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Soil and Crop Productivity of Lowland Rice as Influenced by Establishment and Nutrient Management Practices

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ABSTRACT

The productivity of rice (*Oryza sativa* L.) in north eastern hill region (NEHR) of India is low due to inappropriate cultural practices and nutrient management. Field experiments were conducted for consecutive four years (2004 to 2008) under lowland rainfed condition to evaluate the impact of crop establishment methods and nutrient management practices on soil health, productivity and economics of rice. Three establishment methods *viz.* system of rice intensification (SRI), integrated crop management (ICM) and conventional rice culture (CRC) were evaluated under five nutrient management practices *viz.* recommended dose of fertilizers (RDF) (80:26.2:33.3 N, P, K kg ha^{-1}), Farm yard manure (FYM) 10 t ha^{-1}, 50% RDF + FYM 10 t ha^{-1}, RDF + FYM 5 t ha^{-1} and control (no FYM or fertilizer). The data recorded during fourth year of the study (2008) revealed that SRI rice culture recorded higher yield attributing parameters *viz.* number of panicle hill^{-1} and number of grain panicle^{-1} than ICM and CRC. However, the grain and straw yield were significantly higher with ICM than that of CRC but was at par with SRI. Integrated application of RDF + FYM 5 t ha^{-1} followed by 50% RDF + FYM 10 t ha^{-1} recorded higher value of all the yield attributing parameters and yield of rice compared to control. SRI being at par with ICM recorded significantly higher NPK uptake as compared to CRC. The NPK uptake was highest with combined application of inorganic fertilizer and organic manure. At harvest, available soil NPK were higher under SRI and ICM and integrated use of NPK and FYM 5 t ha^{-1} as compared to other treatments. The highest net return was recorded under ICM rice culture and application of RDF + FYM 5 t ha^{-1}. Thus, ICM rice culture and integrated application of RDF + FYM @ 5 t ha^{-1} can be recommended for sustainable rice production in the NEHR of India.

1. Introduction

Rice (*Oryza sativa* L.) is the staple food of the North Eastern Hill Region (NEHR) of India. Rice is cultivated in about 3.50 m ha in the region with an average productivity of 1.78 t ha^{-1} which is much below to the national average of 2.40 t ha^{-1} (Das et al. 2014). In NEHR, there prevails a diverse but favourable climatic and edaphic condition for the cultivation of rice (Patel et al. 2010). However, even with the favourable conditions and resources available, the production of rice is stagnating. Production of rice can be improved to a great extent by maintaining optimum plant population, by use of young seedlings, optimum number of seedling hill^{-1} and spacing (Das et al. 2010; Patel et al. 2010). The yield components like number of panicle bearing tiller per unit area, number of filled grain panicle^{-1} and thousand grain weights are greatly influenced by agronomical practices like plant population. The yield components in turn, influence the grain yield of rice (Christopher 1999). Appropriate seedling age at transplanting is essential for optimum yield. Uphoff (2002) while emphasizing system of rice intensification (SRI)

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technique opined that early transplanting of younger seedling preserves plant's potential for much greater tillering, more root growth, and better yield. Old seedlings were found to mature later because of delayed formation of tillers and longer time to recover from transplanting shock resulting in poor yield (Makarim et al. 2002). Number of seedlings that are transplanted also influence the yield of the crop (Rajarathinam and Balasubramaniyan 1999). The water scenario of world including NEHR envisaged that rice needs to be produced with less water to feed the ever growing population (Das et al. 2014). SRI and Integrated crop management (ICM) are techniques by which more rice can be produced with less water (Islam et al. 2013). SRI is gaining wider acceptance in many countries including India due to its multiple advantages over conventional method *viz.,* water and seed saving, high yield and less dependence on chemicals (Uphoff 2002; Islam et al. 2013). This system comprised use of younger seedlings (12 to 15 days old), transplanting single seedling hill^{-1}, use of wider spacing (25 cm x 25 cm), intermittent irrigation, uprooting of seedlings by scooping and careful transplanting, weed control with conoweeder, use of organic manures etc. (Patel et al. 2010, Islam et al. 2013). In spite of SRI gaining wider acceptance in many countries, there are some limitations like handlings and establishment of very young seedlings especially in the high rainfall areas. To overcome the limitations of SRI, ICM is an alternative in which 15- 20 days old seedlings are transplanted at spacing of 20 cm x 20 cm with two seedlings hill^{-1}, organic manures and fertilizers are used in integration. Higher yield, input gains, shorter duration and farmers' active involvement are some of the facts that are attracting the researchers, planners and the farmers to SRI and ICM rice cultures (Balasubramaian et al. 2006; Islam et al. 2013).

