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Soil Test Crop Response Correlation Studies Under Integrated Plant Nutrition System for Hybrid Maize on an Alfisol

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Soil Test Crop Response correlation studies were carried out in maize under Integrated Plant Nutrition System (STCR-IPNS) on Typic Rhodustalf of Tamil Nadu, adopting "Inductive cum Targeted yield model". The basic parameters for the "Targeted yield model" *viz.* nutrient requirement (NR), contribution of nutrients from soil (Cs), fertilizer (Cf) and farmyard manure (Cfym) were computed from field experimental data. Using these parameters, the fertiliser prescription equations were developed under IPNS and ready reckoner of fertiliser doses were formulated for desired yield target of maize for a range of soil test values. The quantity of fertilizer nutrients that could be saved due to the application of FYM @ 12.5 t ha^{-1} was assessed to the tune of 40, 20 and 26 kg fertilizer N, P_2O_5 and K_2O respectively, when applied along with the NPK fertilizers. The per cent reduction in fertilizer N, P_2O_5 and K_2O under IPNS increased with increasing soil available NPK.

Key words: Maize, Alfisol, hybrid maize, fertiliser prescription equations and STCR- IPNS

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The production environment and natural resources are continuously shrinking and deteriorating globally and the food demand is expected to be doubled by 2050. There are projections that demand for foodgrains in India would increase to 345 million tonnes in 2030. Therefore, in the next 20 years, production of foodgrains needs to be increased at the rate of 5.5 million tonnes annually.

To meet the foodgrain requirement for ever increasing population of India, the best way is to produce more from limited land resources. Further, the escalation in the cost of fertilisers has caused a serious setback for balanced fertilization. Hence, exclusive dependence on either inorganic fertilizers or organic sources of nutrients is neither economically viable nor environmentally acceptable.

Maize (*Zea mays* L.), called as "Queen of Cereals" is the third most important cereal, next to wheat and rice in the world as well as in India. In Tamil Nadu, it is cultivated in an area of 2.44 lakh hectares with a production of 11.44 lakh tonnes and an average productivity of 4.7 t ha^{-1} which is much higher than the national average (Anon., 2010). Poultry sector is the leading consumer of maize grains in Tamil Nadu and demands 20 lakh tonnes per year indicating a gap of about 8 lakh tonnes which gains attention for technological interventions.

At this juncture, the prescription procedure outlined by Truog (1960) and modified by Ramamoorthy *et al.* (1967) as "Inductive cum Targeted yield model" strikes a balance between 'fertilizing the crop' and 'fertilizing the soil'. This model provides a scientific basis for balanced fertilization and balance between applied nutrients and soil available nutrients. Therefore, the

present investigation was undertaken adopting this model so as to derive a basis for recommending balanced nutrition to hybrid maize on an Alfisol.

Materials and Methods

The present study consisted of two field experiments in two phases *viz.,*fertility gradient experiment with fodder maize CO 1 (phaseI) and the test crop experiment with maize hybrid NK6240 (phase II). The experiments were conducted during 2010-2011 on Palaviduthi (Pvd) soil series (Typic Rhodustalf) at farmer's holding of Perumalkovilpatti village in Dindigul District, Tamil Nadu. The surface soil (0 - 15 cm deep) of the experimental field is yellowish red (5YR 4/6 D) to dark reddish brown (5 YR 3/4), moderately well to well drained, red, non-calcareous, sandy loam in texture with a bulk density of 1.44 Mg m^{-3}. The pH, electrical conductivity and cation exchange capacity of the soil were 7.43, 0.14 dS m^{-1} and 9.1c mol (p^{+}) kg^{-1}, respectively. The initial soil organic carbon available alkaline potassium permanganate nitrogen ($KMnO_4$ - N), Olsen phosphorus (Olsen - P) and ammonium acetate potassium (NH_4OAc - K) were 2.4 g kg-1,198 kg ha^{-1}, 21.5 kg ha^{-1} and 205 kg ha^{-1}, respectively. The P and K fixing capacities of the soil were 100 and 120 kg ha^{-1}, respectively. The available Fe and Mn were in the sufficient range (3.90 and 7.64 mg kg^{-1} respectively) while available Zn and Cu were in the deficient range (0.98 and 0.73 mg kg^{-1} respectively). The total N, P and K contents of the soil was 0.06, 0.07 and 0.12 per cent respectively.

