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Water and Soil Salinity Dynamics and Dry Season Crop Cultivation in Coastal Region of Bangladesh

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Coastal region has a potentiality of crop intensification through introduction of dry season crops. This study aimed to determine the possibility of dry season crop cultivation through water resources management. Water salinity of two rivers named Jabjapia at Dacope, Khulna and Andharmanik at Amtali, Barguna was monitored during 2017 to 2018. River water was trapped into adjacent canals during mid-December. Salinity of trapped water, field water and soil were recorded weekly. Groundwater depth and salinity were monitored from installed observation well near to field. Salt tolerant rice varieties BRRI dhan67 and BINA dhan10 along with popular BRRI dhan28 and BRRI dhan58 were cultivated. *Rabi* crops like sunflower, maize, sweet gourd (pumpkin) and water melon were also cultivated. River water salinity remained below 4.0 dS m^{-1} up to 15th of December in both locations and then rose sharply. So, 10-15 December is the suitable time to trap river water into the canal. Salinity of trapped water remained in permissible limit for irrigation both at Dacope (1.30 to 3.00 dS m^{-1}) and Amtali (1.1 to 2.3 dS m^{-1}) during *boro* season. Although groundwater salinity at Dacope (2.30 to 3.52 dS m^{-1}) was comparatively less than Amtali (3.12 to 11.7 dS m^{-1}), it was not suggested for irrigation. Observed maximum water salinity in rice field was 3.14 and 2.9 dS m^{-1} in April at Dacope and Amtali, respectively. BRRI dhan67 and BINA dhan10 gave similar average grain yield of 6.4 and 6.2 t ha^{-1}, respectively at Dacope. Similar yield trend was found at Amtali. Among the tested *rabi* crops sweet gourd gave the highest maize equivalent yield of 9.67 t ha^{-1} at Dacope. Since coastal regions have large river and canal network, there is a good prospect to increase cropping intensity by introducing salt tolerant varieties and trapping water having recommended salinity level for irrigation.

(**Key words:** *Boro rice, Rabi crops, River, Salinity, Trapped water)*

The coastal area of Bangladesh covers about 20% of the country and over 30 percent of the net cultivable area (Haque, 2006). Agricultural land use pattern in this area is restricted due to different level of salinity. Salinity causes a hostile environment for the normal crop production throughout the year in the coastal belt of Bangladesh (Alam *et al*., 2017). During 1973, salinity affected 83.3 million hectares of land; this increased to 102 million hectares by the year 2000 and in 2009 it was 105.6 million hectares (SRDI, 2010; Alam *et al*., 2017). According to Haque (2006), the factors which contribute significantly to the development of saline soil are, tidal flooding during wet season (June - October), direct inundation by saline water, and upward or lateral movement of saline ground water during dry season (November-May). The severity of salinity problem in Bangladesh increases with the desiccation of the soil. It affects crops depending on degree of salinity at the critical stages of crop growth, which reduces yield and in severe cases total yield is lost.

Wet season rice (T. *aman*) is the main crop in coastal region while dry season remains fallow. Due to water scarcity in Northern-West part of Bangladesh, the government of Bangladesh put more emphasis to shift *boro* rice production to Southern part since there are abundant surface water resources. A large river and canal networks exists in coastal region where water salinity remains very less up to November.

The area of oil seed production is decreasing over the year due to various economic and technical reasons (Miah *et al*, 2014). But there is a good possibility to produce sunflower since some saline tolerant varieties are available (Khatun *et al*., 2016). Besides this, vegetable production is an important issue to meet nutrition demand of coastal people. So *rabi* season

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cultivation of vegetable crops like gourd, cucumber, beans, etc. can solve this issue. Since vast areas of coastal region remain fallow after the month of December, there is a great opportunity to utilize this fallow lands by cultivating dry season crops.

Although Bangladesh Rice Research Institute (BRRI), Bangladesh Agricultural Research Institute (BARI) and Bangladesh Institute of Nuclear Agriculture (BINA) have developed some salt tolerant varieties of different crops, water and soil salinity sometimes rises to higher levels and reduces grain yields. So, variety alone cannot address salinity problem. Thus fresh water harvesting in existing canals could be a solution for dry season crop cultivation. With the above background, a study was undertaken to identify the suitability of fresh water storage and to determine the possibility of dry season cultivation in saline areas of Bangladesh.

