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Refinement of Fertilizer Prescription Equations for Hybrid Maize under Integrated Plant Nutrient System on an Inceptisol

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A B S T R A C T

In order to refine the fertiliser prescription equation for hybrid maize on an Inceptisol (Periyenackampalayam soil series- *Vertic Ustropept*), a field experiment was conducted at farmer's holding of Allapalayam village, Annur block, Coimbatore District of Tamil Nadu in Western Zone of Tamil Nadu during Rabi 2015-16. Basic parameters were calculated from the data generated from the field experiment. Using the basic parameters, crop nutrient requirement per quintal of grain production, contribution of soil available nutrients, contribution of fertilizer nutrients and contribution of farm yard manure were worked out. It was found that hybrid maize requires 1.76, 0.58 and 1.62 kg of N, P_2O_5 and K_2O per quintal of grain produced. Using the basic parameters, fertiliser prescription equations were developed based on integrated plant nutrition system (IPNS). It was estimated that, application of FYM @ 12.5 t ha^{-1} with 28% moisture, 0.53%, 0.26% and 0.50% of N, P and K, respectively along with NPK fertilizers, the extent of saving inorganic fertiliser for hybrid maize was 40, 20 and 30 kg of fertiliser N, P_2O_5 and K_2O, respectively. Thus to maintain consistent soil fertility with high rate of productivity soil test based fertiliser recommendation along with integrated nutrient management will benefit the farmer in saving of fertilizer and sustaining soil health.

Introduction

Efficient nutrient management necessitates balanced fertiliser use and sound management decisions and practices to the productivity of maize and sustained soil fertility. Maize is the third most important food grain in India after wheat and rice. It is a versatile cereal crop which is cultivated widely throughout the world and has the highest production among all the cereals. Soil test based nutrient management practices provide better productivity, profitability, sustainability and environmental safety (Venugopalan *et al.*, 2011).

The fertilizer recommendation should effectively consider the crop needs and nutrients available in the soil before (Anon, 1997). Among the various methods, the soil test crop response approach (STCR) for targeted yield is found to be indicating the unique features like soil test based fertiliser dose and levels of yields that can be achieved. Insufficient nutrient additions compared to nutrient uptake leads to a decline in soil fertility.

The present investigation was carried out with an objective to evolve the sound basis of fertilizer prescriptions for maize crop in

mixed black calcareous soil (Inceptisol) under the conditions of fertilizer scarcity and to ensure maximum fertilizer use efficiency. To maintain the yield level and to sustain soil fertility, an attempt was made to refine fertiliser prescription equation developed for maize variety in Periyanaickenpalayam series to suit hybrid maize. The fertilizer prescription equations developed using this model can be applied to Periyanaickenpalayam soil series and to the similar soil series of other regions by substituting the soil nutrient status of the particular field.

Materials and Methods

The study was conducted in Allapalayam village, Annur block, Coimbatore District of Tamil Nadu, India for the year 2015 to 2016. The experiment was conducted in the farmer's field of Periyanaickenpalayam soil series (mixed black calcareous soil) with the test crop as TNAU maize hybrid CO 6.

The crop received one fourth N and full dose of P_2O_5 and K_2O as basal application and remaining half and one fourth N were applied at 25 days after sowing (DAS) and 45 DAS respectively. Nitrogen was applied through urea, phosphorus through diammonium phosphate (DAP) and potassium through muriate of potash.

The surface soil (0-15 cm) of the experimental field is mixed black calcareous, sandy clay loam in texture with pH 8.10 and electrical conductivity (EC) of 0.13 dS m^{-1}. The initial soil available nutrient *viz*., alkaline $KMnO_4$ –N (Subbiah and Asija, 1956), Olsen-P (Olsen *et al.,* 1954) and NH_4OAc-K (Stanford and English, 1949) were 162, 16.5 and 430 (kg ha^{-1}) respectively.

The initial soil test values were low organic carbon and available N and medium available P and high available K and sufficient in available Cu, Mn, Fe, Zn.