Nutrient management practices can play an important role in enhancing the production of rice. The nutrients from the organic and inorganic sources differ in their relative availability for crop uptake. Chemical fertilizers contain high amount of nutrients and these are the quick source of nutrient supply and readily available as most of the fertilizers are water soluble. In contrast, organic manure are nearly complete source of most of the nutrients but due to their low nutrient content and bulky in nature, they become available for crop uptake gradually but available for longer duration owing to slow decomposition and gradual release of the nutrients into the labile pool. Therefore, an integrated approach with the use of organic and inorganic fertilizers that supplies all the essential nutrients to the crops in sufficient amounts and make the nutrients readily available during crop growth is required (Das et al. 2014).

Scientific data on the performance of rice under various establishment methods are meagre. The nutrient requirement of rice for various establishment methods may also vary. Keeping this background in mind, the present investigation was conducted to evaluate the impact of crop establishment methods and nutrient management practices on productivity and soil fertility. We hypothesized that SRI and ICM establishment methods would give higher productivity under integrated application of organic and inorganic nutrients compared to other establishment methods and application of organic and inorganic nutrients individually.

2. Materials and Methods

2.1 Experimental site

Field experiments were conducted at the low-land Agronomy Farm, ICAR Research Complex for NEH Region, Umiam, Meghalaya, India during four consecutive rainy seasons (2004-08) under rainfed condition. The institute farm is located at $25^0$30'N latitude and $91^0$51'E longitude with an elevation of 950 m above mean sea level. The soil of the experimental field was a *Typic Paleudalf* and low in available phosphorous (P:6.95 kg ha^{-1}), medium in nitrogen (N:277 kg ha^{-1}) and high in potassium (K:258 kg ha^{-1}). The pH and soil organic carbon (SOC) concentration of the soil (0-15 cm depth) was 5.1 and 2.56%, respectively. The experimental site falls under a per-humid subtropical type of climate. The average monthly minimum and maximum temperature during the rice growing seasons ranged from 12.4 to 21.2^{0}C and from 23.9 to 29.1^{0}C, respectively. The average rainfall of the study site is about 2450 mm.

2.2 Treatments details

Treatments consisted of three stand establishment methods *viz.,* SRI, ICM and conventional rice culture (CRC) and five nutrient management practices *viz.,* recommended dose of fertilizer (RDF) (80:60:40 kg N, P_2O_5, K_2O ha^{-1}), farmyard manure (FYM) 10 t ha^{-1}, RDF + FYM 5 t ha^{-1}, 50% RDF + FYM 10 t ha^{-1} and control. The 15 treatment combinations were laid out in a factorial randomized block design and replicated thrice. The gross and net plot sizes were 5.0 m x 4.0 m and 4.0 m x 3.0 m, respectively and the treatments were superimposed in the same plot every year to study the cumulative treatment effects. The nurseries for all the three establishment methods were sown on the same day but transplanting date varied as per the requirement of different establishment methods. For SRI, 10 days old seedling at 1 seedling hill^{-1}was used with 25 cm x 25 cm spacing. While for ICM, it was 20 days old seedlings at 2 seedlings hill^{-1} with a spacing of 20 cm x 20 cm and for CRC, 30 days old seedlings at 3 seedlings hill^{-1}with a spacing of 20 cm x 15 cm was followed. High yielding and medium duration rice variety 'Shahsarang 1' was used as test crop in the experiments. The nursery for SRI and ICM was prepared using a modified mat nursery (MMN) method. Whereas, for CRC the conventional method was used following 40 kg seed ha^{-1}, 500 m^2 nursery area, raised bed of 1.0 m width and 0.15 m height. The three establishment methods (SRI, ICM and CRC) were compared with each other considering respective package of practices as a part of establishment. Rice was monocropped and land remained fallow for rest period of the year.

