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RESEARCH ARTICLE

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Effect of row spacing of Rice transplanter on seedling requirement and grain yield

Abstract:
This study was conducted in the farmer's field during late boro season (2016) in two villages under Rangpur sadar upazila in Rangpur district of Bangladesh to evaluate the effect of wider spacing of mechanical rice transplanter on the seedling tray requirement and grain yield. The two high yielding rice varieties namely BRRI dhan28 and BRRI dhan48 were transplanted in the farmer's field by mechanical rice transplanter and compared with hand transplanting. Seedlings density was reduced at the seed rate higher than 145 gm tray^{-1} indicating higher seed rate increased the seedlings mortality. Seedlings mat prepared by the farmers were varied in seedling height, density and color due to management skill of the respective farmer and irrigation facility in different locations. Seedlings of one square meter area in tray can transplant 331 square meter area in the field. The varietal difference caused variation of the seedlings density in tray. The rice variety BRRI dhan28 was more preferable to the farmers because of color, density and height of the seedlings in trays. Root formation was better in BRRI dhan48 than BRRI dhan28 and number of seedlings per tray was varied in the same nursery due to variation in germination. Soil settlement in immediately puddled soils influenced the plant to plant spacing. The distance between plants determined the tray requirement in a transplanting operation and controlled by the space setting options depending on the seedlings density in trays. Crop establishment in the field was denser in plots transplanted in the same day (≤6 hrs) of puddling than after one day (<24 hrs). Actual plant spacing setting by machine could not be maintained in the field due to variation of soil type, puddle condition, soil settling time, plow pan and water height. Seedling tray requirement depended on the space setting adjustment and seedlings dispensed per hill in the field. The tray requirement was reduced with higher space setting. Irrespective of space settings in the transplanter, mechanically transplanted rice produced the higher grain yield than the hand transplanted rice. These findings revealed that wider spacing of mechanical transplanter (30 cm) along with tender seedlings helped to increase the grain yield.
Keywords: Tender seedlings, plant space setting, tray requirement, grain yield

Introduction:

Bangladesh produces 50 million metric tons of rice (*Oryza sativa* L.) in 11.27 million hectares of land (80% of the total cultivable land) to feed the 160 million people (Kabir *et al.* 2016a). The average cleaned rice production was 3.71 ton per hectare. The population is increasing at an alarming rate and expected to reach 215.4 million within 2050 (Kabir *et al.* 2016b). The nation has to grow more food to meet the demand of growing population. The cultivable land is decreasing at the rate of 0.40% due to expansion of non-agricultural activities such as consturction of housing, factory, office building etc (The Daily Prothom Alo 2015). Agriculture is becoming less attractive and rural youths are not interested to work in this sector rather they prefer to work in service sectors. Therefore, farmers face acute labor shortage in transplantig period. It was reported that delay in transplanting reduced the rice yield of 60, 55 and 9 kg ha^{-1} day^{-1} in the boro, aman and early wet (aus) seasons, respectively (Satter, 1999). Further, due to rapid industrialization and migration to urban areas, the availability of labor became very scarce and with hike in the wages of labor, manual transplanting found costly leading to reduce profits to the farmers. To keep economical consistency over the shifting of manpower from agriculture to service and industry, it requires filling up the labor gap in agricultural operations by mechanical interventions (Islam *et al.*, 2016a). Mechanical transplanting in rice cultivation is being practiced around world for row crop establishment as it allows the use of mechanical weeder and other intercultural operation. In Bangladesh, mechanical transplanting performed satisfactorily by four-row transplanter in small scale at different locations (Islam, 2016). Manual transplanting required 123-150 man-hr ha^{-1} and it would take only 9-11 man-hr ha^{-1} for mechanical transplanting by four-row walking transplanter (Islam *et al.*, 2016b).

