Towards development of early rabi crop establishment techniques: Performance of wheat under different tillage and irrigation conditions in the coastal region of Bangladesh

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Late crop establishment is a major problem for successful harvest of rabi crops in saline coastal zone of Bangladesh. Identification of appropriate crop establishment techniques is also important to overcome the problem. Because selection of proper crop establishment method is the first step towards earlier establishment of rabi crops. An experiment was conducted during December 2013 to May 2014 at Kismat Fultola village in Khulna district to identify appropriate crop establishment techniques for early establishment of wheat. Crop establishment methods tested were: C1: seeds sown after row-spading at soil moisture in between saturation and field capacity, C2: seeds sown in furrows at soil moisture in between saturation and field capacity, and C3: seeds sown on the surface of saturated soil with straw mulch. There were three irrigation regimes: I1 = No irrigation (rainfed), I2 = One irrigation at 15–20 days after emergence (DAE), I3 = Two irrigations at soil suction values of 50 kPa and 70–90 kPa, respectively at 37.5 cm soil depth. Early planting of wheat was 9 December 2013. The establishment techniques and planting dates showed different degrees of influence on the crops. The highest grain yield was obtained in C2 (1.44 t ha⁻¹) and the lowest was found in C1 (1.15 t ha⁻¹). In case of irrigation treatments, the grain yield in I1 (1.49 t ha⁻¹) and I2 (1.35 t ha⁻¹) was significantly higher than that in I3 (1.04 t ha⁻¹). The highest yield (1.49 t ha⁻¹) was obtained from the two irrigations and straw mulch treated plot, even though the yield was less compared to standard wheat yield in that region (2.0–3.0 t ha⁻¹). This is because of less plant density due to uneven germination, damage/death of plants after germination and possibly leaching of the top-dressed nitrogen fertilizer out of root zone through cracks. The results demonstrate that early establishment of rabi crops in the coastal region is possible, which is highly desirable for improving food security and livelihoods of the climate-vulnerable coastal communities of Bangladesh.

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INTRODUCTION

The coastal region of Bangladesh covers 47201 km² land area which is 32 percent of the total geographical area of the country (Mishu 2013). Agriculture sector in the coastal region is vulnerable to different kinds of climatic hazards like salinity, excessive flooding during the rainy season, severe cyclonic storms, and tidal surges throughout the year (Mondal et al. 2013). Salinity in river water increases steadily from December through February and reaches maximum in late March and early April (EGIS 2001). Out of 2.86 million ha of the coastal and offsho##arable land areas, about 1.06 million ha of arable lands are affected by varying degrees of salinity (SRDI 2012). Impact of salinity on agriculture has already been recognized (Karim et al. 1990; SRDI 2012). Furthermore, other problems like poor drainage (Tuong et al. 2014), unavailability of quality irrigation water in the dry season (Rahman and Ahsan 2011) have detrimental impacts on agricultural productivity in the coastal region. Ultimate effects of these stressors have resulted in decreasing agricultural land use in the coastal zone. Agricultural land use in these areas is very poor, which is roughly 50% of the country’s average (Ahmed et al. 2013).
Poor agricultural land use can be easily indicated by looking into the cropping patterns. The existing cropping patterns in the study area-Khulna district (medium saline area in the southwest Bangladesh) are aman-fallow and aman–rabi (Rahman 2013). The predominant cropping practice in the study area (Batiaghatua upazila) is traditional aman rice followed by sesame (rabi crop) planted delayed in the early kharif season (on about 80% of the land area). Late sowing of rabi crops increases the chance of crop damage due to the on-set of monsoon and cyclonic season prior to its harvest. In most cases late-grown sesame and rabi crops in Batiaghatua upazila often get damaged by rainfall and tidal surge prior to its harvest (Mondal 1997; Mondal et al. 2004). Rabi crop is often damaged and sometimes completely destroyed by early rainfall in March–April and by cyclonic events in May (Tuong et al. 2014) due to its late sowing.

