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Soil test crop response-based fertilizer prescriptions under integrated plant nutrient supply for maize-wheat cropping system in Inceptisols

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ABSTRACT

Field experiments were carried out to investigate the soil test crop response-based fertilizer prescriptions under integrated plant nutrient supply by following Ramamoorthy's inductive approach of fertility gradients in Inceptisols at the instructional farm of Krishi Vigyan Kendra, Raigarh, Chhattisgarh on maize (*Zea mays* L) and wheat (*Triticum aestivum* L) during kharif and rabi 2016-17 with well developed fertility gradients. The nutrient requirement, contribution of nutrients from soil, fertilizer and farmyard manure were computed using the data on soil test values, fertilizer nutrient doses, nutrient uptake and maize and wheat yields. The amount of nutrients required to produce one quintal of maize grain was found to be 1.59 kg N, 0.32 kg P and 1.84 kg K. Similarly 2.02 kg N, 0.56 kg P and 2.12 kg K were required for producing one quintal of wheat grain. The contribution from fertilizer for N, P and K was estimated 41.84, 28.28 and 140.33 per cent and 29.03, 18.79 and 74.74 per cent for maize and wheat crops respectively. The per cent contribution from soil was recorded as 22.53 for N, 52.67 for P and 26.40 for K in case of maize and 10.00 for N, 48.29 for P and 8.28 for K in case of wheat crop. The contribution of organic source for N, P and K was recorded 21.76, 4.70 and 12.81 per cent and 3.47, 5.45 and 2.13 per cent for maize and wheat crops respectively. Based on the above basic parameters, soil test-based fertilizers adjustment equations were evolved for maize and wheat to achieve a definite yield target. Ready reckoner charts for fertilizer N, P_2O_5 and K_2O application based on the soil test values for specific yield targets of maize and wheat were also prepared which would be useful for the soil testing laboratories.

Keywords: Maize; wheat; STCR; FYM; fertilizer prescriptions; ready reckoner

INTRODUCTION

Efficient fertilizer use ensures increased production and high profit and is environmental friendly. The most appropriate balanced and economic doses of fertilizers can be evolved on the basis of soil test and crop response studies. Recently about 10 million tonnes gap between nutrients removal by the crops and nutrients addition through various sources has been estimated in the country. The organic resources available (organic manure, crop residues and bio-fertilizers) could meet this gap but at present only one-third of these resources are used in agricultural production. Fertilizers are generally applied to crops on the basis of generalized state level fertilizer recommendations which leads to imbalanced use of fertilizers and economic loss because the fertilizer requirement of a crop is not a static one and it may vary from field to field for same crop on the same soil. Therefore it is essential to protect the soil health by adopting balanced fertilization through soil testing and organic sources as an INM approach (Singh 2017, Singh and Singh 2018). Considering the soil fertility status, crop requirement of nutrients, efficiency of fertilizer, soil and organic sources and the economic condition of the cultivator, it has now been possible to formulate a yield target-oriented fertilizer schedule based on the principle of balanced nutrition of crops. In India, it is established on the theoretical basis and experimental proof for the fact that Liebig's law of minimum operates equally well for N, P and K (Ramamoorthy et al 1967).

Among the various methods of fertilizer recommendation, yield targeting is unique in the sense that this method not only indicates soil test-based fertilizer dose but also the level of yield that farmer can hope to achieve if good agronomic practices are followed in raising the crop. One of the most important advantages of this approach is that farmers have the option to relate their resources with a desired level of yield target. Targeted yield concept thus strikes a balance between fertilizing the crop and soil. In the light of ever increasing prices coupled with increasing demand of chemical fertilizer and depleting soil fertilizer, necessitates the integrated use of organic (renewable) and inorganic (non-renewable) sources of nutrients for sustainable crop production and better soil health. Therefore there is a need for improvement of input use efficiency through proper integration of chemical fertilizers with organic manures by balanced nutrition of crop.

Maize (*Zea mays* L) and wheat (*Triticum aestivum* L) crops are the most important cereal crops of the world that supplement the carbohydrate and protein requirement of population. Maize-wheat cropping system is followed in Chhattisgarh including Raigarh district. Information on soil test-based balanced fertilizer doses for this cropping system is not available for Raigarh district that calls to generate through complex fertilizer experiment using soil test crop response concept on targeted yield approach. Keeping these aspects in view, the present study was undertaken to develop a basis for balanced fertilizer prescriptions based on soil test values for desired yield targets under maize-wheat cropping system in Inceptisols of Raigarh district of Chhattisgarh.