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Mechanical transplanting improves labor efficiency, ensures timeliness in operation, faster transplanting and attains optimum plant density that contributes to high productivity (Islam *et al.*, 2016 and Manjunatha *et al.*, 2009). Seedlings raising is a crucial part of mechanical transplanter. Farmers do not know how to raise seedlings suitable for mechanical rice transplanter. Transplanting of tender seedlings by transplanter avoiding root damage is very much essential for better anchorage of the seedlings and better absorption of nutrients and result higher number of bearing tillers per hill and less mortality rate of side tillers was noticed in 20 days old seedling (Vasudevan *et al.*, 2014). Sang-Su *et al.* (1999) transplanted three rice cultivars with 3 different seedling age to investigate their growth habits and observed that the 10 days old seedlings had more vigorous elongation of plant height and higher tillering ability but lower effective tiller rate, when compared with 35-day or 40-day old seedlings. Aswini *et al.* (2009) reported that 20 day old seedlings were most suitable for all the transplanters under their study. Highest numbers of effective tillers per hill were produced with seedling of 10 days old (Partha *et al.*, 2011). BRRI recommended the plant spacing of 25 ×15 and 20 × 20 cm for boro season (BRRI, 2017). In mechanical transplanter, the spacing between row to row was more than the recommended one as mentioned in BRRI. However, plant to plant spacing can be varied by adjusting the space setting in transplanter. There is a lack on the information of plant spacing of mechanical rice transplanter on the yield attributes of transplanted rice in Bangladesh condition. It was hypothesized that row spacing (30 cm) of mechanical transplanter could reduce the grain yield. Therefore, the present study was undertaken to evaluate the effect of plant to plant spacing in wider row spaced (30 cm) mechanical rice transplanter on the yield of transplanted rice.

Materials and Methods:

This experiment was conducted in the farmers' field during late boro (January-May) 2016 season (dry winter from February to June) in two villages of Ghaghatpara and Kaliganjpara under Rangpur sadar upazila in Rangpur district. The texture in both locations represented loamy soil (Sand: 36.53-50.56%; Silt: 39.35-48.62%; Clay: 10.09-14.85%). The chemical properties of the soil were pH: 5.26-5.30; OM (%): 1.81-2.21; N (%): 0.079-0.097; P (µg/g): 22.50-25.85; K (meq/100g): 0.089-0.102; S (µg/g): 10.28-11.39. The cropping system in the study areas was potato-late boro (March-August)-aman (July to November). The study area lies under AEZ-3 (Tista Meander Floodplain). The climate of this region is of tropical dry and wet type. The average annual rainfall is 2931 mm. The average temperature ranges from 11ºC to 32ºC. The high yielding rice varieties BRRI dhan28 and BRRI dhan48 having good germination were used to raise seedlings in plastic trays (58 × 28 × 2.5 cm). Seedlings were raised in plastic trays for machine transplanting and in traditional seedbed for hand transplanting by the respective farmer. Viable seeds were chosen by specific gravity method. Seeds were immersed in water for 24 hrs and placed in gunny bags. The seeds were started to germinate within next 48 hrs and sown after 72 hrs. Dry soil was sieved and poured in tray after removing stone, stubble and grasses. Sprouted seeds were distributed uniformly on the soil. Water was applied twice a day until complete seed emergence. Mats were ready to transplant when seedlings attained 2-3 leaves and 10-12 cm height. For manual transplanting, pre-germinated seeds were sown on the seed bed. Other management practices were done as of BRRI recommended practices (2017).

During transplanting time by transplanter, sufficient water should be available in the field. Excessive water height increased the floating hill during transplanting. If soil is not properly soaked, the mud sticks with the wheels and difficult to maneuver the transplanter machine. Water height was maintained 1-2 cm for proper anchorage of the seedlings and easy to maneuver the machine. A four-row walking type rice transplanter (model DP488) was used to perform transplanting. This machine featured ten seedlings density setting, six depth control options and six seedlings interval (12.5, 14.0, 16.0, 18.5, 20.0, 21.5 cm) control. Transplanting depth, spacing and density were calibrated before proceeding to the main operation to obtain desire output in field. Fifteen-day and thirty-day old seedlings were transplanted by mechanical and manually, respectively.

Seeding rate (gm tray^{-1}), age of seedlings, space setting, depth of puddling and height of standing water were adjusted before transplanting. Seedling density in tray was measured by placing a 2.54 × 2.54 cm square loop in the tray and number of seedlings contained by the loop were counted and converted to seedlings density per square meter. Data on grain yield were recorded from 54 farmer's plots among which 40 plots were transplanted by transplanter and the rest were manually transplanted as control plots. Rice grain yield per plot was recorded from a 10 m^2 harvest area and adjustment to 14% moisture content. Data were analyzed using MS-Excel 2013 and presented in tabular and graphical form.