MATERIALS AND METHODS

Study locations

The study was conducted in a high saline area of Pankhali, Dacope under Khulna districts and comparatively less saline area of Sekandarkhali, Amtali under Barguna district in Bangladesh during 2017 to 2018. Pankhali is located in polder no 31 at 22.63ºN and 89.50ºE whereas Sekandarkhali village is situated at 22.63ºN and 89.50ºE in polder no 43/1. Jabjapia and Andharmanik rivers are passing away near Pankhali and Sekandarkhali village, respectively.

Data collection and analysis

Three points of both Jabjapia and Andharmanik rivers were selected to monitor river water salinity round the year. An adjacent canal to Jabjapia river of about 2.75 km long and average 13 m wide was trapped with water constructing a temporary earthen dam across the canal on 13th December, 2016 and 19th December 2017. On the other hand 4 km long and 10 m wide canal in Amtali sites was trapped during December to store fresh water from river flow to irrigate rabi and boro crops. Water salinity of the selected points was measured by EC meter (Lutron CD-4301). The measurement was taken twice in a week at 9:00 am to 9:30 am on every Sunday and Thursday. Irrigated rice field water salinity was measured at the same date and time. 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 shallow aquifer, which may be connected to the canal and river water.

Rice crop trial

Boro rice was cultivated using trapped canal water both in Pankhali, Dacope and Amtali during 2016-17 and 2017-18. Two saline tolerant rice varieties BRRI dhan67 and BINA dhan10 were tested along with popular variety BRRI dhan28 in Dacope, Khulna. BRRI dhan67, BRRI dhan58 and BRRI dhan28 were tested in Amtali, Barguna. All the varieties were transplanted in 15-20 January with recommended fertilizer and agronomic management. Irrigation was applied from trapped canal water. During *boro*, 2016-17 seasons about 0.7 ha land was cultivated after *aman* rice in Dacope, Khulna. The following year about 3 ha land was cultivated with *boro* rice with the farmers' keen interest. In the Amtali site, 2 ha and 4.12 ha lands were cultivated during *boro* 2016-17 and 2017-18, respectively.

Non-rice crop trials

Four different crops were cultivated in Dacope, Khulna and Amtali, Barguna in two consecutive years to evaluate their performance in saline condition. In both the locations the experiments were carried out in a randomized complete block design with four replications. Sunflower, maize, sweet gourd (pumpkin, *Curcurbita maxima*) and water melon were taken as indicator crops. Dibbling method was followed during establishment of sunflower and maize crops and pit method was used for sweet gourd and water melon. Seeds of sunflower and maize were planted by putting three seeds per pit and after emergence one plant per pit was maintained. Bangladesh Agricultural Research Institute (BARI) recommended doses of chemical fertilizers were applied. Pits were made properly for sweet gourd and water melon. Pit to pit and line to line distance was 2.0 m. Manure and basal dose of fertilizers were applied during pit preparation. Seedlings were prepared in the poly-bag and 16-20 days old seedlings were sown in the pit. Necessary intercultural operations were done as when necessary for all crops. Data was recorded as per requirement. Observations were made on 10 randomly selected plants from each plot of all replications. For measuring soil salinity soil was collected at 15 days interval. Total yield was calculated by measuring total fruit weight of a plot. The mean values were subjected to statistical analysis using R computer program.

RESULTS AND DISCUSSION

Dynamics of surface water salinity

Water salinity of the river Jabjapia was analyzed and presented in Fig. 1. On an average, salinity of the river water remained below 1.0 dS m^{-1} up to mid-November considered as highly suitable for irrigating crops. Even river water remained suitable (<4.0 dS m^{-1}) for irrigation up to 15th December. After that the river water salinity gradually increased up to the month of April. During the study period (2017 to 2018) the highest salinity of 25.9 dS m^{-1} was found in Jabjapia river on 13th April, 2017 and the value in 2018 was found 19.8 dS m^{-1} on 14th April, 2018. It indicated that after mid-December there is no possibility to use water of Jabjapia river for crop cultivation. After the onset of rains in June, 2017, the river water salinity sharply goes down and from July-December, 2017, there was no salinity and then it again starts to increase as in previous year (Fig. 1).

During trapping of Jabjapia river water on 13th December, 2016 and 19th December 2017, high tide made canal water salinity 1.23 dS m^{-1} and 1.3 dS m^{-1}, respectively. Its salinity increased in a slower rate and reached up to 3 dS m^{-1} in April, 2017 and 2018 due to evaporation and influence of groundwater flow (Fig. 2). This limit was also permissible for crop cultivation. The field water salinity varied corresponding to canal water salinity and successfully grown the crops in Dacope region.

