Indian J. Agric. Res., 49 (5) 2015 : 437-441
Print ISSN:0367-8245 / Online ISSN:0976-058X

AGRICULTURAL RESEARCH COMMUNICATION CENTRE
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# Targeted yield based fertilizer prescriptions for autumn rice (*Oryza sativa* L.) in inceptisols of Assam, India

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Received: 17-09-2014 Accepted: 31-08-2015 DOI: 10.18805/ijare.v49i5.5807

**ABSTRACT**

Soil Test Crop Response (STCR) study was conducted during 2010-11 for autumn rice under integrated plant nutrition system (IPNS) in Inceptisols (Aeric Endoaquepts) in Jorhat district of Assam. The basic parameters were computed from the STCR data, and the fertilizer prescription equations were developed for recommending fertilizer doses in autumn rice. The nutrient requirement (NR) for producing one quintal of autumn rice was found to be 2.40 kg, 0.84 kg and 2.25 kg of N, $P_2O_5$ and $K_2O$, respectively. The percent contribution of nutrients from soil (CS), fertilizer (CF) and FYM (CO) were calculated as 12.49, 45.31 and 32.92 for N, 13.42, 28.52 and 11.84 for $P_2O_5$ and 21.99, 47.58 and 29.76 for $K_2O$, respectively. These equations were validated in farmers' fields during 2012 and the variation between actual yield and targeted yield ranged from +1.36 to +5.33.The fertilizer estimates under STCR-IPNS for 3000 and 4000 kg $ha^{-1}$ targeted yield recorded maximum response ratio and economic benefit in the field trial and confirmed the validity of proposed fertilizer prescription equations for autumn rice.

**Key words:** Autumn rice, Fertilizer prescription equations, Soil test crop response, Targeted yield.

## INTRODUCTION

Fertilizer application is one of the efficient means of increasing agricultural profitability. The fertilizer prices have gone up and hence their use in required amounts depends much upon the purchasing ability of the farmers. 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). Accordingly much attention is given to the integrated use of organic and mineral nutrition for meeting the economic needs of farmers as well as for sustainability in terms of productivity and soil fertility. 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 targeted yield approach (Ramamoorthy *et al.* 1967) had received wide acceptability and popularity in India. Targeted yield concept is based on quantitative idea of the fertilizer needs based on yield and nutritional requirement of the crop, per cent contribution of the soil available nutrient and that of the applied fertilizer. This method not only estimates soil test based fertilizer dose but also the level of yield the farmer can achieve with that particular dose. Targeted yield approach also provides scientific basis for balanced fertilization not only between the nutrients from the external sources but also from the external sources.

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. The area for autumn (*Ahu*) rice in Assam is 1.72 lakh hectare,with a productivity of 1539 kg $ha^{-1}$ (Anonymous. 2014). One of the reasons for lower productivity is imbalanced fertilization of N, P and K nutrients. High cost of fertilizers and their non-availability in lean period remain constraints for the farmers to apply adequate amount of fertilizers to crop. Greater economy in fertilizer use can be made if fertilizers are applied under integrated plant nutrition system (IPNS) on the basis of soil test. Such studies are possible only through inductive-cum-targeted yield approach (Ramamoorthy *et al*. 1967). In Assam, works on soil test crop response correlation under integrated plant nutrition system (STCR-IPNS) has not yet been initiated. Hence, the present study was undertaken to develop fertilizer prescription equations for desired yield targets of autumn rice in Inceptisols of Assam.

## MATERIALS AND METHODS

A field experiment was conducted during 2010-11 on Aeric Endoaquepts at Instructional cum Research Farm of Assam Agricultural University, Jorhat which is located at a latitude of 26°48¢N and longitude of 95°50'E. The soil of the experimental field was sandy clay loam with pH 5.10, organic carbon 0.60 per cent. The P and K fixing capacities of the soil were 145.60 and 224.00 kg $ha^{-1}$, respectively. The amount of available N, P and K were 213.25, 35.91 and

