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FARMERS' RICE YIELD IN FALLOW - T. AMAN RICE - FALLOW CROPPING PATTERN DUE TO VARIABILITY IN GENOTYPE AND MANAGEMENT

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Abstract

Farmers' existing rice production practices provide key indications of interventions for improving yield in their environments. This study aimed to explore those indications in the Fallow - T. Aman rice - Fallow cropping pattern (CP) under rainfed farming practiced by the farmers in Kapasia, Gazipur. Research method employed one-to-one and face-to face interview of 154 farmers practicing the CP. The average yield of T. Aman was estimated as 3.23 t ha^{-1}, slightly below the national average yield of 3.93 t ha^{-1}, in the range of 1.18 to 5.65 t ha^{-1}. Variety was one of the two broad factors that determined the yield variation. The high yeld potential (HYP) category absolutely preferred the production aim, where Swarna-Ranjit (31.2% by farmer) and BRRI dhan49 (24.7% by farmer) were the dominated varieties where average yields were very close (3.51 and 3.36 t ha^{-1}) for Swarna-Ranjit and BRRI dhan49, respectively). Management was the second factor determining the yield variation within varieties. While both the varieties received similar maximum yield (5.65 t ha^{-1}), Swarna-Ranjit produced the minimum yield of 1.40 t ha^{-1} and BRRI dhan49 of 1.98 t ha^{-1}. This study did not find a consistent pattern of response of the three measured management components - transplanting time, seedling age and seedling density to yield in either variety. The yield variance of BRRI dhan49 under three management components was higher compared to Swarna-Ranjit. Farmers practiced relatively a wide range of three management combinations to achieve high yield in Swarna-Ranjit, but a narrow range of the three management combinations for BRRI dhan49 to achieve the same level of yield. It is concluded that the variety-specific agronomic management to be the avenue for yield improvements in farmers' fields.

Introduction

According to FAO (2018), rice sector provides about 70 % of agricultural GDP; it also shares one-sixth of the national income of Bangladesh. For this country, rice is the staple food; in addition, it is a dominant factor of social and political stability (Nath, 2015). Yield can be enhanced through improved genotype and management specific to environments (Anderson *et al*., 2005). A number of studies support that high yield varieties coupled with appropriate management greatly contribute to increased yields (Fischer and Wall, 1976; Byerlee and Anderson, 1994; Anderson *et al*., 2005; Sarangi *et al*., 2016; Salam, 2017).

Suitability of a genotype and its scope for management depend on environment to which the rice crop is cultivated. Depending on the environment, cropping patterns are also developed and practiced. Therefore, genotype and management aspects of yield are largely specific to cropping patterns.

Rice is grown in about 3.20 million hectares of land under 'rainfed low land' system (Rahman *et al*., 2020), accounting for about 27 % of the total rice area. This system is characterized by occasional flood and water stagnation at vegetative phase and periodic drought or moisture stress at reproductive phase of T. Aman rice (Rahman *et al*., 2020). The Fallow - T. Aman rice - Fallow is a cropping pattern (CP) under this system. This CP covers 509,480 ha of land accounting for about 5.89 % of net cropped area (Nasim *et al*., 2017), and 4.29 % of total rice area (based on 11.87 hectare of total rice area as of 2020 (Rabbi *et al*., 2020). The Fallow - T. Aman rice - Fallow CP spreads over 167 upazilas, and, being periodically stressed, characterized by low yield zone under poor genetic and/or crop management scenarios. Thus, there is a scope of exploring yield potential in this environmentally constraint cropping pattern. For improving rice yield under the Fallow - T. Aman rice - Fallow cropping pattern, information is necessary on farmers 'existing rice production practices with respect to genotype and management components. Keeping these views in mind the present study was designed to estimate farmers' rice yield status in the Fallow - T. Aman rice - Fallow cropping pattern; to record farmers variety choice, management practices and their influence on yield; and to map farmers' rice yield of dominant varieties with respect to management.

Materials and Methods

This study was undertaken in Kapasia upazila, Gazipur district of Bangladesh located in between 24°02' and 24°16' north latitudes and 90°30' and 90°42' east longitudes. It belongs to Madhupur Tract of the agro ecological zone (AEZ-28) which has unique combination of physiographic, edaphic, hydrological and agro climatic characteristics. This region is a complex relief where soil developed mostly as heavy grey clay under the Madhupur clay. Predominant general soil type are deep red brown terrace and shallow grey terrace soil and acid basin clays are the major ones. It comprises different kinds of landscape, mainly well drained dissected terrace and valleys and poorly drained level terrace. The AEZ covers 4,244 square kilometer area (FAO, 1988). The composition of land type in the AEZ is 56% high, 18% medium high, 7% medium low, 9% low and 10% homestead and water bodies (FAO, 1988). Characteristically, soil texture is loamy, pH 4.8-5.5 (Kumar *et al.*, 2018). The soils are low (1.0 – 1.7%) in organic matter content and fertility (BBS, 2016). The net cropped area of the Kapasia upazila is 19,600 hectare. Among the cropping patterns, Fallow- T. Aman rice – Fallow occupies 1700 hectare of 8.7% of the net cropped area (BRRI, 2021a) under rainfed cropping systems.

The research site was undertaken through farmers' survey in six (6) out of eleven (11) unions of the upazila. The six unions – Chandpur, Durgapur, Kapasia Sadar, Rayed, Targaon and Tok – were selected as the farmers in the unions had been traditionally practicing the target cropping pattern. Those six unions covered about 80% area under this cropping pattern during 2017 cropping season (Kapasia Upazila Agriculture Office, 2018). The sample size was 154 and drawn 33.1, 21.4, 18.2, 16.2, 9.1 and 1.9%, respectively, from Chandpur, Kapasia, Tok, Rayed, Targaon and Durgapur. Semi-structured questionnaire was developed for collecting data. The questionnaire included rice variety, time of transplanting, seedling age, and seedling number per hill. The questionnaire was pre-tested before finalizing. Survey was executed by face-to-face individual interviewing. The interviews were conducted during March to June 2018, where the interviewees were asked to respond the queries based on recalled data for T. Aman rice growing season of 2017.

