Indian Journal of Agronomy **60** (4): 534–540 (December 2015)

Research Paper

Effect of establishment methods and nutrient management on physiological attributes and water-use efficiency of rice (*Oryza sativa*) in a sub-tropical climate

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Received : July 2015; Revised accepted : December 2015

ABSTRACT

A field experiment was conducted during the rainy (*kharif*) seasons of 2004 to 2008 in acid soils of sub-tropical Meghalaya, under rainfed condition, to evaluate the impact of crop-establishment methods and nutrient-management practices on growth and physiological parameters of rice (*Oryza sativa* L.). Three establishment methods, viz. system of rice intensification (SRI), integrated crop management (ICM) and conventional rice culture (CRC), were evaluated under 5 nutrient-management practices, viz. recommended dose of fertilizers (RDF) (80 : 60 : 40 N, P_2O_5, K_2O kg/ha), farmyard manure (FYM) 10 t/ha, 50% RDF + FYM 10 t/ha, RDF + FYM 5 t/ha and control (no FYM or fertilizer). Seedlings of 10, 20 and 30 days age were transplanted at a spacing of 25 cm × 25 cm, 20 cm × 20 cm and 20 cm × 15 cm for SRI, ICM and CRC respectively. Pooled data of year 2007 and 2008 revealed that SRI method recorded higher values of growth parameters, viz. plant height, number of tillers/hill, number of leaves, dry-matter production and root growth, than ICM and CRC methods. Significantly higher root volume and root dry weight were recorded with SRI than ICM and CRC methods. Application of RDF + FYM 5 t/ha being at par with 50% RDF + FYM 10 t/ha showed relatively taller plants, higher numbers of tillers, leaves, dry matter, root volume and root dry weight/hill than the other nutrient-management practices. The rice crop matured earlier (135 days) under SRI rice culture than that under ICM (141 days) and CRC (148 days) methods. Photosynthetic rate (PR) and water-use efficiency (WUE) were significantly higher under SRI, whereas transpiration rate (TR) was higher under CRC. Rice culture under SRI recorded higher values of yield-attributing parameters, viz. number of panicles/hill and number of grains/panicle than ICM and CRC. However, the grain and straw yields were significantly more with ICM than that of CRC but were at par with, SRI methods. Integrated application of RDF + FYM 5 t/ha followed by 50% RDF + FYM 10 t/ha gave higher value of all the yield-attributing parameters and yield of rice compared to the control. The highest net returns were recorded under ICM rice culture and application of RDF + FYM 5 t/ha.

***Key words* :** Photosynthetic rate, Nutrient management, Rice, Root volume, Water-use efficiency

Maintenance of optimum plant population in rice is a pre-requisite for achieving higher growth (Anbumani *et al*., 2004). The growth and physiological parameters are influenced by the establishment methods and nutrient-management practices (Das *et al*., 2014). The photosynthetic rate (PR), transpiration rate (TR) and water-use efficiency (WUE) are also influenced by the seedling age, method of planting, geometry, nutrient management and water-management practices (Patel *et al*., 2010). Appropriate seedling age at transplanting is also essential for optimum yield (Das *et al*., 2014). Uphoff (2002), while emphasizing system of rice-intensification (SRI) technique, opined that early transplanting of younger seedling preserves potential of plant's for much greater tillering, more root growth, and better yield than older ones. Old seedlings mature later because of delayed formation of tillers and longer time to recover from transplanting shock resulting in poor growth (Makarim *et al*., 2002). Number of seedlings that are transplanted in one hill also influences the yield of the crop. Planting of single seedling/hill gives more yields than that of 2 seedlings/hill (Rajarathinam and Balasubramaniyan, 1999). Method of SRI comprises package of agronomic components like use of younger seedlings (12 to 15 days old), transplanting single seedling/hill, use of wider spacing (25 cm × 25 cm), intermittent irrigation, uprooting of seedlings by scooping and careful transplanting, weed control by cono weeder, use of organic manures etc. (Islam *et al*., 2013). Although SRI is

