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EFFECT OF ESTABLISHMENT METHODS AND VARIETY ON AUS-AMAN CROPPING SYSTEM IN THE COASTAL ZONE OF BANGLADESH

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Abstract

Due to lack of fresh water in the dry season, most of the agricultural land in the coastal zone of Bangladesh remain single cropped with a low yield potential. This study aimed to develop a double rice cropping system with an aus-aman crop. Thus experiment was carried out in 2009 with the hypothesis that (i) late transplanting might secure good aus establishment compared to dry seeded aus and (ii) high yield of late planted aman can be maintained using a suitable photoperiod sensitive variety (BRRI dhan46) than photoperiod insensitive (BRRI dhan49) one. Treatments were two aus establishment methods (M_1 = dry seeded, M_2 = transplanted), two aus seeding dates (D_1 = 30 April, D_2 = 11 May), and two aman varieties (V_1 = sensitive and V_2 = insensitive to photoperiod), two seeding dates (D_1 = 5 August, D_2 = 10 August) established 10 days after aus harvest. Dry seeded aus had similar yield for both late April and early May sowings (4.7 t ha^{-1}), but yield of late sown and transplanted aus had lower yield (3.5 t ha^{-1}) due to submergence between flowering and the start of grain filling, while yield of late sown dry seeded aus was not affected as the crop was more advanced at the time of flooding. For aman rice, BRRI dhan49 had a higher yield (4.5 - 4.8 t ha^{-1}) than BRRI dhan46 (4.2 - 4.4 t ha^{-1}) for both establishment dates. Thus, establishment of a short duration aus rice at the end of April, followed by a medium duration photoperiod insensitive aman variety, it is possible to produce 8 - 9 t ha^{-1} yr^{-1} in moderately saline coastal zones.

Keywords: Establishment method, photoperiod sensitivity, cropping intensity.

Introduction

The major constraints to productivity of the agricultural lands in the polders of the coastal zone of Bangladesh are soil and water salinity during the dry season, waterlogging during the monsoon season, and lack of knowledge of modern agricultural interventions (Karim *et al.*, 1990). Farmers in the coastal zone usually cultivate low-yielding (2.5 t ha^{-1}) traditional aman varieties in the monsoon season. Some farmers also cultivate sesame in the dry season, but this is often damaged by the pre-monsoon rains due to late establishment and thus late maturity.

Several attempts have been made over the past 20 years to increase the productivity of agricultural cropping systems of the coastal zone either by improving existing systems or developing new ones. Mondal *et al.* (2006) showed that yield of the aman crop could be more than doubled by the introduction of modern high yielding varieties (HYV), which also reduced growth duration and advanced the harvest. The earlier aman harvest allowed early establishment of boro rice, that can be irrigated by stored water inside the canal network inside the polder. However, the expansion of this cropping system is constrained by the limited amount of water that can be stored in the canal networks to finish off the boro crop, (Mondal *et al.*, 2015). Thus some other options for increasing the productivity in coastal zone could be aus-aman system

Dry seeding (direct seeding into dry tilled soil) instead of transplanting into puddled soil may enable early aus establishment, as rainfall become stable in late April to mid May.

In water scarce areas of other parts of Asia, the use of dry seeding has enabled double cropping of rice during the rainy season, thereby increasing farm productivity (Tuong and Bouman 2003; Tuong 1999). Dry seeding enables

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early crop establishment on the pre-monsoon rains, rather than waiting until there has been enough rain to puddle the soil for wet seeding or transplanting. But rainfall occurrence plays a key factor that govern secured dry seeded aus establishment. So it also needs minimum irrigation to germinate.

It is hypothesized that transplanting aus rice is more suitable than dry seeding if crop establishment is delayed until rainfall becomes more frequent. Furthermore, it was hypothesized that the use of late planted photoperiod sensitive varieties in the aman season would reduce yield (due to reduced growth duration) in comparison with a suitable photoperiod insensitive variety. Therefore a cropping system experiment was conducted to compare the effects of two aus establishment methods (dry seeded, transplanted), two aus seeding dates (30 April, 11 May), and two aman varieties (sensitive and insensitive to photoperiod) with two transplanting date. The specific objectives were (i) to evaluate the effects of date and establishment methods on the growth and yield of aus crop, and (ii) to evaluate effect of photoperiod sensitivity of aman varieties for the aus-aman system.