2.3 Cultural practices

In MMN, the seedlings were raised in 4 cm layer of soil arranged on a firm surface covered with plastic sheet. A wooden frame of 1.0 m width, 0.04 m height and suitable length divided into equal segments of 0.75 m each was placed over this firm surface covered with plastic sheet. Each segment of the frame was filled with soil mixture uniformly and pre-germinated seeds were sown on the soil surface with a seed rate of 50 g m^{-2} and covered with the same soil mixture. The soil mixture (4 m^3 for 100 m^2 of mat nursery) was prepared by mixing 80 % soil and 20 % well decomposed FYM. To this soil and manure mixture (4 m^3), 1.5 kg of powdered DAP (Di-ammonium phosphate) was added and mixed thoroughly. The seed bed was sprinkled with water using a rose can as and when needed. The nursery bed was protected from heavy rains using straw mulching for the first 5 days. A nursery of 100 m^2 areas and 10-12 kg of good quality seeds were sufficient for one hectare area with ICM method and 50 m^2 nursery with 5-7 kg seeds were enough for SRI method. In SRI, young seedlings of 10 days old with one and half leaf were scooped out from the nursery and transplanted in main field. For ICM, 20 days old seedlings with 2-3 leaves were transplanted. Care was taken to transplant seedlings within 30 minutes of scooping from the nursery to avoid wilting and reduce transplanting shock.

The FYM was applied 20 days ahead of transplanting to the main field and incorporated during ploughing. The supply of N, P and K was ensured through urea, single super phosphate (SSP) and muriate of potash (MOP) fertilizer, respectively. Half dose of N and full dose of P and K were applied as basal. The remaining half dose of N was divided in two equal portions and applied at tillering and panicle initiation stages. Two hand weeding (HW) was done in CRC at 20 and 45 days after transplanting (DAT), while two HW (15 and 45 DAT) and one weeding with cono-weeder (30 DAT) was done in SRI and ICM methods. All the weed biomass was recycled back into the field by incorporation.

No major insect pest and disease problems were observed. A spray of systemic fungicide Bavistin (Carbendazim) @ 2 g l^{-1} was given as preventive measure against blast disease in the nursery.

The complete recommended method of water management for SRI and ICM could not be followed due to the high rainfall pattern in the region. However, to the extent possible the field was given conditions of alternate wetting and drying and only a thin film of water was maintained by closing and opening of bund around the plots as necessary. For easy irrigation and drainage of water, a channel of 30 cm width and 20 cm depth was provided around each individual plots. Whereas, a continuous flooded water level of about 5± 2 cm was maintained in CRC plots. After grain filling stage, the water from all the plots irrespective of establishment methods was drained out.

2.4 Recording yield attributes and yield

Yield attributes like panicle hill^{-1}, panicle length, total number of grains as well as filled and chaffy grain panicle^{-1} and test weight (1000 grain weight) were recorded at maturity from a randomly selected five hills in each plot. Panicles m^{-2} was recorded from a randomly selected one meter square area from each plot. The post-harvest data on grain yield, straw yield and biological yield were recorded from the net plot area of 4.0 m × 3.0 m. Harvest index (HI) was computed by dividing the grain yield (14% moisture) with total biomass production multiplied by 100.

2.5 Soil and plant sampling and analysis

Initial as well as post-harvest composite soil samples were collected (500 g composite sample, one sample from each plot) from 0–15 cm and 15-30 cm depth. The soil samples were air dried, processed using 2 mm sieve and analyzed for soil pH by Piper (1950), soil organic carbon (SOC) by Nelson and Sommers (2005), available N by the alkaline permanganate method (Subbiah and Asija 1956); available P by Bray method (Bray and Kurtz 1945) and available K by neutral normal NH4OAC extraction method (Knudsen et al. 1982). At harvest, grain and straw samples of rice were oven dried at 65º C, ground and sieved through a 0.5 mm sieve and analyzed for total N by a micro-Kjeldahl method (Bremner and Mulvaney 1982). The P concentration of plant tissues digested in HNO_3 and $HClO_4$ was determined by the ammonium molybdate method (Olsen and Sommers 1982) and that of K by flame photometry (Stanford and English 1949). Nutrient uptake (for the above ground biomass only) was estimated by multiplying the N, P and K concentration of grains and straw with their respective dry biomass in kilogram hectare^{-1} and summing up the two values.

