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# Productivity enhancement of rice through crop establishment techniques for livelihood improvement in Eastern Himalayas

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## ABSTRAC

*Performance of three crop establishment methods viz., system of rice intensification (SRI), integrated crop management (ICM) and farmer's practice (conventional rice culture)were evaluated during the year 2014-15 and 2015-16 at farmers field, Longleng District of Nagaland to assess the most suitable establishment methods of rice for higher productivity and profitability. Results revealed that ICM recorded significantly higher grain yield as compared to SRI and the farmers' practices during both the years. The ICM and SRI method of rice cultivation produced 44.5 and 41.2 % higher grain yield as compared to the farmer's practices, respectively. Similarly, the gross returns (Rs.46850 ha$^{-1}$), net returns (Rs.24730 ha$^{-1}$) and benefit: cost ratio (2.15) was recorded significantly highest under ICM. Among all crop establishment methods, the farmer's practice recorded least profit. Hence, the existing farmer's practices can be profitably replaced with adoption of ICM and SRI methods of crop establishment under the foot hill of Eastern Himalayas.*

**Key words:** *Rice, crop establishment methods, grain yield and net returns*

Rice is the major food crop of North East India and occupies an area of ~ 3.5 m ha, which accounts for ~7% of the area and 6.5% of the country's rice production. Productivity of rice in north east states is ~1.5 t/ha is much below the average national productivity (2.26 t/ha). In context to Nagaland, rice is primary food and cultivated in an area of ~18.3 thousand ha and producing ~38.1thousand tonnes with a productivity of ~2.1 t/ha (Anonymous 2014). The Longleng district in the state falls under most backward category as per classification of planning commission of Government of India. The livelihood of the people largely depends on agriculture and allied sectors. Rice is the staple food of this region and cultivated in an area of ~7.4 thousand ha with production of 13.62 thousand tonnes and productivity ~1.83 t/ha. The tribal people of the region are not even able to meet their food requirement due to the lowest crop productivity. The main problems associated with lowest rice productivity is lack of knowledge about improved agricultural practices *viz.* methods of crop establishment method, high yielding cultivars, proper weed management/proper nutrient management (Kumar *et al.* 2016a; Kumar *et al.* 2016b; Chatterjee *et al*. 2016). The poor farmers in the region lost their interest in rice cultivation due to declining in factor productivity and profitability with rise in input costs (Das *et al*. 2010). In this context, new technologies such as SRI and integrated crop management (ICM), an intermediate practice of SRI and conventional rice culture (CTR) *i.e.,* 20 days seedling , medium spacing 20 cm × 20 cm, single seedling/hill), appear to have potential that saves input, protect environment and improve crop productivity and soil health (Sinha and Talati 2007). SRI principles encourage use of organic manure instead of inorganic fertilizers to harness optimum potential. Increased productivity, profitability, employment-generation potential and increase in soil fertility also could be ensured by adopting modern scientific cropping sequence (Roy *et al*. 2011). Keeping this in view, Krishi Vigyan Kendra, Longleng, ICAR Nagaland Centre Jhranapani conducted on farm trial at farmer's field with an objective to evaluate the suitable crop establishment methods in agro-climatic condition of Longleng, Nagaland for achieving the higher crop yield.

