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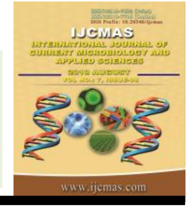

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Soil Test Crop Response Based Integrated Plant Nutrition System for Maize on Vertisol

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A B S T R A C T

Soil Test Crop Response correlation studies under Integrated Plant Nutrition System (STCR-IPNS) were conducted for maize on Vertisol based on Inductive cum Targeted yield model at Southern Zone of Tamil Nadu during 2016-17. After the establishment of three different soil fertility gradients in the same experimental field, 24 treatments comprising different combinations of N, P_2O_5, K_2O and FYM (four levels each of fertiliser N, P_2O_5 and K_2O and three levels of FYM) were superimposed over the three fertility strips in a Fractional Factorial Design with the test crop maize (TNAU maize hybrid CO 6). The results of the present investigation clearly revealed that there was a progressive increase in response with increase in fertilizer N (300 kg ha^{-1}), P_2O_5 (120 kg ha^{-1}) and K_2O (120 kg ha^{-1}) levels. Therefore, using the experimental data, the basic parameters *viz.*, (i) the requirement of N, P_2O_5 and K_2O for maize was found to be 2.08, 0.73 and 1.38 kg q^{-1}, respectively (ii) the per cent contribution of nutrients from soil (Cs) was 43.01, 44.03 and 9.17; from fertilizers (Cf) was 55.00, 49.83 and 76.99 and from farm yard manure (Co) was 49.01, 19.71 and 39.83 for N, P_2O_5 and K_2O, respectively. Making use of the basic parameters, fertiliser prescription equations (FPEs) have been developed and ready reckoner of fertiliser doses was formulated for desired yield targets of maize for a range of soil test values on Vertisol. The findings brought forth the fact that when farm yard manure (FYM) was applied @12.5 t ha^{-1} (with 25% moisture and 0.54, 0.26 and 0.53% NPK, respectively), 45, 22 and 32kgha^{-1} of fertilizer N, P_2O_5 and K_2O could be reduced from the recommended fertiliser doses for maize.

Introduction

Maize (*Zea mays* L.) called "Queen of cereals" is one of the major cereal crop with wide adaptability to diverse agro-climatic conditions globally and stands first with respect to production in the world and in India, it ranks third after rice and wheat. Maize being an exhaustive crop, the nutrient requirement cannot be supplied through native nutrient reserves, and hence the additional nutrient requirement has to be met from fertiliser inputs (Shreenivas *et al.*, 2017). Efficient nutrient management necessitates balanced fertilizer use, sound management decisions and practices to the productivity of maize and sustained soil fertility (Sivaranjani *et al.*, 2018). The area under maize cultivation was 93.6 million hectares accounting to 9.8 percent of the total cultivated area of the world (Giri and Ramana Reddy, 2015). In India, during 2015-16, maize was cultivated in 8.69 million hectares with an average productivity of 2580 kg ha^{-1} while in Tamil Nadu, it was cultivated in an area of 3.64 lakh ha with a production of 23.83 million tones and productivity of 6549 $kgha^{-1}$.

Among the various methods of fertiliser recommendations, the one based on yield targeting is unique because this method not only considers the soil test based fertilizer dose but also the level of yield the farmer can achieve if good agronomic practices are followed to raise the crop. This targeted yield approach is also scientifically sound as the balanced fertilisation is ensured not only among the fertiliser nutrients but also the soil available nutrients (Veeranna and Srijaya, 2017). At this juncture, the prescription procedure outlined by Troug (1960) and modified by Ramamoorthy *et al.,* (1967) as "Inductive-cum-Targeted yield model" provides a scientific basis for balanced fertilization and balance between the applied nutrients and available nutrients. 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) and Tamil Nadu (Santhi *et al.,* 2017) and fertilizer prescriptions have been derived for desired yield targets of various major field and horticultural crops on different soil types. Though soil test based fertilizer prescriptions for various soil types and agro-climatic zones in different parts of Tamil Nadu, STCR studies has not yet been carried out for maize in Vertisol Keeping the above facts in view, the present investigation on Soil Test Crop Response based Integrated Plant Nutrition System was undertaken on Pilamedu soil series (Typic Haplustert) in Southern zone of Tamil Nadu.

