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RESEARCH ARTICLE :

Effect of integrated plant nutrition system on yield and uptake of cotton under soil test crop response correlation studies through drip fertigation on inceptisol

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SUMMARY : Studies on Soil Test Crop Response based Integrated Plant Nutrition System (STCR - IPNS)were conducted during 2011-13 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 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 % of N, P and K, respectively) for cotton was assessed as 40, 20 and 34 kg fertilizer N, P_2O_5 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 :
Soil test crop response, Integrated plant nutrition system, Yield target, Fertilizer prescriptions, Nutrient contribution

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BACKGROUND AND OBJECTIVES

India's economic security continues to be predicted upon the agricultural sector. The present contribution of agriculture and allied sector to the Gross Domestic Product (GDP) is 17.32 per cent (*statisticstimes.com*, 2017). However, the natural resource base of agriculture, which provides for sustainable production is shrinking, degrading and is adversely affecting the production capacity of the ecosystem. On the other hand, the demand for agriculture is rising rapidly with increase in population, per capita income and growing demand from industrial sector. At this juncture, Integrated plant nutrition system

(IPNS) that involves conjoint use of different nutrient sources appears to be a promising strategy for sustaining high yields, restoration of soil health and improvement in fertilizer use efficiency (Das *et al*., 2015).

Fertilizers play vital role in the production and productivity of any crop. But continuous and imbalanced use of high analysis chemical fertilizers influences production potential and soil health. Subsequently, most of the productive soils become unproductive. Chemical fertilizers or organic manures or bio-fertilizers alone cannot sustain the desired levels of soil fertility and crop production under continuous farming practices. Integrated Plant Nutrition System (IPNS) is a way, which not only sustains high crop production over the years but also improves soil health and ensures safer environment. All India production of organic manures including FYM and composts is estimated at 229.4 million tonnes (Mt) (FAI, 2015). At present less than half of the manurial potential of livestock is being utilised, as a large proportion is lost as fuel and droppings in non agricultural areas. Hence, it is wise to use the available resource and sustain crop production and soil health.

Though, the fertilizer consumption in India has increased significantly in the last three decades, the lower per hectare NPK fertilizer consumption and imbalanced consumption ratio (7.5:3.0:1) in 2015-16 (Anonymous, 2016) against an optimum ratio of 4:2:1 leads to widespread negative nutrient balances in most Indian soils. This condition not only mirrors poor soil health, but also represents the 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). The solution to this problem lies in soil testing, 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. 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 is of practical importance for efficient and judicious use of costly fertilizers in increasing crop production (Pant and Gautam, 2012). Natural fibres play a key role in the emerging "green" economy based on energy efficiency, reducing carbon emissions and recyclable waste materials.The Indian textile industry is tilted more towards environment friendly and biodegradable natural fibres of which cotton holds a high share of 60 per cent to the fibre basket. The cotton plant is a heavy feeder and the nutrient management is complex due to the simultaneous production of vegetative and reproductive structures during the active growth phase.On account of the above facts, the present investigation was contemplated on STCR – IPN Sadopting the Inductive cum Targeted yield model on Periyanaickenpalayam soil series (Vertic Ustropept) which aimed at to establish significant relationship between soil test values and crop response to fertilizers and Integrated plant nutrition system and to derive a basis of making fertilizer prescription for targeted yields of transgenic cotton, to evaluate the extent to which fertilizer requirements of transgenic cotton can be reduced under Integrated Plant Nutrition System.

RESOURCES AND METHODS

Studies on Soil Test Crop Response based Integrated Plant Nutrition System (STCR - IPNS) were conducted adopting the Inductive cum Targeted yield model, on a VerticUstropept of Tamil Nadu, India. This study comprised of two field experiments *viz.*, fertility gradient experiment with fodder maize *var.*CO1 (Phase I) and test crop experiment with transgenic cotton RCH-530 BGII (Phase II).

Basic concept :

The methodology adopted in this study is the prescription procedure outlined by Truog (1960) and modified by Ramamoorthy *et al.* (1967) as "Inductive cum Targeted yield model" which provides a scientific basis for balanced fertilization and balance between applied nutrients and soil available nutrients forms. Operational range of variation in soil fertility was created deliberately to generate data covering appropriate range of values for each controllable variable (fertilizer dose) at different levels of uncontrollable variable (soil fertility) which could not be expected to occur at one place normally. Hence, in order to create fertility variations in the same field, a gradient experiment was conducted prior to the test crop experiment to reduce the heterogeneity in the soil population studied, management practices adopted and climatic conditions prevailing.

