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Effect of different approaches of fertilizer recommendations on yield, nutrient uptake and economics of rice under SRI

Shreyansh Mittal and Sanjay K Sharma

Abstract
A field experiment was conducted during *kharif* 2015 at the Experimental Farm of Department of Soil Science, CSK HPKV, Palampur to study the effect of different approaches of fertilizer application on yield, nutrients uptake and economics of rice under System of Rice Intensification (SRI). There were eight treatments (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 all the levels for prescription based fertilizer application gave significantly higher grain and straw yield as compared to other approaches of fertilizer application barring few exceptions. Targeted yield treatments significantly increased the nutrients uptake over all other treatments. The soil test crop response (STCR) based fertilizer application treatments excelled all other approaches of fertilizer application in terms of net returns and benefit cost ratio. However, STCR approach for transplanted rice worked satisfactorily up to yield target of 4.0 t ha^{-1} beyond which deviation in yield from targeted yield was more than 10 per cent.

Keywords: rice, SRI, STCR, deviation, target yield, benefit: cost ratio, RCBD

Introduction
Global demand for food is increasing day by day [1]. At the current rate of population growth, food demand is expected to increase anywhere between 59% to 98% by 2050 [2]. Meeting the targeted demand of food grains is a challenging task for the policy makers, researchers and all other stakeholders. Rice (*Oryza sativa* L.) is one of the most important cereals that hold the key towards food security of the world. In Himachal Pradesh, rice is one of the important cereal crops next to wheat and maize on area basis. The crop is cultivated from foothill plains to an altitude of 2290 m above mean sea level covering an area of about 76.9 thousand hectares with a total production of 125.3 thousand tonnes, however, its productivity in the state is quite low (1.63 t ha^{-1}) compared to the national average [3]. More than 85% rice area is concentrated in low productivity group of Himachal Pradesh which may be due to inadequate plant population, less weed control and imbalanced use of fertilizers. To maintain optimum plant population, continuous efforts are being made to develop technologies for maximizing the production per unit area within the resource constraints. The French Jesuit priest Father Henri de Laulanie in Madagascar, south-eastern coast of Africa, gave the technique of SRI, a new method of transplanted rice culture, during 1983. In India, potential area under SRI is 13.5 million hectares which is 31% of the total rice area. SRI is one of such techniques which besides saving water (approximately 30 per cent) can sustain the productivity at higher level. Grain yields reported from field experiments carried out in different parts of India showed yield increases from SRI ranging from 9.3 per cent to 68 per cent when compared with conventional practice [4].

Likewise, the balanced application of nutrients is one of the most important aspects for sustainable crop production and improvement in quality of produce. Therefore, fertilizer application based on soil testing is being advocated throughout the world. Soil testing helps us to know the nutrients status and their imbalances in the soil and apply required amount of the nutrients to overcome imbalances and sustain yield [5]. 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. There is a very wide range for particular nutrient within a fertility class, thereby ignoring vast differences in its absolute amount in the soil while giving fertilizer recommendation. The STCR based fertilizer recommendations also called "Prescription Based Fertilizer Recommendations" takes into account every bit of nutrient present in soil for achieving targeted yield of crops under a particular agro-climatic situation.

The prescription based fertilizer recommendation approach not only helps to realize higher yield, benefit-cost ratio and response ratio, but also improved nutrient uptake by crop. The purpose of this investigation was to study the effect of different approaches of fertilizer recommendations on yield, economics and nutrient uptake by rice under SRI.

Materials and Methods

The present investigation was carried out during *kharif* 2015 at the Experimental farm of Department of Soil Science, CSK Himachal Pradesh Krishi Vishvavidyalaya, Palampur. Palampur soils have been developed from fluvo-glacial parent material and belong to the order Alfisol and classified as subgroup Typic Hapludalf as per Taxonomic system of soil classification [6]. Geographically, the experimental site 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. The site lies in the Palam valley of Kangra district in the mid hills wet temperate zone (zone 2.2) of Himachal Pradesh. The experiment was laid out in RCBD with eight treatments, each replicated three times with plot size of 10 m^2. The details of the treatments are given below in Table 1.

Table 1: Treatment details

Treatments	
T_1	Fertilizer application as per Farmers' practice
T_2	General recommended dose (90:40:40)
T_3	Soil test based fertilizer application
T_4	Fertilizer based on STCR for yield target of 3.5 t ha^{-1}
T_5	Fertilizer based on STCR for yield target of 4.0 t ha^{-1}
T_6	Fertilizer based on STCR for yield target of 4.5 t ha^{-1}
T_7	Fertilizer based on STCR for yield target of 5.0 t ha^{-1}
T_8	Absolute control

The general recommended dose of fertilizers for rice was 90:40:40 (N: P_2O_5: K_2O). 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, SK are soil test value in kg ha^{-1} for available N, P and K, respectively.