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gaining wider acceptance in many countries, there are some limitations especially in the high-rainfall areas in which the production of rice is not promising as it should have been. To overcome the limitations of SRI, one can go for integrated crop management (ICM) as suggested by Das *et al*. (2014) in which 15–20 days old seedlings are transplanted in medium spacing of 20 cm × 20 cm and 2 seedlings/hill are transplanted, organic manures and fertilizers are used in integration. Nutrient-management practices play an important role in growth and development of rice. Proper utilization and combination of nutrients have a significant effect on the proper growth which in turn enhances its yield attributes and yield (Das *et al*., 2008). Nutrient availability as well as uptake pattern from the organic and inorganic sources differ and thus may have differential influence on crop growth, physiological processes and productivity.

Chemical fertilizers contain very high amount of nutrients and these are the quick source of nutrient supply. However, use of chemical fertilizers alone had led to deterioration in soil health and reduction in fertilizer-use efficiency. In contrast, organic manure are nearly complete source of most of the nutrients and become available for longer duration due to slow decomposition and gradual release of the nutrients into the labile pool (Das *et al*., 2014). After being released into the pool, the nutrients from the fertilizers as well as the manures will behave and interact similarly (Kumaraswamy, 2005). Therefore, an integrated approach with the use of organic and inorganic inputs that nourishes the soil in many ways and supplies all the essential nutrients to the crops in sufficient amounts and make the nutrients readily available during entire crop growth is required. In recent past, SRI and ICM have been gaining attention in North-East India. Most of the efforts in this region are fragmented and without any systematic approach. Scientific data on the performance of rice under various establishment methods are meager. The nutrient requirement of rice for various establishment methods may also vary. Thus, the present research work has been conducted to evaluate the impact of crop-establishment methods and various nutrient-management practices on growth and physiology of lowland rice.

MATERIALS AND METHODS

A field experiment was conducted at the low-land Agronomy Farm, ICAR Research Complex for North Eastern Hill Region, Umiam, Meghalaya, during 4 consecutive rainy seasons (2004 to 2008) under rainfed condition. The institute farm is located at (25° 30'N and 91° 51'E with an elevation of 950 m above mean sea-level). The soil was low in available phosphorus (6.95 kg P/ha), medium in nitrogen (277 kg N/ha) and high in potassium (258 kg K/ha). The pH and organic carbon in soil were 5.1 and 2.56% respectively. The experimental soil was sandy clay loam. The average monthly minimum and maximum temperature during the rice growing seasons ranged from 12.4 to 21.2 °C and from 23.9 to 29.1 °C, respectively. The average annual rainfall of the study site is about 2,450 mm.

Three stand establishment system methods, viz. SRI, ICM and conventional rice culture (CRC) and 5 nutrient-management practices, viz. recommended dose of fertilizer (RDF) (80 : 60 : 40 kg NPK/ha), farmyard manure (FYM) 10 t/ha, RDF + FYM 5 t/ha, 50% RDF + FYM 10 t/ha and control (no manure or fertilizer), were followed in factorial randomized-block design and replicated thrice. The gross and net plot sizes were 5.0 m × 4.0 m and 4.0 m × 3.0 m, respectively, and the treatments were superimposed in the same plot every year to study the cumulative treatment effects. Nurseries for all the 3 establishment methods were sown on the same day, but transplanting date varied as per the requirement of different establishment methods. For SRI, 10-day old seedling at 1 seedling/hill was used with 25 cm × 25 cm spacing, while for ICM, it was 20-day old seedlings at 2 seedlings/hill with a spacing of 20 cm × 20 cm, and for CRC, 30-day old seedlings at 3 seedlings/hill with a spacing of 20 cm × 15 cm was followed. High-yielding and medium-duration rice variety ‘Shahsarang 1’ was used as test crop in the experiment.