Data were collected as hard copy and entered in MS-Excel. All data were tabulated with unique identifier and curated. During the curation process, where data were not clearly recorded and/or had confusion on understanding, the respected interviewees were contacted via mobile phone. In order to analyse structurally, the data categorised for (i) variety diversification, (ii) transplanting time, (iii) seedling age and (iv) seedling density.

(i) Variety diversification: Farmers' rice varieties were grouped into four categories in relation to product speciality. They were Aromatic Scented rice, High yield potential (Fertilizer using efficiency is higher and has potentiality to give higher yield, HYP), Market demand (High value rice varieties) that

have demand in market for their taste at consumer level and photosensitivity (varieties which have photosensitivity to day length).

(ii) Transplanting time: The whole range of the rice transplanting time applied by the farmers was categorised at 15-day interval into five groups, Very early (Upto to 14 July), Early (15-29 July), Mid (30 July -13 August), Late (14-28 August) and Very late (After 28 August).

(iii) Seedling age: The whole range of the rice seedling age used by the farmers was categorised at 10-day interval into four groups, Younger (≤ 30), Middle (31-40), Older (41-50), and Very older > 50.

(iv) Seedling density (seedling number per hill): The whole range of the rice seedling density used by the farmers was categorised into three groups, Standard (≤ 3), High (4-5), and Very high (> 5).

Distribution of farmers rice yields were analysed using Analysis Tool Pack of MS-Excel and presented as Box-Whisker graph and Histogram. Variety and management specific yields were compiled using Pivot Table fuction of MS-Excel. Yields were compared statistically using 95% confident interval. The yields under the groups of three management components (transplanting time, seedling age and seedling density were arranged in a matrix in MS-Excel cells for the two dominant varieties used by the farmers, and presented in a map.

Results

Distribution of rice yield achieved by the farmers

Figure 1 reveals the distribution of rice yields of the sampled farmers in the study area under Fallow - T. Aman rice - Fallow cropping pattern. The yields ranged from 1.18 to 5.65 t ha^{-1}. The figure further shows that the middle 50% of the yield data concentrated within 2.82 to 3.70 t ha^{-1}. The average and median of yields were recorded as 3.23 and 3.29 t ha^{-1}, respectively.

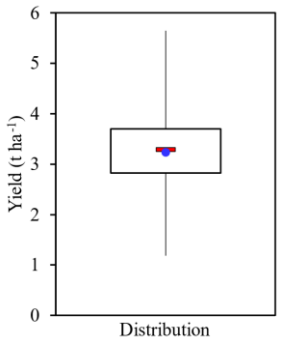

Fig. 1. Distribution of rice yield achieved by farmers in the Fallow - T. Aman rice - Fallow cropping pattern in Kapasia. Box represents middle 50% of the yields, vertical line is the range, and within the box, horizontal line is the median and solid circle is the average.

Frequency distribution of the farmers' rice yields is presented in Figure 2. Results reveal that, yields in the study area more or less followed normal distribution. The maximum frequency (24.0%) of farmers received the yield of 2.5 - 3.0 t ha^{-1}, followed by 22.1 and 20.8% received 3.5 - 4.0 and 3.0 - 3.5 t ha^{-1}, respectively. A small segment of farmers (7.8%) received comparatively low yield (≤ 2.0 t ha^{-1}); On the other hand, 14.9% of the surveyed farmers achieved comparatively high yield (≥ 4.0 t ha^{-1}).

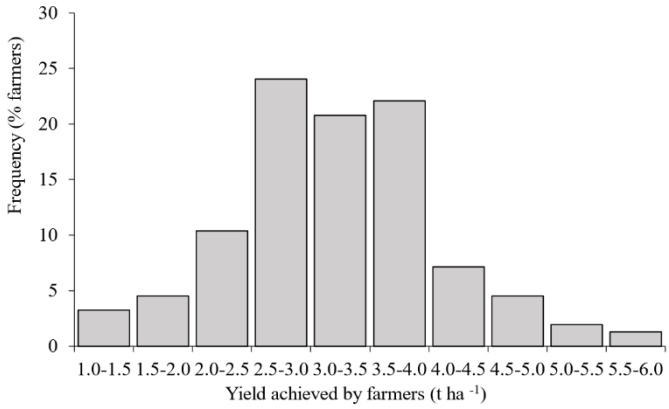

Fig. 2. Frequency distribution of rice yield obtained by the farmers in Fallow - T. Aman rice - Fallow cropping pattern in Kapasia, Gazipur.

Farmers' chosen rice varieties

In the study area, the farmers grew as many as 13 rice varieties (Figure 3). Data shows that, among the varieties, Swarna–Ranjit was the most preferred variety which was chosen by 31.2% farmers, closely followed by BRRI dhan49, adopted by 24.7% farmers. Relatively smaller number of farmers used Swarna–Guti (8.4%), BRRI dhan51 (7.8%), Pajam (7.1%), Kaishabinni (7.1%), Hurabdi (3.9%), BR11 (2.6%), Kalizira (1.9%), Nizershail (1.9%), BRRI dhan41 (1.3%), BR22 (1.3%) and BRRI dhan34 (0.6%) respectively. Only 13.0% surveyed farmers grew local varieties (Kaishabinni, Hurabdi and Kalizira).

