Journal of Pharmacognosy and Phytochemistry

Available online at www.phytojournal.com

E-ISSN: 2278-4136
P-ISSN: 2349-8234
www.phytojournal.com
JPP 2020; 9(2): 1496-1501
Received: 04-01-2020
Accepted: 06-02-2020

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Soil test based fertilizer prescription for hybrid rice crop based on target yield approach with INM in vertisol of Chhattisgarh plain climatic zone

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Abstract
The investigation was under taken during kharif season 2017 and 2018 at Instruction Farm, Indira Gandhi Krishi Vishwavidhyalaya, Raipur (Chhattisgarh) for study the soil test based fertilizer prescription for Hybrid 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 Hybrid rice crop required 1.57 kg N, 0.32 kg P and 1.72 kg K to produce one quintal grain yield. Fertilizer and soil test efficiencies were estimated 41.41, 32.00 and 100.39 percent and 30.44, 72.84 and 15.37 percent, respectively for N, P and K. The efficiency of FYM in terms of available nutrient was evaluated as 13.02, 6.98 and 11.16 percent, respectively for N, P and K. On the basis these parameters, fertilizer N, P_2O_5 and K_2O were derived for different targeted yield of Hybrid Rice by using FYM as organic component in INM approach.

Keywords: STCR, INM, hybrid rice, soil test

Introduction
Rice crops are major constituent of Indian agriculture system. Asia account nearly 90% of the world production and consumption. India occupies largest area under rice after china. Rice is largely cultivated in West Bengal, Punjab, Uttar Pradesh, West Bengal, Assam and Chhattisgarh. In India Rice crop occupied an area of 43.79 million ha with a production of 112.91 million tones and productivity 2578 kg ha^{-1}. In Chhattisgarh Rice crop occupied an area of 3.76 million ha with a production 4.73 million tonnes with an average productivity of 1256 kg ha^{-1} (GOI, 2018) [1]. According to Swaminathan (2009) [2], India's population is likely to reach 1.5 billion by 2030, the challenge facing the country is to produce more food. Hence there is a felt need to increase the production to keep pace with population increase. Due to high yield potential of hybrid rice, there is need to be study the fertilizer and soil response toward the crops.
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 Hybrid Rice crop.

Materials and Methods
A field experiment was conducted at Indira Gandhi Krishi Vishwavidyalaya, Raipur (Chhattisgarh) on Hybrid Rice crop (var.- IRH-103) during two consecutive *Kharif* season in 2017 and 2018 in *Vertiso.l* which is also called *Kanhar* soil in local term. The experimental soil was clayey in texture with 24.1 % Sand, 21.8% silt and 54.1% 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}), 35.82 CEC (c mol(p+) kg^{-1}), 5.6 Organic C (g kg^{-1}), 211 Available N (kg ha^{-1}), 17.8 Available P (kg ha^{-1}) and 489 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 Hybrid Rice and a special field technique developed by Ramamurthy *et al.*, (1967) [3] 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, 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}). 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) [3]. 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 Hybrid Rice under N, P, K alone as well as IPNS.

Results and Discussion

Status of available NPK in soil

Before taking the main complex experiment with Hybrid Rice during *Kharif* season 2017 and 2018, 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 207.2.0-213.1 and 202.7-220.0 kg ha^{-1} during 2017 and 2018 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 12.7-23.4 and 14.8-25.7 kg ha^{-1}. Similarly average soil K ranged from 466.5-492.5 and 475.8-500.4 kg ha^{-1} in consecutive two *Kharif* seasons.

Response of Hybrid Rice to added nutrients

The results (Table 2) showed the range and average values of Hybrid Rice yields in relation to fertility strips during Kharif seasons. The ranges of Hybrid Rice yields were recorded as 33.0-86.2 q ha^{-1} with average of 64.54 q ha^{-1} in L0 strip, 34.0-87.5 q ha^{-1} with average of 67.55 q ha^{-1} in L1 strip and 35.65-88.2 q ha^{-1} with average of 69.65 q ha^{-1} in L2 strip during first Kharif season 2017. Similar trends were also observed during next Kharif season 2018. The increase in Hybrid 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 Hybrid Rice yields with different plant nutrients as independent variables were derived by regression analysis for both the seasons of Hybrid 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 Hybrid Rice grain yield during both the seasons was accounted for by N alone. Therefore, its quadratic term also similarly fit into the data as evidence from the higher R^2 value (0.870 and 0.844) with curvilinear equation in both (2017-18 and 2018-19) 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) [3].

