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Selection of Suitable Sowing Window for *Boro* Rice in Coastal Regions of Bangladesh

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Suitable adaptation strategies for dry season *boro* rice cultivation in coastal regions are important for future food security in Bangladesh. This study assessed the effect of sowing date of dry season *boro* rice as an adaptation strategy, with a focus on maximum utilization of water. The study was conducted at Dacope, Khulna and Amtali, Barguna during the dry seasons of 2016-17 and 2017-18. The experiment comprised six sowing dates between 15th October to 30th December including three varieties BRRI dhan28, BRRI dhan67 and BINA dhan10 in split plot randomized design with three replications. In Dacope and Amtali, salt tolerant varieties BRRI dhan67 and BINA dhan10 produced the highest yield (about 6 t ha^{-1}) when sown in November. Irrespective of locations, the highest irrigation water productivity (1.08 kg m^{-3}) and highest total water productivity (0.80 kg m^{-3}) was found when rice was sown in November. Among the two test locations, the lowest irrigation water was used at Amtali and the highest amount of irrigation was required for Dacope due to comparatively high land and low amount of rainfall. This indicated that boro rice can be grown where the fresh water resources are available during the crop growing season. Early sowing is difficult, because most of the land occupied by T. *aman* rice and late sowing is facing the problem of soil and water salinity. From the perspectives of growth duration, yield performance, water use and water productivity, the best sowing window for *boro* rice was found in between 15th November to 15th December. The data generated during this experiment can now also be used to set-up the APSIM cropping-systems model for subsequent investigations into long-term system performance variability (risk), and also on how these sowing dates and varieties compare under projected future climate change scenarios at these locations.

(***Key words:*** *Cropping intensification, Irrigation, Salinity, Sowing time, Water productivity)*

Rice is one of the world's most important staple food crops. In Asia, it is the main item in the diet of 3.5 billion people. Expected increases in population will require 70% more rice in 2025 than is consumed today (Kim and Krishnan, 2008). The coastal area of Bangladesh covers about 20% of the country and over 30% of the net cultivable area (Haque, 2006). A recent study indicated that the salinity affected area has increased from 8330 km^2 in 1973 to 10560 km^2 in 2009 (Soil Resources Development Institute, 2010). Salinity causes an unfavorable environment and hydrological situation that restrict normal crop production throughout the year.

The production of *boro* rice in coastal areas is an option for increased cropping intensity, but it requires more water compared to other *rabi* crops. In the dry season, most of the coastal regions remain fallow due to a shortage of fresh water and problematic salinity levels later in the *rabi* season. In most areas, the rivers and canal waters become saline in the dry season and the salinity level goes beyond the permissible limits of crops (>4.0 dS m^{-1}) after the middle of February. The soil also becomes saline in the dry season due to high temperature and the consequent soil evaporation which draws saline water up from shallow saline water tables, and deposits salt in the surface soil. For that reason, fresh water resources to flush down salts via irrigation are a limiting factor for crop intensification during the dry season in coastal areas. The dry season irrigated *boro* rice requires a large amount of water for successful cultivation. The water requirement is more in coastal region due to salt flushing, compared with other parts of Bangladesh. But the fresh water resource in the dry

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season is limited in the coastal region. Most of the years during late November and even March, depressions form in the Bay of Bengal, which affect the non-rice crops in the coastal regions through unseasonal rainfall and water-logging of the soil. Therefore, it is difficult to cultivate low water requirement non-rice crops in the heavy textured soil of coastal zones.

Understanding the appropriate sowing time of rice could be a simple and effective way to deal with changes in seasonal variability in climatic parameters. Following expected climate change, a shift in planting date may allow plants to be exposed to more favorable conditions (Chun *et al*., 2016).

The appropriate sowing time of the rice crop is important to maximize grain yield and minimize grain damage and quality deterioration. Delayed sowing results in the poor emergence and reduced production of panicles per meter square and spikelets per panicle, ultimately affecting yield (Hayat *et al*., 2003).

For under developed countries, more emphasis on low-cost strategies is likely to be more effective for large-scale implementation. Farmers can adapt to changed climatic conditions to some degree by changing planting dates, choosing cultivars of different growth duration, or changing crop rotations (Wassmann and Dobermann, 2007). Shifting the rice sowing date could be an effective solution to improve rice yields in a changing climate. Simple adaptation options, such as shifting planting dates, can be applied to significantly increase net water productivity also (Mainuddin *et al*., 2011).

Time of sowing experiments was conducted to establish the suitable sowing time for coastal areas and to minimize irrigation requirement without damaging the crop during the critical growth stages. This study also facilitated an understanding of the response of a range of varieties to different sowing dates. This study was also conducted to optimize the water resources and improving the productivity and profitability in the coastal region.