## MATERIALS AND METHOD

Field experiment was conducted at farmer's field of Krishi Vigyan Kendra, Longleng, ICAR Research Complex for North Eastern Hill Region, Nagaland Centre Jharnapani, Medziphema during two consecutive *kharif* seasons of 2014 and 2015. The experimental site was located at an altitude of 1366 m above mean sea level. Soil of experimental field was sandy loam and acidic in reaction (pH 5.3), high in organic carbon (0.93%), low in available N (296 kg/ha) and medium in available P (12 kg/ha) and K (170 kg/ha).Treatments comprised of three crop establishment methods *viz.* system of rice intensification (SRI), integrated crop management (ICM) and farmer's practices (conventional rice culture) with six replication and laid out in randomized block design. The mean monthly average temperatures varied from 18.3 to 24.9°C in 2014 and 20 to 26.4°C in 2015, respectively. Total rainfall received during cropping period was 1442 and 1160 mm in 2014 and 2015, respectively. However, rainfall distribution over the month was better in 2015 compared to 2014. Monthly rainfall was recorded maximum in June 2014 and July 2015, respectively. Nurseries for the entire three establishment methods were sown on same day but transplanting date varied as per the requirement of the establishment methods. Nursery for SRI and ICM was prepared using a modified mat nursery (MMN) method. However, for CRC conventional method was used following 40 kg seed $ha^{-1}$, 500 $m^2$ nursery areas, raised bed of 1 m width and 0.15 m height. All the crop establishment methods (SRI, ICM and CRC) were compared with each other considering respective package of practices as per treatments. In MMN, seedlings were raised in a 4 cm layer of soil arranged on a farm surface covered with a plastic sheet (Das *et al*. 2013). A wooden frame of 1 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 frame was filled with soil mixture. Pre-germinated seeds were sown on 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 75-80% soil; 15-20% well decomposed FYM and 5% rice hull ash. To this soil and manure mixture (4 $m^{-3}$), 1.5 kg of powdered DAP (diamonium phosphate) was added and mixed thoroughly. Seedbed was sprinkled with water using a rose can as and when need. Nursery bed was protected from heavy rains using straw mulching for first 5 days. Nursery of 100 $m^2$ area and 10-12 kg of good quality seeds was sufficient for 1 ha area with ICM method and a 50 $m^2$ nurseries with 5-7 kg seeds was enough for SRI method. Seedlings attained one and a half leaf stage in about 10 days and young seedlings were transplanted by scooping single seedlings for SRI and on 20th day for ICM method (2-3 leaves). Care was taken to transplant seedlings within 30 minutes of scooping from nursery to avoid wilting and reduce transplanting shock.FYM was applied 20 days ahead of transplanting to the main field and incorporated at ploughing. Supply of N, P and K was ensured through urea, single super phosphate (SSP) and muriate of potash (MOP). Half dose of N and full dose of P and K were applied as basal and remaining half dose of N was applied at tillering and panicle initiation stages. Two hand weeding (HWs) in CRC (20 and 45 days after transplanting (DAT) and two HWs (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 field by incorporation. A spray of bavistin (2 g $lit^{-1}$ of water) was given as preventive measure against blast disease in nursery. For SRI, 12 days old seedling at single seedling/hill was used with the spacing of 25 cm × 25 cm, while for ICM 20 days old seedling at two seedlings/ hill with spacing of 20 cm × 20 cm and CRC (30-35 days old seedlings, spacing: 10 cm x 10 cm and 5-6 seedling $hill^{-1}$) as traditional methods were followed for growing the crop.

### Crop biometric observations and samplings

An area from each plot was ear-marked for destructive sampling and rest of the plot was used for yield estimation. Various biometric data were recorded at different growth stages of crop from ear-marked area of each plot; economic yield was estimated at harvest.

## Plant height

Plant height was measured from randomly selected hills in each plot at different stages leaving border rows. The plant height was recorded from base to the tip of the top most panicle of each hill of rice during flowering stage. Average height of the plants for each plot was worked out from the measured values.

## Tiller number:

Number of tillers was counted from randomly selected hills in each plot at different stages leaving border rows and average number of tillers hill$^{-1}$ was estimated (Thyagarajan *et al.*1995) and converted into number of tillers m$^{-2}$ for each plot.

## Dry matter production :

Three hills taken from border rows in each plot were used to work out dry matter production hill$^{-1}$ at harvest. These plant samples were first sun dried then oven dried at 70$^0$C for 48 hours and weighed to work out the dry matter production.