MATERIAL and METHODS

The field experiments were conducted on maize (Bio 9544) and wheat (GW-273) during kharif and rabi 2016-17 for evaluating the soil test crop response under integrated plant nutrient supply system at the instructional farm of Krishi Vigyan Kendra, Raigarh, Chhattisgarh. The experimental site is located on the northern part of Chhattisgarh and lies at 21°54' N latitude and 83°24' E longitude with an altitude of 215 m amsl. The soil of the experimental field was an Inceptisol of silty clay loam texture with pH 6.50, EC 0.13 dS/m and organic carbon (OC) 5.0 g/kg. The experiments were conducted in two phases following the inductive approach in which fertility ingredients were created by dividing the field into three strips of equal size. No fertilizers were applied in first strip. Second strip was treated with 120, 60 and 60 kg/ha of N, P_2O_5 and K_2O respectively and third strip treated 180, 90 and 90 kg/ha of N, P_2O_5 and K_2O respectively. Green gram was grown for natural transformation of applied fertilizer and grown crop was buried before main experiment and soil of each fertility strip was tested to confirm the creation of fertility ingredients with respect to N, P and K. The purpose of creating the fertility gradients was to obtain variable soil test values in the same field and eliminate the influence of climate and management practices on crop yield instead of conducting experiments in different fields with variable nutrients at different sites. After confirming the establishment of fertility gradients in the experimental field, the experiment was laid out for the second phase by sowing the test crop of maize (Bio 9544) on 13 July 2016 and wheat (GW-273) on 20 November 2016. For soil test crop response studies, each strip was sub-divided into 24 plots of 8.0 x 4 m^2 each. The initial surface (0-15 cm) soil samples were collected from each of the 72 plots and analyzed for available N (Subbiah and Asija 1956), available P (Olsen et al 1954) and available K by neutral normal ammonium acetate (Jackson 1973).

Twenty four selected fertilizer treatment combinations (Table 1) were applied in maize comprising 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, 30, 60 and 90 kg/ha) and same doses in the same treatment structure were taken with wheat crop during rabi 2016-17. Three levels of FYM viz 0, 5 and 10 tonnes/ha were also applied across the width of strip making three blocks of FYM. The different treatments were randomized in such a way that each FYM block fertility strip had the same 24 treatment combinations. Each strip comprised one absolute control, two FYM levels, seven treatments of selected combinations of fertilizer nutrients alone and fourteen treatments in which both fertilizer and FYM were applied jointly. The test crops (maize and wheat) were raised up to maturity by following standard agronomic practices in the same field. N, P and K were applied through urea, single superphosphate (SSP) and muriate of potash (MOP) respectively. Full dose of fertilizer P and K and one-third of N were applied as basal and remaining two-third dose of N was applied in two splits at tillering and PI stage before flowering. Grain and straw yields of the crops were recorded and plant samples were analyzed for N, P and K contents to work out their uptake. The data on grain yield, uptake of N, P and K, available N, P and K fertilizer and FYM nutrient doses for N, P_2O_5 and K_2O were used to compute the basic parameters viz nutrient requirement (NR) contribution

Table 1. Nutrient combinations of fertilizer and FYM treatments in different strips

