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Soil test crop response approach for optimizing integrated plant nutrients supply to achieve targeted yield of hybrid maize *(Zea mays* L.*)* in Mollisols

NIDHI LUTHRA[*1®], AJAYA SRIVASTAVA[1], KAPIL A CHOBHE[2] AND VIJAY KANT SINGH[3]

[1]Department of Soil Science, G.B.Pant University of Agriculture & Technology, Pantnagar, 263145, Uttarakhand

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ABSTRACT

A field experiment was conducted during 2017-18 at Crop Research Centre, G.B.P.U.A.&T., Pantnagar with the objective of developing fertilizer adjustment equations and quantifying doses for achieving targeted yield of hybrid maize (Zea mays L.) by using STCR approach. Response of hybrid maize to four levels of N, P and K and two levels of FYM under different fertility levels was studied. Nutrient requirements (NR) were reported as 2.17, 0.46 and 2.74 kg q^{-1} for N, P and K, respectively. The contribution of nutrients N, P, and K from fertilizers (%CF) was found as 58.2, 62.7 and 420.4% , from soil (%CS) as 33.1, 26.8 and 22.7%, from organic matter FYM (%CFYM) as 45.2, 14.4 and 239.4% , from fertilizer with FYM ($\%CF^*$) as 62.4, 63.5 and 427.6%, respectively. Fertilizer adjustment equations and ready reckoners were developed with and without FYM for different targeted yield and soil test values of N, P and K. It was observed that response of hybrid maize to N, P and K fertilizers was higher when integrated with FYM application as compared to N,P and K alone. The average saving of fertilizer by application of 10 tonnes FYM was 24.52 kg ha^{-1} N, 7.11 kg ha^{-1} P and 3.50 kg ha^{-1} K within the range of soil test value and yield targets on Mollisol.

Key words: Hybrid maize, STCR, grain yield, target yield, fertilizer adjustment equations

INTRODUCTION

In India, maize (*Zea mays* L.) is emerging as the third most important crop after rice and wheat due to its wider adaptibility under diverse agro-climatic conditions. Maize is widely used for human food, animal feed, corn starch industry, corn oil production *etc*. It is estimated by the Indian Institute of Maize Research that hybrids may cover 90% of the total maize growing area by 2050. Being an exhaustive crop, the nutrient requirement of maize cannot be fulfilled only through native nutrient reserves thereby the additional nutrients should be added through chemical fertilizers (Shreenivas *et al.,* 2017). Considering the undenied fact that fertilizer plays a crucial role in enhancing crop yields and the intensification of agriculture is no doubt necessary to feed the ever increasing population. However, to achieve yield targets without degrading and polluting the soil, air, water and environment, fertilizers should be applied considering soil test values and nutrient requirement of the crop (Venkatesh *et al.,* 2021, Pandey *et al.*, 2019). Hence soil testing is necessary to have a locally calibrated soil test crop response research for the efficient working of soil testing advisory. Soil Test Crop Response correlation was designed with the basic assumption that the crop yield is directly proportional to the available nutrient in the soil (Sharma *et al.*, 2015, Sharma *et al.*, 2016). This is a quantitative approach of computing fertilizer doses in accordance with the yield, nutrient requirement of the crop and percent contribution from the soil and fertilizer (Ramamoorthy *et al.,* 1967). This is the fact that the 40 years old fertilizer recommendations may not hold true in the present context as there is an appreciable decline in the nutrient status of the soil due to intensive cultivation across the country. There is a vehement need of revalidating year old package of practices and fertilizer recommendations. Owing to the above rationale the present investigation was done to study the response of N, P, K and FYM on growth and yield of Hybrid maize and to develop optimum fertilizer adjustment equations for determining the fertilizer doses for targeted yields of hybrid maize.

MATERIALS AND METHODS

The experiment was conducted at the N.E. Borlaug Crop Research Centre, G.B. Pant University of Agriculture and Technology, Pantnagar, Uttarakhand during the season 2017-18 as outlined by Ramamoorthy *et al.*

*Corresponding author Email: nidhi27luthra@gmail.com
[2]Division of Soil Science and Agricultural Chemistry, ICAR-IARI, New Delhi 110012,[3] Punjab Agricultural University, Ludhiana-141004, Punjab,[®]Current address: ICAR-IARI, New Delhi

