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PREDICTION OF POST-HARVEST SOIL TEST VALUES AND FERTILISER CALIBRATIONS FOR MAIZE UNDER INTEGRATED PLANT NUTRITION SYSTEM ON ALFISOL

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ABSTRACT

A field experiment was conducted during 2010-11 to develop PHSTVs prediction equations adopting Inductive cum Targeted yield model (Ramamoorthy et al., 1967), on a Typic Rhodustalf of Tamil Nadu, with hybrid maize (NK 6240) under IPNS. The experiment was laid out in a fractional factorial design comprising twenty four treatments and the test crop experiment with hybrid maize was conducted with four levels 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 kg ha^{-1}) and three levels of FYM (0, 6.25 and 12.5 t ha^{-1}). The IPNS treatments were superimposed across the strips. There were 21 fertiliser treatments along with three controls which were randomized in each strip in such a way that all the treatments occurred in both the directions. Using the plot wise pre-sowing soil test values, fertiliser doses and grain yield and/or the uptake of NPK by the crop as dependent variables and post-harvest soil test values as independent variable, PHSTVs prediction equations were developed. The predicted soil test values revealed that the soil fertility was found to decline markedly under unfertilized control and increased based on the fertiliser doses imposed. Significant R^2 values (>0.65) were recorded for these regression equations which could be used with confidence for the prediction of post-harvest $KMnO_4$-N, Olsen-P and NH_4OAc-K. Using the predicted PHSTVs of hybrid maize, soil test based fertiliser recommendation for desired yield targets of any succeeding crop could be prescribed.

Keywords: Alfisol, prediction equation, targeted yield model, hybrid maize, STCR-IPNS

INTRODUCTION

Maize (Zea mays L.), called as “Queen of Cereals” is one of the third most important cereals, next to wheat and rice in the world as well as in India and cultivated in Tamil Nadu. 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.

Insufficient nutrient additions compared to nutrient uptake leads to a decline in soil fertility. To mitigate this problem, instead of blanket recommendations, soil test based nutrient management practices should be adopted for better productivity, profitability, sustainability and environmental safety (Venugopalan et al., 2011). Soil testing is a scientific tool to evaluate soil fertility by predicting the probability of getting a profitable crop response to recommended fertiliser application under specific soil-crop condition. Though there are numerous soil testing laboratories in operation, in a vast country like India with millions of hectares of cultivated land, soil testing for each field season after season and prior to the cultivation of each crop seems to be practically impossible for the want of time, money and labour. Hence the prediction of post-harvest soil fertility status using the pre-sowing soil test values, fertiliser doses and yield or uptake by the crop has much of practical significance. Studies on this aspect were carried out by many workers for various cropping sequences and soil types which have been documented by Muralidharudu et al., (2011).

In this present study, an attempt was made to predict the post-harvest soil test values following the methodology outlined by Ramamoorthy et al., (1971) and to recommend fertilisers for targeted yields of hybrid maize under Integrated Plant Nutrition System on Alfisol.

MATERIALS AND METHODS

Site description and soil characteristics

A field experiments was conducted with maize (hybrid NK 6240) during 2010-2011 on Palaviduthi (Pvd) soil series (Typic Rhodustalf) at farmer's holding of Perumalkovilpatti village in Dindigul District, Tamil Nadu. The soil of the experimental field is moderately well to well drained and 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 9.1 c mol (p^{+}) kg^{-1}, respectively. The initial soil available alkaline potassium permanganate ($KMnO_4$) nitrogen (N), organic carbon, Olsen phosphorus (P) and ammonium acetate (NH_4OAc) potassium (K) were 198 kg ha^{-1}, 2.4 g kg^{-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.