In Amtali area, the river water salinity starts to increase after November and reached its peak at May (Fig. 3). After the onset of rainfall in June, 2017 the salinity level of river water sharply decreased and from July to November the river water became fresh and after that its salinity starts to increase. The canal water was trapped on 20th December, 2016 and canal water salinity was 1.1 dS m^{-1}. Its salinity increased in a slower rate and reached up to 2.3 dS m^{-1} in April, 2017 due to evaporation (Fig. 4). Such level of salinity is also permissible for crop cultivation. The field water salinity varied corresponding to canal water salinity and there was no problem for successfully crop production in Amtali region.

Dynamics of groundwater salinity

Groundwater level and salinity in the experimental field at Dacope varied between 0.00-1.37 m from field surface and 2.30-3.52 dS m^{-1}, respectively (Fig. 5a). During September to October, groundwater level (0.05 m) rose very close to ground surface in Pankhali, went down to maximum level in April. At Amtali, minimum groundwater level was found at 0.91 m and maximum at 2.72 m in September 2017 and March 2018, respectively. In Dacope site, the lowest water salinity of 2.3 dS m^{-1} was observed in January and the highest (3.52 dS m^{-1}) in May. Groundwater salinity in this location remained less than 4.0 dS m^{-1} during the study period and is considered suitable for irrigation development. But, withdrawal of groundwater from the upper low saline aquifer is a risky venture for increasing salinity by intrusion of river high saline water in dry season. Groundwater salinity at Amtali, Barguna was 3.12 to 11.7 dS m^{-1} (Fig. 5 b). The lowest value of 3.12 dS m^{-1} was observed in November, 2017 and the highest value of 11.7 dS m^{-1} in May, 2017 indicating that the upper aquifer groundwater in most cases is not suitable for irrigation.

Water and soil salinity dynamics

Rice field water salinity was always slightly higher than canal water salinity (Fig. 6). In both the locations, salinity increased over time but remains in permissible limit. During *boro*, 2016-17, the highest water salinity in rice field was 3.14 dS m^{-1} on 2nd April when rice crop was in ripening stage. Similarly, maximum field water salinity of 2.9 dS m^{-1} was recorded in Amtali. Since considerable rainfall occurred in April onwards, salinity reduced after this period. It was established that irrigating rice field with less saline water was not responsible for increased field water salinity. So, less saline (<1.3 dS m^{-1}) water trapping could be a good solution to rice as well as dry season *rabi* crop cultivation.

Soil salinity of rice field (0-60 m depth) was analyzed and presented in Fig. 7. Result shows that salinity was increased over depth in both the locations. Soil salinity was higher at Dacope, Khulna than Amtali, Barguna. At 0-15 cm soil depth salinity was 8.4 dS m^{-1} at Dacope and 5.32 dS m^{-1} at Amtali site. Following the rising trend of salinity, at 60 cm depth of soil the highest salinity was 11.31 and 9.18 dS m^{-1} at Dacope and Amtali site, respectively.

In case of non-rice (*rabi* crop) plots, the upper soil (0-15 cm) salinity was slightly higher than the deeper layer in both the locations. In Dacope, Khulna the upper layer soil salinity varied from 6.9 to 10.6 dS m^{-1} (Fig. 8). On the other hand, at Amtali, the upper soil salinity varied from 4.9 to 9.8 dS m^{-1} (Fig. 8). The deeper layers soil salinity was slightly lower in both the sites.

