International Journal of Chemistry Studies
ISSN: 2581-348X
Impact Factor: RJIF 5.44
www.chemistryjournal.in
Volume 2; Issue 2; March 2018; Page No. 01-04

Soil physico-chemical properties under target yield approach based fertilizer recommendations in system of rice intensification (SRI)

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Abstract
A field experiment was conducted during *kharif* 2015 Palampur, Himachal Pradesh to study the influence of different approaches of fertilizer application on physico-chemical and chemical properties of soil in SRI. Eight treatments included in this investigation were control, farmers' practice, general recommended dose, soil test based, yield targets 3.5, 4.0, 4.5 and 5.0 t ha^{-1} replicated thrice in a randomized complete block design (RCBD). The results revealed that soil test crop response (STCR) approach based fertilizer application significantly increased the available nitrogen (N), phosphorus (P) and potassium (K) status in soil as compared to all the other approaches of fertilizer recommendations. However, the values of soil pH, organic carbon (OC) and DTPA extractable micronutrients were not significantly prejudiced by the different approaches of fertilizer recommendations which was obvious and expected in such a short period of about four months.

Keywords: fertilizer, rice, SRI, STCR, target yield, RCBD, available nitrogen (N), phosphorus (P), potassium (K)

1. Introduction
India's resounding success from its past green revolution has been followed by stagnating or declining agricultural productivity, even with increased total fertilizer use in the country over the years. This declining factor productivity is largely due to fertilizer use out of all proportion [1]. Fertilizer is one of the costliest inputs in agriculture and the use of right amount of fertilizer is fundamental for maintenance of soil health. Imbalanced use of fertilizers directly or indirectly causes adverse changes in soil properties. These changes are believed to have significant influences on the quality and productive capacity of the soil. For Indian soils, the most desirable nutrient use ratio (N: P_2O_5: K_2O) given is 4:2:1 whereas the current ratio of 6.7:2.4:1 is far away the mark. There exists a gap of about 10 million tonnes of nutrients (N, P, K) between the crop removal and their addition through fertilizers [2]. To narrow down this much gap, balanced use of fertilizers is most imperative aspect. Therefore, fertilizer application based on soil testing is being advocated throughout the world. Soil testing is widely adopted to know the nutrients status and their imbalances in the soil and apply required amount of the nutrients to overcome imbalances [3]. However, in conventional soil testing the fertilizer recommendation are usually given for different crops by taking into consideration only the available nutrient status of soil prior to raising crop, by categorizing soil into low, medium and high fertility classes. The prescription based fertilizer recommendation approach on the other hand, takes into account every bit of nutrient present in soil for achieving targeted yield of crops under a particular agro-climatic situation. This approach is crop and variety specific and provides scientific basis for balanced fertilization not only between the fertilizer nutrients but also the soil available nutrients themselves [4]. Targeted yield concept strikes a balance between 'fertilizing the crop and fertilizing the soil'. Therefore, this investigation was carried out to evaluate the effect of STCR approach based fertilizer application on soil physico-chemical properties in SRI in comparison to conventional approaches of fertilizer recommendations.

2. Materials and Methods
A field experiment was conducted during *kharif* 2015 at the Experimental farm of Department of Soil Science, CSK Himachal Pradesh Krishi Vishvavidyalaya, Palampur. Geographically, the experimental field is situated at Palampur $32^0 6'$ N latitude and $76^0 3'$ E longitude at an elevation of 1290.8 m above mean sea level. Palampur soils have been developed from fluvo-glacial parent material and belong to the order Alfisol and subgroup Typic Hapludalf as per the Taxonomic system of soil classification [5]. The experiment was laid out in RCBD with eight treatments, each replicated three times with plot size of 10 m^2. The eight different treatments included in this investigation were control, FP i.e. 25 % of general recommended dose of N (22.5 kg N ha^{-1}), General recommended dose, Soil test based fertilizer application, Yield Targets of 3.5, 4.0, 4.5 and 5.0 tonne ha^{-1}. Absolute control (no fertilizer applied) was incorporated to compare improvement in soil fertility status due to fertilizer treatments. General recommended dose of soil fertilizers for rice were 90 kg N, 40 kg P_2O_5 and 40 kg K_2O ha^{-1}. Nitrogen was applied as urea, P as single superphosphate (SSP) and K as muriate of potash (MOP). Fertilizer doses in case of targeted yield treatments were worked out using following equations:

