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RESEARCH ARTICLE

INFLUENCE OF THE NUMBER OF SEEDLINGS PER HILL ON THE PERFORMANCE OF TRADITIONAL RICE CULTIVAR MOULATA IN TIDAL FLOODPLAIN OF SOUTHERN DELTA REGION OF BANGLADESH

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Abstract

Inundation of land due to tidal flooding is a major constraint of crop production in the Southern Delta region of Bangladesh. Aman rice is the only crop grown during the rainy season when the land remains inundated for an extended period April through November. Farmers grow low yielding, tall statured traditional cultivars. A participatory on-farm trial was conducted in two widely dispersed villages of Jhalakati district during 2011-2012 season to optimize seedling number per hill to increase grain yield of rice under tidal wetland condition. Three variables - farmers' usual practice, 5 seedlings and 7 seedlings per hill were tested. Transplanting 7 seedlings per hill contributed to higher yield compared with transplanting 5 seedlings per hill or farmers' practice of random transplanting. Higher yield was associated with greater number of panicles per unit area and increased number of filled spikelets per panicle.

INTRODUCTION

Greater Barisal in the Southern Delta region of Bangladesh is crisscrossed with innumerable rivers, rivulets, creeks and canals. Lands along these rivers are subject to inundation due to cyclic tidal flooding. Brammer (2014) provides a comprehensive account of the physical features of the Gangetic tidal floodplain. Despite favorable temperature for crop growth almost throughout the year, cropping intensity in this region is low (BARC 2007). Aman crop is the only crop grown during rainy season relying with traditional cultivars. Low elevation (msl ≤1.0 m), slow land drainage during post-monsoon period and photosensitivity of cultivars used in aman season harvesting of traditional rice cultivars is delayed until early January. Topographical and hydrological conditions thus restrict growing rabi (dry season) crops in the lower part of Barisal region (AEZ 13).

Monsoonal tidal flooding and consequential inundation of land and often submergence of crop is the major problem of growing rice. Soil submergence and frequent crop inundation due to high tides twice daily over a period of 4-8 months (April-November) is the characteristic feature of tidal floodplain ecosystem. About 80% of the cultivable land of greater Barisal and Patuakhali districts is inundated up to a range of 6-90 cm during monsoon presenting difficulty in growing modern varieties of transplanted aman rice. Farmers use tall statured, photosensitive, long duration, traditional cultivars tolerant to tidal flooding. A few cultivars (for example, Moulata, Sadamota, Lalmota, Dudhkamol, Nakhuchimota) dominate aman cropping (Shamsuzzaman and Haque, 2010). Having endured the climatic variability and environmental hazards, these cultivars are being grown in the region over ages. However, the yield of the traditional varieties is low and research intervention seeking yield improvement has not been substantial.

Rice grain yield is a function of several factors such as number of tillers, spikelets per panicle and 1000 grain weight. Genetic and environmental factors including management conditions regulate phenotypic expression of a cultivar in a given location. Although single grain weight and the number of spikelets per panicle are mostly genetically controlled (Yoshida, 1981), agronomic management influences the number of tillers per unit area or biomass accumulation in a hill to a large degree. Most literature suggests that traditional cultivars are of low tillering capacity (for example, Saito et al., 2006). Number of seedlings transplanted per hill is an important factor regulating the number of tillers per unit area ultimately influencing the number of panicle density and grain yield in rice. Reports on the benefit of younger and lesser number of seedlings per hill on plant growth and grain yield of rice abound (Deb, 2012; Wen and Yang, 1991). Faruk *et al*. (2009) reported that four-week old two seedlings per hill gave high grain yield. Number of seedlings per hill affected all the yield attributes including the number of tillers per hill, grains per panicle, grain yield. Transplanting of 7-21 day-old seedlings with single seedling per hill increased plant growth and grain yield of Ciherang rice (Asbur, 2013). Planting less number of seedlings per hill helps produce healthy tillers which enables normal physiological growth resulting in more panicles with more filled spikelets and thus produces higher grain yield (Rasool *et al.*, 2012). Transplanting with 2 seedlings per hill at a spacing of 20 cm x 20 cm, Hassanuzaman *et al*. (2009) obtained higher grain yield than planting with 1, 3 or 4 seedlings per hill. However, crop establishment in unfavorable tidal wetland is conditioned by duration and depth of water. Tidal flood often damages transplanted aman rice crop causing seedling mortality, particularly at the early stage immediately after transplanting. The rate of seedling survival against abiotic stresses can be enhanced by transplanting increased number of seedlings per hill (Ansari *et al*., 2011). There have been many studies on the relationship of the number of seedlings per hill and rice grain yield under non-stressed conditions. But these relationships do not fit in the case of rice growing in stressed environments. Dargan *et al*. (1974) reported that an increase in plant population from 2 to 4 and 6 seedlings per hill resulted in significantly higher grain yields in a saline-sodic soil. Farmers in tidal floodplain of southern delta region of Bangladesh typically transplant old seedlings, 15 to 25 seedlings per hill, at a relatively wider spacing without maintaining rows (Shamusuzzaman and Haque, 2010).Satyajit *et al*. (2013) reported that transplanting with 5 seedlings per hill gave highest yield of rice in Patuakhali.