The nursery for SRI and ICM was prepared using a modified mat-nursery method. Seedlings were raised in 4.0 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. 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. 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 week. A nursery of 100 m^2 area and 10–12 kg of quality seeds were sufficient for 1 ha area with ICM method and 50 m^2 nursery with 5–7 kg seeds were enough for SRI method. The seedlings attained one and one half leaf stage in about 10 days and young seedlings were transplanted by scooping the single seedlings for SRI and on day 20 for ICM method (2–3 leaves). However, for CRC, the conventional method was used following 40 kg seed/ha, 500 m^2 nursery area, raised bed of 1.0 m width and 0.15 m height. All the establishment methods (SRI, ICM and CRC) were compared with each other considering respective package of practices as a part of treatments. The FYM was applied 20 days ahead of transplanting to the main field and incorporated during ploughing. Supply of N, P and K was ensured through urea, single superphosphate (SSP) and muriate of potash (MOP) fertilizer. Half dose of N and full dose of P and K were applied basal. The remaining N was divided in 2 equal portions and applied at tillering and panicle-initiation stages. Two hand-weedings (HW) in CRC [20 and 45 days after transplanting (DAT)] and 2 HW (15 and 45 DAT) and 1 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. 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 SRI and ICM rice culture. A continuous flooded water level of about 5 ± 2 cm was maintained in CRC plots. For easy irrigation and drainage of water, a channel of 30 cm width and 20 cm depth was provided around each individual plots.

Plant height, tillers/hill, leaves/hill and dry-matter production were recorded at 15-day interval and at harvesting from 5 random hills in each plot. Root parameters were collected at 50% flowering stage from randomly selected 5 hills. Selected hills were carefully removed using a core of 20 cm length and 7 cm diameter and roots were washed gently in tap-water. Root volume was measured in a 1 litre measuring cylinder by the water-displacement method (Das *et al*., 2008). Root dry weight was recorded after oven drying. The photosynthetic rate (PR) µmol $CO_2/m^2/s^1$) and transpiration rate (TR) mmol water/m^2/s^1) of rice were measured in 5 flag leaves in each treatments at 50% flowering stage using portable photosynthesis system (Model CIRAS-2, UK) during morning hours (9-10 am). The ratio between rates of photosynthesis and transpiration (PR/TR) was used to determine instantaneous water-use efficiency (WUE) as described by Rosenberg and Kriiger (1993). The plant and soil data were statistically analyzed using the F-test as per the procedure given by Gomez and Gomez, (1984). The differences between treatments means were compared with the critical difference (CD) at 5% level of probability (P=0.05)**.**

RESULTS AND DISCUSSION

Growth attributes

Among the stand-establishment methods, SRI method produced the tallest plants than CRC and ICM methods. The CRC method resulted in shorter plant height at 30 DAT than SRI and ICM methods (Table 1). Less competition among the plants for resources like moisture and nutrients due to less plant population might led to an increased availability of resources, resulting in an accumulation of dry matter and ultimately increase in plant height under SRI and ICM methods (Munda *et al*., 2007). Nutrient-management practices also had a marked influence on plant height. The best response to nutrient-management practices was seen for plant height at 30 DAT with application of RDF + FYM @ 5 t/ha where taller plants were observed compared to the other nutrient-management

Table 1. Effect of stand-establishment methods and nutrient-management practices on plant height and number of tillers of rice at different stages of growth (Pooled data of year 2007 and 2008)

Treatment	Plant height (cm)			Tillers/hill		
	30 DAT	60 DAT	90 DAT	30 DAT	90 DAT	105 DAT
Establishment method						
SRI	43.0	76.6	89.8	6.9	14.1	13.7
ICM	40.9	74.5	84.5	8.1	11.0	10.6
CRC	39.9	72.2	82.2	8.4	8.4	8.0
SEm±	0.69	0.66	0.76	0.1	0.3	0.2
CD (P=0.05)	1.92	1.83	2.11	0.4	0.7	0.6
Nutrient management						
RDF	41.6	74.3	84.5	8.3	11.1	10.7
FYM 10 t/ha	39.5	74.6	86.1	7.6	11.1	10.7
50% RDF + FYM 10 t/ha	43.8	77.7	89.0	7.9	11.6	11.1
RDF + FYM 5 t/ha	44.2	77.2	87.4	8.5	11.7	11.2
Control	37.4	68.5	80.7	6.8	10.4	10.0
SEm±	0.98	1.08	1.08	0.2	0.3	0.3
CD (P=0.05)	2.02	2.23	2.23	0.4	0.6	0.6