Treatments and soil and plant analysis

The approved treatment structure and lay out design as followed in the All India Coordinated Research Project for Investigations on Soil Test Crop Response Correlation based on "Inductive cum Targeted yield model" (Ramamoorthy et al., 1967) was adopted in the present investigation. There were two phases of field experimentation viz., gradient and test crop experiment. In the gradient experiment, operational range of variation in soil fertility was created deliberately. For this purpose, the experimental field was divided into three equal strips, the first strip received no fertiliser ($N_0P_0K_0$), the second and third strips received one ($N_1P_1K_1$) and two ($N_2P_2K_2$) times the standard dose of N, P_2O_5 and K_2O respectively and a gradient crop of fodder maize (var.CO 1) was grown. The pre-sowing and post-harvest soil samples were collected from each fertility strip and analysed for alkaline $KMnO_4$-N, Olsen-P and NH_4OAc-K. At harvest, plant samples were collected, processed and analysed for N, P and K contents and NPK uptake was computed.

After confirming the establishment of fertility gradients in the experimental field, in the second phase of the field experiment, each strip was divided into 24 plots, and initial soil samples were collected from each plot and 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 test crop experiment with hybrid maize was conducted with four levels 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 kg ha^{-1}) and three levels of FYM (0, 6.25 and 12.5 t ha^{-1}. The IPNS treatments viz., NPK alone, NPK+ FYM @ 6.25 t ha^{-1} and NPK+FYM @ 12.5 t ha^{-1} were superimposed across the strips. There were 21 fertiliser treatments along with three controls which were randomized in each strip in such a way that all the treatments occurred in both the directions. The treatment structure and layout is furnished in Figure 1.

The test crop maize was sown with a spacing of 60 cm x 25 cm. Fertiliser doses were imposed as per the treatments. 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 plotwise 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 mater yield.

Fertiliser prescription equations

Making use of data on the yield of maize, total uptake of N, P and K, initial soil test values for available N, P and K and doses of fertilizer N, P_2O_5 and K_2O applied, the basic parameters viz., nutrient requirement (NR), contribution of nutrients from soil (Cs), fertilizer (Cf) and farmyard manure (Cfym) were calculated as outlined by Ramamoorthy et al. (1967). Making use of these parameters, the fertiliser prescription equations (FPEs) were developed for hybrid maize under NPK alone and IPNS.

Post-harvest soil test values prediction equations (PHSTVs)

Plot wise assessment of yield, NPK uptake, pre-sowing and post-harvest available N, P and K were carried out in the experiment. The pre-sowing soil test values, fertiliser doses and grain yield and/or the uptake of NPK by the crop were used as dependent variables and the post-harvest soil test values (independent variable) were predicted by multiple regression equations, (Ramamoorthy et al., 1971) which were obtained by the statistical evaluation of the dependence of the post-harvest soil test values and the associated parameters (dependant variables).

The functional relationship is as follows:

YPHS = f (F, ISTV, yield / nutrient uptake)

where, YPHS is the post-harvest soil test value; F is the applied fertiliser nutrient and ISTV is the initial soil test value of available N,P and K. The equation will take the mathematical form,

$YPHS = a + b_1F + b_2ISTV + b_3$ yield/uptake

where, a is the absolute constant and b_1, b_2 and b_3 are respective regression co-efficients. Using these regression equations, the post-harvest soil test values of N, P and K were predicted after maize.

RESULTS AND DISCUSSION

Following the methodology outlined by Ramamoorthy et al. (1971), PHSTVs prediction equations were developed for the prediction of post-harvest soil test values after the harvest of maize and are furnished in Table 1 along with the concerned R^2 values. The results indicated that in the case of prediction of $KMnO_4$-N, 90.42, 94.41 and 98.55 per cent of the variations were accounted when maize yield was considered, while the predictability values were 90.07, 93.99 and 98.49 per cent when nitrogen uptake was considered in NPK alone, NPK + FYM @ 6.25 t ha^{-1} and NPK + FYM @ 12.5 t ha^{-1} treatments respectively. For the purpose of comparison, the observed and predicted data based on yield and uptake for a set of selected treatments are furnished in Table 2. The observed mean $KMnO_4$-N value was 205 kg ha^{-1} while the mean predicted value using grain yield and uptake were 207.3 and 207.7 kg ha^{-1} respectively. The mean variation between observed and predicted value was 2.3 and 2.7 kg ha^{-1} while yield and uptake were respectively used for prediction.