Studies reporting the number of seedlings transplanted per hill mainly focus on the performance of modern rice varieties grown with irrigation under favorable conditions. Moreover, agronomic methods appropriate for irrigated modern rice are seldom applicable for growing traditional rice in unfavorable ecosystem like tidal floodplain. Literature on growth and production of traditional aman rice in tidal wetland is rather scarce. The purpose of the present study was to examine the influence of the number of seedlings transplanted per hill on grain yield of traditional rice cultivar in tidal flood ecosystem of southern delta region of Bangladesh.

Materials and Methods

A participatory on-farm trial was conducted in two locations of Rajapur and Jhalakati Sadar upazila of Jhalakati district. The trial sites in two villages – Uttampur (Rajapur upazila) and Sachilapur (Jhalakati sadar upazila) represent typical tidal wetland. Soils of both the sites are clayey to clay loam with low to very low N and P, high to very high in K, and medium high to very high contents of secondary and micro-nutrients (SRDI, 2008). The two villages are 9 km apart but enjoy similar environmental conditions including hydrology. Two rivers – the Bishkhali and the Jangalia flow on the east and the west, respectively. Details of the experimental sites have been described elsewhere (Hamid *et al.*, 2015). The trial was conducted during aman season, June 2011-January 2012.

Five farmers from each location participated in running the trial. Each participating farmer devoted a minimum of 0.134 ha plot for planting experimental rice crop. Three treatments tested in the trial were – (a) farmers' practice, (b) 5 seedlings per hill, and (c) 5 seedlings per hill. Each plot was split into three sub-plots for accommodating the treatments. Plot size varied from 0.143 ha to 0.264 ha. A farmer's whole plot growing the trial crop was considered a replication. The experiment was laid out in a randomized block design.

Traditional rice cultivar Moulata was used as experimental material. Moulata is a tall, photo-sensitive and popular rice cultivar. Two nursery beds, one in each location, were established for raising seedlings. The same source of seeds was used for both the locations. Farmers were supposed to have planted 45-d old seedlings at both the sites. However, the seedling age varied between 44 and 48 days with a mean of 46.6 days. Such a variation in seedling age was not unexpected because transplanting in tidal flood wetland situation largely depends on field hydrological conditions. In farmers practice, participating farmers transplanted seedlings following their traditional practice but in other two treatments seedlings were transplanted in rows at 40 cm x 40 cm spacing. We counted seedlings that farmers used per hill pulling the hills immediately after transplanting. 10 hills were selected at random from each plot and counted the number of seedlings per hill that farmers used. It was observed that seedlings per hill ranged between 7 and 31 with an average of 11.03. In other two treatments, seedlings were transplanted in rows at 40 cm x 40 cm spacing with either 5 seedlings or 7 seedlings per hill. 45 d old seedlings were planted following farmers' traditional practice or in rows at 40 cm x 40 cm. This spacing was chosen because the highest grain yield was obtained in this spacing in an earlier experiment (Shamsuzzaman and Haque, 2010). We counted the hill bases of 5 m^2 sample area from the center of each plot immediately after rice harvest and recorded the number of hills per m^2.

