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Rice Response to Fertilizer Nutrients as Influenced by Integrated Nutrients Management in Vertisols of Chhattisgarh Plain, India

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A B S T R A C T

Field experiment was conducted to development of fertilizer adjustment equations for rice crop in *Vertisol* of Chhattisgarh plain region of Chhattisgarh state. Rice crop required 1.52 kg N, 0.38 kg P and 2.03 kg K to produce one quintal grain yield. Fertilizer and soil test efficiencies were estimated 27.75, 24.60 and 87.15 percent and 25.60, 66.35 and 15.85 percent respectively for N P K. The efficiency of FYM in terms of available nutrient was evaluated as 13.85, 7.10 and 11.05 percent respectively. On the basis these parameters, fertilizer N, P_2O_5 and K_2O were derived for different targeted yield of rice by using FYM as organic component in INM approach.

Introduction

The demand of food grain by expending population of our country must be met out by increasing production from per unit area as there is very limited scope to increase the cultivated area. It requires extensive research on different aspects to provide a scientific basis for enhancing and sustaining food production as well as soil productivity with minimum environmental degradation. Fertilizers are generally applied to crops on the basis of generalized state level fertilizer recommendations. However, the fertilizer requirement of a crop is not a static one and it may vary for the same crop from soil to soil and even from field to field on the same soil. Soil testing as a diagnostic tool, the value of soil testing in both general and specific terms is to identify soil fertility problems and constraints in an area and to give specific fertilizer recommendation based on soil analysis of a farm holding.

Considering the soil fertility status, crop requirement of nutrients, efficiency of soil and fertilizers 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. 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. This forms the basis of fertilizer application for targeted yields.

Materials and Methods

A field experiment was conducted at the farm of Indira Gandhi Krishi Vishwavidyalaya, Raipur (Chhattisgarh) on soil test crop response correlation with hybrid rice (variety Indira Sona) during two kharif consecutive season in 2008-09 and 2009-10 in *Vertisol*. The soil of the experimental field comes under the soil order of *Vertisol*. This soil is locally known as *Kanhar* and identified as Arang II series. It is clayey in texture with 23.3 % Sand, 21.4% silt and 55.3% clay, dark brown to black in color, neutral to alkaline in reaction due to presence of lime concretion in lower horizon. The soil is deep to 1-1.5 meter. The structure varied from coarse angular blocky to massive and cloddy and in few cases from prismatic or columnar. Soil is represented as typical *fine montmorillonitic, hyperthermic, udic chromustert.* Some physico-chemical properties of experimental soil were analyzed which found 7.8 pH (1:2.5), 0.27 EC (dSm^{-1}), 39.55 CEC (c mol (p^{+}) kg^{-1}), 4.2 Organic C ($g\ kg^{-1}$), 224 Available N ($kg\ ha^{-1}$), 16.28 Available P ($kg\ ha^{-1}$) and 454 Available K ($kg\ ha^{-1}$). The experiment was conducted according to approved layout plan of All India Coordinated Research project for Investigation on Soil Test Crop Response Correlation (STCR). A special field technique developed by Ramamurthy *et al.* (1967) was used for this study. The field was divided in to three equal long strips and denoted as L_0, L_1 and L_2. Prior to conducting the actual field experiment, a fertility gradient was created by applying the graded doses of N, P and K fertilizer for obtaining the appropriate variation in soil fertility in different strips. Variation in soil fertility with respect to N, P and K were created by applying 100-75-50 and 200-150-100, $kg\ ha^{-1}$ of N, P_2O_5 and K_2O in L_1 and L_2 strip, respectively and keeping L_0 strip as unfertilized (control). Fodder maize crop was grown during summer season 2008 as a preparatory crop so that fertilizer could interact with soil, plant and microbes and thus become a part of soil system. In this way by growing the exhaust crop, the ranges of soil fertility were created in the fertility strips which were evaluated in terms of variations in fodder yields and soil test values. After the harvest of the fodder crop, the main complex experiment with hybrid rice was conducted in subsequent *kharif* season. Each strip was divided in to three equal sizes for three levels of FYM (0, 5 and 10 $t\ ha^{-1}$) and was treated as block. A representative sample of applied FYM was analyzed for nutrient content and resulted as 0.4. 0.3, 0.8 per cent N, P and K, respectively. The 24 selected fertilizer treatments constituted 4 levels of each of N (0, 60, 120 and 180 $kg\ ha^{-1}$), P_2O_5 (0, 40, 80 and 120 $kg\ ha^{-1}$) and K_2O (0, 40, 80 and 120 $kg\ ha^{-1}$). Theses were distributed in each block of the strips having 8 treatments in each block.