With respect to the prediction of Olsen-P, the extent of predictability were 84.65, 89.19 and 91.54 per cent while yield was used for prediction and 83.31, 88.77 and 92.96 per cent while uptake of phosphorus was used in the case of NPK alone, NPK + FYM @ 6.25 t ha^{-1} and NPK + FYM @ 12.5 t ha^{-1} treatments respectively (Table 2). The observed mean Olsen-P value was 26.1 kg ha^{-1} while the mean predicted value using maize yield and uptake were 25.2 and 25.0 kg ha^{-1} respectively. The mean variation between observed and predicted value were 0.9 and 1.1 kg ha^{-1} while yield and uptake were respectively used.

Similarly in the case of NH_4OAc- K, the predictability were 82.32, 73.78 and 94.08 per cent while yield was used and 80.39, 69.52 and 92.57 per cent when potassium uptake was used for the prediction of post harvest soil nutrient status while considering NPK alone, NPK + FYM @ 6.25 t ha^{-1} and NPK + FYM @ 12.5 t ha^{-1} treatments respectively (Table 2). The observed mean NH_4OAc- K value was 212.5 kg ha^{-1} while the mean predicted value using grain yield of maize and uptake were 211.9 and 212.6 kg ha^{-1} respectively. The mean variation between observed and predicted value were 0.6 and 0.1 kg ha^{-1} while yield and uptake were respectively used.

These results clearly indicated that both observed and predicted soil test values of available N, P and K were in good agreement with each other, proving the validity of the post-harvest soil test values. Prediction equations as evidenced by highly significant correlation (r = 0.98** and 0.94** and 0.95 ** respectively for yield as well as uptake).

The difference between the predicted and observed (experimental) soil test values for the treated plots (five plots in each strip) were found to be very negligible and agree very closely. Analysis for available N, P and K also indicated highly significant relationship with high R^2 values and fall in the category of good fit in the present study taking a value of R^2 above 0.65 as the criterion for good fit and value of R^2 between 0.45 and 0.65 as moderate fit (Anon, 1973). The R^2 values suggested that the prediction equations could be used with confidence for the prediction of available N, P and K after the harvest of maize crop to make the soil test based fertiliser recommendations for any succeeding crop.

Thus, these prediction equations would be useful in prescribing fertiliser recommendations for a cropping sequence. Similar type of prediction equations were developed by Chandrasekar Rao and Singh (1992) for Maize-Wheat and Maize-Wheat-Moong sequence and Andi (1998) for Sunflower-Bhendi sequence on Inceptisol.

Fertiliser recommendations for desired yield targets for hybrid maize based on initial soil test values

Making use of the initial soil test values of available NPK (200: 20: 200 kg ha^{-1}) and fertiliser prescription equations developed for hybrid maize, fertiliser recommendations were calculated for a range of yield targets and the post-harvest soil test values were predicted using the PHSTV prediction equations.

The fertiliser doses to achieve the targeted yield of 60, 80 and 100 q ha^{-1} were 114, 193 and 272 kg N ha^{-1}; 55, 86 and 117 kg P_2O_5 ha^{-1} and 46, 79 and 112 kg K_2O ha^{-1} respectively under NPK alone (Table 4)**.** When FYM was applied at 6.25 t ha^{-1} and at 12.5 t ha^{-1} along with fertilisers, the fertiliser requirements were 94, 173 and 252 kg N ha^{-1}; 45, 76 and 107 kg P_2O_5 ha^{-1} and 33, 66 and 99 kg K_2O ha^{-1} and 74, 153 and 232 kg N ha^{-1}; 35, 66 and 97 kg P_2O_5 ha^{-1} and 20, 53 and 86 kg K_2O ha^{-1}.

