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# Agronomic manipulation on nutrient uptake and status in Sali rice under varied crop establishment in the inceptisol of Assam

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**Abstract**
A field study was undertaken consecutively for two years (2016 and 2017) in Golaghat district of Assam, India to find out the influence of agronomic manipulation especially varied crop establishment on plant nutrient uptake and status in sali rice. The experiment was composed of two methods of crop establishment *viz.* System of rice intensification (SRI) and conventional rice cultivation (CRC); three planting dates *viz.* 26$^{th}$ June, 10$^{th}$ and 25$^{th}$ July and four different crop densities (20 cm x 10 cm, 20 cm x 20 cm, 25 cm x 20 cm & 25 cm x 25 cm). The SRI crops registered significantly higher levels of total nutrient uptake which was contributed as a result of a similar pattern of effect by both grain and straw. Except for $K_2O$ by straw, early planted crops showed significantly increased absorption of nutrients by grain and straw. Increased nutrient uptake was recorded with the reduction in crop density, the highest being associated with crop density of 16 hills m$^{-2}$ *i.e.* 25 cm x 25 cm. Improved yield performance was found with increased uptake of nutrients. Significantly higher level of $P_2O_5$ and $K_2O$ in soil was recorded at the end of two years of investigation under CRC.

**Keywords:** Crop establishment technique, system of rice intensification, conventional, crop nutrition, nutrient uptake, soil nutrient status

## Introduction
The world population is exploding despite shrinking resource bases. Feeding 2050's huge nine billion people, according to FAO, necessitates seventy percent of more food grain production in 2007. Being a staple food of nearly 50% of people worldwide, production maximization of rice from lesser area would prompt efficient use of these declining resources such as land, water, labour, capital and other biotic and abiotic resources including nutrients (Kalita *et al*, 2023) [9]. Crop nutrition is one of the most essential parts of cultivation practices that requires sincere management to ensure maximum crop productivity and by holistically addressing yield-limiting factors, food producers can unlock a new level of productivity and sustainability (Abbott, 2024) [1]. The System of Rice Intensification (SRI) is a holistic agro-ecological crop management practice that would serve far better than that of conventional input-intensive practices with its sincere commitment towards increased rice yield via efficient use of water, nutrient, labour, time, land, etc (Kalita *et al.* 2023 and Pandian *et al.* 2014) [9, 12]. SRI is a unique crop establishment technique of rice that uses single and young seedlings transplanted at wider spacing and relies mostly on organic means of crop nutrition, mechanical weed management as well as intermittent irrigation. The transplants experience the least trauma to the root system and, hence, the plants recover more quickly from the shock of transplanting which preserves the potential for much greater tillering, faster root growth and grain filling as a result of efficient utilization of resources. Rice crops under the conventional system of cultivation are not competent enough to absorb more nutrients from the soil due to their under-developed root system, often leads to inferior yield performance leaving a considerable amount of nutrients unutilized in the soil at harvest (Wahlang *et al.*, 2017) [18]. The better plant growth, less use of chemicals and fertilizer, increased productivity of land and economic use of water helps in maintaining the system productivity as well as sustainability.

An investigation was carried out for winter rice under medium land situations to study the nutrient use and yield response under two dissimilar crop establishment methods planted on three different transplanting windows with four varied planting densities in order to evaluate the varied crop environment for nutrient use.