Results and Discussion:

Calibration of rice transplanter for yield maximization:

Seedling rate in tray:

Seed rate applied by the respective farmers was ranged from 125 to 150 gm tray^{-1}. Seedlings density depended on the seeding rate, germination and uniform placement of seed during tray preparation. Seedlings density followed increasing trend with the increase in seed rate up to 145 gm tray^{-1} (Fig. 1). Seedlings mortality increased in higher seed rate and reduced the seedling density in seedling tray (Hossen, 2016). The amount of seed used in tray preparation varied depending on the variety and germination rate. Seed rate was also varied from one farmer to another due to farmer's perception. Amount of seed used per tray by different farmers had direct influence on the seedlings density obtained per tray and consequently tray requirement in the field. Islam *et al.* (2015) mentioned that tray requirement, number of seedlings dispensed per stroke and missing hill during transplanting operation were subjected to the seed rate and uniformity of seedlings establishment.

Seedlings density in seedling tray:

Seedlings mat prepared by the farmers varied in height, density and color due to management skill of the respective farmer and irrigation facility in different nurseries. Seedlings height at 15-20 DAS (Days after seeding) was varied in 10-15 cm, color ranged from yellowish green to light green and the seedling number in tray ranged between 3000-5000. About 4000-4500 numbers of seedlings were observed in 66% trays (Fig. 2). Seedlings density less than 3000 seedlings tray^{-1} caused excessive missing hills in previous experiments and hence rejected before use. Color of the seedlings depended on the application of irrigation water to the seedlings trays. Farmers used ponds, low lying areas, drainage channels and plots having 2 cm standing water as nursery management. The quality of seedlings in trays could be improved by accelerating diffusion of mechanical transplanting technology through extension programs and repeated practice session.

Effect of seedlings interval setting on seedling requirements:

Seedlings interval setting remarkably influences the tray requirement. At space setting of 21.5 × 30 cm, one square meter of seedlings area could transplant 331 square meter areas in the field followed by 310 square meter for 20 × 30 cm and 301 square meter for 18.5 × 30 cm (Fig. 3). It indicated that tray requirement decreased with the increase in space setting.

Seedlings dispensed in each stroke:

The varietal difference caused variation of the seedlings density in tray which consequently affected the rate of seedlings dispensed per stroke indicated the increase in seedling tray requirement (Fig. 4). Islam (2016) stated that the main objectives of mechanical transplanting are to faster in operation and avoid missing hill. Therefore, seedlings density setting should be adjusted to avoid the missing hill. At the same seedlings density setting, higher seedlings density in tray for BRRI dhan28 caused more seedlings dispensed per stroke than that of BRRI dhan48. Wide range of variations in seedlings dispensed per stroke was observed in the field. Among the two varieties, BRRI dhan28 was more preferable to the farmers because of color, density and height of the seedlings in trays. Root formation of BRRI dhan48 was better than BRRI dhan28 and number of seedlings per tray was varied in the same nursery due to variation in germination.

Plant to plant spacing:

Plant spacing is the major driving factors affecting productivity. The distribution of plant to plant spacing in mechanically transplanted plot is presented in Fig. 5. Transplanter was operated in three space setting (18.5, 20.0 and 21.5 cm). In actual field condition, plant spacing was not confined on the setting value due to slippage and skidding of the transplanter. Soil settlement in puddled soils also influenced the plant to plant spacing. The distance between plants determined the tray requirement in a transplanting operation and controlled by the space setting options depending on the seedlings density in trays. In mechanically transplanted plots, plant to plant spacing was obtained between 17-20 cm which was depended mostly on soil type, soil settling time, water height and depth of puddling. In manually transplanted plots, plant spacing varied from 27 × 25 cm.

Hill density:

The number of hills obtained in the transplanted field was affected by the plant to plant space setting and puddled condition (Fig. 6). Crop establishment in the field was denser in plots transplanted in the same day (≤6 hrs) of puddling than after one day (<24 hrs), perhaps due to slippage of the wheels. Both the plant to plant and line to line spacing contributed to hill density in the field. Achievement of proper hill density affected the plant growth, tiller formation and yield. Hill density achieved by three spaces setting in rice transplanter was mostly around 17 hills m^{-2} in a range of 16-19 hill m^{-2} (Fig. 7). On the other hand, hill density in manually transplanted plots was at least 15% less than the mechanically transplanted plots (Fig. 7).

