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Soil test-based fertilizer recommendation for Rice (*Oryza sativa* L.) using targeted yield concept with INM approach in Vertisol of Chhattisgarh plain climatic zone

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Abstract
The investigation was under taken during *Kharif* season 2019 and 2020 at Research Farm, Indira Gandhi Krishi Vishwavidhyalaya, Raipur (Chhattisgarh) for study the soil test-based fertilizer prescription for Rice crop on the basis of grain yield, nutrient uptake and soil test data which were used for obtaining basic parameters *viz.*, nutrient requirement, contribution of nutrients from soil, fertilizer and organic manure. It was found that rice crop required 1.55 kg N, 0.30 kg P and 1.85 kg K to produce one quintal grain yield. Fertilizer and soil test efficiencies were 31.65, 20.76 and 116.71 percent and 23.82, 57.42 and 11.24 percent, respectively for N, P and K. The efficiency of FYM in terms of available nutrient was evaluated as 9.56, 6.38 and 8.84 percent, respectively for N, P and K. On the basis these parameters, fertilizer prescriptions were derived for different targeted yield of Rice by using FYM as organic component in INM approach for N, P_2O_5 and K_2O.

Keywords: STCR, INM, Rice, Soil test

Introduction
Soil testing is the best tools to assess the nutrient status of soil as well as fertilizer recommendation for crops. Soil test-based target yield concept estimate the nutrient requirement of crop for obtaining a desired yield. In target yield concept, it is assumed that linear relationship found between grain yield and nutrient uptake for crops. For achieving a particular yield, crop required a definite amount of nutrients. This requirement of fertilizer can be estimated by considering the contribution of nutrient from soil available nutrients. Noble Laureate Dr Norman Borlaug (1970) [3] "If high-yielding varieties are the catalysts that have ignited the green revolution, then chemical fertilizer is the fuel that has powered its forward thrust".
Significant linear relationship between grain yield of crops and nutrient uptake forms the basis of targeted yield concept, initially advocated by Troug (1960) [8] which included both soil and plant analysis in scientific basis that proved to be refined and unique technique for most efficient use of fertilizer and soil nutrients. In India, further improved by Ramamoorthy *et al.* (1967) [5] which established the theoretical basis and experimental proof for the fact the Liebig's law of minimum (1840) operates equally well for N, P and K. Subsequently, ICAR started AICRP on soil test crop response correlation (STCR) to develop soil test crops using target yield approach for fertilizer application.
Rice (*Oryza sativa* L.) is the world's most widely consumed grain. India is the world's biggest rice producer, and it ranks second in the globe. India produces a considerable amount of rice, with a production of 1164.78 lakh tonnes and a productivity of 2638 kg/ha in the previous financial year, which is grown over 441.56 lakh hectares. Rice is grown in Chhattisgarh in an area of 36.06 lakh hectares with production of 65.27 lakh tonnes and productivity of 1810 kg/ha (GOI, 2018) [1].
Keeping the above facts in view and the present investigation was carried out in Vertisol to explain the significant relationship between soil test values and crop responses to fertilizer and to develop fertilizer prescription equations with IPNS for desired yield target of Rice crop.