## Materials and Methods

The field experiment was conducted consecutively for two years *viz.* 2016 and 2017 during the sali season in Golaghat district ($26^0$66′99″ N and $93^0$68′26″E; 76 m above msl) of Assam. The soil belonged to sandy loam textural class with good drainage capacity, acidic (5.82) in reaction, medium in organic carbon (0.586%), medium in N (287.72 kg $ha^{-1}$), low in $P_2O_5$ and $K_2O$ (33.20 & 84.86 kg $ha^{-1}$, respectively). The crop received an unevenly distributed rainfall of 1242.60 mm and 1618.80 mm during the period of experimentation *i.e* June to November 2016 and June to November 2017, respectively. The experiment comprised 24 treatment combinations with two crop establishment methods *viz.* $C_1$: System of Rice Intensification (SRI), $C_2$: Conventional rice cultivation (CRC); three planting dates *viz*. $D_1$: 26th June, $D_2$: 10th July, $D_3$: 25th July, and four crop densities *viz.* $H_1$: 33 hills $m^{-2}$ (20 cm x 15 cm); $H_2$ : 25 hills $m^{-2}$(*i.e.* 20 cm x 20 cm); $H_3$: 20 hills $m^{-2}$ (*i.e.* 20 cm x 25 cm); $H_4$ :16 hills $m^{-2}$ (*i.e.* 25 cm x 25 cm). The design was a factorial split-plot with three replications. For crop nutrition, a recommended integrated approach was undertaken. Rock phosphate @ 10 kg $P_2O_5$ and MOP @ 40 kg $K_2O$ ha-1 were applied and mixed well with the soil at the time of final land preparation. For CRC, a triangle was made by making a temporary bund diagonally touching the side bunds at a corner of the plot. The size of the triangle is according to the volume of seedlings to be treated. Inside the triangle, well-decomposed FYM @ 1 t $ha^{-1}$ were mixed well with the inocula of *Azospirillium amazonense* A-10 and *Bacillus megaterium* P-5 @ 4 kg $ha^{-1}$. The root portion of the seedlings was then submerged with the biofertilizer slurry for 8-10 hrs. The seedlings were then transplanted. Care was taken not to wash the seedling root during transplanting. For SRI seedlings, root portions were treated with the slurry on the nursery itself well ahead of lifting for transplanting. The depth of water maintained in the main field was 5 cm for CRC whereas in SRI, it was a maximum of 2 cm depth following alternate wet and dry method up to the flowering stage. The age of the seedlings was 12 days for SRI and 21 days for CRC system. The variety taken was a medium-duration HYV *viz. Shravani*. Nutrient uptake was determined following standard methods as mentioned below-

Nitrogen: Digestion Method (Jackson, 1973)

Phosphorous: Vanadomolybdo Phosphoric (Colorimetric) Method (Jackson, 1958)

Potassium: Tri-acid Digestion Method (Tooth & Prince, 1949)

To estimate the uptake, the estimated content value of respective nutrient was then converted (kg $ha^{-1}$) with the help of the formula mentioned below:

$$\text{Uptake (kg ha}^{-1}) = \frac{\text{Nutrient content} \times \text{Yield (kg ha}^{-1})}{100}$$

## Results and Discussion

### Effect of crop establishment method on nutrient uptake

Methods of crop establishment showed significant influence on nutrient uptake by grain, straw and total uptake in both the year of investigation. The data indicates the highest grain uptake of N, P, and K by the SRI crops (Table 1 and 2). The straw and total uptake also showed a similar trend. The probable reasons that can be ascertained are the addition of substantial quantities of organic manure along with the INM package, cono-weeding and wetting and drying method of irrigation. Additionally, the larger, deeper, less-senescing root mass of SRI crops enabled for accessing larger soil volume led to the extraction of more nutrients. The results corroborate with the findings of Barison and Uphoff (2011) [2], Dass and Chandra (2012) [4] and Wahlang *et al.* (2017) [18].

### Effect of different dates of planting on nutrient uptake

Significant crop response owing to various dates of planting was observed with respect to the uptake of nutrients by grain and straw and total uptake in both years (Table 1 and 2). Significantly highest grain uptake of N, P and K was found in the early (26th June) transplanted crops. N and P uptake by straw was also found to be significantly more in 26th June planting; which is, however at par with the 2nd planting under study (10th July). K uptake by straw was insignificant in both the year of investigation. In agreement with this result, Vishwakarma *et al.* (2016) [17] also revealed more nutrient uptake in early planted rice.