Materials and Methods

The field experiment was carried out in 2016-2017 *kharif* season at farmer holding Manikapuram village of Bodinayakanur taluk, Theni District in Southern zone of Tamil Nadu state, which falls between 9^0 48' N latitude and 77^0 25'E longitude. The soil of the experimental field was deep, black calcareous, moderately drained and clayey. The pH of the soil was slightly alkaline, non-saline and available N, P and K status was low, medium and high respectively. With regard to available micronutrients, sufficient range of iron (Fe), manganese (Mn) and deficient range of zinc (Zn) and copper (Cu) were recorded.

Phase-I-Gradient experiment

The experiment was conducted according to the approved layout plan of All India Coordinated Research Project on Soil Test Crop Response (STCR) and a unique experimental technique (inductive methodology) developed by Ramamoorthy *et al.,* (1967) was adopted in the present investigation. For this purpose, the experimental field was divided into three equal strips and denoted as Strip I (SI), Strip II(SII) and Strip III (SIII)*viz.,* $N_0P_0K_0$, $N_1P_1K_1$ and $N_2P_2K_2$ respectively. Fertility gradients were created by applying the graded doses of fertilizer N, P_2O_5 and K for obtaining the operational range of soil test values in various soil fertility strips. The standard dose of fertiliser P_2O_5 and K_2O (P_1K_1) were fixed based on the phosphorus (100 kg P ha^{-1}) and potassium (80 kg K ha^{-1}) fixing capacities of the soil and the standard dose of N (N_1) was fixed as per the blanket recommendation for fodder sorghum (90 $kgha^{-1}$). Fodder sorghum (*var*. CO 30) was raised during summer 2016 as an exhaust crop (gradient crop) and an operational range of soil test values in respect of available N, P and K was created. The data on post-harvest soil available N, P and K, fodder yield and uptake of N, P and K by fodder sorghum confirmed the creation of soil fertility gradients among the three fertility strips.

Phase-II-test crop experiment

After 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 levels each of N (0, 100, 200 and 300 kg ha^{-1}), P_2O_5 (0, 40, 80, 120 kg ha^{-1}) and K_2O (0, 40, 80, 120 kg ha^{-1}) and the experiment was laid out in fractional factorial design. There were three levels of FYM (0, 6.25 and 12.5 t ha^{-1}) and the IPNS treatments *viz*., NPK+FYM@6.25 t ha^{-1}, NPK+FYM@ 12.5 t ha^{-1} and NPK alone treatments were super imposed across the strips thus forming a total of 72 plots. 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 the directions. The treatment structure is given in Table 1. Pre-sowing soil samples were collected from each plot before the application of fertilizers and manures 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 test crop maize (TNAU Maize hybrid CO 6) was raised during July 2016 and the crop was grown to maturity and the grain and stover yields were recorded plot-wise; grain and straw samples from each plot collected, processed and analyzed for total N (Humphries, 1956), P and K (Piper, 1966) contents and the uptake of N, P and K by maize was computed.

Computation of basic parameters

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

Nutrient Requirement (NR)

Kg of N/ P_2O_5/ K_2O required per quintal (100 kg) of grain yield production, expressed in (kg q^{-1}).

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

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

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

Per cent contribution of nutrients from Fertilizer to total nutrient 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)] / Fertiliser N or P_2O_5 or K_2O applied (kg ha^{-1})} * 100

Percent contribution of nutrients from FYM to total nutrient uptake (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

These parameters were used for developing Fertiliser Prescription Equations (FPEs) for deriving fertilizer doses and the soil test based fertilizer recommendations were prescribed in the form of a ready reckoner (nomograms) for desired yield target of maize under NPK alone as well as under IPNS.

Fertilizer Prescription Equations

Making use of these parameters, the Fertilizer Prescription Equations (FPEs) under NPK alone and IPNS were developed for maize as furnished below:

Fertiliser nitrogen (FN)

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

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

Fertiliser phosphorus (FP_2O_5)

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

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

Fertiliser potassium (FK_2O)

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

FK_2O_5 = {[(NR / (Cf /100))*T] – [(Cs/Cf)*1.21SK] - [(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 the nutrient requirement (N or P_2O_5 or and K_2O) in kg q^{-1}; Cs is the per cent contribution of nutrients from soil, Cf is the 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}.These equations serve as a basis for predicting fertiliser doses for specific yield targets (T) of maize for varied soil available nutrient levels.

