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Effect of Nutrient Management on Soil Fertility and Productivity under SRI Method of Cultivation

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A field study was conducted at the Instructional Farm of Narendra Deva University of Agriculture and Technology, Kumarganj, Faizabad (Uttar Pradesh) during *kharif*, 2012 to evaluate the effect of integration of nitrogen (N) management in rice under SRI (system of rice intensification) method. Seven N management combinations were evaluated in a randomized block design. Growth parameters, yield attributes and grain yield (6.43 t ha^{-1}) were increased significantly with the application of 75% N through fertilizer + 25% N through green manuring (*Sesbania*) over T_5 (50% N through fertilizer + 25% N through FYM + 25% N through green manuring), T_6 (50% N through fertilizer + 50% N through FYM), T_7 (100% N through FYM) and T_1 (Control), and statistically at par with T_2 (100% N through fertilizer) and T_3 (75% N through fertilizer + 25% N through FYM). The maximum uptake of N (123 kg ha^{-1}), phosphorus (37.1 kg ha^{-1}) and potassium (152 kg ha^{-1}) was also recorded with the treatment having 75% N through fertilizer + 25% N through green manuring and minimum with T_1 (Control). Also, the maximum income (Rs. 61358 ha^{-1}) and benefit:cost ratio (1.92) were obtained with this treatment.

Key words: SRI, FYM, green manuring, rice productivity, soil properties, economics

The predicted global requirement of rice by 2050 AD is about 800 million tonnes (Mt), which is 26% higher than the present level of production. In India, rice is grown over an area 44 million hectare (Mha) with a production of 106 Mt in 2013-14. The area and production of rice in Uttar Pradesh is about 13.8 Mha and 14 Mt, respectively with productivity of 2.36 t ha^{-1} (Anonymous 2014). The ever increasing population necessitates to produce more and more with ever shrinking natural resources. Rice farmers in India and many countries are facing growing water constraints and higher costs of N fertilizer application. System of rice intensification (SRI) is an alternative practice to solve the water crisis and increase the productivity of rice by changing the management of plant, soil, water and nutrients (Natrajan 2008). This system is an emerging low input method for production of rice that has the potential to increase crop yield while reducing the consumption of water, seed and fertilizers. In various countries, use of SRI method has been producing average yields 6-8 t ha^{-1}, double of the present world average (Gautam *et al.* 2013). The SRI method can increase yield by 50-100% over the conventional method (Termel *et al.* 2011). Declining trend in productivity due to continuous use of fertilizers alone has been observed.

Integrated nutrient management (INM) aims to improve soil health and sustain high level of productivity. Integrated use of organic and inorganic sources of N in SRI system not only improves the soil fertility and rice yield but also improves the soil health for sustainable production. It is impossible to attain the potential yields of crops without external supply of the nutrients through combination of fertilizers and organic manures. The full dose of N, phosphorus (P), and potassium (K) fails to sustain soil health but combined use of fertilizers, farmyard manure (FYM) and green manuring (GM) could produce higher yields besides improvement of soil fertility (Sarkar *et al.* 2000). In order to keep the soil in good health, it is necessary to use organic sources like FYM and green manuring in conjunction with fertilizers. The information on integration of FYM, green manuring and fertilizers is scarce for optimizing the productivity of rice under SRI. Since organic manures are not available in sufficient quantity, INM using both inorganic and organic manures is currently

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recommended. Evaluating alternative combinations of organic and inorganic fertilization can thus help to determine whether optimization is possible. Nitrogen is one of the major nutrients which determine the growth and development of rice. The N management modules envisage use of FYM and green manures along with fertilizers and opportunity to achieve long-term sustainability in crop production systems (Reddy *et al.* 2003). With these facts in view, experiment was conducted to study the effect of nutrient management on soil fertility and productivity under SRI method of cultivation.