Materials and Methods

Experimental site: Experiment was conducted at Fultola village of Batiaghata upazila of Khulna. The site had a cropping system history of a transplanted local aman variety (yield about 2 - 3 t ha^{-1}), followed by a late planted, low yielding sesame crop.

Experimental design:

Aus season:

Main Plot: Establishment method (M)
M_1 = Dry seeding
M_2 = Transplanting

Subplot: Sowing date for both method (D)
D_1 = 30 April (transplanted 26 May)
D_2 = 11 May (transplanted 6 June)

Aman Season:

Main Plot: Variety (V)
V_1 = BRRI dhan46
V_2 = BRRI dhan49

Subplot: Sowing date (D)
D_1 = 5 August (transplanted 11 September)
D_2 = 10 August (transplanted 11 September)

The crop was established in a strip-plot design with four replications. The size of each sub-subplot were 4 m × 3 m and main plots were 8m × 9m. The main plot and internal bunds were 50 cm × 20 cm and 20 cm × 20 cm, respectively. All bunds were compacted to prevent seepage between adjacent plots.

Crop management: The land was ploughed under dry condition for the dry seeded aus, and was puddled for the transplanted aus and all aman crops. No irrigation was required for puddling aman field due to sufficient rainfall. The dry seeded aus was sown with 20 cm row spacing. Seedlings of 20-day-old seedlings were used in transplanted aus with a spacing of 20 cm × 20 cm.

In the aus and aman seasons, 60 kg P_2O_5, 40 kg K_2O, 10 kg $ZnSO_4$ and 60 kg $CaSO_4$ ha^{-1} were applied into the soil during the last harrowing. In direct seeded aus season, urea was applied at 120 kg N ha^{-1} in four equal splits ─ at 15 DAE, 30 DAE (MT), 45 DAE (5 DBPI), and at heading. Urea was applied in transplanted aus at 120 kg N ha^{-1} in four equal splits─at basal, 20 DAT (MT), 40 DAT and at heading. In the aman season, urea was applied at 120 kg N ha^{-1} ─ at basal, 35 DAT (MT), 45 DAT (5 DBPI) and at heading stages.

Good weed control was achieved in dry seeded rice by applying the pre-emergence herbicide Longstar 25 EC @ 0.2 kg active ingredient (*ai)* ha^{-1} to the moist soil 1 DAS, followed by post-emergence herbicides Ronstar 25 EC and Longstar 25 EC @ 0.2 kg *ai* ha^{-1} after two weeks of emergence, plus hand weeding as needed. In the aman crops, hand weeding was done just before urea top dressing.

Water management: Irrigation water was applied throughout the aus season for both direct seeded and transplanted crops. A water level of 0 - 5 cm was maintained after crop establishment using groundwater from a nearby tube well. Discharge was measured using the volumetric method (Michael, 1978). Aman rice crops were mainly rainfed. During excessive rainfall, water was pumped from the experimental field as needed to maintain a suitable water depth for modern high yielding rice varieties.

Monitoring:

Crop performance: In both seasons, the dates of anthesis and physiological maturity were determined. The date of 50 % anthesis was estimated by visual observation of 10 rows plot^{-1} in each replication. Physiological maturity was taken as the date when 80 % of the grains in the whole field had become golden, following the procedures of Cassman (1994) and IRRI (1994).

Yield components (panicles density, total spikelets panicle^{-1}, % filled spikelets, 1000-grain weight on oven dry weight basis) were determined from 16 hills following the procedures of Cassman (1994) and IRRI (1994). Grain yield was determined in 2 m × 1 m areas in the middle of each sub plot. Grain yield was calculated at 14 % moisture content (Gomez 1972).

Weather data: A standard manual rain gauge and a USWB Class A evaporation pan were installed near the experimental field and monitored daily at 8 AM. Monthly totals of rainfall and evaporation were calculated. Other weather data including maximum temperature (Max T) and minimum temperature (Min T) were collected from Khulna Meteorological Station, about 8 km north of the experimental sites.

