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Research Communication

Prediction of post-harvest soil nutrient status through multiple linear regression for targeted yield of hybrid maize

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ABSTRACT

A field experiment was conducted during 2017–18 at Crop Research Centre (CRC), Govind Ballabh Pant University of Agriculture and Technology, Pantnagar, Uttarakhand, to develop post-harvest soil test values (PHSTVs) and response type of fertilizers with the help of fertilizer prescription equations for achieving targeted yield of hybrid maize following STCR principle. In the present study, the response of hybrid maize to selected four levels of nitrogen (N), phosphorus (P), and potassium (K) and three levels of farm yard manure (FYM) at graded fertility levels was studied. Nutrient requirements (NR) of maize were recorded as 22, 5 and 27 kg/tonnes for N, P, and K, respectively. The contribution of NPK nutrients was observed; from fertilizer (%CF) at 58.2, 62.7, and 420.4%, from soil (%CS) at 33.1, 26.8, and 22.7%, from FYM (% C FYM) at 45.2, 14.4 and 39.4% and from fertilizer with FYM (% IPNM) as 62.4, 63.5 and 427.6%, respectively. Integration of N, P, and K fertilizers with FYM (10 t/ha) resulted in fertilizer savings of 31.2%, 18%, and 16% over NPK alone for a target yield of 4500 kg/ha on soil test values of 150, 35 and 200 kg/ha of $KMnO_4$-N, Olsen-P and NH_4OAc-K, respectively. The fertilizer response type for phosphorus was "+ - - ". The response of hybrid maize to NPK fertilizers was higher when integrated with FYM as compared to NPK alone. The prediction equations for PHSTVs help in predicting soil test values (STVs) which may save the cost of testing.

***Key words*:** Grain yield, Fertilizer response, STCR, Nutrient requirement

Maize (*Zea mays* L.), the third most important crop after rice and wheat spread over 9.47 million ha with the production of 28.6 million tonnes/year in India (Kumar *et al.,* 2023). Maize is a nutrient-exhaustive crop hence, for getting optimum economic yield external nutrient input application is very crucial (Ramkrushna *et al.,* 2022). Low soil fertility levels and nutrient mining by intensively grown nutrients exhaustive crops are the major threats to sustainable crop production. Efficient nutrient management requires balanced fertilizer use and sound management practices (Sivaranjan *et al.,* 2018). Applying fertilizers without considering the soil fertility status and nutrient requirement of the crops, affects the soil health and crop productivity adversely. It is an undeniable fact that 40-year-old fertilizer recommendations may not hold true in the present context as there has been a quantifiable decline in the nutrient status of the soil over the years. Farmers are using imbalanced chemical fertilizers to get higher yields but the decision on fertilizer use requires knowledge of the expected crop yield and crop response to applied nutrients. To overcome these issues, yield targets using the STCR approach can be achieved with an economically viable, environmentally sustainable system without degrading and polluting the soil, air, and water. STCR is based on the quantitative idea of the fertilizer requirement according to the yield and nutritional requirement of the crop, % contribution from the soil available nutrient, and that of the applied fertilizer (Ramamoorthy *et al.,* 1967). Keeping in view the above facts, the present investigation was carried out to study the response type of N, P, K, and PHSTVs for the next crop by using fertilizer prescription equations for hybrid maize.

The experiment was conducted at CRC, Govind Ballabh Pant University of Agriculture and Technology, Pantnagar, Uttarakhand (29º N, 79º 29' E, and 243.84 above mean

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sea-level) during 2017–18 as outlined by Ramamoorthy *et al.,* (1967). The soil was sandy loam with weak fine to medium-fine granular structure. The initial pH, organic carbon (%), available N (kg/ha), available P (kg/ha) and available K (kg/ha) were 6.8, 0.6, 135.5, 12.8, and 170.3, respectively. The experiment was conducted in 2 steps, i.e. fertility gradient (Exp. I) and test crop experiment (Exp. II).