2.6 Statistical analysis

The experimental data pertaining to each parameter of study were subjected to statistical analysis by using the technique of analysis of variance and their significance was tested by "F" test (Gomez and Gomez 1984). Standard error of means (SEm+) and critical difference (CD) at 5% probability (p=0.05) were worked out for each parameter studied to evaluate differences between treatment means.

3. Results and Discussion

3.1 Yield attributes of rice

The results of the first 3 years data were reported by Das et al. (2014), while the 4th year's result is being presented in this paper. Longer panicles were found with SRI method of establishment over ICM and CRC (Table 1). The increase in number of panicles hill^{-1} with SRI over ICM and CRC was 21.4% and 42.3%, respectively. The number of panicles m^{-2} was however found to be higher with ICM method of planting in comparison to SRI due to the higher plant population (Das et al. 2008; Islam et al. 2013). The results showed that SRI recorded significantly higher number of grains panicle^{-1} as compared to ICM and CRC. The wider spacing in SRI helped in receiving better sunlight and created better micro environment which might have helped in better spikelet fertilization (Islam et al. 2013). The number of unfilled grains panicle^{-1} was found to be higher with CRC method. This may be due to the competition for nutrients with the higher plant population which reduces the space, water and soil aeration for better formation of grains. Control treatment recorded the highest no of unfilled grains panicle^{-1}. The highest test weight was recorded under SRI. This may be due to lesser competition for nutrient and other resources which might have resulted in higher production of photosynthates and subsequent translocation of nutrients especially in the post flowering stage of rice enabling better filling and grain formation (Islam et al. 2013; Das et al. 2014). The panicle length, number of panicles hill^{-1} and number of effective grains panicle^{-1} were found to be appreciably higher when nutrients were supplied through combined sources of organic manure and inorganic fertilizer in comparison to sole application of organic or inorganic sources. Beneficial effects of combined application of nutrient sources over control treatment was also reported by others (Dahiphale et al. 2003; Shekhar et al. 2005). Application of nutrients through integration of organic and inorganic sources recorded higher test weight (1000 grain weight) compared to single application of either inorganic or organic source. This might be attributed to integrated effect of all the physico-chemical properties of the soil as well as available nutrient status of the soil, which might have facilitated a steady supply of nutrients throughout the crop growth (Dahiphale et al. 2003).

Table 1. Effect of stand establishment methods and nutrient management practices on yield attributes of lowland rice (year 2008)

Treatment	Panicles hill^{-1}	Panicle length (cm)	Grains panicle^{-1}	Filled grains panicle^{-1}	Unfilled grains panicle^{-1}	Test weight (g 1000 seed^{-1})
Establishment method						
SRI	12.3	25.1	219.3	187.6	31.7	23.5
ICM	9.7	24.8	193.4	160.3	33.1	23.3
CRC	7.1	23.1	169.5	135.4	34.1	22.1
SEm+	0.16	0.57	1.49	1.28	0.83	0.69
LSD (p=0.05)	0.44	1.58	4.14	3.55	2.30	NS
Nutrient management						
RDF	9.5	24.5	191.8	158.9	32.9	22.5
FYM 10 t/ha	9.8	24.5	192.2	159.4	33.2	23.7
50% RDF + FYM 10 t/ha	10.3	24.7	199.8	166.7	32.8	24.0
RDF + FYM 5 t/ha	10.2	24.8	201.4	168.7	33.0	24.4
Control	8.8	23.3	185.1	152.0	33.0	20.4
SEm+	0.20	0.54	2.04	2.01	0.77	0.13
LSD (p=0.05)	0.41	1.14	4.21	4.15	1.59	0.29

