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Validation of Soil Test and Yield Target based Fertilizer Prescription Model for Rice on Inceptisol of Eastern Zone of Uttar Pradesh, India

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A B S T R A C T

On the basis of soil test value of farmer field, fertilizer prescription equations are essential to demonstrate the effectiveness of technology delivery to the stake holders in need. The present study was conducted at Bhojpur to evaluate the model through field experiments in Eastern zone of Uttar-Pradesh. The treatments included control, general recommendation dose, farmer practice, soil test crop response STCR based fertilizer dose for an yield target of 4.5 and 5.0 t ha^{-1}. Based on the initial soil test values of available N, P and K and the quantities of N, P and K contributed through farm yard manure (FYM), fertilizer doses were calculated and applied for STCR and STCR-INM treatments for the respective yield targets. The treatments were imposed and cultivation practices were carried out periodically and the grain yield was recorded at harvest. Using the data on grain yield and fertilizer doses applied, benefit: cost ratio was worked out. The results of the experiments indicated that in the entire three farmer's field, the per cent achievement of the targeted yield was within ±5% variation proving the validity of the equations for prescribing integrated fertilizer doses for rice. The highest mean per cent achievement was recorded in the yield target of 4.5 t ha^{-1} (99.96 %) followed by T_5 (yield target of 5.0 t ha^{-1}) (98.36 %). The highest mean average yield was recorded in T_5 STCR-NPK+FYM 5.0 t ha^{-1} (4918 kg ha^{-1}) recording an increase of 30.93% over farmer's practice. The highest benefit: cost ratio (3.32) was also recorded in STCR-INM (T_5). The post-harvest soil available N, P and K indicated the build up and maintenance of soil fertility due to validation of soil test and yield target based fertilizer recommendation under STCR-INM. The fertilizer prescription equations developed for rice under STCR-INM can be recommended for Alluvial soil of Pratapgarh, Uttar-Pradesh (Inceptisol) for achieving a yield target of 4.5 and 5.0 t ha^{-1} with sustained soil fertility and it can be extrapolated to other agro-climatic zones of Uttar Pradesh on similar and allied soil types.

Introduction

Rice is an important staple food that provides 60-70% of body calorie intake of the consumers (Barah and Pandey, 2005). To assess food security in rice consuming country of the world, rice production should be increased by 50% in this country by 2025. This additional rice will have to be produced on less land with less water, less labour and chemical (Zheng *et al.,* 2004). Similarly, to achieve the projected targets of 680 and 711 million tons by 2015 and 2030, respectively, the productivity of rice has to be increased through the addition of suitable integrated approaches. Rice is grown in almost all the states of the country. West Bengal, Utter Pradesh, Madhya Pradesh, Bihar, Orissa, Andhra Pradesh, Assam, Tamilnadu, Punjab, Maharashtra and Karnataka are major rice growing states and contribute to a total 92% of area and production. India is still amongst the countries with the lowest rice yields. Seventy (70%) of the 414 rice-growing districts report yields lower than the national average, clearly indicating that well after the advent of the high yield technology, a sizable area is categorized as low producing. 60% of the low productivity areas are in Bihar, Orissa, Assam, West Bengal and Utter Pradesh. Surprisingly, 32% of the irrigated rice areas produce low yields (Tiwari, 2012). Rice based cropping systems are the major production systems contributing to food production. Current crop production systems are characterized by inadequate and imbalanced uses of fertilizers e.g. blanket fertilizer recommendations over large domains with least regard to the variability in soil fertility and productivity. Future gains in productivity and input use efficiency require soil and crop management technologies that are tailored to specific characteristics of individual farms or fields. Farm research demonstrated existence of large field variability in terms of soil nutrient supply, nutrient use efficiency, crop response etc. Management of this variability is a principle challenge for further increasing crop productivity of intensive rice crop systems (Rao, 2011).

Fertilizer is one of the costliest inputs in agriculture and the use of the right amount of fertilizer is fundamental for farm profitability and environmental protection (Kimetu *et al.,* 2004). Fertilizer consumption in India was 89.8 thousand tons in 1950-51 which has become 25.53 mt in 2012-2013 (Agricultural Statistics at a Glance, 2014) in future the problem will aggravate as more grain has to be produced dew to continuously increasing population. Therefore, the application of of nutrients needs to be increased to keep the soil fertile. To sustain high yield, soil must have adequate supply of nutrients. Due to continuous intensive cultivation and use of high nutrients demands, the nutrient supplying capacity of soil is becoming a limited factor. This declining factor productivity is largely due to imbalanced fertilization along with fertilizer cost growing up. This needs to be supplied very carefully to maintain the soil fertility and obtain maximum yield. Soil testing as a tool for judicious fertilizer use is well recognized practices all over the world which take care of too little, too much or disproportionate application of nutrients. Fertilizer recommendation for preset yield target is refined technique particularly applicable under condition of fertilizer resources constraint for most efficient use of fertilizer and soil nutrients (Ramamoorthy and Velayutham, 1971). In this technique, the fertilizer are recommended separately for different field separately for different field separately on the basis of soil-test and are pre-set uniform targets yield depending upon the availability of fertilizer inputs.