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108.32 kg ha$^{-1}$, respectively. The statistical design, layout, treatments and methodology followed for the present investigation was as per technical programme of AICRP on Soil Test Crop Response Correlation as described by Ramamoorthy *et al.* (1967). The experiment was conducted in two phases. In the first phase, fertility gradient stabilizing experiment was conducted by transplanting 21 days old seedlings of rice (cv, Ranjit) as an exhaust crop on 7$^{th}$ July 2010 and harvested on 23$^{rd}$ November 2010 to minimise the interference of other soil and management factors affecting crop yield. The field was divided into four equal strips and fertilized with different proportions of recommended fertilizers of 60, 20 and 40 kg ha$^{-1}$ of N, $P_2O_5$ and $K_2O$, respectively ($N_1P_1K_1$), *viz.*, $N_0P_0K_0$, $N_{1/2}P_{1/2}K_{1/2}$, $N_1P_1K_1$ and $N_2P_2K_2$ to create artificial fertility gradient. In the second phase, test crop experiment with autumn rice (cv. Luit) was conducted following harvest of the exhaust crop. Each of the fertility strips was subdivided into 24 subplots to allocate 24 treatments comprising various levels of nitrogen (0, 30, 60, 90 and 120 N kg ha$^{-1}$), phosphorus (0, 30, 60 and 90 $P_2O_5$ kg ha$^{-1}$), potassium (0, 60 and 120 $K_2O$ kg ha$^{-1}$) and farmyard manure (0, 2.5, 5 and 10 t ha$^{-1}$). Fertilizers containing $P_2O_5$ and $K_2O$ were applied one day before transplanting as basal while farmyard manure was applied one week before transplanting. Half of the recommended dose of N fertilizer of N-fertilizer was applied as basal, and the remaining half was applied at maximum tillering and panicle initiation stage. The moisture and N, P and K contents of FYM were 20 per cent, 0.60 per cent, 0.37 per cent and 0.55 per cent, respectively. Pre-sowing soil samples were collected from each plot before the superimposition of the treatments and were analysed for per cent organic carbon (Walkey and Black's method), available N (Alkaline Potassium Permanganate Method), available P (Bray and Kurtz No.1 Method) and available K (Flame Photometric Method). Twenty one days old seedlings of rice (cv. Luit), as test crop, were transplanted on 22$^{nd}$ March 2011 and harvested on 24$^{th}$ June 2011. Highest total rainfall during the study period was 104.6 mm and bright sunshine hours of the crop season ranged from 2.6 to 2.9 per day. Crop yields were recorded and representative grain and straw samples were analysed for N, P and K contents by standard methods *viz.*, modified Kjeldahl's method, Vanadomolybdate and Flame Photometric method, respectively. The observations on crop yield, nutrient uptake, pre-sowing soil available nutrients and applied fertilizer doses were used to calculate the basic parameters *viz.*, nutrient requirement (NR), contribution of nutrient from soil (CS), fertilizer (CF) and organic manure (CO) as per procedure described by Ramamoorthy *et al.* (1967) and Santhi *et al.*(2002).These parameters were used to formulate fertilizer prescription equations and accordingly, soil test based fertilizer recommendations were prescribed in the form of a ready reckoner for desired yield target of autumn rice with NPK alone or under IPNS.

Verification field trials were conducted to validate proposed recommendations at seven locations on farmers' field, Jorhat district with six treatments replicated thrice in a randomized block design. Recommended agronomic practices for autumn rice were followed and crop yield was recorded at harvest and economic comparisons for the treatments were determined. Average values are given in this article for avoiding presentation of voluminous data generated in each location.

## RESULTS AND DISCUSSION

### Fertility gradient establishment experiment

Experimental data on grain yield of exhaust crop and available nutrients in soil from all the four strips after harvest of crop are presented in Table 1.Results revealed that the highest grain yield and available nutrient contents were recorded in the highest fertilizer dose ($N_2P_2K_2$) and the lowest in control ($N_0P_0K_0$) indicating the formation of fertility gradient. Strip-wise range and mean soil test values of pre sowing soils for organic carbon and available nutrients are furnished in Table 2. The average content of soil organic carbon and available nutrients increased with increasing fertilizer doses and the highest content was exhibited in strip $L_2$.The average organic carbon and available N content increased from 0.59 to 0.65 per cent and 198.61 to 232.85 kg ha$^{-1}$, respectively and recorded an increase of 0.05 per cent of organic carbon and 34.24 kg of available N per hectare in strip $L_2$ as compared to strip $L_0$. This increase was due to addition of double dose of NPK fertilizers resulting in higher root and shoot growth *vis-a-vis* increased production of biomass. The results conform to that reported by Thilagam and Natesan (2009). The available P status of soil increased from medium to high level indicating creation of more profound fertility gradient in relation to P, compared to available N. Similar trend was also noted for available potassium in different strips (Table1). There was an increase of 19.18 kg in the content of available K per hectare in the strip $L_2$ over $L_0$. This increase in availability was mainly due to graded dose of fertilizer application and corroborates with the findings of Santhi *et al*. (2010) and Chatterjee *et al*. (2010).