Study site and soil description :

The field experiments were conducted at Eastern block of TNAU farm, Coimbatore, Tamil Nadu, Southern India on 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 gradient and test crop experiments were conducted during October 2011 to April 2013. The soil of the experimental field belongs toPeriyanaickenpalayam series taxonomically referred to as VerticUstropept exhibiting clay loam texture, moderately alkaline reaction (pH 8.4) and non–saline (EC 0.17 dSm^{-1}). The initial soil fertility status showed low organic carbon (4.7 g kg^{-1}), low available N (225 kg ha^{-1}), medium available P (19.9 kg ha^{-1}), high available K (570 kg ha^{-1}). The available Zn, Cu and Mn were in sufficient range (1.29, 1.94 and 11.39 mg kg^{-1}, respectively) while available Fe was in deficient range (3.34 mg kg^{-1}).The total N, P and K contents of the soil was 0.13, 0.09 and 0.45 per cent, respectively. The P and K fixing capacities of the soil were each 100 kg ha^{-1}.

Treatment structure and soil and plant analysis :

The field experiments *viz*., fertility gradient experiment with fodder maize (*var.* CO 1) and the test crop experiment with transgenic cotton (RCH 530 BGII) were conducted at TNAU Farm, Coimbatore on Inceptisol. 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 (AICRP-STCR) based on “Inductive cum Targeted yield model” (Ramamoorthy *et al*., 1967) was adopted in the present investigation.

Gradient 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 ($N_1P_1K_1$) 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 analysed for alkaline $KMnO_4$-N (Subbiah and Asija, 1956), Olsen –P (Olsen *et al*., 1954) and NH_4OAc-K (Stanford and English, 1949). At harvest, plant samples were collected, processed and analyzed for N (Humphries, 1956), P and K contents (Jackson, 1973) and NPK uptake was computed.

Test crop experiment :

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 analyzed for alkaline $KMnO_4$-N, Olsen-P and NH_4OAc-K. The experiment was laid out in a fractional factorial design comprising twenty four treatments and the test crop experiment with 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 theapproved guidelines of AICRP-STCR and fertilizer recommendations were developed.

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 and layout are given in Fig. 1. The test crop cotton was sown with a spacing of 120 cm x 90 cm. Routine cultural operations were followed periodically. The sources of nutrients used in fertigation were urea, single super phosphate and muriate of potash. The crop

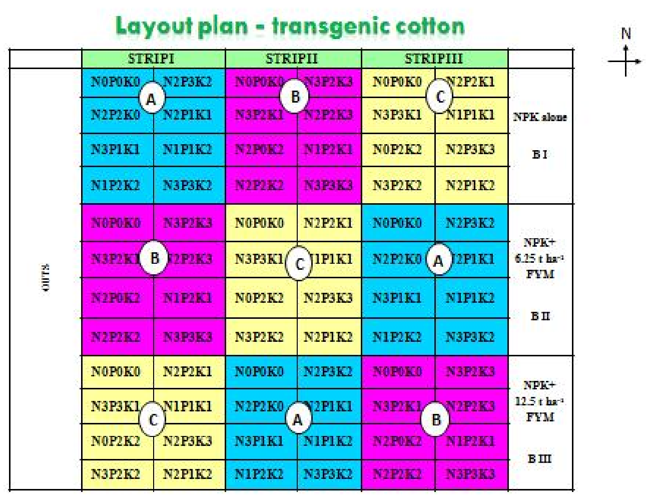

Fig. 1 : **Treatment structure and layout plan of transgenic cotton**

was grown to maturity, harvested and plot wise seed cotton yield was recorded. The seed cotton, plant and post-harvest soil samples were collected from each plot. As done in gradient crop, the soil and plant samples were processed and analyzed and NPK uptake by cotton was computed using the dry matter yield.

Basic parameters for fertilizer prescription equations :

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).