Soil test based fertilizer prescription eliminates over or under usage of fertilizer inputs there by increasing the fertilizer use efficiency and yield of crops. Soil testing becomes one of the vital tools in increasing the yield of crops by optimum prescription of fertilizers to crops and maintenance of soil fertility. Targeted yield approach was first developed by Trung (1960) and Ramomoorthy *et al.,* (1967) established theoretical basis and experimental technique to suit the Indian condition. Soil test based application of plant nutrients helps to realize higher response ratio and benefit: cost ratio as the nutrients are applied in proportion to the magnitude of the deficiency of a particular nutrient and the correction of the nutrients imbalance in soil helps to harness the synergistic effects of balanced fertilization (Rao and Srivastava, 2000). Hence, the present study was carried out for rice on Inceptisols of Pratapgarh, (U.P.) which neutral to slightly acidic in nature. Extrapolation of the results emanated from the study is possible if it is test verified at farmer's holdings. Therefore, to enhance the production of rice and to sustain soil health, development and verification of suitable fertilizer prescription model is highly essential.

Materials and Methods

To validate the fertilizer prescription equations developed for rice under for verification STCR equations for rice involved field experiments carried out at Bhojpur village of district Pratapgarh, (U.P.) during, 2014-15 at three sites followed by laboratory analysis of the soil and plants samples at the Department of Soil Science and Agricultural Chemistry, Institute of Agricultural Sciences, Banaras Hindu University, Varanasi.

Initial soil samples were collected from every farmer's field and analyzed for soil texture was determined by international pipette method (Piper, 1966), and pH in soil samples were measured with Beckman glass electrode in (1:2): soil: water suspension. Electrical conductivity in (1:2): soil: water suspension was determined in saturation extracts with digital EC meter (Richards, 1954). The soil samples were analysed for organic carbon by the method of Walkley and Black (1934), alkaline $KMnO_4$-N (Subbiah and Asija, 1956), Olsen-P (Olsen *et al.*, 1954), NH_4OAc-K flame photometric method (Jackson, 1973). The initial soil test value of different farmer's field is given in table 1. Fertilizer prescription equations for rice developed by Singh *et al.*, (2014) on inseptisol of Varanasi at Institute of Agriculture Science, Banaras Hindu University under STCR approach are given below:

FN=4.76T-0.49SN-0.34M-N

FP_2O_5=1.53T-1.41SP-0.09M-P

FK_2O= 2.92T-0.35SK-0.11M-K

Where, FN, FP_2O_5 and FK_2O are fertilizer N, P_2O_5 and K_2O in kg ha^{-1}, respectively T= targeted grain yield in q ha^{-1}, SN, SP and SK are available N, P and K in kg ha^{-1} respectively M-N, M-P and M-K are N, P and K supplied through the FYM in kg ha^{-1}. The treatments imposed were as follows:

T_1: Control
T_2: Farmer practice
T_3: General recommended dose
T_4: NPK application based on soil test crop response (STCR) equation and at 5 tone FYM (Target yield 4.5 t ha^{-1})
T_5: NPK application based on soil test crop response (STCR) equation and at 5 tone FYM (Target yield 5.0 t ha^{-1})

Based on the initial soil samples values of available N, P_2O_5 and K_2O and the some amount of N, P and K supplied from the FYM, fertilizer doses were calculated applied for STCR treatments for various target yields. In the treatment T_2 and T_3 applied only inorganic fertilizers based on STCR equations developed, While treatments T_4 and T_5 received inorganic +FYM at 5 t ha^{-1} and NPK fertilizers supplied through FYM on STCR equations (Table 2) half dose of N and full dose of P_2O_5 and K_2O were applied and half dose of N applied in two splits. B: C ratio was worked out based on the price of the produce crop yield in local market. Statistical analysis was carried out the finding data of each farmer's field as one replication randomly with randomized block design. Post harvest soil sample collected from each farmer's field and soil organic carbon and analyzed for available N, P and K status.

