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RESEARCH ARTICLE

Prediction of Post-harvest Soil Test Values and Fertilizer Calibrations for a Maize Based Cropping Sequence under Integrated Plant Nutrition System

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ABSTRACT

Field experiments were conducted based on Inductive cum targeted yield concept on Typic Haplustert soils (Pilamedu series - black calcareous) to predict the post-harvest soil test values for prescribing soil test crop response based fertilizer doses under Integrated Plant Nutrition System (STCR-IPNS) for maize based cropping sequence. The experiment comprised of 24 treatments with four levels each of N (0,100,200 and 300 kg ha^{-1}), P_2O_5 (0,40,80 and120 kg ha^{-1}) and K_2O (0,40,80 and120 kg ha^{-1}) and three levels of FYM (0, 6.25 and 12.5 t ha^{-1}) for the test crop maize (TNAU Maize hybrid CO 6) laid out in fractional factorial design. Making use of the experimental data on initial and post-harvest soil test values, fertilizer doses and the grain yield obtained or uptake of N,P and K by maize, Post-Harvest Soil Test Values (PHSTVs) prediction equations with high R^2 values (>0.90) were developed, 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 after kharif maize, soil test based fertilizer prescription for desired yield target of succeeding crop *viz.*, cotton could be prescribed.

Keywords: *Post harvest soil test values, Maize based cropping sequence, STCR-IPNS, Vertisol*

Multi-nutrient deficiencies are emerging widely in India and adopting general or blanket fertilizer recommendations which are not based on soil fertility led to either over or under usage of fertilizer inputs resulting in imbalanced nutrition and declined fertilizer use efficiency. This warranted for the development of yield target based fertilizer prescriptions for a given soil - crop situation through “Inductive cum targeted yield approach” which is unique as it not only indicates soil test based fertilizer dose but also the level of yield that can be obtained if appropriate practices are followed in raising the crop (Ramamoorthy *et al.*,1967). This approach provides scientific basis for balanced fertilization not only between the nutrients from the external sources but also with soil available nutrients. Prescription based fertilizer application is crop and site specific, taking into the nutrient requirement of crops, contribution of nutrients from soil, fertilizer and organic manures and it is more scientific than conventional fertilizer recommendations based on soil testing. Nutrient availability in soil after the harvest of a crop is much influenced by the initial soil nutrient status, the amount of fertilizer nutrients applied and the nature of the crop raised. Of late, monoculture is being replaced by cropping sequence and for adopting soil test based fertilizer prescriptions in a sequence, the soils are to be tested after each crop which is not always practicable. Therefore, it has become necessary to predict the soil test values after the harvest of the crop in the sequence. It is done by developing post - harvest soil test values (PHSTVs) prediction equations by making use of the initial and post-harvest soil test values, applied fertilizer doses and the yields obtained or uptake of nutrients by the crop (Ramamoorthy *et al.*,1971).

MATERIAL AND METHODS

The field experiment was carried out during 2016-2017 *kharif* season at farmer’s holding, Manickapuram village of Bodinayakanur taluk, Theni District in Southern zone of Tamil Nadu state, which falls between 9^0 581’ N latitude and 77^0 245’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. A gradient experiment was conducted according to the approved layout plan of

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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 fertilizer 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 kg ha^{-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.

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 (0,40,80and120 kg ha^{-1}) and K_2O (0,40,80 and120 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 and 2. The 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 were 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.

RESULTS AND DISCUSSION

An attempt was made in the present study to predict the post-harvest soil test values by multiple regression model, which were obtained by the statistical evaluation of the dependence of the post-harvest soil test values based on initial soil test values and other associated parameters like yield or uptake and fertilizer doses. 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 fertilizer nutrient and ISTV is the initial soil test value of the respective nutrient. The equation will take the mathematical form,

$$YPHS = a+b_1F+b_2\ IS+b_3\ yield\ /\ uptake$$

where, a is the absolute constant; b_2 and b_3 are the respective regression co-efficients.

Using these regression equations, the post-harvest soil test values of N, P and K after maize crop were predicted. In this regard, in the present investigation, post-harvest soil test values (PHSTVs) prediction equations were developed for the prediction of post-harvest soil test values after maize and are furnished in Table 3 to 5 along with the concerned R^2 values. In case of prediction of $KMnO_4$-N, when grain yield was considered, the predictability values under NPK alone, NPK plus FYM @ 6.25 t ha^{-1} and NPK plus FYM @ 12.5 t ha^{-1} treatments were 99.2, 98.3 and 97.7 per cent, respectively, while the predictability values were 99.1, 98.3 and 97.3 per cent respectively when nitrogen uptake was considered. For the purpose of comparison, the observed and predicted data based on yield and uptake for a set of selected treatments from each block (NPK alone, NPK + FYM @ 6.25 t ha^{-1} and NPK + FYM @ 12.5 t ha^{-1}) are furnished in Table 5. The observed mean $KMnO_4$-N values were 180.8 kg ha^{-1} while the mean predicted value using grain yield and uptake were 181.7 and 181.9 kg ha^{-1}, respectively. The mean variation between observed and predicted value was 0.8 and 1.0 kg ha^{-1} when yield and uptake respectively were used for prediction.