## Grain yield and harvest index

At physiological maturity plant samples from each plot were harvested manually using 1 m × 1 m frame in the centre of each plot and separated into straw and panicles. Panicles were hand threshed and filled spikelet was separated from unfilled spikelets with a blower. All unfilled spikelets were counted to determine filled spikelet percentage. Grain yield was determined from 1 m$^2$ area in center of each plot and adjusted to standard moisture content of 0.14 g $H_2O$ g$^{-1}$ fresh weight (*Kumar et al.* 2016). The filled grain of 1000 number was counted and weighed for each plot. Moisture content of the grain of each plot was determined and test weight was converted to a standard 12% moisture content. The harvest index was calculated by the formula given below (*Kumar et al.* 2016) for each plot.

$$HI = \frac{\text{Grain yield}}{\text{Biological}\left(\text{Grain+Straw}\right)\text{ yield}}$$

$$\text{Filled Grains (\%)} = \frac{\text{No. of filled grains per panicle}}{\text{Total no. of grains per panicle}} \times 100$$

Grain yield of rice was converted into equivalent value of carbohydrate (t ha$^{-1}$) as given by Gopalan *et al*. (2004). In economics, cost of cultivation was taken into account for calculating economics of treatments and to work out net returns ha$^{-1}$ (Rs. ha$^{-1}$) and benefit: cost ratio. The gross returns were taken as total income received from produce of grain and straw yield based on prevailing market price. Net returns and benefit: cost ratio was calculated with help of following formula:

Net return (ha$^{-1}$) = Gross returns (ha$^{-1}$) - Total cost of cultivation (ha$^{-1}$)

$$\text{Benift : cost ratio} = \frac{\text{Net returns}\left(\text{Rs.ha}^{-1}\right)}{\text{Cost of cultivation}\left(\text{Rs.ha}^{-1}\right)}$$

$$\text{Crop produtivity}\left(\text{kgha}^{-1}\text{day}^{-1}\right) = \frac{\text{Grain yield}\left(\text{kgha}^{-1}\right)}{\text{Total duration of crops}\left(\text{days}\right)}$$

$$\text{Economic efficiency}\left(\text{Rs.ha}^{-1}\text{day}^{-1}\right) = \frac{\text{Net return}\left(\text{Rs.ha}^{-1}\right)}{\text{Total duration of crops}\left(\text{days}\right)}$$

Production efficiency and economic efficiency was calculated using the following formula as suggested by Kumawat *et al*. (2012)

The data of growth and yield attributes, gross and net returns were statistically analysed year-wise according to Gomez and Gomez (1984). All the variables were subjected to analysis of variance (ANOVA) to examine treatment effect. Fisher's least significant difference (LSD) was used to test for significance of differences between various means at 5% level of probability ($p \leq 0.05$).

## RESULTS AND DISCUSSION

The different crop establishment methods were significantly influenced by the growth attributes of the rice during both the years. There was a significant ($p \leq 0.05$) increase in plant height (120.6 and 125.8 cm) under SRI (Fig.1) followed by ICM (118.26 and 123.7cm), respectively in both the years. Significantly lower value of plant height was associated with the farmer's practices (96.23 and 99.5 cm). Data on tillers hill$^{-1}$ was also markedly influenced with different crop establishment methods during both the years of investigation (Fig. 2).The crop establishment method,

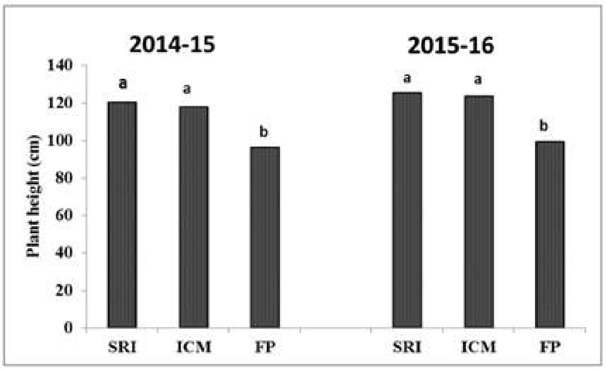


Fig.1. Plant height as influenced by different crop establishment methods. Different lower case letters indicate significant ($p \leq 0.05$)difference among treatments.