Materials and methods

A field experiment was conducted at Indira Gandhi Krishi Vishwavidyalaya, Raipur (Chhattisgarh) on Rice crop (var.-Rajeshwari) during two consecutive *Kharif* season in 2019 and 2020 in Vertisol, which is also called *Kanhar* soil in local term. The experimental soil was clayey in texture with 26.1 % Sand, 28.5% silt and 45.4% clay, neutral to alkaline in reaction. Some physico-chemical properties of experimental soil were analyzed which found 7.4 pH (1:2.5), 0.18 EC (dSm^{-1}), 36.32 CEC (C mol (p+) kg^{-1}), 4.8 Organic C (g kg^{-1}), 213 Available N (kg ha^{-1}), 17.5 Available P (kg ha^{-1}) and 500 Available K (kg ha^{-1}). The experiment was conducted under All India Coordinated Research project for Investigation on Soil Test Crop Response Correlation (STCR) for Rice and a special field technique developed by Ramamurthy *et al.*, (1967) [5] was used. The field was divided in to three equal long strips and low, medium and high fertility gradients (L0, L1 and L2) were created by applying the graded doses of N, P and K fertilizers. Each strips were further divided in to three equal sized blocks for three levels of FYM (0, 5 and 10 t ha^{-1}). The 24 selected fertilizer treatments constituted 4 levels of each of N (0, 50, 100 and 150 kg ha^{-1}), P_2O_5 (0, 30, 60 and 90 kg ha^{-1}) and K_2O (0, 30, 60 and 90 kg ha^{-1}). These were distributed in each block of the strips having 8 treatments in each block. Grain and straw samples were analyzed for N, P and K content (Piper, 1966) [4] and total nutrient uptake was calculated using grain and straw yield data. Using the data on grain yield, nutrient uptake, pre-sowing available soil nutrients and fertilizer doses applied the basic parameter, *viz.* nutrient requirement (kg q^{-1}), contribution of nutrients from soil, fertilizer and organic sources were calculated as described by Ramamoorthy *et al.*, (1967) [5]. These parameters were used for the formulation of fertilizer adjustment equations for deriving fertilizer doses and the soil test-based fertilizer prescription in the form of ready reckoners for desired yield target of Rice under N, P, K alone as well as IPNS.

Calculation of basic parameters

Nutrient requirement (NR)

$$\text{Kg N/P}_2\text{O}_5\text{/K}_2\text{O required per quintal grain production} = \frac{\text{Total uptake of N/P}_2\text{O}_5\text{/K}_2\text{O in kg ha}^{-1}\text{ from grain + straw}}{\text{Grain yield in q ha}^{-1}}$$

Per cent nutrient contribution from soil to total nutrient uptake (Es)

$$\text{Per cent contribution of N/P}_2\text{O}_5\text{/K}_2\text{O from soil} = \frac{\text{Uptake of N (kg ha}^{-1}\text{) from grain + straw from control plot}}{\text{Soil test value for available N/P}_2\text{O}_5\text{/K}_2\text{O (kg ha}^{-1}\text{) from control plot}}$$

Per cent nutrient contribution from fertilizer to total uptake (E_f)

(a)

$$\text{Per cent contribution of N/P}_2\text{O}_5\text{/K}_2\text{O from fertilizer} = \frac{\left(\begin{array}{c}\text{Uptake of N/P}_2\text{O}_5\text{/K}_2\text{O} \\ \text{in kg ha}^{-1} \\ \text{from grain + straw}\end{array}\right) - \left(\begin{array}{c}\text{Soil test value for available} \\ \text{N/P}_2\text{O}_5\text{/K}_2\text{O (kg ha}^{-1}\text{)}\end{array} \times \begin{array}{c}\text{Per cent contribution} \\ \text{of N/P}_2\text{O}_5\text{/K}_2\text{O from soil} \\ \text{/100}\end{array}\right)}{\text{Fertilizer N/P}_2\text{O}_5\text{/K}_2\text{O applied in kg ha}^{-1}} \times 100$$

Per cent nutrient contribution from FYM to total uptake (E_{FYM})

$$\text{Percent contribution of Nutrients from FYM (E}_{FYM}\text{)} = \frac{\left(\begin{array}{c}\text{Nutrient uptake in Kg ha}^{-1}\text{ from} \\ \text{grain+ straw from only FYM} \\ \text{treated plot}\end{array} - \begin{array}{c}\text{Nutrient uptake in kg ha}^{-1}\text{ from} \\ \text{grain + straw from control} \\ \text{plot}\end{array}\right)}{\text{FYM applied in Nutrient form in kg ha}^{-1}} \times 100$$

Yield targeting equations

The yield targeting equations were calculated from the above parameters as given below:

$$\text{F N/P}_2\text{O}_5\text{/K}_2\text{O} = \left(\frac{NR}{E_f} \times Y\right) - \left(\frac{Es}{E_f} \times \text{SN/P}_2\text{O}_5\text{/K}_2\text{O}\right) - \left(\frac{E_{FYM}}{E_f} \times \text{FYM (t ha}^{-1}\text{)}\right)$$