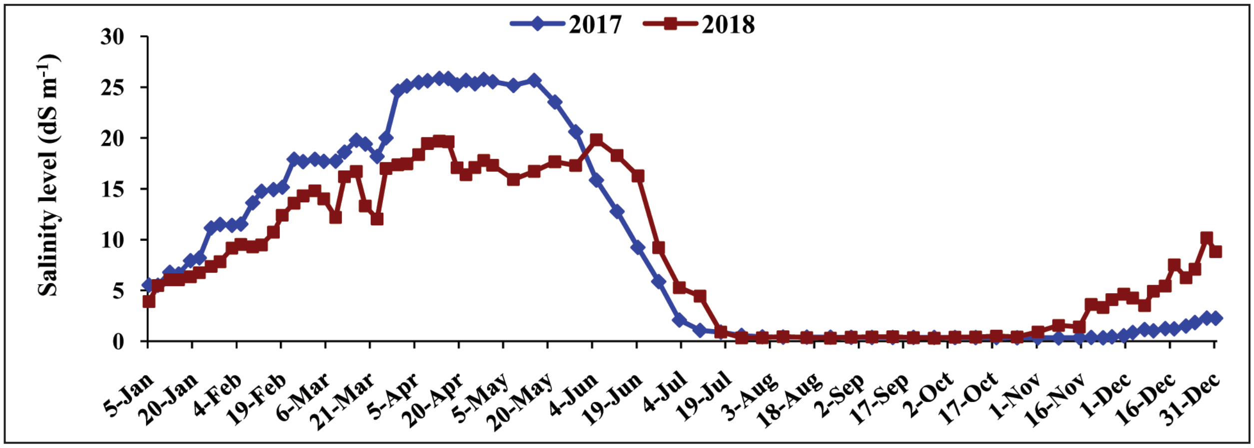

Fig. 1. *Salinity dynamics of Jabjapia river at Dacope, Khulna during 2017 to 2018*