$$F\ N = 5.46\ T - 0.32\ SN$$

$$F\ P_2O_5 = 2.50\ T - 2.67\ SP$$

$$F\ K_2O = 2.82\ T - 0.68\ SK$$

Where, T is the yield target (q ha^{-1}), F N, F P_2O_5, F K_2O are doses of N, P_2O_5 and K_2O, respectively in kg ha^{-1} which are to be added through fertilizer. SN, SP and SK are soil test value in kg ha^{-1} for available N, P and K, respectively. Field experiment was undertaken on a silty clay loam soil characterized by pH of 5.5. Surface soil had organic carbon (11.2 g kg^{-1}), available N (320 kg ha^{-1}), P (30 kg ha^{-1}), K (112 kg ha^{-1}) and DTPA extractable micronutrients iron (Fe) (22.18), manganese (Mn) (19.34), zinc (Zn) (1.18) and copper (Cu) (0.73 mg kg^{-1}).

Rice crop (var. HPR 2612) nursery was raised during *Kharif* 2015 on 9th June for producing robust, healthy rice seedlings in 14 days' time, suitable for transplanting with single seedling along with seed and soil attached per hill under SRI method of cultivation. Fourteen days old seedlings were uprooted one by one by holding them at the base. Seedlings were then transplanted manually by using index finger and thumb at 25cm x 25cm spacing. Transplanting was done on 23rd June, 2015 with one seedling per hill and harvested on 22nd October, 2015. Agronomic and crop management practices followed were those recommended by CSK HPKV, Palampur. Weed control was done by spraying with Butachlor @ 1.5 l ha^{-1} after 3 days of transplanting and two hand weedings were done to get rid of weed infestation.

Soil samples were collected from a depth of 0 – 15 cm before sowing, at 50 per cent flowering stage and after harvest of rice. The samples were air dried, ground in a wooden pestle and mortar, to pass through 2 mm sieve and stored in polythene bags for subsequent analysis [6]. Soil samples so processed were analyzed for pH, OC, available N, P and K before initiation of experiment, at 50 per cent flowering stage and at harvest of the crop. Samples drawn before initiation of experiment and at harvest of the crop were also analysed for micronutrient cations *viz.* Fe, Mn, Zn, Cu by using DTPA extractable method [7]. Soil pH was analysed by using a soil water suspension ratio of 1:2.5[8]. The soil OC was determined by using titration method [9]. Available N was analysed by Alkaline potassium permanganate method [10], P by 0.5N $NaHCO_3$ [11] and K by 1N Ammonium Acetate method [12].

3. Results and Discussion

3.1 Soil physico-chemical and chemical properties at 50% flowering stage

3.1.1 Soil pH

Data pertaining to soil pH revealed that soil pH ranged from 5.3 in control plots to 5.7 in yield targets of 4.5 and 5.0 t ha^{-1}. However, different approaches of fertilizer application had no significant effect on soil pH.

3.1.2 Soil organic carbon

Data on soil OC revealed that organic carbon content ranged from 11.3 g kg^{-1} in control to 11.6 g kg^{-1} in STCR treatment for yield target of 5.0 t ha^{-1}. However, different approaches of fertilizer application had no significant effect on soil organic carbon content. Though, numerically little higher values were observed in the treatments involving balanced application of nutrients.

