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Validation and refinement of soil test based derived fertilizer equation for SRI rice in *Vertisol*

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Abstract
A field experiment was conducted in SRI Rice crop with integrated use of FYM and fertilizer for Validation and refinement of soil test based derived fertilizer equation at the Instructional farm of Indira Gandhi Agricultural University, Raipur (C.G). Based on the experiment the nutrient required to produce one quintal of rice grain yield was found to be 1.57 kg N, 0.30 kg P and 1.71 kg K. The contribution of fertilizer N, P and K were estimated as 41.83, 28.37 and 116.21 per cent. Similarly, the contribution of soil test N, P and K were recorded as 33.55, 81.28 and 19.10 percent. The contribution of organic source (FYM) was observed as 13.8 % N, 6.67 % P and 11.64 % K. The fertilizer adjustment equations evolved during previous season for the Swarna variety of rice was tested and fertilizer application with organic source (FYM). It was also noticed that fertilizer dose applied based on STCR prescription derived previously to achieve a definite yield target could not be obtained. This may be due to differences in various input use efficiency, nutritional requirement. However, further refinement of the equations was tried using nutrients omission plot technique and basic parameters required for the formulation of the fertilizer equations were confirmed. After refinement of the fertilizer prescription equations, it was observed that by calculation with new equation, N and P fertilizer requirement at various soil test levels increased over existing equations developed previously. However, the dose of K fertilizer was lower than existing one. Hence, a new set of N P K doses at different soil test levels were evolved and need to be tested for its suitability under similar soil and crop situation.

Keywords: STCR, rice, SRI, FYM, *vertisol*

Introduction

In India rice (*Oryza sativa*) is the staple food crop for more than two thirds of the population. The slogan "RICE is life" is most appropriate for India as this crop plays a vital role in our national food security and is a means of livelihood for millions of rural households. Over 50% of the world's population depends on rice as their primary source of energy while the demand for rice keeps growing. It is estimated that rice production should be increased by about 40% to meet the growing demand by 2030 due to population growth and changing food habits (Khush, 2005) [3]. India produces rice in a large quantity with a production of 104.4 million tonnes and productivity of 2367 kg ha^{-1} in 2015-16, grown in an area of 44.1 million hectares. Rice is grown in Chhattisgarh in an area of 37.18 lakh hectares with a production of 66.20 lakh tonnes and productivity of 1780 kg ha^{-1} in 2015-16.

Fertilizer is one of the costliest inputs in agriculture and the use of right elements in right amount of fertilizer at right time is fundamental for farm profitability and environmental protection. Soil testing as a diagnostic tool, the value of soil testing both in general and specific terms is to identify soil fertility problems and constraints in an area and to give specific fertilizer recommendation based on soil testing results of a farm holding. At the same time a balanced fertilization has to be considered for maintaining soil health for sustainable use because indiscriminate and imbalanced use of fertilizers has already distorted soil fertility and deteriorated soil health in India (Santhi *et al*. 2011) [6]. Soil test based fertilizer recommendations result in efficient fertilizer use and maintenance of soil fertility.

Several approaches have been used for fertilizer recommendation based on chemical soil test so as to attain maximum yield per unit of fertilizer use. Among the various approaches, the soil test crop response (STCR) studies help to generate fertilizer adjustment equations and calibration charts for recommending fertilizers on the basis of soil tests and achieving targeted yield of crops (Ramamoorthy *et al*. 1967) [2]. The formulation of soil test based fertilizer equations generated for a particular soil type and climatic conditions requires validation for their suitability in similar soil and climatic conditions. If validation is differed more than ±10% then certain refinement can be done in constant values used in fertilizer equations by adjusting efficiencies of fertilizer, Fertilizer application and yield target chosen can be so manipulated that both high profit from fertilizer investment and maintenance of soil fertility can be achieved (Velayutham, 1979) [7].

