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RESEARCH ARTICLE

Inductive Approach as a Basis for Fertilizer Prescription through Integrated Plant Nutrition System for Maize on Vertisol

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ABSTRACT

Field experiments were conducted during 2016-17 at Manickapuram village of Theni District, Southern Zone of Tamil Nadu to study the impact of Inductive approach (artificial gradient)on soil fertility,nutrient uptake and fodder yield of sorghum (*var* CO30) and further,Soil Test Crop Response correlation studies under Integrated Plant Nutrition System (STCR-IPNS) for desired yield targets of maize on Vertisol. The profile study of the experimental site has been described in detail. The artificial fertility gradient was developed by dividing the field into three equal strips and graded levels of fertilizers were applied in the form of Urea, Single Super Phosphate and Muriate of Potash, respectively to strip I ($N_0P_0K_0$), II ($N_1P_1K_1$) and III ($N_2P_2K_2$). The N_1level was fixed based on the blanket recommendation of fodder sorghum and P_1 and K_1 levels were fixed based on the phosphorus (100 kg ha^{-1}) and potassium (80 kg ha^{-1}) fixing capacities of the soil.Sorghum (*var*.CO30) was grown as gradient crop and green fodder yield was recorded at harvest and plant samples were collected and analyzed for N, P and K contents and their uptake was computed. The results confirmed that the application of graded levels of fertilizer N, P_2O_5 and K_2O significantly influenced soil fertility status, N, P and K uptake and green fodder yield of sorghum. Subsequently, the STCR-IPNS studies on maize (hybrids) revealed that the requirement of N, P_2O_5 and K_2O for maize (NR) was found to be 2.08, 0.73 and 1.38 kg q^{-1}respectively. The per cent, nutrient contribution from soil (Cs) was 43.01, 44.03 and 9.17; from fertilizers (Cf) was 55.00, 49.83 and 76.99, and from organic manure (Co) was 49.01, 19.71 and 39.83 for N, P_2O_5 and K_2O, respectively. Using the basic data *viz*., NR, Cs, Cf and Co, fertilizer prescription equations (FPEs) have been developed and ready reckoner of fertilizer doses was formulated for desired yield targets of maize for a range of soil test values on Vertisol. The findings also brought forth the fact that when farm yard manure (FYM) was applied @12.5 t ha^{-1} (with 25 per cent moisture and 0.54, 0.26 and 0.53 per cent NPK, respectively), 45, 22 and 32 kg ha^{-1} of fertilizer N, P_2O_5 and K_2O could be reduced from the recommended fertilizer doses for Maize. Using the nomograms, critical levels of soil available N, P and K were fixed.

Keywords: *Inductive approach, Vertisol, Fertilizer Prescription, STCR-IPNS, Maize*

INTRODUCTION

The fertilizer requirement of a crop depends to a larger extent on native soil fertility and therefore the prescription offertilizer doses should always be made by examining the relationship between soil test values with applied fertilizer doses and crop yield/uptake. 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 and available nutrients. Inductive approach - the unique field experimental technique evolved through creating a macrocosm of soil fertility variability within a microcosm of an experimental field (Ramamoorthy *et al*., 1967) by applying graded doses of fertilizers is best suited to Indian soil and climatic conditions. Based on this concept, Soil Test Crop Response correlation studies under Integrated Plant Nutrition system (STCR-IPNS) were undertaken in different parts of India (Dey and Bhogal, 2016).

In Tamil Nadu, fertilizer prescriptions have been derived for desired yield targets of

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ajor field and horticultural crops on different soil types (Santhi *et al*.,2017). However, STCR studies have not yet been carried out for maize on Vertisol. The formation of the characteristic vertic structure due to pedoturbation (churning) is the principal genetic process (Bhattacharya *et al*., 2006) which forms an invertic horizon (Bss) and the typical characteristic features are the presence of slickensides and pressure faces in Vertisols. Keeping the above facts in view, to develop the STCR-IPNS prescription which is site-specific, the present investigation was undertaken on Vertisol (TypicHaplusterts - Pilamedu soil series, black calcareous) in Southern zone of Tamil Nadu.