The fertilizer materials were used as urea, single supper phosphate and muriate of potash for the source of N P and K nutrient, respectively. Full dose of P_2O_5 and K_2O and $1/3^{rd}$ of N were applied as basal, remaining $2/3^{rd}$ of N applied in two equal splits as top dressing at tillering and panicle initiation stages. Grain and straw samples were analyzed for N, P and K content (Piper 1966) and total nutrient uptake was computed using grain and straw yield data. Using the data on grain yield, nutrient uptake, pre-sowing soil available nutrients and fertilizer doses applied the basic parameter, *viz*. nutrient requirement ($kg\ q^{-1}$), contribution of nutrients from soil and fertilizer sources were calculated as described by Ramamoorthy *et al.* (1967). The contribution of nutrients from applied FYM was estimated by relating the yield with fertilizer nutrients and FYM. These parameters were used for the formulation of fertilizer adjustment equations for deriving fertilizer doses and the soil test based fertilizer recommendations were prescribed in the form of ready reckoners for desired yield target of rice under N, P, K alone as well as IPNS.

Results and Discussion

Soil test levels as affected by past fertilization

As per the approach suggested by Ramamurthy (1967), variation in soil fertility was deliberately created by adding graded fertilizer doses (Table 1) and maize was sown as exhaust crop during summer season, 2008 so that the added nutrients may naturally transform in to the soil system. Fodder yield of maize in different fertility strips indicated that gradient in fertility level exists. After harvest of maize crop, soil samples were analyzed from each strip. Maize yield and soil test data (Table 1) show that there were little variations in soil test N (alkaline $KMnO_4$-N). However, the variations in Olsen's P were quite marked and ammonium acetate extractable- K did not reflect variations in different fertility strips. Gradient with respect to P was observed quite marked, as the nature of P is immobile and subjected to fix in soil particularly high in *Vertisols*. Phosphorus ions react very quickly with soil constituents to form insoluble compounds depending on the nature of soil, and thus remains in soil. However, there was no gradient created with respect to N and K as the nature of N in soil is very dynamic and its different forms are subjected to losses through leaching volatilization and de-nitrification. The high K status of the experimental field soil and maintenance of its dynamic equilibrium might be the possible reason for almost the same soil test K levels in all strips.

Status of available NPK in soil

Before taking the main complex experiment with rice during *kharif* season 2008 and 2009, the soil samples from each plot were taken and analyzed for available N, P and K. Table 2 reveals the range and means values of available nutrients (N, P and K) during two rice seasons. As discussed in previous section, the data indicate no variations in soil test N across the fertility strips in both the rice season. Mean values on soil N ranged from 240-244 and 234-24 kg ha^{-1} during 2008 and 2009 *kharif* season, respectively. The level of soil P increased with respect to fertility strips from L_0 to L_2. Average soil P ranged from 13.90 - 35.30 and 15.23-36.88 kg ha^{-1} in two rice seasons. The available K status did not reflect with respect to fertility strips indicating that the soil of experimental field is well supplied with K.