Traditional varieties are typically grown without applying fertilizers. In the present trial, participating farmers applied 50 kg N ha^{-1} in the form of urea once prior to transplanting seedlings when the land was not flooded in an interval of low tide. Rice was allowed to grow with uncontrolled tidal water and irrigation was not required. Weed growth was also minimal. At maturity rice was harvested cutting at the base. No remarkable variation in phenological events due to treatments was observed. There was difference in days to maturity across locations and plots depending on toposequence. Harvesting spanned between December 20, 2011 and January 14, 2012. Plots located on lower elevations, particularly in the center of the fields got delayed in harvesting.

Trial plots were fairly of large size that allowed large sampling for determination of grain yield and associated attributes. At maturity, a 25 m^2 area was harvested from each sub-plot for yield determination. Grain yield was calculated at 14% moisture content. Five hills were sampled diagonally from each 25-m^2 harvest area to determine yield components. Panicles were hand-threshed and filled- and unfilled grains separated. Dry weights of filled and unfilled spikelets were determined after oven drying samples at 80^oC to constant weight. Ten panicles from each sub-plot were sampled and the number of spikelet per panicle counted. Three sub-samples, each of 50 g of filled spikelets were taken and counted to determine single grain weight. Unfilled spikelets were counted and grain-filling percentage was calculated.

Data were subjected to statistical analysis using ANOVA, and means compared employing LSD.

Results and Discussion

The participatory on-farm trial was conducted in two villages, 9 km apart. Location appears to have no significant influence on plant growth and yield attributes of rice (Table 1). Hill density or the number of hills per m^2 was generally low compared to irrigated rice. Seedlings of indigenous rice varieties grown in tidal floodplain are usually planted wide apart (Elahi *et al*., 2001). Hill density tended to be higher in Rajapur compared with Jhalakati but the difference was not statistically significant. The high CV (23%) indicating large inter-plot variability in hill density probably made the between-the location difference non-significant. Likewise, variability in tiller density, panicles per m^2 and spikelets per panicle within the locations was appreciably high. Land topography, uncontrolled water and management practices might have widely differed across farmers' plots. Average grain yield in Rajapur (3.046 t ha^{-1}) and in Jhalakati (3.007 t ha^{-1}) was statistically similar. Prevailing agro-ecological conditions in two locations, and the agronomic management practices that farmers used did not differ appreciably. This was also reflected in yield and associated plant characteristics. Grain yield of local variety observed in the trial was generally high compared with the yield reported earlier (Amin *et al*., 2006).

Table 1. Effect of location on grain yield and yield attributes of rice

Location	Hills m^{-2}	Tillers $hill^{-1}$	Panicles m^{-2}	Spikelets $panicle^{-1}$	1000-grain wt (g)	Grain yield (t ha^{-1})
Rajapur	6.674	22.2	202.6	86.3	27.56	3.046
Jhalakati	5.972	31.7	182.5	77.9	27.74	3.007
CV	23.02	14.42	11.80	11.05	6.57	9.88
LSD0.05	ns	ns	14.53	5.51	ns	0.226

The number of seedlings per hill in farmers' usual practice as counted immediately after transplanting varied between 7 and 31 m^{-2} with an average of 11.03. The pre-determined planting configuration (0.4 m x 0.4 m) in rows should have been 6.25 hills m^{-2} but the average hill densities found at the end of growing season were 7.0 and 6.7 m^{-2} (Table 2). Farmers' traditional practice of random transplanting gave significantly lower hill density per unit area. However, transforming hill density into seedling density per unit area by multiplying the number of seedlings transplanted per hill by the number of hills m^{-2} shows that farmers' practice of random transplanting gave nearly double the number of seedlings m^{-2} (65.54) than transplanting in rows with 5 seedlings per hill (35.0 m^{-2}).

The treatment variables provided three different environments to evaluate the response of rice. Taking the seedling density at transplanting into account it appears that in row transplanting system, seedlings might have been planted at closer spacing than usually planned. In contrast, the average hill density following farmers' practice was considerably low i.e. 5.8 m^{-2} (Table 2). Hill density was significantly higher in the plots planted with 5 seedlings or 7 seedlings per hill. Transplanting was done in inundated plots during high tides. In the flooded field, maintaining accuracy in planting density or row spacing manually should have been difficult (Roy *et al.,* 2003).

