Effect of Establishment Methods and Nutrient Management Practices on Growth Characters and Yield of Rice (Oryza sativa L.)

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ABSTRACT

Aim: Study was conducted to compare and to identify the best combination of rice crop establishment method and nutrient management in terms of crop growth, development and yield.

Study Design: Experiment was laid out in splitplot design.

Place and Duration of Study: The field experiments were conducted at the research farm of Indian Institute of Rice Research, Hyderabad, Telangana State, India during the kharif and rabi seasons of 2011-12 and 2012-13.

Authors’ contributions

This work was carried out in collaboration among all authors. All authors read and approved the final manuscript.

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Methodology: The treatments consisted of four establishment methods (System of rice intensification (SRI), modified drum seeder, normal drum seeder and normal transplanting) as main plot treatments and four nutrient management practices (100% recommended dosage of nitrogen (RDN) through inorganic, 75% RDN through inorganic+ 25% RDN through organic, 50% RDN through inorganic+50% RDN through organic and 100% RDN through organic) as sub plot treatments with 16 treatment combinations and three replications. The semi dwarf, high yielding Sampada variety was raised during the study period.

Results: Growth parameters like plant height, leaf area index (LAI), dry matter accumulation, number of tillers per square meter were observed at 45,75,105 days after transplanting and at harvest stages. The two years experimental results and the pooled mean data revealed that SRI recorded significantly superior growth parameters at all the crop growth stages followed by modified drum seeder. In respect of subplots 50% RDN through inorganic+50% RDN through organic resulted in superior growth parameters and yield.

Conclusions: The combination of SRI with nutrient management practice 50% nitrogen through urea and 50% nitrogen through vermicompost resulted in greater growth parameters and grain yield.

Keywords: SRI; direct seeding; modified drum seeder; INM.

1. INTRODUCTION

Rice plays a central role in food security and economic growth of India. It is grown in more than one-fifth of the total gross cropped area and contributes more than one-fourth of the total calorie intake [1]. It is the major source of calories for 40% of the world population [2]. About 77% of the global rice production in the world is produced through conventional transplanting methods in puddled soil [3,4]. Conventional transplanting system of rice crop production requires high inputs of labour, water, capital, and energy and hence it has become less profitable at present due to the lack of these resources [3,5]. A shortage of labour during peak periods increase labour wages and make transplanting operation costly [6]. Thus, the farmers prefer direct seeding method as a viable alternative to the drudgery and labour intensive conventional transplanting system.

Direct seeding probably is one of the oldest method of crop establishment which is now practiced in many Asian countries [7]. Direct rice seeding has many advantages to the farmers such as higher economic returns, short crop duration, requires less labour and water suitable for mechanization and have less methane emission [8,9].

Another major concern in rice production systems is the dwindling trend of availability of water resources [10]. Out of 70-80% freshwater used in agriculture, rice accounts for 85% in total and 30% in puddling only. A 10% increase in irrigation efficiency can help bring additional 14 million ha area under irrigation [11]. Hence there is a need to develop and adopt water saving methods in rice cultivation so that production and productivity levels are elevated despite the looming water crisis [11,12]. System of rice intensification (SRI) method was found to save 22 to 38 per cent of water during dry and wet season, respectively over conventional transplanting of rice establishment [13]. Efficient water management and nutrients could be better utilized under SRI along with integration of nutrient sources to realize the maximum rice crop productivity through enhancement of growth and physiological aspects of lowland rice [14].

Intensive agriculture and decreasing the use of organic manures, have led to severe degradation of soil fertility and productivity of rice cropping systems [15]. The decline or stagnation in yield has been attributed to nutrient mining and reduced use of organics manures [16]. Under high input production systems where productivity cannot be further increased with incremental use of mineral fertilizers alone, the addition of organic sources could increase yield through increased soil productivity and higher fertilizeruse efficiency [17,18,19]. Singh and Kumar [20] reported increased yield and nutrient use efficiency in rice with organic manures. The combined use of organic and inorganic fertilizers has been reported to not only meet the nutrient needs of the crop but also has been found to sustain large scale productivity goals [21]. A synergistic effect on crop yield is reported through common use of fertilizer and organics has improved soil fertility. Integrated nutrient management involves maintenance of soil fertility; sustainability of crop production and the beneficial effect of integrated plant nutrient supply(IPNS) in lowland rice has been well reported by several researchers [22].
2. MATERIALS AND METHODS