### Effect of crop densities on nutrient uptake

Among the hill densities, significant maximum uptake of nutrients was registered under wider density *i.e.* 25 cm x 25 cm; however, this was found in parity with other hill densities tried except the closest density (20 cm x 20 cm) which registered the lowest significant nutrient uptake (Table 1 and 2). The higher hill density recorded the significantly lower uptake of nutrients, and with the reduction of density, uptake increased and reached the maximum (125.06 to 132.42 kg N, 20.29 to 22.72 kg $P_2O_5$ and 165.97 to 174.50 kg $K_2O$ $ha^{-1}$) at the lowest density *i.e.* 16 hills $m^{-2}$ during the period of investigation. This might be attributed to the formation of larger root system with a vast absorbing root surface area accessing more nutrients vertically deeper and horizontally expanded zone of rhizosphere under wider spacing. Jogi *et al.* (2013) [8] reported that optimum plant density resulted in increased uptake of nutrients that enhanced the stature of yield parameters, synthesis and translocation of assimilates leading to substantially superior yield. Similar was also opined by Iranie *et al.* (2009) [7] and Singh *et al.* (2013) [14].

### Effect on soil nutrient status on harvest

### Effect of crop establishment methods

Crop response towards the establishment method with respect to soil nutrient status at harvest as portrayed in Table 1 and 2 was found significant except available-N, available-P in the 1st year and available-K in both the year of investigation. In the 1st year *i.e.* in 2016, comparable but marginally higher soil available NPK was observed under conventional method. In 2017, higher values of available-N and available-P were observed under SRI establishment, whereas under the conventional method, significantly lower magnitudes of available-N and P were registered. The effect of crop establishment on soil available-K was found to be insignificant in both the studied years. A marginal build-up of available-K was, however, observed under SRI in the 2nd year. Increased availability of soil available nutrients under SRI method of planting might be due to substantial activities of biological N-fixer as well as conversion of immobile-P into available forms in organic-C rich rhizospheric soil under unique alternate wetting and drying moisture regime of SRI. Further, insufficient nutrient extraction owing to the lesser volume of root system in conventional crops led to build-up of more soil nutrients at the time of harvest. This corroborates the results of Wahlang *et al.* (2017) [18].

**Effect of date of transplanting**

The effect of date of transplanting was found insignificant with respect to soil available nutrient in both the year of the experiment. However, small improvement in soil available N, P and K was seen with delaying of transplanting dates.

**Effect of levels of crop density**

The various levels of crop density failed to have any significant influence on the status of available soil nutrients at harvest in both years. However, improved status of soil nutrients at harvest was observed with the enhancement of hill density, the highest being owed by 33 hills $m^{-2}$.

**Effect on crop yield**

**Effect of Crop Establishment**

The two years of pooled data on grain, as well as straw yield as influenced by crop establishment, have been portrayed in Fig.1. SRI establishment recorded a significantly higher yield of 57.13 q of grains and 61.43 q of straw per ha as against 48.83 and 57.92 q $ha^{-1}$, respectively under conventional method (Fig.1). The increased yield under SRI method might be due to the efficient utilization of light, nutrients and water under optimum crop microclimate conditioned by SRI management practices esp. the AWD moisture regime which eventually resulted effectual utilization of these resources transforming in increased crop yield. This conforms with the findings of Kalita *et al* (2023), Thakur *et al.* (2015), Mitra *et al.* (2013) [9, 15, 11].