Results and Discussion

Maize grain yield, uptake and pre-sowing available NPK status

The range and mean of soil test values and yield of treated and control plots of maize are presented in Table 2. The results showed that the mean $KMnO_4$-N, was 163, 184 and 199 kg ha^{-1} in strip I, II and III respectively. The mean Olsen-P was 19.4, 30 and 37.2 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, 28.9 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, 25.8 and 567 kg ha^{-1}, respectively.

The grain yield in 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 kg $ha^{-1}$with a mean of 9140 kg ha^{-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 the basic parameters and targeted yield equations for calibrating the optimum fertilizer doses. These results are in conformity with the earlier works by Udayakumar and Santhi (2017) for pearl millet on Inceptisol.

Response of maize to fertilizer N, P_2O_5 and K_2O

The results indicated that maize is an exhaustive crop and requires relatively higher nutrient levels and also enhanced the grain yield kg $kg^{-1}$when there is a constant supply of nutrients. In optimization of fertilizer dose, response of maize to 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).

There was an increase response of N, P_2O_5 and K_2O observed with increase in fertilizer levels. The highest response ratio (RR) of N, P_2O_5 and K_2O observed in N_{300}, P_{120} and K_{120} as 10.33, 10.37 and 9.70 respectively (Table 3). Veeranna and Srijaya (2017) reported that increased level of nitrogen had a significant effect on growth and yield of maize (Giri and Ramana Reddy, 2015) and observed an increase in yield with increased level of P_2O_5 application.

Likewise, increase in yield of maize with increase in K_2O levels was reported by Sidharam Patil *et al.*, (2017).

Basic parameters

Using the data of grain yield, total N, P and K uptake by maize and initial soil test values of N, P and K, fertilizer doses of N, P_2O_5 and K_2O and FYM levels, basic parameters *viz*, nutrient requirement (kg q^{-1}), the percent contribution of nutrients from soil (Cs), fertilizers (Cf) and FYM (Cfym) have been derived (Table 4). Using these basic parameters, targeted yield equations of N, P and K nutrients have been derived under NPK alone and IPNS for computing optimal fertilizer doses for attaining yield targets of 9, 10 and 11t ha^{-1}. From the perusal of the data it can be inferred that the amount of nutrient required to produce one quintal of maize was 2.08 kg N, 0.73 kg $P_2O_5$and 1.38 kg K_2O.

The contribution from soil available nutrients towards nutrient uptake was 43.01% for N, 44.03% for $P_2O_5$and 9.17% for K_2O. Among the three nutrients, contribution from soil was higher in P_2O_5 followed by N and K_2O.

The contribution from fertilizer nutrient was 55% for N, 49.83 for $P_2O_5$and 79.99% 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 39.83 % for N, $P_2O_5$and K_2O respectively.

Fertilizer Prescription Equations for desired yield target of maize

Fertilizer prescription equations were evolved for maize to achieve a definite yield target based on the basic parameters *viz.,* nutrient requirement, percent contribution of nutrients from soil, fertilizers and FYM and the equations are furnished below:

STCR-NPK alone

FN=3.78T-0.78 SN

F P_2O_5=1.47 T- 2.02 SP

F K_2O = 1.79 T-0.14 SK

STCR-IPNS (NPK+FYM)

FN=3.78 T-0.78 SN-0.89 ON

FP_2O_5=1.47 T- 2.02 SP -0.91 OP

FK_2O = 1.79 T-0.14 SK -0.62 OK

Table.1 Treatment structure for test crop experiment on Maize

Sl. No	Treatment combination			Levels 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	80	80
5	1	1	1	100	40	40
6	1	2	1	100	80	40
7	1	1	2	100	40	80
8	1	2	2	100	80	80
9	2	1	1	200	40	40
10	2	0	2	200	0	80
11	2	1	2	200	40	80
12	2	2	2	200	80	80
13	2	2	1	200	80	40
14	2	2	0	200	80	0
15	2	2	3	200	80	120
16	2	3	2	200	120	80
17	2	3	3	200	120	120
18	3	1	1	300	40	40
19	3	2	1	300	80	40
20	3	2	2	300	80	80
21	3	3	1	300	120	40
22	3	3	2	300	120	80
23	3	2	3	300	80	120
24	3	3	3	300	120	120