SRI, System of rice intensification; ICM, integrated crop management; CRC, conventional rice culture; FYM, farmyard manure; DAT, days after transplanting; Recommended dose of fertilizer (RDF), 80:60:40 kg N, P_2O_5, K_2O kg/ha practices, but plants of similar height were produced with 50% RDF+ FYM 10 t/ha. At 60 DAT, plants were taller when 50% RDF + FYM 10 t/ha was applied. At 30 DAT, an application of RDF alone produced more plant height over FYM 10 t/ha. However, from 60 DAT onwards similar plant height was observed among the nutrient-management practices. The growth attributes of rice increased at initial stages under RDF (supplied through synthetic fertilizers) as compared to FYM 10 t/ha because nutrients from the fertilizers were readily available (as most of the fertilizers were water-soluble). While, the nutrients supplied through organic manures would become available for crop uptake slowly but would be available for longer duration due to slow decomposition of organic manures and gradual release into the labile form (Das *et al*., 2014).

At 30 DAT, the CRC method resulted in higher number of tillers over SRI and ICM methods (Table 1). Less number of tillers in SRI method at the initial stage was due to the planting of single seedling/hill. The seedlings are small and also widely spaced at this stage which had led to lower tiller number. From 90 DAT till 105 DAT, more tillers/hill were observed under SRI method and during this period the lowest number of tillers/hill was observed with CRC methods. Tillers production reached its peak at 60 DAT in all the establishment methods. At 105 DAT, the number of tillers under SRI was found to be 28.84% and 41.55% higher than CRC and ICM culture, respectively. Transplanting younger seedlings reduced transplanting shock to the seedlings and advanced the tillering process completing more phyllochrons (phyllochron is the time taken to form a new tiller with a leaf and root) (Patel *et al*., 2008) and as a result produced more tillers/hill. Cono-weeder operation also leads to strong root-system which was responsible to supply oxygenated energy for the production of tillers. There was a significant effect on the tillers/hill at different growth stages under the nutrient-management practices. Maximum tillers/hill at 30 to 90 DAT were produced when RDF + FYM 5 t/ha was applied. From 90 to 105 DAT, the number of tillers/hill was maximum with RDF + FYM 10 t/ha which was at par with RDF + FYM 5 t/ha. Minimum number of tillers was noted in the control. Such beneficial effect of combined source of nutrients on plant height might be due to steady release and availability of nutrients to rice from combined application (Das *et al*., 2014).

The number of leaves increased in the subsequent stages up to 60 DAT, and thereafter there was a reduction in the number of leaves in all the establishment methods up to 105 DAT (Fig. 1). At 30 DAT, the number of leaves was relatively higher under CRC and ICM methods than that SRI methods. This may owing to the fact that 3 seedlings with 2–3 number of leaves transplanted under CRC method as compared to 2 seedlings with 2 leaves and 1 seedlings with one and half leaf were transplanted under ICM and SRI method, respectively. However, leaves/hill were significantly higher more SRI culture from 45 to 105 DAT and the lowest number of leaves was observed under CRC method during these stages. The number of leaves was however higher with SRI at later stages and this may be attributed to the production of more number of tillers (Patel *et al*., 2008). The number of leaves decreased during the later stages which might be due to the shedding of leaves. Higher leaves/hill at 15 and 30 DAT was observed with RDF alone which was comparable with RDF + FYM 5 t/ha but significantly superior to FYM 10 t/ha alone (Fig. 2). From 45 to 105 DAT, leaves/hill were the maximum under RDF + FYM 5 t/ha and similar number of leaves was observed when 50% RDF + FYM 10 t/ha was applied. The control showed the minimum number of leaves during all growth stages.

