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Conjunctive use of saline and fresh water increases the productivity of maize in saline coastal region of Bangladesh

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ABSTRACT

Increasing cropping intensification in the southern saline region of Bangladesh is a national priority; however, increased intensification should not be at the cost of exploiting the precious groundwater resources. The best strategy for increasing intensification is through using saline water for irrigation wherever and/or whenever it is possible. In this context, a two years field study was conducted at the Agricultural Research Station of Bangladesh Agricultural Research Institute (BARI) in Satkhira (southern Bangladesh), during the *rabi* (winter) season of 2015–16 (year I) and 2016–17 (year II) with a view to identify an appropriate irrigation scheduling for cultivation of maize in salt-affected areas by conjunctively using the available saline and limited fresh water resources. Six irrigation treatments (T_1 = two irrigation with fresh water: at vegetative (45 days after sowing-DAS) and tasseling (75 DAS); T_2 = three irrigation with fresh water: at vegetative, tasseling and grain filling (105 DAS); T_3 = two irrigation: at vegetative with fresh water + at tasseling with saline canal water; T_4 = three irrigation: at vegetative with fresh water + at tasseling and at grain filling with saline canal water; T_5 = two irrigation with saline canal water: at vegetative and tasseling; and T_6 = three irrigation with saline canal water: at vegetative, tasseling and grain filling) were set. Groundwater (with salinity ranging 1.10–2.23 dS m^{-1} during the growing season across two years) and water from nearby canal (with salinity ranging 4.18–9.74 dS m^{-1}) were used as 'fresh "and 'saline" water, respectively. Results showed that irrigation with fresh ground water and saline canal water has statistically significant effect ($p \leq 0.05$) on yield and yield attributing parameters of maize. Application of three irrigation, all with fresh water (T_2), resulted in highest grain and straw yield as well as improvement in yield attributing characters of maize, followed by three irrigation- first with fresh water and the next two with saline canal water (T_4). While the poorest performance was recorded with two (T_3), or three irrigation (T_6), all with saline water. Compared to T_2, grain yield decreased by 1.2–31.0% across all other treatments in year I, and by 7.4-30.0% across all treatments except T_4 in year II. Considering yield gain, T_4 was best, followed by T_1 and T_3, while T_6, T_5 and T_2 performed poorest. In contrast, significantly highest ($p \leq 0.05$) water productivity was recorded with T_1, followed by T_3, while the lowest with T_6. Results indicated that the moderately saline canal water can be a very handy source of irrigation water for winter maize, when fresh water is scarce. Instead of reducing the number of irrigation events, conjunctive use of freshwater at early sensitive stage combined with saline canal water at a later stage(s) can minimize yield loss of maize.

1. Introduction

Scarcity of quality irrigation water has now been recognized globally as the major constraint to increasing cropping intensification. Insufficiency of water for irrigation is restraining the development of agriculture in many parts of the world (Barrow, 2016; Elliott et al., 2014; Molden et al., 2010). The scarcity of water for agriculture is growing not only because the sources are reducing, but also the quality of water is deteriorating (Elliott et al., 2014; Parsons et al., 2010; Qadir et al., 2010). Among the threats that are deteriorating the quality of irrigation water, soil salinization is the major one in many countries; and the severity of such threat is higher in the low-lying coastal regions (Connor et al., 2012; Daliakopoulos et al., 2016; Ladeiro, 2012; McFarlane et al., 2016). As the sources of good quality water are

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Table 1
Average monthly weather data of Benarpota, Satkhira from November to April of 2015–16 and 2016–17.

Month	2015–16				2016–17			
	Temperature (°C)		Total rainfall (mm)	Sunshine (hours)	Temperature (°C)		Total rainfall (mm)	Sunshine (hours)
	Max.	Min.			Max.	Min.		
November	29.52	19.22	0.00	6.91	30.28	19.42	0.00	6.91
December	25.10	16.11	0.00	2.75	25.92	15.72	0.00	2.75
January	30.06	13.56	12.00	4.63	32.48	13.04	0.00	4.63
February	31.65	18.92	125.60	4.12	30.01	19.27	59.00	4.12
March	33.18	22.20	3.80	7.17	33.25	22.49	8.80	7.17
April	36.50	24.97	0.00	7.65	36.35	25.85	0.00	7.65

decreasing in these regions, the pressure on farmers to utilize moderately saline water for irrigation is also increasing (Gandahi et al., 2017; McFarlane et al., 2016). The United Nations Food and Agriculture Organization and the United Nations Environment Programme estimate that there are currently 4 million km^2 of salinized land globally, of which approximately 20% of agricultural land and 50% of cropland are affected by salinity and threatening the agricultural productivity (Ravindran et al., 2007; Rozena and Flowers, 2008). Soil salinity, caused by high concentration of salts in the soil, is one of the most severe environmental factors limiting the productivity of agricultural crops in such lands.