The present investigation was conducted during kharif and rabi seasons of 2011-12 and 2012-13 at Indian Institute of Rice Research farm, Rajendranagar, Hyderabad, Telangana state, India. The farm is geographically situated at an altitude of 542.7 m above mean sea level on 17° 19' N latitude and 78° 29' E longitudes. According to Troll’s climatic classification, it falls under semi-arid tropics (SAT). The soil was clay loam, alkaline in reaction (pH 8.0 -8.2), with 0.48-0.52% of organic matter, 210-223 kg ha⁻¹ of available nitrogen, 39-43 kg ha⁻¹ of available P and 525-542 kg ha⁻¹ of available K. The semi dwarf, high yielding rice variety Sampadha, having crop duration of 135 days with yield potential of 5.8-6.8 t ha⁻¹ was grown in the experimental site. Usually normal drum seeders are available with close spacing (20×5-8 cm²), but for this study a new drum seeder was fabricated with 25×25 cm² spacing to test the wider spacing efficiency in direct seeding and this treatment was denoted as modified drum seeder. The experiment was laid out in splitplot design with sixteen treatments and three replications. The treatment combinations consisted of four establishment methods i.e., system of rice intensification (SRI) (M₁), modified drum seeder (25×25 cm² spacing) (M₂), normal drum seeder (M₃) and normal transplanting (NTP) (M₄) in main plots and four nutrient management practices i.e., 100% RDN (recommended dose of nitrogen) through inorganic (N₁), 75% RDN through inorganic+25% RDN through organic (N₂), 50% RDN through inorganic+50% RDN through organic (N₃) and 100% RDN through organic (N₄) in sub plots. In case of NTP and SRI the sprouted seeds were broadcasted uniformly in well prepared seed beds. And on the same day seeds were sown in the respective main field plots for drum seeder and modified drum seeder. The recommended dose of fertilizer was 120 Kg N: 60 Kg P₂O₅ : 40 Kg K₂O ha⁻¹. The recommended dose of phosphorus @ 60 kg P₂O₅ kg ha⁻¹ through single super phosphate (SSP), potassium @ 40 kg K₂O ha⁻¹ as muriate of potash (MOP) and ZnSO₄ @ 20 kg ha⁻¹ were applied to all the treatments uniformly as basal application. In case of 100% inorganic treatment nitrogen was applied through urea in three equal splits as ½ as basal, ¼ at maximum tillering and ¼ at panicle initiation stage. In INM treatments urea was applied as the inorganic source of nitrogen in three equal splits at the time of transplanting, 30 DAT (days after transplanting) and at 60 DAT. Every season vermicompost was analysed for nitrogen content and based on nitrogen percentage vermicompost was applied as basal. Twelve days and twenty one days old seedlings were used for transplanting in SRI and NTP respectively. Spacing of 25×25 cm² was maintained in SRI and modified drum seeder methods and for NTP it was 20×15 cm². Statistical analysis of the data was done as per the standard analysis of variance technique for the experimental designs following INDOSTAT software based programme. The treatment means were compared at P<0.05 level of probability using t-test and calculating CD values.

3. RESULTS AND DISCUSSION

3.1 Plant Height

The experimental results revealed that, the average plant height increased linearly up to 105 DAS and continued to increase until maturity. From the data, it can be inferred that maximum plant height was observed with SRI followed by modified drum seeder at all the crop growth stages over normal drum seeder and NTP (Table 1). Taller plants resulted by adopting SRI method might be due to transplanting of younger and single seedling by keeping the roots straight (ensuring that the roots do not assume ‘J’ shape). Wider spacing maintenance in SRI and modified drum seeder in both row to row and plant to plant might have encouraged vigorous root system and the plants get sufficient space above the ground to grow and the increased light transmission in the canopy thus leading to greater plant height. Similar results were reported by [23,24,25,8] and [26]. Among the nutrient management treatments, at all the stages, 50% RDN through inorganic+50% RDN through organic treatment recorded significantly higher plant height, followed by 100% RDN through inorganic treatment and 75% RDN through inorganic+25% RDN through organic treatment, these findings are in accordance with [21,15]. The interaction effect was non-significant among planting methods and nutrient management practices in respect of plant height.

3.2 Leaf Area Index (LAI)

At all the stages LAI recorded was significantly higher in SRI followed by modified drum seeder over normal drum seeder and NTP during both the years (Table 2). The LAI recorded in modified drum seeder was significantly on par with SRI during kharif 2012-13, rabi 2011-12 and 2012-13.
The mean percentage increases of LAI in SRI at 105 DAS were 48.01, 43.21, 37.70 and 34.01% over NTP during kharif 2011, kharif 2012, rabi 2011-12, rabi 2012-13 respectively (Table 2). This might be due to planting in square geometry with wider spacing and single seedling which facilitated for better utilization of the resources to obtain maximum leaf area and higher number of leaves. These results are in conformity with findings of [26,27,14] and [23].

Maximum LAI was observed with the treatment 50% RDN through inorganic+50% RDN through vermicompost at 105 DAS during all the seasons of study. 100% RDN through vermicompost registered lowest LAI at all the stages of crop growth. The treatment 50% RDN through inorganic+50% RDN through organic influenced the plant growth, tiller number and dry matter accumulation and thus manifested higher LAI. [15,16,27,14] and [24] also expressed the similar opinion.

The interaction effect among planting methods and nutrient management practices on leaf area index was found significant at 45DAS during kharif 2011 and pooled kharif mean (Table 2a). The interaction was also significant at 75 DAS during kharif 2011, kharif 2012, kharif pooled mean (Table 2a), rabi 2011, rabi pooled mean at 75 DAS in both the years and in pooled means (Table 2b). The data on interaction revealed that at all these stages SRI in combination with 50% RDN through organic+50% RDN through inorganic source registered higher LAI as compared to all other establishment and nutrient management combinations.