Where, FN FP2O5	= =	Fertilizer N(kg ha-1) Fertilizer P2O5(kg ha-1)
FK2O	=	Fertilizer K2O(kg ha-1)
NR	=	Nutrient requirement of N or P2O5or K2O kg q-1produce.
E_s	=	Per cent contribution from soil
E_f	=	Per cent contribution from fertilizer
E_{FYM} SN	= =	Per cent contribution from FYM Soil test value for available N (kg ha-1)
SP	=	Soil test value for available P (kg ha-1)
SK	=	Soil test value for available K (kg ha-1)
Y	=	Yield target (q ha-1)
FYM	=	Farmyard manure (t ha-1)

Results and Discussion

Status of available NPK in soil

Before taking the main complex experiment with Rice during *Kharif* season 2019 and 2020, the soil samples from each plot were taken and analyzed for available N, P and K. Table 1 reveals the range and means values of available nutrients (N, P and K) during two *Kharif* seasons. Mean values on soil N ranged from 204.5.0-212.9 and 207.3-220.5 kg ha^{-1} during 2019 and 2020 in *Kharif* season, respectively. No variations in soil test N across the fertility strips in both *Kharif* seasons were observed. It may be due the mobile nature of the N in the soil. The level of soil P increased with respect to fertility strips from L0 to L2. Average soil P ranged from 12.30-26.60 and 16.08-26.70 kg ha^{-1}. A distinct gradient with respect to P was detected due to Phosphorus immobility and tendency to fix in soil that is particularly high in Vertisols. Similarly, average soil K ranged from 485.1-493.0 and 482.1-504.8 kg ha^{-1} in consecutive two *Kharif* seasons. The soil 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 2) showed the range and average values of Rice yields in relation to fertility strips during *Kharif* seasons. The ranges of Rice yields were recorded as 22.92-69.26 q ha^{-1} with average of 49.03 q ha^{-1} in L0 strip, 24.68-70.89 q ha^{-1} with average of 51.83 q ha^{-1} in L1 strip and 27.43-71.98 q ha^{-1} with average of 54.56 q ha^{-1} in L2 strip during first *Kharif* season 2019. Similar trends were also observed during next *Kharif* season 2020. The increase in Rice grain yields with respect to fertility strips may be due to fertility gradient in soil P status from L0 to L2 strip.

The relation of Rice yields with different plant nutrients as independent variables were derived by regression analysis for both the seasons of Rice crop to evaluate the yield variations due to various nutrients and presented in the Fig.1. Results indicate that the larger proportion of variation in the Rice grain yield during both the seasons was accounted for by N alone (0.90 and 0.89) in both (2019 and 2020) the seasons. High response of 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.