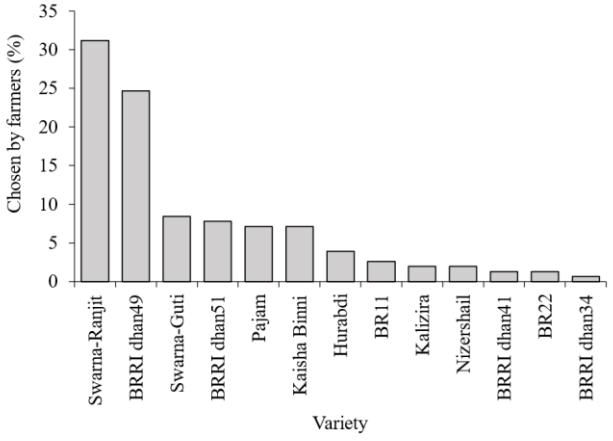

Fig. 3. Status of farmers' rice variety choice in the Fallow - T. Aman rice - Fallow cropping pattern in Kapasia, Gazipur.

Farmers' chosen rice varieties according to purpose of growing

According to purpose of growing, farmers had broadly chosen four categories of rice varieties. They were 'Aromatic' (Var. BRRI dhan34 and Kalizira), 'High yield potential' (Var. BR11, BRRI dhan41, BRRI dhan49, BRRI dhan51, Swarna-Guti and Swarna-Ranjit), market demand (Var. Nizershail and Pajam) and photosensitivity (Var. BR22, Hurabdi and Kaisha Binni). Absolute majority of the farmers

(76.0%) grew rice varieties under the high yield potential category. Only small number of farmers cultivated varieties that belonged to photosensitivity (12.3%), market demand (9.0%) and aromatic (2.5%) category.

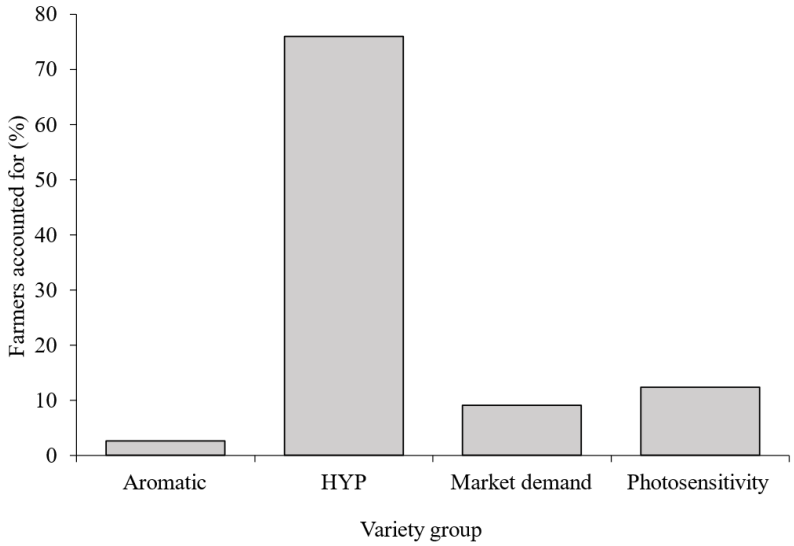

Fig. 4. Status of farmers' rice variety group by the Purpose of growing in the Fallow - T. Aman rice - Fallow cropping pattern in Kapasia, Gazipur. HYP = denotes for high yield potential.

Farmers' chosen rice varieties according to purpose of growing – the distribution of yields

Figure 5 presents the distribution of rice yields achieved by the farmers under the four categories of purpose of growing. The highest average yield was achieved from the, high yield potential (HYP) group (3.41 t ha^{-1}) followed by market demand (2.87 t ha^{-1}) and photosensitivity (2.73 t ha^{-1}) and the lowest in the varieties under aromatic group (1.72 t ha^{-1}). Range of yield in the HYP varieties was 1.40 to 5.65 t ha^{-1} where the middle 50% of the yield data concentrated between 2.82 and 3.94 t ha^{-1}. On the other hand, the range of yield of market demand varieties was 1.69 to 3.94 t ha^{-1} where middle 50% of the yield data concentrated between 2.15 to 3.51 t ha^{-1}. For the photosensitivity group, the range of yield was 1.41 to 3.55 t ha^{-1}, with the middle 50% of the yield data concentrated between 2.37 and 3.06 t ha^{-1}. Under the aromatic rice group, where the average yield was the lowest, the farmers received the yield in the range of 1.18 to 2.96 t ha^{-1} with the middle 50% of the yield between 1.28 and 1.80 t ha^{-1}.

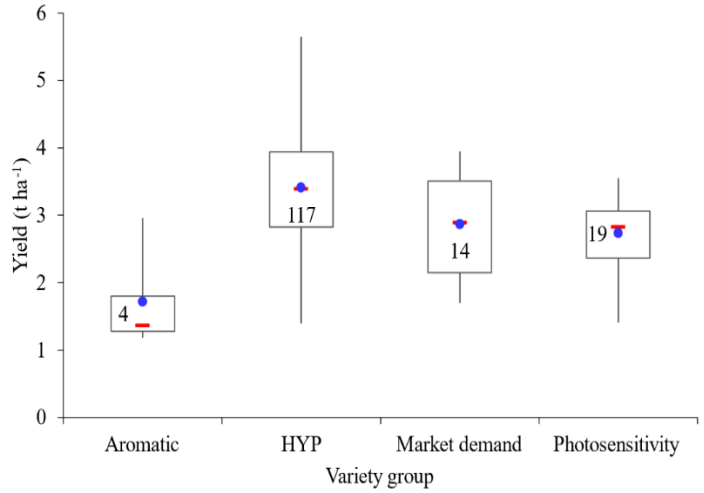

Fig. 5. Distribution of farmers' rice yield according to purpose of growing in Fallow- T. Aman rice - Fallow cropping pattern in Kapasia, Gazipur. Box represents middle 50% of the yield, vertical line is the range, and within the box, horizontal line is the median and solid circle is the average. Values inside the figure denote for sample number within variety group. HYP = denotes for high yield potential.