The treatments include T_1-STCR-NPK alone- 100 % of FD for 5 t ha^{-1}, T_2-STCR-NPK alone- 125 % of FD for 5 t ha^{-1}, T_3-STCR-NPK alone- 150 % of FD for 5 t ha^{-1}, T_4-STCR-NPK alone- 175 % of FD for 5 t ha^{-1}, T_5-STCR-NPK alone- 200 % of FD for 5 t ha^{-1}, T_6-STCR-IPNS - 100 % of FD for 5 t ha^{-1}+ FYM @ 12.5 t ha^{-1}, T_7-STCR-IPNS - 125 % of FD for 5 t ha^{-1}+ FYM @ 12.5 t ha^{-1}, T_8-STCR-IPNS - 150 % of FD for 5 t ha^{-1}+ FYM @ 12.5 t ha^{-1}, T_9 -STCR-IPNS - 175 % of FD for 5 t ha^{-1}+ FYM @ 12.5 t ha^{-1}, T_{10}-STCR-IPNS - 200 % of FD for 5 t ha^{-1}+ FYM @ 12.5 t ha^{-1}, T_{11}-FYM @ 6.25 t ha^{-1} alone, T_{12}-FYM @ 12.5 t ha^{-1} alone, T_{13}-Absolute control.

The experiment was laid out in Randomized block design with three replications. Crop was harvested, grain and straw yield were recorded. Plant samples were analysed for total N, P and K. Soil samples were analysed for chemical properties and available macro nutrients.

The fertilizer prescription equations with and without FYM were developed for maize grain by using basic data NR, C_s, C_f were calculated by adopting the methodology by Ramamoorthy *et al.,* (1967) and those from C_{fym} were estimated as described by Santhi *et al.*,(1999).

The methodology adopted in the present investigation *viz.*, the prescription procedure outlined by Truog (1960) and modified by Ramamoorthy *et al.,* (1967) as "Inductive cum Targeted yield model".

Nutrient Requirement (NR)

Nutrient requirement is calculated as kg of N/ P_2O_5/ K_2O required per quintal (100 kg) of Grain, 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)

C_s = [(Total uptake of N or P_2O_5 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.

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

C_f = {[(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.

Percent contribution of nutrients from organics to total uptake (Co)

Percent contribution from FYM (Cfym)

C_{fym} = {[(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 fertilizer prescription equations for deriving fertilizers doses, and the soil test based fertilizer recommendations were prescribed in the form of a ready table for desired yield target of maize grain under NPK alone as well as under IPNS.

Fertilizer prescription equations

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

Fertilizer nitrogen (FN)

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

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

Fertilizer phosphorus (FP_2O_5)

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

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

Fertilizer potassium (FK_2O)

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

FK_2O= {[(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 nutrient requirement (N or P_2O5 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 $ha^{-1.}$

These equations serve as a basis for predicting fertilizer doses for specific yield targets (T) of hybrid maize for varied soil available nutrient levels.

Results and Discussion

Grain yield

Grain yield of the hybrid maize ranged from 5313 Kg ha^{-1} to 12032 Kg ha^{-1} (Table 1). The N uptake of hybrid maize ranges from 54.39 Kg ha^{-1} to 241.82 Kg ha^{-1} whereas P and K uptake ranged from 6.30 Kg ha^{-1} to 33.57 Kg ha^{-1} and 71.10 Kg $ha^{-1}$to 149.36 Kg ha^{-1}

respectively (Table 1). The results indicated that, maize is an exhaustive crop requires relatively higher nutrient level and also the enhanced grain yield was achieved when there is a consistent supply of nutrients. Application of NPK fertlisers along with FYM might have provided a desirable soil condition for the root development, enhancing nutrient uptake, crop growth and yield of rice (Santhi *et al.,* 1998). The present study emphasis that along with inorganic fertlisers, organic manures also necessary to maintain optimum rhizosphere environment for sustaining maize grain yield at higher level. This study also confirms the role of FYM and chemical fertiliser combinations in increasing grain yield of maize and the results showed that manure and chemical fertiliser can increase grain yield of maize but a combination of them have more effect on increase in grain yield (Bekeo, 2013).