Materials and Methods

A field experiment was conducted for validation at the farm of Indira Gandhi Krishi Vishwavidyalaya, Raipur (Chhattisgarh) The soil of the experimental field comes under the soil order of *Vertisol*. The trial consisted of 14 treatments viz Control (N0 P0 K0), N120 P60 K0, N120 P0 K 40, N0 P60 K40, N120 P60 K40, Yield Target 8 t/ha, Yield Target 10 t/ha with and without FYM. This soil is locally known as Kanhar. It is clayey in texture with 25.0 % Sand, 26.0% silt and 49.0% clay, dark brown to black in color. Some physico-chemical properties of experimental soil were analyzed which found 7.6 pH (1:2.5), 0.18 EC (dSm-^{1}), 35.40 CEC (c mol (p+) kg-^{1}),0.58 Organic C (g kg-^{1}), 198 Available N (kg ha-^{1}), 16 Available P (kg ha-^{1}) and 390 Available K (kg ha-^{1}). Grain and straw samples were analyzed for N, P and K content (Piper 1966) [4]. 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) [5]. 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 prescription in the form of ready reckoners for desired yield target of rice.

Validation experiment

Fertilizer prescription equations for rice under SRI (Swarna), for Vertisol are furnished below:

FN= 3.80 Y – 0.89 SN - 0.33 FYM

F P_2O_5 = 0.99 Y – 2.96 SP - 0.17 FYM

FK_2O = 1.59 Y - 0.17 SK - 0.10 FYM

Where, FN, FP_2O_5 and FK_2O are fertilizer N, P_2O_5 and K_2O in kg ha^{-1} respectively; T - Grain yield target in q ha^{-1}; SN, SP and SK are available N, P and K in kg ha^{-1} respectively; ON, OP and OK are N, P and K supplied through organic manure in kg ha^{-1}.

Results and Discussion

Grain and straw yield

The grain yield recorded in various treatments were given in Table 1 depicted in the mean grain yields of rice differed significantly with main effects of treatment (T) however, FYM application (F) and interaction effect (FT) did not show significant variations. Significantly higher grain yield was recorded with the treatment T_7 (YT 10 t/ha) followed by T_5 (N_{120} P_{60} K_{40}), T_6 (YT 8 t/ha) and T_2 (N_{120} P_{60} K_0). Yield performance severely affected when N and P were omitted. Higher yield of rice (84.50 q/ha) was obtained with the treatment that received higher amount chemical fertilizer coupled with 5 tons of FYM although yield was not as per the yield goal. It was also noticed that fertilizer dose applied based on STCR prescription derived previously to achieve a definite yield target could not be obtained. This may be due to differences in various input use efficiency, nutritional requirement etc. Similarly, the mean straw yield of rice (Table 2) showed the similar trend with that of grain yields. Straw yields affected significantly with main effects of treatment (T), while FYM application (F) and Interaction (TxF) had no significant effect on straw yields. As observed in case of straw yields, higher straw yield was recorded with the treatment T_7 (YT 10 t/ha) followed by T_5 (N_{120} P_{60} K_{40}), T_2 ($N_{120}P_{60}K_0$), T_6 (YT 8 t/ha). Application of FYM with chemical fertilizer enhanced the grain and straw yields as compared to chemical fertilizer only.

Total nitrogen, phosphorus and potassium uptake

Nitrogen uptake by rice (Table 2) affected significantly with main effects of treatment, FYM application and Interaction of treatment with FYM (TxF). Significantly higher N uptake was recorded with the treatment T_7 (YT 10 t/ha) followed by T_6 (YT 8 t/ha), T_5 (N_{120} P_{60} K_{40}), T_2 (N_{120} P_{60} K_0). STCR based fertilizer dose for yield target of 10 t/ha received significantly highest N uptake among all other treatments. Total N uptake was significantly increased with the application of FYM as compared to without FYM. N uptake is the product of content and dry matter yield (grain & straw). Hence, N uptake performed identical with that of grain yields. The per cent increase in N uptake by different fertilizer and manurial treatment was 93 to 195% in rice as reported by Bhandari *et al*. (1992) [1].