Farmers' chosen rice varieties under high yield potential (HYP) Group

Results show that, two rice varieties (Swarna-Ranjit and BRRI dhan49) accounted for about 60% of farmers' choice in the study area of which Swarna-Ranjit was 31.25% and that of BRRI dhan49 was 24.7% (Figure 6). With respect to other varieties, Swarna-Guti was chosen by 8.4%, BRRI dhan51 (7.8%), BR11 (2.6%), BRRI dhan41 (1.3%) of the surveyed farmers.

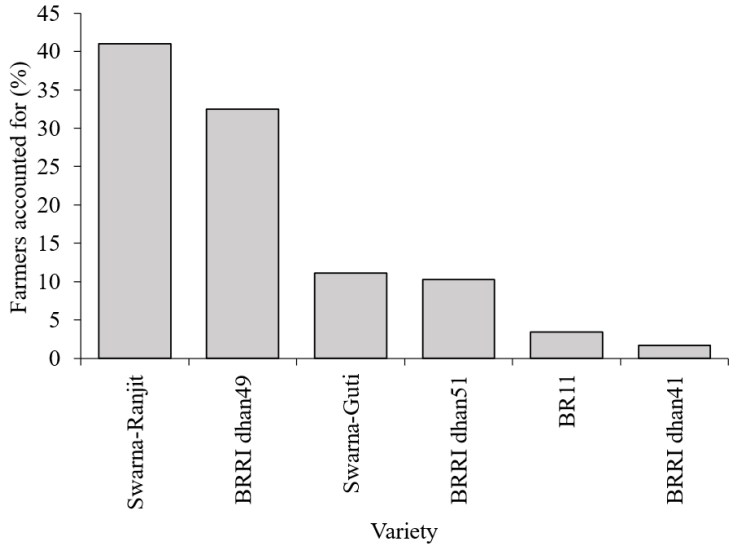

Fig. 6. Status of farmers' rice variety choice for high yield potential (HYP) in Fallow - T. Aman rice - Fallow cropping pattern in Kapasia, Gazipur.

Yield distribution of Swarna-Ranjit and BRRI dhan49, the most chosen varieties under the high yield potential (HYP) group

As mentioned earlier that Swarna-Ranjit and BRRI dhan49 were the most chosen rice varieties in the study area under the high yield potential (HYP) group. It was observed that both the varieties received similar maximum yield (5.65 t ha^{-1}). However, Swarna-Ranjit produced the minimum yield of 1.40 t ha^{-1} and BRRI dhan49 of 1.98 t ha^{-1}. The Figure 7 further shows that the middle 50% yield data of BRRI dhan49 and Swarna-Ranjit was found from 2.82 to 3.83, and 3.12 to 4.0 t ha^{-1}, respectively. The average yield of 3.51 t ha^{-1} was found from Swarna-Ranjit and 3.36 t ha^{-1} from BRRI dhan49. The median yield of 3.51 and 3.39 t ha^{-1} was received from Swarna-Ranjit and BRRI dhan49, respectively. The Figure 7 shows that the middle 50% of yields in Swarna-Ranjit ranged between 3.12 and 4.0 t ha^{-1} whereas with BRRI dhan49 was 2.82 and 3.83 t ha^{-1}.

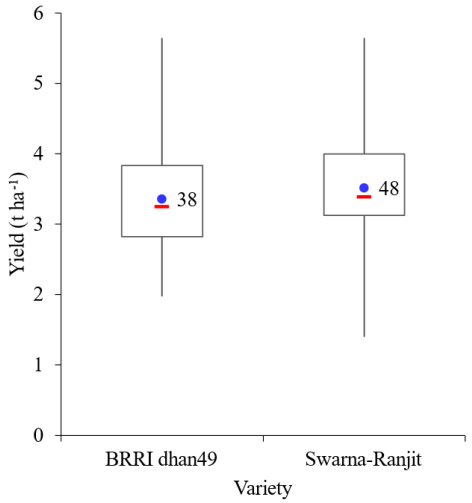

Fig. 7. Rice yield distribution of BRRI dhan49 and Swarna-Ranjit, the most chosen varieties, in the Fallow - T. Aman rice - Fallow cropping pattern in Kapasia, Gazipur. Box represents middle 50% of the yields, vertical line is the range, and within the box, horizontal line is the median and solid circle is the average. Values inside the figure denotes for sample number within variety group.

Management in rice varieties by the farmers

Under the variety choice scenario in the study area, it is already reported the farmers almost equally using BRRI dhan49 and Swarna-Ranjit. Therefore, the variety management aspect highlights on those two varieties.

Management in rice varieties (Transplanting time): For BRRI dhan49, the yield (1.98 t ha^{-1}) was significantly lowest at the very early transplanting window, which significantly increased to 3.68 t ha^{-1} in the early transplanting (Figure 8). The yield then declined in subsequent transplanting windows. However, this decline was not statically significant. On the contrary, for Swarna-Ranjit, the yield (3.81 t ha^{-1}) from very early transplanting window was comparable to other transplanting windows. The lowest yield (3.23 t ha^{-1}) was obtained in early transplanting window which significantly increased to 3.99 t ha^{-1} in the mid transplanting. The yield then declined gradually in later transplanting windows but those declines were not significant.