Plot number	Strip I	Strip II	Strip III	Plot number	Strip I	Strip II	Strip III
1.	$N_2P_3K_3F_2$	$N_0P_0K_0F_2$	$N_2P_2K_0F_2$	13.	$N_3P_3K_1F_2$	$N_2P_1K_1F_2$	$N_3P_1K_1F_2$
2.	$N_3P_3K_3F_2$	$N_1P_2K_1F_2$	$N_3P_2K_2F_2$	14.	$N_3P_3K_2F_2$	$N_2P_2K_3F_2$	$N_1P_2K_2F_2$
3.	$N_0P_0K_0F_1$	$N_1P_1K_2F_1$	$N_0P_0K_0F_1$	15.	$N_2P_1K_2F_1$	$N_3P_3K_2F_1$	$N_2P_2K_1F_1$
4.	$N_2P_3K_2F_1$	$N_0P_0K_0F_1$	$N_1P_2K_1F_1$	16.	$N_1P_2K_2F_1$	$N_3P_3K_3F_1$	$N_2P_0K_2F_1$
5.	$N_2P_2K_3F_0$	$N_3P_1K_1F_0$	$N_1P_1K_2F_0$	17.	$N_1P_2K_1F_0$	$N_2P_2K_2F_0$	$N_3P_3K_1F_0$
6.	$N_2P_2K_2F_0$	$N_2P_1K_2F_0$	$N_0P_2K_2F_0$	18.	$N_1P_1K_1F_0$	$N_1P_2K_2F_0$	$N_3P_3K_3F_0$
7.	$N_0P_0K_0F_2$	$N_1P_1K_1F_2$	$N_2P_2K_2F_2$	19.	$N_1P_1K_2F_2$	$N_2P_0K_2F_2$	$N_0P_0K_0F_2$
8.	$N_0P_2K_2F_2$	$N_2P_2K_1F_2$	$N_2P_1K_2F_2$	20.	$N_3P_2K_3F_2$	$N_3P_2K_1F_2$	$N_2P_3K_2F_2$
9.	$N_3P_1K_1F_1$	$N_3P_3K_1F_1$	$N_2P_1K_1F_1$	21.	$N_2P_2K_0F_1$	$N_0P_2K_2F_1$	$N_3P_2K_1F_1$
10.	$N_3P_2K_2F_1$	$N_3P_2K_3F_1$	$N_1P_1K_1F_1$	22.	$N_2P_2K_2F_1$	$N_2P_3K_3F_1$	$N_2P_2K_3F_1$
11.	$N_3P_2K_1F_0$	$N_3P_2K_2F_0$	$N_3P_3K_2F_0$	23.	$N_2P_1K_1F_0$	$N_2P_3K_2F_0$	$N_0P_0K_0F_0$
12.	$N_0P_0K_0F_0$	$N_0P_0K_0F_0$	$N_3P_2K_3F_0$	24.	$N_2P_2K_1F_0$	$N_2P_2K_0F_0$	$N_2P_3K_3F_0$

N_0, N_1, N_2 and N_3 are 0, 60, 120 and 180 kg N/ha; P_0, P_1, P_2 and P_3 are 0, 30, 60 and 90 kg P_2O_5/ha; K_0, K_1, K_2 and K_3 are 0, 30, 60 and 90 kg K_2O/ha; F_0, F_1 and F_2 are 0, 5 and 10 tonnes FYM/ha respectively

of nutrients from soil (CS), contribution of nutrients from fertilizers (CF) and contribution of nutrients from FYM (CFYM) were computed following the equation given by (Ramamoorthy et al 1967). These basic data were transformed into simple workable fertilizer adjustment equations for calculating N, P and K fertilizers doses for yield targets based on initial soil test values under integrated plant nutrient supply (IPNS).

RESULTS and DISCUSSION

Soil available nutrients

In the experimental soils, range and mean values of available N, P and K after creation of fertility gradients and before sowing (initial) of maize and wheat crops in different strips indicated that soil test values for these nutrients varied widely both among as well as within different strips (Table 2). The available nitrogen varied from 192 to 229 and 179 to 230 kg/ha, available phosphorus from 10.37 to 44.21 and 9.0 to 35.3 kg/ha and available potassium from 172 to 349 and 238 to 337 kg/ha of initial soils of maize and wheat crops respectively. Though these soils are considered to be most fertile, they are deficient in nitrogen and organic content but moderately supplied with phosphorus and potassium. Such variation in nutrient status of experimental sites is ideal for conducting soil test crop response experiments (Singh et al 2019, 2020).

Grain and tuber yield

The grain yield of maize and wheat in control plots ranged from 27.03 to 81.80 q/ha and 6.33 to 37.30 q/ha respectively in different fertility strips (Table 3). Variation in control yield of maize and wheat between strips might be due to variation in soil fertility status. Maize yield increased from 20.86 q/ha in control to 84.14 q/ha where 180, 90 and 90 kg/ha N, P_2O_5, K_2O and 10 tonnes FYM/ha were applied. However wheat yield increased from 6.33 q/ha in control to 37.30 q/ha in highly fertilized plots. This reveals that there was a tremendous response to applied nutrients in maize and wheat crops. The yields in various treatments were in accordance with the doses of nutrient and FYM indicating high responsiveness of the crop to soil fertility and fertilizer application. The average grain yield of maize and wheat in strip I, II and III was 49.64, 54.76, 58.83 and 22.98, 23.83 and 24.72 q/ha respectively. The yields and soil test values (Tables 2, 3) clearly depict their wide variation in control and treated plots. Such type of variation in data is prerequisite for computation of fertilizer adjustment equations for targeted yield of the crop (Sharma and Singhal 2014, Singh et al 2017).