Results and Discussion

Grain yield

The mean grain yield of the three farmers field revealed that the highest grain yield was founding in the treatment T_5 (NPK respectively T_4> T_3>T_2>T_1. The treatment T_5 is obtained higher mean grain yield at all the farmers' field and followed by T_4. In general soil test crop response (STCR) technology treatments recorded higher grain yield followed by general recommended dose, farmer practice and control (Table 2). The grain yield and straw yield were found increasing trend to that of the ascending treatments over T_1. The treatment T_1 is regarded lowest yield (17.00, 17.60 and 18.00 q ha^{-1}) at all three farmers field as compare to STCR fertilizers treatments. Statistical scrutiny of data from the three farmers field revealed that STCR treatments gets high yield ±5% from targeted yield in T_4 and T_5 (4.5 and 5.0 t ha^{-1}). In the experiment of Farmer I, the actual yield obtained was around ±5% from targeted yield. The integrated use of fertilizer and organic manure on the basis of soil test value produce significantly higher yield as compared to blanket application. Combination of organic manure and chemical fertilizers would be quite promising not only in providing greater stability in production, but also in maintaining better soil fertility. The increase yield was due to higher magnitude of yield components *viz.*, increase number and size of spikelets, individual grain weight *etc.* These finding clearly indicated that the highest crop responses in term of yield was founded with the application of sub-optimal dose of NPK and farm yard manure and it was superior than other treatment. Thus, the balanced use of fertilizer either alone or in combination with FYM is necessary for sustaining soil fertility and productivity of crop. Shah and Kumar (2014) also reported that integrated nutrient management showed significant influence on productivity of hybrid rice.

Economics/benefit cost ratio

The yield reported from treatment T_5 and T_4 was 49.27 q ha^{-1} and 44.80 q ha^{1} with benefit: cost ratio 3.41 and 3.34, respectively that are much higher than farmer's practice (2.37) in presented in table 3, due to higher average yield. The fertilizer recommendation for former practices is 100 N: 35 P: 35 K- kg ha^{-1} and for 50 q ha^{-1} and 45 q ha^{-1} target yield treatment recommendation on the basis of soil test value is 143 N: 53 P: 79 K kg ha^{-1} + 5 ton FYM and 119 N: 45 P: 64K kg ha^{-1} + 5 ton FYM, respectively.

The Farmer II 48.57 q ha^{-1} yield obtained from targeted yield of 50 q ha^{-1} with higher benefit: cost ratio (3.24) as compare to farmer's practice (2.31) and General recommendation dose (2.36). The fertilizer recommendation for farmer practices is 110 N: 35 P: 35 K- kg ha^{-1} and for 50 q ha^{-1} target yield treatment recommended on the basis of soil test value is 143 N: 60 P: 79 K kg ha^{-1} + 5 ton FYM. In the experiment of Farmer III, the yield obtained from targeted yield 50 q ha^{-1} of was higher (49.70 q ha^{-1}) than farmer's practice (2.39) with benefit: cost ratio 3.32 with application of 133 N: 60 P: 79 K kg ha^{-1} + 5 ton FYM. In other words treatment of targeted yield 50 q ha^{-1} found most economic treatment as compare to farmer practices and general recommendation. Similar results were also reported by Singh *et al.*, (2015). The similar study was conducted in district Swat during 2007 to make comparative cost benefit analysis of per acre rice production of different rice varieties. For comparison, Cost Benefit Analysis approach was used. The total per acre rice production of these varieties was amounted to Rs. 40000, 52500, 33600, 30400 and 68750, respectively. The Benefit Cost Ratio of amounted was 2.24, 3.20, 1.80, 1.80 and 1.46. Similar results are also viewed by Sellamuthu *et al.*, (2015).

Post harvest soil pH, EC and organic carbon

In general the pH of soil slightly decreases from initial mean value (6.8) at all three sites. The pH of soil of all three locations ranged between 6.63 and 6.80 (Table 4), it was slightly decrease in treated plots but not changed in control plots. The lowest soil pH value was observed in treatment T_5 in all experimental sites. The highest soil pH value was recorded in treatment T_1 (control). This may be due to the fact that the application of higher amount of nitrogenous fertilizer (urea) for obtaining higher targeted yield. Hydrolysis of urea in soil reduces soil pH and application of farm yard manure increases microbial activity in soil, microbes releases organic acids during decomposition of organic matter, it was also decrease soil pH. The overall treatment effect was found to be non significant.