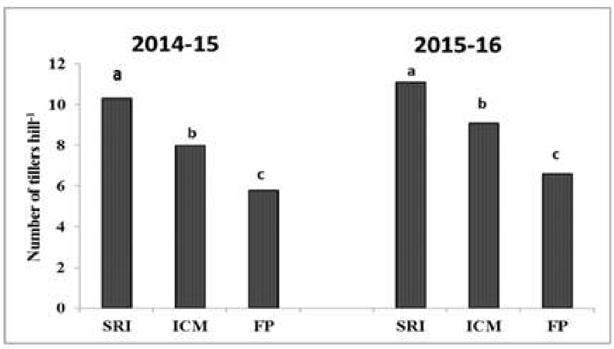


Fig.2. Number of tillers hill$^{-1}$ as influenced by different crop establishment methods. Different lower case letters indicate significant ($p \leq 0.05$)difference among treatments.

SRI recorded significantly higher tillers hill$^{-1}$ (10.3 and 11.1) compared to ICM (8 and 9.1) and the farmers practices (5.8 and 6.6) during both the years. The crop establishment methods of SRI recorded an increase in tillers hill$^{-1}$ of 28.8 and 37.9% in 2014-15 and 21.98 and 37.6% over ICM and CRC, respectively. This might be due to better establishments and young seedlings, which produced more number of tillers in respective treatments (Bohra and Kumar 2015a; Kumar *et al*.2015b; Singh *et al.* 2016 ). Similarly, different crop establishment methods significantly influenced the dry matter production hill$^{-1}$ to each other during both the years. SRI recorded significantly highest dry matter compared to rest of treatment (Fig.9). Crop establishment method of SRI recorded an increase in dry matter production of 9.43 and 50.56% in 2014-15 and 14.88 and 49.13% in 2015-16 over ICM and CRC. The younger seedlings in SRI, when carefully uprooted by keeping roots intact, transplanted soon after removing from nursery might have encouraged a vigorous and deeper root system that resulted in better growth and dry matter production (Shekhar *et al*. 2009; Kumar 2015a; Kumar *et al*. 2015b; Singh *et al*. 2016). Similarly, growth attributes *viz.* plant height, tillers and dry matter was recorded significantly higher under establishment methods of SRI over CRC (Wahlang *et al*. 2015).

Data on yield attributes such as panicle hill$^{-1}$, panicle length, grains panicle$^{-1}$, panicle weight and test weight of rice showed significantly difference among different crop establishment methods (Fig.3-8).Significantly higher panicle hill$^{-1}$ (9.12 and 9.28), panicle length (23.52 and 24.96 cm), grains panicle$^{-1}$ (174.2 and 180), panicle weight (4.4 and 4.68 g) and 1000-seed weight (28.1 and 29.4 g) of rice were recorded with SRI as compared to other crop establishment methods over both the years. However, yield attributes like panicle length, panicle weight and test weight were recorded statistically at par to ICM in both the years.The panicle length was recorded to increase to the tune of 14.4, 10.3% in 2014-15 and 16.4, 14% in 2015-16 under SRI and ICM as compared to CRC. This might be due to the efficient utilization of

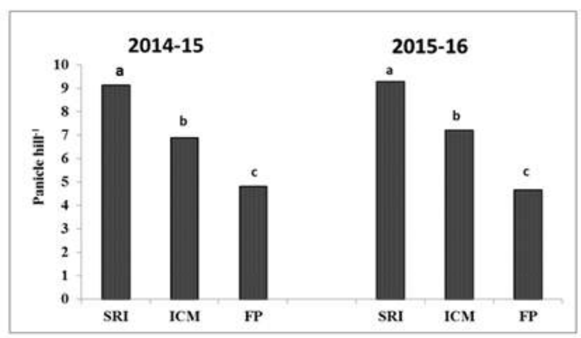


Fig.3. panicle hill$^{-1}$ as influenced by different crop establishment methods. Different lower case letters indicate significant ($p \leq 0.05$) difference among treatments.