MATERIALS AND METHODS

The study was conducted at Dacope, Khulna and Amtali, Barguna during the dry seasons of 2016-17 and 2017-18. Dacope is located in polder no 31 at 22.63° N and 89.50° E, where as Amtali is situated at 22.63° N and 89.50° E in polder no 43/1. The experiment was laid out in a split plot randomized design with three replications. The seeding date was in the main plot and variety in sub-plot. The six-seeding date started from 15 October and ends on 30 December with 15 days interval. Three varieties, namely BRRI dhan28 (popular but non-saline tolerant *boro* variety), BRRI dhan67 and BINA dhan10 (saline tolerant *boro* varieties) were tested in this study. Forty-five days-old rice seedlings were transplanted at 20 cm x 20 cm spacing following Bangladesh Rice Research Institute (BRRI) recommended fertilizer and agronomic management practices. The fertilizer rate was 240-100-70-60-10 kg urea-triple super phosphate (TSP)-muriate of potash (MoP)-gypsum-zinc sulphate per ha. The whole amounts of TSP, MoP, gypsum and zinc sulphate were applied at the time of final land preparation. Urea was applied in 3 equal splits at 15, 30 and 45 days after transplanting. Weeding was done 3 times synchronizing with the top dressing of nitrogen fertilizer. Insecticide was applied 4-5 times to control insect pest infestation. Measured quantities of irrigation water were applied directly from the trapped canal to the experimental plots. Applied water of the experimental plots was measured by the flow meter (3Max). The water salinity was measured before and after irrigation water application by EC meter (Lutron CD-4301).

For monitoring river and trapped canal water salinity, three spots were selected at a certain distance in both the locations of Dacope, Khulna and Amtali, Barguna and the water salinity was measured. The measurement was taken twice in a week at 9:00 am on every Sunday and Thursday. An observation well was installed in one corner of the experimental field within the weather station boundary at Pankhali village of Dacope, Khulna and very near to the experimental field at Sekandarkhali village of Amtali, Barguna to measure groundwater level and salinity. The groundwater level and salinity were measured from a shallow aquifer, which may be connected to the canal and river water.

Grain yield of each plot was estimated from a 5 m^2 area located in the central part of the plots. The exact number of hills in the designated 5 m^2 harvest area was recorded including missing and dead hills. The collected samples were threshed, cleaned and dried properly to determine the grain yield, which was then converted to tonnes per hectare yield at 14% moisture content (Gomez, 1972). Irrigation water productivity (WP_i) and total water productivity (WP_t) was calculated by the following equations:

$$WP_i \quad \frac{Y}{I} \qquad ...(1)$$

Where, Y is grain yield (t ha^{-1}) and I is applied irrigation (mm).

$$WP_t \quad \frac{Y}{I+R} \qquad ...(2)$$

Where, Y is grain yield (t ha^{-1}), I is applied irrigation (mm) and R is rainfall (mm).

RESULTS AND DISCUSSION

Rainfall pattern and irrigation applied

A rainfall of 1064 mm occurred during the rice growing season of 2016-17 at Amtali, which is congenial for rice growth and also created some flooding situation This reduced the irrigation cost and the salinity effect (Fig. 1). But in 2017-18, only 438 mm rainfall occurred (Fig. 1) which was also still congenial for rice growth but with reduced flooding. The rainfall not only reduces the irrigation amount, but it also reduces the salinity effects of soil and water for growing rice. The highest amount of irrigation water (900 mm) was used for the 15th October sowing treatment because early sowing required more water due to its long growth duration and reduced rainfall. The lowest amount of irrigation water (600 mm) was used for the 30th December sowing (Fig. 1) because of the short growth duration in both years.

In the Dacope site, similarly the highest amount of irrigation water (988 mm) was used in the 15th October sowing treatment and the lowest (600 mm) was used for the 30th December sowing (Fig. 2) in both years. In 2016-2017 about 643 mm rainfall was recorded during the boro-growing season, which is congenial for rice growth and reduced the irrigation cost and salinity effect (Fig. 2). In 2017-2018, about 581 mm rainfall was recorded (Fig. 2). Similar to Amtali, the data revealed that early sowing required more irrigation water while the late sowing required less irrigation water due to its short growth duration with higher amount of rainfall.

Yield performance and water productivity

In Amtali, among the six sowing dates (15th October to 15th December) the middle sowing dates (15th November - 15th December) performed better irrespective of all tested varieties in yield (Table 1) in 2016-17 and 2017-18. The growth duration was decreased gradually due to higher temperature effects on the later part of the rice growing season. In this window, the *boro* rice began growing in winter *i.e.* with cool temperatures at seeding, transplanting and up to mid vegetative stage, and after that it grows during summer *i.e.* in warm temperature during booting, flowering and ripening stages. For that reason, late sown of *boro* rice faced comparatively warmer temperature during its growing period and reduced its growth duration.