**Effect of planting**

Fig. 2 shows the pooled data of crop yield as affected by the date of planting. The grain yield of early planted crop was significantly high which was followed by 10th and 25th July planting. A similar pattern was also noticed for straw yield with delaying of planting time. The reduction of yield under delayed transplanting might be due to the coincidence of unfavourable weather conditions resulting in the underdeveloped photosynthetic site that eventually led to insufficient photosynthesis and ineffectual translocation of assimilates from source to sink. Investigations done by many researchers (Diwan *et al.*, 2017; Sharma *et al.*, 2018 and Gautam *et al.*, 2019) [5, 13, 6] worldwide revealed a large impact of weather parameters on growth and yield attributes, and eventually on the yield of rice.

**Table 1:** Influence of method of crop establishment, date of transplanting and hill density on nutrient uptake (kg $ha^{-1}$) at harvest in 2016

| Treatment | Grain | | | Straw | | | Total uptake | | |
|---|---|---|---|---|---|---|---|---|---|
| | N | $P_2O_5$ | $K_2O$ | N | $P_2O_5$ | $K_2O$ | N | $P_2O_5$ | $K_2O$ |
| **Crop establishment (C)** | | | | | | | | | |
| $C_1$ : SRI | 84.53 | 10.37 | 72.01 | 41.19 | 10.01 | 96.02 | 125.72 | 20.37 | 168.03 |
| $C_2$ : Conventional | 70.50 | 8.46 | 60.73 | 38.25 | 8.78 | 88.03 | 108.75 | 17.24 | 148.76 |
| CD (P=0.05) | 3.00 | 0.57 | 2.72 | 2.21 | 0.87 | 6.80 | 4.39 | 1.16 | 8.41 |
| **Date of transplanting (D)** | | | | | | | | | |
| $D_1$ : 26th June | 83.25 | 10.37 | 71.16 | 41.59 | 10.07 | 96.21 | 124.84 | 20.44 | 167.37 |
| $D_2$ : 10th July | 78.74 | 9.45 | 67.24 | 40.30 | 9.51 | 93.22 | 119.03 | 18.97 | 160.46 |
| $D_3$ : 25th July | 70.55 | 8.42 | 60.71 | 37.28 | 8.60 | 86.64 | 107.84 | 17.02 | 147.35 |
| CD (P=0.05) | 3.68 | 0.70 | 3.34 | 2.71 | 1.07 | NS | 6.10 | 1.49 | 10.30 |
| **Crop density (H)** | | | | | | | | | |
| $H_1$ : 20 cm x 15 cm | 66.81 | 7.97 | 57.47 | 35.73 | 8.26 | 83.48 | 102.54 | 16.23 | 140.95 |
| $H_2$ : 20 cm x 20 cm | 77.54 | 9.27 | 66.57 | 40.71 | 9.56 | 94.58 | 118.25 | 18.83 | 161.15 |
| $H_3$ : 20 cm x 25 cm | 81.73 | 10.00 | 69.97 | 41.37 | 9.88 | 95.54 | 123.10 | 19.89 | 165.50 |
| $H_4$ : 25 cm x 25 cm | 83.98 | 10.41 | 71.46 | 41.08 | 9.88 | 94.51 | 125.06 | 20.29 | 165.97 |
| CD (P=0.05) | 6.47 | 1.18 | 5.43 | 3.28 | 1.02 | 8.07 | 7.91 | 1.82 | 11.18 |

**Table 2:** Influence of method of crop establishment, date of transplanting and hill density on nutrient uptake (kg $ha^{-1}$) at harvest in 2017