(1967). The experimental site is located at the Western Himalayan agro-ecological zone (latitude 29º N, longitude 79º 29' E). The texture of the soil was sandy loam with weak fine to medium-fine granular structure, having good water holding capacity and highly productive in nature. Before sowing of the wheat crop, the soil had pH 6.76, EC 0.19 dS m^{-1}, organic carbon 6.2 g kg^{-1}, available N 135 kg ha^{-1}, available P 12.8 kg ha^{-1} and available K 170 kg ha^{-1}. The experiment was conducted in two steps *i.e.* fertility gradient experiment and test crop experiment for developing fertilizer prescription equations. Prior to the test crop experiment, fertility gradient experiment was conducted to create a variation in the soil fertility and to minimize the interference of other management factors affecting crop yield**.** Here, wheat (var UP 2526) was grown by adopting standard agronomic practices in three rectangular strips of equal size (59m × 7.5m) and in each strip, different fertilizer doses, *viz*. no NPK application (strip I), a standard dose of 100 kg NPK ha^{-1} (strip II) and a double dose of 200 kg NPK ha^{-1} (strip III), respectively were applied. After harvesting wheat crop at full maturity, soil samples were collected and analyzed for major nutrients to assess the fertility gradient.

For test crop experiment, the field was divided into 3 equal strips corresponding to those made in the fertility gradient experiment. The experiment was laid out in a fractional factorial design which comprised of 24 treatments (21 treated and 3 control plots) in each strip (total 3 strips), resulting in total 72 plots (63 treated and 9 control plots) of 3m × 3m size. Various combinations of N, P, K and FYM were selected as suggested by AICRP on STCR and hybrid maize was tested with 4 nutrient levels *i.e.* N (0, 60, 120 and 180 kg ha^{-1}), P_2O_5 (0, 30, 60 and 90 kg ha^{-1}) and K_2O (0, 20, 40 and 60 kg ha^{-1}). The treatments (NPK alone, NPK + FYM @ 5.0 t ha^{-1}) were superimposed across the strips. Hybrid maize (var. P 3377) was grown with recommended agronomic practices. Half dose of N, a full dose of P, K and FYM was applied at the time of sowing while one-fourth N was given after 30-45 days after sowing and remaining one-fourth N was given just before tasseling stage. Soil samples (before sowing and after harvesting of the crop) were analyzed for: pH, electrical conductivity, organic carbon, available N (Subbiah and Asija, 1956), available P (Olsen *et al.,* 1954), available K (Hanway and Hiedal, 1952). Plant samples were analyzed for N, P and K content by following standard procedures (Jackson 1967)**.** Nutrient uptake was calculated as a product of nutrient content (%) and grain/straw yield.

Evaluation of Basic Parameters

With the help of obtained data of nutrient uptake, crop yield, soil test values and applied fertilizer nutrients, the basic parameters *i.e.* nutrient required to produce a quintal of hybrid maize grain yield (NR), per cent contribution of nutrients from soil (CS), per cent contribution of nutrients from fertilizers (CF), per cent contribution of nutrients from farm yard manure (CFYM) and per cent contribution of nutrients from fertilizer with FYM (CF*) were computed using the formulae (Ramamoorthy *et al.,* 1967).

RESULTS AND DISCUSSION

Yield and nutrient uptake by wheat

The highest grain yield of wheat was obtained in strip III (48. q ha^{-1}) followed by strip II (42.3 q ha^{-1}) and the least in strip I (14.2 q ha^{-1}). Total uptake of nitrogen, phosphorus and potassium was recorded minimum in strip I as 31.9 kg ha^{-1}, 5.6 kg ha^{-1} and 29.2 kg ha^{-1} , respectively, and maximum in strip III as 119.2 kg ha^{-1} , 22.6 kg ha^{-1} and 93.4 kg ha^{-1} , respectively. Yield and uptake data indicated that fertility gradient has been created since crop yield and total nutrient uptake by the exhaust crop followed the same trend as of the applied fertilizer nutrients, *i.e.* strip III > strip II > strip I. It is the graded levels of N, P and K in strips which influenced the grain yield and nutrient availability and hence nutrient uptake by the crop (Mahajan *et al.,* 2013).

Soil test values after harvesting

The range and average values of soil available nutrients after harvesting of the wheat crop are presented in Table 1. The organic carbon content of experimental field varied from 1.6 to 11.7 g kg^{-1} with an average of 5.6 g kg^{-1}. Available nitrogen varied from 50.2 to 175.6 kg N $ha^{-1}$with a mean value of 109.2 kg N ha^{-1}. Available phosphorus content ranged from 10.5 to 21.7 kg P ha^{-1} with a mean value of 15.8 kg P ha^{-1}. Available potassium ranged from 96.3 to 198.2 kg K ha^{-1} with a mean of 149.7 kg K ha^{-1}.

Organic carbon, available nitrogen, available phosphorus and available potassium were reported highest in strip III followed by strip II and least in strip I. The results were in concordances with the results of Bera *et al., (*2006).