Targeted yield equations and ready reckoners

The amount of nitrogen, phosphrus and potassium (NR) required for production of one quintal of grain yield of maize and wheat was found to be 1.59, 0.32 and 1.84 and 2.02, 0.56 and 2.12 kg/ha respectively (Table 4). Thus it is possible to calculate the N, P_2O_5 and K_2O requirements of the crops for desired specific yield targets (Suri and Verma 2000, Bajendra and Singh 2012). The contribution of nutrients from fertilizer (CF) was estimated 41.84, 28.28 and 140.33 per cent for maize and 29.03, 18.79 and 74.74 per cent for wheat respectively. The per cent contribution from soil (CS) to total nutrient removal

Table 2. Initial soil test values of maize and wheat crops

Strip	Available N (kg/ha)		Available P (kg/ha)		Available K (kg/ha)	
	Range	Mean	Range	Mean	Range	Mean
Maize						
I	197-229	213	10.37-20.52	15.44	183-289	236
II	192-217	205	19.22-38.70	28.96	172-324	248
III	197-229	213	30.05-44.21	37.13	181-349	265
SD		9.12		10.70		42.31
CV (%)		4.37		39.92		18.24
Wheat						
I	193-226	208	9.0-19.6	14.0	238-285	262
II	179-228	210	13.6-26.9	21.1	265-325	300
III	180-230	212	18.0-35.3	27.4	300-337	322
SD		13.69		6.87		28.00
CV (%)		6.51		32.91		9.50

Table 3. Grain yield of maize and wheat

Fertility strip	Grain yield (q/ha)			SD	CV (%)
	Minimum	Maximum	Average		
Maize					
I	20.86	78.43	49.64	18.09	32.32
II	26.71	82.81	54.76	17.92	30.63
III	33.52	84.14	58.83	17.03	28.31
Average	27.03	81.80	54.41	17.52	30.10
Wheat					
I	6.33	36.64	22.98	9.655	42.018
II	7.42	37.09	23.83	9.590	40.244
III	8.44	37.30	24.72	9.625	38.939
Average	6.33	37.30	23.84	9.514	39.909

for N, P_2O_5 and K_2O was recorded 22.53, 52.67 and 26.40 for maize and 10.00, 48.29 and 8.28 for wheat respectively. Ramamoorthy et al (1967) and Santhi et al (2004) also reported efficiency and contribution of soil and fertilizer for grain yield of maize in Inceptisols. However the per cent contribution from organic source (CFYM) was recorded 21.76, 4.70 and 12.81 for maize and 3.47, 5.45 and 2.13 for wheat respectively which was much lower than contribution from fertilizers and soil. These results indicate that there was remarkable contribution of soil nutrients. Similar results have been reported by Singh et al (2014) and Sahu et al (2017) for wheat crop. The soil test-based fertilizer N, P_2O_5 and K_2O adjustment equations for target yield of maize and wheat were developed by using the basic data (Table 4).

Fertilizer adjustment equation with regard to nitrogen, phosphorus and potassium requirement for targated yield of maize was:

FN= 3.81 Y – 0.54 SN – 0.52 FYM, FP= 1.13 Y – 1.86 SP – 0.17 FYM and FK= 1.31 Y – 0.19 SK – 0.09 FYM

Fertilizer adjustment equation with regard to nitrogen, phosphorus and potassium requirement for targated yield of wheat was:

