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# Effect of dates and methods of transplanting of winter rice (*Oryza sativa* L.) on relayed toria (*Brassica campestris*) and soil health

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## ABSTRACT

*A field experiment was carried out at Regional Agricultural Research Station, Shillongani, Nagaon, Assam during kharif - rabi seasons 2014-15 and 2015-16 to evaluate the effect of different dates of rice transplanting and methods of cultivation on productivity of winter rice (Oryza sativa L.) and their effect on rice-toria (Brassica capestris) relay system. The experiment was laid out in a factorial randomized block design for the treatments in rice during kharif season and a split plot design for treatments of relay crops in rabi season assigning dates of transplanting and method of cultivation of rice in the main plots and relay crops in sub- plots with three replications. Rice transplanted on 20$^{th}$ June recorded significantly higher yield attributes and grain yield as compared to the later dates of transplanting, and it was followed by 5$^{th}$ July- transplanted rice. Transplanting on 20$^{th}$ June resulted in higher values in respect of yield attributes, yield of relayed toria, rice equivalent yield (REY) of rice-toria relay system, NPK uptake by rice and toria as well as soil fungal and bacterial population after harvest of rice and toria. System of Rice Intensification (SRI) recorded significantly higher values of yield attributes and grain yield of rice (6034 kg ha$^{-1}$) as compared to conventional method (5499 kg ha$^{-1}$). In case of relayed toria, yield attributes, seed yield (712 kg ha$^{-1}$) and REY of rice-toria relay system (7972 kg ha$^{-1}$) were found higher under SRI method of rice cultivation. Under SRI method, higher uptake of NPK by rice and toria and higher soil fungal and bacterial populations after harvest of rice and toria were observed as compared to conventional method. However, conventional method of rice cultivation recorded significantly higher values of soil available N, $P_2O_5$ and $K_2O$ content at the end of two year-crop cycle over that of SRI.*

***Keywords***: Date of transplanting, method of cultivation, relay, soil health, system of rice intensification and *toria*

In Assam, rice is the main food crop, occupying first position in respect of both area and production. In addition to rice, oilseeds are also important food grains for which soil and climatic conditions of Assam are very congenial. Area under rice, pulses and oilseeds is about 65, 8 and 4 per cent of the total gross cropped area (38.43 lakh ha). In 2012-13, the state was able to produce about 52.33 lakh t of total rice from an area of 24.88 lakh ha but the production of oilseeds were very low *i.e*. 1.87 lakh t from 3.06 lakh ha. Assam has achieved near self-sufficiency in rice production, however, it continues to be deficit in oilseeds. The requirement of oilseeds for the state was 3.75 lakh t in 2012-13. This shows a deficit of 1.88 lakh t (*i.e*. 50% of requirement). Therefore, along with rice, production of oilseed also needs a special attention to meet the requirement for the burgeoning population. In Assam, ricelands can easily be targeted for crop intensification through intensive cropping programme. To increase oilseed production, the cultivated land area cannot be increased directly. In such cases, crop intensification through multiple cropping in rice and rice based cropping systems are of prime importance (Deka *et al.,* 2013).

Although rice is grown in 3 different seasons, among them winter rice, locally known as S*ali* rice, is the most important one, which occupies about 75per cent of total rice area, covering an area of 18-19 lakh ha annually contributing to 65.37per cent of the total rice production in the state. *Sali* rice is grown on medium to low land situation during June or July to November or December. In Assam, productivity of winter (*Sali)* rice is low (2055 kg ha$^{-1}$) as compared to summer (*boro)* rice (2865 kg ha$^{-1}$). Moreover, most of the farmers are small and marginal having fragmented land holding. In this case, the winter rice productivity per unit area can be increased by adoption of SRI (Mohanty *et al.*, 2014 and Dass and Chandra, 2013)

One of the major constraints of growing *rabi* crops after *Sali* rice is delayed sowing due to delayed harvesting of *Sali* rice and problem of land preparation due to excessive residual soil moisture. However, this constraint can be overcome by growing *rabi* crops as relay crops with rice. *Toria* is normally grown as an arable crop in major oilseed growing areas. After winter rice harvest in late November or early December, sowing of *toria* gets delayed. However, possibility is there for timely sowing of toria adopting the practice of relay cropping with rice. It is evident that relay cropping of certain oilseeds with winter rice is quite feasible and profit-making. However, study on relay cropping of *toria* in relation to production system sustainability is not yet done. Relay cropping of toria with different dates of

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winter rice transplanted adopting SRI is not at all investigated for feasibility. Therefore, it becomes imperative to undertake the study to find out the optimum date of transplanting and method of cultivation of rice for increasing the productivity of rice-*toria* relay cropping system (Rautary, 2016).