MATERIAL AND METHODS

Field experiments were conducted on Vertisol during Kharif 2016 at Manickapuram village, Bodinayakanur taluk, Theni District, Tamil Nadu, India based on Inductive approach as followed in the All India Coordinated Research Project for Investigation on Soil Test Crop Response. To develop artificial fertility gradient,the field was divided into three equal strips *viz.*I,II and III wherein, the first strip ($N_0P_0K_0$) receives no fertilizer,the second strip $N_1P_1K_1$receives the standard dose of fertilizers *viz.,* N equivalent to blanket recommendation for fodder sorghum and P_2O_5 and K_2O based on the P and K fixing capacities of the soil (100 and 80 kg ha^{-1}, respectively) and the third strip $N_2P_2K_2$ receives twice the dose of strip II (Table 1). An exhaust crop of fodder sorghum (*var*. CO 30) was grown with a full dose of P_2O_5 and K_2O along with 50 per cent of N fertilizers basal and the remaining 50 per centat 30 days after sowing. The fertilizer sources used were Urea, Single Super Phosphate and Muriate of Potash, respectively for fertilizer N, P_2O_5 and K_2O. Before the application of fertilizers, in each strip, eight pre-sowing as well as after harvest, eight post-harvest soil samples were collected and analyzed for alkaline $KMnO_4$-N (Subbiah and Asija, 1956), Olsen-P (Olsen *et al*., 1954) and NH_4OAc-K status (Hanway and Heidal, 1952). The crop was harvested as fodder and strip-wise green fodder yield was recorded and eight plant samples from each strip were collected and analysed for total N content (Humphries, 1956), P and K (Piper, 1966) contents and N, P and K uptake values were computed. A comparison was made between the pre-sowing and post-harvest soil test values of each strip, post-harvest soil test values among the strips and in terms of yield and N, P and K uptake among the strips.

After confirming the establishment of fertility gradients,in the second phase of the field experiment, each strip was divided into 24 plots so as to accommodate 24 treatments with four level each of N (0,100,200 and 300 Kg.ha^{-1}), P_2O_5 (0, 40, 80 and 120 kg ha^{-1}) and K_2O (0, 40, 80 and 120 kKg.ha^{-1}) and the experiment was laid out in fractional factorial design. There were three levels of FYM (0,6.25 and 12.5 tha^{-1}) and the IPNS treatments *viz*., NPK+FYM@6.25 tha^{-1}, NPK+FYM@ 12.5 tha^{-1}and the NPK alone treatments were super imposed 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 both directions. The lay out of the experiment with treatment structure is given in Fig 1.Pre-sowing soil samples were collected from each plot before the application of fertilizers and FYM and zanalyzed for available N, P and K status. The test crop maize (TNAU Maize hybrid CO 6) was raised from July 2016 to November 2016. The grain and stover yields were recorded and plot-wise grain and stover samples were collected and zanalyzed for total N content (Humphries,1956), P and K contents (Piper,1966) and uptake of N, P and K by maize was computed.

Computation of basic parameters

Making use of data on the grain yield of maize, total uptake of N, P and K, pre-sowing 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), the contribution of nutrients from soil (Cs), fertilizers(Cf) and farmyard manure (Cfym) were calculated as outlined by Ramamoorthy *et al*. (1967).

(i) NutrientRequirement

NR= (Total uptake of N or P_2O_5 or K_2O (kg ha^{-1})) /Grain yield (q ha^{-1})

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

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

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

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)] / FertilizerN or P_2O_5 or K_2O applied (kg ha^{-1})} * 100

(iv) Percent contribution of nutrients from organics to total nutrient uptake

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

Making use of the basic parameters,Fertilizer

Prescription Equations (FPEs) were developed both under NPK alone and IPNS and the formulae is as below:

STCR-NPK alone

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

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

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

STCR-IPNS

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

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

FK_2O = {[(NR / (Cf /100))*T] – [(Cs/Cf)*1.21 SK] - [(Cfym/Cf)*1.21OK]}

where, FN, FP_2O_5 and FK_2O are Fertilizer N, P_2O_5 and K_2O in kg ha^{-1}, respectively; NR is a 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 the 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 fertilizer doses for specific yield targets (T) of maize for varied soil available nutrient levels which is usually furnished as a ready reckoner.