Nutrient uptake

The N, P and K uptake ranged from 54.39 to 241.82 kg ha^{-1}, 6.30 to 33.57 kg ha^{-1} and 71.10 to 151.52 kg ha^{-1}, respectively. Among the treatments, STCR-IPNS-200% of FD for 5 t ha^{-1} + FYM @ 12.5 t ha^{-1}(T_{10}) recorded the highest total N uptake (241.82 kg ha^{-1}), P uptake (33.57 kg ha^{-1}) and K uptake (151.52 kg ha^{-1}) (Table 1). Among the treatments, STCR-IPNS treatment with STCR-IPNS- 200 % FD for 5 t ha^{-1} +FYM @ 12.5 t ha^{-1}(T_{10}) recorded significant and the highest total uptake of N. Whereas, the total uptake of P and K was found to be the highest in STCR-IPNS- 200 % FD for 5 t ha^{-1} +FYM @ 12.5 t ha^{-1} (T_{10}) followed by STCR-IPNS-175 % FD for 5 t ha^{-1} +FYM @ 12.5 t ha^{-1} (T_9) which were on par with each other. STCR-IPNS treatments were found to dominate over STCR-NPK alone treatments.

The improved nutrient uptake in FYM amended plots could be attributed to enhanced organic matter decomposition-mineralization process, better root development and higher nutrient availability (Khan *et al.,* 2009). Similar pattern of response were reported by Tanwar (2014) with combination of manures and fertlisers. Application of organic manures not only increases the uptake of primary nutrients and also enhances the uptake of secondary nutrients (Tanwar, 2014). Absolute control recorded the lowest NPK uptake emphasizing continuous cropping without addition of mineral fertilisers or manures retard the yield of maize due to the poor dry matter production and degrade soil quality in long run.

Response of hybrid maize to fertilizer applied

In optimization of fertiliser dose, response of maize to fertilisers levels play a crucial role. The response of hybrid maize to different graded levels of fertilizer N, P_2O_5 and K_2O were assessed in terms of Response ratio (RR).The response varied from 1061 kg ha^{-1} in FYM @ 6.25 t ha^{-1} to 6829 kg ha^{-1} in STCR-IPNS-200% of FD for 5 t ha^{-1}+ FYM @ 12.5 t ha^{-1} (Table 1). There was a linear increase in response to applied nutrients under STCR-NPK alone and it was at diminishing rate with increasing fertiliser levels which might be due to the increase in fertiliser doses at higher target levels. Under IPNS, the response increased upto STCR-IPNS-200% of FD for 5 t ha^{-1}+ FYM @ 12.5 t ha^{-1}.The magnitude of response was greater under STCR-IPNS treatments when compared to STCR-NPK alone. Similar trend of results was recorded by Coumarvel *et al.,* (2016). The positive response to higher level of fertilisers on grain yield to be ascribed to the overall improvement in crop growth enabled the plant to absorb more nutrients which empowered the plant to synthesize more quantity of photosynthate and accumulating in sink which are converted in to economic yield of grain maize (Joshi *et al.,* 2013; Kadlag and Godke, 2013).

Basic parameters

Nutrient Requirement

Adoption of appropriate site and situation specific nutrient prescriptions will become one of the technological interventions for boosting the yield of maize in the sequence. Nutrient requirement to produce one quintal of hybrid maize 1.76 Kg of N, 0.58 Kg of P_2O_5 and 1.62 Kg of K_2O (Table 2) and (Fig. 1). Relatively, higher quantity of N was required followed by K_2O and P_2O_5 to produce unit quantity of hybrid maize. The requirement of N was 1.08 times higher than K and 3.03 times higher than P_2O_5. Similar trend of nutrient requirement for N, P_2O_5 and K_2O was also reported by Coumarvel (2012) for maize in Palaviduthi soil series (*Typic Rhodustalf)* in Tamil Nadu and Singh *et al.*, (2015) for maize at Varanasi in Inceptisol.