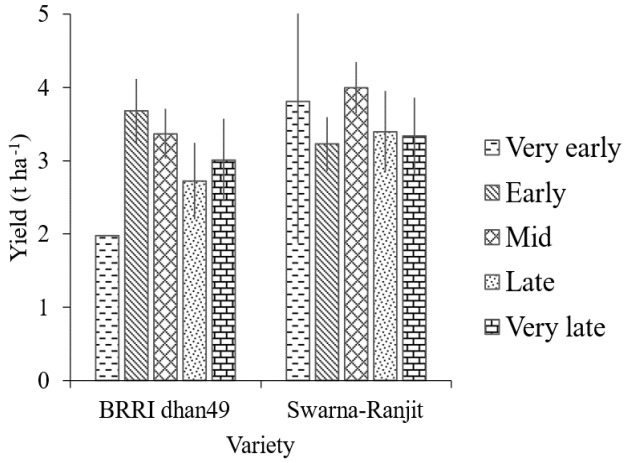

Fig. 8. Response of transplanting time on rice yield in the Fallow - T. Aman rice - Fallow cropping pattern in Kapasia upazila of Gazipur district, Bangladesh. Vertical bars represent 95% confidence intervals of the farmers' yields within each defined transplanting window.

Management in rice varieties (Seedling age): In BRRI dhan49, yield decreased with the increasing of seedling age but differences were not significant (Figure 9). In Swarna-Ranjit younger seedlings produced an average yield of 3.50 t ha^{-1}, which increased to 3.72 t ha^{-1} in the middle-aged seedlings; afterwards, the yield gradually decreased with older and very older seedlings (Figure 9).

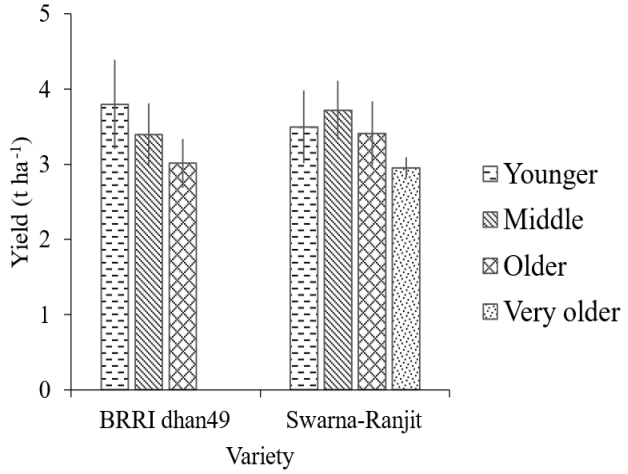

Fig. 9. Response of seedling age on rice yield in the Fallow - T. Aman rice - Fallow cropping pattern in Kapasia, Gazipur. Vertical bars represent 95% confidence interval of the farmers' yields within each defined seedling age group.

Management in rice varieties (Seedling density): Yield decreased with the increase of seedling density in BRRI dhan49 (Figure 10). However, with Swarna-Ranjit, no yield difference was found between high and very high seedling density.

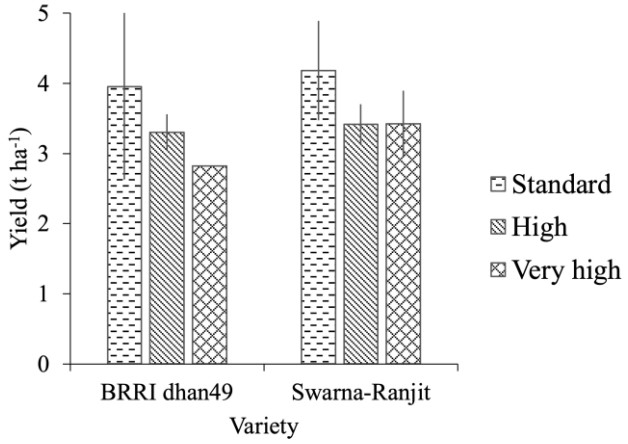

Fig. 10. Response of seedling density on rice yield in the Fallow - T. Aman rice - Fallow cropping pattern in Kapasia upazila of Gazipur district, Bangladesh. Vertical bars represent 95% confidence interval of the farmers' yields within each defined seedling age group.

Comparing the variance in rice yield of two varieties under three management practices

The yield variance of BRRI dhan49 under three management components was higher compared to Swarna-Ranjit (Figure 11). The yield variance for transplanting time window in BRRI dhan49 was higher (0.43 t ha^{-1}) comparted to Swarna-Ranjit (0.11 t ha^{-1}). In BRRI dhan49, seedling age accounted for a yield variance of 0.15 t ha^{-1}, slightly higher than Swarna-Ranjit (0.10 t ha^{-1}). The variance of yield for seedling density was high between the two varieties (0.32 and 0.20 t ha^{-1} for BRRI dhan49 and Swarna-Ranjit, respectively).

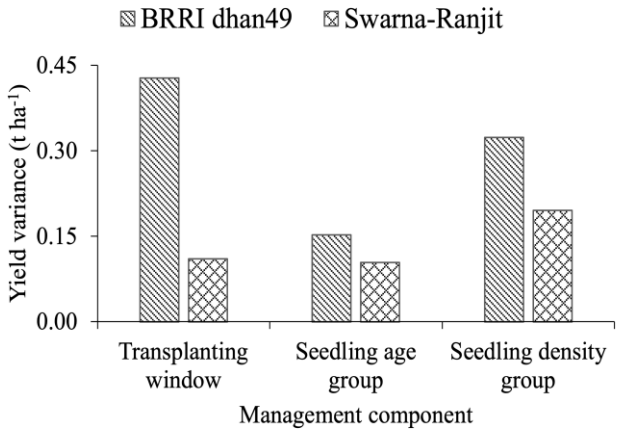

Fig. 11. Comparing variance in rice yield for two varieties under three management components in Fallow - T. Aman rice - Fallow cropping pattern in Kapasia upazila of Gazipur district, Bangladesh.