For 60, 80 and 100 q ha^{-1} of yield targets of hybrid maize, the predicted post harvest soil test values are 203, 215 and 226 kg ha^{-1} of $KMnO_4$-N; 19.6, 23.9 and 28.2 kg Olsen-P and 212, 220 and 229 kg ha^{-1} NH_4OAc- K respectively under NPK alone. Similarly the post harvest soil test values were calculated under IPNS situations and results are given in Table 3.

The results indicated that irrespective of the yield targets, there was build up of soil available NPK and the magnitude was higher with increasing yield targets. Among the three nutrient management practices, the magnitude of build up was relatively higher with NPK + FYM @ 12.5 t ha^{-1} followed by NPK + FYM @ 6.25 t ha^{-1} and NPK alone. This highlighted the significance of IPNS in a cropping sequence. Similar type of computing fertiliser recommendations were developed by Santhi and Selvakumari (1998) for Rice-Rice-Blackgram on Inceptisol and Sanjay Srivastava et al. (1999) for Pigeon Pea-Wheat and Coumaravel (2012) for Maize-Tomato sequence.

CONCLUSION

To conclude, PHSTVs prediction equations were developed adopting Inductive cum Targeted yield model on a Typic Rhodustalf of Tamil Nadu, with hybrid maize under IPNS. Significant and high R^2 values were recorded for these regression equations which could be used with confidence for the prediction of post-harvest $KMnO_4$-N, Olsen-P and NH_4OAc-K. The comparison made between both observed and predicted soil test values of available N, P and K were in good agreement with each other, proving the validity of the post-harvest soil test values. The predicted PHSTVs after maize indicated build up of soil fertility and magnitude was higher with increasing yield targets and under IPNS. Therefore, using the predicted PHSTVs of the hybrid maize, soil test based fertiliser recommendation for desired yield targets of any succeeding crop could be prescribed on Alfisol.

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Fig.1. Treatment Structure - Layout of test crop maize

