uptake of N, P and K, initial soil test values for available N, P and K and doses of fertiliser N, P_2O_5 and K_2O applied, the basic parameters were computed.

Application of adequate amount of nutrients is a pre-requisite for exploiting genetic potential of any crop. Cotton which is a heavy feeder exhibits vigorous growth and dry matter production (DMP) and is responsive to application of fertilizers. Nutrient requirement to produce one quintal (100 kg) of seed cotton was 4.43 kg of N, 2.20 kg of P_2O_5 and 4.83 kg of K_2O (Table 4). In the present investigation, the requirement of K_2O was higher followed by N and P_2O_5. The requirement of K_2O was 1.09 times higher than N and 2.20 times higher than P_2O_5. Similar trend of nutrient requirement for N, P_2O_5 and K_2O was also reported by (AICRP Report 2011) for rainfed transgenic cotton on black calcareous soil, Subba Rao and Rathore (2003) for rainfed cotton (var.Narasimha) on a vertisol. Jagvir Singh and Blaise (2000) have also reported the affinity of cotton towards potassium.

Table 3. Response of transgenic cotton to different levels of fertilizer nutrients

S. No.	Nitrogen (N)			Phosphorus (P_2O_5)			Potassium (K_2O)		
	Level (kg ha^{-1})	Response (Kg)	Response Ratio (kg kg^{-1})	Level (kg ha^{-1})	Response (Kg)	Response Ratio (kg kg^{-1})	Level (kg ha^{-1})	Response (Kg)	Response Ratio (kg kg^{-1})
1.	60	252	4.20	30	92	3.07	40	97	2.43
2.	120	572	4.77	60	271	4.52	80	214	2.68
3.	180	956	5.30	90	413	4.60	120	354	2.95

The per cent contribution of nutrients from soil Cs to the total uptake was computed from the absolute control plots and it expresses the capacity of the crop to extract nutrients from the soil. In the present study, it was found that the soil had contributed 24.65 per cent of available N, 48.95 per cent of available P and 11.06 per cent of available K respectively towards the total N, P and K uptake by cotton (Table 4). The nutrient contribution of the soil to transgenic cotton was the highest for P as compared to that by N and K. With regard to N and K, comparatively lower Cs was recorded which might be due to the preferential nature of cotton towards the applied N and K_2O than the native N and K. This is in accordance with the work of Maharastra on transgenic cotton.var Mallika (Muralidharudu, 2007) and Subba Rao (2003) for rainfed cotton on a Vertisol.

Table 4. Nutrient requirement, per cent contribution of nutrients from soil, fertiliser and FYM for transgenic cotton

Parameters	Basic Data		
	N	P_2O_5	K_2O
Nutrient requirement (kg q^{-1})	4.43	2.20	4.83
Per cent contribution from soil (Cs)	24.65	48.95	11.06
Per cent contribution from fertilisers (Cf)	52.01	49.89	73.35
Per cent contribution from FYM (Cfym)	38.19	16.43	40.35

The per cent contribution from fertilizer nutrients (Cf) towards the total uptake by cotton was 52.01, 49.89 and 73.35 per cent, respectively for N, P_2O_5 and K_2O (Table 4) and followed the order of K_2O > N > P_2O_5. The estimated per cent contribution of nutrients from fertilizers (Cf) to total uptake clearly revealed the fact that the magnitude of contribution by fertilizer K_2O was 1.47 times higher than P_2O_5 and 1.41 times as that of N. The contribution from fertilizers was higher than from the soil for all the three nutrients. Anon *(*2011) also reported similar trend for transgenic cotton hybrid BRAHMA on black calcareous soil. The contribution of nutrients towards the growth of the crop was higher from fertilizers than that of soil for all the three nutrients (N, P_2O_5 and K_2O). Muralidharudu (2007) observed similar trend of results for jute in West Bengal and wheat on an Inceptisol in Punjab.