Mapping of farmers' rice yield under BRRI dhan49 and Swarna-Ranjit

Among the possible 60 combinations of three management components (five transplanting time window, four seedling age group and three seedling density group), BRRI dhan49 was used in 16 and that of Swarna-Ranjit in 23 combinations (Figure 12).

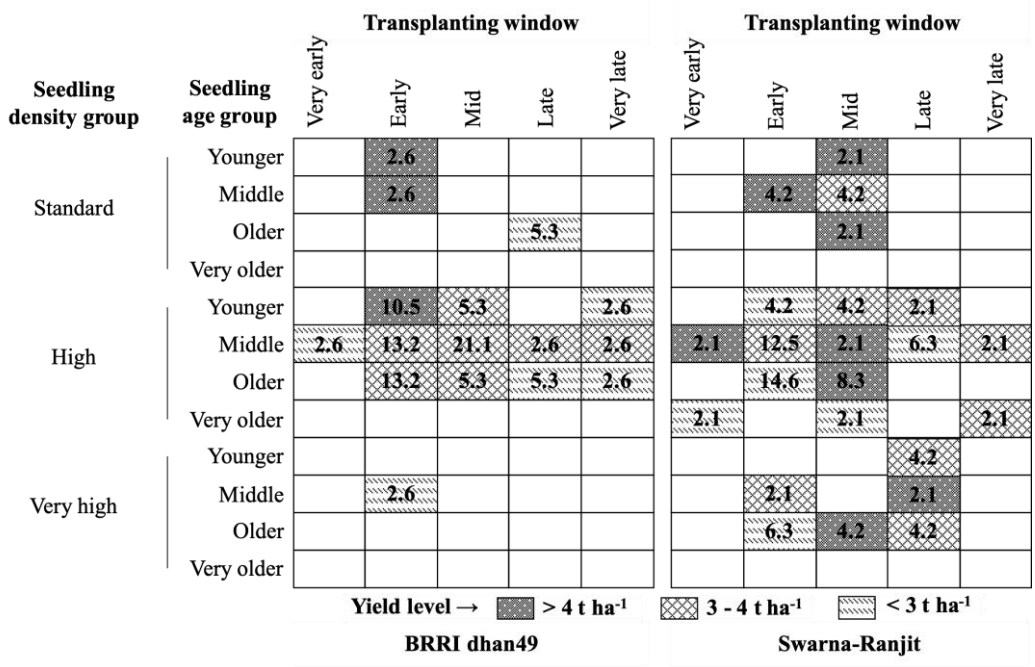

Fig.12. Mapping farmers' rice yield (shade), together with respective frequency (number in the shade), for two varieties under three management combination (transplanting time, seedling age and seedling density) in Fallow - T. Aman rice - Fallow cropping pattern in Kapasia upazila of Gazipur district, Bangladesh.

About 68% farmers grew BRRI dhan49 in six combinations of management - transplanting in early or mid-windows, using younger or middle or older seedings, and all under high seedling density. About 67% of the farmers who achieved the highest level of yields (> 4.0 t ha^{-1}) for this variety, belonged to this management segment. On the contrary, about 46% farmers grew Swarna-Ranjit in the same six combinations of management. Only about 38% of the farmers who achieved the highest level of yields (> 4.0 t ha^{-1}) for this variety, belonged to this management segment.

Discussion

This study investigates the insights of farmers' rice yield and its variability in the rainfed-based Fallow - T. Aman rice - Fallow cropping pattern in Kapasia, Gazipur. Rice crop under this pattern can get stressed as provision of supplementary irrigation is missing due to lack of facilities. In relation to the first objective, the average yield status of the surveyed farmers was 3.23 t ha^{-1}. This yield was slightly below the national average of T. Aman rice yield, 3.93 t ha^{-1} (equivalent clean rice yield of 2.63 t ha^{-1} as of 2019-20 data, BRRI, 2021b). The yield, however, was not similar to all the farmers; it spread from 1.18 to 5.65 t ha^{-1} indicating some farmers performed well and some did not. Farmers' yield variability within a region is expected because the systems with which the farmers grow rice is likely to be different to one another. The systems include choice of variety and management components.

Variety plays an important role in yield variation in T. Aman season, like all other rice types. Varietal difference during the season can cause large variation in yield as wide as 2.60 and 5.50 t ha^{-1} (BRRI, 2012a; BRRI, 2013; BRRI, 2014a; BRRI, 2014b; BRRI, 2018). In relation to the second objective, it was observed that farmers grew as many as 13 varieties which impacted on yield variation. For example, Kalizira yielded as low as 1.18 t ha^{-1}, whereas both BRRI dhan49 and Swarna-Ranjit yielded 5.65 t ha^{-1}. Other studies also show much lower yield in aromatic rice compared to HYP group (Singh *et al*., 2000; Hossain *et al*., 2008). The major thrust of the farmers, however, was to achieve high yield as the survey revealed as high as 76% of them choose varieties for HYP group. The study observed that the yields varied according to the variety-type targeted by the farmers. Six rice varieties were cultivated under HYP group, where the two varieties, BRRI dhan49 and Swarna-Ranjit, accounted for about three-quarter of the choice, 41 and 33%, respectively, among this category. Of the two widely chosen varieties in the study area, the average yield of Swarna-Ranjit was slightly higher (~5%) than BRRI dhan49.