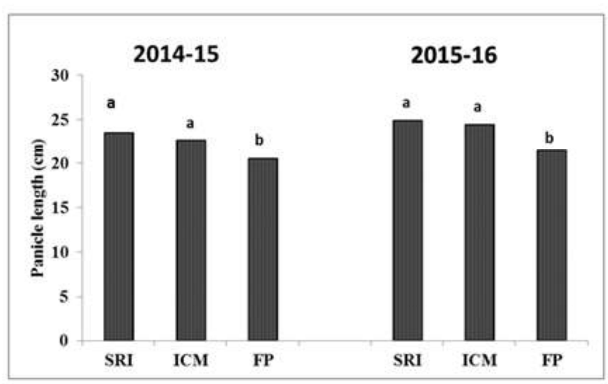
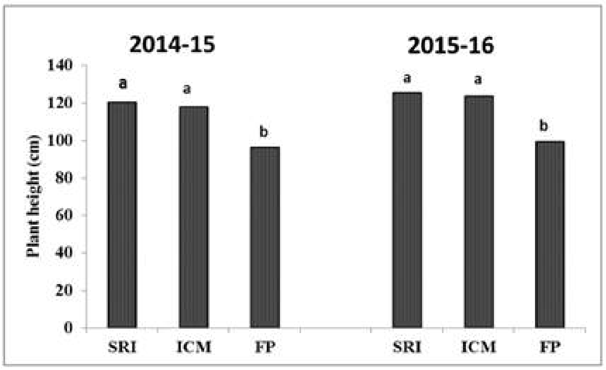


Fig.4. Panicle length as influenced by different crop establishment methods. Different lower case letters indicate significant ($p \leq 0.05$)difference among treatments.

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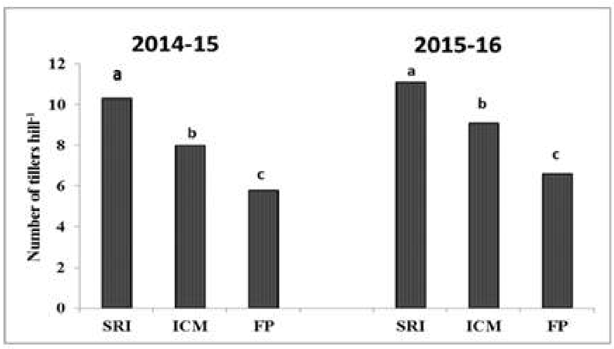


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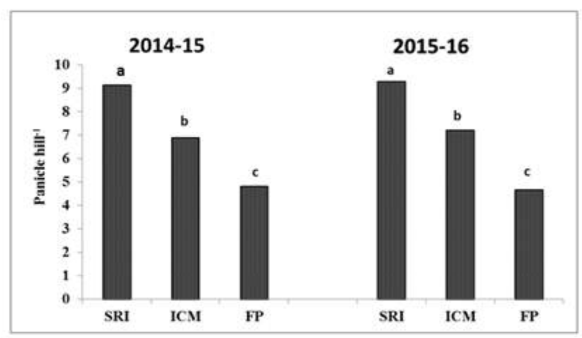


Fig.3. panicle hill$^{-1}$ as influenced by different crop establishment methods. Different lower case letters indicate significant ($p \leq 0.05$) difference among treatments.

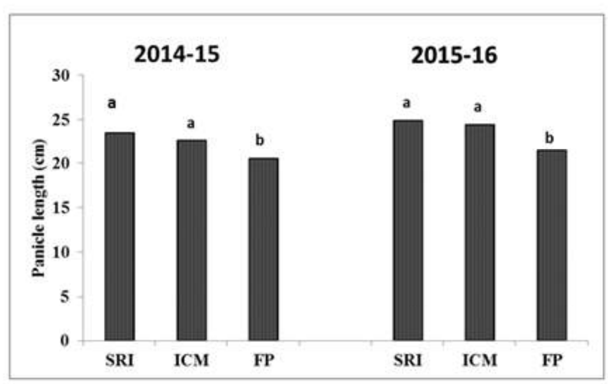


Fig.4. Panicle length as influenced by different crop establishment methods. Different lower case letters indicate significant ($p \leq 0.05$)difference among treatments.