Nutrient requirement (NR):

NR = [Total uptake of N or P_2O_5 or K_2O (kg ha^{-1}) / Seed cotton yield (q ha^{-1})] ....(1)

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

Cs = [Total uptake of N or P2O5 or K_2O in control plot (kg ha^{-1}) / (Soil test value for available Nor P_2O_5 or K_2O in control plot (kg ha^{-1})] * 100 ....(2)

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

Cf = {[(Total uptake of N or P_2O_5 or K_2O in treated plot (kg ha^{-1})) - (Soil test value for available N or P_2O_5 or K_2O in control plot (kg ha^{-1}) * Average Cs)] / Fertilizer N or P_2O_5 or K_2O applied (kg ha^{-1})} * 100 ....(3)

Per cent contribution of nutrients from organics to total uptake (Co):

Per cent contribution from FYM (*Cfym*):

Cfym = {[(Total uptake of N or P or K in FYM treated plot (kg ha^{-1})) – (Soil test value for available N or P or K in FYM treated plot (kg ha^{-1}) * Average Cs)] / Nutrient N/P/K added through FYM (kg ha^{-1})} * 100 ....(4)

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

Fertilizer prescription equations :

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

Fertilizer nitrogen (FN):

FN = {[(NR / (Cf /100))*T] – [(Cs/Cf)*SN]} ....(5)

FN = {[(NR / (Cf /100))*T] – [(Cs/Cf)*SN] - [(Cfym/Cf)*ON]} ....(6)

Fertilizer phosphorus (FP_2O_5):

FP_2O_5 = {[(NR / (Cf /100))*T] – [(Cs/Cf)*2.29SP]} ....(7)

FP_2O_5 = {[(NR / (Cf /100))*T] – [(Cs/Cf)*2.29SP] - [(Cfym/Cf)*2.29OP]} ....(8)

Fertilizer potassium (FK_2O):

FK_2O = {[(NR / (Cf /100))*T] – [(Cs/Cf)*1.21SK]} ....(9)

FP_2O_5 = {[(NR / (Cf /100))*T] – [(Cs/Cf)*2.29SK] - [(Cfym/Cf)*1.21OK]} ....(10)

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 fertilizer, 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}.

Observations and Analysis

The results obtained from the present study as well as discussions have been summarized under following heads:

Basic parameters :

Nutrient requirement of cotton :

Application of adequate amount of nutrients is a pre-requisite for exploiting genetic potential of any crop. The data emanated from the present investigation revealed that the 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 and the requirement of K_2O was higher which is followed by N and P_2O_5 (Table 1). 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 Anonymous (2012) for rainfed transgenic cotton on black calcareous soil and by Subba Rao and Rathore (2003) for rainfed cotton (var.Narasimha) on Vertisol. The major demand for K by the plant comes at boll set stage and

Table 1: Nutrient requirement, per cent contribution from soil, fertilizer and FYM for cotton

Parameters	Basic data		
	N	P_2O_5	K_20
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 fertilizers (Cf)	52.01	49.89	73.35
Per cent contribution from FYM (Cfym)	38.19	16.43	40.35
Response yardstick (kg kg^{-1})		5.13	

therefore even in soils with high available K, in-season can develop K shortage due to the heavy demand during rapid boll set and fill (Gormus, 2002).

Contribution of nutrients from soil (Cs) to total uptake of cotton:

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 has 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. The contribution of nutrients from soil to cotton was higher for P followed 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 findings of Subba Rao and Rathore (2003) for rainfed cotton on Vertisol, Muralidharudu *et al*. (2007) on transgenic cotton.var. Mallika and Popat Kadu *et al*. (2012) on *Kharif* cotton in Maharashtra.

Contribution of nutrients from fertilizers (Cf) to total uptake of cotton :

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 and followed the order of $K_2O > N > P_2O_5$. The response yardstick recorded was 5.13 kg kg^{-1}. 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. Similar trend of Cf was reported by Popat Kadu *et al.* (2012) on *Kharif* cotton in Maharashtra.The contribution of nutrients towards the total uptake by cotton was higher from fertilizers than that from soil for all the three nutrients *viz*., N, P and K.

Contribution of nutrients from FYM for cotton:

The fourth basic parameter for the targeted yield model, the per cent contribution of N, P_2O_5 and K_2O from FYM was computed in the present study. The estimated per cent contribution of N, P_2O_5 and K_2O from FYM (Cfym) were 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. The present findings corroborated with the findings of Santhi *et al*. (2002) and Saranya *et al*. (2012).

Fertilizer prescription equations and optimization of fertilizer doses for transgenic cotton:

Using the basic parameters computed for cotton (NR, Cs and Cf), fertilizer prescription equations were developed and are furnished below.

STCR-NPK alone :

$$FN = 8.51\,T - 0.47\,SN$$
$$FP_2O_5 = 4.41T - 2.25\,SP$$
$$FK_2O = 6.59\,T - 0.18\,SK$$

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 seed cotton yield target in q ha^{-1} and SN, SP and SK are alkaline $KMnO_4$-N, Olsen-P and NH_4OAc-K in kg ha^{-1}, respectively.