The yield potential of a variety can be influenced by management (Lampayan *et al.,* 1994; Anderson *et al.,* 2005; Alam *et al*., 2013; Sarangi *et al*., 2016). This study specifically investigated management factors influencing the yield of BRRI dhan49 and Swarna-Ranjit, those two varieties were dominant in the studied cropping pattern. The very early transplanting negatively impacted the yield in BRRI dhan49 (BRRI, 2012b), the effect of transplanting time was not evident in Swarna-Ranjit. In recent observations, BRRI dhan49 was found to express erratic flowering behaviour during early transplanting times (pre-mid-July), probably because of its reaction to photoperiod (BRRI, *Personal Communication*). The older aged seedlings tended to reduce yield, though insignificantly, in BRRI dhan49, but it was not the case for Swarna-Ranjit, except for the very old seedlings (over 50 days). The pattern of yield response in BRRI dhan49 to seedling age was similar to that reported by Hasanuzzaman *et al.* (2014) for the same variety who found decreased yield with increased seedling age of 25 day-old onward. On the contrary, no significant yield variation for seedling age in the range of 30 to 60 days was found for BRRI dhan49 (Yasmeen *et al*., 2016). A lower yield was achieved in both the varieties when the seedling density was used over 3 per hill; which corroborates with the var. BR11, BRRI dhan32 and BRRI dhan33 (Alam *et al*., 2012) and Hashemi (Bozorgi *et al*., 2011). Taking the response of the three management components together, the variance of yield in BRRI dhan49 was more than Swarna-Ranjit especially with respect to transplanting time and seedling density (number $hill^{-1}$). Swarna-type varieties occupied 20.68% of T. Aman rice area compared to 14.30% by BRRI dhan49 (BRRI, 2020). However, in stressed area such as in the Northern Region (Dinajpur, Rajshahi and Rangpur) the adoption of Swarna-type varieties was 7 to 16 times higher than BRRI dhan49 (BRRI, 2020). It may be noted that Swarna-Ranjit is a mega variety for low land in rainfed rice system in Assam, India, covering 50% area (Chetia, 2018).

Farmers achieved high level of yields by concentrating on few specific combinations of management of var. BRRI dhan49 - transplanting in early window, using younger or middle aged seedlings with standard or high seedling density. On the other hand, farmers who grew Swarna-Ranjit adopted diverse combinations of management to achieve high level of yields. The findings indicate that the farmers are already experienced with the suitable management options transplating high yield for BRRI dhan49, and probably not for Swarna- Ranjit. It may also reveals that the yield potential of Swarna-Ranjit can be explored in wide variety of management options. The issues of response of yield in 'Swarna-Ranjit' to management options should need to be thoroughly investigated in future research.

Conclusion

Farmers obtained wide range of yield of rice under the Fallow - T. Aman rice - Fallow cropping pattern in the study area. Relatively a wide range of three management combinations (transplanting time,

seedling age and seedling density) was employed to achieve high yield in var. Swarna-Ranjit under high yield potential. On the contrary, var. BRRI dhan49, under the same growing purpose produced high yield under narrow range of the three management combinations. It is concluded that the thrust for yield improvements in farmers' fields should centre around variety-specific agronomic management.

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References

Alam, M.S., M.A. Baki, M.S. Sultana, K.J. Ali and M.S. Islam. 2012. Effect of variety, spacing and number of seedlings per hill on the yield potentials of transplant aman rice. Int. J. Agron. Agri. R. 2(12): 10-15. https://www.innspub.net/wp-content/uploads/2021/12/IJAAR-Vol-19-No-5-p-1-9.pdf.

Alam, M.M., M.R. Karim and J.K. Ladha. 2013. Integrating best management practices for rice with farmers' crop management techniques: A potential option for minimizing rice yield gap. Field Crop Res. 144: 62-68. https://doi.org/10.1016/j.fcr.2013.01.010.

Anderson, W.K., M.A. Hamza, D.L. Sharma, M.F.D. Antuono, F.C. Hoyle, N. Hill, B.J. Shackley, M. Amjad and C. Zaicou-Kunesch. 2005. The role of management in yield improvement of the wheat crop—a review with special emphasis on Western Australia. Aust. J. Agric. Res. 56: 1137–1149. https://doi.org/10.1071/AR05077.

BBS. 2016. Yearbook of Agriculture 2015. Bangladesh Bureau of Statistics (BBS), Statistics and Informatics Division (SID), Ministry of Planning, Government of the People's Republic of Bangladesh, Dhaka, Bangladesh, p.9.

Bozorgi, H.R., A. Faraji, R.K. Danesh, A. Keshavarz, E. Azarpour and F. Tarighi. 2011. Effect of Plant Density and Yield Components of Rice. World Appl. Sci. J. 12(11): 2053-2057. http://idosi.org/wasj/wasj12(11)/17.pdf.

BRRI. 2012a. BRRI Annual Report 2009-2010. Bangladesh Rice Research Institute (BRRI), Gazipur 1701, Bangladesh, p.211.

BRRI. 2012b. BRRI Annual Report 2009-2010. Bangladesh Rice Research Institute (BRRI), Gazipur 1701, Bangladesh, p.327.

BRRI. 2013. BRRI Annual Report 2010-2011. Bangladesh Rice Research Institute (BRRI), Gazipur 1701, Bangladesh, p.262.

BRRI. 2014a. BRRI Annual Report 2011-2012, Bangladesh Rice Research Institute (BRRI), Gazipur 1701, Bangladesh, p.334.

BRRI. 2014b. BRRI Annual Report 2012-2013. Bangladesh Rice Research Institute (BRRI), Gazipur 1701, Bangladesh, p.317.

BRRI. 2018. BRRI Annual Report 2017-2018, Bangladesh Rice Research Institute (BRRI), Gazipur 1701, Bangladesh, p.331.

BRRI. 2020. Annual Research Review - XV Agricultural Economics Division. Annual Research Review Workshop 2019-20. Bangladesh Rice Research Institute, Gazipur 1701, Bangladesh, p.3.

BRRI. 2021a. Cropping Pattern, Intensity and Diversity in Dhaka Region. Bangladesh Rice J. 21(2): 1-155. http://www.brri.gov.bd/site/page/55d231c8-8ba2-46d9-93bf-a63d5aa129a4.