The data revealed that irrespective of variety, 30th November sowing treatment produced the highest yield (Table 1) in both years. This is considered to be the

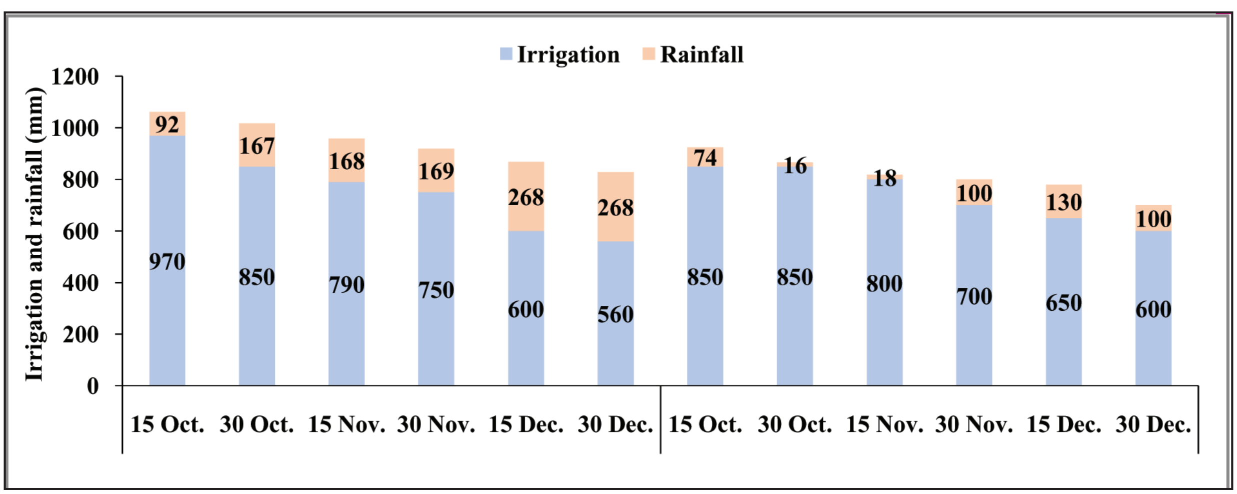

Fig. 1. *Applied irrigation and rainfall in rice growing season (boro 2016-17 and 2017-18) for the different sowing date treatments at Amtali, Barguna*

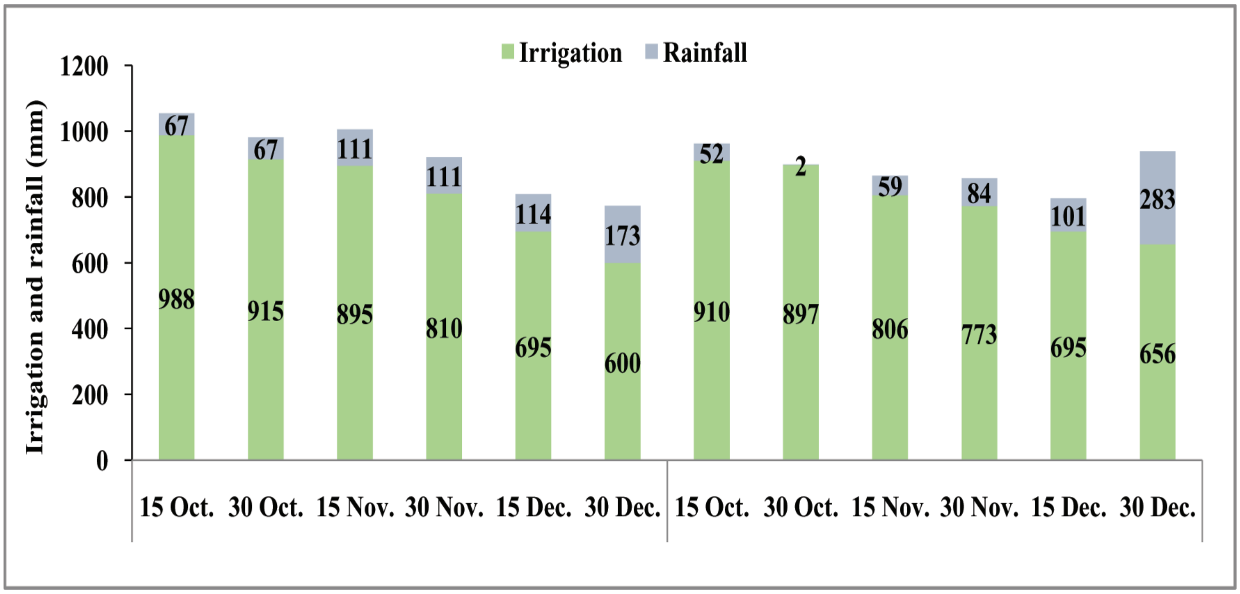

Fig. 2. *Applied irrigation and rainfall in rice growing season (boro 2016-17 and 2017-18), at Dacope, Khulna*

Table 1. *Time of sowing effects on yield and growth duration of BRRI dhan28, BRRI dhan67 and BINA dhan10 at Amtali during boro 2016-17 and 2017-18*