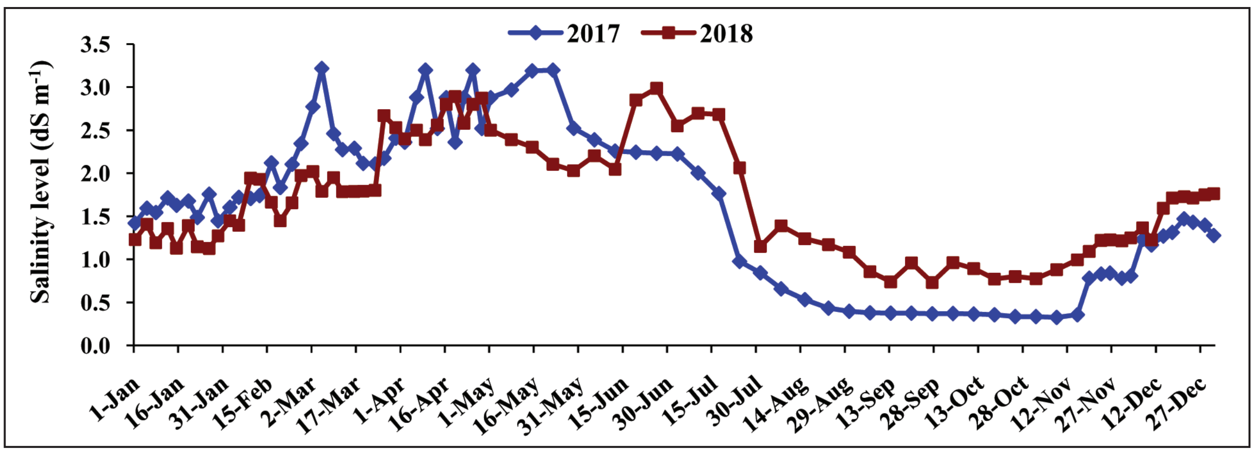

Fig. 2. *Salinity of trapped canal water in Dacope, Khulna during 2017 to 2018*

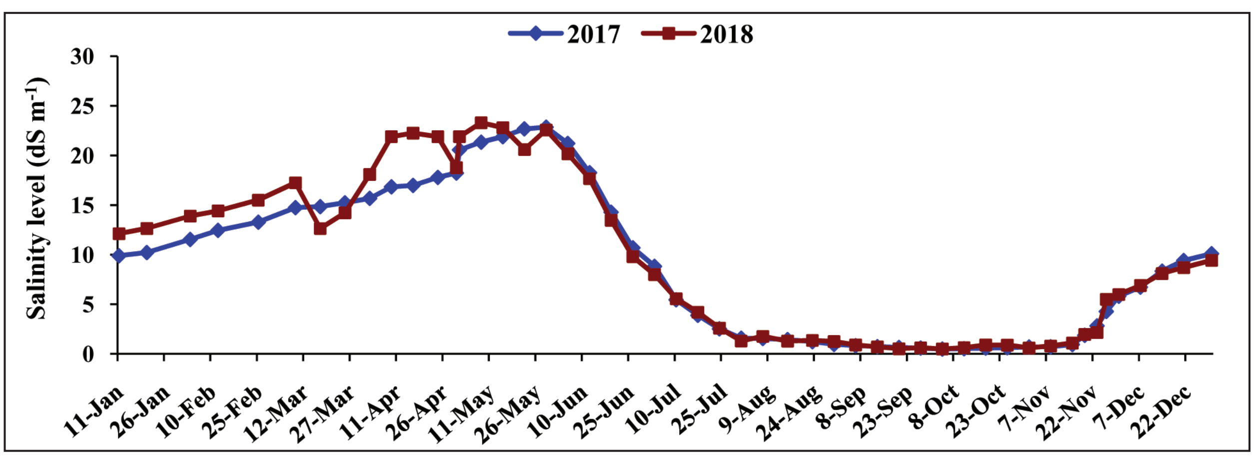

Fig. 3. *Salinity of Andharmanik river during 2017 to 2018 at Amtali, Barguna*

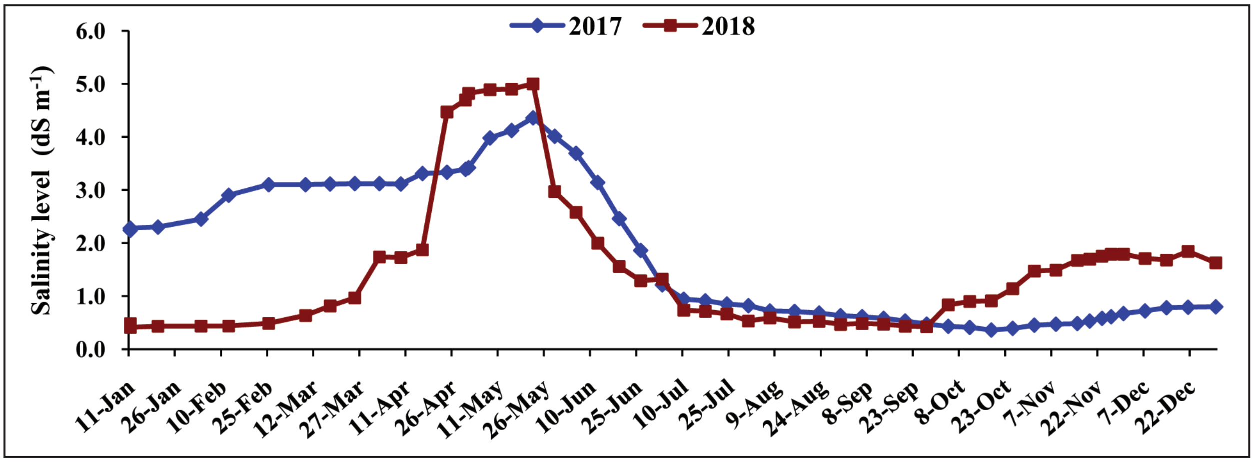

Fig. 4. *Trapped canal water salinity at Amtali, Barguna from 2017 to 2018*

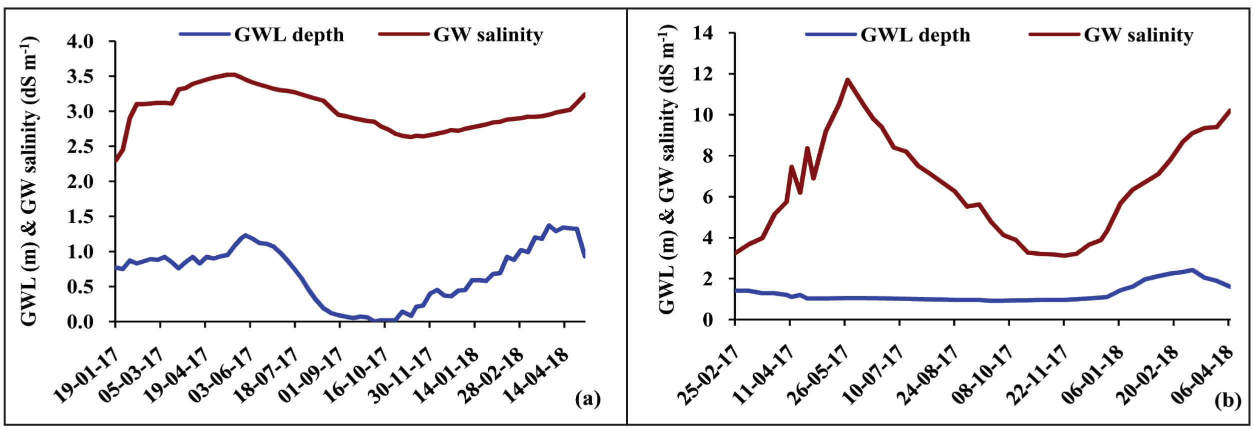

Fig. 5. *Groundwater level fluctuation and salinity dynamics at a) Pankhali, Dacope and b) Amtali, Barguna from 2017 to 2018*