In experiment, I, wheat ('UP 2526') was grown into three rectangular strips (I, II, and III) of equal size (59 m × 7.5 m) by adopting standard agronomic practices. The graded fertilizer doses imposed in strips I, II, and III were ($N_0P_0K_0$ as 0:0:0), ($N_{½}P_{½}K_{½}$ as 100: 100: 100), and ($N_1P_1K_1$ as 200: 200: 200), respectively.

For Experiment II, the field was divided into 3 equal strips corresponding to those made in experiment I. The experiment was laid out in a fractional factorial design comprising 8 treatments (7 treated + 1 control) in each FYM block covering 24 treatments (21 treated and 3 control plots) in each strip, resulting in a total of 72 plots (63 treated and 9 control plots) of 3 m × 3 m size. Various treatment combinations of N, P, K, and FYM were selected as suggested by AICRP on STCR. Hybrid maize (var. P 3377) was tested with 4 levels of N (0, 60, 120, and 180 kg/ha), P_2O_5 (0, 30, 60 and 90 kg/ha), and K_2O (0, 20, 40 and 60 kg/ha). Half a dose of N, a full dose of P, K, and FYM were applied as basal, and the remaining N was in two splits at 30–45 DAS and just before tasseling was applied.

Soil samples (before sowing and after harvesting of the crop) were analyzed for pH, EC, Organic carbon, Available N, Olsen's P, and Available K. Plant samples were also analyzed for total N, P, and K content by following the procedures outlined by Jackson (1967). The uptake of nutrients was obtained as the product of their concentrations and yield. With the help of data on nutrient uptake, crop yield, soil test values and fertilizer nutrients applied, nutrient required in kg to produce a tonnes of hybrid maize grain yield (NR), % contribution of nutrients from soil (CS), % contribution of nutrients from fertilizers (CF), % contribution of nutrients from farm yard manure (CFYM) and % contribution of nutrients from fertilizer with FYM (IPNM) were calculated as described by Ramamoorthy *et al.,* (1967). These basic parameters were transformed into simple, workable fertilizer adjustment equations, and a ready reckoner was prepared to calculate a specific yield target based on soil test values as per the method described by Ramamoorthy *et al.,* (1967).

The pre-sowing soil test values, fertilizer doses grain yield, and/or the uptake of NPK by the crop were used as independent variables and the PHSTVs as dependent 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 (independent variables).

Yield and nutrient uptake by exhaust crop wheat

Yield and NPK uptake of exhaust crop wheat indicated that fertility gradient has been created successfully since it followed the same trend as of the applied fertilizer nutrients, *i.e.* strip III > strip II > strip I. Strip III recorded an increase of 241.8 and 15.1 % in grain yield over strip I and II, respectively. Straw yield in strip III recorded an increase of 279.7 and 19% over strips I and II, respectively. It may be due to the application of graded levels of N, P, and K in strips which influenced the grain yield nutrient availability and nutrient uptake by the crop. The results corroborate with the findings of Singh *et al.,* (2020) and Singh *et al.,* (2021).

Soil fertility, yield, and nutrient uptake by hybrid maize

The range and average values of soil available nutrients, grain yield, and nutrient uptake by hybrid maize are given in Table 1. Organic carbon (OC) was slightly higher in strip III as compared to strip II and strip I. Available soil nitrogen, phosphorus, and potassium followed the following trend; strip III > strip II > strip I due to the highest N, P, and K fertilizer application in strip III. The results were in concordance with the results of Singh *et al.,* (2020). The highest grain yield, N, P, and K uptake was recorded in strip III followed by strip II, and least in strip I. Increased uptake of nutrients following an application of NPK fertilizers and FYM was due to the addition of nutrients and proliferous root system developed under balanced nutrient application resulting in more absorption of water and nutrients and creating an adequate soil physical environment (Singh *et al*., 2014). The integrated use of organic and inorganic fertilizers has proved superior to applied alone concerning nutrient uptake (Sharma *et al*., 2016). Increment in potassium uptake was observed in almost all the integrated treatments over the chemical fertilization. This might be due to enhancement in K availability by shifting the equilibrium among the forms of K from relatively exchangeable K to soluble K forms in the soil and also by reducing leaching losses (Pradeep *et al.,* 2012).