**Test crop experiment:** The grain yield of autumn rice and nutrient uptake by the crop under different strips are given in Table 2. Maximum yield (23.65 kg ha$^{-1}$) was obtained in strip $L_2$ followed by $L_1$ (23.12 kg ha$^{-1}$), $L_{1/2}$ (21.62 kg ha$^{-1}$)

**TABLE 1** : Effect of graded levels of N, $P_2O_5$ and $K_2O$ on grain yield and soil available nutrients after harvest of exhaust crop (rice cv. Ranjit)

| Strip | Grain yieldt ha$^{-1}$ | Available Nutrients (kg ha$^{-1}$) | | |
|---|---|---|---|---|
| | | N | P | K |
| I | 4.00 | 65.00 | 8.40 | 76.00 |
| II | 5.00 | 104.98 | 12.65 | 107.65 |
| III | 5.57 | 131.27 | 19.46 | 137.79 |
| IV | 5.90 | 152.60 | 28.75 | 153.10 |

**TABLE: 2** Soil test values prior to test crop and grain yield, nutrient uptake by autumn rice under different strips

| Particulars | Strip $L_0$ | | Strip $L_{1/2}$ | | Strip $L_1$ | | Strip $L_2$ | |
|---|---|---|---|---|---|---|---|---|
| | Range | Mean | Range | Mean | Range | Mean | Range | Mean |
| Organic carbon (%) | 0.50-0.65 | 0.59 | 0.55-0.65 | 0.60 | 0.55-0.68 | 0.63 | 0.60-0.68 | 0.65 |
| Available N (kg $ha^{-1}$) | 169.35-219.52 | 198.61 | 188.16-250.88 | 211.68 | 188.16-250.88 | 223.44 | 219.52-288.51 | 232.85 |
| Available $P_2O_5$ (kg $ha^{-1}$) | 31.81-41.04 | 34.18 | 41.04-49.83 | 45.65 | 51.80-60.71 | 55.26 | 60.52-69.39 | 65.01 |
| Available $K_2O$ (kg $ha^{-1}$) | 97.57-108.32 | 101.01 | 102.05-113.03 | 107.27 | 106.25-119.19 | 113.55 | 113.03-124.94 | 120.19 |
| Grain yield (kg $ha^{-1}$) | 16.50-22.75 | 19.34 | 16.50-25.75 | 21.62 | 16.58-30.25 | 23.12 | 18.11-30.85 | 23.65 |
| N uptake (kg $ha^{-1}$) | 22.00-59.46 | 40.26 | 22.25-68.96 | 50.05 | 25.10-82.25 | 59.49 | 25.95-83.50 | 64.96 |
| P uptake (kg $ha^{-1}$) | 5.15-21.48 | 14.93 | 5.15-27.14 | 18.40 | 7.74-32.29 | 20.66 | 8.24-35.70 | 22.36 |
| K uptake (kg $ha^{-1}$) | 20.83-53.36 | 37.50 | 23.00-79.59 | 48.57 | 24.88-92.82 | 55.47 | 25.76-106.90 | 62.84 |

and the lowest in strip $L_o$ (19.34 kg $ha^{-1}$). The increase in grain yield with double recommended dose over control was 22.28%. Similarly, strip-wise average nutrient uptake was in the order of strips $L_2 > L_1 > L_{1/2} > L_o$. The results indicated 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 (Santhi *et al*. 2002 and Chatterjee *et al*. 2010).

**Basic parameters:** The basic data *viz*., the nutrient requirement for producing one quintal of autumn rice, the per cent contribution of nutrients from soil, fertilizer and FYM were calculated from the initial soil test values, crop yield and nutrient uptake and are furnished in Table 3. These basic parameters were used for formulating the fertilizer prescription equation with NPK alone or along with FYM.