### 3.3 Dry Matter Production (kg ha\(^{-1}\))

Increases in dry matter production of rice was rather slow up to 45 DAS, thereafter it increased linearly up to 105 DAS and further, it continued to increase slowly until maturity (Table 3).

At 45 DAS the numerically higher values were observed with SRI (1989.8, 2607, 2290.1 and 3126.5 g of total dry matter m\(^{-2}\) during 2013 and 2014, respectively) followed by modified drum seeder, over other treatments (Table 3). The similar trend was also observed at 75, 105 DAS and at harvest. Highest values of dry matter accumulation was observed at harvest with SRI which was 17.49, 23.57, 14.79 and 23.72% higher as compared to normal transplanting during 2011 kharif, 2012 kharif, 2011-12 rabi and 2012-13 rabi. The higher dry matter production in SRI planting method was attributed to planting of young and single seedling at shallow depth in wider spacing and two direction cono-weeding which lead to taller plants, higher leaf area, LAI, better root growth, profuse and strong tillers with higher crop growth rate. The results obtained in this investigation are in conformity to the findings of [26,25].

Among all the nutrient management treatments 50% RDN through inorganic+50% RDN through organic recorded significantly higher dry matter accumulation, followed by 100% inorganic treatment, over other treatments. At all the stages of crop growth lowest dry matter accumulation was observed with 100% organic treatment. At harvest 100% organic treatment recorded 16.05%, 9.49%, 13.03%, 9.59%, 11.23% and 12.55% lower dry matter accumulation as compared to 50% inorganic+50% organic in kharif 2011, kharif 2012, rabi 2011-12 and 2012-13, in pooled mean kharif and in pooled mean rabi respectively. These findings were in conformity with the results of [16] and [15].

### 3.4 Number of Tillers m\(^{-2}\)

The average number of tillers m\(^{-2}\) of rice increased linearly up to 90 DAS. Narrow spacing in normal drum seeder and normal transplanting, wider spacing in SRI and modified drum seeder led to significant difference in number of tillers m\(^{-2}\). But number of tillers m\(^{-2}\) recorded was significantly higher in SRI over modified drum seeder at 60 and 90 DAS and of pooled means, respectively (Table 4). At all the growth stages NTP recorded significantly lower number of panicles m\(^{-2}\) as compared to other establishment methods. As compared to normal transplanting SRI practice gets the benefit of the early phyllochron stages (less than four leaves) having higher potential to quick recovery and to produce more tillers. If transplanting is done beyond the fourth phyllochron (after about 15 days), the first primary tiller does not emerge and all of the descendents of this tiller are lost. Similarly, if transplanting is further delayed by the length of another phyllochron, the second primary tiller and all its descendents are also forgone. Planting in square method with wider spacing resulted in profuse tillering under SRI cultivation and facilitated plants for better utilization of the resources. Similar findings have also been reported by [26,8,9,25].

In both the years application of 50% RDN through inorganic source+50% RDN through organic source recorded significantly higher tiller
number m$^{-2}$ over other all nutrient management practices. Several researchers observed similar results. 50% inorganic fertilizer with 50% organic source improved the general soil environment, physicochemical and biological conditions thus favouring the increased and timely availability of macro and micro nutrients helped in profuse tillering.

3.5. Grain Yield (kg ha$^{-1}$)

The higher grain yield of 6535 kg ha$^{-1}$ & 6140 kg ha$^{-1}$ was recorded by SRI method during 2012 & 2011 kharif seasons respectively. Next to SRI method modified drum seeder proved its significant superiority over normal drum seeder and normal transplanting. During 2011 kharif modified drum seeder remained at par with normal drum seeder but was found significantly superior over normal transplanting normal drum seeder (Table 5). The pooled data also indicated that SRI method stood first with grain yield of 6337.5 kg ha$^{-1}$ followed by modified drum seeder, normal drum seeder and normal transplanting. In terms of percentage increase in yield due to SRI over modified drum seeder, normal drum seeder and normal transplanting was 9.27, 18.24, 21.74% respectively. During rabi season of 2011-12 and 2012-13 SRI method was found significantly superior than the remaining three crop establishment methods. There was high yield difference of 579 kg ha$^{-1}$ and 358 kg ha$^{-1}$ between SRI and modified drum seeder in first and second rabi seasons respectively. The pooled data also showed the advantage of 468 kg ha$^{-1}$ by SRI over modified drum seeder. These results were in accordance with the findings of [28,29].

The yield advantage due to SRI over conventional planting was mainly due to more number of tiller production per unit area accompanied by maximum panicle bearing tillers with low spikelet sterility. Since planting of young seedlings of 12 days in main field with immediate establishment have facilitated early initiation of tillers. It is evident that highest tillers production was observed with SRI planting. Controlled irrigation also augmented the fresh root production till flowering stage and does helped in supplementation of nutrient requires for supporting of filling capacity of panicles.