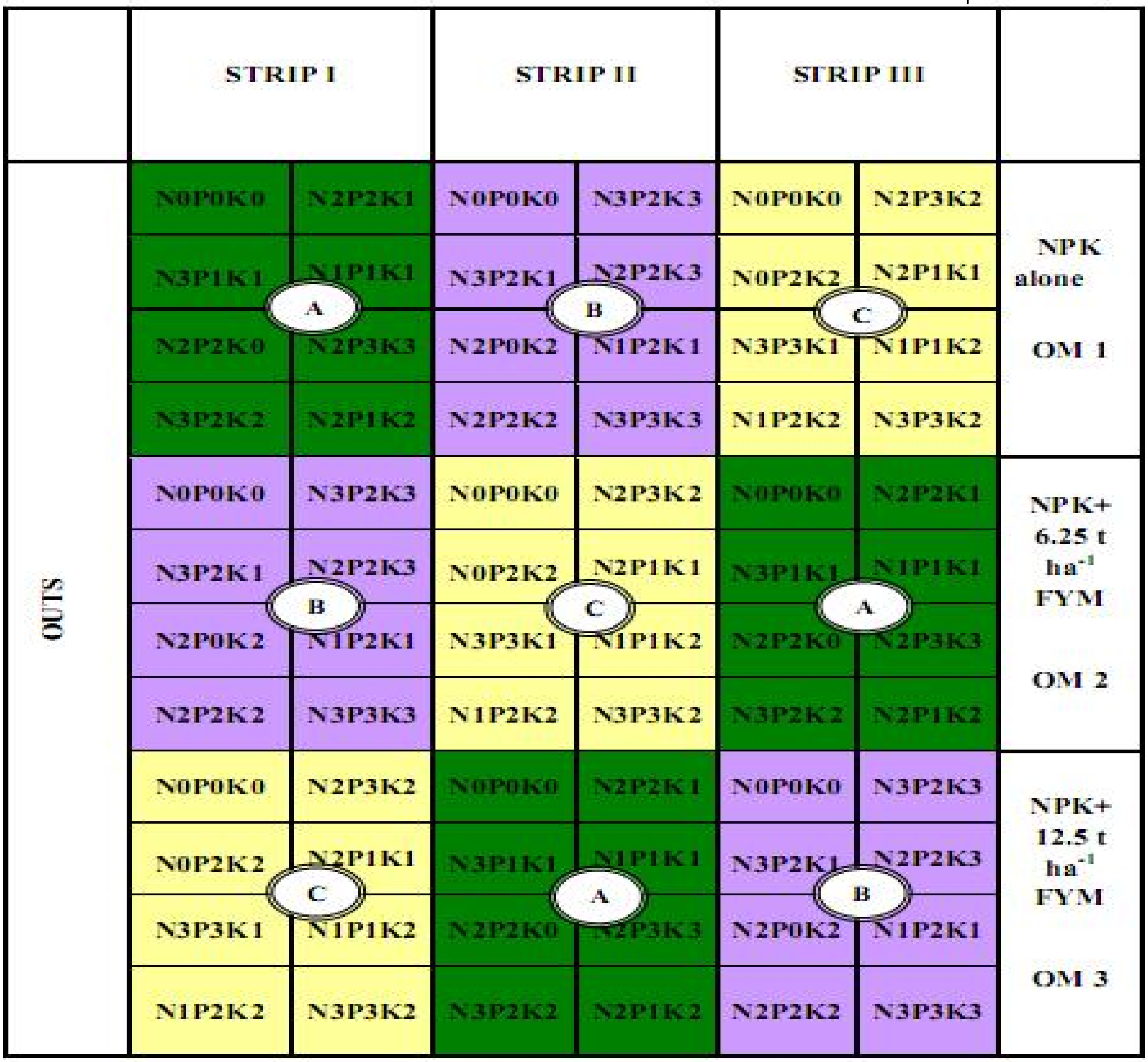

Table 1. Prediction equations for post harvest soil test values of available N, P and K for hybrid maize

Treatments	R^2
NPK alone	
YPHN= 5.2038 + 0.8443** SN + 0.0455 FN + 0.004 grain yield	0.9042**
YPHN= 9.6285 + 0.8673** SN + 0.0659 FN + 0.1149 N uptake	0.9007**
YPHP= -2.5334 + 0.6442** SP + 0.0926** FP + 0.0007 grain yield	0.8465**
YPHP= 0.5168 + 0.6014** SP + 0.0789* FP + 0.1733 P uptake	0.8331**
YPHK= 100.85 + 0.476** SK + 0.165* FK + 0.0014 grain yield	0.8232**
YPHK= 106.29 + 0.4707** SK + 0.1638** FK + 0.0875 K uptake	0.8039**
NPK+ FYM @6.25 t ha^{-1}	
YPHN= 8.1902 + 0.7975** SN - 0.0477 FN + 0.0073** grain yield	0.9441**
YPHN= 29.0428 + 0.7723** SN - 0.0034 FN + 0.2043** N uptake	0.9399**
YPHP= -8.8748 + 0.7805** SP + 0.0769* FP + 0.0013 grain yield	0.8919**
YPHP= -5.6932 + 0.8226** SP + 0.0716* FP + 0.2191 P uptake	0.8877**
YPHK= 97.2813 + 0.4854** SK + 0.1089 FK + 0.0024** grain yield	0.7378**
YPHK= 116.264 + 0.4356** SK + 0.0895 FK + 0.1533* K uptake	0.6952**
NPK+ FYM @12.5 t ha^{-1}	
YPHN= -7.6933 + 0.8138** SN + 0.0376 FN + 0.0067* grain yield	0.9855**
YPHN= 0.1336 + 0.857** SN + 0.064 FN + 0.1928* N uptake	0.9849**
YPHP= -9.3804 + 0.5594** SP + 0.0861** FP + 0.0021* grain yield	0.9154**
YPHP= -3.7641 + 0.5552** SP + 0.0821** FP + 0.4048** P uptake	0.9296**
YPHK= 42.801 + 0.6347** SK + 0.2871** FK + 0.0033** grain yield	0.9408**
YPHK= 55.1588 + 0.6225** SK + 0.2769** FK + 0.2118** K uptake	0.9257**