Response of rice to added nutrients

The results (Table 3) showed the range and average values of rice yields in relation to fertility strips during two rice crop seasons. The ranges of rice yields were recorded as 21.54 - 67.62 q ha^{-1} with average of 55.23 q ha^{-1} in L_0 strip, 35.86-67.77 q ha^{-1} with average of 58.69 q ha^{-1} in L_1 strip and 41.20-67.27 q ha^{-1} with average of 61.18 q ha^{-1} in L_2 strip during first rice season 2008. It was also noticed that standard deviation (SD) and per cent coefficient of variation (CV) levels were higher in L_0 strip and they reduced under L_1 and L_2 strips. Similar trends were also observed during next rice season 2009. This indicates that variation in soil test values was higher in L_0 strip then those of L_1 and L_2 strips which reflected on crop yields. The increase in rice grain yields with respect to fertility strips may be due to fertility gradient in soil P status from L_0 to L_2 strip.

The relation of rice yields with different nutrients as independent variables were derived by regression analysis for both the rice season to evaluate the contribution of soil tests in modifying the crop response to added fertilizer nutrients as presented in the Table 4.

Results indicate that the larger proportion of variation in the hybrid rice grain yield was accounted for by N alone. However, its quadratic term gave better fit into the data as evidence from the higher R^2 value (0.80) with curvilinear equation (Eq. No. 2) in both the seasons. High response of hybrid rice was attributed to the high N requirement and being a mobile nature of this element, it is accessible to the plant in the root system sorption zone (Ramamoorthy *et al.*, 1967). Fertilizer P_2O_5 and K_2O were the next to explain the rest of variations.

The P ions react very quickly with soil constituents to form insoluble compounds and are thus rendered immobile in the soil. Furthermore, the requirement of P nutrient in rice is lower than N. The curvilinear nature of rice yield response to P application can therefore be attributed to the above facts. Response of rice to FYM was significant but had less marked as compared to fertilizer N, P and K. Fertilizer N application with FYM could explain 21 and 31% more grain yield variation (Eq. No. 11) than fertilizer P_2O_5 with FYM and fertilizer K_2O with FYM (Eq. No. 12 & 13). This relation shows the better efficiency of fertilizer N with FYM application.

The rice responses to FYM and fertilizer N, P, K in two rice seasons (2008 & 2009) have also been depicted in Figs. 1 to 4 on above facts. Mahindar Kumar *et al.,* (2009), Pandey *et al.*, (2009), Singh *et al.*, (2009) and Banerjee and Pal (2009) have reported on response of different crops to applied N P K and FYM.

Relationship between yield and nutrient uptake

A close association was observed between the yield of hybrid rice and total N, P and K uptake in both years 2008-09 and 2009-10. This relation was used to estimate the nutrient requirement for rice (Table 5). The nutrient requirement (NR) is defined as the amount of nutrient required to produce unit amount of yield per unit quantity of fertilizer applied. The nutrient requirement can be given by the regression coefficient (b_1) of yield (Y) and total nutrient uptake (U).

$Y = b_1 U$ or $U = 1/b_1 * Y$

Where, $1/b_1$ gives the NR

The amount of nutrients absorbed by the crop decides a definite amount of biomass production. The amount of nutrient required to produce one quintal of rice grain during *kharif* season 2008 was found to be 1.49 kg N, 0.39 kg P and 2.13 kg K and 1.54 kg N, 0.37 kg P and 1.92 kg K in the next *kharif* season 2009. The overall mean values (Table 6) can be considered as 1.52 kg N, 0.38 kg P and 2.03 kg K to calculate the fertilizer requirement of rice based on the soil test results to achieve a definite yield target.

Several workers have reported the nutrient requirement of different crops at various places. Ramamoorthy *et al.,* (1967) reported for wheat crop which required 2.5 kg N, 0.8 kg P_2O_5 and 1.0 kg K_2O for one quintal of grain production. Stanford *et al.,* (1965) reported for sugarcane crop as 0.91 kg N uptake to produce a ton of net cane. Prasad *et al.* (1981) estimated the nutrient requirement of sugarcane at Sugarcane Research Institute, Pusa, Bihar, for the production of 1 ton of cane as 1.71 kg N, 0.18 kg P_2O_5 and 1.80 kg K_2O.