Rice variety 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. On 9th day of sowing, 0.5 per cent of urea solution was drenched over the seedling bed. Seedlings were allowed to grow up to 14 days in a weed free situation. 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 with one seedling per hill along with soil and seed attached. Farm yard manure @ 10 t ha^{-1} was incorporated in puddled plots in all the treatments and mixed well with the help of spades. Whole of P and K were applied as basal dose at the time of puddling in rice through single super phosphate (16% P_2O_5) and muriate of potash (60% K_2O), respectively. Half of the nitrogen was applied through urea (46% N) at the time of puddling. Another half was top dressed in two equal splits each at tillering and panicle initiation stages of rice.

Representative samples of plant (straw and grain) were collected at harvest and then, dried in oven at 65°C for 48 hours, ground with the help of willey mill and were digested. After digestion, N was determined by Modified Kjeldahl's method [7], P by Vanado molybdate phosphoric acid yellow colour method [7], K was determined with the help of Wet digestion [8].

Results and Discussion

Grain and straw yield

The data pertaining to the effect of different approaches of fertilizer recommendations on grain and straw yield of rice grown under SRI are given in Table 2. All treatments significantly increased the grain yield of rice over control. The soil test based fertilizers application significantly enhanced the grain yield (14.9 per cent) as compared to farmers' practice. However, soil test based was statistically at par with general recommended dose and the treatment for yield target of 3.5 t ha^{-1} in terms of grain yield. The STCR treatments for yield targets of 4.5 and 5.0 t ha^{-1} were significantly better than soil test based and general recommended dose. Like grain yield, there was significant increase in straw yield of rice crop in all the treatments over control. The treatments for yield targets of 5.0 t ha^{-1} had higher straw yield as compared to all the other treatments.

Lowest grains and straw yield in control plots was due to the continuous removal of fertilizers without addition of any external input. The increase in grain and straw yield of rice in farmers' practice over control might be due to addition of 25 per cent of the recommended dose of nitrogen fertilizers. The higher grain and straw yield of the crop in targeted yield treatments over general recommended dose and soil test based might be due to balanced and judicious use of the N, P and K fertilizers. Similar results were also reported by 9, 10 and 11. The per cent deviation from yield targets of 3.5, 4.0, 4.5 and 5.0 t ha^{-1} was -5.7,-9.3, -11.1 and 10.8, respectively. Percent deviation up to yield target of 4.0 t ha^{-1} was less than -10, whereas above 4.0 t ha^{-1}, it was greater than -10, which indicates that the fertilizer adjustment equations in case of rice work effectively up to yield target of 4.0 t ha^{-1}.

Table 2: Effect of different approaches of fertilizer recommendations on grain and straw yield of rice grown under SRI

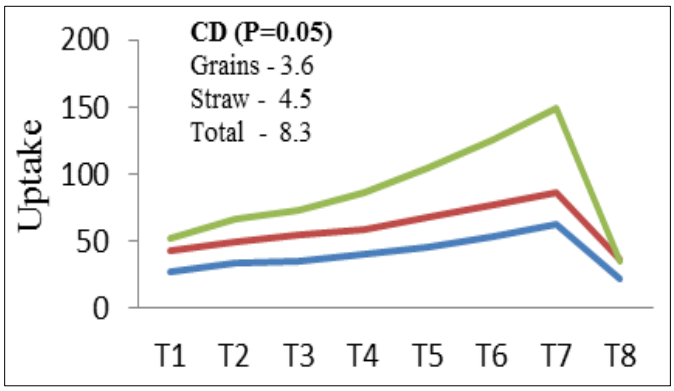
Treatment	Grain yield (t ha^{-1})	Straw yield (t ha^{-1})	Percent deviation
Farmers' Practice	2.68	6.93	-
General Recommended Dose	3.06	7.32	-
Soil test based	3.08	7.93	-
STCR based for yield target of 3.5 t ha^{-1}	3.30	8.07	-5.7
STCR based for yield target of 4 t ha^{-1}	3.63	8.70	-9.3
STCR based for yield target of 4.5 t ha^{-1}	4.00	9.23	-11.1
STCR based for yield target of 5 t ha^{-1}	4.46	10.03	-10.8
Control	2.28	6.27	-
CD (P=0.05)	0.30	0.39	-