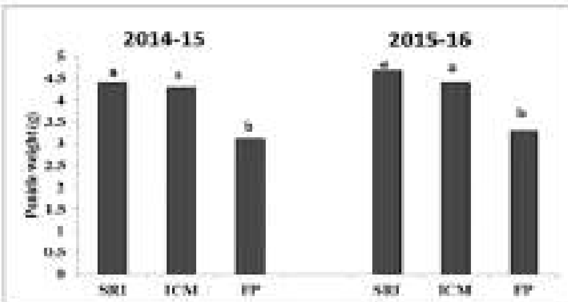


Fig.5. Panicle weight as influenced by different crop establishment methods. Different lower case letters indicate significant ($p \le 0.05$) difference among treatments.

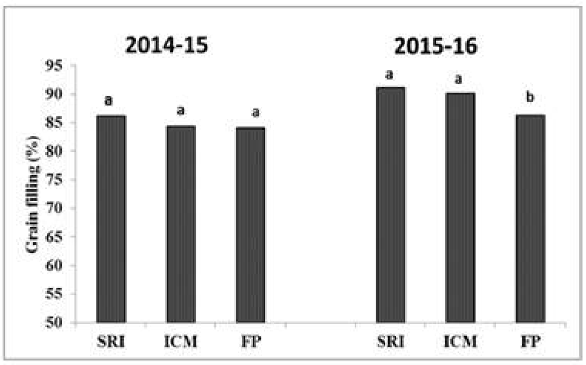


Fig.6. Grain filling (%) as influenced by different crop establishment methods. Different lower case letters indicate significant ($p \le 0.05$) difference among treatments.

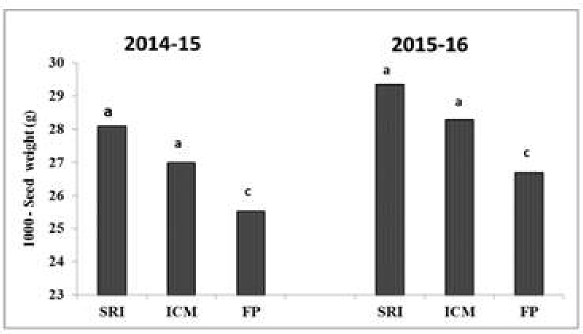


Fig.7. 1000-Seed weight as influenced by different crop establishment methods. Different lower case letters indicate significant ($p \le 0.05$) difference among treatments.

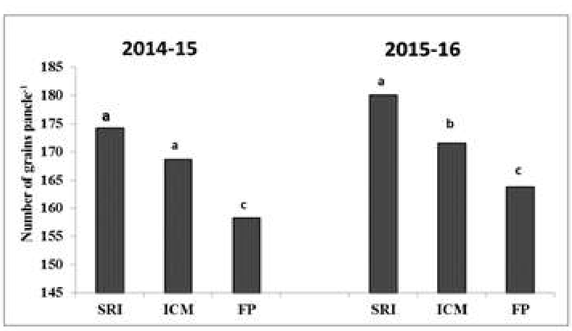


Fig.8. Number of grains panicle$^{-1}$ as influenced by different crop establishment methods. Different lower case letters indicate significant ($p \le 0.05$) difference among treatments.