## MATERIALS AND METHODS

A field experiment was conducted during the consecutive *kharif* and *rabi* seasons of 2014-15 and 2015-16 at the Regional Agricultural Research Station, Shillongani, Nagaon, Assam ($26^{0}$ N latitude, $90^{0}45^{'}$ E longitude and at an altitude of 50.2 m above from the mean sea level). The climate of this region is sub-tropical with hot humid summer and relatively dry and cold winter. The crop experienced favourable weather conditions in both the years of experimentation. Total amount of rainfall received during the crop growth period were 1220.6 and 1286.8 mm during 2014-15 and 2015-16. In winter, water table recedes beyond root zone depth of the field crops. The maximum temperature rises up to 36 $^{0}$C in July-August and the minimum falls to 7 $^{0}$C in January and the relative humidity from 82 to 95 per cent in the morning and from 64 to 85 per cent in the evening. The soil of the experimental site was sandy loam in texture, acidic in reaction (pH 5.61), medium in organic carbon (0.84 %), medium in available N, $P_2O_5$ and $K_2O$ (296, 21 and 195 kg ha$^{-1}$, respectively). Fertilizers @ 60: 20:40 and 60:30:30 kg ha$^{-1}$ N, $P_2O_5$ and $K_2O$ were applied in rice and *toria*, respectively. The treatments comprised three dates of rice transplanting *viz*., 20$^{th}$ June, 5$^{th}$ July and 20$^{th}$ July and two methods of rice cultivation *viz*., conventional and SRI with *toria* as relay crop. The experiment was laid out in a factorial randomized block design with six treatment combinations replicated four times. Winter rice variety 'Ranjit' and toria variety 'TS 38' were used for the study. *Toria* seeds were broadcasted @ 13 kg ha$^{-1}$ in the standing rice crop at optimum soil moisture saturation prior to harvest of.10-30 days as per variation of dates of transplanting. Based on proper soil moisture content, *toria* was sown on 1 November in 2014 and 26 October in 2015. Rice was harvested from net plot while toria was harvested from gross plot. Soil samples were collected before sowing and at the end of second year for analyse of chemical properties following the standard procedures such as alkaline potassium permanganate method (Subbiah and Asija, 1956,) Bray-I Method (Jackson, 1973) and Flame Phtometric Method (Baruah and Borthakur, 1997) for N, $P_2O_5$ and $K_2O$, respectively. The plant samples (both seed and stover) of rice and toria were collected separately after threshing and dried in oven at $65^{0}$ C for 72 hrs. The oven-dried samples were finely ground and chemically analysed for N, P and K content by modified Kjeldahl method, colorimetrically by tri-acid digestion and yellow colour method and by flame photometer (Jackson, 1973), respectively. The uptake of nutrients was calculated by multiplying the dry matter yield with respective percentage of nutrients.

For counting of soil microbial population *viz*., fungal and bacterial, soil samples from 0-15 cm depth from three spots of each plot were collected before transplanting of rice and at harvest of each crop and then fungal and bacterial populations in soil were enumerated by following the standard serial dilution technique and pour-plate method using different media (Pramer and Schmidt, 1965). The bacterial population was counted on third day and that of fungal population on fifth day of incubation using the following formula.

Total viable count = Average number of colonies × size of aliquot × Dilution factor

The REY of relay toria and rice-toria relay system were calculated by using the following formula.

$$\text{REY of toria} = \frac{\text{Yield of toria (kg ha-1)} \times \text{price of toria (Rs. kg-1)}}{\text{Price of rice (Rs. kg-1)}}$$

REY of rice-*toria* relay system = Rice yield + REY of *toria*

Gross return of rice –*toria* system=REY of rice-*toria* system (kg ha$^{-1}$) x price of rice (Rs. kg$^{-1}$). The data pertaining to each of the characters of the experimental crops were tabulated and finally analyzed statistically as per the procedure prescribed for Factorial RBD as well as split-plot design (SPD) described by Panse and Sukhatme (1985). The significance or non-significance of the variances due to treatment effects was tested by 'F' test. Critical difference was calculated wherever 'F' test was significant.

