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Yield response of aman rice to transplanting geometry and seedlings per hill in South-western Coastal soil of Bangladesh

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Key words: Plant spacing, Seedlings, Aman rice, Coastal region, Growth, Yield

Abstract

In a condition of limited scope of horizontal yield expansion, rice yield can be increased by efficient utilization of land through proper transplanting arrangement with maximum number of plant population unit^{-1} area. Thus, the present experiment was conducted in the farmer's field at Batiaghata upazila of Khulna district, Bangladesh during T. *aman* season (Jul-Nov) to evaluate the effect of transplanting geometry and number of seedlings hill^{-1} on growth and yield of aman rice (Binadhan-7, a short duration variety of its' early harvest can create opportunity to cultivate winter crops in this region). The experiment had four types of transplanting geometry (single row rectangular system, single row triangular system, double row rectangular system and double row triangular system) and three levels of seedling hill^{-1} (3, 4 and 5 seedlings) with three replications. The results showed that individually transplanting geometry or number of seedlings hill^{-1} had substantial influence on yield attributes and yield but their interaction effect had non-significant influence on almost all measured parameters except number of tillers and effective tillers hill^{-1}. The maximum grain yield (5.6 t ha^{-1}) was achieved from double row triangular system yet the highest plant height, effective tillers hill^{-1}, grain panicle^{-1}, 1000 grain weight and straw yield were obtained from single row triangular system. In case of seeding hill^{-1}, 3 seedlings hill^{-1} produced the highest grain yield (5.33 t ha^{-1}) plant height, effective tillers hill^{-1}, grain panicle^{-1}, 1000 grain weight and straw yield. It can be concluded that double row transplanting geometry with 3 seedlings hill^{-1} can utilize the land efficiently for grain yield and be recommended for cultivation of Binadhan-7 in the coastal region of south-western Bangladesh.

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Introduction

Rice is the most widely cultivated cereals and the people of Bangladesh depend on rice as staple food which has a tremendous influence on agrarian economy. The total area and production of rice in Bangladesh are 11.45 million hectares and 34.5 million tons, respectively, per year (BBS, 2015). Due to the high population pressure, urbanization and industrialization the total cultivable land area has been continuously declining at the rate of more than 1% per year (Shelley *et al.*, 2016). There is no opportunity to increase the cultivable land hence the rice production area; much of the additional rice demand (in future) will have to come from higher average yield on existing land. The national average yield of rice in Bangladesh is very low (3.04 t ha^{-1}) compared to that of other rice growing countries (FAO, 2009). Horizontal expansion of rice area, rice yield per unit area should be increased to meet this ever-increasing demand of this staple food in the country through the adoption of improved management practices. Among the management practices transplanting geometry and appropriate number of seedlings $hill^{-1}$ are important.

Plant spacing directly affects the normal physiological activities through intra-specific competition (Oad *et al.*, 2001). Inappropriate arrangement of rice hill reduced yield up to 20-30% (IRRI, 1997). When the planting density exceed the optimum level (closer), competition among plants for light and nutrients becomes severe and consequently restrict the plant growth and declines the grain yield. On the other hand, wider space allows the individual plants to more radiant energy, nutrients and water that facilitates better growth, produce more tillers but minimize the number of hills per unit area which results in lower grain yield (Baloch *et al.*, 2002; Vijayakumar *et al.*, 2004; Gozubenli, 2010; Kandil *et al.*, 2010). The optimum spacing ensures the plant to grow properly in their aerial and underground parts through efficient utilization of solar radiation and nutrients (Khan *et al.*, 2005). Number of seedlings $hill^{-1}$ is an important factor that influence plant population $unit^{-1}$ area, availability of sunlight and nutrients, photosynthesis and respiration, which ultimately influence the yield (Chowdhury *et al.*, 1993). Optimum number of seedlings $hill^{-1}$ may facilitate the rice plant to grow properly both in the aerial and below ground parts by better utilization of solar energy, nutrient, space, water and also minimize seedling cost.

