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Soil Test Based Fertilizer Prescription Equation for Rice (*cv.* ADT 45) in Inceptisols of Puducherry, India

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Abstract **– Soil Test Crop Response (STCR) study was conducted during 2015-16 for rice (cv. ADT 45) under integrated plant nutrition system (IPNS) in Inceptisols (*Typic Ustropept*) in Karikkalampakkam village of U.T of Puducherry. Using the basic data, fertilizer adjustment equations have been developed for prescribing optimum fertilizer doses to attain different yield targets. The requirement of N, P_2O_5 and K_2O for rice was found to be 1.25, 0.73 and 1.01 kg q $^{-1}$, respectively. The per cent nutrient contributions from soil were 13.48, 15.81 and 10.48; from fertilizers 40.46, 44.64 and 58.60, and from organic manure 34.26, 19.89 and 41.51 for N, P_2O_5 and K_2O, respectively. The fertilizer adjustment equations at varying soil test values for attaining yield of 6 t ha^{-1} and 7 t ha^{-1} of rice have been calibrated based on the targeted yield concept. The targeted yield equations and the fertilizer ready reckoners developed for rice will be useful for large scale recommendation by the soil testing laboratory of Puducherry. In STCR approach, Post-harvest soil tests for NPK disclosed that there was maintenance of soil fertility.**

Keywords **– Fertilizer prescription equations, STCR, Targeted yield, Nutrient requirement.**

I. INTRODUCTION

Rice (*Oryza sativa* L.) is central to the lives of billions of people around the world. At the global level, rice is the most widely grown crop which occupies an area of about 161.8 million hectares, of which Asia covers about 143.2 million hectares. The slogan 'Rice is life' is most appropriate for India; as this crop plays a vital role in our India's food security and is a mean of livelihood for millions of rural households [1]

The long term food security requires a balance between increasing crop production, maintaining soil health and environment sustainability. The annual consumption of fertilizer, in nutrient forms (N, P and K) has increased has increased from 0.07 million tons in 1951-52 to more than 28 million tons in 2010-11. The nutrient use efficiency has gone down from 16 kg food grain produced per kg NPK applied during 1970's to 8 kg food grain produced per kg NPK applied during 1990's and around 6 kg now due to increasing deficiency of secondary and micronutrient [14].

Therefore, it is necessary to supplement crops with organic and inorganic fertilizer sources in order to maintain the nutrient supply and also to correct the deficiency of secondary and micronutrients. But blanket fertilizer recommendation results in over / under use of fertilizer entailing economic and yield losses. Among the various methods of fertilizer recommendations, the one based on yield targeting is unique in the sense that this method not only indicates soil test based fertilizer doses but also the level of yield the farmer can hope to achieve if good agronomic practices are followed in the raising crop. The present investigation is aimed at prescription based fertilizer applications on soil test basis for specific yield targets of rice to recommend to the farmers for proper quantity of fertilizer for sustainable crop production.

II. MATERIAL AND METHODS

A field experiment was conducted during 2015-16 under All India-Coordinated Research Project on Soil Test Crop Response Correlation at farmer's field in the karikkalampakkam village in union territory of Puducherry. The soil of the experimental field was sandy clay loam in texture with a bulk density of 1.17 Mg m^{-3}, particle density of 2.00 Mg m^{-3} and per cent pore space of 41.5. The soil is slightly alkaline and non-saline in nature with cation exchange capacity of 32.5 cmol (p^+) kg^{-1}. The P and K fixing capacities of the soil were 150 and 100 kg ha^{-1} respectively. The total N, P and K contents of the soil was 0.127, 0.213 and 0.224 per cent, respectively. The fertility status of the soil was low in $KMnO_4$-N (170.8 kg ha^{-1}) and organic carbon (0.48 %), high in Olsen-P (65.4 kg ha^{-1}) and medium in NH_4OAc-K (236 kg ha^{-1}).