Sowing date	Variety	Yield (t ha^{-1})		Growth duration	
		2016-17	2017-18	2016-17	2017-18
15th October	BRRI dhan28	4.42ijklmn	4.7ghijkl	155cd	155cd
	BRRI dhan67	4.27jklmn	4.69ghijkl	159bc	159bc
	BINA dhan10	4.36ijklmn	4.56hijkl	151e	151e
30th October	BRRI dhan28	4.20klmn	4.76ghijkl	160b	160b
	BRRI dhan67	4.02lmno	4.49hijklm	164a	164a
	BINA dhan10	4.26jklmn	4.49hijklm	159b	159b
15th November	BRRI dhan28	6.12abc	5.11efghij	150e	150e
	BRRI dhan67	6.30ab	6.06abcd	153de	153de
	BINA dhan10	6.43a	6.35ab	151e	151e
30th November	BRRI dhan28	6.45a	6.09abcd	142fg	142fg
	BRRI dhan67	6.34ab	5.76abcdef	145f	145f
	BINA dhan10	6.34ab	5.37cdefgh	140gh	140gh
15th December	BRRI dhan28	5.51bcdefg	5.94abcde	141g	141g
	BRRI dhan67	5.83abcdef	5.59abcdefg	143fg	143fg
	BINA dhan10	5.20defghi	5.02fghijk	138h	138h
30th December	BRRI dhan28	4.25jklmn	4.37ijklmn	129i	129i
	BRRI dhan67	3.55no	3.61mno	132i	132i
	BINA dhan10	4.18klmno	3.28o	125j	125j
LSD (0.05)		0.91		3.34	
CV (%)		11.00		1.39	

*Values followed by same letter in a column indicates that they are not statistically different optimum rice sowing time all over the country. In the growing seasons of 2016-17 and 2017-18 among the tested varieties, the salt tolerant varieties, BRRI dhan67, and BINA dhan10, produced a similar higher yield compared to non-salt tolerant variety BRRI dhan28, due to the low salinity level of irrigation water.

In the Amtali area, the river water salinity starts to increase after November, 2016 and reached its peak in May, 2017. After the onset of rainfall in June, 2017 the salinity level of rice pond water sharply decreased and from July to November, 2017 the river water became fresh and after that its salinity began to increase (Fig. 3). The canal water was trapped on 20th December-2016 and at that time canal water salinity was 1.1 dS m^{-1}. Its salinity increased at a slower rate and reached 2.3 dS m^{-1} by April, 2017 due to evaporation and possible interaction with saline water table (Fig. 3). The field water salinity varied corresponding to the canal water salinity and crops could be successfully grown in Amtali region. The salinity level of the trapped irrigation water during the whole rice-growing season was within permissible limits for rice irrigation (Fig. 3), indicating that if the water resource is available, farmers can grow rice successfully.

The irrigation water productivity varied from 0.54 to 1.08 kg m^{-3} and 0.54 to 1.07 kg m^{-3} in both 2016-17 and 2017-18, respectively (Figs. 4 and 5). The total water (irrigation + rainfall) productivity varied from 0.50 to 0.72 kg m^{-3} and 0.42 to 0.80 kg m^{-3} similarly. In both years, the highest total water productivity was achieved in the 30th November sowing date treatment, due to its higher yield and reduced amount of irrigation water needed for its shorter growth duration.

In Dacope, among the six sowing dates, those within the period 15th November to 15th December performed better across all tested varieties in yield (Table 2). The growth duration decreased gradually due to the higher temperature effect on the later part of the rice growing season. The data revealed that irrespective of variety, 15th December sowing produced the highest yield in 2016-17 and 30th November produced the highest yield in 2017-18. Among the tested varieties both the salt tolerant ones, BRRI dhan67 and BINA dhan10, produced a similar higher yield compared to the non-salt-tolerant variety BRRI dhan28 due to low salinity level of irrigation water (Table 2).

The salinity of the Jabjapia river was measured twice in a week at three selected places in the experimental area. The average salinity of the river water remained below 1.0 dS m^{-1} up to December, 2016 (Fig. 6) and is considered highly suitable for irrigating crops. Even the river water remained suitable (<4.0 dS m^{-1}) for irrigation up to end of December, 2016. After that the river water salinity gradually increased and at the end of *rabi/ boro* cropping season it reached about 25 dS m^{-1} in April, 2017. It indicated that after December there is no possibility to use river water for crop cultivation. The canal water was trapped on 13th December 2016 during