RESULTS AND DISCUSSION

The soil of the experimental field belongs to Pilamedu soil series taxonomically Typic Haplustert.

Table 1.Fertilizer doses applied to the gradient crop of fodder sorghum

Strip	Levels of Nutrients			Fertilizer doses (kg ha^{-1})		
	N	P_2O_5	K_2O	N	P_2O_5	K_2O
I	N_0	P_0	K_0	0	0	0
II	N_1	P_1	K_1	90	229	97
III	N_2	P_2	K_2	180	458	194

Profile description of the experimental site

The soil profile has A, B and C horizons and the A horizon is a ploughed layer (Ap). The B horizon in this soil indicate both structural (Btk1) as well as slickensided (Btk3) horizons. The C horizon is calcareous dominated by $CaCO_3$ as Ck horizon and presence of ustic moisture regime in this soil under great group level as Usterts. The soil colour ranges from very dark grey (7.5YR 3/1) to brown (7.5YR 4/4) and texture is clay which influences other morphological properties such as structure, consistency and porosity.

Table 2. Effect of application of graded levels of N, P_2O_5 and K_2O on post-harvest soil fertility status of gradient experiment

Strip	Fertilizer doses (kg ha^{-1})			Pre-sowing soil test values			Post-harvest soil test values		
	N	P_2O_5	K_2O	$KMnO_4$–N	Olsen-P	NH_4OAc-K (kg ha^{-1})	$KMnO_4$–N	Olsen-P	NH_4OAc-K (kg ha^{-1})
I	0	0	0	175	21.0	562	165	18.5	550
II	90	229	97	173	21.2	558	187	30.0	578
III	180	458	194	170	20.8	556	200	36.5	590
						SEd	3.34	1.54	3.69
						CD (P= 0.05)	7	3.3	8

This soil possess higher CEC values and the dry consistence of the surface soil is firm and wet consistency is sticky and plastic, and become very sticky and very plastic in the subsurface layer beyond 0.40-0.50 m and occurrence of well-developed slickensides. Well-developed slickensides appear within a depth of 0.37 to 0.69 mand 0.5 to 1.0 cm wide cracks limited up to 0.35 m depth were observed which extended upto0.50m. The structure of the surface soil is moderate medium subangular blocky to moderate strong angular blocky in the sub surface horizon. Very fine, fine and medium root distribution was observed within first 0.50 m beyond which only very fine roots were observed.

Table 3.Effect of application of graded levels of N, P_2O_5 and K_2O on yield and nutrient uptake by fodder sorghum

Strip	Fertilizer doses (kg ha^{-1})			Green fodder yield (t ha^{-1})	Nutrient uptake (kg ha^{-1})		
	N	P_2O_5	K_2O		N	P	K
I	0	0	0	11.32	35.39	9.13	26.10
II	90	229	97	23.45	60.13	15.50	57.35
III	180	458	194	29.94	81.52	20.80	75.88
			SEd	1.06	3.34	1.02	2.76
			CD (P= 0.05)	2.27	7.15	2.18	5.91

The coarse fragments (2cm size)accounts for 5-8 per cent of the soil mass with strong effervescence. Based on the above profile features, the soil taxonomy of the experimental site is very fine montmorillonitic is hyperthermicTypic Haplustert. The initial surface soil pH is slightly alkaline (8.1), electrical conductivity is non-saline (0.60 dS m^{-1}); soil available $KMnO_4$-N, Olsen-P and NH_4OAc-K were 173,20.8 and 560 kg ha^{-1}, respectively. The DTPA extractable zinc (Zn), iron(Fe) and copper (Cu) were in deficient range, whereas manganese (Mn) was insufficient range.