FN= 6.96 Y – 0.34 SN – 0.12 FYM, FP= 2.96 Y – 2.57 SP – 0.29 FYM and FK= 2.83 Y – 0.11 SK – 0.03 FYM

The developed equations were useful in creating fertilizer prescription for maize and wheat crops in Inceptisols of Raigarh district of Chhattisgarh having similar soil and agro-climatic conditions. The equations are dynamic in nature as the doses of nutrients vary with the target yield of maize and wheat. The doses of fertilizer nutrients decreased with each unit increase in soil test values and vice-versa. These equations can be used for fertilizers alone or with FYM in maize-wheat cropping systems of Chhattisgarh. The soil test crop response (STCR)-based fertilizer application would serve the purpose of balance nutrient supply to the crops and improved efficiencies of inputs. The ready reckoner of soil-based fertilizer recommendations for various soil test values of N, P and K for getting different yield targets of maize and wheat were preferred (Table 5). Fertilizer rates increased as yield target of maize and wheat increased and fertilizer doses decreased as soil test values increased. Thus in targeted yield concept, yield potential of the crop variety and soil test values were taken into consideration while making fertilizer prescriptions (Singh et al 2018).

Table 4. Soil test-based fertilizer adjustment equations for targeted yield of maize and wheat

Parameter	Maize			Wheat		
	N	P_2O_5	K_2O	N	P_2O_5	K_2O
NR (kg/q)	1.59	0.32	1.84	2.02	0.56	2.12
CF (%)	41.84	28.28	140.33	29.03	18.79	74.74
CS (%)	22.53	52.67	26.40	10.00	48.29	8.28
CFYM (%)	21.76	4.70	12.81	3.47	5.45	2.13

Fertilizer adjustment equations:

Maize

FN= 3.81 Y – 0.54 SN – 0.52 FYM

FP= 1.13 Y – 1.86 SP – 0.17 FYM

FK= 1.31 Y – 0.19 SK – 0.09 FYM

Wheat

FN= 6.96 Y – 0.34 SN – 0.12 FYM

FP= 2.96 Y – 2.57 SP – 0.29 FYM

FK= 2.83 Y – 0.11 SK – 0.03 FYM

NR= Nutrient requirement, CF= Contribution of nutrients from fertilizers, CS= Contribution of nutrients from soil, CFYM= Contribution of nutrients from FYM, FN= N from fertilizer, FP= P from fertilizer, FK= K from fertilizer, SN= N from soil, SP= P from soil, SK= K from soil, Y= Yield

Table 5. Ready reckoner of soil test-based fertilizer recommendations for maize (Bio 9544) and wheat (GW-273) in Inceptisols with 5 tonnes of FYM

Soil test values (kg/ha)			Yield target of maize (q/ha)									Yield target of wheat (q/ha)								
			60			70			80			20			25			30		
N	P	K	FN	FP	FK	FN	FP	FK	FN	FP	FK	FN	FP	FK	FN	FP	FK	FN	FP	FK
150	4	200	145	60	50	183	71	63	221	82	76	88	47	34	122	62	49	157	77	63
175	6	225	132	56	45	170	67	58	208	78	71	79	42	32	114	57	46	149	72	60
200	8	250	118	52	40	156	63	53	194	75	66	71	37	29	105	52	43	140	67	57
225	10	275	105	48	35	143	60	49	181	71	62	62	32	26	97	47	40	132	62	55
250	12	300	91	45	31	129	56	44	167	67	57	54	27	23	88	42	38	123	57	52
275	14	325	78	41	26	116	52	39	154	64	52	45	22	21	80	37	35	115	51	49
300	16	350	64	37	21	102	48	34	140	60	47	37	17	18	71	31	32	106	46	46
325	18	375	51	33	16	89	45	30	127	56	43	28	11	15	63	26	29	98	41	44
350	20	400	37	30	12	75	41	25	113	52	38	20	6	12	54	21	27	89	36	41
375	22	450	24	26	7	62	37	20	100	49	33	11	6	10	46	16	24	81	31	38
400	24	500	10	22	2	48	34	15	86	45	28	3	6	7	37	11	21	72	26	35

FN= N from fertilizer, FP= P from fertilizer, FK= K from fertilizer

CONCLUSION

From these results it may be concluded that the soil test-based fertilizer N, P_2O_5 and K_2O adjustment equations for target yield of maize and wheat under integrated plant nutrient supply (IPNS) would result in balanced fertilization to achieve a pre-decided yield targets. The soil test crop response (STCR)-based fertilizer prescriptions may be popularized for higher production of maize and wheat as well as higher efficiency use of nutrients so as to improve farmers' economy. The fertilizers may be calculated for lower/ higher yield targets depending upon the availability of inputs. The ready reckoner may be used by soil testing laboratories for fertilizer recommendations in Chhattisgarh.

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