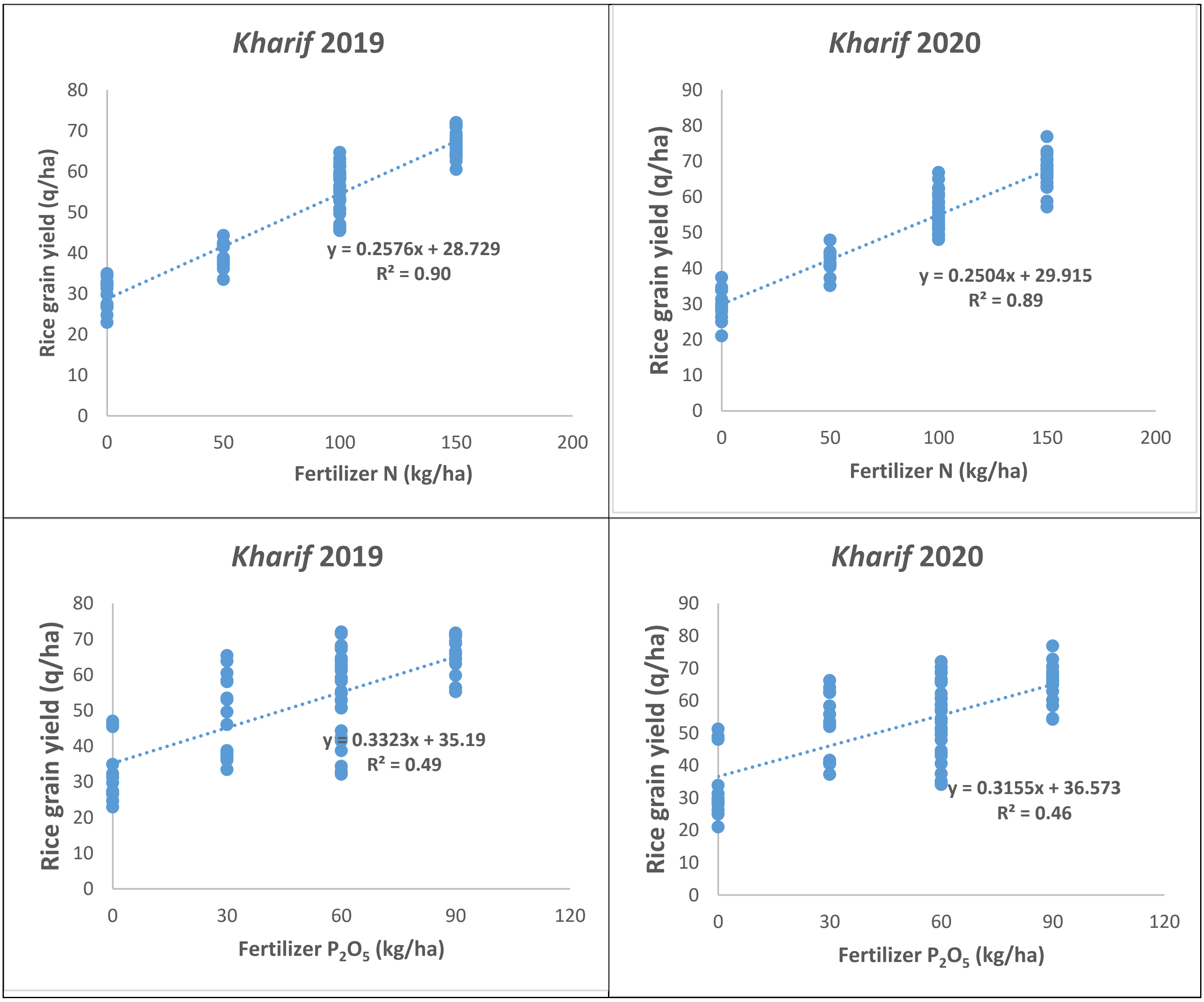
Table 1: Range and average values of soil available N, P and K (kg ha^{-1}) before Rice

Available nutrients	Fertility strips									
	***Kharif* season 2019**					***Kharif* season 2020**				
	L_0	**L_1**	**L_2**	**SD**	**CV**	**L_0**	**L_1**	**L_2**	**SD**	**CV**
Alkaline $KMnO_4$-N (kg ha^{-1})	195-214 (204.5)	197-221 (208.5)	202-222 (212.9)	7.25	3.47	196-218 (207.3)	197-231 (214.0)	199-233 (220.5)	9.45	4.42
Olsen P (kg ha^{-1})	10.91-14.63 (12.30)	15.28-29.99 (23.88)	20.66-31.99 (26.60)	7.00	33.46	9.04-22.27 (16.08)	12.53-30.74 (23.78)	16.71-34.34 (26.70)	6.34	28.65
Amm. acetate extractable K (kg ha^{-1})	428-520 (485.1)	444-546 (491.8)	448-559 (493.0)	28.64	5.84	432-507 (482.1)	447-528 (481.2)	470-560 (504.8)	25.74	5.26

(Data in parenthesis are mean values)

Table 2: Range and mean of grain yields of Rice in relation to fertility gradients during *Kharif* season.