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 Hybrid Rice is lower than N. The curvilinear nature of Hybrid Rice yield response to P application can therefore be attributed to the above facts. 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 Hybrid Rice responses to fertilizer N, P, K and FYM during 2017-18 & 2018-19 have also been depicted in Figs.1.

Efficiencies of Fertilizer, Soil test and FYM for Hybrid 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 Hybrid Rice grain was found to be 1.57 kg N, 0.32 kg P and 1.72 kg K, fertilizer efficiencies of N, P and K were estimated as 41.41, 32.00 and 100.39 per cent, respectively (Table 4). Similarly, average soil test efficiencies estimated for N, P and K were as 30.44, 72.84 and 15.37 per cent, respectively. The efficiencies of organic source for N, P and K (FYM) were observed as 13.02, 6.98 and 11.16 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.

Relationship between yield and nutrient uptake

A relationship was observed between the yield of Hybrid Rice and total N, P and K uptake during both the years. This relation was used to estimate the nutrient requirement for Hybrid 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 1: Range and average values of soil available N, P and K (kg ha^{-1}) before Hybrid Rice

Available nutrients	Fertility strips Kharif season 2017-18				Fertility strips Kharif season 2018-19			
Soil Nutrients	**L0**	**L1**	**L2**	**SD**	**L0**	**L1**	**L2**	**SD**
Alkaline $KMnO_4^-$ N	182.0-228.0 (207.2)	186.0-231.0 (213.1)	201.0-234.0 (222.7)	12.68	176.2-223.6 (202.7)	196.6-229.9 (216.6)	199.5-233.4 (220.0)	12.45
Olsen's P	10.2-15.6 (12.7)	10.5-29.0 (20.9)	19.0-28.3 (23.4)	5.73	7.88-19.53 (14.8)	14.86-29.39 (22.5)	18.64-30.28 (25.7)	5.87
Neutral normal Amm.acetate extractable K	436.1-503.4 (466.5)	457.5-507.0 (480.7)	453.2-525.4 (492.5)	20.62	428.74-516.10 (475.8)	462.34-518.34 (488.9)	448.9-536.3 (500.4)	22.39

(Data in parenthesis are mean values)

Table 2: Range and mean of grain yields of SRI Hybrid Rice in relation to fertility gradients.

Year	Fertility strips			All strips	SD	CV (%)
	L_0	L_1	L_2			
2017-18	33.0-86.2 (64.54)	34.0-87.5 (67.55)	35.65-88.2 (69.65)	33.0-88.2	18.06	26.85
2018-19	32.0-91.5 (68.31)	37.0-94.0 (72.27)	41.2-94.1 (75.18)	32.0-94.1	18.58	25.83

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

Nutrients	2017-18		2018-19	
	Y =b1 U	R^2	Y =b1 U	R^2
N	Y = 0.642U	0.971	Y = 0.644 U	0.968
P	Y = 3.118 U	0.898	Y = 3.139 U	0.884
K	Y = 0.582 U	0.813	Y = 0.595 U	0.795

Table 4: Nutrient requirements, efficiencies of Fertilizer, Soil and FYM for SRI Hybrid Rice (var. IRH-103)

Nutrients	NR (kg q^{-1})			Fertilizer efficiency (%)			Soil test efficiency (%)			FYM efficiency (%)		
	2017	2018	Avg	2017	2018	Avg	2017	2018	Avg	2017	2018	Avg
N	1.57	1.57	1.57	42.92	39.89	41.41	28.21	32.66	30.44	13.02	13.01	13.02
P	0.32	0.32	0.32	33.46	30.54	32.00	72.29	73.38	72.84	8.53	5.43	6.98
K	1.72	1.71	1.72	106.24	94.54	100.39	14.34	16.39	15.37	12.21	10.10	11.16

