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RESEARCH ARTICLE

Responses and screening of white jute (*Corchorus capsularis* L.) genotypes against salinity stresses

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Abbreviation
BJC= Bangladeshi Jute of *Corchorus capsularis*
BJRI= Bangladesh Jute Research Institute
dS/m= Desi-siemens per meter
GDP= Gross Domestic Product
SRDI= Soil Resource Development Institute

ABSTRACT

Soil salinity, a serious threat to jute cultivation in saline areas (southern parts) of Bangladesh. Bangladesh Jute Research Institute (BJRI) has developed a moderately salt tolerant White Jute variety (BJRI Deshi pat-8; BJC 2197) in 2013 which can't grow well in saline areas having more than 8.0 dSm^{-1} salinity stress. Hence, 23 whitejute accessions and one control variety (BJC 2197) were tested to isolate the salt tolerant accession(s) for hybridization purpose followed by augmented design in farmers' field having nearly 8.0-9.0 dSm^{-1} salinity at Patuakhali district during mid-March to mid-August 2019. The experimental plot size was 3.0 m^2 (3 m × 1 m) for each genotype having 3 lines of 1.0 m length, plant-plant: 10-15 cm and line- line: 30 cm distance. Soil salinity was recorded during sowing, vegetative and plant maturity stages. In this study, the highest plant height 2.84 m was recorded in Acc. 2750 followed by Acc. 2589 (2.76 m) and Acc. 1779 (2.69 m). The highest fiber yield (9.0 g $plant^{-1}$) was observed in Acc. 1779 followed by Acc. 2589 (8.40 g $plant^{-1}$) and Acc. 2750 (8.0 g $plant^{-1}$). The lowest plant mortality rate (2.5%) was found in Acc.2750 followed by Acc.1779 (6.24%), Acc. 1780 (7.50), Acc. 3556 (11.10%), Acc. 2589 (11.20%) and BJC 2197 (16.5%). Few seeds were germinated in Acc. 3020 and Acc. 3658 but plants were died after 20 days of sowing. Six genotypes of cluster I showed higher diversity in Euclidean cluster analysis. The Acc. 2750, Acc. 1779, Acc. 2589 of cluster I having relative salinity tolerance and good fiber yield capacity would be grown in next year for confirmation as well as hybridization with the existing salinity susceptible variety to develop high yielding white jute variety for saline areas.

Introduction

Among the most important fibrous plants, Jute is second only to cotton in world's production of textile fibers (1). Chromosome number of jute is 2n=2x=14 and it belongs to the genus: *Corchorus*, which is under the family: *Tiliaceae* (2). The genus comprises more than 170 species with *C. olitorius* L. and *C. capsularis* L. as commercially cultivated species (3). Among which, *C. olitorius* L. along with most of *Corchorus* species considered to have originated along equatorial regions of East Africa and subsequently domesticated in India as fibre crop (4, 5). However, another cultivated species (*C. capsularis* L.) supposed to have originated and domesticated in South China and Indo Burma regions (6, 7). They are distributed throughout the tropical and sub-tropical regions of the world, particularly in Asia, Africa and Latin America (6, 8). For broadening the genetic base of new cultivars, genetic improvement of the cultivars of jute (*C. olitorius* L. and *C. capsularis* L.) is necessary (9, 10). These two jute species indeed more or less related with each other for the morphological characters but their maternal origins are different and incompatibility lies between them in respect of inter species hybridization (5, 11). On the contrary, the genetic variability present at the intraspecific level is low (12).

Soil salinity is a major abiotic stress and challenge for agricultural crop production which adversely affects crop production in arid and semi-arid lands in

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the worldwide and Bangladesh is no exception under this impediment (13). Evaluation of jute genotypes for salt tolerance is highly important because of salt affected areas are constantly increasing worldwide especially in Bangladesh where salt tolerant jute variety is unavailable (14).

It is a major abiotic stress and challenge for agricultural crop production which adversely affects crop production in arid and semi-arid lands in the worldwide and Bangladesh is no exception under this impediment (13). According to one study (15), salinity stress has inhibitory effect on both seed germination and seedling growth of tossa jute and the jute varieties differed significantly in their tolerance to this salinity stress. Seed germination and seedling growth of tossa jute variety were completely inhibited at 300 mM NaCl at artificial environment.