The southwestern region holds an environment different from other parts of Bangladesh. T. aman is the only crop in this area and rest of the time land remains fallow. Most of the farmers in southwestern coastal region prefer to cultivate long duration, low yield potential local aman rice varieties with traditional cultivation practices (Mondal *et al.*, 2004). The yield of rice can be increased by improved agronomic management practices such as maximum utilization of land with optimum number of plant population per unit area by adjusting transplanting geometry, suitable number of seedlings per hill. Proper transplanting geometry provide better space and accommodate more number of hills per unit area than usual that may considerably influence the yield. Cultivation of HYV aman (Binadhan-7) rice with proper management may facilitate to vacant the land earlier and create a window of cultivating winter crops (otherwise the vast land area remains fallow) (Kabir *et al.*, 2019; Bell *et al.*, 2019) along with the better yield that improve the socio-economic condition of the farmer's in this region. Therefore, the present study was conducted to evaluate the effect of transplanting geometry and seedlings $hill^{-1}$ on growth and yield of HYV aman rice (Binadhan-7) in the coastal zone of southwestern Bangladesh.

Materials and methods

Experimental site

The experiment was conducted in farmer's field at Hogladanga village of Batiaghata, Khulna, Bangladesh during the period from July to November 2016 (T. *aman* season). The site of the experiment was located at 22°73' N latitude and 89°52' E longitude with an altitude of 5m above the sea level in the Gangetic Tidal Floodplain (*AEZ-13*). The study site was medium highland with clay-loam soil texture and neutral in pH.

Experimental design and treatment

The factorial experiment consisted of four transplanting geometry (*viz,* T_1= Single row with rectangular system, T_2= Single row triangular system, T_3= Double row rectangular system and T_4= Double row triangular system) and three levels of seedlings (S_1= 3 seedlings hill^{-1}, S_2= 4 seedlings hill^{-1} and S_3= 5 seedlings hill^{-1}). The experiment was arranged in randomized complete block design and replicated thrice. The size of the unit plot was 10m^2 (4cm x 2.5cm) and the spacing between replication to replication was 1.0m and plot to plot was 0.75m. Row spacing in single row system was 20cm and in double row system was 20-10-20cm maintaining 15cm hill to hill spacing in both single and double row systems (Fig. 1). Numbers of transplanted hills plot-1 were varied from 39 to 50 due variation of transplanting geometry (Fig. 2).

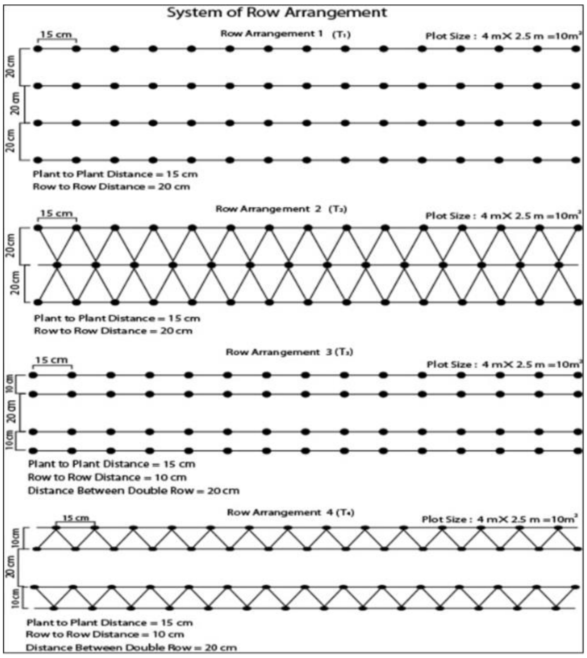

Fig. 1. Planting geometry with plant to plant and row to rows spacing (T_1= single row rectangular system, T_2= single row triangular system, T_3= double row rectangular system and T_4= double row triangular system).