Statistical analysis: The aus crop data were analyzed with standard strip-plot ANOVA with establishment method as main plot and date as subplot. The aman crop data were analyzed with strip plot ANOVA with variety as main plot and date as subplot. The least significant difference (LSD) test was used to compare significant differences between treatment means. The level of significance was set at 5 % level in all cases.

Results and Discussion

Weather: The wet season started in May and usually ended between late September and mid October (Fig. 1a). Annual rainfall was about 1600 mm, about 70 % of which occurred from July to September, compared with the long term (1999 to 2006) average of 1685 mm. Rainfall was unusually high in August 2009 and unusually low in April. Evaporation was usually similar to the long term values except low evaporation from March - May in 2009. Monthly evaporation ranged from 83 to 95 mm from Aug to February. Higher evaporation was observed around 105 to 147 mm in March to June of 2009.

Temperature was favourable for rice throughout the cropping period (Fig. 1b). Mean monthly minimum and maximum temperatures during the aus-aman period were similar to the long term average each year. Mean maximum temperature tended to be highest during the period of establishment of aus (April/May, around 36^{0}C), and fluctuated around 32^{0}C, during the remainder of the aus-aman season each year. Mean monthly minimum temperature was around 20 to 25 ^{0}C throughout the aus-aman period each year.

Effect of sowing date and irrigation method and establishment method on aus crop performance

Phenology: Duration of 30 April dry seeded and transplanted aus crops (BRRI dhan65) was similar. Delay sowing to 11 May reduced crop duration of the dry seeded crop to (100 day) but increased (119 day) in case of transplanted crop (Table 1). The longer duration of the late sown transplanted crop was due to both later flowering and a longer grain filling period. The longer grain filling period was due to the fact that the crop was flooded (80 cm water depth) for about 7 days during flowering and early grain filling.

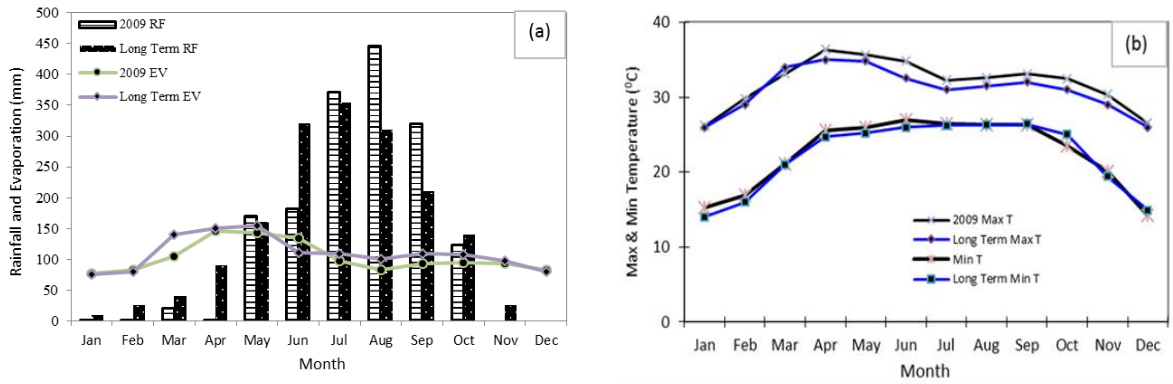

Fig. 1. (a) Monthly total rainfall (RF) and evaporation (EV), and (b) monthly average maximum and minimum temperatures during study period in comparison to the long term (1999 - 2006) data for Khulna City.

Yield and yield components: Yield of BRRI dhan65 ranged from 3.5 to 4.7 t ha^{-1} (Fig. 2). The interaction between establishment method and sowing date on grain yield was significant at $p<0.064$. The interaction was due to a large decline in yield of transplanted rice for the second sowing due to submergence between flowering and the start of grain filling. The panicles were fully submerged, whereas the other treatments were more advanced and the panicles were above the water.

Table 1. Time of flowering (days after sowing, DAS) and physiological maturity of aus crops as affected by establishment method and date of seeding.