Two main causes associated with the late sowing of rabi crops have been identified. Firstly, most of the agricultural land is flooded during monsoon. Floodwater generally starts receding from October and continued up to late December. High tide often inundates the fields even in December (Haque 2006). Thus the drainage from the agricultural lands in the tidal ecosystem has to be delayed and even after the harvest of T. aman rice. Such late drainage results in delaying rabi crop cultivation. Secondly, after receding flood water the soils still remain too wet until mid–February to early March and hence become unsuitable for tillage prior to this (Ritu and Mondal 2015). Eventually, the farmers cannot plough their lands at optimum time for sowing seeds due to excess soil moisture, thus establishment of rabi crops is delayed.

The keys to solve this problem as well as increasing productivity of rabi crops in the coastal region of Bangladesh are improved water management and early establishment strategies of rabi crops. As suggested by (Mondal et al. 2013), these strategies may include (i) draining the fields rapidly at the end of the rainy season to allow timely establishment of rabi crops, (ii) developing appropriate crop establishment techniques for judicious utilization of residual soil moisture, and (iii) maximizing the availability of freshwater for irrigation during the dry season for rabi crops cultivation. Several recent studies have shown that, given the ability to drain excess water, HYV can be successfully grown during the rainy season with yields of 4 to 5 t ha⁻¹ (Bhattacharya et al. 2015; Mondal et al. 2015; Saha et al. 2015). Furthermore, Mondal et al. (2015) also showed the possibility to manipulate the sluice gate in a sub-polder to enable effective drainage, and to harvest HYV before the end of November. The early harvest of aman then creates the opportunity to grow high yielding and high value crops such as maize and sunflower. A study conducted by Rahman (2015) has demonstrated the high potential for increasing crop production in the coastal zone by early establishment of rabi crops such as maize and sunflower. Different tillage management practices were used as treatments to evaluate the early crop establishment techniques for maize and sunflower. However, there is still ample scope to strengthen early establishment technology by testing different crop establishment methods for other different crops. Therefore, the present study was undertaken to investigate the possibilities of early establishment of wheat crop through combining irrigation and tillage treatments in the rabi season. The specific objective of this study was to test the impacts of different tillage management practices and different irrigation scheduling towards early establishing of wheat cultivation in the coastal saline soils.

MATERIALS AND METHODS

Experimental Site

The study was conducted during December 2013 to May 2014 in Polder 30 at Kismat-fultola village (22.7263°N, 89.5163°E) in Batiaghatua upazila under Khulna district of the south-west coastal zone of Bangladesh. Most agricultural lands in polder 30 have an elevation of 1–2 m above mean sea level. The climate is subtropical, with average annual rainfall of 1,850 mm, two dominant seasons—a cool winter from December to February with mean monthly minimum temperatures of 12–15°C, and a hot summer in April to June with mean monthly maximum temperatures of 37–38°C. The soil was a slightly alkaline (pH about 8) silty clay with a bulk density of 1.45 g cm⁻³ at 15 cm (Mondal et al. 2006). Salinity of the topsoil (0–15 cm) ranges from 4.0 to 12.5 dS m⁻¹ (electrical conductivity of the saturation extract) in the dry season and remains below 4.0 dS m⁻¹ in the wet season (Mondal et al. 2006). River water salinity remains below 1 dS m⁻¹ from July to December and gradually increases from January and reaches a peak of around 20 dS m⁻¹ in April or May (Mondal et al. 2006). The salinity of the groundwater at 40 m depth at the study site is about 4 dS m⁻¹ throughout the year.

Experimental Treatments

An experiment was conducted in split plot design to test the performance of wheat under different management practices in coastal saline soil having a total experimental area of 50m × 60 m. The experiment was conducted to test the performance of wheat under three crop establishment and three irrigation methods in a split plot design, with six replications.