**Table 1.** Yield under different establishment methods

| Establis-hment met-hods | Grain yield (t ha$^{-1}$) | | Straw yield (t ha$^{-1}$) | | Carbohyd-rates yield (t ha$^{-1}$) | |
|---|---|---|---|---|---|---|
| | 2014-15 | 2015-16 | 2014-15 | 2015-16 | 2014-15 | 2015-16 |
| SRI | 4.45 | 4.67 | 5.52 | 5.98 | 3.17 | 3.32 |
| ICM | 4.57 | 4.80 | 5.37 | 5.84 | 3.26 | 3.41 |
| FP | 3.16 | 3.31 | 4.77 | 5.13 | 2.25 | 2.36 |
| SEm± | 0.06 | 0.07 | 0.09 | 0.12 | 0.04 | 0.05 |
| LSD(P< 0.05) | 0.19 | 0.23 | 0.29 | 0.37 | 0.13 | 0.16 |

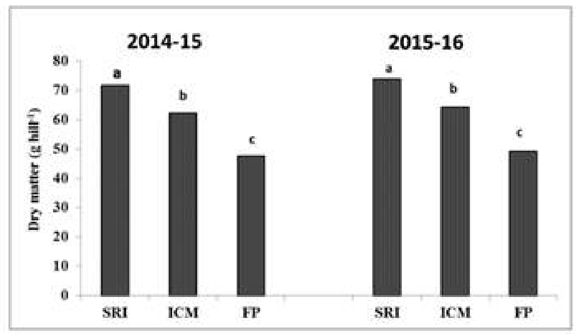


Fig.9. Dry matter (g hill$^{-1}$) as influenced by different crop establishment methods. Different lower case letters indicate significant ($p \le 0.05$) difference among treatments.

resources and less inter and intra-plant competition among widely spaced plants resulted in better grain filling, higher grain weight and more filled grain panicle$^{-1}$, which increased yield attributing characters (Uphoff 2007). Reddy *et al.* (2007) reported an increase in no. of panicles by 14.4%, grains panicle$^{-1}$ by 16.8% and 1000-grain weight by 2.9% under SRI over CRC.

Data on yield parameters viz. grain and straw yield and harvest index (HI) were significantly influenced by different crop establishment methods during both the years. The significantly higher grain yield (4.67 and 4.8 t/ha) and straw yield were recorded with ICM followed by SRI (4.45 and 5.52 t/ha) and CRC (3.16 and 4.77 t ha$^{-1}$) in both the years (Table 1). The crop establishment methods were recorded to increase the grain yield to the tune of 40.9 and 44.7% in 2014-15 and 41 and 44.8% in 2015-16, respectively over the farmers practice. This might be due to crop establishment methods ICM and SRI produced more yield attributes like panicle hill$^{-1}$, panicle length, grains panicle$^{-1}$, panicle weight as compared to the farmers' practices (Kumar 2015a; Kumar *et al.* 2015b; Singh *et*

**Table 2.** Economics of different establishment method

| Establishment methods | Gross returns (Rs. $ha^{-1}$) | | Net returns(Rs. $ha^{-1}$) | | B:C ratio | | *Eco. Eff. (Rs. $ha^{-1}day^{-1}$) | |
|---|---|---|---|---|---|---|---|---|
| | 2014-15 | 2015-16 | 2014-15 | 2015-16 | 2014-15 | 2015-16 | 2014-15 | 2015-16 |
| SRI | 44520 | 46695 | 23097 | 25272 | 2.07 | 2.18 | 184.53 | 202.07 |
| ICM | 45735 | 47962 | 23615 | 25842 | 2.09 | 2.17 | 177.74 | 194.54 |
| FP | 31600 | 33097 | 9370 | 10867 | 1.4 | 1.5 | 66.5 | 77.2 |
| SEm± | 614 | 747 | 717.2 | 775.3 | 0.03 | 0.37 | 4.56 | 6.33 |
| LSD (P<0.05) | 1864 | 2268 | 1872 | 2351 | 0.09 | 0.11 | 13.85 | 19.20 |

* Eco. Eff.: Economic efficiency

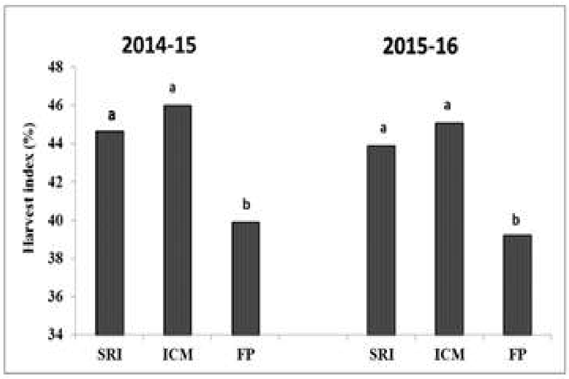


Fig.10. Harvest index (%) as influenced by different crop establishment methods. Different lower case letters indicate significant ($p \leq 0.05$) difference among treatments.

