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Soil test crop response based fertilizer recommendation under integrated plant nutrient supply for rice-wheat cropping system in Inceptisols of Raigarh, Chhattisgarh

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ABSTRACT

Field experiments were carried out on rice (Oryza sativa) and wheat (Triticum aestivum) during Kharif and Rabi seasons 2014-15 to investigate the soil test crop response based fertilizer recommendation under integrated plant nutrient supply by following Ramamoorthy's inductive approach of fertility gradients in Inceptisol at the Instructional Farm of Krishi Vigyan Kendra, Raigarh (C.G.). The experiments were conducted on well developed fertility gradients. The nutrient requirement (NR), contribution of nutrients from soil (CS), fertilizer (CF) and farm yard manure (CFYM) were computed using the data on soil test values, fertilizer nutrients doses, nutrient uptake and rice and wheat yields. About 1.53 kg N, 0.33 kg P and 2.08 kg K were required to produce one quintal of rice grain Similarly, 2.02 kg N, 0.56 kg P and 2.12 kg K were required for producing one quintal of wheat grain. The per cent contribution from fertilizer for N, P and K was estimated 36.36, 19.60 and 104.53 and 29.03, 18.79 and 74.74 per cent for rice and wheat crops, respectively. The per cent contribution from soil was recorded as 18.13 for N, 61.40 for P and 20.94 for K in rice and 10.00 for N, 48.29 for P and 8.28 for K in wheat crop. The per cent contribution of organic source (FYM) for N, P and K were recorded 6.95, 3.35 and 2.92 and 3.47, 5.45 and 2.13 for rice and wheat crops, respectively. Based on the above basic parameters, soil test based fertilizers adjustment equations were evolved for rice and wheat crop to achieve a definite yield target. Ready reckoners chart for fertilizer N, P_2O_5 and K_2O application based on the soil test values for specific yield targets of rice and wheat were also prepared which are useful for the soil testing laboratories.

Key words: Rice, wheat, STCR, FYM, fertilizer recommendations, ready reckoner

INTRODUCTION

Efficient fertilizer use ensures increased production, high profit and environmental protection. The most appropriate balanced and economic doses of fertilizers can be evolved on the basis of soil test and crop response studies. At present, 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) presently 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 lead imbalance 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 source as an INM approach (Singh 2017 and Singh and Singh 2018). Considering the soil fertility status, crop requirement of nutrients, efficiency of fertilizer, soil and organic source 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, Ramamoorthy *et al.* (1967) established the theoretical basis and experimental proof for the fact that Liebig's law of minimum operates equally well for N, P and K. Among the various methods of fertilizer recommendation, yield targeting is unique in the sense that this method not only indicate 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

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inorganic (non-renewable) sources of nutrient for sustainable crop production and better soil health. Therefore, there is a need for improvement of input use efficiency through proper integration of chemical fertilizer with organic manure by balanced nutrition of crop. Rice (*Oryza sativa*) and wheat (*Triticum aestivum*) crops are the most important cereal crops of the world that supplement the carbohydrate and protein requirement of our population. Rice-Wheat cropping system is followed in major part of 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 balanced fertilizer recommendation based on soil test values for desired yield targets under rice-wheat cropping system in Inceptisols, Raigarh district of Chhattisgarh.

MATERIALS AND METHODS

The field experiments were conducted on rice (MTU-1010) and wheat (GW-273) during 2014-15 for evaluating the soil test crop response under integrated plant nutrient supply system at the Instructional Farm of Krishi Vigyan Kendra, Raigarh (C.G.). 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 above the mean sea level (MSL). The soil of the experimental fields was an Inceptisol of silty clay loam texture with pH 6.50, EC 0.13 dSm^{-1} and organic carbon 5.0 g kg^{-1}. The experiments were conducted in two phases following the inductive approach in which fertility gradients 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^{-1} of N, P_2O_5 and K_2O, respectively and third strip was treated with 240, 120 and 120 kg ha^{-1} of N, P_2O_5 and K_2O, respectively. Green gram was grown for natural transformation of applied fertilizer and grown crop was burried before main experiment and soil of each fertility strip was tested to confirm the creation of fertility gradient 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.