Main plots: Crop establishment method

- C₁ = Seeds sown after tillage of the seed row using a spade (5 cm wide strips)
- C₂ = Seeds sown in furrows made using a hand kota (local name)
- C₃ = Seeds sown on the saturated soil surface with 2.5 t ha⁻¹ (5 cm) straw mulch (zero tillage)

Sub-plots: Irrigation scheduling

- I₁ = No irrigation (rainfed)
- I₂ = One irrigation at 15–20 days after emergence (DAE)
- I₃ = First irrigation when soil tension increased to 50 kPa and second irrigation when soil tension was 70–90 kPa at 37.5 cm soil depth,

Experiment Conduction

Crop management

The salt and heat tolerant wheat variety BARI gom25 (growth duration of 110 d) was sown in rows (20 cm spacing, 3–4 cm depth) on 9 December 2013 and harvested on 2 April 2014. Seed rate was 125 kg ha⁻¹. According to BARI recommendations, the doses of N–P–K–S–B fertilizers were 250, 150, 100, 110 and 7.5 kg ha⁻¹, respectively (Hossain et al. 2006). All the fertilizers except urea were applied prior to sowing when soil remained at saturated condition. Half of urea was applied 5–10 days after crop emergence and the rest half was top-dressed during first irrigation (Hossain et al. 2006). Hand weeding was done two times at 20 and 40 days after emergence (DAE) synchronizing with the topdressing of urea and soil earthing up (where applicable). In order to control insect pest (rats) rodenticide was used and in addition protective plastic sheet was used to protect field from rat.

Crop monitoring

Five randomly selected plants in each plot were tagged and monitored for crop development until harvest. Plants were
selected leaving 50 cm space from all corners to avoid border effects. The booting (BT), shooting, heading, flowering (FL) emergence and physiological maturity (PM) dates of wheat were recorded. Separate records of each plot from all replications were kept in the notebook. The date of 50% emergence (date when first leaf appears) was determined in 5 rows × 1 m at two locations diagonally. For BT monitoring, the main stem was dissected for observation. The stem was considered to have reached BT when the spike is visible to naked eyes (i.e. about 1 mm long). The crop was considered to have reached BT when 10 stems out of 12 main stems had visible spikes. The date of 50% anthesis was determined by counting the number of spikes in which anthesis commenced from selected 10 plants at 4 corners of the harvested area at the designated sampling area. PM date was determined when 80% of the spikes in 10 rows at the designated harvested area (in the middle) have turned yellow. The yield attributes and selected agronomic parameters of wheat, such as plant height, total and productive tillers, spike length, filled and unfilled grains per spike, 1000 grain weight and straw yield, were taken from five 1 m² area of each plot, four from four corners and one from the middle of the plot. Grain yield was calculated in t/ha considering the harvest of whole plot (30 m²). Plant height of wheat was measured at fifteen days interval in every subplot.

Irrigation water monitoring
Source of irrigation water was nearby canal (locally called Khal). Irrigation water salinity was more than 4 dS m⁻¹ in both I₁ and first irrigation of I₂ treatments. As canal water was highly saline (EC = 10 dS m⁻¹) in case of second irrigation of treatment I₂. Canal water was mixed with pond (re-excavated by farmers) water with EC of 3 dS m⁻¹ to irrigate wheat. Irrigation was provided by using a low lift pump (LLP) connected with hose pipe. Discharge of the LLP was measured by volumetric method by using a 20 L bucket and stop watch. Salinity of the irrigation water was measured using a portable EC Meter.

Soil moisture monitoring
Gravimetric soil moisture content was determined for soil samples collected from 0–15, 15–30, 30–45, 45–60, and 60–80 cm layers using a soil auger. Sampling was done at 15 days intervals from seed sowing until harvest. Soil water tension was measured using tensiometers installed at 37.5 cm depth in each plot of wheat. Tensiometer reading (kPa) was recorded at 9 am daily.