Efficiencies of fertilizer, soil test and FYM

The efficiencies of fertilizer, soil test and FYM were estimated by using the conventional methods with the help of STCR software developed by IISS, Bhopal. Table 7 contained the results for rice season 2008 and 2009. The average values based on two rice season for fertilizer efficiencies of N P and K were estimated as 27.20, 24.60 and 87.15 per cent, respectively. Similarly, average soil test efficiencies estimated for N P and K were as 25.60, 66.35 and 15.85 per cent, respectively. The efficiencies of organic source (FYM) were observed as 13.85 % N, 7.10 % P and 11.05 % K.

It is well known that 2/3rd of the applied fertilizer N is lost through leaching, volatilization, denitrification and by run-off particularly in rice crop. Similarly, a large fraction of applied fertilizer P is fixed in soil by reacting with dominant cations present in the soil like Ca, Mg, Fe, Mn etc.

Table.1 Fertilizer doses added to various strips and fodder yield of maize during summer season, 2008 to create fertility gradient (Pre-requisite for main complex experiment)

Fertility Strips	Fertilizer doses (kg ha^{-1})			Fodder yield (t ha^{-1})	Post harvest soil test values (kg ha^{-1})		
	N	P_2O_5	K_2O		SN	SP	SK
L_0	0	0	0	19.24	235	10.28	442
L_1	100	75	50	21.24	242	17.82	465
L_2	200	150	100	26.12	249	27.34	475

Table.2 Range and average values of available N, P and K (kg ha-1) before rice (kharif seasons, 2008 and 2009)

Available nutrients	Fertility strips							
	Kharif season 2008				Kharif season 2009			
	L_0	L_1	L_2	SD	L_0	L_1	L_2	SD
Alkaline $KMnO_4$-N (kg ha^{-1})	172 - 254 (240)	188 - 258 (241)	215 - 258 (244)	15.25	170 - 247 (234)	187 - 250 (236)	206 - 255 (243)	15.13
Olsen P (kg ha^{-1})	10.2- 18.6 (13.90)	18.6 - 31.8 (25.10)	29.7- 42.6 (35.3)	9.36	10.9 - 23.7 (15.23)	16.4 - 36.9 (27.04)	25.4 - 46.3 (36.88)	9.98
Amm. acetate extractable K (kg ha^{-1})	461- 541 (497)	464 - 562 (499)	450 - 538 (499)	23.40	448 - 535 (503)	452 - 540 (504)	459 - 541 (505)	20.37

Table.3 Range and mean of grain yields of rice during kharif season 2008 and 2009 in relation to fertility strips

Fertility Strips	Grain yield (q ha^{-1})			SD	CV (%)
	Minimun	Maximum	Average		
Kharif season, 2008					
L_0	21.54	67.62	55.23	12.18	22.05
L_1	35.86	67.77	58.69	9.32	15.88
L_2	41.20	67.29	61.18	8.03	13.13
All strips	21.54	67.77	58.37	10.16	17.40
Kharif season, 2009					
L_0	19.23	67.65	56.52	13.03	23.05
L_1	32.44	69.77	58.97	10.03	17.01
L_2	40.46	67.02	61.14	8.04	13.15
All strips	19.23	69.77	58.88	10.59	17.98

Table.4 Selected regression model to account for yield variation of hybrid rice 2008 and 2009