	Dry seeded		Transplanted	
	30 Apr	11May	30 Apr	11May
Flowering	75	70	78	78
Grain filling	32	30	31	41
Physiological maturity	107	100	109	119

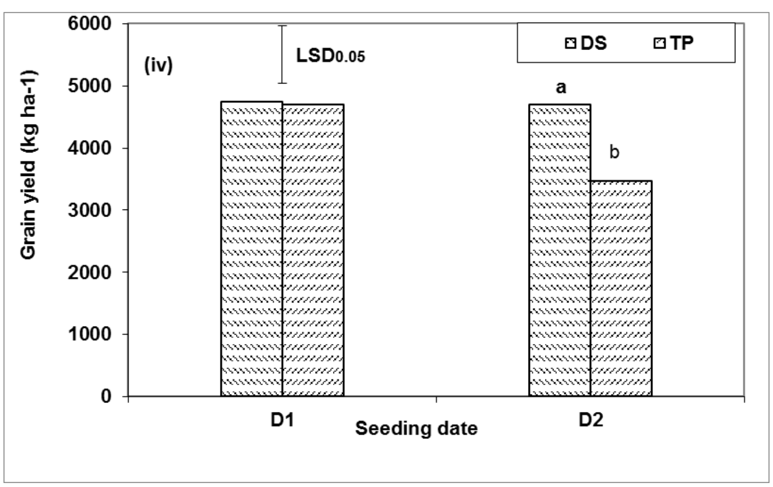

Fig. 2. Grain yield of aus rice as affected by establishment method and sowing date in 2009. DS = dry seeding, TP = transplanting, D_1 = sowing on 30 April, D_2 = sowing on 11 May. Vertical bars are the LSD (P = 0.05) for the interaction between sowing date and establishment method.

The submergence of spikelets panicle^{-1} the later sown transplanted rice resulted in a 23 % reduction in the number of spikelets panicle^{-1}, whereas the number of spikelets panicle^{-1} in the dry seeded rice increased with the second sowing (Table 2). This is consistent with the findings of Reddy and Mitra (1985) who found that submergence of rice at flowering is very detrimental to grain yield. Delaying sowing reduced panicle density of both the dry seeded and transplanted rice, but in the case of the dry seeded rice, this was compensated for by more spikelets panicle^{-1}. Within sowing date, panicle density of dry seeded rice was much higher than for transplanted rice as commonly found (Sudhir *et al.*, 2011).

Table 2. Effect of sowing date and establishment method on yield components of aus in 2009.

	Establishment method[1] (M)						
Seeding date[2]	DS	TP	Mean D		DS	TP	Mean D
Panicle density (no. m^{-2})					Spikelets panicle^{-1} (no.)		
D_1	534	406	470a	D_1	63 b	75 a	
D_2	403	318	361b	D_2	72 a	58 b	
Mean M	468a	362b					
					$LSD_{.05}$ = 11.42		
Filled spikelets (%)					Thousand-grain weight (g)		
D_1	80	80	80 y	D_1	21.7	21.8	21.7 x
D_2	84	84	84 x	D_2	21.7	21.3	21.5 x
Mean M	82 a	82 a		Mean M	21.7 a	21.5 a	

[1]DS = dry seeded, TP = transplanted; [2]D_1 = sowing on 30 April 2009, D_2 = sowing on 11 May 2009; [3] In each row, mean values followed by the same letter (a, b) were not significantly different at the 5% level by LSD. Mean values were averaged over four replications; [4]In each column, mean values followed by the same letter (x, y) were not significantly different at the 5% level by LSD. Mean values were averaged over four replications; [5]$LSD_{.05}$ = LSD for comparing establishment methods under the same seeding date; [6]$LSD._{05}$ = LSD for comparing seeding date for same establishment method

Effect of transplanting date and variety on performance of aman rice

Phenology: Growth duration of BRRI dhan46 ranged from 121 to 126 days, and for BRRI dhan49 the range was 123 to 138 days (Table 3). Both the aman seedling of first date was destroyed due to heavy rainfall on 5 August. Thus the second set of seedling sown on 10 August was transplanted in the same date (11 September).

Table 3. Effect of sowing date and variety on time (days after sowing, DAS) of flowering and physiological maturity of aman crops.