Rainfall and evaporation monitoring
A standard rain gauge and a USWB class A evaporation pan previously installed about 200 m from the experimental field were used to monitor rainfall and pan evaporation at 9 am daily. Daily maximum and minimum temperatures were also collected from the Khulna meteorological station, about 8 km north of the experimental site.

Statistical Analysis
The data were analyzed for significance of difference among the means with 5% level of significance using the Statistical Tool for Agricultural Research (STAR) software (STAR 2014).

RESULTS AND DISCUSSION
Weather Condition during Growing Period of Wheat
Rainfall was low throughout the growth period of wheat (9 December–2 April 2014). Only three rainfall events, 23, 13 and 245 mm, were recorded in February, March and May, respectively (Figure 1). There was 23 mm rainfall on 16–17 February at flowering stage of wheat and 13 mm on 23–25 March at ripening stage of wheat. No other rain was received during the growth period of wheat. Evaporation gradually increased from January (mean monthly total 64 mm) to April (total 191 mm). Mean monthly maximum temperature varied from 26°C in January to 36°C in April, while mean monthly minimum temperature varied from 15°C in January to 26°C in May. Daily sunshine hours was lowest in January (5.4 h) and the highest in April (8.8 h) (Figure 1). Early established wheat was harvested on 2 April 2014 whereas previous studies showed that the harvesting of rabi crops in coastal region is not possible before mid-May. Figure 1 shows that there was a heavy rainfall (245 mm) on 14 May 2014, which indicated that there was a possibility of crop damage if crops were not early established. Therefore, early establishment of rabi crops is important for safe harvest of rabi crops.

Variation of Soil Moisture with Irrigation
Trend of soil moisture contents at different layers is shown in Fig. 2. Initially soil moisture content was about 38%–40% in first two layers, but it was higher in deeper layers (45%–48%). It has gradually decreased until mid-January. After first irrigation on 25 January 2014, soil moisture started to increase. After second irrigation (13 February 2014) and two rain events (16 February and 17 February 2014) there was an increasing trend of moisture content (Figure 2).

Variation of Soil Water Tension with Crop Establishment Methods
The level of soil water tension in different crop establishment
Irrigation Water Requirement

Two irrigations were given in treatment I_1 based on the tensiometer reading. One irrigation was supplied in I_2 according to the set criteria for wheat (Table 1). Among the crop establishment methods, C_3 required the lowest irrigation (Table 1). Results indicate that mulching can be very effective in conserving soil water in the coastal area.

Table 1. Water applied for wheat cultivation in the rabi season of 2013–14

| Crop establishment | Irrigation methods | I_1 = rainfed | I_2 = one irrigation | I_3 = two irrigation |
|--------------------|-------------------|---------------|----------------------|----------------------|
|                    | R (mm)            | IR (mm)       | Total (mm)           | R (mm)              | IR (mm)       | Total (mm) |
| C_1                | 35.5              | 0             | 35.5                 | 35.5                | 47.3         | 82.8       |
| C_2                | 35.5              | 0             | 35.5                 | 35.5                | 50.9         | 86.4       |
| C_3                | 35.5              | 0             | 35.5                 | 35.5                | 27.0         | 62.5       |

(R=Rainfall, IR=Irrigation)

Variation of Phenology Dates of Wheat

Different crop establishment methods did not have much influence on the phenology dates of wheat (Table 2). In mulched plot (C_3) all phenology dates were slightly delayed possibly because of higher soil moisture compared with other treatments. However, this crop establishment method (C_3) produced maximum yield. The result is similar to that of Khan (2005) who observed that inhibition germination and seedling growth became more pronounced with increasing rate of wheat straw mulching that may be explained by increased concentration of individual allelochemicals or their compound effect of Phytotoxic compounds namely phenolics, cyclic hydroxamic acids (alkaloids).