Table 2. Influence of seedlings per hill on plant characters of rice grown in tidal wetland

	Hills m^{-2}	Tillers $hill^{-1}$	Panicles $hill^{-1}$	Unproductive tillers $hill^{-1}$	Plant height (cm)
Farmer-practice (11.3)	5.8	24.8	23.3	1.6	141
5 seedlings /hill	7.0	27.5	24.3	2.2	144
7 seedlings /hill	6.7	27.3	26.9	2.3	144
LSD 0.05	0.29	ns	2.1	ns	ns

There was significant difference in grain yield due to variation in the number of seedlings transplanted per hill (Table 3). Interaction effect of location and seedling number per hill on the grain yield or yield attributes was not statistically significant. Transplanting 7 seedlings per hill gave higher grain yield (3.262 t ha^{-1}) which was followed by 5 seedlings per hill (2.903 t ha^{-1}). Transplanting larger number of seedlings following farmers' practice produced the lower yield (2.882 t ha^{-1}). The difference in grain yield between farmers' practice of random planting and transplanting 5 seedlings per hill was not statistically significant. It is probable that in Farmers' adopted random planting of larger number of seedlings per hill presented strong plant competition within the hills for nutrients, light and space (Saha and Saha, 1998) that might have resulted in lower yield. The number of tillers per hill was also significantly lower in farmers' practice of random transplanting (Table 2). Transplanting methods exerted no significant effect on plant height.

Tillering is one of the most important agronomic traits related to grain yield in rice. Hill density appears to have little influence on the number of tillers per hill. The number of panicles varied between 192 and 208 m^{-2} across the treatments; but the difference was not statistically significant. Spikelets per panicle varied between 67.5 and 75.8 across treatments. The average number of spikelets per panicle was, however, low (Amin *et al*., 2006). Roy *et al.* (2014) reported that the number of spikelets per panicle in indigenous rice is generally lower. Transplanting 5- and 7 seedlings per hill produced identical but more spikelets per panicle compared with those of farmers' practice. Transplanting larger number of seedlings following farmers' traditional practice probably presented greater intra-plant competition that resulted in reduced number of spikelets per panicle (Saha and Saha, 1998). Grain filling percentage was relatively high and the treatment differences exerted no significant influence on grain filling percentage. Grain size or 1000 grain weight tended to decrease with increasing the number of seedlings transplanted per hill. Transplanting 5 seedlings and 7 seedlings per hill had identical but higher grain size than that with farmers' practice. Grain filling or seed set rate is the most stable yield component followed by 1000 grain weight (Zhang and Huang 1990) while grain yield per plant, total biomass per plant, and panicle number per plant are the most unstable traits.

Available literatures (e.g., Sarker *et al*. 2012; Faruk *et al*., 2009) suggest that lesser the number of seedlings per hill transplanted, greater was the number of tillers per hill, effective tillers per unit area, spikelets per panicle and grain yields. Seedling age at transplanting is also an important factor in the growth and yield of rice (Hamid *et al*., 2015). Risk of seedling damage due to tidal flood restricted us to use younger seedlings in the present study. Contrary to a general perception that traditional cultivars are of low tiller capacity (Saito and Futakuchi, 2009), indigenous variety produced and retained 21.5 to 31.7 tillers per hill. Our results are in agreement with (Jahn *et al*., 2011) who reported high tillering capacity of certain indigenous rice varieties. Planting density, between 5.8 and 7.0 hills m^{-2}, was also much lower compared with recommended planting density of high yielding varieties of rice. But the sparsely transplanted hills in rows displayed fairly a high tiller density at harvest developing and retaining larger number of tillers per unit area.

Table 3. Yield and yield contributing characters of rice as influenced by the number of seedlings per hill

	Tillers m^{-2}	Panicles m^{-2}	Spikelets $panicle^{-1}$	Grain filling %	1000 grain wt. (g)	Yield (t ha^{-1})
Farmer-practice	220	191.6	67.5	0.88	26.8	2.882
5 seedlings/hill	203	192.3	73.4	0.87	28.0	2.903
7 seedlings/hill	233	208.4	75.8	0.88	27.7	3.262
CV (%)	16.3	11.0	8.4	5.85	3.76	11.47
LSD 0.05	17.672	11.345	5.274	ns	ns	0.293

Conclusion

Traditional rice cultivars suitable for growing in tidal floodplain are generally of high tillering capacity requiring widely spaced planting. Compared with farmers' traditional practice of random transplanting, transplanting in rows with 7 seedlings per hill at 40 x 40 cm configuration clearly gives a yield advantage of over 26%.

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