| Treatment | Grain | | | Straw | | | Total uptake | | |
|---|---|---|---|---|---|---|---|---|---|
| | N | $P_2O_5$ | $K_2O$ | N | $P_2O_5$ | $K_2O$ | N | $P_2O_5$ | $K_2O$ |
| **Crop establishment (C)** | | | | | | | | | |
| $C_1$: SRI | 89.95 | 11.60 | 76.50 | 43.40 | 11.31 | 100.11 | 133.35 | 22.91 | 176.61 |
| $C_2$: Conventional | 76.06 | 9.49 | 65.36 | 40.40 | 9.73 | 92.13 | 116.46 | 19.22 | 157.49 |
| CD (P=0.05) | 2.91 | 0.61 | 3.33 | 2.28 | 1.08 | 6.87 | 4.91 | 1.45 | 9.36 |
| **Date of transplanting (D)** | | | | | | | | | |
| $D_1$: 26th June | 88.86 | 11.42 | 75.95 | 43.75 | 11.22 | 100.24 | 132.62 | 22.64 | 176.19 |
| $D_2$: 10th July | 83.85 | 10.57 | 71.36 | 42.48 | 10.66 | 97.53 | 126.32 | 21.24 | 168.89 |
| $D_3$:25th July | 76.31 | 9.65 | 65.47 | 39.47 | 9.67 | 90.59 | 115.78 | 19.32 | 156.06 |
| CD (P=0.05) | 3.57 | 0.75 | 4.07 | 2.79 | 1.33 | NS | 6.35 | 1.77 | 11.46 |
| **Crop density (H)** | | | | | | | | | |
| $H_1$: 20 cm x 15 cm | 72.60 | 9.05 | 62.29 | 38.07 | 9.47 | 87.60 | 110.67 | 18.51 | 149.89 |
| $H_2$: 20 cm x 20 cm | 83.06 | 10.42 | 70.96 | 43.09 | 10.58 | 98.78 | 126.15 | 21.00 | 169.74 |
| $H_3$: 20 cm x 25 cm | 87.09 | 11.13 | 74.51 | 43.29 | 10.90 | 99.55 | 130.38 | 22.02 | 174.06 |
| $H_4$: 25 cm x 25 cm | 89.28 | 11.59 | 75.94 | 43.14 | 11.13 | 98.56 | 132.42 | 22.72 | 174.50 |
| CD (P=0.05) | 5.37 | 0.88 | 3.49 | 3.44 | 1.07 | 8.59 | 8.40 | 1.74 | 12.74 |

**Table 3:** Effect of method of crop establishment, date of transplanting and hill density on nutrient status at harvest; kg $ha^{-1}$

| Treatment | N | | $P_2O_5$ | | $K_2O$ | |
|---|---|---|---|---|---|---|
| | 2016 | 2017 | 2016 | 2017 | 2016 | 2017 |
| **Crop establishment (C)** | | | | | | |
| $C_1$ : SRI | 276.38 | 282.59 | 24.72 | 28.37 | 78.14 | 82.56 |
| $C_2$ : Conventional | 278.89 | 278.86 | 26.00 | 27.08 | 80.81 | 82.10 |
| CD (P=0.05) | NS | 3.66 | NS | 1.21 | NS | NS |
| **Date of transplanting (D)** | | | | | | |
| $D_1$ : 26th June | 276.29 | 279.58 | 24.63 | 27.02 | 78.68 | 81.64 |
| $D_2$ : 10th July | 277.87 | 280.81 | 25.28 | 27.66 | 79.48 | 82.46 |
| $D_3$ : 25th July | 278.76 | 281.78 | 26.17 | 28.50 | 80.25 | 82.89 |
| CD (P=0.05) | NS | NS | NS | NS | NS | NS |
| **Crop density (H)** | | | | | | |
| $H_1$ : 20 cm x 15 cm | 280.34 | 285.37 | 26.74 | 29.18 | 81.15 | 83.83 |
| $H_2$ : 20 cm x 20 cm | 278.92 | 282.30 | 26.27 | 28.32 | 80.45 | 83.05 |
| $H_3$ : 20 cm x 25 cm | 276.44 | 278.56 | 24.55 | 27.03 | 78.72 | 81.70 |
| $H_4$ : 25 cm x 25 cm | 274.84 | 276.67 | 23.88 | 26.38 | 77.57 | 80.74 |
| CD (P=0.05) | NS | NS | NS | NS | NS | NS |