3.1.3 Available nitrogen

The available NPK status at 50 per cent flowering in rice was affected significantly due to different approaches of fertilizer application as shown in (Table 1). The FP significantly increased the available nitrogen over control and the increase was 2.3 per cent. Likewise, in soil test based application of fertilizers, the available nitrogen content increased significantly by 6.3 per cent over the farmers' practice. However, soil test based was statistically at par with general recommended dose. The targeted yield treatments were significantly increased the available nitrogen as compared to the rest of the treatments. The treatment for yield target of 5.0 t ha^{-1} significantly improved the available nitrogen by 8.3, 5.4 and 2.6 per cent as compared to yield targets of 3.5, 4.0 and 4.5 t ha^{-1}. In farmers' practice, its content significantly improved over control which might be due to supply of @ 25 per cent of the recommended dose of nitrogen. The lower content of available nitrogen in control plots was a result of mining of soil available nitrogen as no external input was applied in this treatment. A significant buildup of N in soil receiving NPK was also reported by 13 and 14. Similarly, significantly higher soil available plant nutrients was also reported by 15. Higher soil available nitrogen in targeted yield treatments was obtained as compared to other approaches of fertilizer application [16].

Table 1: Effect of target yield approach based fertilizer recommendations on available N, P and K content in soil at 50% flowering stage in SRI

Treatment	Available N (kg ha^{-1})	Available P (kg ha^{-1})	Available K (kg ha^{-1})
Farmers' Practice	313.6	22.9	120
General Recommended Dose	328.2	36.4	135
Soil test based	334.5	33.9	138
STCR based for yield target of 3.5 t ha^{-1}	341.8	30.1	126
STCR based for yield target of 4 t ha^{-1}	351.2	30.9	131
STCR based for yield target of 4.5 t ha^{-1}	360.6	32.1	141
STCR based for yield target of 5 t ha^{-1}	370.0	38.3	147
Control	306.3	21.5	117
CD (P= 0.05)	6.9	3.8	5.2

3.1.4 Available phosphorus

Like soil available N, available P was also significantly higher in all treatments over control and FP (Table 1). However, FP and control were statistically at par with one another. The lower available phosphorus content in control and FP was due to no phosphorus application coupled with sufficient drain

through crop harvest. General recommended dose and conventional soil test based treatments significantly increased the available P as compared to the FP. The soil test based dose was however, statistically at par with general recommended dose. Treatment for yield target of 5.0 t ha^{-1} recorded significantly higher available P in comparison to all the other treatments which might be due to higher application of P in this treatment. All the other STCR based treatments were statistically at par with soil test based application of fertilizers. Similarly, increase in available P with increased level of NPK has also been reported by 17, 18 and 19.

3.1.5 Available potassium

Similar to soil available N and P, available K also significantly higher in the treatment of general recommended dose by about 13 and 15 per cent over FP and control, respectively (Table 1). However, soil test based application was statistically at par with general recommended dose. The available K content in control and FP was minimum due to continuous cropping, its mining and no addition of external inputs. Reddy *et al*. also reported a decline in available potassium content of the soil due to intensive cropping over the years without addition of fertilizers [22]. Available potassium content was significantly higher in treatment for yield target of 5.0 t ha^{-1} as compared to all the other treatments. Higher available K in soil with the application of higher dose of potassium fertilizers was also reported by 17 and 20.

3.2 Soil physico-chemical and chemical properties at harvesting stage

3.2.1 Soil pH

The data showed that different approaches of fertilizer recommendations did not significantly influence the value of soil pH. Data revealed that soil pH ranged from 5.6 in control plots to 5.9 in STCR treatment for yield target of 5.0 t ha^{-1}.

3.2.2 Soil organic carbon

A close look on the data revealed that soil organic carbon ranged from minimum value of 11.5 g kg^{-1} in control to maximum 11.7 g kg^{-1} in the treatment for yield target of 5.0 t ha^{-1}. However, differences between treatments were not significant which was obvious and expected in such a short duration of about four months. Though, numerically little higher values were observed in the treatments involving balanced application of nutrients.