Table 2. Phenology date of wheat in different treatments

| Treatment | Maximum tillering (DAS) | Spike initiation (DAS) | Booting (DAS) | 50% Flowering (DAS) | Maturity (DAS) |
|-----------|-------------------------|------------------------|---------------|---------------------|---------------|
| C_1       | 19                      | 39                     | 56            | 62                  | 72            | 94           |
| C_2       | 19                      | 41                     | 57            | 63                  | 74            | 95           |
| C_3       | 21                      | 42                     | 60            | 65                  | 76            | 97           |

* DAS is for days after sowing

Effects of Crop Establishment Treatments on Performance of Wheat

The crop establishment methods have significantly influenced the spike length of wheat (Table 3). The highest spike length (10.83 cm) was found in C_3, and the lowest was obtained in C_2 (9.23 cm). The results are supportive with that of Chang et al. (1991) who reported that mulched establishment method had significantly higher spike population and grains/spike than un-mulched plot. The number of filled grains spike^{-1} differed significantly among the crop establishment methods. The highest filled grain spike^{-1} was produced in C_3 (41.97 spike^{-1}), which was significantly higher than C_1 and C_2. There was no significant difference in 1000-grain weight under different crop establishment methods (Table 3). Among the crop establishment methods, C_3 produced the highest straw yield (2.18 t ha^{-1}), which was significantly different than that produced in C_1 and C_2 (Table 3). But grain yield was not significantly affected by the crop establishment methods. However, the highest grain yield was obtained in C_3 (1.44 t ha^{-1}) and the lowest was found in C_1 (1.15 t ha^{-1}). The results can be explained by the findings of Li et al. (1991) that mulched materials have the ability to increase water holding capacity of the soil, retard soil evaporation (Schillinger and Bolton, 1993) and control weeds to the acceptable level (Davis 1994) resulting in higher economic and biological yields. Yield of wheat at no-mulch plots were much lower than that of mulch plot because of crack formation in no-mulch plots. The result shows that mulching can reduce soil cracking considerably and that can be an important option for successful early establishment of rabi crops.

Table 3. Yield and yield attributes of wheat for different crop establishment methods

| Crop establishment methods | Spike length (cm) | Grain (%) | 1000 Grain wt (g) | Grain yield (t ha^{-1}) |
|----------------------------|------------------|-----------|-------------------|------------------------|
| C_1                        | 9.16             | 38.26     | 40.01             | 1.06                   |
| C_2                        | 9.23             | 37.74     | 32.32             | 1.17                   |
| C_3                        | 10.83            | 49.44     | 41.97             | 1.27                   |

LSD_{0.05} 0.238 NS 2.39 NS 0.76 NS

*NS= Non significant

Effects of Irrigation Treatments on Performance of Wheat

Irrigation water was not evenly distributed in all crop establishment methods in wheat due to formation of cracks, which affected plant density and maybe one of the major

Figure 3. Variation of soil water tension at 37.5 cm with different crop establishment methods
reasons of low yields. However, irrigation regimes had significant effect on grain yield (Table 4). Irrigation method I1 produced the longest spike (10.23 cm), which was significantly higher than that observed in I2 and I3 (Table 4). Among all three irrigation regimes, I2 produced the highest straw yield (1.95 t ha$^{-1}$) and I1 produced the lowest straw yield (0.99 t ha$^{-1}$) (Table 4). The grain yield in I2 (1.49 t ha$^{-1}$) and I3 (1.35 t ha$^{-1}$) was statistically similar but was significantly higher than that harvested in I1 (1.04 t ha$^{-1}$). Two irrigations (I1) (based on tenesiometer reading) produced highest yield of wheat (1.49 t ha$^{-1}$), which indicates that more irrigation is required to get optimum yield of wheat. Irrigation water in coastal region is highly saline, so conservation of available soil moisture would be more preferable solution in this regard.