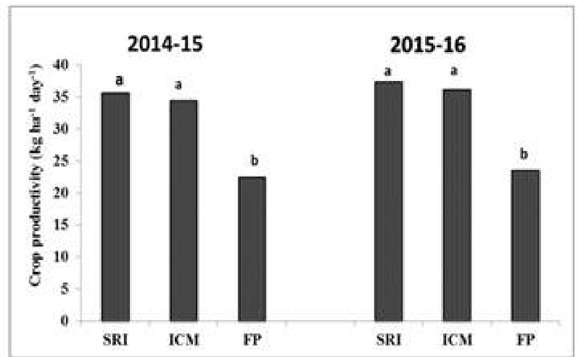


Fig.11. Crop productivity as influenced by different crop establishment methods. Different lower case letters indicate significant ($p \leq 0.05$) difference among treatments.

*al.* 2016). Wahling *et al*. (2015) reported yield attributes *i.e.,* number of panicles $m^{-2}$, panicle length and test weight was recorded significantly higher under SRI followed by ICM and CRC, whereas, yield was recorded higher with ICM followed by SRI than CRC. Similarly, the maximum HI (%) was recorded under ICM (45.98 and 45.08) followed by SRI and lowest with CRC (Fig. 10). This might be due to the higher grain yield produced by ICM through diverting more sources to sink in respective treatments.Carbohydrates yield was significantly influenced with different crop establishment methods and these attributes was recorded significantly higher under ICM (3.26 and 3.41 $th^{-1}$) followed by SRI (3.17 and 3.32 t $ha^{-1}$) and farmers practice (2.25 and 2.36 t $ha^{-1}$) during 2014-15 and 2015-16, respectively (Table 1). Whereas, crop productivity was recorded markedly higher under SRI (35.58 & 37.33 kg $ha^{-1}day^{-1}$) compared to ICM (34.41 and 36.09 kg $ha^{-1}day^{-1}$) and CRC (22.40 and 23.49) during both the year (Fig 11).This might be due to higher production associated with the respective treatments (Kumar *et al.* 2015a & 2015b). Stoop *et al.*(2002) reported that yield increase in SRI was attributed to more ear-bearing tillers, number of filled grains $panicle^{-1}$ and panicle length compared with CRC.

Different crop establishment method significantly influenced economics of rice during both the years. Among crop establishment methods, the maximum cost of cultivation was in recorded under SRI (Rs.24177 $ha^{-1}$) followed by ICM (Rs.24730 $ha^{-1}$ ). The gross returns (Rs.45735 and 47962 $ha^{-1}$), net returns (Rs.23615 and 25842 $ha^{-1}$) and benefit: cost ratio (2.17 and 2.18) was recorded markedly higher under ICM followed by the SRI (Table 2). This might be due to higher crop production associated with respective treatments (Kumar *et al.* 2015a).The higher net returns under ICM and SRI has been reported by Das *et al.* (2013); Kumar *et al*. (2015b) and Bohra and Kumar (2015).The maximum economic efficiency was recorded under SRI (Rs.202.1 $ha^{-1}day^{-1}$) compared to ICM (Rs.194.54$ha^{-1}day^{-1}$) and CRC (Rs.77.2 $ha^{-1}day^{-1}$). This might be due to SRI crop matures early compared other methods (Kumar *et al*. 2015a).

Based on the above study, it may be concluded that crop establishment methods, ICM produced higher yield as well as monetary returns under the foot hill condition of Nagaland under the Eastern Himalayas.

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