Fig.1 Nutrient requirement (kg q^{-1}) to hybrid maize

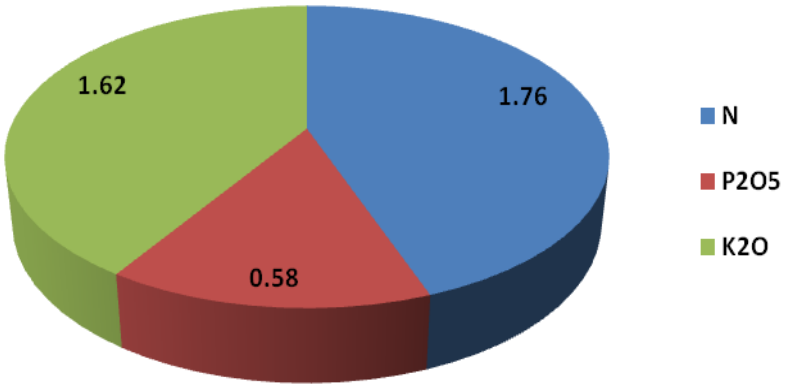
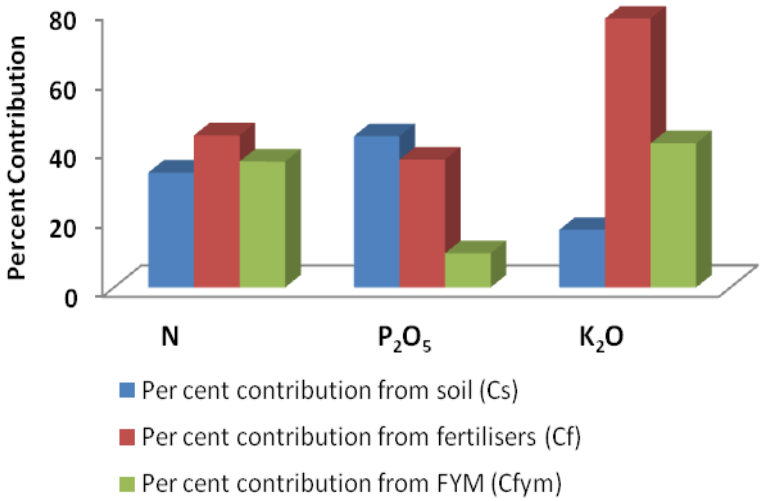


Fig.2 Per cent contribution from soil, fertilizer and FYM



Fertilizer prescription equations for Hybrid maize

STCR- NPK alone	STCR-(NPK + FYM)
FN = 4.01 T - 0.76 SN	FN = 4.01 T - 0.76 SN - 0.83 ON
FP_2O_5 = 1.57 T - 2.71 SP	FP_2O_5 = 1.57 T – 2.71 SP – 0.61 OP
FK_2O = 2.09 T – 0.26 SK	FK_2O = 2.09 T – 0.26 SK – 0.65 OK

Table.1 Experimental data for refinement of fertiliser prescription equations for maize (Mean of three replications)