Grain yield influenced by rice transplanter:

Effect of plant spacing on grain yield:

Grain yield is a function of inter play of various yield components such as number of productive tillers, spikelets panicle^{-1} and 1000 grain weight (Partha and Haque, 2011). The line to line spacing was fixed to 30 cm and plant to plant spacing can be varied in mechanical transplanter. During transplanting, three seedlings interval setting (18.5×30, 20×30 and 21.5×30 cm) was applied from space setting panel of the transplanter. Yield data of those plots in respect to space setting were compared with manually transplanted rice. It was observed that yield was slightly increased with the increase in plant to plant space setting (Fig. 8). El-Kassa by *et al.* (2012) conducted field experiment on plant density and seedlings age on two cultivars in Egypt and observed that the highest values of all traits were recorded when using Egyptian Hybrid1 cultivar, youngest seedlings age (15 day old) and widest spacing between hills (30 × 30 cm). On the other hand, the lowest values were recorded when using Giza 178 cultivar, the oldest seedlings age (25 day old) and closest spacing between hills 20 × 20 cm. The yield variation was occurred not only by the variation of spacing as there were many other factors (e.g. seedlings quality, post transplanting crop nourishment, insect infestation, etc.). Plant spacing set by machine could not be maintained in the field due to variation of soil type, puddle condition, soil settling time, and plow pan and water height. Data on actual plant spacing was collected immediately after transplanting from each field and corresponding yield data was recorded after harvesting (Fig. 9). In BRRI dhan28, yield variation was observed among different plant to plant spacing. However, in BRRI dhan48, yield variation showed inconsistent due to variation of plant spacing.

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The seedlings age was higher in traditional than mechanically transplanted rice. The existing spacing seemed to be higher than the BRRI recommended spacing of 25 ×15 cm. It was observed that tillering ability was higher in tender age seedlings and more spaces were required to flourish. Pasuquin *et al.* (2008) reported that tiller production could be optimized by transplanting seedlings at younger ages. The maximum number of tillers produced by the rice plant was inversely proportional to the length of the phyllochron (Katayama, 1951; Nemato *et al.*, 1995), which was depended upon the extent of stresses. Wider spacing, availability of solar radiation, medium temperature, soil aeration, and nutrient supply promoted shorter phyllochrons which increased the number of tillers in the rice plant (Anonymous, 2004). The observation results supported that there was no yield penalty on the use wider row spacing (30 cm) and plant to plant space setting in mechanically transplanted rice. Of course, there must have boundary limit of plant spacing on grain yield. From commercial point of view, it was very much important to reduce the seedlings tray requirement in each area of transplanting to make the business venture profitable. Use of higher spacing within the boundary limit reduced the seedlings tray requirement in mechanical transplanting (Islam *et al*., 2015).

Effect of transplanting method on grain yield:

Among the different factors responsible for realizing potential yield of rice, the transplanting time, method and seedlings age at the time of transplanting are important non-monetary inputs. Seedlings age at transplanting is an important factor for uniform stand of rice (Paddalia, 1980). Mechanically transplanted rice produced 4-6% higher grain yield than the hand transplanted rice for both the variety due to use of tender aged seedlings (Fig. 10). This result is in accordance with the findings of Islam (2016) and Islam *et al.* (2016b). Makarim *et al.* (2002) stated that the performance of tender aged seedlings showed better than older seedlings. Tillering influenced the panicle intensity as well as grain yield of rice (Quyen *et al.*, 2004). McHugh *et al.* (2002) and Thiyagarajan *et al.* (2002) observed that 8-15 day and 10-day old seedlings transplanted at 25 hills m^{-2} showed the highest grain yield in Madagascar and Sumatra. Krishna and Biradarpatil (2009) observed high grain yields of 3.25 t ha^{-1} with 12-day old seedlings than 8-, 16- and 25-day old seedlings and the yield decline of seedlings of latter three ages was primarily attributed to the reduction in the number of tillers. Younger seedlings could relieve the transplanting stress in a shorter period of time compared to that of older seedlings due to the higher nitrogen content in the former (Yamamoto *et al.*, 1998), and the plants' ability to faster resumption of the rate of phyllochron development (Anonymous, 2004).

Conclusion:

Wider row spacing of mechanical transplanter and use of tender seedlings showed positive effect on the grain yield. However, the use of 30 cm row spacing reduced the tray requirement which contributed to reduce the cost of raising seedlings in tray. These findings revealed that the use of tender seedlings in rice transplanter helped to increase the grain yield over the aged seedlings in manually transplanted rice.