Table.1 Initial soil fertility status of the field experiments of various farmers

S. No.	Farmer	Sand (%)	Silt (%)	Clay (%)	pH	EC (dSm^{-1})	OC (%)	$KMnO_4$-N (kg ha^{-1})	Olsen's P (kg ha^{-1})	NH_4OAc-K (kg ha^{-1})
1.	Farmer I	50.30	32.60	32.60	6.7	0.45	0.45	157	19	145
2.	Farmer II	53.32	28.26	28.46	6.9	0.63	0.35	170	17	132
3.	Farmer III	50.40	27.50	27.50	6.8	0.32	0.32	173	23	135

Table.2 Fertilizer doses (kg ha^{-1}) imposed in three farmers field locations based on fertilizer prescription equation

S. No.	Treatment	Farmer I			Farmer II			Farmer III		
		N	P	K	N	P Kgha^{-1}	K	N	P	K
1.	Control	0	0	0	0	0	0	0	0	0
2.	Farmer practice	135	35	35	110	35	35	100	40	30
3.	General recommendation dose	120	55	55	140	75	70	135	70	65
4.	Target yield 45 q/ha	119	45	64(5)*	119	52	64(5)*	109	52	64(5)*
5.	Target yield 50 q/ha	143	53	79(5)*	143	60	79(5)*	133	60	79(5)*

Note: The number indicated in bracket is FYM (t ha^{-1})

Table.3 Economics of verification trails for rice crop of Bhojpur in Pratapgarh district

Treatments	Fertilizer dose NPK (kg ha^{-1}) and FYM (t ha^{-1})	Actual mean yield (kg ha^{-1})	Additional yield (kg ha^{-1})	Value of additional yield (Rs.)	Cost of fertilizer (Rs.)	Net benefit (Rs.)	B/C ratio
Farmer I: Name – Shri Ram Kinkar Singh, Village- Bhojpur							
T_1-Control	0-0-0	1760	-	-	-	-	-
T_2-FP	100-35-35	2873	1113	15582	4627	10955	2.37
T_3-GRD	120-55-55	3578	1827	25578	6625	18953	2.86
T_4-TY 45 q ha^{-1}	119-45-64 & 5	4480	2793	39102	8782	30320	3.34
T_4- TY 50 q ha^{-1}	143-53-79& 5	4927	1367	44338	10043	34295	3.41
Farmer II: Name – Shri Ram Pratap Singh, Village-Bhojpur							
T_1-Control	0-0-0	1700	-	-	-	-	-
T_2-FP	100-35-35	2835	1135	15890	4801	11089	2.31
T_3-GRD	140-75-70	3735	2035	28490	8492	19998	2.36
T_4- TY 45 q ha^{-1}	119-52-64 & 5	4450	2825	39550	9175	30375	3.20
T_4- TY 50 q ha^{-1}	143-60-79& 5	4857	3157	44198	10436	33762	3.24
Farmer III: Name - Shri Chandra Pratap Singh, Village-Bhojpur							
T_1-Control	0-0-0	1800	-	-	-	-	-
T_2-FP	100-40-30	2956	1156	16184	4777	11407	2.39
T_3-GRD	135-70-65	3957	2157	30198	7992	22206	2.78
T_4- TY 45 q ha^{-1}	109-52-64 & 5	4566	2766	38724	9001	29723	3.30
T_4- TY 50 q ha^{-1}	133-60-79& 5	4970	3170	44380	10262	34118	3.32

Note: Paddy at Rs14/kg, N at Rs 17.39/kg, P_2O_5 at Rs 56.25/kg, K_2O at Rs 26.66/kg, FYM at Rs 0.5/kg

A miner modification was made in the ready reckoner,T_1 control, T_2 FP: Farmers practice i.e. the fertilizer doses the farmers generally applied in the area,T_3 GRD: General recommendation T_4 and T_5 STCR targeted yield 45 and 50 q ha^{-1} of agricultural department of the district on the basis of soil test value, B: C ratio: benefit cost ratios.

Table.4 Post harvest soil fertility by various treatments for rice crop of Bhojpur in Pratapgarh district

S. No.	Treatments	Farmer I						Farmer II						Farmer III					
		pH	EC (dS m^{-1})	OC (%)	N	P	K	pH	EC (dS m^{-1})	OC (%)	N	P	K	pH	EC (dS m^{-1})	OC (%)	N	P	K
					(kg ha^{-1})						(kg ha^{-1})						(kg ha^{-1})		
1	Control	6.80	0.20	0.40	160	20	140	6.75	0.25	0.33	157	19	135	6.78	0.24	0.31	165	20	145
2	Farmer practice	6.70	0.23	0.45	163	22	145	6.70	0.26	0.35	162	22	145	6.70	0.28	0.35	170	22	155
3	GRD	6.65	0.25	0.48	175	29.5	155	6.63	0.26	0.40	174	25	165	6.65	0.29	0.38	190	25	175
4	STCR-Target yield (45q/ha)	6.73	0.29	0.54	180	32	170	6.70	0.28	0.45	180	29.5	170	6.70	0.32	0.43	200	32	180
5	STCR-Target yield (50q/ha)	6.63	0.32	0.59	200	35	185	6.63	030	0.49	195	32	180	6.65	0.36	0.46	211.3	38	195
	SEm±	0.15	0.03	0.03	2.02	1.00	2.23	0.14	0.01	0.02	1.17	0.92	0.71	0.16	0.03	0.01	1.98	0.93	2.12
	CD at 5 (%)	0.45	0.08	0.09	5.95	2.97	6.59	0.43	0.04	0.07	3.45	2.70	2.80	0.47	0.09	0.03	5.85	2.75	6.25