In the gradient experiment, wide variation in soil fertility was created by adopting the Inductive Methodology developed by Ramamoorthy *et al*. (1967). For this purpose, the experimental field was divided into three equal strips, the first strip (strip I)

received no fertilizer ($N_0P_0K_0$), the second (strip II) and third strips (strip III) received one ($N_1P_1K_1$) and two ($N_2P_2K_2$) times the standard dose of fertilizer 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 thus making a total of 24 samples and analysed for alkaline $KMnO_4$-N, Olsen - P and NH_4OAc- K. At harvest, 24 plant samples were collected, processed and analysed for N, P and K contents.

After the harvest of fodder maize, in the test crop experiment each strip was divided into 24 plots and pre-sowing 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 treatments consisted of four levels of N (0, 100, 200 and 300 kg ha^{-1}), four levels of P_2O_5 (0, 40, 80 and 120 kg ha^{-1}) and four levels of 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 IPNS treatments (NPK alone, FYM @ 6.25 t ha^{-1} and 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 given in Table 1. Twenty five per cent of N and whole of FYM, P_2O_5 and K_2O were applied as basal dose. After the basal application of FYM and NPK fertilizers, the test crop maize (Hybrid NK 6240) was sown with a spacing of 60 cm x 25 cm. Fifty per cent of N was top dressed at 25 days after sowing and remaining 25 per cent of N was applied as second top dressing on 45 days after sowing. Routine cultural operations were followed periodically. The crop was grown to maturity, harvested and plot wise grain yields were recorded. The grain, plant and post-harvest soil samples were collected from each plot and processed and analysed for N (Humphries, 1956), P and K contents (Jackson,1973), and NPK uptake by maize was computed using the dry matter yield.

Making use of the 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 fertilizer N, P_2O_5 and K_2O applied, the basic parameters for maize *viz*., nutrient requirement (NR), per cent contribution of nutrients from soil (Cs), fertilizer (Cf) and farmyard manure (Cfym) were calculated as outlined by Ramamoorthy *et al. (*1967).

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

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

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

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

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

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

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

Per cent contribution from FYM (Cfym)

These parameters were used for developing fertilizer prescription equations for deriving fertilizers doses, and soil test based fertiliser recommendations were prescribed in the form of a ready table for desired yield target of

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

hybrid maize under NPK alone as well as under IPNS.

Targeted yield equations

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

i) Fertilizer nitrogen (FN)

ii) Fertilizer phosphorus (FP_2O_5)

iii) Fertilizer potassium (FK_2O)

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 of N or P_2O_5 or and K_2O in kg q^{-1};Cs is

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

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

the per cent contribution of nutrients from soil; Cf is the

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

$$FPO_{2\ 5} = \frac{NR}{Cf/100} T - \frac{Cs}{Cf} \times 2.29 \times SP - \frac{Cfym}{} \times 2.29 \times OP$$

per cent contribution of nutrients from fertilizer; Cfym is the percent contribution of nutrients from FYM, T is

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

$$FKO_{2} = \frac{NR}{Cf/100} T - \frac{Cs}{Cf} \times 1.21 \times SK - \frac{Cfym}{Cf} \times 1.21 \times OK$$

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 formed the basis for predicting fertilizer doses for specific yield targets (T) of hybrid maize for varied soil available nutrient levels.

Results and Discussion

The range and mean grain yield of maize furnished in Table 2 indicated that the grain yield ranged from 3200 kg ha^{-1} in absolute control of strip I to 10700 kg ha^{-1} in $N_{300}P_{80}K_{80}$ + FYM @ 12.5 t ha^{-1} of strip II with mean values of 7221, 7660 and 7881 kg ha^{-1} in strip I, II and III respectively. The N uptake of maize varied from 44.1 to 238.3 kg ha^{-1}; P uptake varied from 7.5 to 42.4 kg ha^{-1} and K uptake from 29.0 to 130.8 kg ha^{-1} in strips I, II and III, respectively.