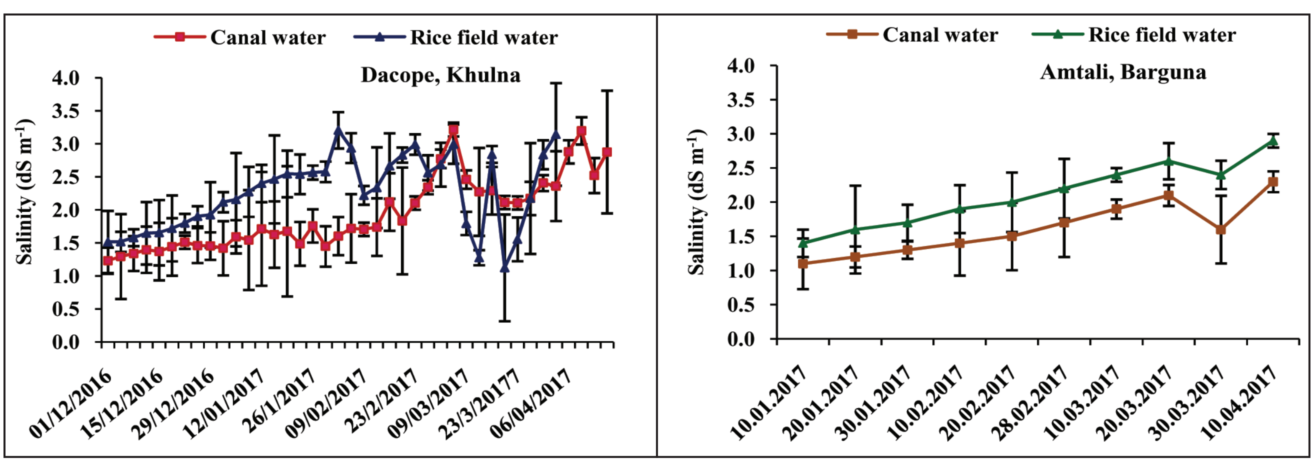

Fig. 6. *Water salinity of canal and rice field water at Dacope, Khulna and Amtali, Barguna during boro, 2016-17*

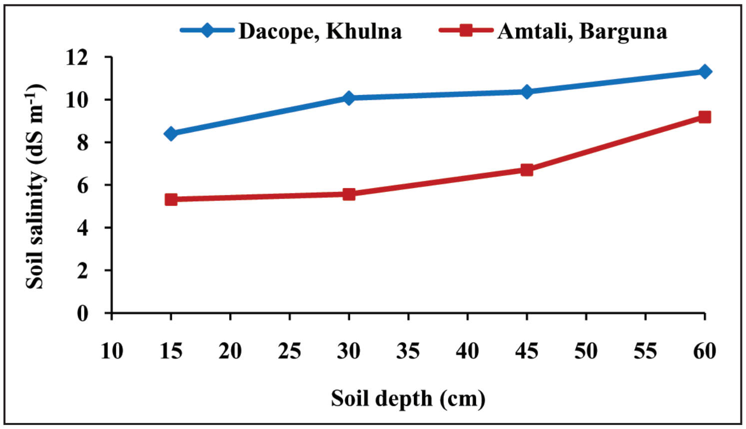

Fig. 7. *Soil salinity in rice field at different soil depths at Dacope, Khulna and Amtali, Barguna during boro, 2016-17*