The extent of predictability with respect to Olsen-P was 98.3, 96.3 and 97.4 per cent, while yield was used for prediction and 98.4, 97.3 and 97.8 per cent, while uptake of phosphorus was used in the case of NPK alone, NPK plus FYM @ 6.25 t ha^{-1} and NPK plus FYM @ 12.5 t ha^{-1} treatments, respectively (Table 3 to 5). The observed mean Olsen-P value was 28.9 kg ha^{-1}, while the predicted mean value using grain yield and uptake (Table 6) was 29.2 and 29.1 kg ha^{-1}, respectively. The mean variation between observed and predicted values were 0.3 and 0.2 kg ha^{-1} for both yield and uptake respectively were used.

Table 1. Treatment structure for test crop experiment on Maize

Treatment combination			Levels of nutrients (kg ha^{-1})		
N	P	K	N	P_2O_5	K_2O
0	0	0	0	0	0
0	0	0	0	0	0
0	0	0	0	0	0
0	2	2	0	80	80
1	1	1	100	40	40
1	2	1	100	80	40
1	1	2	100	40	80
1	2	2	100	80	80
2	1	1	200	40	40
2	0	2	200	0	80
2	1	2	200	40	80
2	2	2	200	80	80
2	2	1	200	80	40
2	2	0	200	80	0
2	2	3	200	80	120
2	3	2	200	120	80
2	3	3	200	120	120
3	1	1	300	40	40
3	2	1	300	80	40
3	2	2	300	80	80
3	3	1	300	120	40
3	3	2	300	120	80
3	2	3	300	80	120
3	3	3	300	120	120

Likewise, in case of NH_4OAc-K, the predictability was 96.7, 98.3 and 98.5 per cent, when yield was used and 96.8, 98.6 and 98.5 per cent, when potassium uptake was used for the prediction of post-harvest soil K status under NPK alone, NPK plus FYM @ 6.25 t ha^{-1} and NPK plus FYM @ 12.5 t ha^{-1}treatments, respectively (Table 3 to 5).The observed mean NH_4OAc-K value was 569.6kg ha^{-1}, while the mean predicted value using grain yield and uptake (Table 6) was 571.3 and 569.9 kg ha^{-1}, respectively. The mean variation between observed and predicted values was 1.7 and 0.3 kg ha^{-1} for both yield and uptake respectively were used.

Table 2. Levels of fertilizer nutrients and FYM for 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	0.00
1	100	40	40	6.25
2	200	80	80	12.5
3	300	120	120	-

The data on 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 = 0.99** and 0.99** respectively for N with yield as well as uptake). While it was r = 0.99** and 0.99** for P with regard to yield and uptake respectively and in the case of K, r = 0.99** and 0.99**, respectively for yield and uptake. The difference between the predicted and observed (experimental) soil test values for the treated plots (five plots in each block) were found to be negligible and agree very closely.

Fertilizer prescription for desired yield target of maize-cotton cropping sequence based on initial soil test values

Using the fertilizer prescription equations (FPEs) for maize (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) and an average initial soil test value of available N,P and K (190:18:525 $kgha^{-1}$), fertilizer prescriptions were computed for a range of desired yield target under NPK alone and IPNS (NPK + FYM @ 12.5 t ha^{-1}). The post-harvest soil test values were predicted using the PHSTVs prediction equations for maize. A perusal of the data in Table 7 showed that the quantity of fertilizers required to produce 9.0, 10.0 and 11.0 t $ha^{-1}$of grain yield was 192, 230 and 268 kg N ha^{-1}; 96,111 and 125 kg P_2O_5 ha^{-1} and 88, 106 and 123 kg K_2O ha^{-1},respectively under NPK alone. When FYM was applied @ 12.5 t ha^{-1} along with fertilizers, the fertilizer requirements were 147, 185 and 223 kg N ha^{-1}; 74,89 and 103 kg P_2O_5 ha^{-1} and 56,74 and 91 kg K_2O ha^{-1}.