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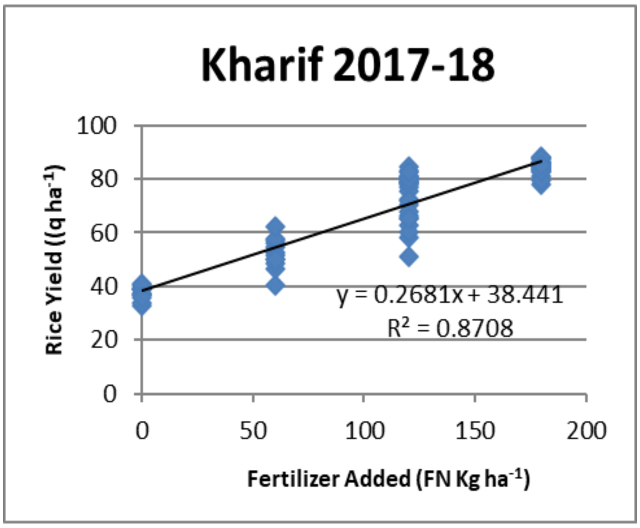
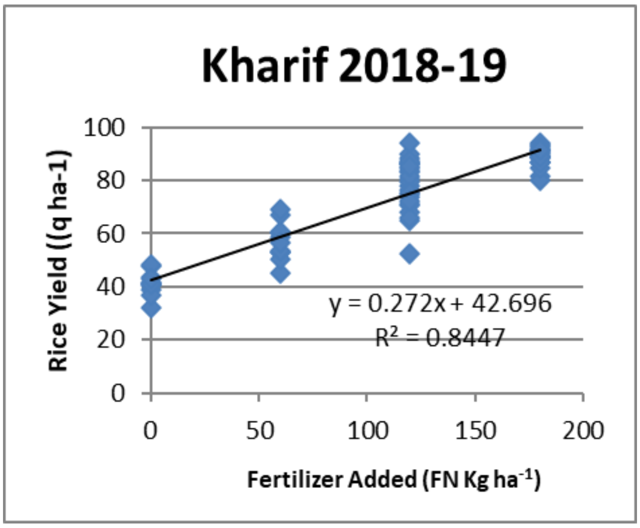
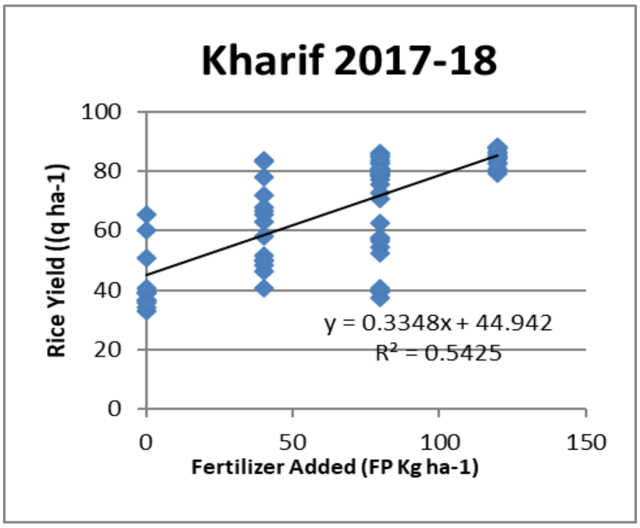
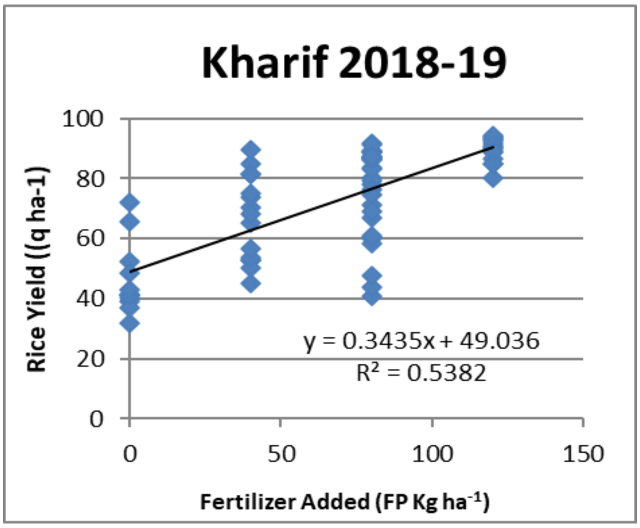