Fertilizer prescription equations for cotton under IPNS :

Fertilizer prescription equations for cotton under IPNS through drip fertigation was developed using the basic parameters (NR, Cs, Cf, and C_{fym}) and is furnished below.

$$FN = 8.51\,T - 0.47\,SN – 0.73\,ON$$
$$FP_2O_5 = 4.41T - 2.25\,SP - 0.75\,OP$$
$$FK_2O = 6.59\,T - 0.18\,SK - 0.66\,OK$$

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 seed cotton 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}.

Making use of the fertilizer prescription equations for cotton, fertilizer prescriptions for desired yield targets of 30, 35 and 40 quintals of seed cotton yield per hectare were calculated for a range of soil test values. An average soil available N, P and K status of 200, 20 and 550 kg ha^{-1}, respectively was considered to compare the fertilizer recommendation for 30, 35 and 40 q ha^{-1} seed cotton yield for Vertic Ustropept under drip fertigation. The results indicated that for aiming 30 q ha^{-1} seed cotton yield with a soil test value of 200, 20 and 550 kg ha^{-1} of $KMnO_4$-N, Olsen-P and NH_4OAc-K, the fertilizer N, P_2O_5 and K_2O requirements would be 161, 87 and 99 kg ha^{-1} respectively. For the same soil test values, the doses of fertilizer N, P_2O_5 and K_2O required would be 204, 109 and 132 kg ha^{-1} for the production of 35 q ha^{-1} and to produce 40 q ha^{-1} seed cotton yield, the requirement of fertilizer N, P_2O_5 and K_2O would be 246, 131 and 165 kg ha^{-1}, respectively. These estimates indicated that for every quintal increase in yield per hectare, 8.6 kg N, 4.4 kg P_2O_5 and 6.6 kg K_2O are required additionally.

Influence of IPNS on seed cotton yield and nutrient uptake by cotton:

The range and mean values of seed cotton yield and nutrient uptake by cotton revealed that there was an increase in yield to the tune of 24.6 per cent due to the application of FYM alone @ 6.25 t ha^{-1}. The per cent yield increase due to the application of FYM @ 12.5 t ha^{-1} were 34.69 and 8.1 over absolute control and FYM @ 6.25 t ha^{-1}, respectively.

Similarly, the per cent increase in yield due to NPK

Table 2 : Soil test based fertilizer prescription for yield target of 30, 35 and 40 q ha^{-1} of cotton (kg ha^{-1})

Soil test values (kg ha^{-1})	Fertilizer-N (kg ha^{-1})								
	NPK alone	NPK+ FYM	Per cent reduction over NPK	NPK alone	NPK+ FYM	Per cent reduction over NPK	NPK alone	NPK+ FYM	Per cent reduction over NPK
$KMnO_4$-N		30 q ha^{-1}			**35 q ha^{-1}**			40 q ha^{-1}	
160	180	140	22.2	223	183	18.0	265	225	15.1
180	171	131	23.4	213	173	18.8	256	216	15.6
200	161	121	24.8	204	164	19.6	246	206	16.2
220	152	112	26.3	194	154	20.6	237	197	16.9
240	143	103	28.1	185	145	21.6	228	188	17.6
260	133	93	30.1	176	136	22.8	218	178	18.3
280	124	84	32.3	166	126	24.1	209	169	19.2
					Fertilizer-P_2O_5 (kg ha^{-1})				
Olsen-P		30 q ha^{-1}			35 q ha^{-1}			40 q ha^{-1}	
10	110	90	18.2	132	112	15.2	154	134	13.0
12	105	85	19.0	127	107	15.7	149	129	13.4
14	101	81	19.8	123	103	16.3	145	125	13.8
16	96	76	20.8	118	98	16.9	140	120	14.2
18	92	72	21.8	114	94	17.6	136	116	14.7
20	87	67	22.9	109	89	18.3	131	111	15.2
22	83	63	24.2	105	85	19.1	127	107	15.8
					Fertilizer-K_2O (kg ha^{-1})				
NH_4OAc-K		30 q ha^{-1}			35 q ha^{-1}			40 q ha^{-1}	
300	144	110	23.7	177	143	19.2	210	176	16.2
350	135	101	25.2	168	134	20.3	201	167	16.9
400	126	92	27.0	159	125	21.4	192	158	17.7
450	117	83	29.1	150	116	22.7	183	149	18.6
500	108	74	31.6	141	107	24.2	174	140	19.6
550	99	65	34.4	132	98	25.8	165	131	20.7
600	90	56	37.9	123	89	27.7	156	122	21.9