Table 1: Description statistics of soil available nutrients after wheat crop experiment

Particular		Strip I	Strip II	Strip III	Whole plot
Organic carbon (g kg $^{-1}$)	Range	1.5 -11.7	1.5-8.5	2.3-14.4	1.5-11.7
	Mean±SD	5.1 ±0.26	5.4 ±0.22	6.1 ± 0.26	5.5 ± 0.24
	Median	4.4	5.6	6.4	5.0
Alkaline $KMnO_4$-N (kg ha^{-1})	Range	50.2-125.4	87.8-138	87.8-175.6	50.2-175.6
	Mean±SD	93.5 ±19.2	109.8 ±17	124.4 ±20.9	109.2 ±22.7
	Median	87.8	112.9	125.4	112.9
Olsen's-P (kg ha^{-1})	Range	10.5-18.4	11.2-18.9	11.2-21.7	10.5- 21.7
	Mean±SD	14.4 ±5.0	15.3 ±4.6	17.7 ±6.2	15.8± 2.7
	Median	35.1	35.9	43.1	15.8
NH_4OAc-K (kg ha^{-1})	Range	96.3-165.8	127.7-163.5	127.7-198.2	96.3-198.2
	Mean±SD	135.9 ±15.3	148.0 ±9.9	165.3 ±14.0	149.7 ± 17.8
	Median	136.1	150.1	162.9	150.1

Statistical verification of proper creation of fertility gradient

Regression analysis was performed by taking the soil available nutrients *i.e*. nitrogen (SN), phosphorus (SP) and potassium (SK) separately as dependent variables and grain yield, fertilizer N, P, K and combination of soil test values and fertilizer N, P and K as independent variables. The results clearly inferred that the fertility gradient was created properly and it was significant with respect to N, P and K levels. Similar inferences were drawn by Singh (2020) in Mollisol of Uttarakhand.

Dependent variable	P level	R^2	Mean	SD	CV
SN	$<0.01^{**}$	0.661	149.75	22.72	20.80
SP	$<0.01^{**}$	0.770	36.18	6.13	16.95
SK	$<0.01^{**}$	0.761	149.75	17.85	11.92

Test crop experiment

Grain yield and nutrient uptake

Grain yield of maize varied from 7.8 to 105 q ha^{-1} with a mean of 56.5 q ha^{-1} (Table 2). Highest grain yield was recorded in strip III (66.8) followed by strip II (56.6 q ha^{-1}) and least in strip I (46.0 q ha^{-1}). Biomass yield of maize varied from 72.2 to 404.4 q ha^{-1} with a mean of 172.5 q ha^{-1}. Highest biomass yield was recorded in strip III (296.1 q ha^{-1}) followed by strip II (232.2 q ha^{-1}) and lowest in strip I (191.6 q ha^{-1}). Total Nitrogen uptake by the plant varied from 13.6 to 211.5 kg ha^{-1} with a mean of 113.0 kg ha^{-1}. Phosphorus uptake varied from 4.1 to 41.0 kg ha^{-1} with a mean of 22.9 kg ha^{-1}. Potassium uptake varied from 12.2 to 262.0 kg ha^{-1} with a mean of 149.5 kg ha^{-1}. On application of NPK fertilizers and FYM, there is an increase in the uptake of nutrients due to proliferous root system developed under balanced nutrient application which resulted in more absorption of water and nutrients along with adequate soil physical environment (Singh *et al.* 2014).

Basic parameters

The basic parameters for N, P and K respectively : NR was 2.17 kg, 0.46 kg and 2.74 kg , %CS was 33.1, 26.8 and 22.7, %CF was 62.4, 63.5 and 427.6 with FYM and 58.2, 62.7 and 420.4 without FYM and %CF* was 45.2, 14.4 and 239.4. Similar trend was also reported by Santhi *et al.* (2011) for beet root in Alfisols. The results thus obtained indicated that nutrient contribution from fertilizer with FYM was greater than that from without FYM and soil. This may be due to FYM which might have enhanced the microbial population leading to the higher availability of nutrients and thereby efficiency of added nutrients increased. Also, the organic acids released during the decomposition of added FYM in the soil might have solubilized the fixed phosphorus and increased its availability

Table 2: Descriptive statistics of hybrid maize grain yield and total nutrient uptake under different strips