## RESULTS AND DISCUSSION

### *Yield attributes and grain yield of rice*

The different dates of transplanting had no significant effect on panicle length in both the years (Table 1). The highest panicle weight of 6.08 and 5.96 g panicle$^{-1}$ were recorded in the crops planted on 20$^{th}$ June which was at par with 5$^{th}$ July transplanting and was significantly higher than 20$^{th}$ July transplanting. This was due to production of higher number of filled grains panicle$^{-1}$ in the former treatment.

Rice grown under SRI recorded significantly longer panicle (28.17 and 27.89 cm in 2014 and 2015) as compared to conventional method (Table 1). These results are in agreement with the findings of Singh *et al*. (2013) and Uzzaman *et al*. (2015). The methods of rice cultivation also exerted significant effect on panicle weight. The highest value (6.32 and 6.30 g panicle$^{-1}$ during 2014 and 2015) was noted under SRI which was significantly higher than those under conventional

**Table 1: Yield attributes and grain yield of rice as influenced by date of transplanting and method of cultivation**

| Treatment | Panicle length (cm) | | Panicle weight (g panicle $^{-1}$) | | 1000-grain weight(g) | | Grain yield (q ha$^{-1}$) | | Pooled |
|---|---|---|---|---|---|---|---|---|---|
| | 2014 | 2015 | 2014 | 2015 | 2014 | 2015 | 2014 | 2015 | |
| **Date of transplanting** | | | | | | | | | |
| 20th June | 27.20 | 26.79 | 6.08 | 5.96 | 20.12 | 20.03 | 59.61 | 58.79 | 59.19 |
| 5th July | 27.08 | 26.56 | 5.78 | 5.84 | 19.97 | 19.91 | 58.44 | 57.73 | 58.09 |
| 20th July | 26.85 | 26.43 | 5.33 | 5.26 | 19.95 | 19.94 | 55.92 | 55.16 | 55.55 |
| **SEm (±)** | **0.85** | **0.66** | **0.18** | **0.20** | **0.12** | **0.11** | **1.11** | **1.02** | **0.99** |
| **LSD (0.05)** | **NS** | **NS** | **0.56** | **0.63** | **NS** | **NS** | **3.49** | **3.21** | **3.12** |
| **Method of cultivation** | | | | | | | | | |
| Conventional | 25.92 | 25.30 | 5.15 | 5.08 | 19.54 | 19.49 | 55.21 | 54.54 | 54.99 |
| SRI | 28.17 | 27.89 | 6.32 | 6.30 | 20.50 | 20.43 | 60.77 | 59.91 | 60.34 |
| **SEm (±)** | **0.69** | **0.54** | **0.14** | **0.17** | **0.10** | **0.09** | **1.04** | **0.96** | **0.88** |
| **LSD (0.05)** | **2.19** | **1.71** | **0.44** | **0.38** | **0.32** | **0.30** | **3.28** | **3.05** | **2.77** |
| **Interaction** | | | | | | | | | |
| **SEm (±)** | **1.20** | **0.94** | **0.27** | **0.39** | **0.17** | **0.16** | **1.98** | **1.87** | **1.79** |
| **LSD (0.05)** | **NS** | **NS** | **NS** | **NS** | **NS** | **NS** | **NS** | **NS** | **NS** |