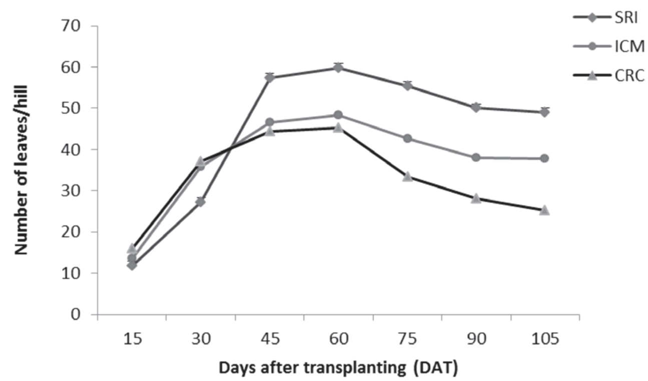

Fig. 1. Effect of stand-establishment methods on number of leaves/hill (SRI, System of rice intensification; ICM, integrated crop management; CRC, convention rice culture). Recommended dose of fertilizer (RDF), 80:60:40 kg N, P_2O_5, K_2O kg/ha

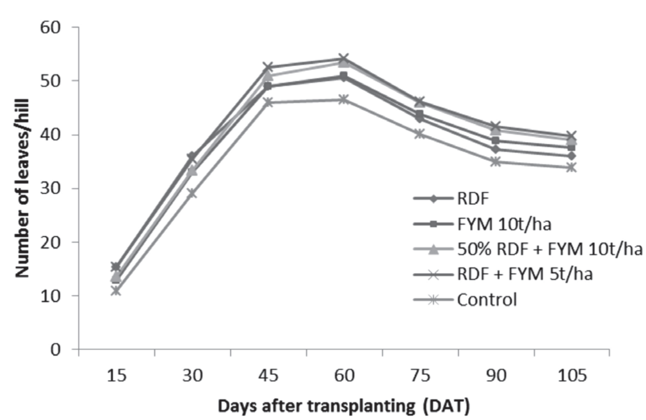

Fig. 2. Effect of nutrient-management practices on the number of leaves/hill; (SRI, System of rice intensification; ICM, integrated crop management; CRC, conventional rice culture; FYM, farmyard manure). Recommended dose of fertilizer (RDF), 80:60:40 kg N, P_2O_5, K_2O kg/ha

The rice variety 'Shahsarang 1' matured earliest under SRI rice culture as compared to ICM and CRC methods (Table 2). Transplanting at younger stage of seedlings reduced transplanting shock to the seedlings, thus it advanced the tillering process (Patel *et al*., 2008). This advantage was carried over by the crop and completed life-cycle earlier than CRC method (Shekhar *et al*., 2009). All nutrient-management practices, however, did not influence the duration of rice. The dry-matter production increased steadily up to the maturity stage, although the magnitude differed with stage of the crop and treatments (Table 2). At the flowering and harvesting stages, the maximum dry matter was observed under SRI method of establishment. The lowest dry-matter production was observed with CRC establishment method, being 33.28 and 24.60% lower than SRI and ICM methods at harvesting, respectively. In SRI method, the use of wider spacing enables the crop to get more sunlight and increase the photosynthetic activity. The plant also has less competition for nutrients and water which enables better growth of the plant. The increase in dry-matter production of rice under SRI over CRC was also reported by Xiuming *et al*. (2004) and Islam *et al*. (2013). Nutrient sources also had an appreciable influence on the dry-matter production of the plant. Integrated application of RDF + FYM 5 t/ha resulted in the maximum dry-matter production, closely followed by the application of 50% RDF + FYM 10 t/ha. At flowering stage an application of RDF produced significantly higher dry-matter than the control. Such beneficial effect of combined source of nutrients on dry-matter production might be owing to steady release and availability of nutrients to rice from combined application. The organic manure alone on the other hand may not be able to supply the required quantity of nutrient in the initial stage of crop growth, which is one of the most important factors for plant growth and development.