Table 1: Fertilizer and FYM treatment combinations in different strips

Plot No.	Strip I	Strip II	Strip III
1	$N_2P_3K_3F_2$	$N_0P_0K_0F_2$	$N_2P_2K_0F_2$
2	$N_3P_3K_3F_2$	$N_1P_2K_1F_2$	$N_3P_2K_2F_2$
3	$N_0P_0K_0F_1$	$N_1P_1K_2F_1$	$N_0P_0K_0F_1$
4	$N_2P_3K_2F_1$	$N_0P_0K_0F_1$	$N_1P_2K_1F_1$
5	$N_2P_2K_3F_0$	$N_3P_1K_1F_0$	$N_1P_1K_2F_0$
6	$N_2P_2K_2F_0$	$N_2P_1K_2F_0$	$N_0P_2K_2F_0$
7	$N_0P_0K_0F_2$	$N_1P_1K_1F_2$	$N_2P_2K_2F_2$
8	$N_OP_2K_2F_2$	$N_2P_2K_1F_2$	$N_2P_1K_2F_2$
9	$N_3P_1K_1F_1$	$N_3P_3K_1F_1$	$N_2P_1K_1F_1$
10	$N_3P_2K_2F_1$	$N_3P_2K_3F_1$	$N_1P_1K_1F_1$
11	$N_3P_2K_1F_0$	$N_3P_2K_2F_0$	$N_3P_3K_2F_0$
12	$N_0P_0K_0F_0$	$N_0P_0K_0F_0$	$N_3P_2K_3F_0$
13	$N_3P_3K_1F_2$	$N_2P_1K_1F_2$	$N_3P_1K_1F_2$
14	$N_3P_3K_2F_2$	$N_2P_2K_3F_2$	$N_1P_2K_2F_2$
15	$N_2P_1K_2F_1$	$N_3P_3K_2F_1$	$N_2P_2K_1F_1$
16	$N_1P_2K_2F_1$	$N_3P_3K_3F_1$	$N_2P_0K_2F_1$
17	$N_1P_2K_1F_0$	$N_2P_2K_2F_0$	$N_3P_3K_1F^0$
18	$N_1P_1K_1F_0$	$N_1P_2K_2F_0$	$N_3P_3K_3F_0$
19	$N_1P_1K_2F_2$	$N_2P_0K_2F_2$	$N_0P_0K_0F_2$
20	$N_3P_2K_3F_2$	$N_3P_2K_1F_2$	$N_2P_3K_2F_2$
21	$N_2P_2K_0F_1$	$N_0P_2K_2F_1$	$N_3P_2K_1F_1$
22	$N_2P_2K_2F_1$	$N_2P_3K_3F_1$	$N_2P_2K_3F_1$
23	$N_2P_1K_1F_0$	$N_2P_3K_2F_0$	$N_0P_0K_0F_0$
24	$N_2P_2K_1F_0$	$N_2P_2K_0F_0$	$N_2P_3K_3F_0$

Where N_0, N_1, N_2 and N_3 are 0,50,100 and 150 kg N ha^{-1}, P_0, P_1, P_2 and P_3 are 0,30,60 and 90 kg P_2O_5 ha^{-1} , K_0, K_1, K_2 and K_3 are 0,30,60 and 90 kg K_2O ha^{-1} and F_0, F_1 and F_2 are 0, 5 and 10 t FYM ha^{-1}, respectively

After confirming the establishment of fertility gradient in the experimental field, the experiment was laid out for the second phase by sowing the test crop of rice (MTU-1010) 24th July, 2014 and wheat (GW-273) 28th November, 2014. 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 rice comprising 4 levels of N (0, 50, 100, 150 kg h^{-1}),

P_2O_5 (0, 30, 60, 90 kg h^{-1}) and K_2O (0, 30, 60 90 kg h^{-1}) and same doses in the same treatment structure was taken with wheat crop during *Rabi* seasson. Three levels of FYM *i.e.* 0, 5 and 10 t ha^{-1} was 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 of 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 (rice and wheat) were raised up to maturity by following standard agronomic practices in same field. The 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 was 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 and 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 of nutrients from soil (CS), fertilizers (CF) and FYM (CFYM) were computed following the equations given by Ramamoorthy *et al* (1967). These basic data was 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 IPNS.