	Flowering (DAS)		Duration of grain filling (days)		Physiological maturity (DAS)	
Transpl. date[1]	BRRI dhan46	BRRI dhan49	BRRI dhan46	BRRI dhan49	BRRI dhan46	BRRI dhan49
11 Sept	93	96	33	44	126	138
11 Sept	90	92	31	31	121	123

[1]Seedlings were transplanted 30 DAS, except for the first sowing when the seedling were transplanted 35 DAS (sown on 5 Aug)

BRRI dhan46 showed photoperiod sensitivity and growth duration was decreased by 5 days with a delay in sowing of only 5 day. However, in the case of BRRI dhan49, there was a large decrease (by 13 days) in the duration of the period from flowering to PM with delayed sowing (Table 3).

Yield and yield component: The interaction between sowing date and variety on grain yield was not significant. Grain yield of BRRI dhan49 (4.7 t ha^{-1}) was significantly higher than of BRRI dhan46 (4.3 t ha^{-1}) (Fig. 3).

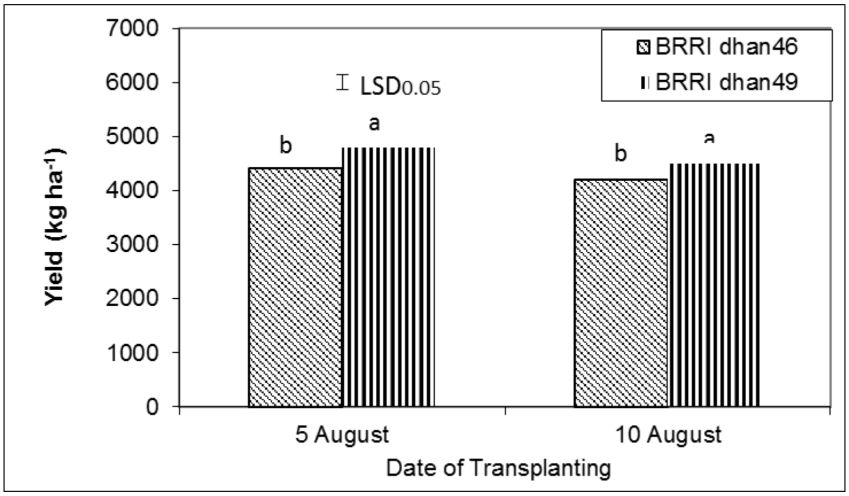

Fig. 3. Grain yield of aman affected by variety during the 2009 aman cropping season. Vertical bar is the LSD (P = 0.05) between sowing dates.

There was no effect of seeding date on grain yield. The higher yield of BRRI dhan49 was associated with significantly more spikelets panicle^{-1} and significantly higher spikelet fertility, although this was partly compensated for by lower grain weight (Table 4). The results suggested that BRRI dhan49 can still give acceptable yields, even if sowing is delayed until 10 August, despite its photoperiod sensitivity. This is consistent with a recent BRRI finding that BRRI dhan49 gave yields of 4.5 t ha^{-1} when 35 days old seedlings were transplanted on 15 September (BRRI, 2009a).

Table 4. Effect of variety and seeding date on yield components of aman rice in 2009.

Transplanting date[2]	Varieties[1]			Varieties		
	V_1	V_2	Mean D	V_1	V_2	Mean D
Panicle density (no. m^{-2})				Spikelets panicle^{-1} (no.)		
D_1	251	293	272	83	110	96
D_2	274	250	262	83	102	93
Mean V	263	271		83 b	106 a	
LSD$_{.05}$[3]						
Filled spikelets (%)				Thousand-grain weight (g)		
D_1	72	81	76	23.1	17.6	20.4
D_2	68	82	75	22.6	17.9	20.2
Mean V	70 b[4]	82 a		22.9 a	17.7 b	
LSD $_{.05}$						

[1] V_1 = BRRI dhan46 (photoperiod-sensitive), V_2 = BRRI dhan49 (photoperiod-insensitive);[2] D_1 = sowing on 5 Aug and transplanting on 11 Sep (35-day-old seedlings), D_2 = sowing on 10 Aug and transplanting on 11 Sep (30-day-old seedlings); [3]LSD.05 = LSD values for comparing seeding dates for the same variety at the 5% level of significance; [4]In each row, mean values followed by the same letter were not significantly different at the 5% level by LSD. Mean values were averaged over 4 replications.