**Table 2: NPK-uptake by rice at harvest as influenced by date of transplanting and method of cultivation of rice**

| Treatments | Total N-uptake (kg ha$^{-1}$) | | Total P-uptake (kg ha$^{-1}$) | | Total K-uptake (kg ha$^{-1}$) | |
|---|---|---|---|---|---|---|
| | 2014 | 2015 | 2014 | 2015 | 2014 | 2015 |
| **Date of transplanting** | | | | | | |
| 20th June | 68.49 | 66.08 | 22.08 | 20.56 | 62.69 | 60.96 |
| 5th July | 67.05 | 64.68 | 21.03 | 19.77 | 61.34 | 60.21 |
| 20th July | 62.99 | 64.43 | 19.26 | 18.19 | 58.40 | 56.42 |
| **SEm (±)** | **2.21** | **1.63** | **0.55** | **0.35** | **1.62** | **1.63** |
| **LSD (0.05)** | **NS** | **NS** | **1.75** | **1.09** | **NS** | **NS** |
| **Method of cultivation** | | | | | | |
| Conventional | 63.26 | 60.69 | 19.71 | 18.47 | 58.49 | 56.43 |
| SRI | 69.10 | 69.43 | 21.88 | 20.54 | 63.13 | 61.97 |
| **SEm (±)** | **1.79** | **1.33** | **0.45** | **0.28** | **1.32** | **1.33** |
| **LSD (0.05)** | **5.66** | **4.19** | **1.43** | **0.89** | **4.18** | **4.19** |
| **Interaction** | | | | | | |
| **SEm (±)** | **3.11** | **2.31** | **0.784** | **0.491** | **2.30** | **2.31** |
| **LSD (0.05)** | **NS** | **NS** | **NS** | **NS** | **NS** | **NS** |

**Table 3: Yield attributes and seed yield of *toria* as affected by transplanting date and method of cultivation of rice**

| Treatments | Siliquae plant$^{-1}$ | | Seeds siliquae$^{-1}$ | | 1000- seed weight (g) | | Seed yield (kg ha$^{-1}$) | |
|---|---|---|---|---|---|---|---|---|
| | **2014-15** | **2015-16** | **2014-15** | **2015-16** | **2014-15** | **2015-16** | **2014-15** | **2015-16** |
| **Date of transplanting** | | | | | | | | |
| 20$^{th}$ June | 124.65 | 112.43 | 15.52 | 14.95 | 2.87 | 2.78 | 871 | 741 |
| 5$^{th}$ July | 122.73 | 110.40 | 15.63 | 15.05 | 2.85 | 2.75 | 812 | 736 |
| 20$^{th}$ July | 120.45 | 105.55 | 14.78 | 14.37 | 2.81 | 2.67 | 717 | 653 |
| **SEm (±)** | **1.17** | **1.34** | **0.27** | **0.28** | **0.17** | **0.19** | **29** | **44** |
| **LSD (0.05)** | **3.70** | **4.25** | **NS** | **NS** | **NS** | **NS** | **91** | **138** |
| **Method of cultivation** | | | | | | | | |
| Conventional | 122.86 | 110.02 | 15.37 | 14.80 | 2.84 | 2.75 | 827 | 712 |
| SRI | 122.36 | 108.90 | 15.26 | 14.78 | 2.85 | 2.71 | 773 | 708 |
| **SEm (±)** | **0.96** | **1.10** | **0.22** | **0.23** | **0.14** | **0.15** | **26** | **34** |
| **LSD (0.05)** | **NS** | **NS** | **NS** | **NS** | **NS** | **NS** | **NS** | **NS** |
| **Interaction** | | | | | | | | |
| **SEm (±)** | **1.66** | **1.91** | **0.38** | **0.40** | **0.25** | **0.27** | **55** | **66** |
| **LSD (0.05)** | **NS** | **NS** | **NS** | **NS** | **NS** | **NS** | **NS** | **NS** |

**Table 4: Rice equivalent yield of toria and rice-*toria* relay system as influenced by date of transplanting and method of cultivation of rice**

| Treatments | Rice equivalent yield of *toria* (kg ha$^{-1}$) | | | Rice equivalent yield of rice-*toria* relay system (kg ha$^{-1}$) | | |
|---|---|---|---|---|---|---|
| | **2014-15** | **2015-16** | **Pooled** | **2014-15** | **2015-16** | **Pooled** |
| **Date of transplanting** | | | | | | |
| 20$^{th}$ June | 2230 | 1897 | 2063 | 8187 | 7843 | 8015 |
| 5$^{th}$ July | 2079 | 1884 | 1981 | 7925 | 7743 | 7834 |
| 20$^{th}$ July | 1835 | 1672 | 1754 | 7429 | 7282 | 7347 |
| **SEm (±)** | **100** | **138** | **92** | **168** | **202** | **167** |
| **LSD (0.05)** | **NS** | **NS** | **NS** | **529** | **NS** | **527** |
| **Method of cultivation** | | | | | | |
| Conventional | 2117 | 1823 | 1970 | 7638 | 7355 | 7491 |
| SRI | 1979 | 1812 | 1896 | 8056 | 7889 | 7972 |
| **SEm (±)** | **82** | **113** | **34** | **137** | **165** | **136** |
| **LSD (0.05)** | **NS** | **NS** | **NS** | **NS** | **520** | **431** |
| **Interaction** | | | | | | |
| **SEm (±)** | **142** | **195** | **90** | **237** | **286** | **236** |
| **LSD (0.05)** | **NS** | **NS** | **NS** | **NS** | **NS** | **NS** |