Sl. No.	Treatment	Grain Yield	UN	UP	UK	SN	SP	SK	FN	FP_2O_5	FK_2O	FYM (t ha^{-1})
		----------(kg ha^{-1})----------										
1	STCR-NPK alone- 100 % of FD for 5 t ha^{-1}	8148	142.63	20.90	115.76	164	16.0	435	203	87	67	-
2	STCR-NPK alone-125 % of FD for 5 t ha^{-1}	8704	168.04	24.09	128.48	164	15.5	435	254	109	83	-
3	STCR-NPK alone-150 % of FD for 5 t ha^{-1}	9683	185.85	27.49	138.27	166	15.6	435	304	131	100	-
4	STCR-NPK alone -175 % of FD for 5 t ha^{-1}	10278	197.57	28.88	147.65	166	15.6	437	355	153	116	-
5	STCR-NPK alone- 200 % of FD for 5 t ha^{-1}	10486	204.34	30.20	151.52	165	16.1	435	406	174	133	-
6	STCR-IPNS - 100 % of FD for 5 t ha^{-1}+ FYM @ 12.5 t ha^{-1}	9245	170.29	25.54	113.79	166	16.0	438	203	87	67	12.5
7	STCR-IPNS -125 % of FD for 5 t ha^{-1}+ FYM @ 12.5 t ha^{-1}	10203	190.31	28.20	125.68	166	15.8	439	254	109	83	12.5
8	STCR-IPNS -150 % of FD for 5 t ha^{-1}+ FYM @ 12.5 t ha^{-1}	10992	210.20	30.82	135.85	166	16.4	439	304	131	100	12.5
9	STCR-IPNS -175 % of FD for 5 t ha^{-1}+ FYM @ 12.5 t ha^{-1}	11393	226.50	32.35	143.63	166	16.6	437	355	153	116	12.5
10	STCR-IPNS -200 % of FD for 5 t ha^{-1}+ FYM @ 12.5 t ha^{-1}	12032	241.82	33.57	149.36	166	16.4	439	406	174	133	12.5
11	FYM @ 6.25 t ha^{-1} alone	6234	64.03	7.84	81.05	166	16.4	435	24	17	23	6.25
12	FYM @ 12.5 t ha^{-1} alone	6625	71.20	8.63	90.39	165	16.4	436	48	33	46	12.5
13	Absolute Control.	5313	54.39	6.30	71.10	164	16.4	428				
	Mean	9180	163.31	23.44	122.50	165	16.0	436				
	SEd	174.40	4.54	0.90	3.40							
	CD (p=0.05)	359.95	9.37	1.86	7.01							

Table.2 Basic parameters for maize and Fertiliser prescription equations

Parameters	Basic data		
	N	P_2O_5	K_2O
Nutrient requirement (kg q^{-1})	1.76	0.58	1.62
Per cent contribution from soil (Cs)	33.16	43.66	16.61
Per cent contribution from fertilisers (Cf)	43.91	36.90	77.63
Per cent contribution from FYM (Cfym)	36.35	9.85	41.60

Table.3 Soil test based fertiliser N /P_2O_5/K_2O for desired yield targets of maize under NPK alone and IPNS (kg ha^{-1})

Fertilisers (kg ha^{-1})	Treatments		
	NPK alone	NPK+ FYM@ 12.5 t ha^{-1}	Per cent reduction due to IPNS over NPK alone
10 t ha^{-1} $KMnO_4$-N (kg ha^{-1})			
150	288	248	13.76
175	269	229	14.73
200	250	211	15.84
225	231	192	17.13
250	212	173	18.65
275	194	154	20.47
10 t ha^{-1} Olsen P (kg ha^{-1})			
12	125	104	16.19
14	119	99	16.93
16	114	94	17.73
18	108	88	18.62
20	103	83	19.60
22	98	77	20.69
10 t ha^{-1} NH_4OAC-K (kg ha^{-1})			
350	118	89	24.98
375	112	82	26.43
400	105	76	28.06
425	99	69	29.89
450	92	63	31.99
475	86	56	34.40

Percent contribution of nutrients from soil (Cs)

The ability of the crop to remove nutrients from the soil has been calculated in terms of the per cent contribution of nutrients from soil (Cs) to the total uptake in absolute control plots. In the present investigation, it was found that the soil has contributed 33.16 per cent of available N, 43.66 per cent of P_2O_5 and 16.61 per cent of K_2O (Table 2) and (Fig. 2) respectively towards the total N, P and K uptake by hybrid maize.