**Table 4.** Effect of irrigation on yield and yield attributes of wheat

| Irrigation methods | Total tiller | Spike length (cm) | Straw yield (t ha$^{-1}$) | Grain yield (t ha$^{-1}$) |
|--------------------|--------------|-------------------|--------------------------|--------------------------|
| I1                 | 116.30b      | 9.89b             | 0.99b                    | 1.04 b                   |
| I2                 | 140.70a      | 10.23a            | 1.95a                    | 1.35 a                   |
| I3                 | 133.82ab     | 9.86b             | 1.51ab                   | 1.49 a                   |
| LSD$_{0.05}$       | 19.32        | 0.324             | 0.65                     | 0.236                    |

*NS* - Non significant
*Common letter(s) within the same column do not differ significantly at 5% level of significance analyzed by Least Significant Difference Test.

**CONCLUSION**

Along with the early sowing date combination of mulching and two or more irrigation seem to be the best combination for obtaining good yield and safe harvest of wheat in the coastal saline soil. This study concludes that early establishment of *rabi* crops in coastal region is possible which can easily save crops from the natural calamities that is a great problem for existing cultivation practices. Furthermore, high yielding and high value crops (wheat, mungbean, and sunflower) may be a good option instead of low yielding traditional *rabi* crops which is highly desirable for improving food security and livelihoods of the climate-vulnerable coastal communities of Bangladesh. Further study needs to be conducted for evaluating the appropriate sowing dates of *rabi* crops in the coastal regions of Bangladesh. Cost-benefit analysis needs to be performed, and social acceptance of these changes needs to be further studied. In addition to this, study is needed to be designed on different mulching including living mulch not only to reduce soil cracking and soil salinity, but also to conserve soil moisture for better growth and development of *rabi* crops in the coastal zone of Bangladesh.

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**CONFLICT OF INTEREST**

The authors declare that there is no conflict of interests regarding the publication of this paper.

**REFERENCES**

Ahmed B, Rasel HM, Hasan MR, Miah MSU. 2013. Effects of Soil Salinity on Crop Production rate of the South West Zone of Bangladesh. International Conference on Mechanical, Industrial and Materials Engineering (ICMIME2013) 1-3 November, 2013, RUET, Rajshahi, Bangladesh.

Bhattacharya J, Mondal MK, Humphreys E, Saha NK, Rashid MH, Paul PC, Ritu SP. 2015. Rice–rice-*rabi* cropping systems for increasing the productivity of low salinity regions of the coastal zone of Bangladesh. https://www.researchgate.net/publication/282664588. Accessed on 20 August 2015.

Bond JJ, and Willis,WO. 1969. Soil water evaporation–surface residue rate and placement effects. Soil Sci Soc Am Proc 33: 445–448.

Chang YH, Ruy YH, Youn KB, Ha YW, Yoon B, Shin MG. 1991. Study on tilled row sowing method simultaneously with rice harvest by drill seeder attached to combine in paddy field. Research Report of the Rural Development Administration, Upload and Industrial Crops, Korea, No. 33, pp. 16–21.

Davis JM. 1994. Comparison of mulches for fresh–market basil production. Hort Sci 29: 267–268.

EGIS. 2001. Environmental and Social Impact Assessment of Gorai River Restoration Project, Vol. 1. Bangladesh Water Development Board.

Haque SA. 2006. Salinity problems and crop production in coastal regions of Bangladesh. Pakistan J Bot. 38(5):1359–1365.

Hossain MH, Rahman MM, Rashid MH, Farid A, Quyum TM, Ahmed MA, Alam MS, Sahahuddin KM. 2006. *KrishiProjekti Hatboi* (Handbook on agro-technology), fourth edition, Bangladesh Agricultural Research Institute, Gazipur 1701, Bangladesh, pp. 15-20.

Karim Z, Hussain SG, and Ahmed M. 1990. Salinity problems and crop intensification in the coastal regions of Bangladesh. Soils publication No. 33. BARC, 17 p.