*Note: Sale price of seeds of rice =Rs.12.50 per kg and toria= Rs. 32.00 per kg*

**Table 5: Total NPK-uptake by *toria* at harvest as influenced by date of transplanting and method of cultivation of rice**

| Treatments | Total uptake by *toria* (kg ha$^{-1}$) | | | | | |
|---|---|---|---|---|---|---|
| | N-uptake | | P-uptake | | K-uptake | |
| | 2014-15 | 2015-16 | 2014-15 | 2015-16 | 2014-15 | 2015-16 |
| **Date of rice transplanting** | | | | | | |
| 20$^{th}$ June | 38.93 | 34.71 | 9.97 | 8.78 | 19.85 | 18.28 |
| 5$^{th}$ July | 36.84 | 34.69 | 9.38 | 8.68 | 19.12 | 18.38 |
| 20$^{th}$ July | 33.31 | 31.07 | 7.92 | 7.27 | 17.00 | 16.21 |
| **SEm (±)** | **1.05** | **0.99** | **0.26** | **0.34** | **0.61** | **0.51** |
| **LSD (0.05)** | **3.30** | **NS** | **0.83** | **1.07** | **1.93** | **1.61** |
| **Method of cultivation** | | | | | | |
| Conventional | 37.17 | 33.59 | 9.31 | 8.28 | 18.96 | 17.55 |
| SRI | 35.54 | 33.63 | 8.87 | 8.22 | 18.34 | 17.70 |
| **SEm (±)** | **0.94** | **0.81** | **0.22** | **0.28** | **0.50** | **0.42** |
| **LSD (0.05)** | **NS** | **NS** | **NS** | **NS** | **NS** | **NS** |
| **Interaction** | | | | | | |
| **SEm (±)** | **1.63** | **1.41** | **0.37** | **0.48** | **0.87** | **0.72** |
| **LSD (0.05)** | **NS** | **NS** | **NS** | **NS** | **NS** | **NS** |

**Table 6: Soil microbial population after harvest of rice and *toria* as influenced by date of transplanting and method of cultivation**

| Treatments | After rice harvest | | | | After toria harvest | | | |
|---|---|---|---|---|---|---|---|---|
| | Fungi ($10^5$ cfu g$^{-1}$ soil) | | Bacteria ($10^6$ cfu g$^{-1}$ soil) | | Fungi ($10^5$ cfu g$^{-1}$ soil) | | Bacteria ($10^6$ cfu g$^{-1}$ soil) | |
| | 2014 | 2015 | 2014 | 2015 | 2014 | 2015 | 2014 | 2015 |
| **Date of transplanting** | | | | | | | | |
| 20$^{th}$ June | 26.33 | 29.03 | 36.53 | 39.6 | 47.10 | 50.83 | 58.50 | 61.73 |
| 5$^{th}$ July | 26.10 | 28.53 | 36.36 | 39.43 | 45.03 | 48.60 | 55.96 | 60.03 |
| 20$^{th}$ July | 25.33 | 27.73 | 32.93 | 36.16 | 44.33 | 48.40 | 53.96 | 59.36 |
| **SEm (±)** | **1.36** | **1.34** | **1.99** | **1.66** | **2.90** | **2.37** | **3.91** | **3.12** |
| **LSD (0.05)** | **NS** | **NS** | **NS** | **NS** | **NS** | **NS** | **NS** | **NS** |
| **Method of cultivation** | | | | | | | | |
| Conventional | 25.76 | 28.15 | 35.10 | 38.30 | 44.48 | 48.22 | 55.13 | 59.31 |
| SRI | 26.25 | 28.70 | 35.45 | 38.49 | 46.48 | 50.33 | 57.15 | 61.44 |
| **SEm (±)** | **1.11** | **1.10** | **1.62** | **1.36** | **2.18** | **1.75** | **3.01** | **2.36** |
| **LSD (0.05)** | **NS** | **NS** | **NS** | **NS** | **NS** | **NS** | **NS** | **NS** |
| **Interaction** | | | | | | | | |
| **SEm (±)** | **2.73** | **2.71** | **3.99** | **3.33** | **4.51** | **3.76** | **5.95** | **4.83** |
| **LSD (0.05)** | **NS** | **NS** | **NS** | **NS** | **NS** | **NS** | **NS** | **NS** |