*Significant at P = 0.05 ; ** Significant at P = 0.01
PH = post harvest ; FN, FP and FK = Fertilizer doses of N, P and K
UN, UP and UK = Total uptake of N, P and K

Table 2. Observed and Predicted post-harvest soil $KMnO_4$-N, Olsen –P and NH_4OAc- K (kg ha^{-1}) for hybrid maize

Treatments	$KMnO_4$-N			Olsen –P			NH_4OAc- K		
	Observed	Predicted based on		Observed	Predicted based on		Observed	Predicted based on	
		Yield	Up take		Yield	Up take		Yield	Up take
NPK alone									
N0P0K0 (SI)	174	173	173	16	12	12	178	174	175
N0P2K2 (SIII)	213	217	217	33	25	25	229	210	213
N1P1K1 (SIII)	180	187	188	18	19	19	179	191	191
N2P2K2 (SII)	220	220	220	26	25	25	228	243	243
N3P3K3 (SII)	235	230	230	35	35	34	234	233	233
NPK + FYM @ 6.25 tha^{-1}									
N0P0K0 (SI)	173	175	177	16	13	13	176	178	179
N0P2K2 (SII)	189	194	195	27	29	27	218	222	222
N1P1K1 (SII)	223	231	231	30	33	34	227	223	222
N2P2K2 (SI)	203	211	213	19	21	21	210	205	205
N3P3K3 (SI)	215	216	215	26	26	26	223	221	221
NPK + FYM @ 12.5 tha^{-1}									
N0P0K0 (SI)	170	171	173	17	12	12	175	177	179
N0P2K2 (SI)	176	172	172	20	21	21	198	203	204
N1P1K1 (SI)	203	215	215	24	27	26	209	196	198
N2P2K2 (SIII)	243	246	245	38	37	37	240	245	245
N3P3K3 (SIII)	258	252	252	46	43	43	263	258	259
Mean	205	207.3	207.7	26.1	25.2	25.0	212.5	211.9	212.6
'r' value		0.98**	0.98**		0.94**	0.94**		0.95**	0.95**

SI- Strip I; SII – Strip II and SIII – Strip III

Table 3. Fertiliser prescriptions and predicted post-harvest soil test values for hybrid maize based on initial soil test values

Yield target (q ha^{-1})	Fertiliser doses (kg ha^{-1})			PHSTV (kg ha^{-1})		
	N	P_2O_5	K_2O	N	P	K
Under NPK alone						
60	114	55	46	203	19.6	212
80	193	86	79	215	23.9	220
100	272	117	112	226	28.2	229
NPK +FYM @6.25 t ha^{-1}						
60	94	45	33	207	18	212
80	173	76	66	218	23	221
100	252	107	99	229	28	229
NPK +FYM @12.5 t ha^{-1}						
60	74	35	20	198	17.4	195
80	153	66	53	214	24.3	211
100	232	97	86	231	31.2	227

ISTV: $KMnO_4$ – N = 200 kg ha^{-1} ; Olsen – P = 20 kg ha^{-1} ; NH_4 OAc = 200 kg ha^{-1}

Fertiliser Prescription equations

STCR-NPK alone	**STCR-IPNS (NPK + FYM)**
FN = 3.96 T - 0.62 SN	FN = 3.96 T - 0.62 SN – 0.69 ON
FP_2O_5 = 1.56T - 1.93 SP	FP_2O_5 = 1.56T - 1.93 SP - 0.60 OP
FK_2O = 1.66 T - 0.27 SK	FK_2O = 1.66 T - 0.27 SK - 0.49 OK

FN, FP_2O_5 and FK_2O - fertiliser N, P_2O_5 and K_2O (kg ha^{-1}); T - Yield target (q ha^{-1}); SN, SP and SK - alkaline $KMnO_4$-N, Olsen-P and NH_4OAc-K (kg ha^{-1}); ON, OP and OK - N, P and K through FYM (kg ha^{-1})

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