Higher root volume and root dry weight were recorded under SRI rice culture compared to those observed under ICM and SRI methods (Table 2). The ICM rice culture also recorded significantly more root volume and dry weight than that under CRC method. The secret that roots grow large under SRI method of establishment was owing to young seedlings are transplanted at shallow depth and wider spacing, soil was kept well aerated and rich with diverse microorganisms (Islam *et al*., 2013). Continuous mechanical disturbance to the soil through cono-weeder loosened the soil and supply oxygen directly to the growing roots to result into more active and long functioning sturdy root-system and thus, root degeneration was minimal (Patel *et al*., 2008). Higher root dry weight and root volume under SRI method also led to proliferation of root-system by contributing to higher biomass (Das *et al*., 2014). Application of RDF + FYM 5 t/ha being at par with other treatments recorded significantly higher root volume than that of the control. The root dry weight was the highest under RDF + FYM 5 t/ha, but it was at par with 50% RDF + FYM 10t/ha, FYM 10 t/ha and RDF.

Physiological parameters

The PR and WUE were significantly higher under SRI,

Table 2. Effect of stand-establishment methods and nutrient-management practices on crop duration, root growth, dry-matter production and yield of rice (Pooled data of year 2007 and 2008)

Treatment	Duration (days)	Root volume (cc/hill)	Root dry weight (g/hill)	Dry-matter production (g/hill) at harvesting	Photosynthesis rate (PR) (µmol CO_2/m^2/s)	Transpiration rate (TR) (mmol/m^2/s)	Water-use efficiency (PR/TR)
Establishment method							
SRI	135	59.2	12.16	77.5	25.2	8.01	3.15
ICM	141	52.9	10.29	68.0	24.7	7.95	3.11
CRC	148	42.3	7.74	51.3	21.6	7.84	2.76
SEm±	2.2	3.0	0.89	1.8	0.19	0.14	0.13
CD (P=0.05)	4.5	6.2	1.82	5.0	0.39	0.29	0.27
Nutrient management							
RDF	142	46.3	9.91	62.6	23.2	8.04	2.89
FYM 10 t/ha	143	46.4	10.11	66.0	21.8	7.87	2.77
50% RDF + FYM 10 t/ha	143	52.3	12.11	70.0	25.5	8.13	3.14
RDF + FYM 5 t/ha	143	59.0	12.80	71.5	26.4	8.16	3.24
Control	140	42.4	7.99	57.8	20.2	7.72	2.62
SEm±	2.1	5.2	1.27	2.4	0.33	0.17	0.18
CD (P=0.05)	NS	10.8	2.62	4.9	0.68	0.35	0.37

whereas TR was higher under CRC method (Table 2). Higher WUE of rice under SRI (Das *et al*., 2014) and under alternate wetting and drying than that under ICM method has been reported (Patel *et al*., 2010). This is in confirmation with Viraktamath and Kumar (2007), where SRI could save 22 and 38% water during dry and wet season, respectively, over conventional methods. The PR, TR and WUE were significantly higher with RDF + FYM 5 t/ha over the control and were similar to that with 50% NPK + FYM 10 t/ha. The control treatment recorded the lowest values of PR, TR and WUE.

Yield attributes, yield and economics

Yield attributes like panicles/hill and total number of grains and 1,000-grain weight were recorded at maturity from a randomly selected 5 hills in each plot. The post-harvest data on grain yield and straw yield were recorded from the net plot area of 4.0 m × 3.0 m. The increase in number of panicles/hill with SRI over ICM and CRC methods was 21.38% and 42.27% respectively (Table 3). The results showed that there was a significant difference in the number of grains per panicle. The wider spacing in SRI method helped in receiving better sunlight and created better micro-environment which might have helped in better spikelet fertilization (Islam *et al*., 2013). The highest 1,000-seed weight was recorded under SRI method. This may be owing to lesser competition for nutrient and other resources which would have resulted in higher production 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 number of panicles/hill were found to be appreciably higher when nutrients were supplied through combined sources of organic manure and inorganic fertilizer than the sole application of organic or inorganic sources. Dahiphale *et al*., 2005 also reported beneficial effects of combined application of nutrient sources over the control treatment. Application of organic with inorganic sources recorded higher 1,000-grain weight. 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*., (2005).