The statistical design, methodology, treatment and layout followed for the present investigation was as per technical programme of AICRP on Soil Test Crop Response Correlation as described by [8]. The experiment was conducted in two phases. In the first phase, The experimental area was divided in 3 equal strips and fertility gradient were created by applying three graded level of N, P and K for 0X (Control), 1X (120:343:121) and 2X (240:686:242) of fertilizer and growing rice (kulla ponni). A wide range of soil test values in respect of available N, P and K. In the second phase, each of the 3 strips were sub-divided into 24 plots of which 21 plots in each strips received fertilizer treatments with various selected combinations and 4 levels of fertilizer nitrogen (0, 50, 100 and 150 kg N ha^{-1}), Phosphorus (0, 25, 50 and 75 kg P_2O_5 ha^{-1}) and potassium (0, 25, 50 and 75 kg K_2O ha^{-1}) while, other three were kept as unfertilized (control). For generating the soil test based integrated recommendations, each strip was divided in three equal size blocks (OM 1, OM 2 and OM 3). The OM2 and OM3 were treated with organic manure *viz.,* farmyard manure (FYM) two weeks before sowing. Quantity of organic manure (6.25 t ha^{-1}) in OM 2 was doubled to that OM 3 (12.5 t ha^{-1}). The remaining OM 1 kept as control.

The gradient crop and test crop I experiment were conducted during 2015. In the present investigation without altering the layout of field, Test crop II (rice cv. ADT 45) was grown in the same field. Full dose of P, K and half dose of N was top-dressed at 21 days after sowing of rice crop. Representative soil samples (0-15 cm) were collected from each of the 72 plots before application of fertilizer and manure for transplanting rice crop. The soil sample were analyzed for available N before sowing of the crop by alkaline $KMnO_4$ method by [12] and 0.5 M $NaHCO_3$ extractable P [7]. Available K in soils was extracted by neutral normal ammonium acetate [11] and determined flamephotometrically. The plot-wise yield data for grain and straw were recorded at the harvest of rice crop. The grain and straw samples were analyzed for N by modified micro- Kjeldahl procedure. The P content in the di-acid (HNO_3:$HClO_4$:5:4) digest was estimated by Vanadomolybdate phosphoric acid yellow color method [5] using spectrophotometer. Potassium content in the acid digest was measured using flame photometer and total uptake was calculated.

With the help of nutrient uptake data and soil test values, the basic data (nutrient requirement in kg q^{-1} of grain, per cent contribution from soil and applied fertilizer) were computed following [8]. The basic data, in turn was transformed into simple workable fertilizer adjustment equations for calculating fertilizers N, P and K doses for yield targets based on initial soil test values. The detailed methodology has been outlined earlier by [13].

III. Result and Discussion

The range and mean of soil test values and yield of three strips are presented in table 1. Maximum yield (7110 kg ha^{-1}) was obtained in strip III and the lowest in the strip I (2640 kg ha^{-1}). The data on initial soil test values revealed that alkaline $KMnO_4$-N ranged from 120.4 to 170.8 kg ha^{-1} with a mean value of 151.6 kg ha^{-1} in strip I, from 165.2 to 221.2 with a mean values of 205.3 kg ha^{-1} in strip II and from 170.8 to 243.8 kg ha^{-1} with a mean value of 211.2 kg ha^{-1} in strip III. The Olsen-P ranged from 37.3 to 55.8, 42.9 to 59.2 and 47.4 to 61.3 kg ha^{-1} respectively in strip I, II and III. The mean values of Olsen-P were 45.4, 51.3 and 53.6 kg ha^{-1} in strip I, II and III respectively. The range of NH_4OAc-K varied between 182 and 210 with mean values of 203.4 kg ha^{-1} in strip I, 205 and 240 with the mean value of 226.9 kg ha^{-1} in strip II and 232 and 286 with a mean value of 263.8 kg ha^{-1} in strip III. When the uptake of nutrients were concerned, the N uptake in strip I, II and III ranged respectively from 19.4 to 82.6, 22.4 to 83.6 and 24.8 to 101.2 with the mean values of 54.9, 65.2 and 72.7 kg ha^{-1}. The P uptake ranged from 6.5-18.9 kg ha^{-1} with a mean of 14.6 kg ha^{-1} in strip I, from 6.9 to 24.8 kg ha^{-1} with a mean of 16.8 kg ha^{-1} in strip II and from 7.3 to 24.7 kg ha^{-1} with a mean of 17.7 kg ha^{-1} in strip III. The K uptake ranged from 21.3 to 47.0, 22.2 to 57.6 and 25.1 to 60.6 kg ha^{-1} in strip I, II and III respectively. The mean K uptake values were 40.4, 44.0 and 47.5 kg ha^{-1} respectively in strip I, II and III. The above results showed that a wide variability existed in the soil test values, grain yield and nutrient uptake, which is a pre-requisite for calculating the basic parameters and fertilizer prescription equations for calibrating the fertilizer doses for specific yield targets [4].It was further identified that, the rice yield was positively correlated with soil nitrogen (r=0.536*), fertilizer nitrogen (r=0.910**), soil phosphorus (r=0.512*). The result of the above findings was in conformity with findings of [6], [9] [3] and [15] who also reported such increase in yield and uptake of nutrients by rice with increase in fertilizer levels. Furthermore, application of organic manures not only increased the supply of easily assimilated major nutrients to plants, besides mobilizing unavailable nutrients into available form; due to improvement in soil physico-chemical and biological properties by providing carbon and nitrogen source to microbes, further it also increased the activity of soil enzymes [10]