Table 3. Prediction equations for post-harvest soil test values of available N, P and K for maize under NPK alone

PHSTVs Prediction equations	R^2
YPHN = 6.933 + 0.918**SN + 0.033* FN + 0.0009 yield	0.992**
YPHN = 5.297 + 0.942**SN + 0.038** FN+ 0.023 uptake	0.991**
YPHP = 0.452 + 0.963** SP + 0.044** FP - 0.0001 yield	0.983**
YPHP = 0.902 + 0.970** SP + 0.049** FP - 0.02 uptake	0.984**
YPHK = 2.853 + 0.992** SK + 0.091** FK - 0.0006** yield	0.967**
YPHK = 4.17 + 0.990** SK + 0.088** FK - 0.051** uptake	0.968**

*Significant at P = 0.05; **Significant at P = 0.01; PH = Post-Harvest; FN, FP and FK = fertilizer N, $P_2O_5$and K_2O respectively in kg ha^{-1}; SN, SP and SK = Soil available N, P and K, respectively in kg ha^{-1}.

Table 4. Prediction equations for post-harvest soil test values of available N, P and K for maize under NPK+ FYM @ 6.25 t ha^{-1}

PHSTVs Prediction equations	R^2
YPHN = 4.421 + 0.950** SN + 0.035 FN + 0.0003* yield	0.983**
YPHN = 4.049 + 0.956** SN + 0.036 FN - 0.009* uptake	0.983**
YPHP = 2.849 + 1.014** SP + 0.072** FP - 0.0009 yield	0.963**
YPHP = 1.284 + 0.986**SP + 0.079** FP - 0.189* uptake	0.973**
YPHK = 3.598 + 0.993** SK + 0.082** FK - 0.0002 yield	0.983**
YPHK = 4.428 + 0.994**SK + 0.085** FK -0.034** uptake	0.986**

*Significant at P = 0.05; **Significant at P = 0.01; PH = Post-Harvest; FN, FP and FK = fertilizer N, $P_2O_5$and K_2O respectively in kg ha^{-1}; SN, SP and SK = Soil available N, P and K, respectively in kg ha^{-1}.

The predicted post-harvest soil test values were 195, 196 and 200 kg ha^{-1} of $KMnO_4$-N; 21.0, 21.0 and 21.0 kg ha^{-1} Olsen-P and 526, 527 and 528 kg ha^{-1} NH_4OAc-K respectively under NPK alone for 9.0, 10.0 and 11.0 t $ha^{-1}$of yield targets of maize. Similarly the post-harvest soil test values were calculated under IPNS and the values were 197,198 and 201 kg ha^{-1} of $KMnO_4$-N, 23.0, 24.0 and 24.0 kg ha^{-1} of Olsen-P and 531,534 and 537 kg ha^{-1} of NH_4OAc-K under NPK plus FYM 12.5 t ha^{-1}. The results indicated that irrespective of yield targets, there was either maintenance or built up of post-harvest soil available N, P and K as compared to the initial status and the magnitude was higher with increasing yield targets. Between NPK alone and IPNS, the magnitude of built-up was relatively higher with IPNS.

Table 5. Prediction equations for post-harvest soil test values of available N, P and K for maize under NPK+ FYM @ 12.5 t ha^{-1}

PHSTVs Prediction equations	R^2
YPHN = 9.528 + 0.809** SN + 0.022 FN + 0.003* yield	0.977**
YPHN = 4.365 + 0.906** SN + 0.038 FN + 0.066* uptake	0.973**
YPHP = 2.383 + 0.918** SP + 0.106** FP - 0.0004 yield	0.974**
YPHP = 1.079 + 0.912**SP + 0.111** FP - 0.092* uptake	0.978**
YPHK = 10.535 + 0.970** SK + 0.140** FK + 0.0004 yield	0.985**
YPHK = 4.089 + 0.984**SK + 0.145** FK + 0.015** uptake	0.985**

*Significant at P = 0.05; **Significant at P = 0.01; PH = Post-Harvest; FN, FP and FK = fertilizer N, $P_2O_5$and K_2O respectively in kg ha^{-1}; SN, SP and SK = Soil available N, P and K, respectively in kg ha^{-1}.

Using the predicted PHSTVs and already existing fertilizer prescription equations (FPEs) for any succeeding crop *viz*., cotton on similar or allied soil series, fertilizer prescriptions can very well be computed

Table 6. Observed and predicted post-harvest soil $KMnO_4$-N, Olsen-P and NH_4OAc-K for maize