Table 4. Initial soil available NPK, yield and NPK uptake by maize in various strips of test crop experiment (kg ha^{-1})

Parameters (kg ha^{-1})	Strip I		Strip II		Strip III		Overall NPK Treated		Overall Control (NPK)	
	Range	Mean	Range	Mean	Range	Mean	Range	Mean	Range	Mean
$KMnO_4$-N	158-166	163	178-187	184	195-203	199	158-203	182	158-198	181
Olsen-P	16-20	19.4	26-32	29.7	33-39	37.2	16-39	28.9	16-34	25.8
NH_4OAc-K	553-563	557	566-576	570	580-588	585	553-558	571	554-582	567
Grain Yield	3317-9924	7670	4230-10674	8660	4734-11187	9140	6291-11187	8996	3317-6836	4918
N uptake	68.2-223.7	166.2	76.3-234.5	176.7	82.1-248	188.7	123.7-248.0	189.7	68.2-110.7	89.9
P uptake	9.4-42.6	25.4	12.1-43.2	28.5	13.7-46.9	30.5	14.8-46.9	30.2	9.4-17.3	13.7
K uptake	49.9-122.0	89.1	52.8-137.8	96.0	57.7-137.6	104.4	63.4-137.6	101.6	49.9-73.5	60.5

The data of the gradient experiment showed that the $KMnO_4$-N ranged from 170 to 175 kg $ha^{-1}$with a mean value of 175, 173and 170kg ha^{-1} for strip I II and III respectively. The Olsen-P ranged from 20.8 to 21.2kg $ha^{-1}$with a mean value of 21.0,21.2 and 20.8 kg $ha^{-1}$and the NH_4OAc-K ranged from 556 to 562 kg $ha^{-1}$with a mean value of 562,558 and 556 kg ha^{-1} for the strip I, II and III respectively (Table 2).

Table 5. Response of maize to different levels of fertilizer nutrients

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})
100	957	9.57	40	337	8.41	40	307	7.68
200	1990	9.95	80	717	8.96	80	634	7.93
300	3100	10.33	120	1244	10.37	120	1164	9.70

The mean values of post-harvest $KMnO_4$-N were 165,187 and 200 kg ha^{-1} in the strip I, II and III, respectively (Table 2). The mean values of post-harvest Olsen-P status were 18.5,30 and 36.5kg ha^{-1} in the strip I, II and III, respectively. The mean value of post-harvest NH_4OAc-K were 550 in strip I, 578 in strip II and 590 kg ha^{-1} in strip III. The statistical analysis showed that each strip significantly different from the other and the effect on graded levels of N, P and K fertilizers resulted in a significant increase in the soil available N, P and K status of the soil indicating the creation of soil fertility gradients in the experimental field.

Green fodder yield

The graded levels of N,P and K fertilization have a significant effect on green fodder yield of fodder sorghum (Table 3).The strip I ($N_0P_0K_0$) where

Table 6. Basic data for developing fertilizer prescription equations for maize on Vertisol

Nutrients	Basic data			
	NR (kg q^{-1})	Cs(%)	Cf (%)	Cfym (%)
N	2.08	43.01	55.00	49.01
P_2O_5	0.73	44.03	49.83	19.71
K_2O	1.38	9.17	76.99	39.83