The effect of treatments in EC found no significant but it increases slightly with increase doses of fertilizer from initial value (0.45, 0.63 and 0.32) in all three sites (Table 4). The electrical conductivity ranged between 0.20 to 0.36 dS m^{-1}. The highest soil electrical conductivity was observed in treatment T_5 in all soil samples collected from experiment conducted at farmer's field. The EC of soil is result of soluble salts present in soil at any particular temperature. The application of fertilizer and organic manure increases soluble salts in soil resulted electrical conductivity rises. The effect of treatments on soil organic carbon found significant and in it increase from initial values (0.45, 0.35 and 0.32%) in all three sites. In experiments the data indicated that organic carbon of soil under various treatments ranges from 0.40 to 0.59, 0.33 to 0.49 and 0.31 to 0.46 in control and treatment T_5 at farmer I, farmer II and farmer III, respectively (Table 4). In general all soil samples collected from experiment conducted at farmers field showed that the higher concentration of organic carbon were recorded in the treatment T_5 and lower value was recorded in the treatment T_1.

The organic carbon content of soil with minimum value of organic in T_1 (0.40, 0.33 and 0.31) had increased significantly and attained maximum value in the treatment T_5 at all farmer's plot. Fertilizer application further helped in increasing the organic carbon content, which is due to increased contribution from the biomass, as it is also observed that the fertilizer application increased the crop yield. Contribution from root stubble could also be expected to follow the same trend. Similar views were expressed by Thakur *et al.,* (2011).

Post Harvest Soil Available Nutrients

The data on $KMnO_4$-N, Olsen-P and NH_4OAc-K indicated the build-up and maintenance of post harvest soil fertility due to soil test based fertilizer recommendation under INM. Despite higher removal of nutrients, the fertility status was maintained in STCR-INM as compared to the general recommendation and farmer practice given in (Table 4). This might be attributed to the prevention of losses of nutrients under INM, even after meeting the crop needs. Greater profit consistent with maintenance of soil fertility status was realized when fertilizer was applied for appropriate yield targets in succession over years using STCR-INM concept (Ramamoorthy and Velayutham, 2011). Application of FYM in conjunction with chemical fertilizers will not only increase the productivity of all the cropping sequences but also improve the soil fertility (Gupta and Jagannath, 1998). Santhi *et al.*, (2011) established that soil-test-based fertilizer prescription for beet root was found to be useful in increasing yield and also maintained soil fertility.

From experiment we found that the highest targeted yield of STCR-INM treatment T_5 and T_4 all three farmers experimental field within ±5% deviation certifying the validity of the equations for prescribing integrated fertilizer dose for rice. The post harvest soil available N, P and K status indicated the build-up soil nutrients and maintain soil fertility due to soil test based fertilizer recommendation under STCR approach. Hence, the fertilizer prescription equation developed for rice under STCR-INM is recommended for Alluvial soils of Pratapgarh (U.P.) for getting yield target of 4.5 and 5.0 t ha^{-1} with sustained soil health.

It was concluded from the present investigation that the percent achievement of the targeted yield of all the three verification trials was within ± 5% variation proving the validity of the equations for prescribing integrated fertilizer doses for rice. The grain yield of rice from the three verification trials indicated that STCR-INM 45 and 50 q ha^{-1} (target yield) was found significantly higher grain yield over all other treatments, whereas farmer practice recorded significantly lower yield. Among the treatments, STCR-INM recorded relatively higher benefit: cost ratio and per cent achievement than other treatments. The post-harvest soil organic carbon and soil available N, P and K status indicated the build-up and maintenance of soil fertility due to soil test based fertilizer recommendation under INM. Hence, the fertilizer prescription equations developed for rice under INM on Inceptisol can be recommended for Bhojpur village of the district Pratapgarh (U.P.) for achieving yield target of 4.5 and 5.0 t ha^{-1} with sustained soil health.

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