Among the subplots 50% RDN through inorganic + 50% RDN through organic proved its superiority during all the seasons of experiment. During first kharif season 50% RDN through inorganic + 50% RDN through organic remained at par with 100% RDN through inorganic. But 2012 kharif data and the kharif pooled data indicated the significant superiority of 50% RDN through inorganic + 50% RDN through organic source. Both the rabi seasons data revealed that 50% RDN through inorganic + 50% RDN through organic was on par with 100% RDN through inorganic and found significantly better over remaining other treatments. The results emphasize the concepts of INM for high grain production and also sustainability of soil fertility [30,31]. During all the seasons 100% organic treatment recorded lowest grain yield [32].

The interaction effect of planting methods and nutrient management practices on grain yield during all the seasons of study and in pooled means was found to be significant (Table 5a). During kharif 2011, kharif 2012, rabi 2011-12, rabi 2012-13 and in kharif and rabi pooled means showed that SRI in combination with 50% RDN through inorganic source +50% RDN through organic source recorded significantly higher grain yield over other establishment and nutrient combinations.

3.6 Straw Yield (kg ha$^{-1}$)

Straw yield of rice was significantly higher in SRI and during kharif and rabi seasons of 2012-13 it was significantly on par with modified drum seeder treatment (Table 6). During all the seasons straw yield recorded by modified drum seeder was statistically on par with normal drum seeder. By observing the data of all the four seasons it was evident that wider spacing treatments recorded higher straw yield as compared to closer spacing treatments. It was probably due to more dry matter production per unit area caused by better nutrient absorption from soil, increased rate of metabolic processes, higher rate of light absorption and increased rate of photosynthetic activity that produced higher plant height and leaf area index as compared to normal transplanting. These results are in agreement with the findings of [28,29,33].

During all the four seasons and in pooled means highest straw yield was observed with treatment 50% RDN through inorganic source + 50% RDN through organic source. The superiority of this treatment was because of adequate supply of nitrogen throughout crop growth period that led to higher dry matter production [31]. The lowest straw yield was found with treatment 100% organic during all the seasons [32].
Table 1. Plant height (cm) at different stages of crop growth as influenced by establishment methods and nutrient management practices

|               | 45 DAS | 75 DAS | 105 DAS | At harvest |
|---------------|--------|--------|---------|------------|
|               | Kharif | Rabi   | Kharif  | Rabi       | Kharif | Rabi |
| **MAIN PLOTS**|        |        |         |            |        |      |
| M1 (SRI)      | 37.75  | 40.90  | 76.58   | 82.68      | 93.49  | 100.61 |
| M2 (Modified Drum Seeder) | 34.10  | 36.10  | 69.22   | 70.83      | 87.00  | 91.59  | 90.50 |
| M3 (Normal Drum Seeder) | 34.50  | 36.50  | 70.78   | 80.08      | 79.61  | 84.01  | 89.70 | 94.70 |
| M4 (NTP)      | 32.00  | 32.50  | 60.57   | 66.09      | 74.36  | 80.73  | 83.10 | 89.50 |
| S.E.M         | 0.40   | 0.80   | 1.88    | 0.97       | 1.62   | 1.59   | 2.30  | 2.20 |
| CD (P=.05)    | 1.30   | 2.80   | 6.49    | 3.36       | 5.60   | 5.49   | 8.00  | 7.50 |
| **SUBPLOTS**  |        |        |         |            |        |      |
| N1 (100% Inorg) | 35.40  | 37.80  | 71.45   | 76.45      | 85.82  | 91.18  | 93.40 | 98.60 |
| N2 (75% Inorg+25% org) | 32.70  | 34.30  | 67.00   | 73.11      | 80.21  | 86.23  | 87.40 | 94.00 |
| N3 (50% Inorg+50% org) | 39.20  | 41.60  | 76.82   | 81.25      | 93.33  | 96.15  | 101.20 | 104.10 |
| N4 (100%org)  | 30.90  | 32.40  | 61.87   | 68.86      | 75.11  | 83.38  | 82.90 | 89.20 |
| S.E.M         | 0.80   | 1.00   | 1.34    | 1.33       | 1.68   | 1.69   | 1.90  | 2.00 |
| CD (P=.05)    | 2.40   | 2.80   | 3.91    | 3.89       | 4.90   | 4.92   | 5.60  | 5.90 |
| MEAN          | 34.60  | 36.50  | 69.28   | 74.92      | 83.62  | 89.23  | 91.20 | 96.50 |

**INTERACTIONS**

*Sub at same level of Main*
| S.E.M | 1.70 | 1.90 | 2.68 | 2.66 | 3.38 | 3.37 | 3.90 | 4.00 |
| CD (P=.05) | NS | NS | NS | NS | NS | NS | NS | NS |