Basic parameters

The data indicated that nutrient contribution from chemical fertilizer along with FYM was greater than soil and without FYM (Table 2). The application of FYM might have played an important role in enhancing the microbial population which leads to the higher availability of nutrients and thereby efficiency of added nutrients. The organic acids released during the decomposition of added FYM in the soil might played a role in solubilizing phosphorus (Sharma *et al.,* 2016).

Table 1. Soil fertility status after exhaust crop experiment and grain yield and total nutrient uptake by hybrid maize under different strips

Particulars	Strip I		Strip II		Strip III		Whole plot	
	Range	Mean	Range	Mean	Range	Mean	Range	Mean
Organic carbon	0.15–1.17	0.51	0.16–0.86	0.54	0.23–1.44	0.61	0.16–1.17	0.56
Alkaline $KMnO_4$-N(kg/ ha)	50.2–125.5	93.5	87.9–138	109.8	87.8–175.6	124.4	50.2–175.6	109.2
Olsen's-P (kg/ha)	10.5–18.4	14.4	11.2–18.9	15.3	11.2–21.7	17.7	10.5–21.7	15.8
NH_4OAc-K(kg/ha)	96.3–165.8	135.9	127.7–163.5	148.0	127.7–198	165.3	96.3–198.2	149.7
			Maize					
Grain yield (t/ha)	0.78– 10.50	4.60	1.44–8.89	5.66	2.17–9.33	6.68	0.78–10.50	5.65
N Uptake (kg/ha)	13.6–188.4	95.7	31.4–211.5	121.7	46.5–191	148.9	13.6–211.5	113.0
P Uptake (kg/ha)	4.1–35.7	19.8	9.0–41.0	23.0	8.6-36.8	30.1	4.1–41.0	23.0
K Uptake (kg/ha)	12.2–258.2	129.7	24–232.6	156.0	38.6–262.0	209.9	12.2–262.0	149.5

Table 2. Nutrient requirement and contribution of nutrients from soil, fertilizers, and FYM

Parameter	N	P	K
Nutrient requirement (NR) (kg/t)	22	5	27
Contribution from soil (CS) (%)	33.1	26.8	22.7
Contribution from fertilizer (CF) (%)	58.2	62.7	420.4
Contribution from FYM (CFYM) (%)	45.2	14.4	39.4
Contribution from fertilizer and FYM (IPNM) (%)	62.4	63.5	427.6

Fertilizer adjustment equations

Fertilizer adjustment equations for calculating the nutrient requirement with and without FYM were developed with the help of basic data. Using these fertilizer equations, ready reckoners are prepared for NPK alone and NPK + FYM @10 kg/ ha for achieving 4500 kg/ha yield targets of hybrid maize (Table 3). Fertilizer application using the above equations would be more economical and environmentally friendly. Fertilizer adjustment equations for hybrid maize are:

NPK alone

FN = 3.6 T–0.56 SN

FP_2O_5 = 0.71 T–0.97 SP

FK_2O = 0.64 T–0.06 SK

NPK + FYM

FN = 3.36 T–0.53 SN–0.72 FYM

FP_2O_5=0.70 T–0.96 SP–0.52 FYM

FK_2O = 0.63 T–0.06 SK–0.11 FYM

Multiple regression study and fertilizer response type

Relationship between grain yield as the dependent variable and the soil test values (SN, SP, SK), fertilizer doses (FN, FP, FK), FYM doses (ON, OP, OK) as well as interactions between soil test values and fertilizer doses as independent variables were established through a multiple regression equation.