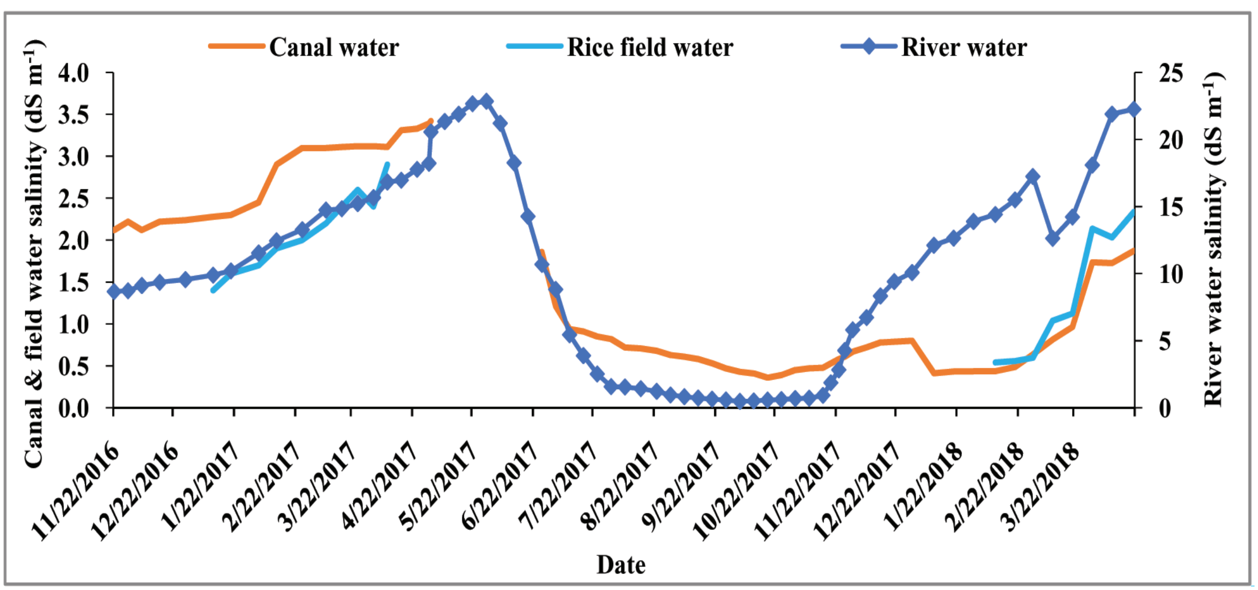

Fig. 3. *River, canal and rice field water salinity at Amtali, Barguna during dry season, 2016-18*

Table 2. *Time of sowing effects on plant yield and growth duration of BRRI dhan28, BRRI dhan67 and BINA dhan10 at Dacope during boro 2016-17 and 2017-18*

Sowing date	Variety	Yield (t ha^{-1})		Growth duration	
		2016-17	2017-18	2016-17	2017-18
15th October	BRRI dhan28	5.3fghi	4.8ij	158 de	157ef
	BRRI dhan67	5.1ghij	5.0hij	160bc	159cd
	BINA dhan10	4.6j	5.5cdefgh	164a	162b
30th October	BRRI dhan28	5.5cdefgh	4.9ij	155g	156fg
	BRRI dhan67	5.8abcdef	5.5cdefgh	155g	158 de
	BINA dhan10	5.6bcdefgh	5.4defghi	159cd	159cd
15th November	BRRI dhan28	5.7bcdef	5.1ghij	146j	152hi
	BRRI dhan67	5.8abcdef	6.1abc	151i	156fg
	BINA dhan10	6.0abcd	6.0abcd	153h	155fg
30th November	BRRI dhan28	5.5cdefgh	5.6bcdefg	140no	143lm
	BRRI dhan67	5.8abcdef	6.0abc	141mn	15 hi
	BINA dhan10	5.9abcde	6.4a	144kl	152hi
15th December	BRRI dhan28	6.4a	5.1ghij	131r	138o
	BRRI dhan67	5.1ghij	6.2ab	136p	145jk
	BINA dhan10	6.2ab	5.7bcdef	139o	143l
30th December	BRRI dhan28	5.0hij	5.03hij	126t	133q
	BRRI dhan67	5.5cdefgh	5.1ghij	128s	136p
	BINA dhan10	5.6bcdefg	4.6j	132qr	136p
LSD (0.05) CV (%)		0.62 6.9		1.68 0.69	

*Values followed by same letter in a column indicates that they are not statistically different

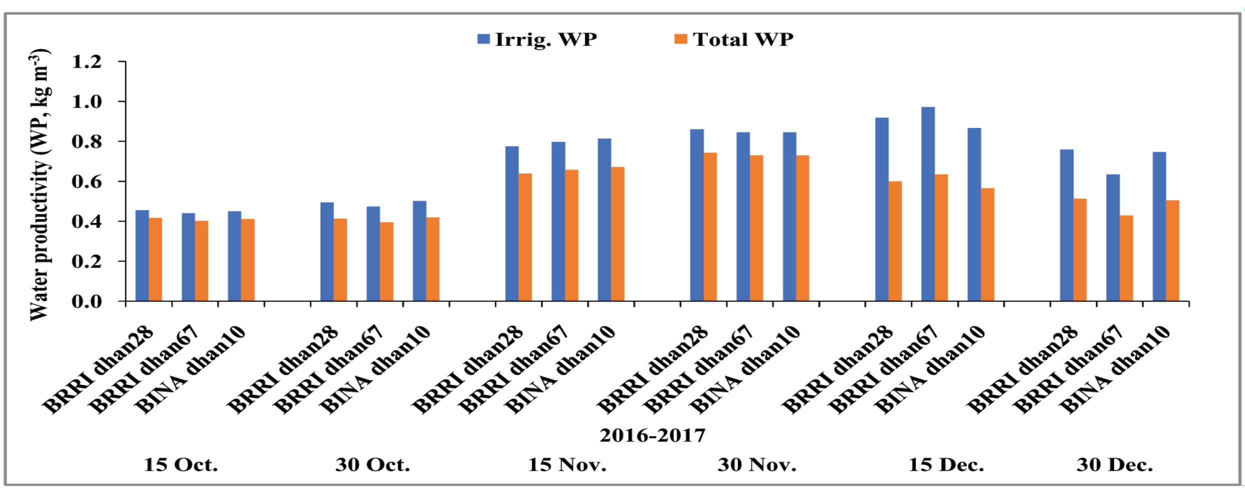

Fig. 4. *Irrigation and total water (irrigation + rainfall) water productivity of different varieties under different sowing dates at Amtali, Barguna during boro 2016-17*