Field and crop management

The sprouted seeds of Binadhan-7 (planting material) were sown in the seed bed. The main field was prepared by ploughing and cross ploughing followed by laddering. The field was free from weeds and stubbles before transplanting of seedling. Urea, TSP, MoP, Gypsum, Zinc Sulphate fertilizers were as used as the source of N, P, K, S and Zn and the entire amount (except urea) was applied during the final land preparation. Urea was applied in three equal splits 10, 25 and 40 days after transplanting (DAT). 25 days old healthy seedlings were carefully uprooted and transplanted as per the treatments. An intercultural operation (gap filling, weeding, plant protection etc.) was done as and when necessary. The crops were harvested at full maturity when >80% grain turn into golden yellow in colour.

Sampling and data collection

Five hills from each plot excluding the border rows were randomly selected for data collection (plant height, tiller hill^{-1}, effective tiller hill^{-1}, panicle length, grain panicle^{-1}, sterile grain panicle^{-1} and 1000 grain weight). For yield calculation 4m^2 (2.0m x 2.0m) areas were selected from the center of the each plot. After that grains from the respective plot were threshed, cleaned and sun dried at 14% moisture content. The straw also sundried properly. Finally the grain and straw from each plot was measures and converted to t ha^{-1}. Data on total dry matter and harvest index were calculated from the recorded grain and straw yield.

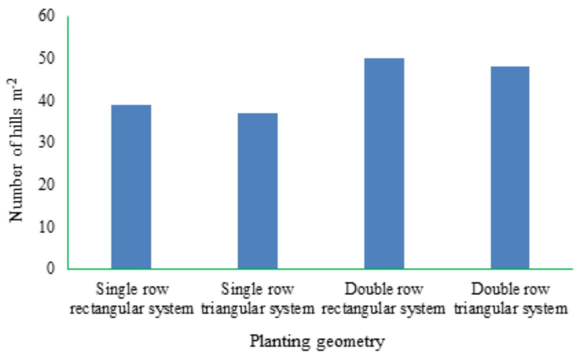

Fig. 2. Accommodate in different planting geometry.

Statistical analysis

All the collected and recorded data were compiled and statistically analyzed following analysis of variance technique (two-way ANOVA) with the help of 'Statistix-8' a statistical package. The treatment means were compared and adjusted by Duncan's New Multiple Range Test (DMRT) (Gomez and Gomez, 1984).

Results and discussion

Plant height

Transplanting geometry had significant influence on plant height (Fig. 3A). Single row triangular system produced the tallest plant (97.92cm) which was statistically at par with single row with rectangular system, the shortest plant (87.85cm) was found in double row rectangular system. Number of seedlings hill^{-1} had no significant effect on plant height (Fig. 3B). Plant height also non-significant due to the interaction effect of transplanting geometry and seedlings hill^{-1} (Fig. 3C).