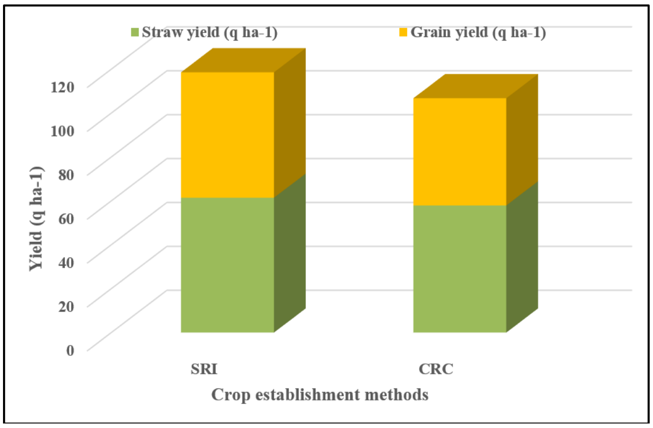


**Fig 1:** Crop yield as influenced by methods of crop establishment

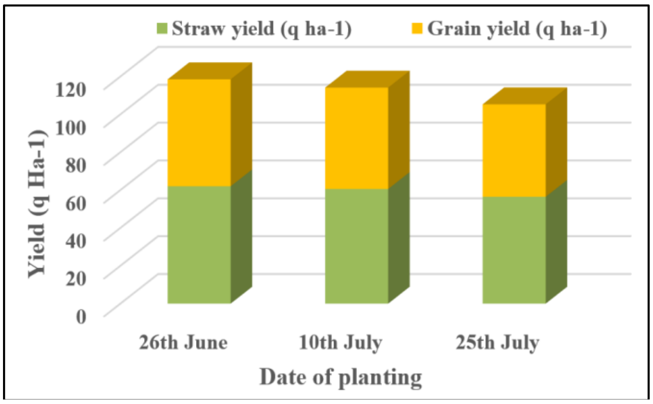


**Fig 2:** Crop yield as influenced by Dates of transplanting

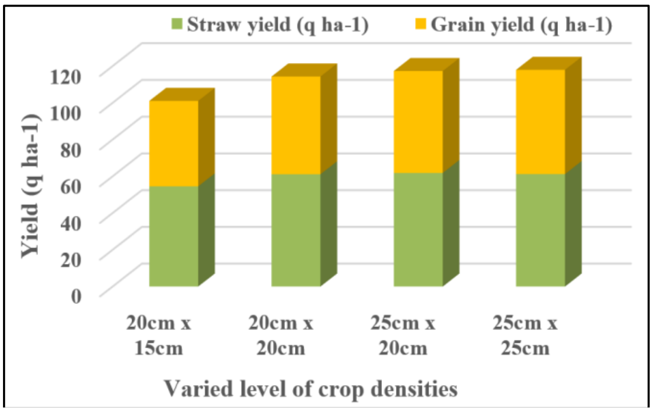


**Fig 3:** Crop yield as influenced by various levels of crop densities

### Effect of levels of crop density

The significant influence of crop density towards yield performance is shown in Fig.3. Among different levels of crop densities, the significantly highest grain yield was recorded under the lowest crop density (25 cm x 25 cm). However, comparable result was found under 25 cm x 20 cm and 20 cm x 20 cm but the closest one registered the significant lowest value which might be due to increased competition for growth resources negatively affecting the growth and yield attributes. Improvement of yield under wider hill density was recorded by many (Chakrabortty, *et al* 2014*;* Kalita, *et al* 2023, Kalita *et al* 2024) [3, 9, 10].

## Conclusion

The two consecutive years of field investigation revealed that improved absorption and subsequent yield enhancement of sali rice in Inceptisol of Assam could be achieved by creating a favourable crop environment through wider transplanting of individual seedlings at 25 cm x 25 cm apart, following the SRI method of crop establishment. This approach, implemented as early as 26th June found to be more effective.

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