fertilizers were not applied recorded the fodder yield of 11.32 t ha^{-1}; in strip II ($N_1P_1K_1$) where the N was applied based on the blanket recommendation (90 kgha^{-1}), P_2O_5andK_2O were applied equal to P and K fixing capacities of the soil, the fodder yield obtained was 23.45t ha^{-1} which was 107.2 percent, increase over strip I. In strip III ($N_3P_3K_3$), where the fertilizer N, P_2O_5 and K_2O applied were twice the dose as that of strip II, the fodder yield was 29.94t ha^{-1} recording an increase of 165.5 and 27.7 percent, over strip I and strip II respectively. It might be due to the fact that graded levels of fertilizer application enhanced the growth and yield parameters which ultimately reflected in increased total green yield. Giri *et al.* (2015) found that applicationof graded levels of fertilizers to gradient crop of sorghum enhanced the nutrient uptake and dry matter yield from strip I to III in Alfisol. Vedhika Sahu *et al*. (2017) recorded the increased fodder maize yield fromthe strip I to III in Vertisol. The results of the present study are in close agreement with the findings of Coumaravel *et al.* (2013) in fodder maize and Singh (2014) in sorghum.

Table 7. Ready reckoner of fertilizer doses at varying soil test values for specific yield targets of maize on Vertisol

Parameter	NPK alone (kg ha^{-1})	NPK+FYM @ 12.5 t ha^{-1}	Reduction over NPK alone (%)	NPK alone (kg ha^{-1})	NPK+FYM @ 12.5 t ha^{-1}	Reduction over NPK alone (%)
	Grain yield target (10t ha^{-1})			Grain yield target (11t ha^{-1})		
$KMnO_4$-N (kg ha^{-1})						
180	238	193	19	275	230	16
200	222	177	20	260	215	17
220	206	161	22	244	199	18
240	191	146	24	229	184	20
260	175	130	26	213	168	21
280	160	115	28	197	152	23
300	144	99	31	182	137	25
Olsen-P (kg ha^{-1})						
10	127	105	17	142	119	15
12	123	101	18	137	115	16
14	119	97	18	133	111	17
16	115	92	20	129	107	17
18	111	88	21	125	103	18
20	107	84	21	121	99	18
22	103	80	22	117	95	19
NH_4OAc-K (kg ha^{-1})						
400	123	91	26	141	109	23
425	120	87	28	137	105	23
450	116	84	28	134	102	24
475	113	80	29	130	98	25
500	109	77	29	127	95	25
525	106	73	31	123	91	26
550	102	70	31	120	88	27

N P and K uptake

Nitrogen uptake by fodder sorghum was significantly higher in strip III (81.52 kg ha^{-1}) as compared to strip II (60.13 kg ha^{-1}) and strip I (35.39 kg ha^{-1}) recording an increase of 35.6 per centover strip II and 130.2 per cent over strip I(Table 3). The mean values of phosphorus uptake by sorghum were 9.13,15.5 and 20.8 kg ha^{-1} in the strip I, II and III, respectively. The P uptake increased with the improvement in soil fertility gradient and the level of fertilizer application. The significant difference in P uptake was realized due to change in the fertility gradient. The percent increase in P uptake in strip III over strip IIand strip I were 34.2 and 127.8 per cent, respectively (Table 3).The significantly higher K uptake was obtained in strip III with a mean value of 75.88 kg ha^{-1}. The mean values of K uptake were 57.35 and 26.1 kg ha^{-1} in strip II and strip I respectively. The percent increase in K uptake in strip III over strip II and strip I was 32.3 and 190.7 percent, respectively.

Table 8. Critical levels of soil available N, P and K for maize as influenced by yield targeting under NPK alone and IPNS

Treatments	NPK alone			IPNS (NPK+ FYM @ 12.5 t ha^{-1})		
	SN	SP	SK	SN	SP	SK
				kg ha^{-1}		
9.0 t ha^{-1}	437	66	1151	392	44	1106
10.0 t ha^{-1}	485	73	1279	440	51	1247
11.0 t ha^{-1}	534	81	1407	489	59	1375

It is evident from the present study that application of graded levels of N, P_2O_5 and K_2O significantly increased the N, P and K uptake and in turn reflected in the fodder yield with increasing levels of fertilizer doses. These results are in close conformity with those reported by Bhoya Mitesh *et al*. (2013), Singh (2014) and Udayakumar and Santhi (2017) in fodder sorghum.