**TABLE 3** Basic parameters for production of unit quintal grain of autumn rice

| Parameters | N | $P_2O_5$ | $K_2O$ |
|---|---|---|---|
| Nutrient requirement (kg $q^{-1}$) | 2.40 | 0.84 | 2.25 |
| Percent contribution from soil (CS) | 12.49 | 13.42 | 21.99 |
| Percent contribution from fertilizer (CF) | 45.31 | 28.52 | 47.58 |
| Percent contribution from FYM (CO) | 32.92 | 11.84 | 29.76 |

The nutrient requirements for production of one quintal of autumn rice were computed as 2.40 kg of N, 0.84 kg of $P_2O_5$ and 2.25 kg of $K_2O$. The per cent contribution from soil and fertilizers were 12.49 and 45.31 for N, 13.42 and 28.52 for $P_2O_5$ and 21.99 and 47.58 for $K_2O$, respectively. The estimated CF revealed that the magnitude of contribution by fertilizer N, $P_2O_5$ and $K_2O$ were 3.63, 2.13 and 2.16 times higher than that of the soil. With regard to N, comparatively more contribution was recorded from fertilizers than that of $P_2O_5$ and $K_2O$. The split application of N at critical stages of crop growth might have resulted in higher percent contribution of nutrients from the fertilizer source. (Gayathri *et al*. 2009).

The per cent contribution of N, $P_2O_5$ and $K_2O$ from FYM was 32.92, 11.84 and 29.76, respectively. The data showed that contribution of N was the highest followed by $K_2O$ and $P_2O_5$. FYM might have provided enough carbon which served as source of energy for buildup of bacterial population which in turn enhanced the contribution of N. The findings are in close conformity with those reported by Meena *et al*. (2001) and Santhi *et al*. (2002).

Relationship between grain yield as dependent variable and the soil test values, fertilizer doses, farmyard manure doses, interactions between soil test values, fertilizer doses and among fertilizer nutrients as independent variables was established through a multiple regression equation of quadratic model.

$$Y = 2.707 + 0.011^* SN - 0.038^* SP + 0.058^* SK + 6.023 SOC + 0.057^* UN + 0.146^* UP + 0.059^* UK + 0.003^* FN -0.006^* FP - 6.397^* FK - 0.029^* OM \quad (R^2 = 0.965^{**})$$

It was observed from $R^2$ value that variation up to 96.5 per cent in rice grain yield could be explained by the differences in soil test values and fertilizer doses. Significant linear relationships between grain yield and nutrient removal by the crop testified that target yield equations in terms of nutrient uptake, soil test values and applied organic manure and fertilizer could be developed.

**Fertilizer prescription equations for desired yield targets of autumn rice**

Soil test based fertilizer prescription equations for targeted yield of autumn rice under NPK alone as well as IPNS were formulated using the basic parameters and are furnished in Table 4. On the basis of these equations, a ready reckoner was prepared for a range of soil test values for yield target of 40 q $ha^{-1}$ under NPK alone and IPNS (Table 5).

**TABLE 4** Soil test based fertilizer prescription equations for autumn rice

| Particulars | NPK alone | NPK with FYM (IPNS) |
|---|---|---|
| FN | 5.30T*-0.27SN | 5.30T-0.27SN-0.72 ON |
| F $P_2O_5$ | 2.94T-0.47S$P_2O_5$ | 2.94T-0.47S$P_2O_5$-0.41OP |
| F $K_2O$ | 4.72 T-0.46S$K_2O$ | 4.72T-0.46S$K_2O$-0.62OK |

*Targeted Yield

**TABLE 5** Ready reckoner for yield target of 40 q $ha^{-1}$ under NPK and IPNS.

| Initial status | Target yield (40 q $ha^{-1}$) | | |
|---|---|---|---|
| N: $P_2O_5$: $K_2O$ | NPK alone | NPK+5 tonne FYM $ha^{-1}$ | NPK+10 tonne FYM $ha^{-1}$ |
| 200: 10: 120 | 158: 113: 134 | 140: 109: 118 | 122: 105: 103 |
| 250: 15: 125 | 144: 110: 131 | 126: 106: 115 | 108: 101: 100 |
| 300: 20: 130 | 131: 108: 129 | 113: 104: 113 | 95: 99: 98 |
| 350: 25: 135 | 117: 106: 127 | 99: 102: 111 | 81: 98: 96 |
| 400: 30: 140 | 104: 103: 124 | 86: 99: 108 | 68: 95: 93 |
| 450: 35: 145 | 90: 101: 122 | 72: 97: 106 | 54: 93: 91 |

Requirements of N, P and K fertilizers decreased with increase in soil test values. In case of NPK alone, fertilizer N recommendation was found in the range between 90 and 158 kg $ha^{-1}$, fertilizer $P_2O_5$ between 101 and 113 kg $ha^{-1}$ and fertilizer $K_2O$ between 122 and 134 kg $ha^{-1}$ under varying degree of soil fertility status.