Treat-ments	$KMnO_4$-N (kg ha^{-1})			Olsen-P (kg ha^{-1})			NH_4OAc-K (kg ha^{-1})		
	Observed	Predicted based on		Observed	Predicted based on		Observed	Predicted based on	
		Yield	Uptake		Yield	Uptake		Yield	Uptake
NPK alone									
$N_0P_0K_0$	155	152	155	15	15	17	541	543	540
$N_0P_2K_2$	194	192	192	38	37	39	584	585	585
$N_1P_1K_1$	207	202	208	39	39	40	574	570	570
$N_2P_2K_2$	189	195	190	33	35	34	572	571	564
$N_3P_3K_3$	193	197	195	33	34	32	583	585	585
NPK + FYM @ 6.25 t ha^{-1}									
$N_0P_0K_0$	162	166	163	15	15	14	552	551	556
$N_0P_2K_2$	181	186	180	32	32	31	575	574	580
$N_1P_1K_1$	191	190	189	32	31	33	570	571	572
$N_2P_2K_2$	167	169	170	22	23	21	562	567	569
$N_3P_3K_3$	174	176	179	24	25	23	560	568	561
NPK + FYM @ 12.5 t ha^{-1}									
$N_0P_0K_0$	154	148	155	15	16	17	549	548	545
$N_0P_2K_2$	160	162	157	24	25	25	569	571	571
$N_1P_1K_1$	166	164	167	24	24	26	558	555	559
$N_2P_2K_2$	206	207	207	44	43	41	591	591	589
$N_3P_3K_3$	214	210	213	44	44	44	604	605	602
Mean	181	181	181	28.9	29.2	29.1	570	570	570
'r' value		0.98**	0.99**		0.99**	0.99**		0.98**	0.97**

**=significant at P=0.01

under different nutrient management practices. Such a computed model is furnished in Table 6. The data emanated from the model clearly revealed that both STCR-NPK alone and STCR-IPNS resulted in sustained soil fertility at the end of the sequence. Between the two situations, STCR - IPNS resulted in relatively higher post - harvest soil fertility.

Table 7. Fertilizer prescriptions for maize-cotton sequence based on initial soil test values under NPK alone and IPNS

i.NPK alone

Yield target (t ha^{-1})	First crop (maize)						Yield target (q ha^{-1})	Second crop (cotton)					
	Fertilizer doses (kg ha^{-1})			PHSTV (kg ha^{-1})				Fertilizer doses* (kg ha^{-1})			PHSTV (kg ha^{-1})		
	FN	FP_2O_5	FK_2O	N	P	K		FN	FP_2O_5	FK_2O	N	P	K
9.0	192	96	88	195	21	526	30.0	164	122	103	191	21	521
10.0	230	111	106	196	21	527	35.0	206	144	136	193	22	529
11.0	268	125	123	200	21	528	40.0	246	167	169	199	24	537

ii. IPNS (NPK+FYM @ 12.5 t ha^{-1})

Yield target (t ha^{-1})	First crop (maize)						Yield target (q ha^{-1})	Second crop (cotton)					
	Fertilizer doses (kg ha^{-1})			PHSTV (kg ha^{-1})				Fertilizer doses* (kg ha^{-1})			PHSTV (kg ha^{-1})		
	FN	FP_2O_5	FK_2O	N	P	K		FN	FP_2O_5	FK_2O	N	P	K
9.0	147	74	56	197	23	531	30.0	123	101	68	195	22	529
10.0	185	89	74	198	24	534	35.0	165	123	101	198	24	537
11.0	223	103	91	201	24	537	40.0	206	145	133	203	26	545

NB: PHSTV: Post-harvest soil test value; Initial soil test value (ISTV): $KMnO_4$-N=190 kg ha^{-1}; Olsen-P=18 kg ha^{-1} and NH_4OAc-K=525 kg ha^{-1}.
Blanket dose for cotton (Hybrid): 120:60:60 kg N, P_2O_5 and K_2O kg ha^{-1}.

*computed using the already existing fertilizer prescription equations for cotton (varieties) on black calcareous soils.

** maintenance dose (50 per cent of the blanket dose).

Earlier prediction equations were reported by Santhi and Selvakumari (1998) for rice-rice-blackgram, Srivastava *et al*. (1999) for pigeon pea-wheat, Bera *et al*. (2006) for rice-rice, Praveena *et al.* (2013) for cotton based sequence, Dey and Das (2014) for rice-wheat, rice-maize and rice-rice sequences, Dhinesh (2015) for brinjal-aggregatum onion sequence, Coumaravel *et al.*(2016) for maize-tomato sequence and Udayakumar (2017) for pearl millet-black gram and pearl millet-bhendi sequence.

CONCLUSION

The PHSTVs prediction equations developed in the present study found to have high predictability for $KMnO_4$-N, Olsen-P and NH_4OAc-K suggesting that the prediction equations could be used with confidence for the prediction of soil available N, P and K after maize. These prediction equations could be used for predicting the post-harvest soil test values after maize and the predicted soil available N, P and K would become the initial soil test values for the succeeding crop in the sequence. Using the predicted initial soil test values and the fertilizer prescription equations for the corresponding crop in the sequence after maize, fertilizer doses can be prescribed for the succeeding crop *viz.,* cotton.

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