Yield of the aus–aman cropping system: Total system yield of aus-aman varied from 7.9 to 9.6 t ha^{-1}, and there was no significant interaction between aman variety and aus establishment method (Fig. 4). With dry seeded aus in the system, total yield (8.8 to 9.6 t ha^{-1}) was not affected by aus sowing date or aman variety. However, with late sowing of transplanted aus, system yield was lower with the photoperiod sensitive variety (BRRI dhan49) (7.9 to 8.3 t ha^{-1}) than with the non-photoperiod sensitive variety (BRRI dhan46) (8.7 to 9.2 t ha^{-1}).

The experiment conducted using a short duration aus rice variety (BRRI dhan65) under dry seeded and transplanted method followed by two photoperiod-sensitive and photoperiod-insensitive aman varieties to develop suitable technical package for aus–aman cropping system with stable and high yield in areas of the coastal zone.

It was observed that in areas without suitable water for supplementary irrigation, seeding of aus can be delayed until 10 May, followed by transplanting during the first week of June, as rainfall becomes stable. In most years, this would allow field preparation taking advantage of rainfall or tidal flooding. Late crop establishment, however, would expose the newly established aus crop to higher risk of submergence from high rainfall or flooding from surrounding areas.

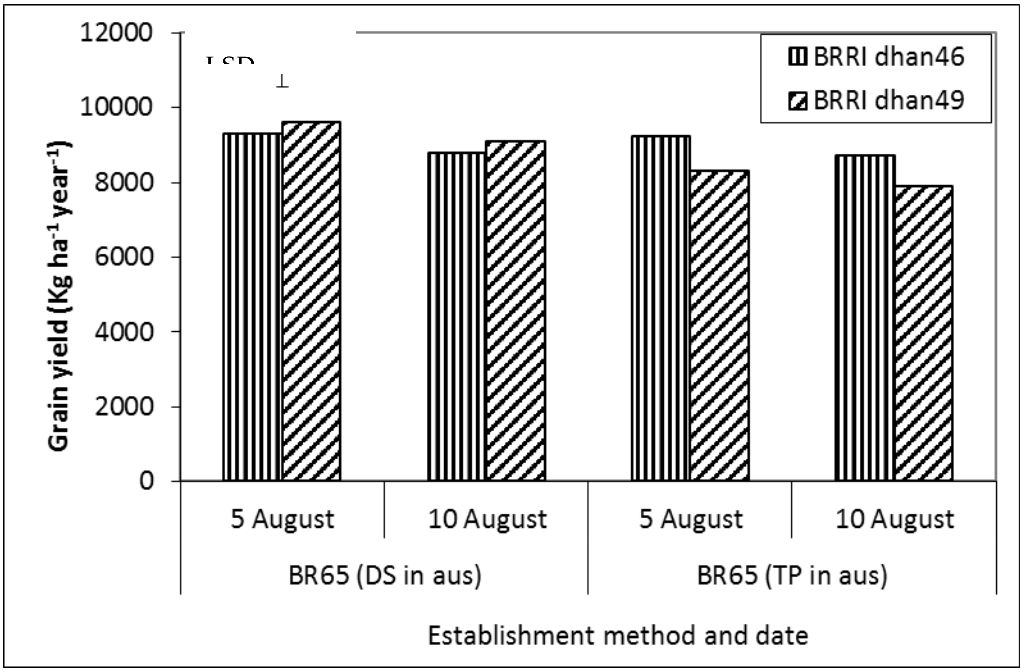

Fig. 4. Total grain yield of the aus-aman cropping system as affected by aus establishment method and sowing date and aman variety in 2009. Vertical bar is the LSD (P = 0.05) between sowing dates.

The combinations of BRRI dhan65 (aus) + BRRI dhan49 (aman) gave the best yields under favourable conditions. The use of photoperiod-insensitive varieties (such as BRRI dhan49) in the aman season would give greater flexibility to the aus–aman cropping calendar than a photoperiod-sensitive variety such as BRRI dhan49.

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