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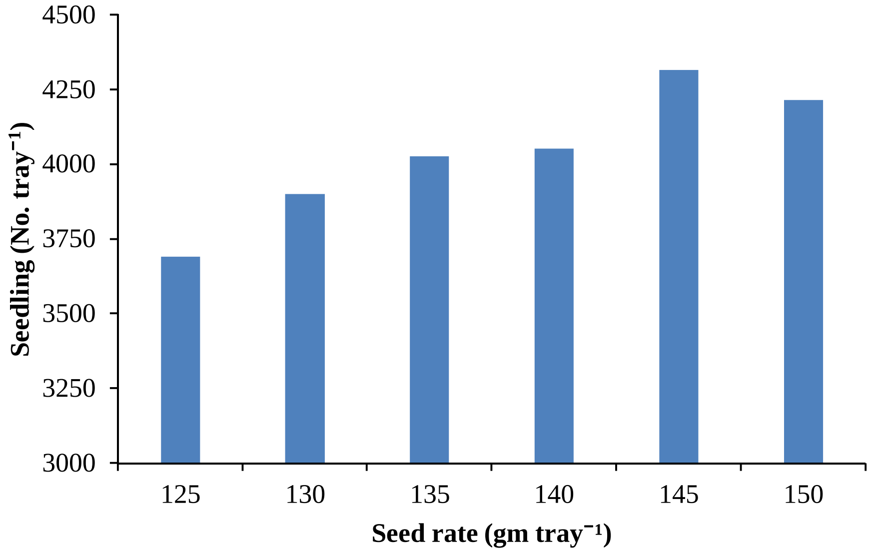

Figure 1. Effect of seed rate on seedling density in seedling tray.

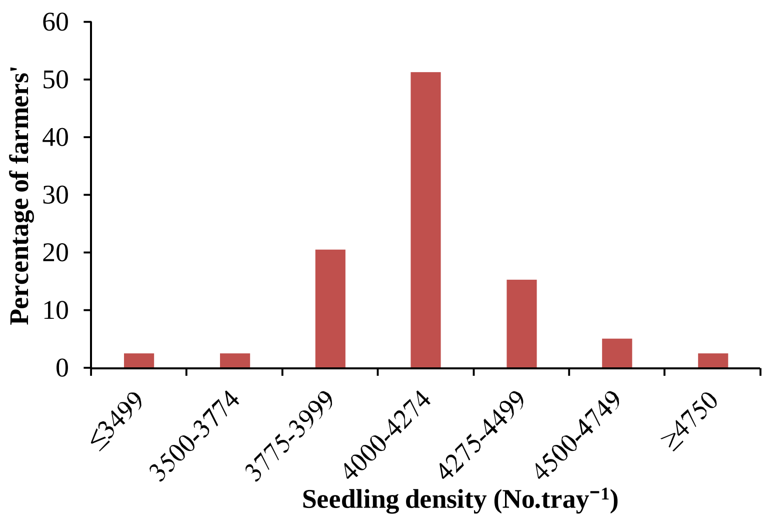

Figure 2. Seedling density in farmers' managed tray.

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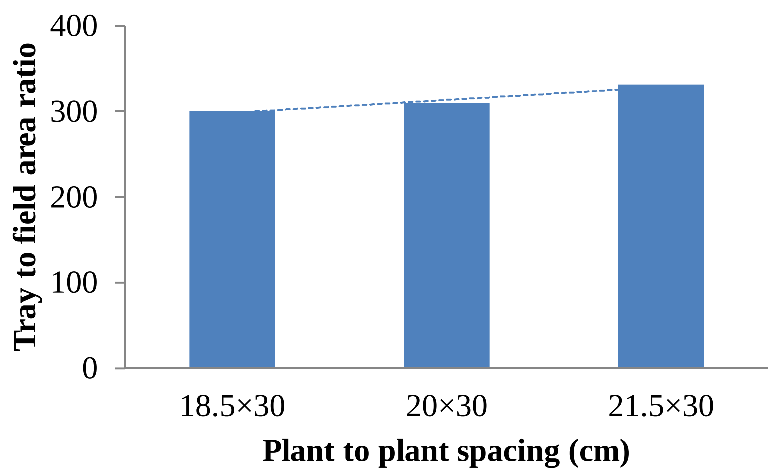

Figure 3. Effect of space setting of rice transplanter on field area coverage by seedling mat.