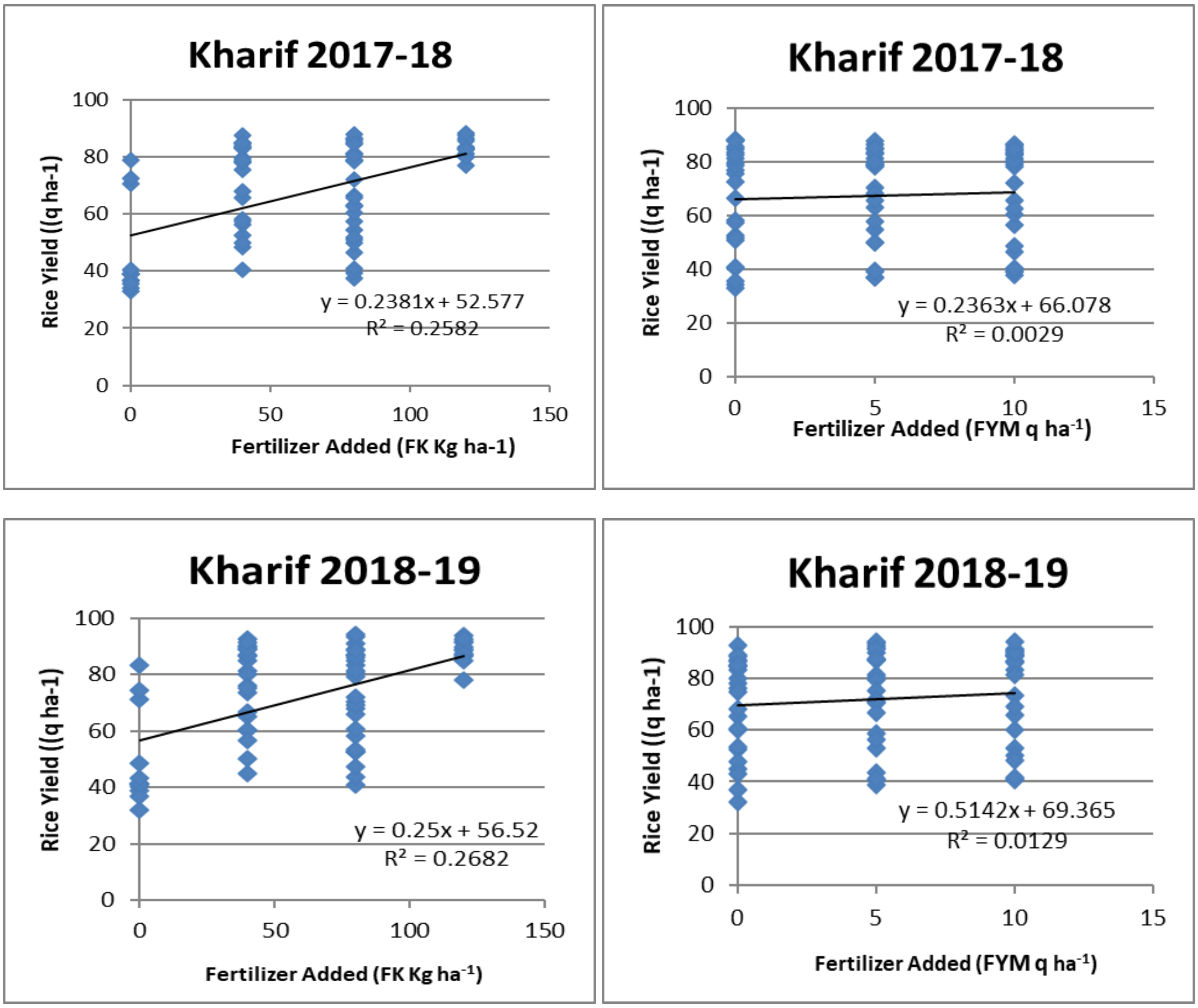
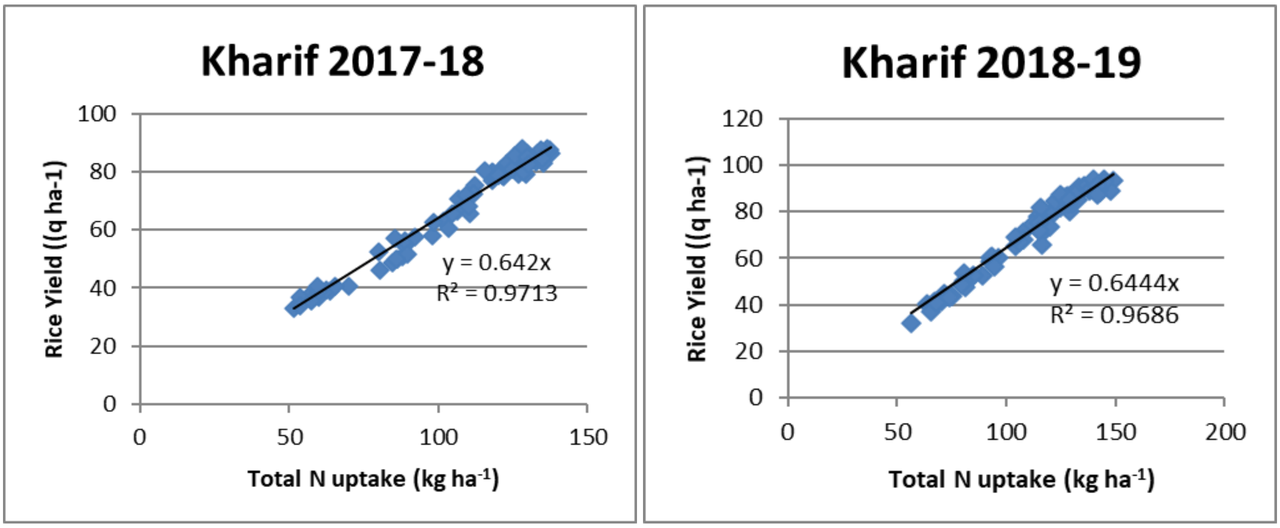