Test Crop experiment

Maize grain yield, Uptake and Initial available NPK status

The range and mean of soil test values and yield of treated and control plots of maize are presented in Table 4. The results showed that the mean $KMnO_4$-N was 163,184 and 199 kg ha^{-1} in the strip I, II and III respectively. The mean Olsen-P was 19, 30 and 37 kg ha^{-1} in Strip I,II and III respectively.With regard to NH_4OAc-K, the mean values were 557,570 and 585 kgha^{-1} in strip I, II and III respectively. The overall mean values of $KMnO_4$-N, Olsen-P and NH_4OAc-K in NPK treated plots were 182,29 and 571 kg ha^{-1} respectively. The overall mean values of $KMnO_4$-N, Olsen-P and NH_4OAc-K in control plots were 181, 26 and 567 kg ha^{-1}, respectively.

The grain yield inthe strip I ranged from 3317 to 9924 kg.ha^{-1} with a mean value of 7670 kg.ha^{-1}, from 4230 to 10674 kg ha^{-1} with a mean of 8660 kg.ha^{-1} in strip II and in strip III from 4734 to 11187 kgha^{-1} with a mean of 9140 kgha^{-1}. The mean grain yield of overall NPK treated and control plots were 8996 and 4918 kg.ha^{-1}, respectively. The percent increase of 82.9 over control was recorded. The N uptake varied from 68.2 to 248 kg.ha^{-1}, P uptake was from 9.4 to 46.9 kg.ha^{-1} and the K uptake varied from 49.9 to 137.6 kg.ha^{-1} respectively in strip I, II and III. The overall mean values of N P and K uptake in NPK treated plots were 189.7, 30.2 and 101.6 kg ha^{-1}, respectively. The mean values of N, P and K uptake in overall control plots were 89.9,13.7 and 60.5, respectively.

It was evident from the above data that a wide variability has existed in the soil test values and grain yield of treated and control plots which is essential for developing basic data and targeted yield equations for calibrating the optimum fertilizer doses for maize on Vertisol. These results are in conformity with the earlier work by Udayakumar and Santhi (2017) for pearl millet on Inceptisol.

Response of Maize to fertilizer N, P_2O_5 and K_2O

In the optimization of fertilizer doses, the response of maize to different fertilizer levels plays a crucial role. The response of hybrid maize to different graded levels of N, P_2O_5 and K_2O were assessed in terms of response ratio (RR). An increase in the response of N, P_2O_5 and K_2O was observed with increase in fertilizer levels. The highest response ratio (RR) of N, P_2O_5, and K_2O was observed in N_{300},P_{120} and K_{120} as 10.33,10.37 and 9.70 respectively(Table 5).Veeranna and Srijaya (2017) reported that an increased level of nitrogen had a significant effect on growth and yield of maize.Giri and Ramanareddy (2015) observed an increase in yield with an increased level of P_2O_5 application. Likewise, an increase in yield of maize with an increase in K_2O levels was reported by SidharamPatil*et al*. (2017).

Basic parameters

Using the data of maize grain yield, N,P and K uptake and initial soil test values of N,Pand

K,fertilizer doses of N,P_2O_5 and K_2O, basic data *viz.*,nutrient requirement (kg q^{-1}),the percent contribution of nutrients from soil (Cs),fertilizer(Cf) and FYM(Cfym) have been derived. Using the basic data, fertilizer prescription equations for N, P and K have been developed for computing optimal fertilizer doses for attaining yield targets of 9,10 and 11t ha^{-1}. These basic parameters were used for formulating the fertilizer prescription equations under NPK alone and IPNS. From the perusal of the data, it can be inferred that the amount of nutrient required to produce one quintal of maize