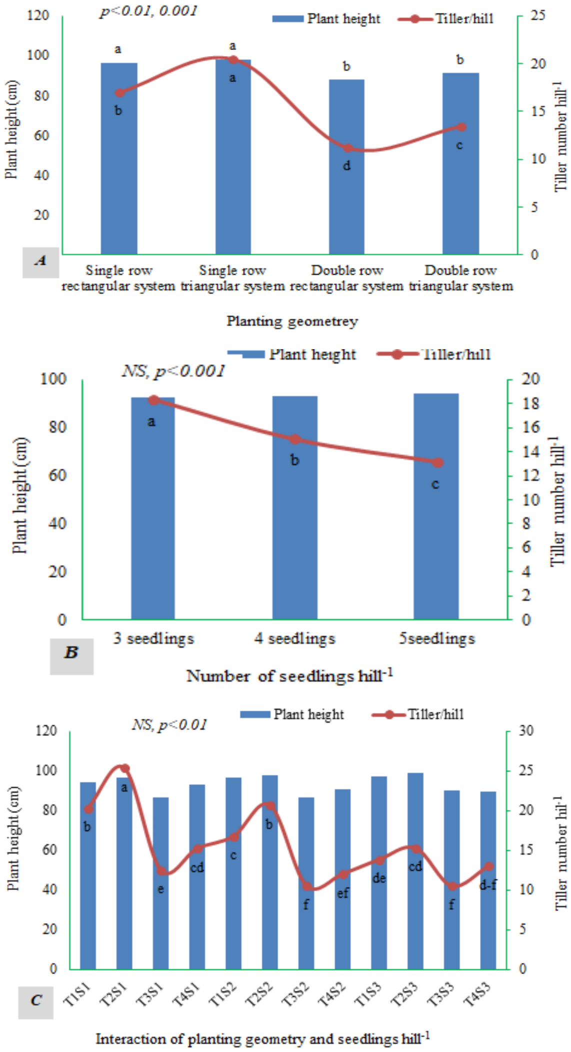

Fig. 3. Effect of planting geometry (*A*), number of seedlings hill^{-1} (*B*) and their interaction (*C*) on plant height and tiller number hill^{-1} of Binadhan-7 grown in the coastal region of southwestern Bangladesh.

T_1= Single row rectangular system, T_2= Single row triangular system, T_3= Double row rectangular system and T_4= Double row triangular system

S_1= 3 seedlings hill^{-1}, S_2= 4 seedlings hill^{-1} and S_3= 5 seedlings hill^{-1}

In the single row arrangement, the number of hill unit^{-1} area was minimum compared to that of double row arrangement as a results plants got more space (both aerial and below ground) which might stimulate the growth of plant and enhance plant height. In addition transplanting in triangular system each hills got more space and light than rectangular system that facilitates better growth. Usually less irradiance than that of optimum makes the plant taller. The results of this study are in agreement with the findings of Miah *et al.* (1990) and Alam *et al.* (2012) who reported that plant height affected significantly by spacing.

Number of tiller hill^{-1}

Tiller number hill^{-1} varied significantly with the transplanting geometry (Fig. 3A). Maximum number of tiller hill^{-1} (20.5) was recorded from single row triangular system whereas the minimum (11.2) of that was obtained from double row rectangular system. Number of tiller hill^{-1} substantially decrease with the increase of number of seedlings hill^{-1} (Fig. 3B). Three (3) seedlings hill^{-1} produced the maximum number (18.4) of tiller hill^{-1} while the minimum (13.18) was recoded from 5 seedlings hill^{-1}. Tiller number hill^{-1} was varied significantly by the interaction of transplanting geometry and seedlings hill^{-1} (Fig. 3C). Single row triangular system with 3 seedlings hill^{-1} produced the maximum number of tiller hill^{-1} (25.4) while the minimum (10.53) was found in double row triangular system with 5 seedlings hill^{-1}. Plants acquire more sunlight and air if they grow in wider spacing and can generate more tillers whereas lessens the tillers with closer spacing. Similar findings also reported by Barua *et al.* (2014) that significant variation was observed in the interaction effect of spacing and number of seedling hill^{-1} on number of number of tiller hill^{-1}.

Effective tiller hill^{-1}

Effective tiller hill^{-1} was significantly affected by the transplanting geometry (Table 1). Single row triangular system produced the highest number (18.5) of effective tillers hill^{-1} and the lowest number (10.8) was recorded form double row rectangular system. Various number of seedlings hill^{-1} had significant effect on number of effective tiller hill^{-1} (Table 1). The highest number (16.6) of effective tiller hill^{-1} was achieved from 3 seedlings hill^{-1} and the lowest (12.41) was obtained from 5 seedlings hill^{-1}. The interaction effect of transplanting geometry and seedlings hill^{-1} had significant influence on number of effective tiller hill^{-1} (Table 2). Single row triangular system with 3 seedlings hill^{-1} produced the highest number (22.0) of effective tiller hill^{-1} while the lowest number (10.20) was found in double row rectangular system with 5 seedlings hill^{-1}. Number of effective tillers decreased with the increase in number unit^{-1} area. Single row triangular system gets enough space than other system that facilitates to produce more effective tillers hill^{-1}. The results also supported by Sarkar *et al.* (2011) and Dutta *et al.* (2003). On the other hand effective tillers decreased with the increased of seedling number hill^{-1}. The results are in agreement with Paul *et al.* (2002) who reported that 2 seedlings hill^{-1} produced the maximum effective tiller hill^{-1}. Results regarding effective tillers hill^{-1} indicated that at closed spacing almost at the tillers were effective while at wider spacing all the tillers were not effective (non-bearing tillers hill^{-1} were more in wider spacing) yet wider spacing had higher number of tillers and effective tillers hill^{-1}.