Fig 1: Response of Hybrid Rice to different levels of FYM application and fertilizer N, P_2O_5 and K_2O.



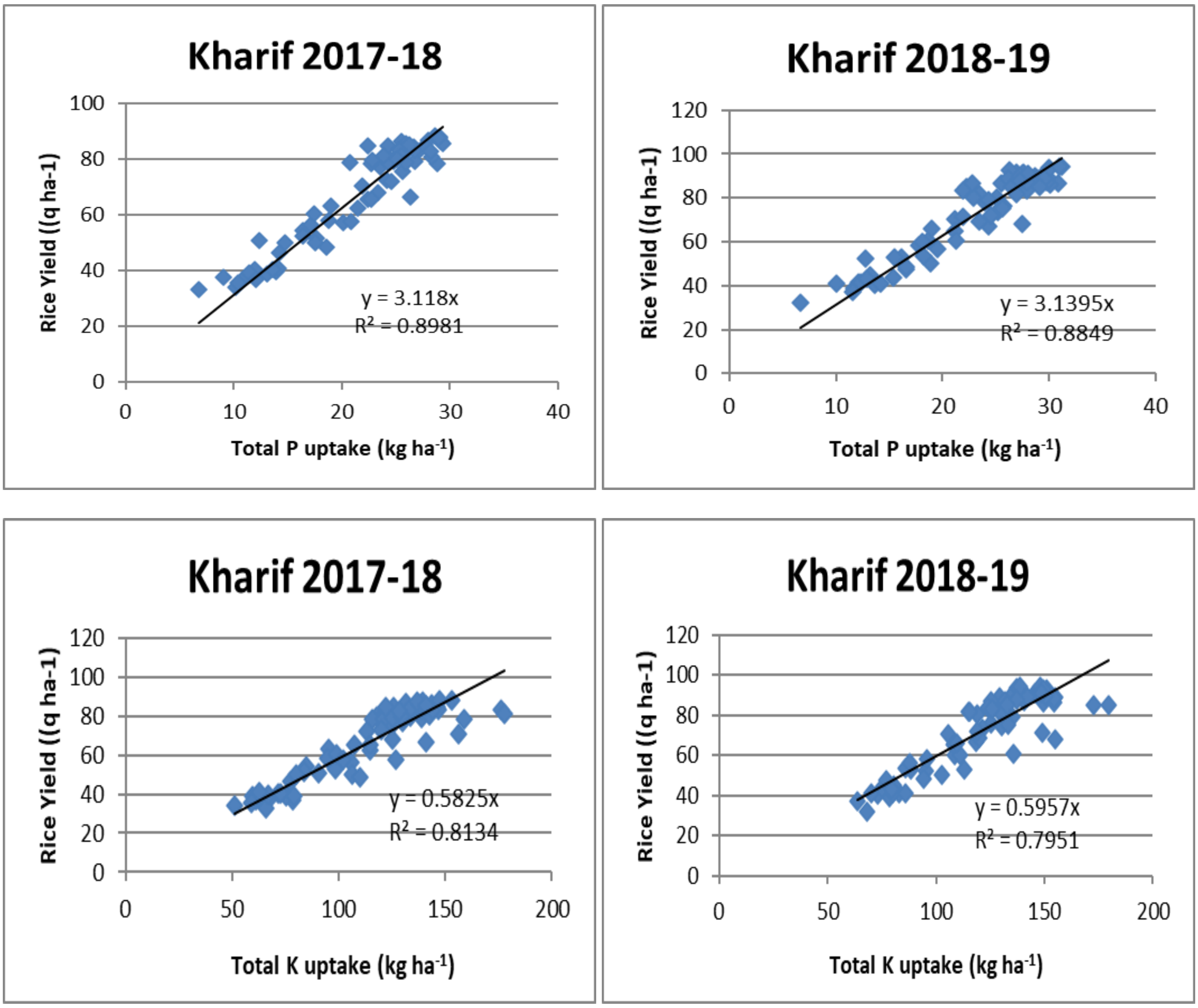


Fig 2: Relationship between Hybrid Rice grain yield and total NPK uptake

Estimation of Fertilizer adjustment equation

Fertilizer adjustment equations were evolved for Hybrid 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 Hybrid Rice crop for fertilizer N, P_2O_5 and K_2O in SRI system. Such kind of fertilizer prescription equation for different crops (rice, wheat, maize, mustard and rapeseed) have been documented by Milap-Chand *et al.* (2006) [5], Srivastava *et al.*, (2017) [6].

Table 5: Fertilizer adjustment equations for SRI Hybrid Rice (IRH-103) estimated based on response data

S. No.	Fertilizer adjustment equations
1	FN= 3.79 Y – 0.74 SN - 0.31 FYM
2	FP = 1.00 Y – 2.28 SP - 0.22 FYM
3	FK = 1.71 Y - 0.15 SK - 0.11 FYM

*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 Hybrid Rice (*var.*, IRH-103) 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 and suitable for different yield goals, soil fertility and resources of the farmer (Dev *et al.*, 1985) [7]. Several workers have also used this approach for fertilizer prescription (Rashid *et al.*, 1988; Powelson *et al.*, 1989) [8, 9].