Year	Fertility strips			All strips
	L_0	**L_1**	**L_2**	
2019	22.92-69.26 (49.03)	24.68-70.89 (51.83)	27.43-71.98 (54.56)	33.0-88.2
SD	14.06	14.12	14.43	14.18
CV (%)	28.67	27.25	26.45	27.38
2020	21.01-66.07 (49.28)	24.93-70.51 (52.59)	28.72-76.87 (55.17)	21.01-76.87
SD	13.46	13.99	14.12	13.88
CV (%)	27.31	26.60	25.60	26.51



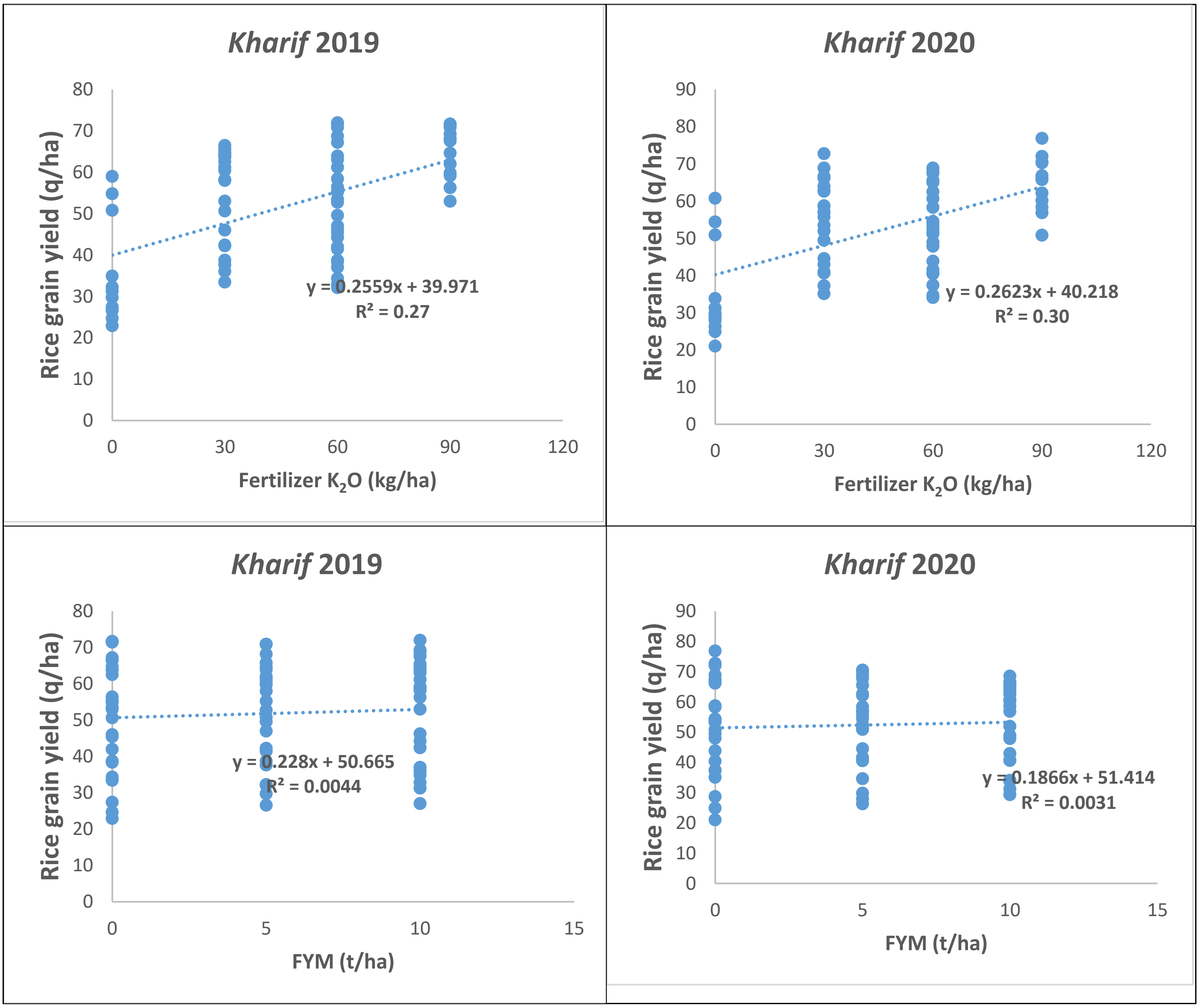
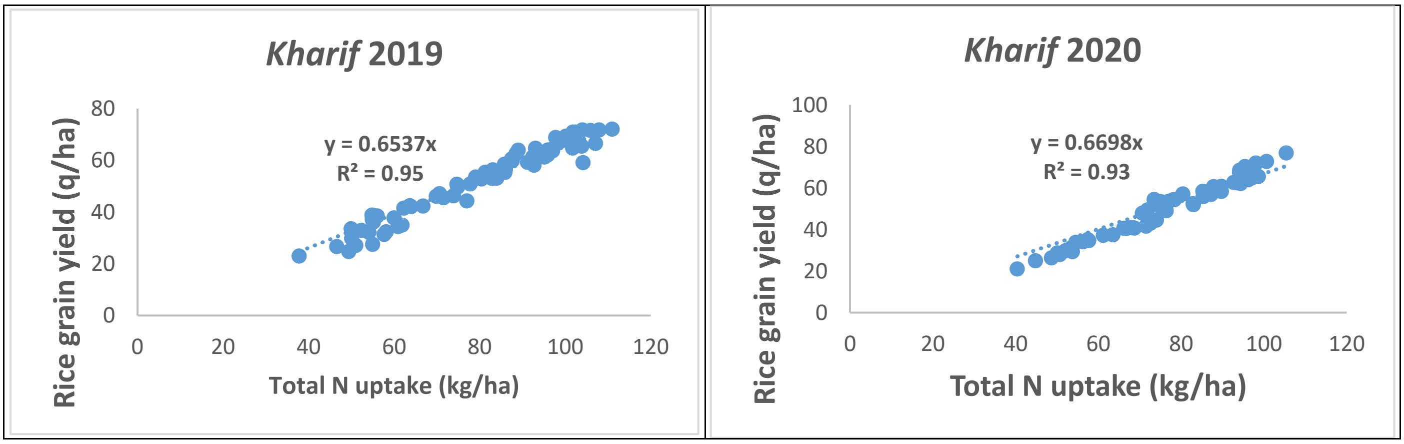