*Main at same level of Sub*
| S.E.M | 1.50 | 1.90 | 2.99 | 2.50 | 3.33 | 3.32 | 4.10 | 4.10 |
| CD (P=.05) | NS | NS | NS | NS | NS | NS | NS | NS |
Table 2. LAI at different stages of crop growth as influenced by establishment methods and nutrient management practices

|                  | 45 DAS Kharif | 45 DAS Rabi | 75 DAS Kharif | 75 DAS Rabi | 105 DAS Kharif | 105 DAS Rabi | At harvest |
|------------------|---------------|-------------|---------------|-------------|----------------|--------------|-----------|
| MAIN PLOTS       |               |             |               |             |                |              |           |
| M1 (SRI)         | 1.44          | 1.63        | 1.54          | 1.73        | 2.00           | 1.86         | 4.31      |
| M2 (Modified)    | 1.30          | 1.45        | 1.37          | 1.47        | 1.60           | 1.54         | 3.38      |
| M3 (Normal)      | 1.06          | 1.31        | 1.19          | 1.19        | 1.38           | 1.28         | 2.58      |
| M4 (NTP)         | 0.84          | 1.15        | 1.00          | 1.07        | 1.19           | 1.13         | 2.21      |
| S.E.M            | 0.03          | 0.03        | 0.05          | 0.05        | 0.06           | 0.04         | 0.07      |
| CD (P<0.05)      | 0.10          | 0.11        | 0.06          | 0.18        | 0.20           | 0.15         | 0.25      |
| SUBPLOTS         |               |             |               |             |                |              |           |
| N1 (100% Inorg)  | 1.33          | 1.53        | 1.43          | 1.48        | 1.64           | 1.56         | 3.28      |
| N2 (75% Inorg+25% org) | 1.00  | 1.25        | 1.13          | 1.25        | 1.44           | 1.34         | 2.84      |
| N3 (50% Inorg-50% org) | 1.52  | 1.70        | 1.61          | 1.63        | 1.88           | 1.75         | 3.98      |
| N4 (100%org)     | 0.79          | 1.06        | 0.93          | 1.09        | 1.23           | 1.16         | 2.39      |
| S.E.M            | 0.03          | 0.04        | 0.02          | 0.05        | 0.05           | 0.04         | 0.08      |
| CD (P<0.05)      | 0.08          | 0.12        | 0.06          | 0.13        | 0.14           | 0.11         | 0.23      |
| MEAN             | 1.16          | 1.39        | 1.27          | 1.36        | 1.54           | 1.45         | 3.12      |
| INTERACTIONS     |               |             |               |             |                |              |           |
| Sub at same level of Main S.E.m± | 0.06          | 0.08        | 0.04          | 0.09        | 0.10           | 0.07         | 0.16      |
| CD (P<0.05)      | 0.16          | NS          | 0.12          | NS          | NS             | NS           | 0.47      |
| Main at same level of Sub S.E.m± | 0.06          | 0.08        | 0.04          | 0.09        | 0.10           | 0.08         | 0.16      |
| CD (P<0.05)      | 0.17          | NS          | 0.12          | NS          | NS             | NS           | 0.47      |

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Table 3. Dry matter accumulation (kg ha\(^{-1}\)) at different stages of crop growth as influenced by establishment methods and nutrient management practices

|                | 45 DAS | 75 DAS | 105 DAS | At harvest |
|----------------|--------|--------|---------|------------|
|                | Kharif | Rabi   | Kharif  | Rabi       | Kharif    | Rabi     | Kharif   | Rabi       | Kharif   | Rabi   | Kharif   | Rabi   |
| **MAIN PLOTS** |        |        |         |            |           |          |          |            |           |        |          |        |
| M1 (SRI)       |        |        |         |            |           |          |          |            |           |        |          |        |
| M2 (Modifying Drum seeder) |        |        |         |            |           |          |          |            |           |        |          |        |
| M3 (Normal Drum seeder) |        |        |         |            |           |          |          |            |           |        |          |        |
| M4 (NTP)       |        |        |         |            |           |          |          |            |           |        |          |        |
| S.E.M          |        |        |         |            |           |          |          |            |           |        |          |        |
|                 |        |        |         |            |           |          |          |            |           |        |          |        |
| **SUBPLOTS**   |        |        |         |            |           |          |          |            |           |        |          |        |
| N1 (100% Inorg) |        |        |         |            |           |          |          |            |           |        |          |        |
| N2 (75% Inorg+25% org) |        |        |         |            |           |          |          |            |           |        |          |        |
| N3 (50% Inorg+50% org) |        |        |         |            |           |          |          |            |           |        |          |        |
| N4 (100%org)   |        |        |         |            |           |          |          |            |           |        |          |        |
| S.E.M          |        |        |         |            |           |          |          |            |           |        |          |        |
|                 |        |        |         |            |           |          |          |            |           |        |          |        |
| **INTERACTIONS** |        |        |         |            |           |          |          |            |           |        |          |        |
| Sub at same level of Main S.E.M |        |        |         |            |           |          |          |            |           |        |          |        |
| CD (P<0.05)    |        |        |         |            |           |          |          |            |           |        |          |        |
| NS NS NS NS NS NS NS NS NS NS NS NS NS NS NS NS NS NS NS NS NS NS NS NS NS NS NS NS NS NS NS NS NS NS |
| Main at same level of Sub S.E.M |        |        |         |            |           |          |          |            |           |        |          |        |
| CD (P<0.05)    |        |        |         |            |           |          |          |            |           |        |          |        |
| NS NS NS NS NS NS NS NS NS NS NS NS NS NS NS NS NS NS NS NS NS NS NS NS NS NS NS NS NS NS NS NS NS NS NS |