*Note: Initial soil fungal population= 36.53 ($10^5$ cfu g$^{-1}$ soil); Initial soil bacterial population= 48.13 ($10^6$ cfu g$^{-1}$ soil)*

**Table 7: Effect of date and method of rice transplanting on available N, $P_2O_5$ and $K_2O$ content in soil at the end of two year-crop cycle**

| Treatments | Available N, $P_2O_5$ and $K_2O$ content (kg $ha^{-1}$) | | |
|---|---|---|---|
| | N content | $P_2O_5$ content | $K_2O$ content |
| **Date of transplanting** | | | |
| 20th June | 291.28 | 17.72 | 156.60 |
| 5th July | 296.14 | 16.86 | 163.24 |
| 20th July | 312.13 | 22.53 | 173.66 |
| **SEm (±)** | **2.70** | **0.58** | **1.14** |
| **LSD (P=0.05)** | **8.52** | **1.83** | **3.60** |
| **Method of cultivation** | | | |
| Conventional | 292.89 | 17.48 | 150.02 |
| SRI | 306.81 | 20.60 | 178.98 |
| **SEm (±)** | **2.20** | **0.47** | **0.93** |
| **LSD (0.05)** | **6.96** | **1.49** | **2.94** |
| **Interaction** | | | |
| **SEm (±)** | **3.82** | **0.82** | **1.62** |
| **LSD (0.05)** | **12.05** | **2.59** | **5.10** |

method. Higher panicle weight was owing to higher number of filled grains $panicle^{-1}$ under SRI. SRI accrued in significantly higher 1000-grain weight (20.50 and 20.43g in 2014 and 2015, respectively) than conventional method. These results are in conformity with the findings of Uzzaman *et al*. (2015) and Ranjitha and Reddy (2014). Higher 1000-grain weight in SRI might be due to better translocation of photosynthetates and dry-matter partitioning to the grains as compared to that under conventional method.

Different dates of transplanting brought about significant differences in grain yield (Table 1). Grain yield was found to decrease with delay in transplanting. The highest grain yield (5961, 5879 and 5919 kg $ha^{-1}$ in 2014, 2015 and pooled, respectively) was recorded under 20th June which were at par with that of 5th July transplanting and were significantly higher than that of 20th July. Early transplanting favoured better uptake of N, P and K and thereby increased growth and yield attributes and ultimately reflected on yield. Higher grain yield under early planting might also be attributed to relatively early crop establishment and better tillering. Similar reduction in yield due to delayed transplanting was also reported by Ashem *et al.* (2010) and Changmai (2015). SRI gave significantly higher grain yield (6077, 5991 and 6034 kg $ha^{-1}$ in 2014, 2015 and pooled, respectively) than conventional method. Similar results were also reported by Singh *et al*. (2013) in Bangladesh and Ranjitha and Reddy (2014) in Hyderabad. The increase in grain yield under SRI was owing to vigorous root growth resulting in better N, P and K uptake and reproductive growth and ultimately higher yield of rice (Table 1).

***Total nutrient uptake by rice***

During 2014 and 2015, there was no statistical difference in total N and K-uptake by rice due to different dates of transplanting. However, its effect on total P uptake was found significant (Table 2). The highest total P uptake (22.08 and 20.56 kg $ha^{-1}$ in 2014 and 2015, respectively) was recorded in rice transplanted on 20 June and the lowest was in rice transplanted on 20th July. SRI resulted in significantly higher uptake of total N, P and K (69.10 and 69.43, 21.88 and 20.54, 61.13 and 61.97 kg $ha^{-1}$ in 2014 and 2015, respectively) as compared to conventional method. This was due to the higher yield and higher N, P and K content in grain and straw which was, in turn, because of better vegetative and reproductive growth leading to production of more biomass. These results are in agreement with the findings of Vallois and Uphoff (2000) in Madagascar and Ranjitha and Reddy (2014) in Hyderabad. In SRI method, application of more organic manure along with inorganic fertilizers and incorporation of weeds by cono weeder increased release of nutrients to the soil, which led to enhanced biomass production and ultimately resulted in higher NPK uptake.