RESULTS AND DISCUSSION

Soil available nutrients

The data on range and mean values of available N, P and K after creation of fertility gradients and before sowing of rice 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 N bebore sowing of rice and wheat varied from 175 to 228 and 173 to 230 kg ha^{-1}, respectively. Available P varied from 10.8 to 32.5 and 9.0 to 35.3 kg ha^{-1} and available K from 241 to 337 and 238 to 337 kg ha^{-1} before sowing of rice and wheat, respectively. Such variation in nutrient status of different plots and strips is ideal for conducting soil test crop response experiments.

Table 2: Soil test values before sowing of rice and wheat

Strip	Available N (kg ha^{-1})		Available P (kg ha^{-1})		Available K (kg ha^{-1})	
	Range	Mean	Range	Mean	Range	Mean
			Rice			
I	175-122	206	10.8-17.1	13.7	241-280	262
II	181-228	209		20.6	269-322	300
III	181-226	211	14.5-25.5	26.7	302-337	323
SD		11.84		6.07		27.86
CV (%)		5.68	21.1-32.5	29.75		9.45
			Wheat			
I	173-226	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		27.4	300-337	322
SD		13.69	18.0-35.3	6.87		28.00
CV (%)		6.51		32.91		9.50

Yield

The grain yield of rice and wheat in control plots ranged from 20.25 to 25.12 q ha^{-1} and 6.33 to 8.44 q ha^{-1}, respectively in different fertility strips (Table 3). Variation in control yield of rice and wheat between strips might be due to variation in soil fertility status. Rice yield increased from 20.25 q ha^{-1} in control to 65.43 q ha^{-1} where 150, 90 and 90 kg ha^{-1} N, P_2O_5 and K_2O, respectively and 10 t FYM ha^{-1} were applied. However, wheat yield increased from 6.33 q ha^{-1} in control to 37.30 q ha^{-1} in highly fertilized plots. This reveals that there was a tremendous response to applied nutrients in rice and wheat. The yields in various treatments were in accordance with the doses nutrient and FYM, indicating high responsiveness of the crop to soil fertility and fertilizer application. Mean grain yield of rice and wheat in strip I, II and III were 44.46, 46.66 and 47.90 and 22.98, 23.83 and 24.72 q ha^{-1}, respectively. The data on yields and soil test values (Table 2 and 3) clearly depicted 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 and Singh *et al.* 2017).

Table 3: Grain yield of rice and wheat

Fertility strip	Grain yield (q ha^{-1})			SD	CV (%)
	Minimum	Maximum	Average		
Rice					
I	20.25	65.43	44.46	14.265	32.085
II	23.03	65.05	46.66	13.794	29.562
III	25.12	65.06	47.90	13.863	28.941
Overall	20.25	65.43	46.34	13.851	29.890
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
Overall	6.33	37.30	23.84	9.514	39.909

Basic data for targeted yield equations and ready reckoners

Requirement of N, P_2O_5 and K_2O for production of one quintal rice and wheat was 1.53 and 2.02 0.33 and 0.56 and 2.08 and 2.12 kg ha^{-1}, 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. The per cent contribution from fertilizer for these nutrients were 36.36, 19.60 and 104.53 for rice and 29.03, 18.79 and 74.74 for wheat, respectively. However, the per cent contribution from FYM was 6.95, 3.35 and 2.92 for rice and 3.47, 5.45 and 2.13 for wheat, respectively, which was much lower than contribution from fertilizers and soil.