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Table 4. Number of tillers m$^{-2}$ at various growth stages as influenced by establishment methods and nutrient management practices

| Establishment Methods | Kharif | Rabi | Pool | Kharif | Pooled | Kharif | Rabi | Pool |
|-----------------------|--------|------|------|--------|--------|--------|------|------|
| **MAIN PLOTS**        | 60 DAS |      |      | 90 DAS |        |        |      |      |
| M1 (SRI)              | 281.33 | 330.75 | 306.04 | 327.00 | 374.17 | 350.58 | 385.08 | 373.17 |
| M2 (Modified Drum Seeder) | 273.50 | 309.25 | 291.38 | 275.50 | 359.33 | 317.42 | 324.67 | 356.25 |
| M3 (Normal Drum seeder) | 184.00 | 247.50 | 215.75 | 198.33 | 245.26 | 221.79 | 282.50 | 307.50 |
| M4 (NTP)              | 145.50 | 236.83 | 191.17 | 180.00 | 218.42 | 199.21 | 270.75 | 297.00 |
| **S.E.M**             | 6.99   | 6.83  | 6.14  | 9.06   | 11.51  | 8.62   | 7.23   | 9.68   |
| **C.D. (P=.05)**      | 24.19  | 23.63 | 21.23 | 31.34  | 39.84  | 29.84  | 25.00  | 33.49  |

| **SUBPLOTS**          |        |      |      |        |        |        |      |      |
| N1 (100% Inorg)       | 246.50 | 291.83 | 269.17 | 270.75 | 312.17 | 291.46 | 334.08 | 350.25 |
| N2 (75% Inorg+25% org) | 293.83 | 263.25 | 221.04 | 227.25 | 271.92 | 249.58 | 284.25 | 319.25 |
| N3 (50% Inorg+50% org) | 284.50 | 317.00 | 300.25 | 300.08 | 347.67 | 323.88 | 368.83 | 377.08 |
| N4 (100%org)          | 160.50 | 247.25 | 203.88 | 182.75 | 265.42 | 224.08 | 252.00 | 299.25 |
| **S.E.M**             | 8.77   | 8.96  | 5.75  | 6.21   | 10.81  | 5.83   | 9.42   | 11.48  |
| **C.D. (P=.05)**      | 25.59  | 26.14 | 16.77 | 18.12  | 31.55  | 17.02  | 27.51  | 33.50  |
| **MEAN**              | 221.08 | 281.08 | 251.08 | 245.21 | 299.29 | 272.25 | 309.79 | 338.66 |

| **INTERACTIONS**      |        |      |      |        |        |        |      |      |
| Sub at same level of Main |      |      |      |        |        |        |      |      |
| S.E.M                  | 17.53  | 17.91 | 11.49 | 12.42  | 21.62  | 11.66  | 18.85  | 22.95  |
| CD (P=.05)             | NS     | NS    | NS    | NS     | NS     | NS     | NS     | NS     |
| Main at same level of Sub |      |      |      |        |        |        |      |      |
| S.E.M                  | 16.72  | 16.95 | 11.69 | 14.06  | 21.98  | 13.28  | 17.85  | 22.11  |
| CD (P=.05)             | NS     | NS    | NS    | NS     | NS     | NS     | NS     | NS     |
| Treatments                      | Kharif          | Rabi             |       |
|--------------------------------|-----------------|------------------|-------|
| **MAIN PLOTS**                 |                 |                  |       |
| M1 (SRI)                       | 6140            | 6338             | 6438  |
| M2 (Modified Drum seeder)      | 5356            | 5800             | 5859  |
| M3 (Normal Drum seeder)        | 5084            | 5359             | 5392  |
| M4 (NTP)                       | 4944            | 5206             | 5356  |
| S.E.M                          | 137             | 34               | 112   |
| C.D. (P=.05)                   | 475             | 117              | 388   |
| **SUBPLOTS**                   |                 |                  |       |
| N1 (100% Inorg)                | 5363            | 5743             | 5898  |
| N2 (75% Inorg+25% org)         | 5300            | 5563             | 5591  |
| N3 (50% Inorg+50% org)         | 5693            | 6033             | 6033  |
| N4 (100%org)                   | 5168            | 5547             | 5523  |
| S.E.M                          | 107             | 67               | 108   |
| C.D. (P=.05)                   | 311             | 196              | 316   |
| **GENERAL MEAN**               | 5381            | 5970             | 5676  |
| **INTERACTIONS**               |                 |                  |       |
| Sub at same level of Main      |                 |                  |       |
| S.E.M                          | 213             | 134              | 216   |
| C.D. (P=.05)                   | 622             | 391              | 631   |
| Main at same level of Sub      |                 |                  |       |
| S.E.M                          | 230             | 121              | 218   |
| C.D. (P=.05)                   | 716             | 358              | 669   |