Table 1. Individual effect of planting geometry and seedlings hill^{-1} on yield attributes of T. *aman* rice (Binadhan-7) grown in the coastal region of southwestern Bangladesh.

Treatments	Effective tillers hill^{-1}	Panicle length (cm)	Grain panicle^{-1}	1000 grain weight (g)	Harvest Index (%)
Planting geometry					
Single row rectangular system	15.45b	19.79ab	62.51b	21.27b	49.04b
Single row triangular system	18.53a	20.49a	70.25a	23.42a	50.28ab
Double row rectangular system	10.77d	18.28c	53.37c	18.94d	50.43ab
Double row triangular system	13.00c	19.37b	60.45b	19.98c	51.54a
SE (±)	0.77	0.37	1.28	0.70	0.69
Significance level	***	*	***	***	*
Seedlings hill^{-1}					
3 seedlings	16.58a	20.53	68.55a	22.45a	51.19a
4 seedlings	14.35b	19.87	61.41b	20.55b	50.40ab
5 seedlings	12.41c	20.28	54.96c	19.71c	49.38b
SE (±)	0.67	0.32	1.11	0.29	0.59
Significance level	***	*	***	***	*
CV (%)	11.44	3.89	4.42	3.40	2.92

***, ** and * indicate significant at 0.1%, 1% and 5% level of significance respectively. Fig. in a column having same letter do not differ significantly whereas Fig. having dissimilar letters differ significantly as per DMRT.

Table 2. Interaction effect of planting geometry and seedlings hill^{-1} on yield attributes of T. *aman* rice (Binadhan-7) grown in the coastal region of southwestern Bangladesh.

Interaction	Effective tillers hill^{-1}	Panicle length (cm)	Grain panicle^{-1}	1000 grain weight (g)	Harvest Index (%)
T_1S_1	17.60bc	19.52	70.98	23.09	50.25
T_2S_1	22.00a	20.92	78.26	24.79	50.86
T_3S_1	11.87g	21.31	58.51	20.30	51.29
T_4S_1	14.87cde	20.38	66.49	21.62	52.38
T_1S_2	16.13cd	19.70	66.06	20.83	49.22
T_2S_2	18.93b	19.84	69.06	23.01	51.35
T_3S_2	10.27g	20.70	53.97	18.44	49.96
T_4S_2	12.07fg	19.26	61.58d	19.92	51.09
T_1S_3	12.73efg	20.15	55.51	19.90	47.67
T_2S_3	14.67def	20.71	63.44	22.46	48.64
T_3S_3	10.20g	20.02	47.63	18.09	50.06
T_4S_3	12.07fg	20.27	53.29	18.43	51.18
SE (±)	1.35	0.64	2.23	0.58	1.20
Significance level	*	NS	NS	NS	NS
CV (%)	11.44	3.89	4.42	3.40	2.92

* and NS indicate significant 5% level of significance and no significant respectively. Fig. in a column having same letter or without letter do not differ significantly whereas Fig. having dissimilar letters differ significantly as per DMRT

T_1 = Single row rectangular system, T_2 = Single row triangular system,

T_3 = Double row rectangular system and T_4 = Double row triangular system

S_1 = 3 seedlings hill^{-1}, S_2 = 4 seedlings hill^{-1} and S_3 = 5 seedlings hill^{-1}

Panicle length

Transplanting geometry had significant influence on panicle length (Table 1). The longest panicle (20.49cm) was obtained from single row triangular system which was statistically identical to single row rectangular system while the shortest (18.28cm) was found in double row rectangular system. Number of seedlings hill^{-1} had no significant influence on panicle length (Table 1). The results also supported by Hasanuzzaman *et al.* (2009) who stated that panicle length was unaffected by the number of seedlings hill^{-1}. Panicle length was also non-significant due to the interaction effect of transplanting geometry and seedlings hill^{-1} (Table 2). Higher density in double row system and more seedlings hill^{-1} produce the shortest panicle due to inter and intra spacing competition. Similar findings also reported by Bozorgi *et al.* (2011). Usually the panicle length declines steadily with the higher number of seedlings hill^{-1} (Karmakar *et al.* 2002).