Among the stand-establishment methods, ICM method of establishment being at par with SRI gave significantly higher grain yield than CRC method (Table 3). This might be due to the use of young seedlings with closer spacing of 20 cm × 20 cm, which produces more effective panicles per unit area (Viraktamath and Kumar, 2007). The highest straw yield was also obtained with ICM establishment method which was at par with SRI but significantly superior to CRC method. The comparable increase of straw yield in ICM over SRI method may be on account of higher plant population per unit area. The ICM method also had the advantages of better handling of the 20-day old seedlings than 10-day old seedlings and the ability to face the adverse condition such as heavy rainfall, wind damage etc. compared to the seedlings of SRI method which are young and tender. The lowest grain yield was

Table 3. Effect of stand establishment methods and nutrient management practices on yield attributes, yield and economics of rice (Pooled data of year 2007 and 2008)

Treatment	Panicles/ hill	Total number of grains/ panicle	1,000-grain weight (g)	Grain yield (t/ha)	Straw yield (t/ha)	Cost of cultivation (₹/ha)	Net returns (₹/ha)
Establishment method							
SRI	12.3	219.3	23.5	5.29	6.97	19,515	24,184
ICM	9.7	193.4	23.3	5.45	7.14	20,532	24,429
CRC	7.1	169.5	22.1	5.00	6.55	22,392	18,834
SEm±	0.16	1.49	0.69	0.06	0.10		
CD (P=0.05)	0.44	4.14	NS	0.17	0.27		
Nutrient management							
Recommended NPK	9.5	191.8	22.5	5.15	6.88	19,918	22,688
FYM 10 t/ha	9.8	192.2	23.7	5.28	6.94	21,709	21,882
50% RDF + FYM 10 t/ha	10.3	199.8	24.0	5.53	7.07	23,293	22,247
RDF + FYM 5 t/ha	10.2	201.4	24.4	5.65	7.13	22,398	24,044
Control	8.8	185.1	20.4	4.61	6.41	16,191	21,554
SEm±	0.20	2.04	0.13	0.09	0.07		
CD (P=0.05)	0.41	4.21	0.29	0.19	0.13		

SRI, System of rice intensification; ICM, integrated crop management; CRC, conventional rice culture; FYM, Farmyard manure; DAT, days after transplanting; PR, photosynthesis rate; TR, transpiration rate; Recommended dose of fertilizer (RDF), 80:60:40 kg N, P_2O_5, K_2O kg/ha recorded under conventional rice culture and this was mainly due to the lower values of yield attributes per unit area (Munda *et al*., 2007). The highest grain yield was achieved in plots where inorganic and organic sources were added as integrated nutrient management (Table 3). It may be owing to the synergistic effects of inorganic and organic source of nutrients (Benipal *et al.,* 2003). Grain yield increased with integrated nutrient management over 100% recommended RDF was to the extent of 21.2 to 76.8%. Straw-yield response to integrated use of optimal NPK fertilizers and FYM was obtained with recommended NPK + FYM 5 t/ha and 50% recommended NPK + FYM 10 t/ha. This might be due to favourable soil condition and synchronized release of nutrients throughout the crop growth period (Murali and Setty, 2004).

The highest cost for all the stand-establishment methods was observed with the application of 50% RDF + FYM 10 t/ha and the lowest with the control. ICM and SRI establishment methods recorded the higher net returns compared to CRC methods. Higher net returns under ICM and SRI compared to CRC were also reported by Shekhar *et al*. (2009). Application of combined source of RDF with FYM 5 t/ha recorded the maximum net returns for the various stand-establishment methods. The higher returns under RDF + FYM 5 t/ha was due to higher productivity of rice owing to favourable effect of integrated application of recommended fertilizer along with FYM (Das *et al*., 2014).

Thus, it can be concluded that the practice of SRI with integrated use of RDF + FYM 5 t /ha or 50% RDF + FYM 10 t/ha is a viable technology for the north eastern region of India for increasing growth, photosynthetic rate and water-use efficiency of rice.

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