Table 4: Basic data and soil test based fertilizer adjustment equations for targeted yield of rice and wheat

Parameters	Rice			Wheat		
	N	P_2O_5	K_2O	N	P_2O_5	K_2O
NR (kg q^{-1})	1.53	0.33	2.08	2.02	0.56	2.12
CF (%)	36.36	19.60	104.53	29.03	18.79	74.74
CS (%)	18.13	61.40	20.94	10.00	48.29	8.28
CFYM (%)	6.95	3.35	2.92	3.47	5.45	2.13
Fertilizer adjustment equations	FN = 4.21 Y - 0.50 SN - 0.19 FYM FP = 1.69 Y – 3.13 SP - 0.17 FYM FK = 1.99 Y - 0.20 SK - 0.03 FYM			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		

The per cent contribution of soil to total nutrient removal for N, P_2O_5 and K_2O was 18.13, 61.40 and 20.94 for rice and 10.00, 48.29 and 8.28 for wheat, respectively. These results indicated 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 in UP and Chhattisgarh, respectively. The soil test based fertilizer N, P_2O_5 and K_2O adjustment equations for target yield of rice 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 rice and wheat were FN = 4.21 Y - 0.50 SN - 0.19 FYM, FP = 1.69 Y – 3.13 SP - 0.17 FYM and FK = 1.99 Y - 0.20 SK - 0.03 FYM and 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, respectively. The developed eqations were useful in creating fertilizer recommendations for rice and wheat crops in Inceptisols of Raigarh and adjoining areas 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 rice and wheat. The doses of fertilizer nutrients decreased with each unit increase in soil test values and vice-versa. These equation can be used for fertilizers alone or with FYM in rice-wheat croping systems of Chhattisgarh. The 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 rice and wheat were preferred (Table 5). Fertilizer rates increased as yield target of rise 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 recommendation.

Table 5: Ready reckoner of soil test based fertilizer recommendations for rice (MTU-1010) and wheat (GW-273) in *Inceptisols* with 5 tons of FYM

Rice											
Soil Test values (kg ha^{-1})			Yield Target (q ha^{-1})								
			40			50			60		
N	P	K	FN	FP	FK	FN	FP	FK	FN	FP	FK
100	4	200	117	54	39	160	71	59	202	88	79
125	6	225	105	48	34	147	65	54	189	82	74
150	8	250	92	42	29	135	59	49	177	76	69
175	10	275	80	35	24	122	52	44	164	69	64
200	12	300	67	29	19	110	46	39	152	63	59
225	14	325	55	23	14	97	40	34	139	57	54
250	16	350	42	17	9	85	34	29	127	50	49
275	18	375	30	10	4	72	27	24	114	44	44
300	20	400	17	4	4	60	21	19	102	38	39
325	22	425	5	4	4	47	15	14	89	32	34
350	24	450	5	4	4	35	9	9	77	25	29
375	26	475	5	4	4	22	2	4	64	19	24
400	28	500	5	4	4	10	2	4	52	13	19
Wheat											
Soil Test values (kg ha^{-1})			Yield Target (q ha^{-1})								
			20			25			30		
N	P	K	FN	FP	FK	FN	FP	FK	FN	FP	FK
150	4	200	88	47	34	122	62	49	157	77	63
175	6	225	79	42	32	114	57	46	149	72	60
200	8	250	71	37	29	105	52	43	140	67	57
225	10	275	62	32	26	97	47	40	132	62	55
250	12	300	54	27	23	88	42	38	123	57	52
275	14	325	45	22	21	80	37	35	115	51	49
300	16	350	37	17	18	71	31	32	106	46	46
325	18	375	28	11	15	63	26	29	98	41	44
350	20	400	20	6	12	54	21	27	89	36	41
375	22	425	11	6	10	46	16	24	81	31	38
400	24	450	3	6	7	37	11	21	72	26	35
425	26	475	3	6	4	29	6	18	64	21	33
450	28	500	3	6	4	20	6	16	55	15	30

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 rice and wheat under IPNS would result in balanced fertilization to achieve a pre-desided yield targets. The STCR based fertilizer recommendations may be popularized for higher production of rice and wheat as well as higher efficiency use of nutrients so as to improvement of farmer's economy. The fertilizers may be calculated for lower/higher yields targets depending upon the availability of inputs. The ready reckoner may be used by soil testing laboratories for fertilizer recommendations in Chhattisgarh state.

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