Yield = - 77.7752 + 0.1417 * SN + 1.1004 * SP + 0.2432 * SK + 0.0118 * FN + 1.9499 * FP + 0.1208 * FK + 0.0009 * FN2 - 0.0138 * FP2 - 0.0073 * FK2 + 0.0004 * FNSN - 0.0360 * FPSP + 0.0033 * FKSK - 4.0672 * ON + 4.2668 * OK, R^2= 0.7312**

Out of eight possible responses, only in (+ - -) type of response site-specific optimum fertilizer dose of nutrient can be derived by differentiation provided that the three coefficients are significant at least 5% level of significance (STCR manual, 1985). The fertilizer response type thus derived from the regression equation given below suggests that the site-specific optimum fertilizer dose can be derived for phosphorus, i.e. "+ - -". While potassium with response type "+ -+" showed the optimum fertilizer dose and the maximum yield increase with the increasing soil test value.

Table 3. Ready reckoner for soil test-based fertilizer recommendations of N, P, and K for 4,500 kg/ha for hybrid maize

Soil test value (kg/ha)			Fertilizer dose NPK alone (kg/ha)			Fertilizer dose NPK + FYM (kg/ha)			% reduction over fertilizer alone		
N	P	K	N	P_2O_5	K_2O	N	P_2O_5	K_2O	N	P_2O_5	K_2O
70	10	60	123	64	31	96	57	27	22.1	11.6	11.8
80	12.5	80	117	62	30	90	55	26	22.8	12.0	12.3
90	15	100	112	60	29	85	52	25	23.7	12.5	12.7
100	17.5	120	106	57	27	80	50	24	24.6	13.0	13.3
110	20	140	100	55	26	75	47	22	25.6	13.5	13.9
120	25	160	94	50	25	69	43	21	26.7	14.7	14.5
125	30	180	92	45	23	67	38	20	27.4	16.2	15.2
150	35	200	77	40	22	53	33	19	31.2	18.0	16.0

R^2 value	Nutrient	Response type
0.7312	Nitrogen	+++
	Phosphorus	+--
	Potassium	+-+

Prediction equations for PHSTVs of available N, P, and K for maize

PHSTVs prediction equations were developed for available N, P, and K for availing STVs. The predicted soil test values can be utilized for recommending the fertilizer doses for succeeding crops and hence, eliminating the need for soil tests after each crop. This provides a way for prescribing the fertilizer recommendations for the whole cropping sequence based on initial soil test values. The prediction equations given below with the R^2 value between 0.27 and 0.61 ($p > 0.01$), suggest that these equations could be used with confidence for the prediction of available N, P, and K after maize to make the soil test-based fertilizer recommendations for any succeeding crop.

Based on yield

PHN = - 9.3972 + 0.6124 * SN + 0.3250 * FN - 0.0123 * Y* $R^2 = 0.54^{**}$
PHP = 7.4910 + 0.1871 * SP + 0.1629 * FP + 0.0468 * Y $R^2 = 0.48^{**}$
PHK = 125.0024 + 0.1634 * SK + 0.3551 * FK + 0.0926 * Y $R^2 = 0.27^{**}$

Based on uptake

PHN = - 6.9759 + 0.5605 * SN + 0.2839 * FN + 0.0803 * UN $R^2 = 0.55^{**}$
PHP = 7.3058 + 0.0387 * SP + 0.1388 * FP + 0.2479 * UP $R^2 = 0.61^{**}$
PHK = 128.4252 + 0.1170 * SK + 0.1785 * FK + 0.0889 * UK $R^2 = 0.36^{**}$

** Regression is significant at the 0.01 level

* Regression is significant at the 0.05 level

Based on the present study, it may be concluded that investigation provides a strong relationship for the fertilizer recommendations based on the target yield concept which can effectively work for 4500 kg/ha targeted yield in hybrid maize grown on Mollisols of Uttarakhand. Besides this, target yield-based fertilizer recommendations not only provide balanced nutrition to crops but are also able to sustain crop productivity as well as soil health.

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