Under IPNS with FYM 5 t $ha^{-1}$, requirements of N, $P_2O_5$ and $K_2O$ ranged between 72 and 140 kg $ha^{-1}$, 97 and 109 kg $ha^{-1}$ and 106 and 118 kg $ha^{-1}$, respectively at the different levels of soil test values. There was further decrease with 10 t FYM $ha^{-1}$ and the doses varied between 54 and 122 kg $ha^{-1}$ for N, 93 and 105 for $P_2O_5$ and 91 and 103 kg $ha^{-1}$ for $K_2O$ against targeted yield of 40 q $ha^{-1}$. Application of FYM along with soil test based fertilizer recommendation (300: 20: 130) would save 18, 4 and 16 kg $ha^{-1}$ of N, $P_2O_5$ and $K_2O$ at 5 t $ha^{-1}$ and 36, 8 and 31 kg $ha^{-1}$ of N, $P_2O_5$ and $K_2O$ at 10 t $ha^{-1}$. Similar results were also reported by Jadav *et.al*. for garlic in inceptisols.

**Verification trial:** The proposed recommendations were validated in seven farmers' fields in Inceptisols for autumn rice. In all the locations, significantly higher grain yield was recorded for IPNS with 5 t $ha^{-1}$ followed by NPK alone for yield targets of 4000 kg $ha^{-1}$ (Table 6). Per cent deviations between yield target and actual yield were +1.36 to +5.33. Highest net profit and benefit cost ratios were recorded for 5 t $ha^{-1}$ farmyard manure + yield target 4000 kg $ha^{-1}$ (T6) that the response of rice to STCR calibrated fertilizer doses, net profit and benefit cost ratios due to soil test based fertilizer dose were greater than those under general recommended dose. Chatterjee *et al.* (2010) earlier reported higher net profit and benefit: cost ratio through targeted yield approach in comparison to general recommended dose for potato in Uttarakhand.

The findings of the present study clearly revealed that the fertilizer prescription equations developed with NPK alone or under IPNS could be used effectively in Jorhat district of Assam for achieving the yield target of autumn rice up to 4000 kg $ha^{-1}$ The practice of fertilizing crops on the basis of yield targets appears precise, meaningful and economically viable and needs to be popularized among farmers, however long-term sustainability of higher productivity and profitability offers scope for further study.

**TABLE 6:** Economics of verification trial for autumn rice

| Treatment | Fertilizer dose N-$P_2O_5$-$K_2O$-FYM (kg $ha^{-1}$) | Actual mean yield (kg$ha^{-1}$) | Response ratio | Deviation in yield (%) | Net profit (Rs) | B/C ratio |
|---|---|---|---|---|---|---|
| $T_1$ Control | 0-0-0-0 | 1050 | - | | - | 1.10 |
| $T_2$ General recommendation | 40-20-20-0 | 2040 | 9.90 | | 9061 | 1.65 |
| $T_3$ Yield target 3000 kg $ha^{-1}$ | 86-70-22-0 | 3045 | 11.71 | 1.48 | 15,919 | 1.96 |
| $T_4$ Yield target 4000 kg $ha^{-1}$ | 138-99-70-0 | 4055 | 10.25 | 1.36 | 21,745 | 2.10 |
| $T_5$ FYM 5 tonnes $ha^{-1}$ + yield target 3000 kg $ha^{-1}$ | 71-65-15-5000 | 3175 | 14.69 | 5.15 | 18,063 | 2.16 |
| $T_6$ FYM 5 tonnes $ha^{-1}$ + yield target 4000 kg $ha^{-1}$ | 123-94-63-5000 | 4225 | 11.85 | 5.33 | 25,085 | 2.33 |
| CD(P= 0.05)CV=12.40 | | 77 | | | | |

Rate N@ Rs 10.00 $kg^{-1}$, $P_2O_5$@ Rs10.00 $kg^{-1}$, $K_2O$@ Rs 18.00 $kg^{-1}$, cost of rice grain= Rice @Rs 25.00 $kg^{-1}$

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