Nutrient uptake by crop

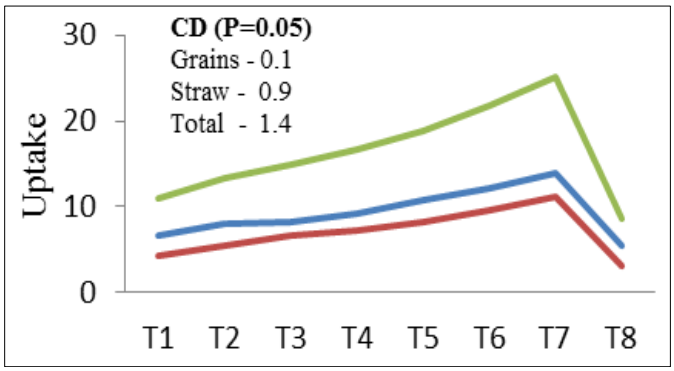
The data pertaining to the effect of different approaches of fertilizer application on the N, P and K uptake by rice is given in Figure 1. Nitrogen uptake by rice grains varied from 22.6 kg ha^{-1}in control to 62.5 kg ha^{-1} in treatment for yield target of 5.0 t ha^{-1}. Application of N, P and K based on target yield concept, soil test based, general recommended dose and farmers' practice resulted in a significant increase in N uptake by rice grain over control. The STCR treatment for yield target of 3.5 t ha^{-1} was also better than soil test based and general recommended dose. Nitrogen uptake by grain was significantly higher in treatments for yield targets of 4.5 t ha^{-1} and 5.0 t ha^{-1} as compared to treatments for yield targets of 3.5 t ha^{-1} and 4.0 t ha^{-1}. In straw, N uptake in soil test based treatment was significantly higher by 28.3 and 11.6 per cent over control, farmers' practice and general recommended dose. There was consistent increase in N uptake by straw following fertilizer application based on STCR approach for different yield targets over all the other treatments. Total N uptake in treatment for yield target of 5.0 t ha^{-1} was significantly better as compared to all the other treatments. The increases in total N uptake under this treatment over treatments for yield targets of 3.5, 4.0 and 4.5 t ha^{-1} were 71.7, 42.4 and 18.7 per cent, respectively. The targeted yield treatments resulted in significantly higher total N uptake as compared to soil test based, general recommended dose, farmer's practice and control. STCR based fertilizer application in targeted yield treatments have improved the plant health by accelerating the initial process of plant growth such as cell division and number of root hairs enabling the plant to have healthy root system that helped in better absorption of nutrients and moisture from soil and ultimately the yield. These results are in conformity with the findings of 12 and 13.

Phosphorus uptake by rice crop followed approximately similar trend as N uptake by crop. Phosphorus uptake in rice grain was minimum (5.4 kg ha^{-1}) in control and maximum (14 kg ha$^{-1)}$ in the treatment for yield target of 5.0 t ha^{-1}. The targeted yield treatments significantly improved the P uptake as compared to other approaches of fertilizer application. The application of general recommended dose and conventional soil test based application of nutrients significantly increased the P uptake by 19.4 and 23.9 per cent, respectively as compared to the farmers' practice. However, soil test based was statistically at par with general recommended dose and treatment for yield target of 3.5 t ha^{-1}. Like P uptake by grain, its uptake by straw was also highest (11.2 kg ha^{-1}) under yield target of 5.0 t ha^{-1} and lowest (3.2 kg ha^{-1}) in control. All other approaches of fertilizer application significantly increased the P uptake by straw over control and farmers' practice. The total P uptake was maximum (25.1 kg ha^{-1}) in the treatment for yield target of 5.0 t ha^{-1} followed by the treatments for yield targets of 4.5 t ha^{-1} (21.8 kg ha^{-1}), 4.0 t ha^{-1} (18.9 kg ha^{-1}) and 3.5 t ha^{-1} (16.6 kg ha^{-1}). The lowest P uptake (8.6 kg ha^{-1}) in control plots was due to the lower yield in this treatment. The higher uptake values in targeted yield treatments as compared to other treatments were due to more biomass production in these treatments over the latter. Similar findings were reported by 13 and 14.