STRIP I	STRIP II	STRIP III	
$N_2P_3K_2$	$N_0P_0K_0$	$N_2P_2K_1$	
$N_2P_1K_1$	$N_2P_2K_3$	$N_1P_1K_1$	
$N_1P_1K_2$	$N_1P_2K_1$	$N_2P_3K_3$	NPK alone B I
A $N_3P_3K_2$	B $N_3P_3K_3$	C $N_2P_1K_2$	
$N_1P_2K_2$	$N_2P_2K_2$	$N_0P_0K_0$	
$N_3P_1K_1$	$N_2P_0K_2$	$N_0P_2K_2$	
$N_2P_2K_0$	$N_3P_2K_1$	$N_3P_3K_1$	
$N_0P_0K_0$	$N_3P_2K_3$	$N_3P_2K_2$	
$N_0P_0K_0$	$N_2P_2K_1$	$N_2P_3K_2$	
$N_2P_2K_3$	$N_1P_1K_1$	$N_2P_1K_1$	
$N_1P_2K_1$	$N_2P_3K_3$	$N_1P_1K_2$	NPK + FYM @ 6.25 t ha^{-1} B II
B $N_3P_3K_3$	C $N_2P_1K_2$	A $N_3P_3K_2$	
$N_2P_2K_2$	$N_0P_0K_0$	$N_1P_2K_2$	
$N_2P_0K_2$	$N_0P_2K_2$	$N_3P_1K_1$	
$N_3P_2K_1$	$N_3P_3K_1$	$N_2P_2K_0$	
$N_3P_2K_3$	$N_3P_2K_2$	$N_0P_0K_0$	
$N_2P_2K_1$	$N_2P_3K_2$	$N_0P_0K_0$	
$N_1P_1K_1$	$N_2P_1K_1$	$N_2P_2K_3$	
$N_2P_3K_3$	$N_1P_1K_2$	$N_1P_2K_1$	NPK + FYM @ 12.5 t ha^{-1} BIII
C $N_2P_1K_2$	A $N_3P_3K_2$	B $N_3P_3K_3$	
$N_0P_0K_0$	$N_1P_2K_2$	$N_2P_2K_2$	
$N_0P_2K_2$	$N_3P_1K_1$	$N_2P_0K_2$	
$N_3P_3K_1$	$N_2P_2K_0$	$N_3P_2K_1$	
$N_3P_2K_2$	$N_0P_0K_0$	$N_3P_2K_3$	

Treatment structure

1. $N_0P_0K_0$
2. $N_0P_0K_0$
3. $N_0P_0K_0$
4. $N_0P_2K_2$
5. $N_1P_1K_1$
6. $N_1P_2K_{`1}$
7. $N_1P_1K_2$
8. $N_1P_2K_2$
9. $N_2P_1K_1$
10. $N_2P_0K_2$
11. $N_2P_1K_2$
12. $N_2P_2K_2$
13. $N_2P_2K_1$
14. $N_2P_2K_0$
15. $N_2P_2K_3$
16. $N_2P_3K_2$
17. $N_2P_3K_3$
18. $N_3P_1K_1$
19. $N_3P_2K_1$
20. $N_3P_2K_2$
21. $N_3P_3K_1$
22. $N_3P_3K_2$
23. $N_3P_2K_3$
24. $N_3P_3K_3$

Fig. 1. Layout plan of the test crop experiment with maize

was 2.08 kg N, 0.73 kg $P_2O_5$and 1.38 kg K_2O. The contribution from soil available nutrient towards nutrient uptake was 43.01 per cent for N,44.03 per cent for $P_2O_5$and 9.17 per cent for K_2O. Among the three nutrients, the contribution from soil was higher inK_2O followed by $P_2O_5$and N. The contribution from fertilizer nutrient was 55 per cent for N,49.83 for $P_2O_5$and 76.99 per cent for K_2O. From the data, the contribution from fertilizer was higher than that from the soil and followed the order of K_2O>N>P_2O_5. The contribution of nutrients from FYM was 49.01,19.71 and 39.83per cent for N, P_2O_5 and K_2O respectively (Table 6).