SRI: System of rice intensification, ICM: Integrated crop management, CRC: Conventional rice culture, RDF: Recommended dose of fertilizer, SEm+: Standard error of mean, LSD: Least significant difference, FYM: Farm yard manure, RDF: 80:60:40 kg N, P_2O_5, K_2O ha^{-1}

3.2 Yield of rice

Among the stand establishment methods, ICM method of establishment being at par with SRI gave significantly higher grain yield than CRC (Table 2). This might be due to transplanting of young seedlings with closer spacing, which produces more effective panicles per unit area (Viraktamath and Kumar 2007). The highest straw yield was also obtained under ICM establishment method which was at par with SRI but significantly superior to CRC. The comparable increase of straw yield under ICM over SRI may be on account of higher plant population per unit area. ICM also had the advantages of better handling of the 20 days seedlings than 10 days old seedlings and the ability to face the adverse condition such as heavy rainfall, wind damage etc. compared to the seedlings of SRI which are young and tender (Rajendran 2007). Lowest grain yield was recorded under CRC and this was mainly due to the lower values of yield attributes per unit area (Munda et al. 2007). However, there was no significant difference in harvest index for crop establishment methods.

The highest grain yield was recorded in plots where inorganic and organic sources were supplied through integrated nutrient management (Table 2). It may be due to the synergistic effects of inorganic and organic source of nutrients (Benipal et al. 2003; Das et al. 2006). Grain yield increase with integrated nutrient management over RDF was to the extent of 21.2 to 76.8 %. Straw yield also responded well to integrated use RDF + FYM 5 t ha^{-1} and 50% RDF + FYM 10 t ha^{-1}. This might be due to favourable soil condition and synchronized release of nutrients throughout the crop growth period (Murali and Setty, 2004). The increase in nitrogen concentration in plants might also be the reason for the overall increase in biomass production. Combined application of nutrient being at par with RDF and FYM 10 t ha^{-1} recorded higher harvest index in comparison to control. The interaction effect between stand establishment methods and nutrient management options was also significant for crop productivity (Table 3). The ICM rice culture along with RDF + FYM 5 t ha^{-1} recorded the highest grain yield (5.88 t ha^{-1}), straw yield (7.37 t ha^{-1}) and harvest index (44.35).

Table 2. Effect of stand establishment methods and nutrient management practices on yield of lowland rice (2008)

Treatment	Grain yield (t ha^{-1})	Straw yield (t ha^{-1})	Biomass yield (t ha^{-1})	Harvest Index (%)
Establishment method				
SRI	5.29	6.97	12.26	43.2
ICM	5.45	7.14	12.59	43.3
CRC	5.00	6.55	11.55	43.2
SEm+	0.06	0.10	0.12	0.33
LSD (*p*=0.05)	0.17	0.27	0.33	NS
Nutrient management				
RDF	5.15	6.88	12.04	42.8
FYM 10 t/ha	5.28	6.94	12.22	43.2
50% RDF + FYM 10 t/ha	5.53	7.07	12.60	43.8
RDF + FYM 5 t/ha	5.65	7.13	12.78	44.3
Control	4.61	6.41	11.02	41.7
SEm+	0.09	0.07	0.12	0.48
LSD (*p*=0.05)	0.19	0.13	0.25	0.99
Interaction (Establishment method × nutrient management)	0.34	0.34	-	1.79

Table 3. Interaction effect between stand establishment methods and nutrient management practices on yield of lowland rice (2008)

Treatment	Grain yield (t ha^{-1})			Straw yield (t ha^{-1})			Harvest index (%)		
	SRI	ICM	CRC	SRI	ICM	CRC	SRI	ICM	CRC
RDF	5.22	5.33	4.92	6.98	7.13	6.53	42.8	42.7	43.0
FYM 10 t ha^{-1}	5.34	5.48	5.03	7.03	7.19	6.59	43.2	43.3	43.3
50% RDF + FYM 10 t ha^{-1}	5.54	5.78	5.27	7.11	7.35	6.75	43.5	44.1	43.8
RDF + FYM 5 t ha^{-1}	5.74	5.88	5.33	7.24	7.37	6.79	44.4	44.4	44.3
Control	4.63	4.78	4.43	6.48	6.65	6.10	41.7	41.8	41.7
SEm+	0.16			0.15			0.08		
LSD (*p*=0.05)	0.34			0.33			0.18		