The data on pre-sowing soil test values of maize revealed that, the mean $KMnO_4$-N was 186, 206, 225 kg ha^{-1}; the mean Olsen-P was 19, 30 and 38 kg ha^{-1} ; the mean NH_4OAc-K was 181, 208 and 230 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 pre-sowing soil available nutrient status and variations in the grain yield of maize and NPK uptake, which is a prerequisite for calculating the basic parameters and fertilizer prescription equations for calibrating the fertiliser doses for specific yield target. Anon., (2011) reported similar existence of operational range of available N, P and K on various soil types.

Nutrient requirement

To produce one quintal of maize 2.00 kg of N, 0.76 kg of P_2O_5 and 1.27 kg of K_2O were required. Among the three nutrients, the requirement of N is the highest followed by K_2O and P_2O_5. The requirement of N is 1.57 times higher than K_2O and 2.63 times higher than P_2O_5. Similar trend of nutrient requirement for N, P_2O_5 and K_2O was reported by Muralidharudu *et al*.(2011) for maize.

Table 1. Treatment structure for Hybrid maize

Sl. No	Treatment combinations			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

Levels of fertilizer nutrients and FYM for hybrid maize

Level	N (kg ha^{-1})	P_2O_5 (kg ha^{-1})	K_2O (kg ha^{-1})	FYM (t ha^{-1})
0	0	0	0	0
1	100	40	40	6.25
2	200	80	80	12.5
3	300	120	120	-

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

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 31.54 per cent of available N, 40.93 per cent of available P and 16.83 percent of available K respectively towards the total N, P and K uptake by maize. Among the three nutrients, the per cent contribution from soil was higher for P followed by N and K. With regard to K_2O, comparatively lower Cs was recorded which might be due to the preferential nature of maize towards the applied K_2O than the native K_2O. The above findings are in accordance with Muralidharudu *et al*. (2011) for maize.

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

The per cent contribution of nutrients from fertilisers (Cf) of maize to the total uptake was computed from the NPK applied plots. In the present investigation, the contribution from applied fertilizer was 50.50, 48.62 and 76.56 per cent, respectively for N, P_2O_5 and K_2O which was in the order of K_2O > N > P_2O_5. The response yardstick recorded was 13.90 kg kg^{-1}. The estimated Cf clearly revealed the fact that the

Table 2. Pre-sowing soil available NPK, yield and NPK uptake by hybrid maize in various fertility strips (kg ha^{-1})

Parameter	Strip I		Strip II		Strip III	
(kg ha^{-1})	Range	Mean	Range	Mean	Range	Mean
$KMnO_4$ –N	183-192	186	203-213	206	220-230	225
Olsen–P	16-20	19	27-32	30	34-39	38
NH_4OAc-K	176-185	181	205-215	208	225-235	230
Grain yield	3200-10356	7221	3700-10700	7660	3781-10684	7881
N uptake	44.1-224.6	144.3	65.1-238.3	158.4	71.2-237.9	165.8
P uptake	7.5-41.3	25.0	11.0-42.4	27.2	14.0-42.3	28.1
K uptake	29.0-116.4	75.1	37.0-133.3	81.2	46.5-130.8	85.2

magnitude of contribution by fertilizer K_2O was 1.57 times higher than P_2O_5 and 1.52 times as that of N. With regard to N, P_2O_5 and K_2O, comparatively more contribution was recorded from fertilizer source than from the soil source which is in close conformity with the results of Chandrasekhra Reddy and Riazuddin Ahmed (2000) and Natesan *et al*. (2007) for maize on Inceptisols.

Table 3. Nutrient requirement, per cent contribution of nutrients from soil, fertilisers and FYM for hybrid maize

Crop	Parameter	Basic Data		
		N	P_2O_5	K_2O
Maize	Nutrient requirement (kg q^{-1})	2.00	0.76	1.27
	Per cent contribution from soil (Cs)	31.54	40.93	16.83
	Per cent contribution from fertilisers (Cf)	50.50	48.62	76.56
	Per cent contribution from FYM (Cfym)	34.70	12.83	31.25

Contribution of nutrients from FYM for maize

The estimated per cent contribution of N, P_2O_5 and K_2O from FYM (Cfym) were 34.70, 12.83 and 31.25 respectively for maize which indicated that relatively higher contribution was recorded for N followed by K_2O and P_2O_5 for maize. Similar computation of Cfym was reported by Santhi *et al*. (2002) for onion and Benbi *et al*. (2007) for rice and wheat.