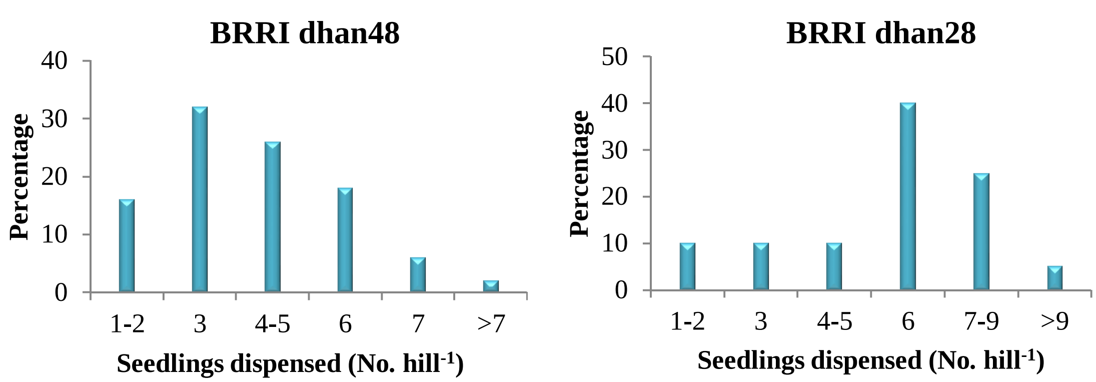

Figure 4. Seedlings dispensed in each stroke during transplanting.

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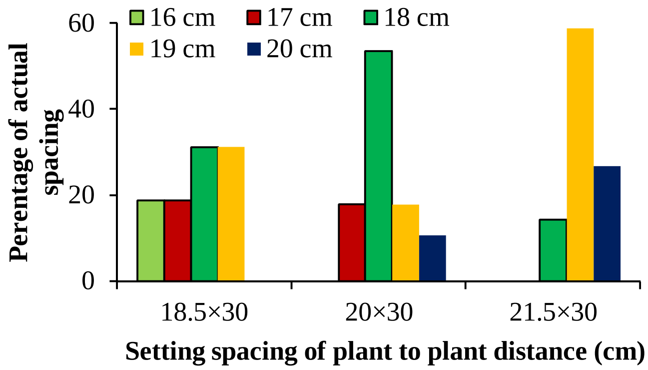

Figure 5. Relationship between spaces setting of rice transplanter and actual plant to plant distance in field.

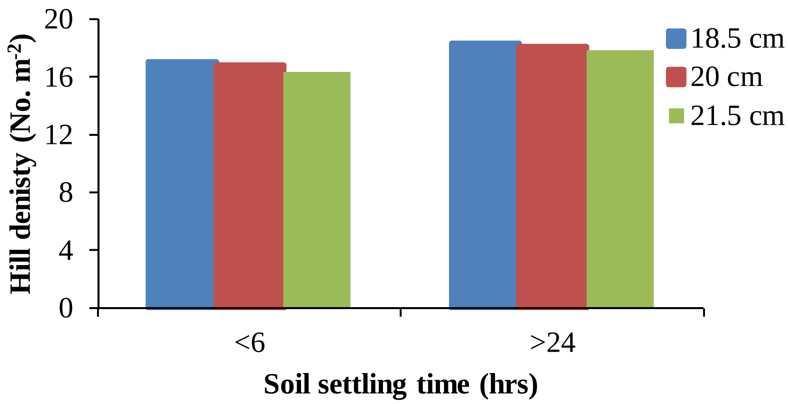

Figure 6. Hill density with respect to soil settling time.

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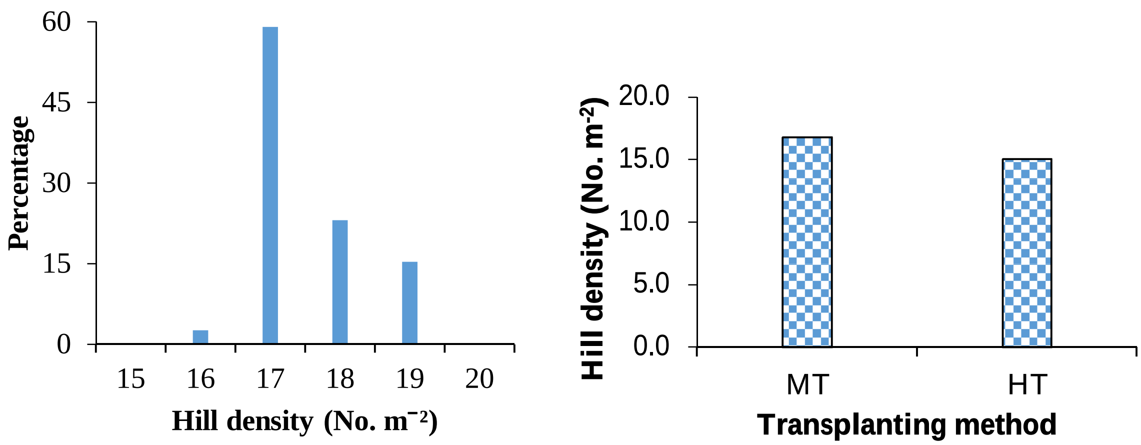