Fig 1: Response of Rice to different levels of FYM application and fertilizer N, P2O5 and K2O.



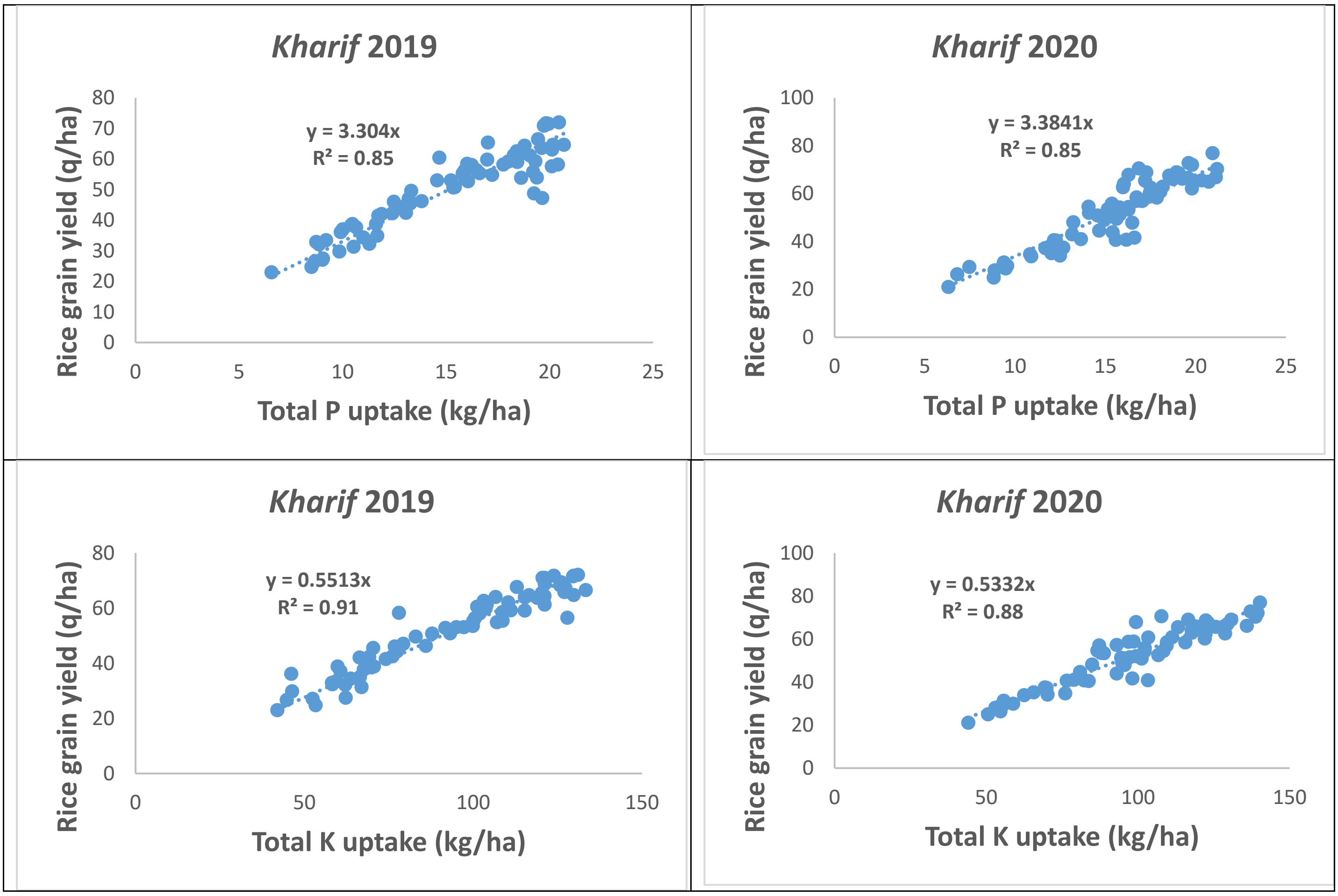


Fig 2: Relationship between grain yield and (a) total N, (b) total P and (c) total K uptake of rice

Fertilizer P and K 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. Similar yield variation was recorded when FYM also included with three major nutrients. This indicates that FYM contribution is very poor towards yield variation as the nutrient content and their release pattern may be lower. The Rice responses to fertilizer N, P, K and FYM during 2019 & 2020 have also been depicted in Figs.1.

Relationship between yield and nutrient uptake

A relationship was observed between the yield of Rice and total N, P and K uptake during both the years. This relation was used to estimate the nutrient requirement for Rice (Table 3 and Fig.2). The nutrient requirement (NR) is defined as the amount of nutrient required to produce unit amount of yield. The nutrient requirement can be given by the regression coefficient (b1) of yield (Y) and total nutrient uptake (U).

Y =b1 U or U= 1/b1* Y

Where, 1/b1 gives the NR (Nutrient Requirement)

Table 3: Relation of Rice yield (Y) with total nutrient uptake (U)

Nutrients	2019		2020	
	Y =b1 U	R^2	Y =b1 U	R^2
N	Y = 0.654U	0.95	Y = 0.670 U	0.93
P	Y = 3.304 U	0.85	Y = 3.384 U	0.85
K	Y = 0.551 U	0.91	Y= 0.533 U	0.88

Efficiencies of Fertilizer, Soil test and FYM for Rice

The amount of nutrients absorbed by the crop decides a definite amount of biomass produce. The average values based on two *Kharif* season for nutrient requirement to produce one quintal of Rice grain was found to be 1.55 kg N, 0.30 kg P and 1.85 kg K, fertilizer efficiencies of N, P and K were estimated as 31.65, 20.76 and 116.71 per cent, respectively (Table 4). Similarly, average soil test efficiencies estimated for N, P and K were as 23.82, 57.42 and 11.24 per cent, respectively. The efficiencies of organic source for N, P and K (FYM) were observed as 9.56, 6.38 and 8.84 per cent.
High efficiency of applied fertilizer K observed due to higher uptake of this nutrient as soil K status was high in experimental field resulted poor response and due to luxury consumption high K uptake could be misleading the estimation of applied K efficiency.