The estimated per cent contribution of N, P_2O_5 and K_2O from FYM (Cfym) was 38.19, 16.43 and 40.35, respectively for cotton which indicated that relatively higher contribution was recorded for K_2O followed by N and P_2O_5 for cotton. The response yardstick recorded was 5.13 kg kg^{-1}. Similarly, the contribution of nutrients from FYM for cotton also indicated that relatively higher contribution was recorded for K_2O followed by N and P_2O_5. The present findings corroborated with the findings of Saranya *et al*. (2012) and Santhi *et al*. (2002).

Fertilizer Prescription Equations for Transgenic Cotton

Soil test based fertilizer prescription equations for desired yield target of cotton were formulated using the basic parameters and are furnished below:

STCR-NPK alone

FN = 8.51 T - 0.47 SN

FP_2O_5 = 4.41T - 2.25 SP

FK_2O = 6.59 T - 0.18 SK

STCR-IPNS (NPK + FYM)

FN = 8.51 T - 0.47 SN – 0.73 ON

FP_2O_5 = 4.41T - 2.25 SP - 0.75 OP

FK_2O = 6.59 T - 0.18 SK - 0.66 OK

where, FN, FP_2O_5 and FK_2O are fertilizer N, P_2O_5 and K_2O in kg ha^{-1}, respectively; T is the yield target in quintal ha^{-1} (1 quintal = 100 kg ha^{-1}); SN, SP and SK respectively are alkaline $KMnO_4$-N, Olsen-P and NH_4OAc-K in kg ha^{-1} and ON, OP and OK are the quantities of N, P and K supplied through FYM in kg ha^{-1}.

Fertilizer response is denoted by the functional relationship between increase in crop yield and added fertilizers. It can be expressed graphically by a curve or algebraically by an equation. Milap Chand *et al.* (2006) reported the superiority of the target yield concept over other practices for different crops as it gave higher yields, net benefit and optimal economic returns. The yield targets were achieved within reasonable limits when the fertilizer was applied on soil test basis in majority of the crops thus establishing the utility of the prescription equations for recommending soil test based fertilizer application. With this background, in the present investigation, Soil test based fertilizer prescription equations for desired yield target of cotton was developed using the basic parameters obtained. The data clearly revealed the fact that the fertiliser N, P_2O_5 and K_2O requirements decreased with increase in soil test values and increased with increase in yield targets.

Realizing the superiority of the targeted yield approach, Santhi *et al.* (2012) documented in a handbook, the soil test and yield target based integrated fertilizer prescriptions, for a range of 44 soil - crop situations in Tamil Nadu which include cereals, millets, oilseeds, sugarcane, cotton, vegetables, spices and medicinal plants.

Fertilizer prescription under IPNS for desired yield target of Transgenic cotton

A ready reckoner table was prepared using these equations for a range of soil test values and for yield targets of 3.0 and 3.5 t ha^{-1} of seed cotton (Table 5). For achieving an yield target of 3.0 t ha^{-1} of seed cotton with soil test values of 280, 20 and 500 kg ha^{-1} of $KMnO_4$-N, Olsen-P and NH_4OAc-K, the fertiliser N, P_2O_5 and K_2O doses required were 124, 87 and 108 kg ha^{-1}, respectively under NPK alone and 84, 67 and 74 kg ha^{-1} under IPNS (NPK + FYM @ 12.5 t ha^{-1} with 32, 0.64, 0.31 and 0.61 per cent of moisture, N, P and K respectively). Similarly, for the target of 35 q ha^{-1}, the respective values were 166, 109 and 141 kg ha^{-1} under NPK alone and 126, 89 and 107 under IPNS. Under IPNS, the fertiliser savings were 40, 20 and 34 kg ha^{-1}, respectively, when FYM was applied @12.5 t ha^{-1} along with NPK fertilizers.