Similarly, Phosphorus uptake by rice (Table 2) affected significantly with main effects of treatment while FYM application and their interaction effect did not show significant result. Significantly higher P uptake was recorded with the treatment T_5 (N_{120} P_{60} K_{40}), followed by T_7 (YT 10 t/ha), T_6 (YT 8 t/ha), T_2 (N_{120} P_{60} K_0). Application of RDF (T_5) performed significantly higher P uptake and was at par with that of T_7 (YT 10 t/ha). P uptake severely affected when P was omitted. Total P uptake was significantly increased with the application of FYM as compared to without FYM

Table 1: Average grain and straw yield (q/ha) of rice in relation to different fertilizer treatments with and without FYM application.

Treatments (T)	Grain yield (q/ha)			Straw yield (q/ha)		
	Without FYM	With FYM	Mean	Without FYM	With FYM	Mean
$N_0P_0K_0$ T_1	38.00	42.44	40.22	39.11	42.93	41.02
$N_{120}P_{60}K_0$ T_2	65.67	66.96	66.31	66.23	68.10	67.16
$N_{120}P_0K_{40}$ T_3	58.60	62.44	60.52	60.15	61.07	60.61
$N_0P_{60}K_{40}$ T_4	45.50	47.27	46.38	46.40	48.57	47.48
$N_{120}P_{60}K_{40}$ T_5	75.96	78.63	77.29	77.02	80.92	78.97
YT 8 t/ha T_6	68.71	70.73	69.72	66.01	66.97	66.49
YT 10 t/ha T_7	83.79	85.21	84.50	86.18	88.56	87.37
Mean	62.31	64.81	63.56			
CD at 5% level	T* = 6.99, F = NS, FT = NS			T* = 6.73, F=NS, FT = NS		

Table 2: Total N, P and K uptake (kg/ha) by rice (Swarna) in relation to different fertilizer treatments with and without FYM application.

Treatment (T)	Total Nitrogen Uptake (kg/ha)			Total P Uptake (kg/ha)			Total KUptake (kg/ha)		
	Without FYM	With FYM	Mean	Without FYM	With FYM	Mean	Without FYM	With FYM	Mean
$N_0P_0K_0$ T_1	66.440	67.790	67.110	13.00	13.30	13.15	74.490	75.330	74.910
$N_{120}P_{60}K_0$ T_2	101.10	105.35	103.22	16.86	18.23	17.54	106.87	112.53	109.70
$N_{120}P_0K_{40}$ T_3	94.690	99.860	97.270	16.20	17.07	16.63	96.180	104.02	100.10
$N_0P_{60}K_{40}$ T_4	67.100	71.770	69.430	11.62	12.51	12.06	82.620	87.120	84.870
$N_{120}P_{60}K_{40}$ T_5	114.83	116.63	115.73	28.14	30.03	29.08	114.75	120.92	117.83
YT 8 t/ha T_6	116.55	115.88	116.21	24.21	25.55	24.88	116.90	127.22	122.06
YT 10 t/ha T_7	141.49	149.09	145.29	27.71	28.55	28.13	142.39	148.10	145.24
Mean	100.31	103.76	102.03	19.79	20.62	20.21	107.17	108.45	116.38
CD at 5% level	T*=2.22, F*=1.19, FT= 3.13			T*= 0.6, F=NS, FT= NS			T*=1.77, F*=0.95, FT=2.50		

Similarly, Potassium uptake by rice (Table 2) affected significantly with main effects of treatment and FYM application. Interaction of treatment with FYM (TxF) had significant effect on K uptake. Significantly higher K uptake was recorded with the treatment T_7 (YT 10 t/ha) followed by T_6 (YT 8 t/ha), T_5 ($N_{120}P_{60}K_{40}$) and T_2 (N_{120} P_{60} K_0) and T_3 (N_{120} P_0 K_{40}). STCR based fertilizer dose for yield target of 10 t/ha received significantly highest K uptake. Total K uptake was significantly increased with the application of FYM over its no application.