Table 5. Grain yield (kg ha\(^{-1}\)) as influenced by establishment methods and nutrient management practices.
### Table 5a. Interaction of crop establishment methods and nutrient management practices on grain yield (kg ha⁻¹)

| Establishment methods | Kharif 2011 | Kharif 2012 | Rabi 2011-12 | Rabi 2012-13 | Rabi pooled mean |
|-----------------------|-------------|-------------|--------------|--------------|-----------------|
|                       | N₁       | N₂       | N₃       | MEAN       | N₁       | N₂       | N₃       | MEAN       | N₁       | N₂       | N₃       | MEAN       |
| M1-SRI                | 6292     | 6092     | 6762     | 5414       | 6140     | 6974     | 6821     | 6523       | 5822     | 6535     | 6556     | 6307       | 6868     | 5618       | 6337     | 6534     | 6310     | 7090     | 5817     | 6438     | 7058     | 6646     | 7073     | 5801     | 6645     | 6796     | 6478     | 7081     | 5809     | 6541     |
| M2-Modified Drum Seeder | 5482     | 4942     | 5749     | 5249       | 5356     | 6643     | 6525     | 5872       | 583     | 6244     | 6053     | 5407     | 6196     | 5542     | 5799     | 6079     | 6018     | 6055     | 5283     | 5859     | 6363     | 6041     | 6603     | 6141     | 6287     | 6220     | 6329     | 5711     | 6072     |
| M3-Normal Drum Seeder  | 4753     | 5451     | 4910     | 5222       | 5084     | 6221     | 5929     | 5539       | 4851     | 5653     | 5354     | 5494     | 5563     | 5036     | 5359     | 5416     | 5495     | 5315     | 5882     | 5392     | 6433     | 5995     | 6023     | 5907     | 6090     | 5924     | 5474     | 5669     | 5894     | 5740     |
| M4-NTP                | 4923     | 4714     | 5351     | 4787       | 4944     | 5695     | 5121     | 5375       | 5681     | 5468     | 5022     | 5044     | 5522     | 5233     | 5205     | 5562     | 5082     | 5670     | 5109     | 5356     | 5777     | 6128     | 6127     | 6209     | 6025     | 5669     | 5604     | 5898     | 5589     | 5690     |
| MEAN                  | 5363     | 5300     | 5693     | 5168       | 6388     | 6124     | 5827     | 5547       | 5743     | 5563     | 6038     | 5357     | 5898     | 5591     | 6033     | 5523     | 6408     | 6203     | 6457     | 5980     | 6152     | 5896     | 6244     | 5751     |
| Sub at same level of main | 213     | 622     | 185      | 539       | 134      | 391      | 216      | 631       | 211      | 665      | 121      | 358      | 218      | 669      | 217      | 668      | 157      | 465      |
| Sub at same level of sub | 230     | 716     | 211      | 665       | 121      | 358      | 218      | 669      | 217      | 668      |

### Table 6. Straw yield (kg ha⁻¹) of rice as influenced by establishment methods and nutrient management practices means

| Establishment methods | Kharif 2011 | Kharif 2012 | Pooled | Rabi 2011 | Rabi 2012 | Pooled |
|-----------------------|-------------|-------------|--------|-----------|-----------|--------|
|                       | N₁       | N₂       | N₃       | MEAN       | N₁       | N₂       | N₃       | MEAN       | N₁       | N₂       | N₃       | MEAN       |
| M1 (SRI)              | 7188.08   | 7542.75   | 7365.42 | 7342.08   | 7652.58 | 7497.33 |
| M2 (Modified Drum Seeder) | 6109.92 | 6956.08   | 6533.00 | 6679.17   | 7121.67 | 6900.42 |
| M3 (Normal Drum Seeder) | 5793.08 | 6480.75   | 6136.92 | 6083.42   | 6539.33 | 6311.38 |
| M4 (NTP)              | 5278.08   | 5974.58   | 5626.33 | 5759.00   | 6302.17 | 6030.58 |
| S.Emot                | 140.83    | 185.79    | 123.59  | 155.42    | 195.07  | 126.46  |
| C.D. at 5%            | 487.35    | 642.92    | 427.68  | 537.81    | 675.04  | 437.62  |
| SUBPLOTS              |           |           |         |           |         |        |
| N1 (100% Inorg)       | 6138.33   | 6922.25   | 6530.29 | 6588.42   | 7044.25 | 6816.33 |
| N2 (75% Inorg+25% org) | 5996.17   | 6545.25   | 6270.71 | 6313.42   | 6749.17 | 6531.29 |
| N3 (50% Inorg+50% org) | 6617.25   | 7391.67   | 7005.46 | 7026.00   | 7486.33 | 7256.17 |
| N4 (100%Korg)         | 5617.42   | 6093.00   | 5855.21 | 5935.83   | 6336.00 | 6135.92 |
| S.Emot                | 131.83    | 158.55    | 92.02   | 147.15    | 170.44  | 106.65  |
| C.D. at 5%            | 384.78    | 462.77    | 268.58  | 429.50    | 497.49  | 311.28  |
| General Mean          | 6092.29   | 6738.54   | 6415.42 | 6465.92   | 6903.94 | 6684.93 |
| INTERACTIONS          |           |           |         |           |         |        |
| Sub at same level of Main | S.Emot | 263.66    | 317.10  | 184.04    | 294.30  | 340.89  |
| CD at 5%              | NS       | NS       | NS      | NS        | NS      | NS      |
| Main at same level of Sub | S.Emot | 268.28    | 331.56  | 201.68    | 298.52  | 353.85  |
| CD at 5%              | NS       | NS       | NS      | NS        | NS      | NS      |
Table 7a. Interaction of crop establishment methods and nutrient management practices on LAI