Fertilizer prescription equations for hybrid maize

Soil test based fertilizer prescription equations for desired yield target of hybrid maize were formulated using the basic parameters as below:

where, FN, FP_2O_5 and FK_2O were fertilizer N, P_2O_5 and K_2O in kg ha^{-1}, respectively; T was the yield target in q ha^{-1}; SN, SP and SK respectively were alkaline $KMnO_4$-N, Olsen-P and NH_4OAc-K in kg ha^{-1} and ON, OP and OK were the quantities of N, P and K supplied through FYM in kg ha^{-1}. Santhi *et al.*(2012) documented in a handbook the soil test and

Table 4. Soil test based fertiliser prescription under IPNS for an yield target of 10 t ha^{-1} of hybrid maize (kg ha^{-1})

Parameter	IPNS				
	NPK alone (kg ha^{-1})	NPK+ FYM 6.25 t ha^{-1} (kg ha^{-1})	Per cent reduction over NPK alone	NPK+ FYM12.5 t ha^{-1} (kg ha^{-1})	Per cent reduction over NPK alone
$KMnO_4$-N (kg ha^{-1})					
160	297	277	6.7	257	13.5
180	284	264	7.0	244	14.1
200	272	252	7.4	232	14.7
220	260	240	7.7	220	15.4
240	247	227	8.1	207	16.2
260	235	215	8.5	195	17.0
280	222	202	9.0	182	18.0
Olsen-P (kg ha^{-1})					
10	137	127	7.3	117	14.6
12	133	123	7.5	113	15.0
14	129	119	7.8	109	15.5
16	125	115	8.0	105	16.0
18	121	111	8.3	101	16.5
20	117	107	8.6	97	17.1
22	114	104	8.8	94	17.5
NH_4OAC-K (kg ha^{-1})					
160	123	110	10.6	97	21.1
180	117	104	11.1	91	22.2
200	112	99	11.6	86	23.2
220	107	94	12.2	81	24.3
240	101	88	12.9	75	25.7
260	96	83	13.5	70	27.1
280	90	77	14.4	64	28.9

yield target based integrated fertilizer prescriptions, for a range of 44 soil - crop situations in Tamil Nadu which included cereals, millets, pulses, oilseeds, vegetables, spices and medicinal plants.

Fertilizer prescription under IPNS for desired yield target of maize

A ready reckoner was prepared based on these equations for a range of soil test values and for yield targets of 10 t ha^{-1} for maize (Table 4). The data revealed that the fertilizer N, P_2O_5 and K_2O requirements decreased with increase in soil test values.

For a yield target of 10 t ha^{-1} of maize with a soil test value of 200, 20 and 200 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 272, 117 and 112 kg ha^{-1} when FYM @12.5 t ha^{-1} with 28, 0.66, 0.38 and 0.60 per cent moisture, N, P and K, respectively was applied along with fertilizer NPK, the required fertilizer N,P_2O_5 and K_2O doses were 232, 97 and 86 kg ha^{-1} respectively. Under IPNS, the savings of fertilizer N, P_2O_5 and K_2O

NPKalone

FN = 3.96 T - 0.62 SN

FP_2O_5 = 1.56 T – 1.93 SP

FK_2O = 1.66 T - 0.27 SK

NPK + FYM

FN = 3.96 T - 0.62 SN - 0.69 ON

FP_2O_5 = 1.56 T – 1.93 SP – 0.60 OP

FK_2O = 1.66 T - 0.27 SK – 0.49 OK

were 40, 20 and 26 kg ha^{-1} respectively for NPK plus FYM @ 12.5 t ha^{-1}. The per cent reduction in NPK fertilisers under IPNS also increased with increasing soil fertility levels with reference to NPK.

Therefore, in the present investigation, soil test based fertilizer prescription for hybrid maize was developed on Typic Rhodustalf soils of Tamil Nadu taking into account the nutrient requirement and contribution of NPK from the nutrient sources (soil, fertilizer and FYM). This concept provides balanced nutrition to hybrid maize through STCR-IPNS.

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