BRRI. 2021b. *Bangladesher Dhaner Jomi, Uthpdan O Pholoner Data* (Rice Area, Production and Yield in Bangladesh). Rice Database. http://www.brri.gov.bd/site/page/f6e878c8-ceac-402d-9bed-6fb29a787428.

Byerlee, D. and J.R. Anderson. 1994. Technology transfer systems for improved crop management: lessons for the future. In: Agricultural technology: policy issues for the international community. Commonwealth Agricultural Bureaux International, Cambridge, UK. pp.208–230.

Chetia, S.K., M. Kalita, R.K. Verma, B. Barua, T. Ahmed, M.K. Modi and N.K. Singh. 2018. Flood proofing of Ranjit, a popular variety of North-Eastern India through transfer of Sub1 rice QTL by modified marker-assisted backcross breeding. Indian J. Genet. 78(2): 166-173. DOI: 10.5958/0975-6906.2018.00021.4.

FAO. 1988. Land Resources Appraisal of Bangladesh for Agricultural Development- Report 2: Agro ecological regions of Bangladesh. Food and Agriculture Organization of the United Nations, Rome, Italy, p.570. https://www.fao.org/3/s7223e/s7223e.pdf.

FAO. 2018. Rice prices and growth, and poverty reduction in Bangladesh. Background paper to the UNCTAD-FAO Commodities and Development Report 2017 Commodity Markets, Economic Growth and Development. Food and Agriculture Organization of the United Nations, Rome, p.35. https://www.fao.org/3/i8332en/i8332en.pdf.

Fischer, R.A. and P.C. Wall. 1976. Wheat breeding in Mexico and yield increases. J. Australian Inst. Agric. Sci. 42: 139–148.

Hasanuzzaman, M., M.A. Hasan, M. Sadekuzzaman, M.M. Bahadur and M.R. Islam. 2014. Dry matter accumulation, leaf characteristics and yield of Aman rice as influenced by seedling ages. J. Bangladesh Soc. Agric. Sci. Technol. 11(1&2): 35-40.

Hossain, M.F., M.S. Islam, M.M. Rahman, M.O. Faruk and M.G. Ershad. 2008. Yield and quality performance of some aromatic rice varieties of Bangladesh. J. Agrofor. Environ. 2(2): 155-158. https://www.academia.edu/15192562.

Kumar, U., M. Mukta and M.Y. Mia. 2018. Changes in soil properties of four agro-ecological zones of Tangail district in Bangladesh. Progressive Agriculture. 29(4): 284-294. DOI: https://doi.org/10.3329/pa.v29i4.41342.

Lampayan, R.M., A.F.M. Saleh, S.I. Bhuiyan and M.A. Lantican. 1994. A cognitive model of farmers' rice crop establishment decisions in rainfed lowlands. In: Proceedings of the International Agricultural Engineering Conference. Asian Institute of Technology, Bangkok, Thailand, December, 1994. pp.727–739.

Nasim, M., S.M. Shahidullah, A. Saha, M.A. Muttaleb, T.L. Aditya, M.A. Ali and M.S. Kabir. 2017. Distribution of Crops and Cropping Patterns in Bangladesh. Bangladesh Rice J. 21(2): 1-155. https://www.banglajol.info/index.php/BRJ/article/view/38195.

Nath, N.C. 2015. Food security in Bangladesh: Status, challenges and strategic policy options. Paper presented at 19th Biennial Conference of the Bangladesh Economic Association (BAE), held on 8-10 January, 2015, Dhaka, Bangladesh. https://bea-bd.org/site/images/pdf/080.pdf.

Rabbi, S.M.H.A, P.L. Biswas, E.S.M.H. Rashid, N.M.F. Rahman, K.M. Iftekharuddaula, M.S. Rahman, M.A.R. Sarkar, M.A.A. Mamun, M.U. Salam and M.S. Kabir. 2020. Increasing rice yield through targeting genetic potentials by rice types. Bangladesh Rice J. 24 (2) : 67-82. DOI: https://doi.org/10.3329/brj.v24i2.53449.

Rahman, M.S., M.M. Haque, M.J. Kabir, A.K.M.S. Islam, M.A.R. Sarkar, M.A.A. Mamun, M.U. Salam and M.S. Kabir. 2020. Enhancing rice productivity in the unfavorable ecosystems of Bangladesh. Bangladesh Rice J. 24(2) : 83-102. DOI: https://doi.org/10.3329/brj.v24i2.53450.

Salam, M.U. 2017. Improving Productivity of Mungbean in South-central region of Bangladesh. Consultancy Report. USAID-AESA Project, House no.7, Road no. 2, Banani, Dhaka-1213, Bangladesh. http://www.aesabd.org/download/AESA-Mungbean-Study-Report-Oct-2017.pdf.

Sarangi, S.K., B. Maji, S. Singh, D.K. Sharma, D. Burman, S. Mandal, U.S. Singh, A.M. Ismail and S.M. Haefele. 2016. Using improved variety and management enhances rice productivity in stagnant flood-affected tropical coastal zones. Field Crop Res. 190: 70-81. https://doi.org/10.1016/j.fcr.2015.10.024.

Singh, K., U.S. Khush, G.S. Khush and R. Rohilla. 2000. Genetics and biotechnology of R quality traits in aromatic rices. In: Aromatic Rices, R.K. Singh, U.S. Singh and G.S. Khush (Eds.). Oxford & IBH Publishing Co. Pvt. Ltd. New Delhi, India, pp.47-69. http://books.irri.org/8120414209_content.pdf.

Yasmeen, R., S. Akter, T. halder, A. Biswas, M.M. Rahman and L. Ferdousi. 2016. Performance study of some T. Aman Varieties under normal transplanting and Double Transplanting system. SAARC J. Agric. 14(1): 37-45. DOI: https://doi.org/10.3329/sja.v14i1.29574.