Table 6: Ready Reckoners for soil test based fertilizer N, P_2O_5 and K_2O recommendation of SRI Hybrid Rice (*IRH-103*) in Vertisol with 5 tonnes of FYM

Soil Test values (kg/ha)			Yield Target of SRI Rice (q/ha)								
			65 (q/ha)			75 (q/ha)			85 (q/ha)		
N	P	K	FN	FP	FK	FN	FP	FK	FN	FP	FK
150	4	200	134	55	81	172	65	98	210	75	115
175	6	225	115	50	77	153	60	94	191	70	111
200	8	250	97	46	73	135	56	90	173	66	107
225	10	275	78	41	69	116	51	86	154	61	104
250	12	300	60	37	66	98	47	83	136	57	100
275	14	325	41	32	62	79	42	79	117	52	96
300	16	350	23	27	58	61	37	75	99	47	92
325	18	375	4	23	54	42	33	71	80	43	89
350	20	400	4	18	51	24	28	68	62	38	85
375	22	425	4	14	47	5	24	64	43	34	81
400	24	450	4	9	43	5	19	60	25	29	77

Conclusion

The fertilizer requirement reduced with the using INM approach resulting in the saving of chemical fertilizer. A slightly lower yield target mainly considered for a poor resource farmers to obtain maximum profit per unit cost spent on fertilizer, whereas, a higher yield targeted for a resourceful farmers who are interested for maximum potential production per hectare of land. Hence, for maintaining of soil fertility, it is necessary to choose appropriate yield targets and fertilizer use practices which achieve the both objectives of high yield and maintenance of soil fertility.

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