Among the countries affected by the worst salinity, Bangladesh is affected by both soil and water salinity (Hoque and Haque, 2016; Parvin et al., 2017; Rahman et al., 2017). Nineteen districts in the coastal areas in southern Bangladesh cover about 32 percent area of the country, where more than 40 million people are seriously affected by salinity (Displacement Solutions, 2012; Mondal and Haque, 2015; Parvin et al., 2017). Over the last 40 years, the area under salinity in the coastal Bangladesh has increased by about 27 percent, and prediction suggests that an additional 2–3 percent area will be affected by 2030 (Displacement Solutions, 2012; Huq et al., 2015; Mahmuduzzaman et al., 2014). Due to increasing soil and water salinity, farmers in these areas are suffering from lack of fresh quality water for irrigation, as a result vast land areas are kept aside of agricultural production and left the small-landowners poor (Hoque and Haque, 2016; Huq et al., 2015). Despite the continual deterioration of the fresh water in the coastal areas, there are ample sources of saline water, which could be an alternative option for irrigation, if suitable crops and appropriate soil and water management practices are followed. The scarcity of freshwater in Bangladesh as well as in other saline coastal areas in South Asia has led the agricultural scientists to recommend the conjunctive use of freshwater and moderately saline water to irrigate crops in the salinity affected areas (Al Khamisi et al., 2013; Mojid and Hossain, 2013; Singh, 2014).

Modern maize hybrids have been identified as high-yielding crops during all seasons, especially in *rabi* (winter) season, across South Asia (Timsina et al., 2010, 2016). Maize has very high potential in both saline and non-saline areas in the coastal region of southern Bangladesh due to its high yielding potentiality and relatively tolerance to salinity (Farooq et al., 2015; Rahman, 2012; Mondal et al., 2001). The effect of saline irrigation water on maize yield has been studied by a number of investigators; however, most of the experiments in those studies were conducted in controlled environment using synthetic saline water (Billah et al., 2017; Blanco et al., 2008; Leogrande et al., 2016; Ma et al., 2008). Also, most of these researches studied salt sensitivity by imposing a fixed level of water salinity during entire or some parts of the growing season (Billah et al., 2017; Blanco et al., 2008; Feng et al., 2017), despite the fact that the actual growing situations at the field level are fairly different. In most of the areas in coastal Bangladesh, significant spatial and temporal variations in soil and water salinity exist (Rahman et al., 2017; Parvin et al., 2017). Therefore, it is important that the research should be carried out in the truly saline affected areas to find out the ways to sensibly utilize the scarce fresh and abundant saline water by generating knowledge of how plants respond to salinity at different growth stages. In this context, a field experiment was conducted in two consecutive years in the coastal saline area of Bangladesh with a view to identify an appropriate irrigation scheduling method for cultivation of maize by conjunctively using the limited fresh water and the abundant saline water resources.

2. Materials and methods

2.1. Experimental site

The experiment was conducted during *rabi* (winter) season of 2015–16 (year 1) and 2016–17 (year II) at the experimental field of Agricultural Research Station (ARS), Bangladesh Agricultural Research Institute (BARI), Benarpota, Satkhira. The same field was used for experiments in both years. The annual average maximum temperature of the study location is 35.5 °C and minimum temperature is 12.5 °C, where April-May is the warmest period and December-January is the coolest period of the year (Table 1).

The experimental site lies in Agro-Ecological Zone-13 (AEZ 13) that consists of tidal floodplain with extensive area affected by medium to high salinity in the southwest of the country. Major soil type under AEZ 13 is non-calcareous grey floodplain soil, mostly clay with medium to high organic matter content, high bulk density, and high field capacity (38.5–40.9%) (Banglapedia, 2014; Shil et al., 2016). According to FAO/UNESCO soil map of the world, soil of the experimental site can be classified as Humic Gleysol (FAO, 2018). Table 2 provides the basic soil physical properties, and Table 3 soil chemical properties of the experimental site analyzed prior to establishment of the experiment.

2.2. Treatments and experimental design

The experiment was laid out in a Randomized Complete Block Design (RCBD) with four (4) replications. Six irrigation treatments: T_1 = two irrigation: first at vegetative (45 days after sowing-DAS) and second at tasseling (75 DAS) with fresh water; T_2 = three irrigation: first at vegetative, second at tasseling and third at grain filling (105 DAS) with fresh water; T_3 = two irrigation: first at vegetative stage with fresh water + s at tasseling with canal saline water; T_4 = three irrigation: first at vegetative with fresh water + s at tasseling and third

Table 2
Particle size distribution, texture, bulk density, and field capacity of the soil of the experimental site at different depths.

Soil depth (cm)	Particle size distribution			Soil textural class	Bulk density ($g\,cm^{-3}$)	Field capacity (% v/v)
	% Sand	% Silt	% Clay			
0 – 15	4.9	56.7	38.5	Silty clay	1.5	40.9
15–30	7.2	58.6	34.2	Silty clay	1.4	39.2
30–45	8.1	59.1	32.8	Silty clay	1.4	38.5