Among the three nutrients, relative supply of nutrients was in the order of P>N>K. Similar

findings were reported by Praveena Katharine *et al.,* (2013) for cotton in Periyanaickenpalayam soil series (*Typic Ustropept)* of Tamil Nadu.

Percent contribution of nutrients from fertiliser (Cf)

The per cent contribution of nutrients from fertiliser nutrients (Cf) towards the total uptake by hybrid maize was 43.91, 36. 90 and 77.63 per cent (Table 2) and (Fig. 2) respectively for N, P_2O_5 and K_2O and followed the order of K_2O > N > P_2O_5.

The estimated per cent contribution of nutrients from fertilisers (Cf) to total uptake clearly revealed that the amount of contribution by fertiliser K_2O was 1.76 times higher than N and 2.10 times as that of P_2O_5.

Contribution of nutrient from FYM

The per cent contribution of N, P_2O_5 and K_2O from FYM (Cfym) was computed in the present investigation to evaluate the extent of reduction in NPK fertiliser requirements of hybrid maize through IPNS.

The estimated per cent contribution of N, P_2O_5 and K_2O from FYM (Cfym) were 36.35, 9.85 and 41.60 (Table 2) and (Fig. 2) respectively for hybrid maize which indicated that relatively higher contribution was recorded for N and K_2O followed by P_2O_5.

The present findings corroborated with the findings of Praveena Katharine *et al.,* (2013) and Singh *et al.,* (2015).

Fertilizer prescription equations for Hybrid maize

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 grain 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}.

Soil test based fertiliser doses for desired yield targets of hybrid maize (TNAU Maize Hybrid CO 6) under IPNS

Ready reckoner of fertiliser doses (nomograms) were formulated for desired yield targets of maize, (TNAU Maize Hybrid CO 6) for a range of soil test values under IPNS (NPK plus FYM @ 12.5 t ha^{-1}). Using the fertiliser prescription equations under IPNS, the extent of saving of chemical fertilisers was computed. The results showed that with the application of FYM @ 12.5 t ha^{-1} (with 28 % moisture, 0.53 %, 0.26 % and 0.50 % NPK, respectively), there was a saving of 40, 20 and 30 kg of fertiliser N, P_2O_5 and K_2O, respectively. In general, depending on the moisture and N, P and K contents of FYM at the time of application, the corresponding quantities of nutrients in terms of fertiliser N, P_2O_5 and K_2O can be deducted from the recommended doses of nutrients. To obtain an yield target of 10 t ha^{-1} with a soil test value of 200, 16 and 400 kg of N, P and K ha^{-1}, 250, 114 and 105 kg of N, P_2O_5 and K_2O ha^{-1} have to be applied if fertilizers are applied as NPK alone where in IPNS (NPK + 12.5 t FYM ha^{-1}), 211, 94 and 76 kg of N, P_2O_5 and K_2O ha^{-1} is sufficient to produce 10 t ha^{-1}. STCR-IPNS saves 15.84, 17.73 and 28.06 percent of N, P_2O_5 and K_2O if the contribution of FYM is accounted (Table 3).

In conclusion, STCR-IPNS based fertilizer prescription envisages a balanced form of nutrient supply to the hybrid maize and maintains the soil fertility with magnitude of higher economic production. In the present investigation, soil test based fertilizer prescription equations for desired yield target

with the graded level fertiliser for hybrid maize was developed using the basic parameters obtained. These fertiliser prescription equations could serve as a basis to prescribe the actual quantities of fertiliser doses under IPNS when FYM was applied along with NPK fertilisers. It was evident that, application of FYM @ 12.5 t ha^{-1} with 28% moisture, 0.53%, 0.26% and 0.50% of N, P and K, respectively along with NPK fertilizers to hybrid maize can save 40, 20 and 30 kg of fertiliser N, P_2O_5 and K_2O, respectively in black calcareous soils (Periyenackampalayam soil series- *Vertic Ustropept*). Thus to maintain consistent soil fertility with high rate of productivity, STCR-IPNS based fertilizer prescription becomes essential.

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