Materials and Methods

The field experiment was conducted during the *kharif* season at Instructional Farm of Narendra Deva University of Agriculture and Technology (NDUAT), Kumarganj, Faizabad (26.48° N, 82.12° E, 113 m above mean sea level). The area falls under sub-humid climate receiving mean annual rainfall of about 1200 mm and about 85% of the total rainfall is concentrated from mid July to November. Seven treatments *viz.,* T_1: Control, T_2: 100% N through fertilizer, T_3: 75% N through fertilizer + 25% N through FYM, T_4: 75% N through fertilizer + 25% N through green manuring (*Sesbania aculeata*), T_5: 50% N through fertilizer + 25% N through FYM + 25% N through green manuring, T_6: 50% N through fertilizer + 50% N through FYM, and T_7: 100% N through FYM were comprised in randomized block design (RBD) and replicated thrice. The rice variety NDR-359 was used during the present investigation. Modified rice mat nursery was raised for producing robust, healthy rice seedlings in 12 days time suitable for transplanting under SRI method of cultivation. The already treated incubated and pre-sprouted rice seeds were used. One seedling per hill was transplanted manually by using index finger and thumb at 25 cm × 25 cm spacing in plots of 5 m × 4 m and it was raised under SRI method (early seedling and alternate drying and wetting condition). Recommended dose of N (150 kg ha^{-1}) was applied as per treatment. Phosphorus (60 kg P_2O_5 ha^{-1}) and potash (60 kg K_2O ha^{-1}) were applied uniformly as basal through single superphosphate (SSP) and muriate of potash (MOP), respectively in all treatments. Treatment-wise N was applied through urea, FYM and green manure (*Sesbania aculeata*) on the basis of N content. The FYM was incorporated in soil two weeks before transplanting. On dry weight basis, it contained 31.8% C, 0.96% N, 0.29% P and 0.48% K. Green manuring crop (*Sesbania aculeata*) was incorporated in soil before transplanting. The C, N, P and K contents in *Sesbania aculeata* were 41%, 2.07%, 0.19% and 1.85% respectively. Weeding was done manually at 30 and 65 days after transplanting and irrigation was done as and when required. The harvesting of the crop was done on 125 days after transplanting. The soil of experimental field was silty loam in texture having pH (1:2.5) 8.3 and electrical conductivity (EC) 0.33 dS m^{-1}. The soil was low in organic carbon (2.4 g kg^{-1}) and available N (140 kg ha^{-1}), medium in available P (12 kg ha^{-1}) and K (264 kg ha^{-1}). Soil samples from all three replications (0-0.15 m) were taken before starting the experiment and from each treatment after the harvest of the crop. The soil samples were air-dried, ground and analyzed for pH in 1:2.5 soil : water suspension, organic carbon by the Walkley and Black (1934) method, available N by $KMnO_4$ oxidized N (Subbiah and Asija 1956), available P (Olsen *et al.* 1954), available K by extraction with 1*N* ammonium acetate (NH_4OAc) solution at pH 7.0 (Jackson 1973).

Results and Discussion

Growth, Yield Attributes and Yield

The growth, yield attributes and yield of rice influenced by the integrated N management modules (Table 1). Maximum plant height (130 cm), number of tillers (19), effective tillers hill^{-1} (16), panicle length (30 cm), grains panicle^{-1}, grain (6.43 t ha^{-1}) and straw yield (8.10 t ha^{-1}) were recorded with the T_4 (75% N through fertilizer + 25% N through green manuring). An additional rice grain yield of 0.33 t ha^{-1} was achieved with the application of T_4 receiving 75% N through fertilizer + 25% N through green manuring. It was also observed that the supplement of 25% N with green manuring was more effective in increasing yield than with FYM. This might be due to rice young seedlings planted carefully under SRI method of cultivation which improved the growth and yield parameters of the crop (Barison 2002). The yield data obtained clearly demonstrate the superiority of the integrated use of organic and fertilizers, which provided greater stability in crop production in comparison to mineral treatment. The decomposition of succulent green manure and FYM which favoured for greater release of nutrients and their continuous availability in soil for sustaining higher grain and straw yield of rice. Khanam *et al.* (1997), Sharma *et al.* (2001) and Singh *et al.* (2002) found the highest yield of rice when fertilizers were applied in combination of FYM and green manuring. Bindra and Thakur (1994) and Reddy *et al.* (2003) reported the

Table 1. Effect of integrated N management on growth attributes and rice yield under SRI method of cultivation