Eq. No.	Model	R^2
Rice, 2008		
1	$Y = 45.72 + 0.119\ FN$	0.62
2	$Y = 39.91 + 0.335\ FN – 0.0011\ FN^2$	0.80
3	$Y = 48.84 + 0.157\ FP$	0.55
4	$Y = 45.06 + 0.347\ FP – 0.0015\ FP^2$	0.63
5	$Y = 50.48 + 0.143\ FK$	0.39
6	$Y = 47.09 + 0.325\ FK – 0.0015\ FK^2$	0.46
7	$Y = 59.63 + 0.49\ FYM$	0.20
8	$Y = 59.19 + 1.04\ FYM – 0.0543\ FYM^2$	0.18
9	$Y = 43.215 + 0.100\ FN + 0.066\ FP$	0.64
10	$Y = 12.186 + 0.109\ FN + 0.142\ SN$	0.63
11	$Y = 49.977 + 0.124\ FN + 0.604\ FYM$	0.65
12	$Y = 44.814 + 0.158\ FP + 0.604\ FYM$	0.44
13	$Y = 46.678 + 0.141\ FK + 0.604\ FYM$	0.34

	Rice, 2009	
1	$Y = 46.20 + 0.120\ FN$	0.58
2	$Y = 39.99 + 0.351\ FN – 0.0012\ FN^2$	0.79
3	$Y = 48.84 + 0.166\ FP$	0.58
4	$Y = 44.33 + 0.392\ FP – 0.0018\ FP^2$	0.69
5	$Y = 50.59 + 0.15\ FK$	0.43
6	$Y = 44.77 + 0.422\ FK – 0.0021\ FK^2$	0.57
7	$Y = 60.48 + 0.445\ FYM$	0.16
8	$Y = 59.99 + 1.028\ FYM – 0.058\ FYM^2$	0.16
9	$Y = 43.170+0.099FN+0.076FP$	0.62
10	$Y = 42.185 + 0.093\ FN+0.056\ FP+0.047\ FK$	0.64
11	$Y = 42.286 + 0.127FN + 0.587\ FYM$	0.62
12	$Y = 44.904 + 0.167FP + 0.587\ FYM$	0.44
13	$Y = 46.872 + 0.147\ FK + 0.587\ FYM$	0.34

Where, FN, FP and FK are fertilizer N, P_2O_5 and K_2O (Kg ha^{-1}) respectively. FYM is Farm Yard Manure (t ha^{-1}). SN, SP and SK are soil test values (kg ha^{-1}) for $KMnO_4$- N, Olsen's P and ammonium acetate extractable K and Y is crop yield.

Table.5 Relation of rice yield (Y) with total nutrient uptake (U)

Nutrient	2008		2009	
	$Y = b_1 U$	R^2	$Y = b_1 U$	R^2
N	Y = 0.67 U	0.98	Y = 0.65 U	0.97
P	Y = 2.57 U	0.97	Y = 2.67 U	0.95
K	Y = 0.47 U	0.96	Y= 0.52 U	0.96

Table.6 Nutrient requirements for hybrid rice

Nutrients	Nutrient requirement for one quintal grain yield of hybrid rice (kg q^{-1})		
	2008	2009	Mean
N	1.49	1.54	1.52
P	0.39	0.37	0.38
K	2.13	1.92	2.03

Table.7 Efficiencies of fertilizer, soil and FYM for hybrid rice

Nutrient	Nitrogen			Phosphorus			Potassium		
	2008	2009	Mean	2008	2009	Mean	2008	2009	Mean
Fertilizer efficiency (%)	26.1	29.4	27.75	28.3	20.9	24.60	92.9	81.4	87.15
Soil Test efficiency (%)	25.8	25.4	25.60	61.9	70.8	66.35	16.6	15.1	15.85
FYM efficiency (%)	13.5	14.2	13.85	7.9	6.3	7.10	12.4	9.7	11.05