3.3 Soil pH and organic carbon content

The effect of stand establishment methods and nutrient management practices was not significant on soil pH (Table 4). The soil was found to be strongly acidic in nature. The pH of the soil even though non- significant was higher for SRI plots than ICM and CRC plots in the surface and sub-surface layer. The SRI recorded significantly higher soil organic carbon (SOC) concentrations in 0-15 cm soil layer compared to CRC. The turning of weeds into the soil by using cono-weeder resulted in decomposition of the weeds and turned into organic matter. However, there was no significant effect of stand establishment on the SOC at 15-30 cm soil layer. There was an increase in the SOC content of the soil due to the combined use of organic manure and fertilizer for continuous four years. This may be attributed to the inclusion of FYM which added humus to the soil and thus, mass per unit volume decreased resulting in increased SOC content (Naik and Yakadri, 2004). The increase in SOC content in the manurial combination is also attributed to the direct incorporation of organic matter into the soil. The subsequent decomposition of these materials might have resulted in the enhanced SOC concentration of the soil.

3.4 Post-harvest nutrient status of the soil

The available N in soil was significantly higher under SRI compared to that under ICM and CRC plots in 0-15 cm and 15-30 cm soil at rice harvest (Table 4). The most effective contribution of application of inorganic fertilizer and organic manure to available nutrient status of the soil was observed when RDF was applied as inorganic source along with FYM 5 t ha^{-1}. The increase in available N due to the organic material application resulted in the greater multiplication of soil microbes, caused the addition of organic materials and enhanced the conversion of organically bound N to inorganic forms.SRI plots recorded significantly higher available P content than CRC but comparable with ICM plots. The increase in the availability of P under SRI may be due to high content of available SOC which may help converting the immobilized P into labile or inorganic P. Application of inorganic P along with FYM increased the mineralization of organic P due to active microbial action and reduction in fixation of P. Generally, addition of organic manures like FYM with inorganic fertilizers had the beneficial effect in increasing the phosphate availability (Tandon, 1987). The available K was found to increase after harvest of the crop for the surface and sub-surface soils respectively. Application of 50% RDF + FYM 10 t ha^{-1} and RDF + FYM 5 t ha^{-1} raised the status of available K (Verma and Nand Ram, 1994).

Table 4. Effect of stand establishment methods and nutrient management practices on pH, soil organic carbon (SOC) and available nutrient content in soil after four crop of rice (2008)

Treatments	pH		SOC (%)		Available N (kg ha^{-1})		Available P_2O_5 (kg ha^{-1})		Available K_2O (kg ha^{-1})	
	0-15 cm	15-30 cm	0-15 cm	15-30 cm	0-15 cm	15-30 cm	0-15 cm	15-30 cm	0-15 cm	15-30 cm
Establishment method										
SRI	5.50	5.49	2.30	2.17	235.9	216.5	13.2	11.4	250.6	240.0
ICM	5.53	5.47	2.26	2.16	229.8	213.4	12.3	10.8	241.0	232.1
CRC	5.53	5.50	2.20	2.09	222.4	204.1	11.4	10.6	229.6	221.5
SEm+	0.03	0.05	0.03	0.06	4.13	3.66	0.42	0.46	6.26	7.96
LSD (p=0.05)	NS	NS	0.08	NS	11.46	10.2	1.16	NS	17.38	NS
Nutrient management										
RDF	5.43	5.44	2.22	2.12	218.5	201.9	11.4	9.42	233.2	222.6
FYM 10 t ha^{-1}	5.56	5.54	2.23	2.13	223.5	207.1	12.5	10.9	241.2	236.6
50% RDF + FYM 10 t ha^{-1}	5.53	5.51	2.37	2.23	250.9	226.1	14.0	13.1	253.8	242.6
RDF + FYM 5 t ha^{-1}	5.51	5.49	2.39	2.22	252.9	234.7	14.8	13.7	258.6	247.8
Control	5.49	5.43	2.10	2.00	201.0	186.1	8.72	7.54	215.2	207.0
SEm+	0.08	0.06	0.06	0.06	7.13	6.81	0.50	0.53	6.19	6.51
CD (p=0.05)	NS	NS	0.12	0.12	14.72	14.1	1.03	1.09	12.78	13.4