Khanh TD. 2005. The exploitation of crop allelopathy in sustainable agricultural production. J Agron Crop Sci, 191(3):172–184.

Li WW, Kong OL, Song LW, Yang HS. 1991. Study on the effect of straw mulching in the orchard. J Fruit Sci, 8: 163–165.

Mishu MMR, Zaman MKB. 2013. Agricultural Vulnerability in the Context of Coastal Region of Bangladesh. Bangladesh Res Pub J 9(1): 64-68.

Mondal MK. 1997. Management of soil and water resources for higher productivity of the coastal saline rice lands of Bangladesh. PhD Dissertation, University of the Philippines LosBanos, Philippines.

Mondal MK, Humphreys E, Singh US. 2013. Agrarian straightjacket: Constraints to achieve yield potential in rice. Paper presented in the International Workshop on “Moving from Water Problems to Water Solutions: Research Needs Assessment for the Eastern Gangetic Plains” held in New Delhi, India on 7–8 May 2013.

Mondal MK, Tuong TP, Ritu SP, Choudhury MHK, Chasi AM, Majumder PK, Islam MM, Adhikary SK. 2006. Coastal water resource use for higher productivity of the coastal saline rice lands of Bangladesh. PhD Dissertation, University of the Philippines LosBanos, Philippines.

Mondal MK, Ritu SP, Choudhury MHK, Chasi AM, Mannan MA, Majumder PK, Islam MM, Adhikary SK. 2004. Appropriate water management strategy for boro rice cultivation in the coastal saline environment. In proceedings of the workshop on Coastal water management and uptake technologies held at Hotel Castle Salam, Khulna, Bangladesh, pp.28–37.

Mondal MK, Humphreys E, Tuong TP, Rahman, MN, and Islam MK. 2015. Community water management and cropping system synchronization: The keys to unlocking the production potential of the polder ecosystems in Bangladesh.

Rahman MN, Amin MGM, Mondal MK, Humphreys E. 2015. *Rabi* crop establishment methods for increasing land...
productivity in the coastal zone of Bangladesh, Conference Proceedings of Revitalizing the Ganges Coastal Zone: Turning Science into Policy and Practices. https://www.researchgate.net/publication/277140507. Accessed on 18 January 2016.

Rahman MM, Ahsan M. 2011. Salinity constraints and agricultural productivity in coastal saline area of Bangladesh, Soil Resources in Bangladesh: Assessment and Utilization.

Ritu SP, Mondal MK. 2006. Soil and water salinity relations in the southwest coastal region of Bangladesh. J Prog Agric, 17(1): 249–256.

Saha NK, Mondal MK, Humphreys E, Bhattacharya J, Rashid MH, Paul PLC, Ritu SP. 2015. Triple rice in a year: Is it a feasible option for the low salinity areas of the coastal zone of Bangladesh? https://www.researchgate.net/publication/282664431. Accessed on 18 January 2016.

Schillinger WF and Bolton FE. 1993. Fallow water storage in tilled vs. untilled soils in the Pacific Northwest. J Prod Agric, (6): 276–269.

Soil Resources Development Institute (SRDI). 2012. Saline soils of Bangladesh. Soil fertility assessment, soil degradation and its impact on agriculture program of SRDI, Mrittika Bhaban, KrishikhamarSarak, Farmgate, Dhaka 1215.

Tuong TP, Humphreys E, Khan ZH, Nelson A, Mondal MK, Buisson MC, George P. 2014. Message from the Ganges Basin Development Challenge (GBDC): Unlocking the production potential of the polders of the coastal zone of Bangladesh through water management investment and reform. GBDC, World Fish Bangladesh office, Dhaka 1213, Bangladesh.

STAR. 2014. Biometrics and Breeding Informatics, PBGB Division, International Rice Research Institute, Los Baños, Laguna. Available at http://bbi.irri.org/