Table 4: Nutrient requirements, efficiencies of Fertilizer, Soil and FYM for Rice (var. Rajeshwari)

Nutrient	Nitrogen			Phosphorus			Potassium		
	2019	2020	Mean	2019	2020	Mean	2019	2020	Mean
Nutrient requirement (kg q^{-1})	1.56	1.54	1.55	0.29	0.30	0.30	1.80	1.89	1.85
Fertilizer efficiency (%)	31.12	32.18	31.65	20.81	20.70	20.76	114.85	118.56	116.71
Soil Test efficiency (%)	24.07	23.56	23.82	57.86	56.98	57.42	11.07	11.40	11.24
FYM efficiency (%)	10.43	8.68	9.56	5.59	7.17	6.38	10.47	7.20	8.84

Estimation of Fertilizer adjustment equation

Fertilizer adjustment equations were evolved for Rice crop to achieve a definite yield target based on the basic parameters *viz*. nutrient requirement, efficiencies of fertilizer, soil test and organic source (FYM). The following equations given in Table- 5 were evolved for Rice crop for fertilizer N, P_2O_5 and K_2O in rice-safflower cropping system. Such kind of fertilizer prescription equation for different crops have been documented by, Srivastava *et al.*, (2017) [7], Sahu *et al.* 2020 [6] and Gupta *et al.*, 2020 [2].

Table 5: Fertilizer adjustment equations for Rice (Rajeshwari) estimated based on response data

S. No.	Fertilizer adjustment equations
1	FN = 4.79Y – 0.75 SN - 0.30 ON
2	FP = 1.40 Y – 2.77 SP - 0.31 OP
3	FK = 1.56 Y - 0.10 SK - 0.08 OK

*where FN FP and FK are fertilizer N, P_2O_5 and K_2O in kg ha^{-1}, Y = Targeted yield of Crop in q ha^{-1}, SN, SP and SK are soil test values for available N, P and K. FYM is Farm Yard Manure in t ha^{-1}.

Ready reckoners' chart for fertilizer recommendations

The ready reckoners for Rice (*var.*, Rajeshwari) with the use of 5 tones of FYM are shown in Table 6. The maximum target yield of the crop may be fixed up to the level of maximum yield achieved in experimental field. 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 (Singh *et al*., 2015). Several workers have also used this approach for fertilizer prescription (Srivastava *et al*., 2017; Gupta *et al*., 2020 and Sahu *et al*., 2020) [7, 2, 6]

Table 6: Ready Reckoners for soil test based fertilizer N, P_2O_5 and K_2O recommendation of Rice (*var. Rajeshwari*) in Vertisol with 5 tonnes of FYM

Soil Test values (kg/ha)			Yield Target of Rice (q/ha)								
			50 (q/ha)			60 (q/ha)			70 (q/ha)		
N	P	K	FN	FP	FK	FN	FP	FK	FN	FP	FK
150	4	200	120	54	55	168	68	71	216	82	87
175	6	225	102	49	53	149	63	69	197	77	84
200	8	250	83	43	51	131	57	66	179	71	82
225	10	275	64	38	48	112	52	64	160	66	79
250	12	300	45	32	46	93	46	61	141	60	77
275	14	325	26	27	43	74	40	59	122	54	75
300	16	350	8	21	41	55	35	57	103	49	72
325	18	375	8	15	39	37	29	54	84	43	70
350	20	400	8	10	36	18	24	52	66	38	67
375	22	425	8	4	34	8	18	49	47	32	65
400	24	450	8	4	31	8	13	47	28	27	63

Where, FN, FP and FK are fertilizer N, P_2O_5 and K_2O (Kg ha^{-1}) respectively. SN, SP and SK are soil test values (kg ha^{-1}) for $KMnO_4$- N, Olsen's P and ammonium acetate extractable K.

Conclusion

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. 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.

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