Treatments	Plant height (cm)	No. of tillers hill^{-1}	No. of effective tillers hill^{-1}	Panicle length (cm)	No. of grains panicle^{-1}	Grain yield (t ha^{-1})	Straw yield (t ha^{-1})
T_1: Control	103.0	8.3	7.0	22.2	139.8	4.18	5.61
T_2: 100% N through fertilizer	124.4	16.6	14.5	29.0	173.9	6.10	8.02
T_3: 75% N through fertilizer + 25% N through FYM	119.0	14.5	13.2	28.9	169.5	5.86	7.72
T_4: 75% N through fertilizer + 25% N through GM	130.1	19.6	16.8	30.3	178.6	6.43	8.10
T_5: 50% N through fertilizer + 25% N through FYM + 25% N through GM	115.9	12.5	11.0	27.4	156.7	5.26	6.87
T_6: 50% N through fertilizer + 50% N through FYM	110.9	11.7	10.3	25.0	150.8	4.80	6.59
T_7: 100% N through FYM	107.1	10.6	8.3	24.6	143.4	4.56	6.07
CD (P=0.05)	13.0	3.08	3.04	2.47	14.92	0.53	0.71

superiority of yield attributes such as effective tiller hill^{-1}, panicle length and number of grains panicle^{-1} in SRI method of cultivation resulted higher grain yield. Higher grain was recorded due to planting of younger seedlings with controlled water management than that recorded by older seedlings under submergence (Upholf 2005). The efficiency of inorganic fertilization might have also been increased when it was applied along with organic manures and brought a beneficial effect on rice grain yield due to increase in effective tillers as described by Srinivas *et al.* (2010). Planting of rice seedlings in early stage need to be provided more space to express their full potentials of growth of leaves, tillers and roots. The SRI techniques provides more space than traditional planting along with other favourable condition which allows the plants roots to grow preferably both vertically and horizontally increasing root penetration for absorption of nutrients, while results in the development of plant with higher grain yield. The increased yield was due to higher magnitude of yield components. The increased uptake of nutrients might be attributed to the favourable soil conditions which increased the availability of nutrients under SRI management practices.

Soil Fertility Status

Organic Carbon

Use of chemical fertilizers and their combination with organics resulted in increase in organic carbon content of soil (Table 2). The highest build-up of organic carbon (3.3 g kg^{-1}) was recorded in T_7 (100% N through FYM) which was at par with T_6 (50% N through fertilizer + 50% N through FYM) and T_5 (50% N though fertilizer + 25% N through FYM + 25% N through GM) and found significantly superior over rest of the treatments. Thus, integrated application of organic manures alone or in combination with fertilizers recorded higher values of organic carbon compared to application of fertilizers alone. The increase in organic carbon content in the manurial treatment combinations is attributed to direct addition of organic manure in the soil which stimulated the growth and activity of microorganisms and also due to better root growth, resulting in higher production of biomass, crop stubbles and residues. The subsequent decomposition of these materials might have resulted in the enhanced carbon content of soil (Rudrappa *et al.* 2006; Moharana *et al.* 2012). These results are in line with the findings of Majumder

Table 2. Effect of integrated N management on soil properties after harvest of the rice crop under SRI method of cultivation

Treatments	Organic carbon (g kg^{-1})	Available N (kg ha^{-1})	Available P (kg ha^{-1})	Available K (kg ha^{-1})
T_1: Control	2.4	141	12.4	255
T_2: 100% N through fertilizer	2.5	151	16.1	275
T_3: 75% N through fertilizer + 25% N through FYM	2.8	149	15.2	270
T_4: 75% N through fertilizer + 25% N through GM	2.9	153	17.0	280
T_5: 50% N through fertilizer + 25% N through FYM + 25% N through GM	3.0	148	15.0	265
T_6: 50% N through fertilizer + 50% N through FYM	3.0	146	13.2	264
T_7: 100% N through FYM	3.3	145	13.2	264
CD (P=0.05)	0.3	5.52	1.63	11.6

et al. (2008) and Nayak *et al. (*2012). Addition of organic nutrient source might have created environment conducive for formation of humic acid and stimulated the activity of soil microorganisms, resulting in an increase in the organic carbon content of the soil (Mishra and Sharma 1997) and (Srilatha *et al.* 2013).