Combined source of nutrients activates the soil biologically, thereby increase the mineralization of organic K from FYM which might be possible reason for enhanced K availability (Singh et al. 2005). The bio-degeneration of root biomass left on the soil after harvest could also be the reason for the increase in available K after harvest of the crop. The beneficial effect of FYM on available K may be ascribed to the reduction of K fixation and release of K due to the interaction of organic matter with clay, besides the direct K addition to the K pool (Tandon 1987). A decline of available K was observed under control among all the establishment methods.

3.5 Nutrient uptake

Nutrient concentration and dry matter production contributes to nutrient uptake of a plant. The highest N uptake was observed under ICM establishment method which was comparable with SRI (Table 5). The higher availability of N increased the N uptake in these plots. SRI method of establishment had significantly higher P uptake than the other establishment methods. The massive and long functioning rice root under SRI which comes in contact with larger volume of soil might have absorbed more amounts of moisture and nutrients which is in evidence with significant phosphorus uptake (Patel et al. 2008). However, uptake of K was higher under ICM as compared to CRC. The increase in nutrient uptake with these treatments over CRC may be attributed to the higher dry matter production and better nutrient availability (Barison, 2002). Significantly higher N, P and K uptake was recorded under integrated application of nutrients over control treatment. The increase in nutrient uptake with combined source of nutrients may be due to the increased dry matter production and nutrient concentrations caused by synergic effect of balanced fertilization (Saha et al. 2007).

Conclusion

The four years study indicated that ICM has greater potential in terms of yield and ecological benefit compared to SRI and CRC. Integrated use of RDF along with 5 t FYM ha^{-1} or 50% RDF with FYM 10 t ha^{-1} can be adopted depending on the availability of resources as both were found better than sole application o0f fertilizer or manure for higher productivity. Judicious combination of inorganic fertilizer and organic manure would improve the productivity besides maintaining the soil fertility on long term basis.

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Table 5. Effect of stand establishment methods and nutrient management practices on N, P, and K uptake of lowland rice (2008)

Treatment	Nutrient uptake in grain (kg ha^{-1})			Nutrient uptake in straw (kg ha^{-1})			Total nutrient uptake in rice (kg ha^{-1})		
	N	P	K	N	P	K	N	P	K
Establishment method									
SRI	88.8	17.4	14.1	47.0	12.8	104.1	138.6	30.4	118.2
ICM	89.2	16.7	13.9	48.4	12.4	105.3	137.9	29.1	118.6
CRC	81.3	14.6	12.0	43.1	10.3	94.0	124.4	24.5	106.5
SE (d)	1.2	0.3	0.8	0.6	0.4	1.6	1.2	0.6	1.9
LSD (*p*=0.05)	3.4	0.9	2.1	1.7	1.0	4.5	3.3	1.6	5.2
Nutrient management									
RDF	82.9	14.4	12.0	48.8	12.2	102.5	131.6	26.6	114.4
FYM 10 t ha^{-1}	85.2	16.9	13.1	48.0	11.0	107.1	133.1	28.2	119.4
50% RDF + FYM 10 t ha^{-1}	94.2	18.9	14.7	50.3	13.0	110.5	145.1	31.9	125.2
RDF + FYM 5 t ha^{-1}	97.2	19.2	16.0	51.2	12.9	111.7	148.3	32.0	126.8
Control	72.7	11.9	11.0	37.3	10.1	74.9	110.1	22.0	85.8
SEm+	1.1	0.5	0.8	1.1	0.6	1.4	1.6	0.9	1.4
CD (*p*=0.05)	2.2	1.1	1.7	2.3	1.2	2.9	3.2	1.8	2.8

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