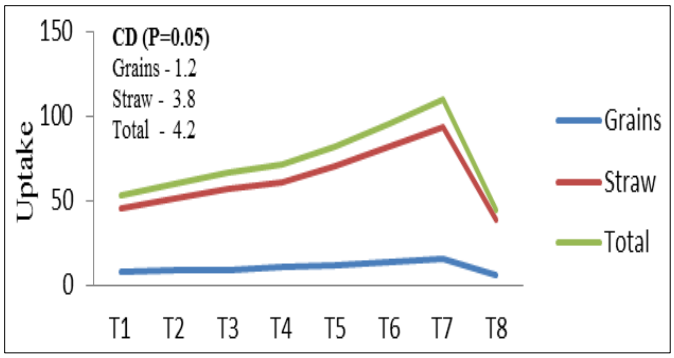
Like N and P uptake, maximum increase in K uptake was recorded under treatment for yield target of 5.0 t ha^{-1}. Potassium uptake by rice grain ranged from 6.0 kg ha^{-1} in control to 15.9 kg ha^{-1} in treatment for yield target of 5.0 t ha^{-1}. The treatment for yield target of 5.0 t ha^{-1} increased K uptake by 55.9, 32.5 and 14.4 per cent as compared to the treatments comprising yield targets of 3.5, 4.0 and 4.5 t ha^{-1}, respectively. Like K uptake by grain, its uptake by straw was also highest (93.7 kg ha^{-1}) under treatment for yield target of 5.0 t ha^{-1} and lowest (38.3 kg ha^{-1}) in control. Similar to K uptake by grain and straw, the total K uptake was maximum (109.6 kg ha^{-1}) in the treatment for yield target of 5.0 t ha^{-1}. Similar positive influence of inorganic fertilizers application based on STCR approach on total K uptake by the crop has been reported by 13, 15 and 16.



(a) Nitrogen



(b) Phosphorus



(c) Potassium

Fig 1: Effect of different approaches of fertilizer recommendations on N, P and K uptake (kg ha^{-1}) at harvest of rice grown under SRI

Economics Analysis

Economic analysis of the treatments is of utmost importance in any study to work out the suitability of any intervention for higher returns. The data pertaining to the effect of different treatment on economic parameters have been presented in Table 3. The cost of cultivation in control was worked out to ₹ 30,000 ha^{-1}. It increased by 22.6 per cent (₹ 36,784 ha^{-1}) where fertilizers on the basis of STCR approach were applied for yield target of 5.0 t ha^{-1}.

Table 3: Effect of treatments on profitability of rice grown under SRI

Treatment	Cost of cultivation (₹ha^{-1})	Gross returns (₹ ha^{-1})	Net returns (₹ ha^{-1})	B:C Ratio
Farmers' Practice	30271	56145	25875	1.85
General Recommended Dose	34803	62572	27768	1.80
Soil test based	34427	64493	30066	1.87
STCR based for yield target of 3.5 t ha^{-1}	32216	67968	35753	2.11
STCR based for yield target of 4 t ha^{-1}	33713	74433	40721	2.21
STCR based for yield target of 4.5 t ha^{-1}	35358	81083	45726	2.29
STCR based for yield target of 5 t ha^{-1}	36784	89802	53017	2.44
Control	30000	48727	18727	1.62

Sale price of rice grains (₹kg^{-1}) =14.50, Straw rate= 250 ₹q $^{-1}$
Cost of nutrients (₹ kg^{-1}) Urea=5.41, SSP=₹ 10.5, MOP =₹ 16.8. FYM = ₹1000 t^{-1}. General cost of cultivation without fertilizers =₹ 30,000 ha^{-1}

However, higher yields realized under the STCR based treatments resulted in higher gross returns. For example highest gross returns in treatment for yield target of 5.0 t ha^{-1} amounted to ₹ 89,802 ha^{-1} followed by yield target of 4.5 t ha^{-1} (₹ 81,083 ha^{-1}) and least gross returns were observed in control (₹ 48,727 ha^{-1}). Net returns was highest in STCR based treatment for 5.0 t ha^{-1} yield target (₹.53,017 ha^{-1}), followed by treatment for 4.5 t ha^{-1} yield target (₹ 45,726 ha^{-1}), 4.0 t ha^{-1} yield target (₹ 40,721ha^{-1}) and 3.5 t ha^{-1} yield target (₹ 35,753 ha^{-1}). Control was found to be least remunerative (₹ 18,727 ha^{-1}) in comparison to the other approaches of fertilizer application. With respect to the benefit drawn per unit rupee invested on input, it was observed that the B:C ratio was highest in the targeted yield treatments (2.11, 2.21, 2.29, and 2.44 for treatments for yield targets of 3.5, 4.0, 4.5 and 5.0 t ha^{-1}), followed by soil test based fertilizer application (1.87), general recommended dose (1.80) and control (1.62) due to higher yield, balanced and judicious use of N, P and K fertilizers. Similar results were reported by 17, 18, 19 and 20.

Conclusions

As a result, STCR based fertilizer application increased the N, P, uptake by rice crop and it is also superior as compared to other approaches of fertilizer application in terms of yield, net returns and benefit cost ratio. However, STCR approach for transplanted rice worked satisfactorily up to yield target of 4.0 t ha^{-1} beyond which deviation in yield from targeted yield was more than 10 per cent. This indicates that for yield targets above 4.0 t ha^{-1}, new fertilizer recommendations based on STCR concept should be evolved under SRI.

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