Table 5. Soil test based fertiliser prescription for yield targets of 3.0 and 3.5 t ha^{-1} of transgenic cotton (kg ha^{-1})

Soil test values	Treatments					
	NPK alone (kg ha^{-1})	NPK+ FYM 12.5 t ha^{-1} (kg ha^{-1})	Per cent reduction over NPK	NPK alone (kg ha^{-1})	NPK+ FYM 12.5 t ha^{-1} (kg ha^{-1})	Per cent reduction over NPK
	Yield target – 3.0 t ha^{-1}			Yield target – 3.5 t ha^{-1}		
$KMnO_4$-N (kg ha^{-1})						
160	180	140	22.2	223	183	18.0
180	171	131	23.4	213	173	18.8
200	161	121	24.8	204	164	19.6
220	152	112	26.3	194	154	20.6
240	143	103	28.1	185	145	21.6
260	133	93	30.1	176	136	22.8
280	124	84	32.3	166	126	24.1
Olsen-P (kg ha^{-1})						
10	110	90	18.2	132	112	15.2
12	105	85	19.0	127	107	15.7
14	101	81	19.8	123	103	16.3
16	96	76	20.8	118	98	16.9
18	92	72	21.8	114	94	17.6
20	87	67	22.9	109	89	18.3
22	83	63	24.2	105	85	19.1
NH_4OAC-K (kg ha^{-1})						
300	144	110	23.7	177	143	19.2
350	135	101	25.2	168	134	20.3
400	126	92	27.0	159	125	21.4
450	117	83	29.1	150	116	22.7
500	108	74	31.6	141	107	24.2
550	99	65	34.4	132	98	25.8
600	90	56	37.9	123	89	27.7

In the present investigation, there was a marked response to the application of NPK fertilizers, the magnitude of response was higher under IPNS as compared to NPK alone. The per cent reduction in NPK fertilizers under IPNS also increased with increasing soil fertility levels with reference to NPK and decreased with increase in yield targets. These could be achieved by integrated use of FYM with NPK fertilizers. The role of FYM is multidimensional ranging from building up of organic matter, maintaining favourable soil physical properties and balanced supply of nutrients. In the present investigation also, these factors might have contributed for the yield enhancement in cotton when NPK fertilizers are coupled with FYM. Similar trend of results were reported by Coumaravel (2012) in maize and AICRP Report (2011) in transgenic cotton.

Conclusion

To conclude, in the present investigation, soil test based IPNS for desired yield targets of transgenic cotton was developed on Vertic Ustropept of Tamil Nadu under drip fertigation taking into account the nutrient requirement and contribution of NPK from various nutrient sources (soil, fertiliser and FYM). This envisages a balanced nutrient supply to transgenic cotton which is site specific and can play a major component of precision agriculture.

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References

AICRP Report. 2011. In: Progress report of the All India Coordinated Research Project for Investigation on Soil Test Crop Response Correlation, Tamil Nadu Agricultural University, Coimbatore, 28–44pp.

Andi, K. 1998. Soil test crop response studies under integrated plant nutrition system for Bhendi – Sunflower cropping sequence on Inceptisol. Ph.D. Dissertation submitted to TNAU, Coimbatore.

Clive James, 2012. ISAAA Brief 43-2011: Executive Summary. Global Status of Commercialized Biotech/ GM Crops: 2011. International service for the acquisition of Agri – biotech service.

Coumaravel, K. 2012. Soil test crop response correlation studies through integrated plant nutrition system for maize – tomato sequence. Ph.D. (Ag) Thesis. Submitted to TNAU, Coimbatore.

Global Water Initiative, 2005. GEF International Waters Conference, The Coca-Cola Company, June 2005.

Humphries, E.C. 1956. Mineral components and ash analysis. Modern methods of plant analysis. Springer – Verlag, Berlin 1: 468-562.

Jackson, M.L. 1973. Soil chemical analysis. Prentice Hall of India Private Ltd., New Delhi. pp.498.

Jagvir Singh and Blaise,D. 2000. Nutrient management in Rainfed cotton. CICR technical bulletin no: 6. Central Institute for Cotton Research, Nagpur.

Jayaprakash, N. 2008. Nutrient dynamics under drip fertigation in cotton. M.Sc. (Ag) Thesis submitted to Tamil Nadu Agricultural University, Coimbatore.