Particular		Strip I	Strip II	Strip III	Whole plot
Grain (q ha^{-1})	Range	7.8 - 105	14.4 - 88.9	21.7 - 93.3	7.8 - 105
	Mean±SD	46.0±27.3	56.6 ±22.3	66.8 ±21.9	56.5 ±25.1
	Median	40.8	59.4	73.0	59.7
Biomass yield (q ha^{-1})	Range	72.2 -344.4	131.1 -404.4	172.2 - 355.5	72.2-404.4
	Mean±SD	191.6 ±64.6	232.2 ±55.4	296.1 ±44.6	172.5 ±64.7
	Median	133.0	164.7	227.2	173.3
Nitrogen Uptake (kg ha^{-1})	Range	13.6-188.4	31.4-211.5	46.5-191.0	13.6-211.5
	Mean±SD	95.7 ±44.7	121.7 ±39.1	148.9 ±39.2	113.0 ±45.6
	Median	79.5	116.3	145.4	113.2
Phosphorus Uptake (kg ha^{-1})	Range	4.1-35.7	9.1-41.0	8.6-36.8	4.1-41.0
	Mean±SD	19.7 ±8.3	23.0 ±7.2	30.1 ±7.0	22.9±8.5
	Median	16.8	21.2	29.6	22.7
Potassium Uptake (kg ha^{-1})	Range	12.2-258.2	23.9-232.6	38.6-262.0	12.2-262.0
	Mean±SD	129.7 ±66.4	156.0 ±58.4	209.9 ±64.9	149.5 ±69.7
	Median	100.5	148.8	209.1	156.3

Fertilizer adjustment equations

Fertilizer adjustment equations given below were derived for calculating the nutrient requirement with and without FYM for targetted yield with the help of obtained basic data.

Using these equations, ready recknors were prepared without FYM and with FYM @ 10 t ha^{-1} (Table 3) for achieving 30 and 50 q ha^{-1} yield targets of hybrid maize for different levels of soil available nitrogen, phosphorus and potassium.

Table 3: Nutrient requirements of Hybrid maize at 30 and 50 q ha^{-1} yield targets

$KMnO_4$-N (kg ha^{-1})	Target yield 30 (q ha^{-1})		Target yield 50 (q ha^{-1})	
	Fertilizer N requirement (kg ha^{-1})			
	Without FYM	10 t ha^{-1} FYM (ROFA %)	Without FYM	10 t ha^{-1} FYM (ROFA %)
90	57.0	34.3 (+21.5)	129.2	101.7 (+8.5)
100	51.3	29.0 (+24.5)	123.5	96.4 (+8.9)
110	45.6	23.7 (+28.4)	117.8	91.1 (+9.4)
120	39.9	18.4 (+33.8)	112.1	85.8 (+9.9)
Olsen's P (kg ha^{-1})	Fertilizer P requirement (kg ha^{-1})			
20	29.7	22.7 (+12.8)	62.6	55.2 (+5.8)
25	24.8	17.9 (+15.8)	57.7	50.3 (+6.3)
30	19.9	13.1 (+20.5)	52.8	45.5 (+6.9)
35	15.0	8.2 (+29.0)	47.9	40.7 (+7.6)
NH_4OA_C-K (kg ha^{-1})	Fertilizer K requirement (kg ha^{-1})			
100	16.6	13.3 (+5.3)	32.1	28.4 (+5.2)
120	15.4	11.9 (+5.5)	30.8	27.1 (+5.4)
140	14.1	10.7 (+5.8)	29.5	25.9 (+5.6)
160	12.8	9.4 (+6.3)	28.2	24.6 (+5.9)

(ROFA %) = Reduction over fertilizer alone

Fertilizer recommendations using the fertilizer equations are economically viable and environmentally sustainable.

Without FYM

FN = 3.6T-0.56SN
FP_2O_5 = 0.71T-0.97SP
FK_2O = 0.64T-0.06SK
With FYM
FN = 3.36T-0.53SN-0.72FYM
FP_2O_5=0.70T-0.96SP-0.52FYM
FK_2O = 0.63T-0.06SK-0.11FYM

Fertilizer equivalence of FYM for maize

Fertilizer equivalence of FYM was calculated by taking differences in fertilizer requirement of nutrient in question with and without FYM at a particular soil test value and target yield. The average saving of fertilizer by application of 10 tonnes FYM was 24.52 kg ha^{-1} N, 7.11 kg ha^{-1} P and 3.50 kg ha^{-1} K within the range of soil test value and yield targets on Mollisol. These results represent that the required dose of fertilizer to obtain desired targetted yield are reduced under integrated plant nutrient system which results in net saving of the fertilizer and cost of production (Singh *et al.,* 2017).

The present investigation provides a sound basis for recommending fertilizer doses based on target yield concept which can effectively work for 30 and 50 q ha^{-1} yield targets in Hybrid maize grown on Mollisols of Uttarakhand. These target yield based fertilizer recommendations not only provide balanced nutrition to crop but also sustain the crop productivity and soil fertility. Farmers with limited resources could also fetch good profit by applying fertilizers according to their targetted yield and available resources. For the optimum utilization of both renewable and non- renewable resources and the concern for quality of soil health and environment, the research on soil testing needs more emphasis and modifications to meet the future challenges.

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