Fertilizer PrescriptionEquations under IPNS for desired yield target of maize

(i) STCR-NPK alone (ii) STCR-IPNS (NPK+FYM)

(I)		(II)
FN=3.79 T-0.78 SN		FN=3.79 T-0.78 SN-0.89 ON
FP_2O_5=1.47 T- 2.02 SP		FP_2O_5=1.47 T- 2.02 SP -0.91 OP
FK_2O = 1.79 T-0.14 SK		FK_2O = 1.79 T-0.14 SK -0.52 OK

Using the fertilizer prescription equations, the ready reckoners were prepared for yield target of 9,10 and 11.0 tha^{-1} of maize for a range of soil test values for Vertisol under NPK alone and IPNS. From the perusal of the ready reckoner in Table7, it can be observed that the fertilizer requirement to attain a desired yield target of maize decreased with an increase in soil test values and increased with increase in yield targets. The fertilizer doses required for average soil test value of 180,22 and 525 kgha^{-1}of$KMnO_4$-N, Olsen-P and NH_4OAc-K,the quantity of fertilizer N, P_2O_5 and K_2O for a yield target of 10.0 and 11.0 tha^{-1}was 238,103 and 106 kgha^{-1}and 275,117 and 123 kgha^{-1}, respectively. When FYM (25 per cent moisture and 0.54,0.26 and 0.53 per cent of N, P and K) was applied @ 12.5tha^{-1}along with fertilizer NPK, the required N, P_2O_5 and K_2O doses were 193, 80 and 73 and 230, 95 and 91kgha^{-1}for yield target of 10 and 11t ha^{-1}, respectively. Therefore under IPNS(and 32 kg of fertilizer N P_2O_5 and K_2O respectively could be reduced from the recommended dose of fertilizers for a specific soil test value and yield target resulting in economy of fertilizer use. Therefore the integrated use of FYM along with NPK fertilizers not only maximized the yield but also resulted in enhanced use efficiency of applied fertilizers and the profitability. This would pave way for improvement in soil health by the way of increased microbial population and also through favourable soil physical properties thereby conserve the soil fertility over a long time. In the present study also these factors contributed to the improvement in yield of maize by the integrated use of NPK along with FYM. These findings are in conformity with those reported by Udayakumar and Santhi (2017) on Inceptisol, Srivastava *et al.* (2017) and VedhikaSahu*et al*. (2017) for rice on Vertisol of Chhattisgarh.

Critical levels of soil available N,P and K

Critical soil test values are the soil test values above which there would be no requirement of fertilizer application for indicated levels of crop yield (Randhawa and Velayutham, 1982). Accordingly, in the present investigation, the critical soil test values of $KMnO_4$-N, Olsen-P and NH_4OAc-K were fixed for the desired yield target of maize under NPK alone and IPNS. Making use of the fertilizer doses computed for desired yield target of maize for a range of soil test values, the critical soil test levels for $KMnO_4$-N, Olsen-P and NH_4OAc-K were fixed. For 9.0 t ha^{-1} yield target, the critical levels of soil available N, P and K were 437,66 and 1151 kg ha^{-1} under NPK alone; 392,44 and 1106 kg ha^{-1} for NPK plus FYM @ 12.5 t ha^{-1}. Similarly, critical soil test levels for 10.0 and 11.0 t ha^{-1} yield target of maize are furnished in Table 8. The results showed that IPNS resulted in relatively low critical soil test levels when compared to NPK alone confirming the efficient and economic use of fertilizers. With a view to avoiding nutrient mining, if the soil test values are above the critical levels, a maintenance dose of fertilizer N, P_2O_5 and K_2O is prescribed.

CONCLUSION

It could be concluded that inductive approach formed the basis for developing soil test based fertilizer prescription for hybrid maize onPilamedu soil series (TypicHaplustert) of Tamil Nadu taking into account the nutrient requirement and contribution of N P and K from various nutrient sources (soil, fertilizer and FYM). This can be adopted in similar and allied soil types of Tamil Nadu. Therefore, there will be a balanced supply of nutrients coupled with recycling of organic manures avoiding either over or under usage of fertilizer inputs.

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