Khosa, M.K., Sekhon, B.S., Ravi, M.S., Benipal, D.S. and Benbi, D.K. 2012. Performance of target yield based fertilizer prescription equations in rice-wheat cropping system in Punjab. *Indian J. Fert*., **8(2)**:14-18

Milap Chand, Benbi, D.K. and Benipal, D.S. 2006. Fertiliser recommendations based on soil tests for yield targets of mustard and rapeseed and their validations under farmer's field conditions in Punjab. *J. Indian. Soc. Soil Sci*., **54(3)**: 316-321.

Muralidharudu, Y., Rathore, A. and Subba Rao, A. 2007. In: *18th Progress report of All India Coordinated Project for investigation on Soil Test Crop Response Correlation,* Indian Institute of Soil Science, Bhopal. pp 1-215.

Nalayini, P., Paulraj, S. and Sankaranarayanan, K. 2010. Drip fertigation of major, secondary and micronutrients for enhancing the productivity of ELS Transgenic cotton. *In Proc Transgenic Cotton: Opportunities and Prospects.* pp.166-171.

Olsen, S.R., Cole, C.V., Watanabe, F.S. and Dean, L. 1954. Estimation of available phosphorus in soils by extraction with sodium bicarbonate. U.S.D.A. Circ. 939. U.S. Govt. Printing Office, Washington, DC.

Policepatil, A. S. 2007. Performance of Bt cotton hybrids as Influenced by site specific nutrient Management approach for realising target Yields. M.Sc.(Ag.) Dessertation submitted to UAS, Dharwad.

Ramamoorthy, B., Narasimham, R.K. and Dinesh, R.S. 1967. Fertiliser application for specific yield targets on Sonora 64 (wheat). *Indian Fmg* **17**: 43-45.

Santhi, R., Natesan, R. and Selvakumari, G. 2002. Soil Test Crop Response Correlation Studies under integrated plant nutrition system for onion (*Allium cepa L. var. aggregatum*) in Inceptisol of Tamil Nadu. *J. Indian Soc.Sci* 50: 489-492

Santhi, R., Maragatham, S., Sellamuthu, K.M., Natesan, R., Duraisami, V.P., Pradip Dey and Subba Rao, A. 2012. A Handbook on Soil Test and Yield target based integrated fertiliser prescriptions, AICRP-STCR, TNAU, Coimbatore.

Saranya, S., Santhi, R., Appavu, K. and Rajamani, K. 2012. Soil Test based integrated plant nutrition system for ashwagandha on Inceptisols. *Indian J. Agric Res* 46: 88-90.

Stanford, S. and English, L. 1949. Use of flame photometer in rapid soil tests of K and Ca. *Agron J.* **41**: 446

Subba Rao, A. and Rathore, A. 2003. In: *17th Progress report of the All India Coordinated Research Project for Investigation on Soil Test Crop Response Correlation,* Indian Institute of Soil Science, Bhopal. pp 14-15

Subbiah BV and Asija GL. 1956. A rapid procedure for the estimation of available nitrogen in soils. *Curr. Sci.* **25:** 259-260.

Supriya Pal, 2010. Indian cotton production: Current scenario. *The Indian Textile J.*, March 2010

Tandon, H.L.S. 2007. Soil Nutrient Balance Sheets in India: Importance, Status, Issues, and Concerns. *Better Crops – India* : 15-19.

Truog, E. 1960. Fifty years of soil testing. *Trans 7th Intl. Congr. Soil Sci. Vol. III Commission IV paper No.7:* pp: 46-53.

Velayutham, 2011. The law of optimum and soil test based fertiliser use for targeted yield of crops for sustainable agriculture. Memorial lecture of Dr.B.Ramamoorthy held at TNAU, Coimbatore, December 28, 2011.

Venugopalan, M.V., Blaise, D., Yadav, M.S. and Rachana Deshmukh. 2011. Fertilizer response and nutrient management strategies for cotton. *Indian J. Fert*.,**7(4):** 82-94.

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