Table.2 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		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	30.0	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	82.1-248.0	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	104.3	63.4-137.6	101.6	49.9-73.5	60.5

Table.3 Response of maize 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.	100	957	9.57	40	336	8.41	40	331	7.92
2.	200	1990	9.95	80	717	9.00	80	615	7.68
3.	300	3100	10.33	120	1244	10.37	120	1303	9.70

Table.4 Basic Parameters for maize on Vertisol

Nutrients	Basic data			
	NR (q ha^{-1})	C_S (%)	C_f (%)	C_{fym} (%)
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

Table.5 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 (10 t 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	23	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	19	129	107	17
18	111	88	20	125	103	18
20	107	84	21	121	99	18
22	103	80	21	117	95	19
NH_4OAc-K (kg ha^{-1})						
400	123	91	25	141	109	22
425	120	87	26	137	105	22
450	116	84	27	134	102	23
475	113	80	27	130	98	23
500	109	77	28	127	95	24
525	106	73	29	123	91	24
550	102	70	30	120	88	26

Based on the fertilizer prescription equations the ready reckoners (nomograms) were prepared for desired yield target of 9.0, 10.0 and 11.0 t ha^{-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 Table 5, it can be observed that the fertilizer requirement to attain a desired yield target of maize decreased with increase in soil test values and increased with increase in yield targets. The fertilizer doses required for an average soil test value of 180, 22 and 550 kg ha^{-1} of$KMnO_4$-N, Olsen-P and NH_4OAc-K, the quantity of fertilizer N, P_2O_5 and K_2O for an yield target of 10 and 11 t ha^{-1} was 238, 103 and 102kg $ha^{-1}$and 275, 117 and 120kg ha^{-1}, respectively. Concurrently, when FYM (25% moisture and 0.54, 0.26 and 0.53 % of N, P and K) was applied @ 12.5 t ha^{-1}along with fertilizer NPK, the required N, P_2O_5 and K_2O doses were 193, 80 and 70 and 230, 95 and 88 kg ha^{-1} for yield target of 10 and 11t ha^{-1}, respectively. Therefore under IPNS (NPK+FYM@12.5 t ha^{-1}), 45, 22 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 fertilizer not only maximized of yield but also accelerated the profitability. It also improved the soil fertility by the way of increased microbial population and also favorable soil physical properties, thereby conserve the soil fertility for long time. In the present study also, these factors contributed the improvement in yield of maize by the integrated use of NPK along with FYM. In recent times, the fertilizer recommendations derived from STCR approaches may be more appropriate than other approaches.

Realizing the above fact, Santhi *et al.,* (2017) documented a hand book on soil test and yield target based fertilizer prescriptions under IPNS for cereals, millets pulses, oilseeds, sugarcane, cotton, vegetables, spices, and medicinal plants on 17 soil series for Tamil Nadu. The desired target were achieved when the soil test based fertilizer application are prescribed to the farmers. With this back ground, in the present investigation, soil test based fertilizer prescription equations for desired yield target of maize was developed using the basic parameters obtained.

The soil test based IPNS provide positive effect of increased yield which may be due to their effect on root growth, nutrient uptake, simulation of many different enzymes related photosynthesis, efficient response to plant nutrient requirement, integrated supply of nutrients from different sources and improved nutrient supply. The targeted yield equations based on soil tests will not only ensure sustainable crop production but also steer the farmers towards economic use of costly fertilizer inputs (Tegegnework *et al.,* 2015). These findings are in conformity with those reported by Santhi *et al.,* (2011) on Alfisol and by Udayakumar and Santhi (2017) on Inceptisol in pearl millet. Srivastava *et al.,* (2017) and Vedhika Sahu *et al.,* (2017) reported the enhanced yield of rice on Vertisol of Chhattisgarh.

In the present investigation, Soil Test Crop Response based Integrated Plant Nutrition System for desired yield targets of maize has been developed for deep black calcareous, Pilamedu soil series (Typic Haplustert) of Tamil Nadu. The targeted yield approach of fertilizer prescription ensures nutrient balancing to suit desired yield targets based on resource availability of the farmer with sustained soil fertility.

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