alone, NPK plus FYM @ 6.25 t $ha^{-1}$and NPK plus FYM @ 12.5 t ha^{-1} were 112.9, 114.7 and 117.4 over absolute control. Irrespective of the strips, between the two levels of FYM (6.25 and 12.5 t ha^{-1}), there was an increase in response for cotton at FYM @12.5 t ha^{-1} as compared to FYM @ 6.25 t ha^{-1}. NPK plus FYM @ 6.25 t ha^{-1} and NPK plus FYM @ 12.5 t ha^{-1} recorded a per cent increase in yield to the tune of 72.2 and 61.4 over their corresponding FYM alone treatments (Table 3 and 4).

The role of FYM is multidimensional ranging from building up of organic matter, maintaining favourable soil physical properties and balanced supply of nutrients. Further, FYM acts directly by increasing the crop yield either by accelerating the respiratory process through cell permeability or by hormone growth action. In the present investigation also, these factors might have contributed for the yield enhancement in cotton when NPK fertilizers are coupled with FYM.

The extent of saving of inorganic fertilizers for transgenic cotton with the application of FYM @ 6.25 t ha^{-1} (with 32 p% moisture and 0.64, 0.31 and 0.61 per cent of N, P and K, respectively), was 20, 10 and 17 kg of fertilizer N, P_2O_5 and K_2O, respectively. If FYM @ 12.5 t ha^{-1} was applied the savings were 40, 20 and 34 kg of fertilizer N, P_2O_5 and K_2O, respectively. 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. Similar trend of results were reported by Santhi *et al*. (2011) in beetroot on Alfisol, Anonymous (2012) in transgenic cotton on Vertisol and and Coumaravel (2012) in maize on Alfisol.

Thus, in the present investigation, using targeted yield model, fertilizer prescriptionsunder IPNS were developed for transgenic cotton on Periyanaickenpalayam soil series (Vertic Ustropept) under drip fertigation. These prescriptions can play a vital role in practicing site and situation specific fertilizer recommendations.

Table 3 : Pre-sowing soil available NPK, yield and uptake by cotton in absolute control and FYM applied plots (kg ha^{-1})

Parameters	Range (kg ha^{-1})		Mean (kg ha^{-1})
	Minimum	Maximum	
	Absolute control		
$KMnO_4$ –N	210	252	234
Olsen–P	16	49	29
NH_4OAc-K	555	610	583
Seed cotton yield	1082	1406	1254
N uptake	43.2	63.8	54.9
P uptake	8.7	13.0	11.6
K uptake	52.2	69.9	61.5
	FYM @ 6.25 t ha^{-1} alone		
$KMnO_4$ –N	208	253	231
Olsen–P	15	36	28
NH_4OAc-K	554	606	582
Seed cotton yield	1348	1751	1563
N uptake	57.7	79	68.2
P uptake	12	19	16.5
K uptake	61.3	79	72.9
	FYM @ 12.5 t ha^{-1} alone		
$KMnO_4$-N	212	252	233
Olsen–P	17	36	28
NH_4OAc-K	556	613	586
Seed cotton yield	1477	1874	1689
N uptake	63.5	91.5	77.4
P uptake	15.7	20.3	18.4
K uptake	63.7	91.7	77.6

Table 4: Pre-sowing soil available NPK, yield and uptake by cotton in NPK alone and IPNS plots (kg ha^{-1})

Parameters	Range (kg ha^{-1})		Mean (kg ha^{-1})
	Minimum	Maximum	
NPK alone			
$KMnO_4$ –N	210	259	236
Olsen–P	15	38	28
NH_4OAc-K	551	610	583
Seed Cotton yield	2012	3300	2670
N uptake	86.7	151.6	117.7
P uptake	17.4	37.2	26.0
K uptake	76.3	135.9	106.9
NPK+ FYM@6.25 t ha^{-1}			
$KMnO_4$-N	210	258	236
Olsen–P	15	41	29
NH_4OAc-K	550	613	584.6
Seed Cotton yield	2051	3324	2692
N uptake	89.0	150.1	118.1
P uptake	18.0	41.7	26.1
K uptake	74.7	137.7	107.1
NPK+ FYM@12.5 t ha^{-1}			
$KMnO_4$-N	207	260	235
Olsen–P	15	41	28
NH_4OAc-K	551	613	584
Seed Cotton yield	1846	3405	2726
N uptake	68.3	153.6	120.3
P uptake	16.5	47.7	27.5
K uptake	64.1	140.8	108.7

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