Table.8 Fertilizer adjustment equations for hybrid rice

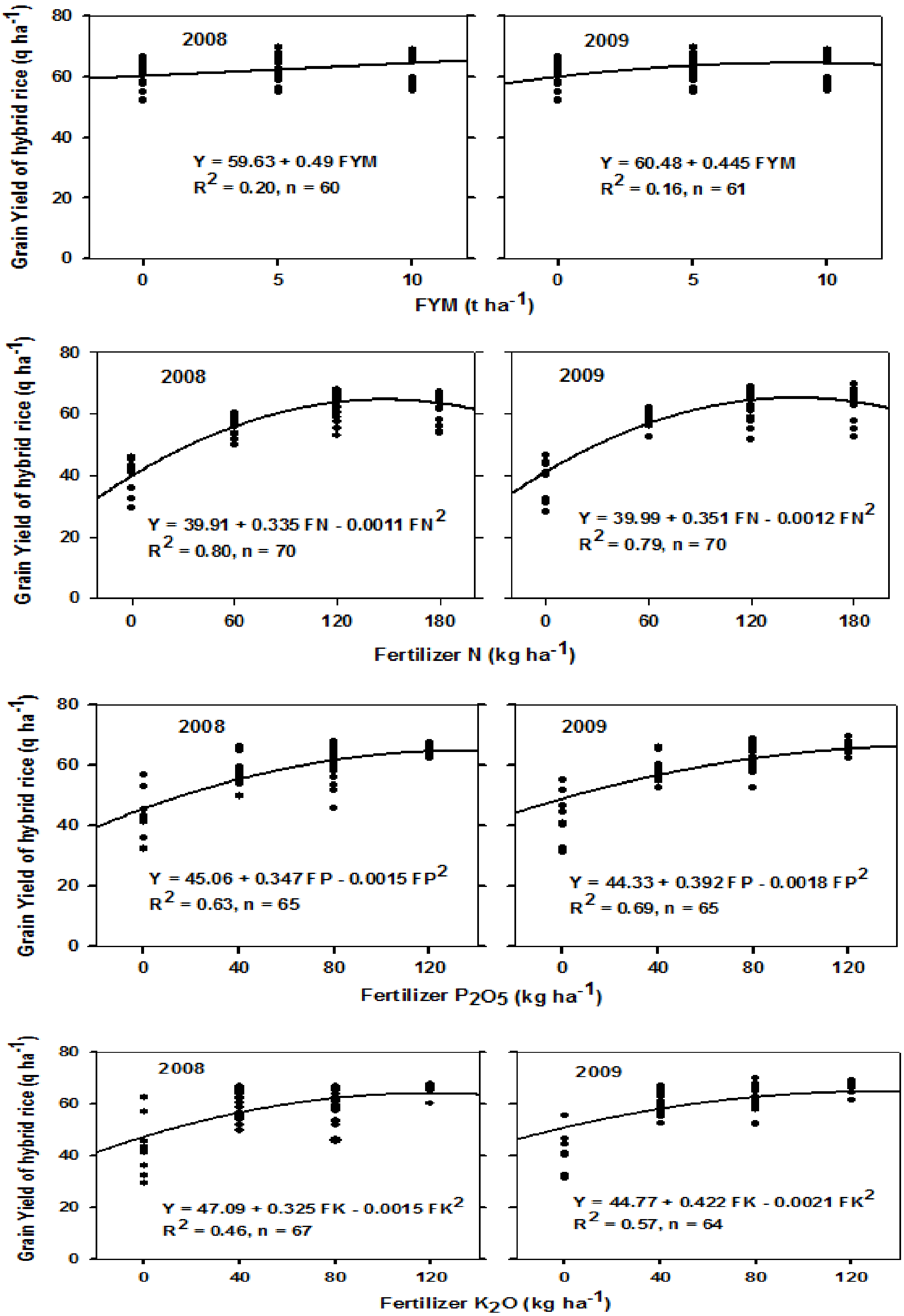
S. No.	Fertilizer adjustment equations for hybrid rice
1	FN = 5.48 Y – 0.92 SN - 0.50 FYM
2	FP = 1.54 Y – 2.70 SP - 0.29 FYM
3	FK = 2.34 Y - 0.18 SK - 0.13 FYM

Where, FN, FP and FK are fertilizer N, P_2O_5 and K_2O (Kg ha^{-1}) respectively. FYM is Farm Yard Manure (t ha^{-1}). SN, SP and SK are soil test values (kg ha^{-1}) for $KMnO_4$- N; Olsen's P and ammonium acetate extractable K and Y is crop yield in q ha^{-1}.