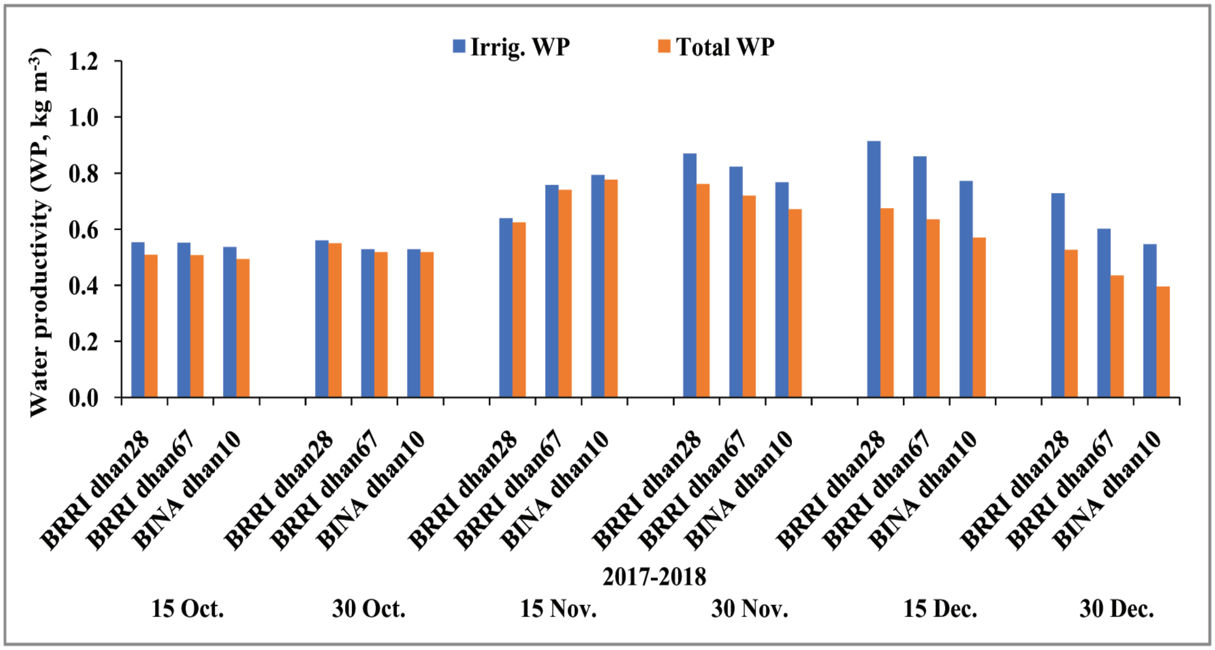

***Fig. 5.** Irrigation and total water (irrigation + rainfall) water productivity of different varieties under different sowing dates at Amtali, Barguna during boro 2017-18*