Basic parameters: The basic data in terms of nutrient requirement in kg q^{-1} grain production and per cent utilization efficiency of soil, fertilizer and manure provides a basic for quantitative balanced fertilizer recommendations for targeted crop production were furnished in the table 2.

The nutrient requirements for production of one quintal of rice were computed as 1.25 kg of N, 0.73 kg of P_2O_5 and 1.01 kg of K_2O. The contribution towards nutrient uptake from soil available was 13.5 % for N, 15.8 % for P and 10.5 % for K. The contribution towards nutrient uptake from fertilizer was 40.5 % for N, 44.6 % for P and

Table 1. Pre-sowing soil available NPK, yield and NPK uptake by rice in various strips (kg ha^{-1})

Parameters (kg ha^{-1})	Strip I		Strip II		Strip III	
	Range	Mean	Range	Mean	Range	Mean
$KMnO_4$ –N	120.4-170.8	151.6	165.2-221.2	205.3	170.8-243.8	211.2
Olsen–P	37.3-55.8	45.4	42.9-59.2	51.3	47.4-61.3	53.6
NH_4OAc-K	182.0-210.0	203.4	205.0-240.0	226.9	232.0-286.0	263.8
Grain yield	2640-6400	4954	2710-6580	5177	2810-7110	5405
N uptake	19.4-82.6	54.9	22.4-83.6	65.2	24.8-101.2	72.7
P uptake	6.5-18.9	14.6	6.9-24.8	16.8	7.3-24.7	17.7
K uptake	21.3-47.0	40.4	22.2-57.6	44.0	25.1-60.6	47.5

Table 2. Basic data for rice yield in Inceptisol of Puducherry

Nutrients	Basic data			
	NR (q ha^{-1})	CS (%)	CF (%)	CFYM (%)
N	1.25	13.5	40.5	34.3
P_2O_5	0.73	15.8	44.6	19.9
K_2O	1.01	10.5	58.6	41.5

Where, FN, FP_2O_5, FK_2O= Fertilizer N, P, K kg ha-1; NR= Nutrient requirement (kg) to produce one tonne of grain production, CS= Contribution of nutrients from soil nutrient (%), CF= Contribution of nutrients from applied fertilizer nutrient (%); CFYM= Contribution of nutrients from applied FYM (%); 58.6 % for K. Among the three nutrients, the per cent contribution from soil was higher for P_2O_5 followed by N and K. The contribution towards nutrient uptake from FYM was 34.3 % for N, 19.9 % for P and 41.5 % for K. The contribution towards nutrient uptake from the fertilizer was more compared to other sources. This is because of the combined use of organic manure and inorganic fertilizers checks nutrient losses and conserves nutrients by forming organic-mineral complexes and thus ensures continuous nutrient availability to rice plant which increases the nutrient uptake [2]

The contribution towards nutrient uptake from the FYM was more next to fertilizer. The improvement in soil physico-chemical and biological properties by providing carbon and nitrogen sources to microbes it also increased the activity of soil enzymes which increases the nutrient availability [10].