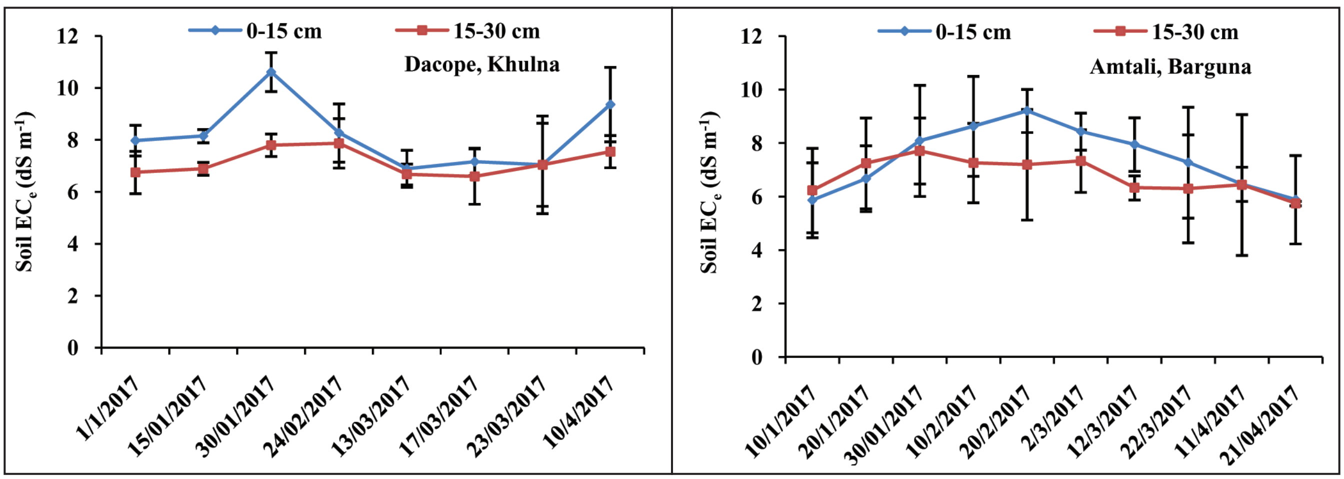

Fig. 8. *Soil salinity in sunflower plot at Dacope, Khulna and Amtali, Barguna during rabi, 2016-17*

Crop intensification

Dry season rice cultivation

At Dacope, Khulna 0.7 and 3 ha areas were cultivated during boro, 2017 and 2017-18 where BRRI dhan67, BRRI dhan28 and BINA dhan10 gave average yield of 6.4, 6.2 and 5.0 t ha^{-1}, respectively (Table 1). At Amtali, Barguna, about 2 ha and 4 ha areas were successfully brought under *boro* rice cultivation during *boro* 2016-17 and 2017-18 seasons, respectively. At this site, BRRI dhan67 (6.2 t ha^{-1}) performed the best among all tested varieties followed by BRRI dhan58 (5.6 t ha^{-1}) and BRRI dhan28 (4.7 t ha^{-1}) (Table 1). Since BRRI dhan67 can tolerate 8 dS m^{-1} salinity (BRRI, 2018), its cultivation with trapped less saline water can be one of the best options for dry season crop cultivation in saline prone areas of Bangladesh.

Performance of rabi crops

Sunflower produced statistically similar yield every year in both the locations. The highest yield (2.33 t ha^{-1}) of sunflower was obtained from Amtali, Barguna site in 2017-18 and the lowest (1.96 t ha^{-1}) in 2016-17 (Table 2). The yield of sunflower is more or less similar with national average yield (2.5 t ha^{-1}) for both the locations under favorable condition (BBS, 2017). Although sunflower can tolerate salinity up to 15 dS m^{-1} with some yield reduction (Miller, 1995), the highest salinity in our case was 10.6 dS m^{-1} in the study locations. It indicated that sunflower can be grown easily in both the study sites.

The highest yield (8.51 t ha^{-1}) of maize was found at Dacope, Khulna during 2017-18, which was statistically similar with previous year's yield (8.46 t ha^{-1}) (Table 2).

Table 1. *Yield of different rice varieties in Dacope, Khulna and Amtali, Barguna during boro, 2016-17 and 2017-18*

Variety	Area covered (ha)		Yield (t ha^{-1})		Average yield (t ha^{-1})
	2016-17	2017-18	2016-17	2017-18	
	Dacope, Khulna				
BRRI dhan67	0.3	1.13	6.3	6.49	6.4
BINA dhan10	0.2	1.05	6.2	6.22	6.2
BRRI dhan28	0.2	0.81	5.1	4.92	5.0
LSD (0.05)			0.86	1.2	
CV (%)			7.9	9.7	
	Amtali, Barguna				
BRRI dhan67	1	3.14	7.1	5.3	6.2
BRRI dhan58	0.5	0.31	6.2	5.0	5.6
BRRI dhan28	0.5	0.67	4.7	4.7	4.7
LSD (0.05)			0.65	0.6	
CV (%)			4.3	4.6	