Figure 7. Hill density in mechanical and manual transplanted plots.

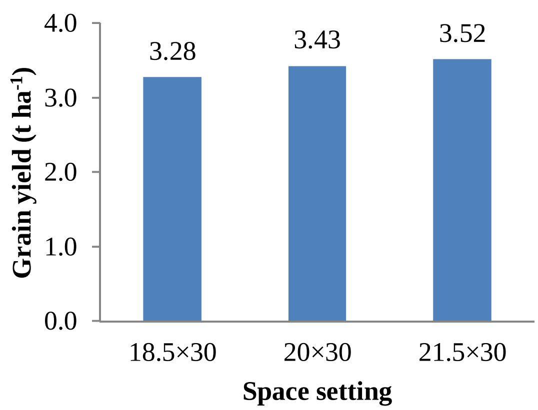

Figure 8. Effect of seedlings interval setting on grain yield.

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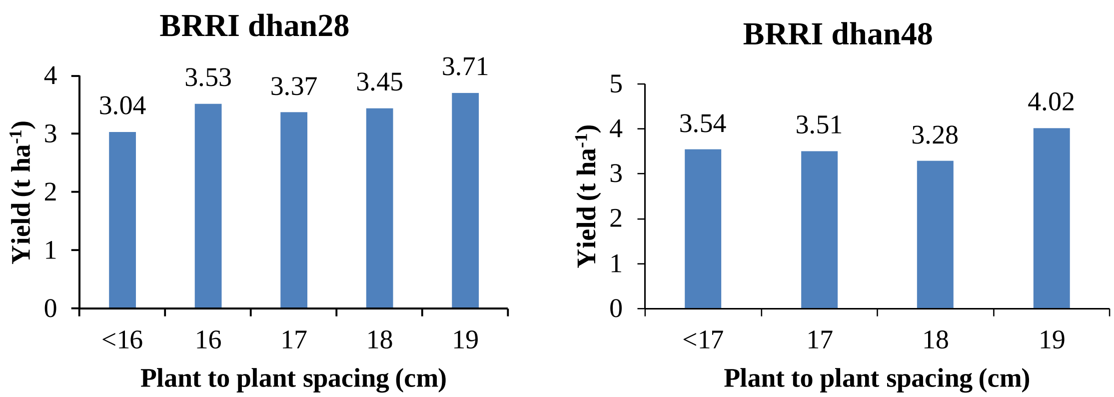

Figure 9. Effect of plant spacing on grain yield.

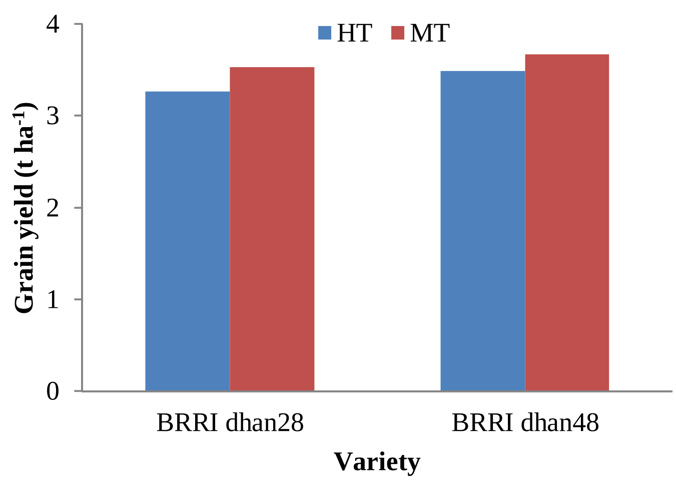

Figure 10. Comparative yield advantages of mechanically and hand transplanted rice.

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