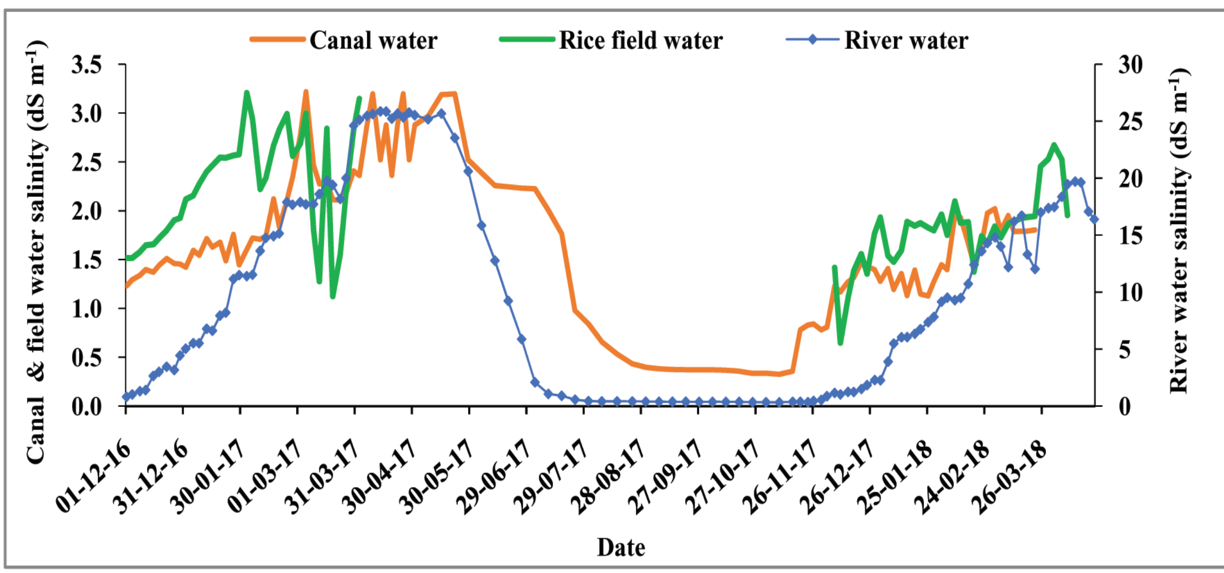

***Fig. 6.** River, canal and rice field water salinity at Dacope, Khulna during dry season, 2016-18*

high tide with a water salinity of 1.23 dS m^{-1}. Its salinity increased at a slower rate and reached 3 dS m^{-1} in March, 2017 due to evaporation and influence of groundwater flow (Fig. 6). This limit was also permissible for crop cultivation. After the onset of the rainy season in June 2017, the river water salinity sharply fell and from July-December, 2017, there was effectively no salinity. After this time, river water salinity starts to increase as in the previous year (Fig. 6).

The salinity level of the trapped irrigation water within the whole rice growing season was within the permissible limit, indicating that if the water resource is available, farmers can grow rice successfully. On the other hand, after the 30th December sowing date, the salinity level was high in the field (Fig. 6) so that optimum sowing date can be chosen within 30th

November to 15th December.

The irrigation water productivity in Dacope, varied from 0.54 to 0.96 kg m^{-3} and the total (irrigation + rainfall) water productivity varied from 0.50 to 0.75 kg m^{-3}. These increased at late sowing due to its higher yield and less amount of irrigation water needed for its shorter growth duration (Figs. 7 and 8).

Comparing the two test locations, the highest amount of irrigation was required for Dacope due to the comparatively high land and a lesser amount

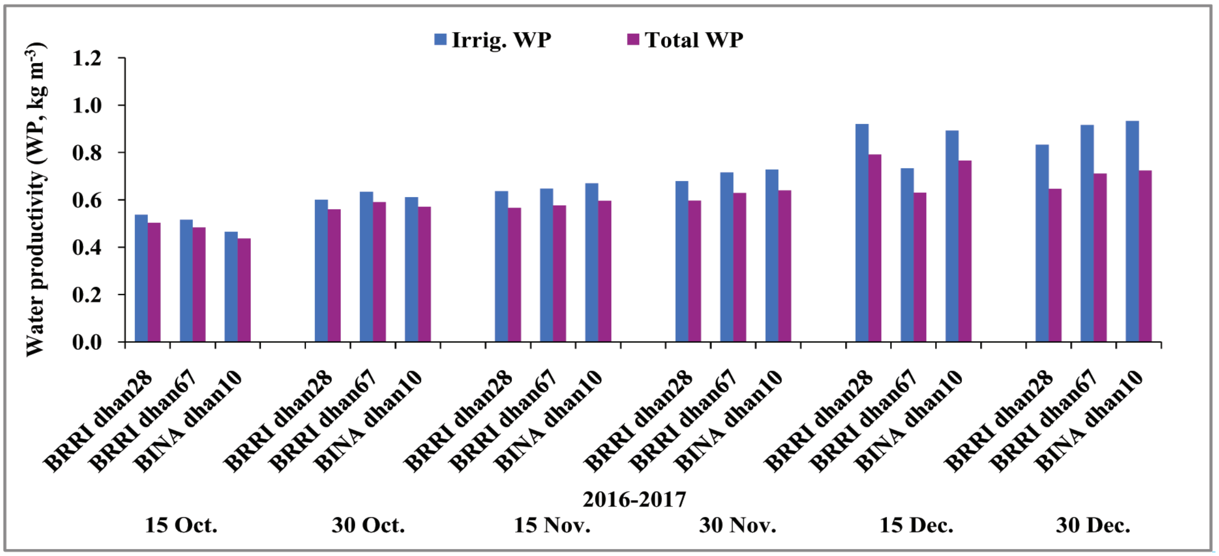

Fig. 7. *Irrigation and total (irrigation + rainfall) water productivity of different variety under different sowing date, Dacope, Khulna during boro 2016-17*