***Yield attributes and grain yield of relayed toria***

The number of siliquae plant$^{-1}$ differed significantly due to varying dates of rice transplanting (Table 3). The highest number of siliquae plant$^{-1}$ was recorded under rice transplanted on 20$^{th}$ June followed by 5$^{th}$ July and significantly higher over 20$^{th}$ July transplanted rice and was *owing to better growth of the relay crop favoured by desired days of association with early transplanted rice*. The effect of different dates of rice transplanting was found significant on seed yield of relayed *toria*. Significantly higher seed yield of toria was resulted in by 20$^{th}$ June rice transplanting as compared to 20$^{th}$ July transplanting in both the years. The maximum *toria* yield under 20$^{th}$ June transplanting was owing to better plant stand and higher siliquae plant$^{-1}$ and seeds siliquae$^{-1}$ (Rachid *et al*., 2014). The effect of methods of rice cultivation on siliquae plant$^{-1}$ was found insignificant and both the factors failed to exert significant effect on seeds siliquae$^{-1}$ and 1000-seed weight of relayed toria (Rautary, 2016). There was no statistical difference between two methods of rice cultivation in respect of seed yield of *toria* (Table 3).

***Rice equivalent yield (REY) of relayed toria and rice-toria relay system***

Date of transplanting and method of rice cultivation had no significant effect on REY of *toria* (Table 4). The highest REY of *toria* was recorded under 20$^{th}$ June rice transplanting which was decreased with further delay in transplanting. The date of rice transplanting showed significant effect on rice equivalent yield (REY) of rice-*toria* relay system in 2014-15 and pooled. The highest REY of rice-*toria* system was recorded under 20$^{th}$ June rice transplanting which was at par with 5$^{th}$ July planting and were significantly higher than that of 20$^{th}$ July planting. This indicated that delay in rice transplanting cause significant reduction in yield of both rice and relay crops. The method of rice cultivation had significant effect on REY of rice-*toria* relay system in 2015-16 and pooled data (Table 4). REY of rice-*toria* system under SRI was significantly higher than the conventional method and this was mainly because of the higher yield of rice under this treatment.

***Total NPK-uptake by toria***

Dates of rice transplanting had significant effect on total NPK-uptake by toria. The highest total N, P and K-uptake by toria was recorded under 20$^{th}$ June rice transplanting which was at par with 5$^{th}$ July transplanting and both dates of transplanting were superior to 20$^{th}$ July transplanting (Table 5). Higher biomass production in toria under 20$^{th}$ June rice transplanting resulted in higher total N, P and K- uptake under this treatment. Method of rice cultivation had no significant effect on nutrient uptake by *toria*.

***Soil fungal and bacterial population after rice and toria harvest***

The different dates of transplanting and method of rice cultivation did not exert significant effect on soil fungal and bacterial population after rice and *toria* harvest (Table 6).

***Soil nutrient status at the end of two year crop cycle***

The dates of rice transplanting brought about significant differences in available N, $P_2O_5$ and $K_2O$ content in soil (Table 7). The lowest available N, $P_2O_5$ and $K_2O$ in soil was recorded under 20$^{th}$ June transplanting. As N, P and K uptake by rice and *toria* was higher under 20$^{th}$ June transplanted rice as compared to latter dates of transplanting, lower available soil N, $P_2O_5$ and $K_2O$ after harvest of *toria* was the resultant. Method of rice cultivation had also significant effect on the available N, $P_2O_5$ and $K_2O$ in soil (Table 7). Significantly higher available N, $P_2O_5$ and $K_2O$ (306.81, 20.60 and 178.98 kg ha$^{-1}$, respectively) was found under SRI as compared to conventional method. Higher soil N, $P_2O_5$ and $K_2O$ under SRI might be owing to more nutrient availability and higher soil microbial population resulting from application of more organic manure. Similar findings were also reported by Singh *et al.* (1999) and Manna *et al*. (2006).

The study envisages that to maximize production of rice-*toria* relay system, winter rice is to be transplanted on 20$^{th}$ June adopting SRI method of cultivation.

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