Grains panicle^{-1}

Transplanting geometry had significant impact on number of grains panicle (Table 1). Maximum number (70.25) of grains panicle^{-1} was obtained from single row triangular system while the minimum (53.37) was recorded from double row rectangular system. Number of grains panicle^{-1} was varied significantly by the number of seedlings hill^{-1} (Table 1). Three seedlings hill^{-1} produced the highest number of grains panicle^{-1} whereas the lowest was found in 5 seedlings hill^{-1}. Interaction effect of transplanting geometry and seedlings hill^{-1} had no significant impact on number of grains panicle^{-1} (Table 2). Closer spacing and increased number of seedlings hill^{-1} reduced the number of grains panicle. The longest panicle in single row triangular system and 3 seedlings hill^{-1} leads to produce more grains panicle^{-1}.

1000 grain weight

1000 grain weight was influenced significantly due to the effect of transplanting geometry (Table 1). The highest 1000 grain weight (23.4g) was attained in single row triangular system and the lowest (18.9g) was recorded from double row rectangular system. Number of seedlings hill^{-1} had significant influenced on 1000 grain weight (Table 1). 1000 grain weight was maximum in 3 seedlings hill^{-1} whereas the minimum was obtained from 5 seedlings hill^{-1}. 1000 grain weight was not varied significantly by the interaction of transplanting geometry and number of seedlings hill^{-1} (Table 2). 1000 grain weight was highest in wider spacing and minimum seedling hill^{-1}. This is due to the better uptake and utilization solar energy and nutrient. The results corroborated by Ninad *et al.* (2017) who observed that wider spacing and 3 seedling hill^{-1} produced the highest 1000 grain weight.

Grain yield

The transplanting geometry exerted significant effect on grain yield (Fig. 4A). The highest grain yield (5.6 t ha^{-1}) was attained from double row triangular system which was statistically at par to double row rectangular system while the lowest (4.5 t ha^{-1}) was obtained from single row rectangular system. Grain yield was ~22% more in double row triangular system than the usual practice of single row rectangular system (from equal land area). Significant variation of grain yield was found due to the number of seedlings hill^{-1} (Fig. 4B). Three seedlings hill^{-1} produced the maximum seed yield (5.3 t ha^{-1}) whereas the minimum (4.59 t ha^{-1}) was found in 5 seedlings hill^{-1}.

Interaction of transplanting geometry and seedlings hill^{-1} had no significant effect on grain yield (Fig. 4C). Yet the growth and yield attributes were highest in wider spacing single row triangular system but grain yield was highest in double row triangular system due to the more number of hills unit^{-1} area (Fig. 1).

The above results are in agreement with others (Baloch *et al.*, 2002; Vijayakumar *et al.*, 2004; Gozubenli 2010 and Kandil *et al.*, 2010) who stated that wider space allows the individual plants to produce more tillers but it provides the minimum number of hills per unit area which results in lower grain yield. The grain yield of T. aman had increased substantially by adopting a simple technique, the planting geometry. As T. aman is the only crop per year in this area, maximum utilization of land in rice might benefit the resource-poor farmers from the same land area.