Table 3: Estimation of basic parameters based on the nutrient omission plot technique

Nutrient	Nutrient requirement (kg q^{-1}) of rice (Swarna)	Fertilizer efficiency (%)	Soil test Efficiency (%)	FYM Efficiency (%)
N	1.57	41.83	33.55	13.8
P	0.30	28.37	81.28	7.07
K	1.71	116.1	19.10	12.5

Derivation of fertilizer prescriptions equation based on basic parameters evolved during current season experiment

The derivation of new fertilizer equations using the basic parameters (Table 3) like nutrient requirement, efficiencies of fertilizer, soil and organic source were developed for rice as elaborated below.

$$FN = \frac{NR}{CF/100} \times Y - \frac{CS}{CF} \times STVN - \frac{CFYM}{CFYM} \times FYM$$

Where, FN is fertilizer nutrients (N, P and K kg/ha), NR – nutrient requirement of N, P and K (kg/q); CS, CF and CFYM – percentage contributions (efficiency) of N P & K nutrients from soil, fertilizer and farmyard manure, respectively; STVN is soil test value for available N, P and K (kg/ha); FYM is Farm Yard Manure, Y – yield (q/ha) of the test crop.

Table 4: Fertilizer adjustment equation derived for rice cv. Swarna.

Nutrient management strategy	Fertilizer adjustment equation
STCR-IPNS	FN = 3.74 Y - 0.80 SN - 0.33 FYM
	FP = 1.06 Y – 2.86 SP – 0.25 FYM
	FK = 1.47 Y – 0.16SK – 0.11 FYM

Where, FN, FP and FK are fertilizer N, P2O5 and K2O (kg ha^{-1}) respectively. FYM is Farm Yard Manure (t ha^{-1}). SN, SP and SK are soil test values (kg ha^{-1}) for KMnO4 -N, Olsen's P and ammonium acetate extractable K and Y is crop yield in q ha^{-1}.

Table 5: Comparison of soil test based fertilizer recommendations by existing equation and new developed equation for rice to achieve 8t yield target in *Vertisol* with 5 t of FYM.

Soil test value (kg/ha)			Yield target of rice (q/ha)					
			Existing equation			New equation		
N	P	K	FN	FP	FK	FN	FP	FK
150	4	200	169	67	93	178	72	85
175	6	225	147	61	88	158	66	81
200	8	250	124	55	84	138	61	77
225	10	275	102	49	80	118	55	73
250	12	300	80	43	76	98	49	69
275	14	325	58	37	71	78	44	65
300	16	350	35	31	67	58	38	61
325	18	375	13	25	63	38	32	57
350	20	400	13	19	59	18	26	53
375	22	425	13	13	54	18	21	49
400	24	450	13	7	50	18	15	45

Where, FN, FP and FK are fertilizer N, P2O5 and K2O (Kg ha-1) respectively. SN, SP and SK are soil test values (kg ha-1) for KMnO4- N, Olsen's P and ammonium acetate extractable K

Ready reckoners for fertilizer recommendations of rice

The comparative ready reckoners table was prepared based on the equations derived previously for rice with existing equation and new currently developed equations with five tonnes of FYM application (Tables 4). It was noticed that by calculation with new equation, N and P fertilizer requirement at various soil test levels increased over existing equations developed previously. However, the doses of K fertilizer were lower than existing one. Hence, a new set of N P K doses at different soil test levels were evolved and need to be tested for its suitability under similar soil and crop situation. It was remarkably noticed that yield targets of 8 and 10 t/ha were not achived with existing equation derived during previous season with SRI Rice.

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) [2]. The existing equations derived during 2016 for Swarna variety of rice were refined by the estimation of new basic parameters as mentioned above. The new equations have been compared with that of existing one and can be said superior over existing after validation (Table 5).

Conclusion

The study revealed that percent achievement of the aimed yield target was within + 10 per cent variation in the trials confirming the validity of the equations. It is evident that the fertilizer requirements decreased with increase in soil test values and differences between two equations resulted higher at increasing soil test levels particularly for N fertilizer. This may be due to lower contribution of N from soil and FYM sources. However, fertilizer doses with new equations have estimated higher amount of N and P which might fulfill the nutrient requirement for higher yield target although this needs field validation in the next crop season.

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