| Establishment methods | N1  | N2  | N3  | N4  | MEAN | N1  | N2  | N3  | N4  | MEAN | N1  | N2  | N3  | N4  | MEAN | N1  | N2  | N3  | N4  | MEAN |
|-----------------------|-----|-----|-----|-----|------|-----|-----|-----|-----|------|-----|-----|-----|-----|------|-----|-----|-----|-----|------|
| M1- SRI               | 1.74| 1.10| 1.96| 0.98| 1.44 | 2.03| 1.80| 1.24| 1.09| 1.54 | 4.65| 3.84| 5.86| 2.90| 4.31 | 4.34| 3.39| 5.21| 2.71| 3.91 |
| M2- Modified drum seeder| 1.45| 1.24| 1.65| 0.84| 1.30 | 1.72| 1.50| 1.25| 1.03| 1.37| 3.45| 3.17| 4.06| 2.84| 3.38 | 3.30| 2.98| 4.01| 2.70| 3.25 |
| M3- Normal drum seeder | 1.23| 0.96| 1.36| 0.70| 1.06 | 1.44| 1.33| 1.14| 0.84| 1.19| 2.65| 2.39| 3.24| 2.04| 2.58 | 2.42| 2.09| 2.96| 1.98| 2.36 |
| M4- NTP               | 0.90| 0.71| 1.10| 0.65| 0.84 | 1.25| 1.10| 0.88| 0.75| 1.00| 2.36| 1.96| 2.74| 1.78| 2.21 | 2.36| 2.07| 2.67| 1.84| 2.24 |
| MEAN                  | 1.33| 1.00| 1.52| 0.79| 1.61 | 1.43| 1.13| 0.93| 0.38| 2.84| 1.96| 2.74| 1.78| 2.21 | 2.36| 2.07| 2.67| 1.84| 2.24 |
| S.Em±                 |      |      |      |      | 5.8± |      |      |      |      |      |      |      |      |      |      |      |      |      |      |
| CD at 5%              |      |      |      |      |      |      |      |      |      |      |      |      |      |      |      |      |      |      |      |
| Sub at same level of main | 0.06|      |      |      | 0.04 |      |      |      |      |      |      |      |      |      |      |      |      |      |      |
| Main at same level of sub | 0.06|      |      |      | 0.17 |      |      |      |      |      |      |      |      |      |      |      |      |      |      |

Table 7b. Interaction of crop establishment methods and nutrient management practices on LA

| Establishment methods | N1  | N2  | N3  | N4  | MEAN | N1  | N2  | N3  | N4  | MEAN | N1  | N2  | N3  | N4  | MEAN | N1  | N2  | N3  | N4  | MEAN |
|-----------------------|-----|-----|-----|-----|------|-----|-----|-----|-----|------|-----|-----|-----|-----|------|-----|-----|-----|-----|------|
| M1- SRI               | 5.26| 4.12| 6.09| 3.40| 4.72 | 6.15| 5.45| 4.42| 3.71| 4.93 |      |      |      |      |      |      |      |      |      |      |
| M2- Modified drum seeder| 3.76| 3.39| 4.10| 3.23| 3.62 | 4.50| 4.02| 3.66| 3.41| 3.90 |      |      |      |      |      |      |      |      |      |      |
| M3- Normal drum seeder | 3.49| 3.15| 3.61| 2.98| 3.31 | 3.97| 3.70| 3.33| 3.03| 3.51 |      |      |      |      |      |      |      |      |      |      |
| M4- NTP               | 2.86| 2.70| 3.09| 2.12| 2.69 | 3.26| 3.00| 2.78| 2.35| 2.85 |      |      |      |      |      |      |      |      |      |      |
| MEAN                  | 1.84| 1.34| 4.22| 2.93| 4.47 | 4.47| 4.04| 3.55| 3.12|      |      |      |      |      |      |      |      |      |      |
| S.Em±                 |      |      |      |      | 5.8± |      |      |      |      |      |      |      |      |      |      |      |      |      |      |
| CD at 5%              |      |      |      |      |      |      |      |      |      |      |      |      |      |      |      |      |      |      |      |
| Sub at same level of main | 0.25|      |      |      | 0.74 |      |      |      |      |      |      |      |      |      |      |      |      |      |      |
| Main at same level of sub | 0.25|      |      |      | 0.78 |      |      |      |      |      |      |      |      |      |      |      |      |      |      |
4. CONCLUSIONS

SRI registered superior growth characters and higher yield of rice over other establishment methods. Among nutrient management practices 50% inorganic+50% organic performed better in terms of growth and yield. A combination of SRI along with 50% inorganic+50% organic nutrient management practice recorded significantly superior growth characters and higher yield over the rest of the treatments.

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COMPETING INTERESTS

Authors have declared that no competing interests exist.

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