Table.9 Ready reckoners for fertilizer N P and K recommendations based on soil test levels with 5 tons of FYM for hybrid rice (Indira Sona) in Vertisols of Chhattisgarh

Soil Test levels (kgha^{-1})			Yield target of hybrid rice (q ha^{-1})								
			50			60			70		
SN	SP	SK	FN	FP	FK	FN	FP	FK	FN	FP	FK
150	6	250	134	59	71	188	75	95	243	90	118
175	8	275	111	54	67	165	69	90	220	85	114
200	10	300	88	49	62	142	64	86	197	79	109
225	12	325	65	43	58	119	59	81	174	74	105
250	14	350	42	38	53	96	53	77	151	69	100
275	16	375	19	32	49	73	48	72	128	63	96
300	18	400	00	27	44	50	42	68	105	58	91
325	20	425	00	22	40	27	37	63	82	52	87
350	22	450	00	16	35	04	32	59	59	47	82
375	24	475	00	11	31	00	26	54	36	42	78
400	26	500	00	05	26	00	21	50	13	36	73

Figure.1 Response of hybrid rice to different levels of FYM application and fertilizer of N, P_2O_5, K_2O, in Kharif season 2008 & 2009



High efficiency of applied fertilizer K observed seems to be due to higher uptake of this nutrient as luxury consumption. In case of cauliflower crop, fertilizer efficiency was observed more than 100 % which shows the experimental field soil is well supplied with native soil K having high status of ammonium acetate extractable (available) K. Soil test efficiencies for N and K were recorded less than fertilizer sources and reverse trend was seen in case of soil test Ramamoorthy *et al.*, (1967) reported the efficiency of soil N, P and K were 37, 14 and 44 per cent, respectively and the efficiency of fertilizer N, P and K were 34, 41 and 36 per cent, respectively.

The contributions (%) from soil and fertilizer nutrients were 21.31 and 44.37 for N, 25.38 and 27.71 for P and 5.76 and 48.57 for K, respectively for wheat crop. Similarly Santhi *et al.*, (2004) reported the contribution of soil and fertilizer nutrients as 14.13 and 38.28 per cent for N, 35.33 and 56.61 per cent for P_2O_5 and 14.33 and 70.03 per cent for K_2O, respectively for onion bulb yield in *Inceptisol* of Tamil Nadu.

Estimation of fertilizer adjustment equations

Based on the basic parameters viz. nutrient requirement, efficiencies of fertilizer, soil test and organic source (FYM), fertilizer adjustment equations were evolved for rice crop to achieve a definite yield target. The following equations were evolved for rice for fertilizer N, P_2O_5 and K_2O.

Ready reckoners chart of fertilizer recommendations for hybrid rice

The ready reckoners for rice with the use of 5 tonnes of FYM are shown in Table 9. The fertilizer requirement reduced with the use of FYM resulting in the saving of chemical fertilizer although it is a meager amount however, application of chemical fertilizer with FYM in integrated manner has beneficial by several ways in terms of soil fertility and physical properties improvement. It is further evident that the fertilizer requirements decreased with increase in soil test values. Therefore, a slightly lower yield target may be considered for a poor resource farmers to obtain maximum profit per unit cost spent on fertilizer, whereas, a higher yield target for a resourceful farmers who are interested for maximum potential production per hectare of land. Hence, for maintaining soil fertility, it is necessary to choose appropriate yield targets and fertilizer use practices that achieve the twin objectives of high yield and maintenance of soil fertility.

Thus the targeted yield approach of fertilizer recommendation ensures nutrient balancing to suit the situations involving different yield goals, soil fertility and resources of the farmer (Dev *et al.*, 1985). Several workers have used this approach of fertilizer prescription (Rashid *et al.*, 1988; Powelson *et al.*, 1989; Yuam and Haung, 1995 and Arya, 2003).

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