Table 2. *Yield of non-rice crops at Dacope, Khulna and Amtali, Barguna during 2016 to 2018*

Year	Sunflower (t ha^{-1})			Maize (t ha^{-1})			Sweet gourd (t ha^{-1})			Water melon (t ha^{-1})		
	Dacope	Amtali	Year wise avg. (t ha^{-1})	Dacope	Amtali	Year wise avg. (t ha^{-1})	Dacope	Amtali	Year wise avg. (t ha^{-1})	Dacope	Amtali	Year wise avg. (t ha^{-1})
2016-17	2.31a (7.24)	1.96a (6.14)	2.13a (6.67)	8.42a	7.54b	7.98a	10.66ab (8.53)	8.3b (7.19)	9.48a (7.86)	4.33b (5.77)	7.53a (10.0)	5.93a (7.9)
2017-18	2.29a (7.18)	2.53a (7.92)	2.41a (7.55)	8.51a	7.70b	8.12a	13.50a (10.8)	8.86b (7.67)	11.18a (9.24)	5.39ab (7.18)	4.12b (5.49)	4.76a (6.34)
Location wise avg. (t ha^{-1})	2.30a (7.20)	2.25a (7.04)	2.28 (7.12)	8.46a	7.62b	8.04	12.08a (9.66)	8.58b (7.43)	10.33 (8.55)	4.86a (6.48)	5.82a (7.76)	5.34 (7.12)
CV (%)	14.2			11.95			11.70			13.2		
LSD0.05	NS			1.14			1.35			2.5		

Figures in parentheses are maize equivalent yield (MEY)

In Amtali, Barguna, there were also no statistical differences in maize yields. The average yield was 8.46 t ha^{-1} and 7.62 t ha^{-1} in Dacope, Khulna and Amtali, Barguna, respectively while the national average of maize is about 10 t ha^{-1} (BBS, 2017).

The highest yield of sweet gourd (13.50 t ha^{-1}) was found in Dacope, Khulna during 2017-18 (Table 2). The average yields of sweet gourd were 12.08 t ha^{-1} and 8.58 t ha^{-1} in Dacope, Khulna and Amtali, Barguna, respectively. This yield is much lower than the national average (20-25 t ha^{-1}) of sweet gourd under recommended conditions. Some adverse factors like salinity and lack of irrigation may be the cause of yield reduction in our investigation.

Performance of watermelon was comparatively poor than the other three crops in both the locations over two consecutive years. The highest yield (7.53 t ha^{-1}) of watermelon was found in Amtali, Barguna during 2017-18, which was much lower than the national average (18-22 t ha^{-1}) (Table 2).

To compare the yield of different crops, all crops yield were converted to the yield of maize crops so that a valid comparison among the crops can be made. Based on the maize equivalent yield (MEY) sweet gourd produced the highest average yield (9.66 t ha^{-1}) compared to other crops followed by dibbled maize in Dacope (Table 2). The lowest (6.48 t ha^{-1}) MEY was observed in Dacope, Khulna for watermelon.

Although the national average yield of sweet gourd and watermelon are higher but it is remarkable that sweet gourd and watermelon were cultivated under stress conditions like salinity and lack of irrigation water and moreover, land remains fallow during *rabi* season in the study areas.

Fresh water resource development is one of the crucial issues for sustainable crop and soil salinity management in coastal areas of Bangladesh. In both the study locations, river water became saline (> 4.0 dS m^{-1}) after December and as high as 20-25 dS m^{-1} in April to May. Therefore, surface fresh water was trapped in local canals within December is the only option for dry season crop production. In both the locations, groundwater level was found in very close to the soil surface, which creates drainage congestions of those locations. In most cases shallow aquifer groundwater salinity was not within the permissible limit and unsuitable for irrigation. Whereas the trapped water salinity remains within permissible limit (< 3.0 dS m^{-1}) round the year, which satisfied irrigation water quality standards in both the locations. BRRI dhan67, BINA dhan10 and BRRI dhan58 showed better yield in each year in both the locations. Soil salinity was higher in Dacope, Khulna than Amtali, Barguna. All the *rabi* crops (sunflower, maize, sweet gourd and water melon) showed good yield performance in existing saline stress condition. So, cultivation of salt tolerant crop varieties with trapped less saline water could be a good option to increase cropping intensity in the coastal Bangladesh.

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