Fertilizer prescription equations for desired yield targets of rice

Soil test based fertilizer prescription equations for targeted yield of rice under NPK alone as well as IPNS were formulated using the basic parameters and are furnished in Table 3. On the basis of these equations, a ready reckoner was prepared for a range of soil test values for yield target of 60 q ha^{-1} and 70 q ha^{-1} for developing fertilizer recommendations in Inceptisol of Puducherry and adjoining areas having similar soil and agro-climatic conditions. The ready reckoner for the yield target of 60 q ha^{-1} was presented in the table 4. Requirement of N, P and K fertilizer decreased with increase in soil test values and increase in amount of FYM added. In case of NPK alone, fertilizer N, fertilizer P_2O_5 and fertilizer K_2O recommendation were found in the range between 92 to 132, 80 to 89 and 55 to 81 respectively at the different levels of soil test values.

Table 3. Soil test based fertilizer prescription equations for rice

Particulars	NPK alone	IPNS (NPK with FYM)
FN	3.06T* - 0.33SN	3.06 T – 0.33 SN – 0.85 ON
FP_2O_5	1.63T – 0.81 SP	1.63 T – 0.81 SP – 1.02 OP
FK_2O	1.70T – 0.22 SK	1.70 T – 0.22 SK – 0.85 OK

*Yield target

Under IPNS with FYM 6.25 t ha^{-1}, requirements of Fertilizer N, fertilizer P_2O_5 and fertilizer K_2O recommendation ranged between 75 to 108, 65 to 75 and 32 to 58, respectively at the different levels of soil test values. In case of IPNS with FYM 12.5 t ha^{-1}, requirement of Fertilizer N, fertilizer P_2O_5 and fertilizer K_2O recommendation ranged between 75 to 81, 51 to 61 and 25 to 35, respectively under varying degree of soil fertility status. The experiment results revealed that application of FYM along with soil test based fertilizer recommendation (200:20:180) would save 25, 14 and 23 kg of fertilizer N, fertilizer P_2O_5, and fertilizer K_2O respectively at 6.25 t ha^{-1} and 50, 30 and 46 kg ha^{-1} at 12.5 t ha^{-1}.From above finding, it can be concluded that integrated nutrient application through organic manure and inorganic fertilizer were superior over the sole application of inorganic fertilizer alone in recording both higher yield and nutrient uptake by rice. The IPNS improves the soil fertility which helps to achieve the sustained yield in rice with less environment pollution. Moreover, STCR based fertilizer recommendation gives idea about yield target can be achieved with good agronomic practices and also STCR based fertilizer recommendation increases the profit by achieving higher yield and reduce the cost of production by fertilizers savings. Finally, the fertilizer prescription equation developed could be used for making fertilizer recommendation for targeted yields of rice (cv. ADT 45) in Inceptisol of Puducherry.

Table 4. Ready reckoner for yield target of 60 q ha^{-1} under NPK alone and IPNS

Initial status	Targeted yield (60 q ha^{-1})		
$N:P_2O_5:K_2O$	NPK alone	NPK + 6.25 t FYM ha^{-1}	NPK + 12.5 t FYM ha^{-1}
160:10:100	132:89:81	108:75:58	81:61:35
180:12:120	125:88:76	102:73:53	75:59:30
200:14:140	118:86:72	95:72:49	75:57:26
220:16:160	112:84:68	88:70:45	75:56:25
240:18:180	105:83:63	81:68:40	75:54:25
260:20:200	98:81:59	78:67:36	75:52:25
280:22:220	92:80:55	75:65:32	75:51:25

CONCLUSION

From the present investigation, it could be concluded that IPNS treatments were superior over the NPK alone treatments in recording higher yield and nutrient uptake by rice. The cost of production of rice can be reduced by saving fertilizer through IPNS treatments improve the soil fertility which helps to achieve the sustained yield in rie with less environment pollution. It was precise and meaningful fertilizer recommendations for rice. Before adoption and common recommendation of fertilizer adjustment equations, it can be test verified by conducting few more verification trails with rice on Inceptisol of Puducherry.

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