3.2.3 Available nitrogen

The soil available nitrogen status at harvest of rice was affected significantly due to different approaches of fertilizer application as shown in Table 2. The available nitrogen status in control was significantly lower (284.3 kg ha^{-1}) as compared to the rest of the treatments. Maximum available nitrogen (333.5 kg ha^{-1}) was observed in STCR treatment for yield target of 5.0 t ha^{-1}. As compared to the control, even farmers' practice recorded 3.7 per cent higher available nitrogen content in soil. Further, soil test based increased it by 3.2 per cent over the farmers practice. However, soil test based application of fertilizers was statistically at par with general recommended dose. Among STCR treatments, treatment for yield target of 3.5 t ha^{-1} significantly enhanced the available nitrogen in soil by 3.5 per cent and 2.1 per cent as compared to general recommended and soil test based dose, respectively. The targeted yield treatments significantly increased the available nitrogen as compared to other. Available nitrogen in soil was 3.8 and 1.9 per cent higher in STCR treatment for target yield of 5.0 t ha^{-1} over targeted yield treatments 4.0 and 4.5 t ha^{-1}, respectively.

3.2.4 Available phosphorus

The data pertaining to available P at harvest of rice crop have been presented in (Table 2). The highest available phosphorus was recorded in the treatment for target yield of 5.0 t ha^{-1}. The application of general recommended dose and conventional soil test based application of nutrients significantly increased the available P by 33 and 27 per cent, respectively as compared to the farmers' practice. General recommended dose significantly improved the soil available phosphorus content in comparison to treatments for yield targets of 3.5, 4.0 and 4.5 t ha^{-1}.

Table 2: Effect of target yield approach based fertilizer recommendations on available N, P and K content in soil at 50% flowering stage in SRI

Treatment	Available N (kg ha^{-1})	Available P (kg ha^{-1})	Available K (kg ha^{-1})
Farmers' Practice	313.6	22.9	120
General Recommended Dose	328.2	36.4	135
Soil test based	334.5	33.9	138
STCR based for yield target of 3.5 t ha^{-1}	341.8	30.1	126
STCR based for yield target of 4 t ha^{-1}	351.2	30.9	131
STCR based for yield target of 4.5 t ha^{-1}	360.6	32.1	141
STCR based for yield target of 5 t ha^{-1}	370.0	38.3	147
Control	306.3	21.5	117
CD (P= 0.05)	6.9	3.8	5.2

3.2.5 Available potassium

General recommended dose significantly improved available potassium content in soil by 11 per cent over control and 9.1 per cent over farmers' practice (Table 2). However, farmers' practice and control were statistically at par with one another. In the soil test based treatment, the enhancement in available potassium to the tune of 14.8 per cent over the control and 12 per cent over the farmers' practice was recorded. The targeted yield treatment 5.0 t ha^{-1} recorded highest available K content. It was 12.4, 9.5 and 2.4 per cent higher as compared to the treatments comprising yield targets of 3.5 t ha^{-1}, 4.0 t ha^{-1} and 4.5 t ha^{-1}, respectively.

Low available NPK in control was due to mining of available nitrogen as no external application was made in this treatment. The significant increase of available N in FP over control was due to addition of 25 per cent of the recommended dose of nitrogen fertilizers. The increase in available NPK content in case of targeted yield treatments may be due to higher, balanced and judicious application of fertilizers. These results were in conformity with the findings of 17, 20, and 21. Reddy *et al*. also reported a decline in available potassium content of the soil due to intensive cropping over the years without the addition of fertilizers [22].

3.4.6 DTPA extractable micronutrients

Available Cu, Zn, Mn and Fe varied from 0.71, 1.17, 18.2 and 21.6 mg kg^{-1} in control to 0.72, 1.19, 18.8 and 22.2 mg kg^{-1} in treatment for yield target of 5.0 t ha^{-1}, respectively. However, different approaches of fertilizer application did not significantly influence the soil available micronutrients status at harvest in rice crop.

4. Conclusions

The present investigation suggested that application of fertilizers based on targeted yield treatments significantly improved the available N, P and K status in soil as compared to all the other approaches of fertilizer application. However, different approaches did not significantly influence the value of soil pH, OC and DTPA extractable micronutrients which was understandable and predictable in such a short duration of about four months.

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