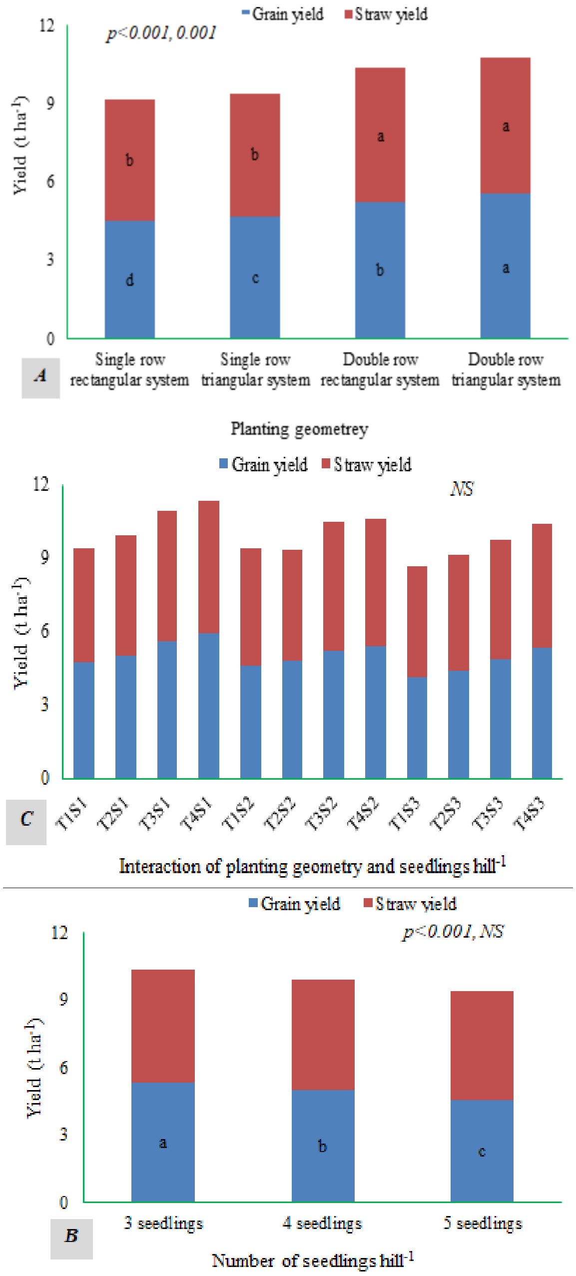

Fig. 4. Effect of planting geometry (*A*), number of seedlings hill^{-1} (*B*) and their interaction (*C*) on grain and straw yield of Binadhan-7 grown in the coastal region of southwestern Bangladesh.

T_1= Single row rectangular system, T_2= Single row triangular system, T_3= Double row rectangular system and T_4 = Double row triangular system

S_1= 3 seedlings hill^{-1}, S_2= 4 seedlings hill^{-1} and S_3= 5 seedlings hill^{-1}

Straw yield

Different transplanting geometry had significant influence on straw yield (Fig. 4A). The highest straw yield (5.2 t ha^{-1}) was recorded from double row triangular system which was statistically similar to double row rectangular system while the lowest (4.7 t ha^{-1}) was obtained from single row rectangular system. Straw yield was not influence significantly by the number of seedlings hill^{-1} (Fig. 4B). Interaction of transplanting geometry and number of seedlings had no significant effect on straw yield (Fig. 4C). Straw yield increased in closer spacing due to the higher number of hills (with and without panicle) unit^{-1} area.

The finding of the study in line with the results of Baloch *et al.* (2002) who stated that maximum number of hills unit^{-1} produced more straw yield.

Harvest index

Harvest index varied significantly by the different transplanting geometry (Table 1). Maximum harvest index (51.5%) was calculated from double row triangular system which was statistically similar to double row rectangular system and single row triangular system whereas the minimum (49.04%) was found in single row rectangular system. Different number of seedlings hill^{-1} significantly affect the harvest index (Table 1). The highest harvest index (51.2%) was calculated in 3 seedlings hill^{-1} which was statistically identical to 4 seedlings hill^{-1} while the lowest (49.4%) was found in 5 seedlings hill^{-1}. Interaction of transplanting geometry and number of seedlings had no significant effect on harvest index (Table 2).

Conclusion

From the results of the study it is revealed that transplanting geometry and seedlings hill^{-1} had substantial impact on growth and yield of aman rice. Individually double row triangular system and 3 seedlings hill^{-1} produced the maximum grain yield followed by double row rectangular system. Considering the grain yield, double row triangular system and 3 seedlings hill^{-1} can be suggested for transplanting of Binadhan-7 in the coastal region of southwestern Bangladesh. Further research should be conducted on other short duration HYV rice varieties for increasing rice productivity as little scope of horizontal expansion is available.

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