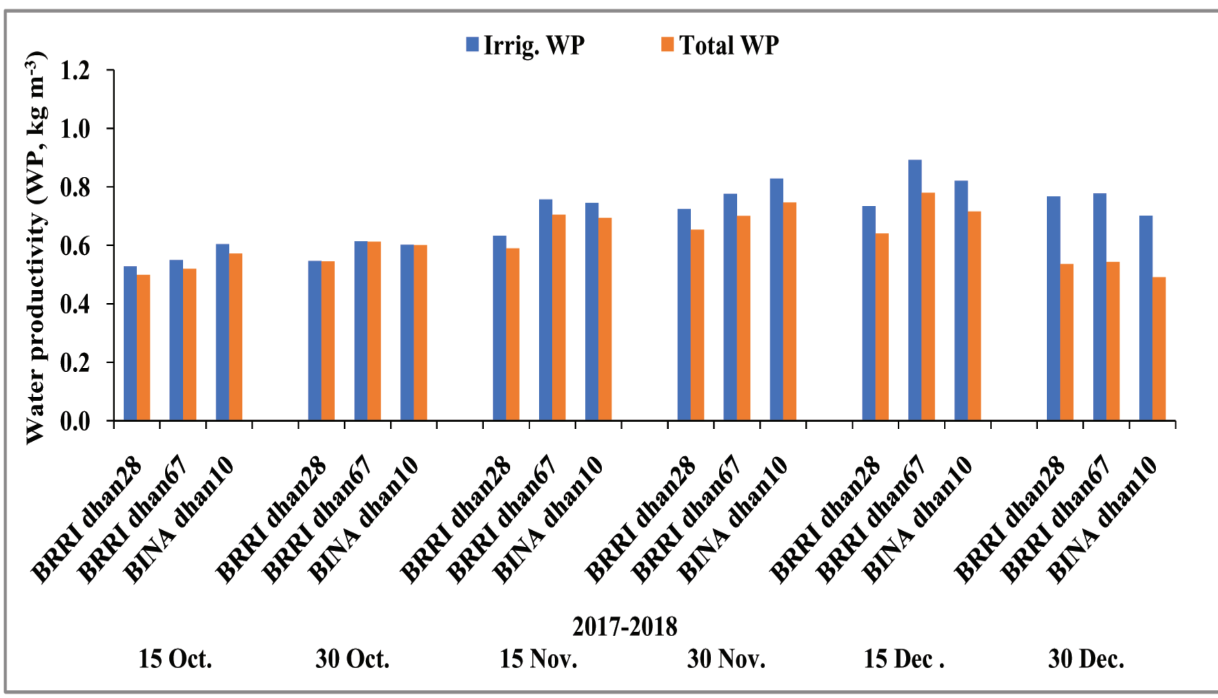

Fig. 8. *Irrigation and total (irrigation + rainfall) water productivity of different varieties under different sowing dates at Dacope, Khulna during boro 2016-17 and 2017-18*

of rainfall. This experiment showed that the highest amount of irrigation water was used in 15th October sowing treatment and the lowest in the 30th December sowing treatment, across both locations. Maximum rainfall was recorded after the 15th November sowing date, which reduced the irrigation amount required. The water productivity depends upon the rice production and water requirement. Irrespective of location, irrigation water productivity varied from 0.54 to 1.08 kg m^{-3} and the total water productivity varied from 0.42 to 0.80 kg m^{-3} for all the tested varieties. The findings are similar with (Bouman and Toung, 2001) who reported 0.3 to 1.1 kg m^{-3} water productivity with continuous submergence regimes.

Shortage of available fields makes early transplanting (September-October) difficult in both Dacope and Amtali regions because of the late harvesting of Aman rice. Most of the T. *aman* rice is currently harvest at the end of December so that it is not currently possible to sowing between 15th to 30th October. On the other hand, when transplanted late (December-January), there was yield loss due to high salinity level.

In both Dacope and Amtali, salt tolerant varieties, BRRI dhan67 and BINA dhan10 produced the highest yield (about 6 t ha^{-1}) when planted in November in both the years. This indicated that *boro* rice can be grown successfully in the coastal region. Production of *boro* rice in the coastal area is an option for cropping intensification in the comparatively low land areas where water receding delayed after T. *aman* harvest. But *boro* rice requires more water than other non-rice crops. The 15th November to 15th December sowing date of *boro* rice reduces potential crop water requirement compared to early sowing date. It also reduced irrigation requirement compared to early sowing date because of increased rainfall availability during the later periods of crop growth.

Experiments have the constraints that they are conducted over relatively short periods of time and a limited number of years, hence it cannot give a comprehensive insight into how the experimental treatments would perform in different seasons and also at different locations. The data collected in this experiment will now be used to calibrated and validate the APSIM cropping systems model (Gaydon *et al*., 2017), which can then be used to extend the experimental assessment by simulating a much wider number of years of recorded historical climate, as well as future climate change scenarios. This will provide a greater insight into risks and variability within the system than this experiment can give on its own.

Boro rice can be successfully grown in all tested locations. In both Dacope and Amtali, the salinity-tolerant varieties BRRI dhan67 and BINA dhan10 produced the highest yield due to their salt tolerant ability (~ 6 t ha^{-1}) when planted in November. Irrigation water productivity varied from 0.54 to 1.0 kg m^{-3} and total water productivity varied from 0.42 to 0.80 kg m^{-3} for all the tested varieties. The production of *boro* rice in the coastal area is an option for cropping system intensification in the comparatively low land areas, particularly where the recession of monsoon flood-water is delayed after T. *aman* harvest. A good choice of sowing dates from a production and water demand perspective is between 15th November to 15th December. The data collected as part of this experiment can now also be used to calibrate and validate the APSIM cropping systems model, thereby allowing a subsequent modeling assessment of broader system risk and variability associated with the different sowing dates and varieties, as well as performance under future climate change conditions.

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