Available Nitrogen

A perusal of data in table 2 indicated a declining trend in available N status (140 kg ha^{-1} from its initial (149 kg ha^{-1}) in control after harvest of the crop. The maximum decline was in control. The decreased available N status in the absolute control treatment may be due to the removal of native soil N in the absence of external supply of N through fertilizers and manures. However, the build-up of available N (153 kg ha^{-1}) was observed in treatment T_5 (75% N through fertilizer + 25% N through GM, (100% N through fertilizer) and (75% N through fertilizer + 25% N through FYM) which were higher over rest of the treatments. This increase may be attributed in increase microbial activity under the INM treatments which favoured N mineralization. The increase in available N status due to organic manure application might be due to the multiplication of soil microbes leading to enhanced conversion of organically bound N into inorganic forms and rapid mineralization. The favourable soil condition under organic manure application might have helped the mineralization of soil and leading to build-up higher available N (Walia *et al.* 2010). These results are in line with the findings of Thamaraiselvi *et al.* (2012) and Sharma *et al.* (2013) who also observed that available N status in soil increased with use of recommended dose of fertilizer in combination with manure. Similar findings were also observed by Tiwari *et al.* (1980). Joseph *et al.* (2006) also observed that incorporation of *Dhaincha* in rice exerted a positive influence on NH_4^+-N and NO_3^--N status of soil. The SRI method provides soil conditions that are favorable for the mycorhizal fungi and many soil microbes, which enhance the nutrient status of soil (Uphoff and Randriamiharisoa 2002).

Available Phosphorus

The minimum available P status was found in control. Incorporation of green manure along with fertilizer recorded significantly higher available P (17 kg ha^{-1}) which was at par with 100% N through fertilizer) and 75%N through fertilizer + 25% N through FYM and significantly superior over rest of the treatments. The increased availability of available P with organics could be ascribed to their solubilizing effect on native insoluble P fractions through release of various acids, thus resulting into a significant improvement in available P status of the soil (Urkurkar *et al.* 2010). In addition, the organic matter may also reduce the fixation of phosphate by providing protective cover on sesqui-oxides and thus increase the available P in soil solution (Bharadwaj *et al.* 1994). The SRI method which accelerates the activity of P solubilizing microbes and effect of green manure on the available P may be ascribed to the reduction of fixation and release of P due to organic matter (Mishra and Sharma 1997). Alternate wetting and drying conditions of SRI method might have increased mineralization of organic forms to inorganic forms and solubilization of nutrients (Turner and Haygarth 2001). This might be due to favourable soil condition under SRI method which accelerates the activity of P solubilizing microbes and effect of green manure on the available P which may be ascribed to the reduction of fixation and release of P due to organic matter (Mishra and Sharma 1997).

Available Potassium

Application of green manure and FYM in combination with inorganic sources of nutrients increased the available K content of surface soil over control (Table 2). Higher amount of available K (280 kg ha^{-1}) was recorded with T_4 (75% N through fertilizer + 25% N through GM) which was at par with T_2 and T_3 and significantly superior over rest of the treatments. Increase in available K due to green manuring and FYM along with inorganics application may be attributed to the direct addition of K to the available pool of the soil. This may probably also be due to solubilized K from K-bearing minerals by the organic acids released as a decomposition of green manuring and FYM. The increase in available K under integrated treatments might be due to addition of organic matter that reduced K-fixation and released K due to interaction of organic matter with clay, besides the direct K addition to the pool of soil (Urkurkar *et al.* 2010; Subehia and Sepehya 2012).

Economics

Maximum gross return (Rs. 93384) and net return (Rs. 61357 ha^{-1}) were obtained with the application of T_4 (75% N through fertilizer +25% N through GM followed by T_4 100% N through fertilizer (Table 3). The maximum B: C ratio was also observed in the application of 75% N through fertilizer + 25%

Table 3. Effect of integrated N management on economics of the various treatment combinations of the rice crop under SRI method of cultivation

Treatments	Gross returns (Rs.)	Total cost of cultivation (Rs.)	Net returns (Rs)	B:C ratio
T_1: Control	61482	27504	33977	1.23
T_2: 100% N through fertilizer	89210	30591	58619	1.91
T_3: 75% N through fertilizer + 25% N through FYM	85802	34444	51357	1.49
T_4: 75% N through fertilizer + 25% N through GM	93384	32026	61357	1.92
T_5: 50% N through fertilizer + 25% N through FYM + 25% N through GM	76858	37379	39478	1.05
T_6: 50% N through fertilizer + 50% N through FYM	70782	38697	32084	0.83
T_7: 100% N through FYM	66914	47404	19509	0.41
CD (P=0.05)				

N through GM. The minimum net return (Rs.19509) and benefit:cost ratio (0.41) were obtained with the application of 100% N through FYM. It might be due to highest cost of FYM. However, it improves the fertility status of soil. These results also corroborated with the findings of Parasuraman (2005).

Conclusions

From the present investigation, it may be concluded that 75% N through fertilizer + 25% N through green manuring was found superior for increasing yield productivity and profitability under SRI method of rice cultivation.

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