According to one study (16), the Kalapara coastal belt is one of the nearest areas to the Bay of Bengal in Bangladesh. The greatest sources of saline water is the Bay of Bengal. The deficiencies micronutrients are common in saline soil. In the coastal region, the reduction of food crop production has significant impact on the national economy of Bangladesh (17). The salt stress is varied due to the reduction of fresh water flow from upstream tidal flow and groundwater discharge (18). The saline affected coastal areas of Bangladesh cover 32% of the country consisting of 19 districts and accommodate more than 35 million people (19). Increased salinization of arable land is expected to have devastating global effects, with prediction of 30% land loss within the next 25 years, and up to 50% by 2050 (13). About 70% of cultivable land of Bangladesh suffered from different degrees of salinity (16, 17). Salinity levels of Bangladesh vary in different months of the year. In the months of March-April, the peak dry season, maximum salinity occurs and minimum in the months of July-August after the onset of monsoon rain (20). Soil salinity causes physiological disorder in uptake and recycling of nutrients within the plant biological systems (21). In Bangladesh, about 1.51 m ha of arable lands are affected by varying degrees of salinity which adversely impairs crop ecosystem (22). Salinity is one of the major problems in the coastal region of Bangladesh that contributes to 20% of the total land area. About 53% of the coastal region is affected by different degrees of salinity (23). During 1973, salinity affected 83.3 million hectares of land; this was increased to 102 million hectares by 2000. After that, salinity affected a recorded 105.6 million hectares during 2009 (22). Among these affected areas, around 2.5 million hectares of low-lying coastal lands represents 0.9 to 2.1 salinity level (SL) in Bangladesh (17, 24). Over the last 35 years, salinity has increased around 26 % in the coastal region of Bangladesh (25).

At present, due to population density and increasing land salinization problems, breeding for salinity tolerance in many crops needs to be paid more attention. So, cultivation of jute is regularly being pressed to the marginal lands with higher grades of soil salinity year round (26). Bangladesh, the second largest producer of jute, produces the best quality jute in the world and leads the export market (27). In addition, this crop is particularly important in Bangladesh where many small families depend on the income from growing and selling jute (28). Recently it was reported that the jute can grow readily in saline soils. Considering its tolerance especially to the chlorine salinity, jute has been recently suggested as a promising candidate for planting in wet lands and saline soils (28). Different jute genotypes would possess different tolerances to salinity, so it is necessary to screen out high salt tolerant jute genotypes for utilization in coastal region. Screening and identifying genotypes that maintain productivity under saline conditions is an effective approach (29).

Jute is an important bast fibre producing cash crop (30). Jute is the source of highly versatile environment friendly natural fibre. Bangladesh is the second largest jute producing country in the world and it earns a remarkable amount of foreign currency annually by exporting jute products (31). The contribution of jute is about 4% in GDP and earns about 5% of foreign exchange in 2019 (32-34). Multivariate method such as cluster analysis has proven to be useful for characterizing, evaluating and classifying germplasm for diversity when a large number of accessions or genotypes to be assessed for several characteristics of morphological and genetical importance (35, 36). Salt tolerant jute can grow readily in saline soils (26, 37). Screening for salt tolerance under field conditions is often not feasible due to the heterogeneous nature of field soil and seasonal fluctuations in rainfall (38).

Salt tolerant white jute variety should be developed for utilizing the saline areas of Bangladesh. But there is no sufficient information on salt tolerance of jute crop in Bangladesh (39).

Therefore, the present study was conducted to screen out the salinity tolerant white jute genotype(s) which will be used as breeding materials (parent) for developing high yielding salinity tolerant white jute variety.

Materials and Methods

Location of the experiment

The salinity affected areas are located in the southern belt of Bangladesh like Satkhira, Khulna and Patuakhali Districts (16). The experiment was conducted in farmer's field of saline zone at Kalapara of Patuakhali District (21°56'59.8"N 90°10'37.3"E) of Bangladesh during 15 March-15 August, 2019.

Plant materials

Twenty-four White Jute genotypes including one moderately salt (8.0-9.0 dSm^{-1}) tolerant variety named BJRI Deshi Pat-8 (BJC 2197) were used in this study (Table 1). Seed materials were collected from the Gene Bank and Breeding Division of Bangladesh Jute Research Institute.

Experimental design

Twenty three new accessions and a moderately salt tolerant variety (control) of white jute were investigated for salinity tolerance in this study. An

Table 1. Experimental plant materials with source of collection

SL. No.	Accession/ Genotype	Source of collection	SL. No.	Accession/ Genotype	Source of collection	SL. No.	Accession/ Genotype	Source of collection
1	Acc-1779	Gene Bank, BJRI, Dhaka.	9	Acc-2759	Gene Bank, BJRI, Dhaka.	17	Acc-3596	Gene Bank, BJRI, Dhaka.
2	Acc-1780		10	Acc-2999		18	Acc-3654	
3	Acc-1781		11	Acc-3015		19	Acc-3658	
4	Acc-2589		12	Acc-3017		20	Acc-3662	
5	Acc-2593		13	Acc-3020		21	Acc-3663	
6	Acc-2730		14	Acc-3026		22	Acc-3665	
7	Acc-2749		15	Acc-3556		23	Acc-3668	
8	Acc-2750		16	Acc-3563		24	BJRI Deshi Pat (Control)	Breeding Division, BJRI, Dhaka.

augmented design without replication of the tested genotypes except control variety was used for preliminary screening purpose (40, Fig. 1). The control variety was replicated to compare the tested genotypes with it very easily, and the data of replicated control variety were averaged and compared with the values of tested genotypes.

Growing, harvesting, retting, drying of jute fibers and sticks

The experimental plot size was 3.0 m^2 (3 m × 1 m) for each genotype having 3 lines of 1.0 m length, plant-plant: 10-15 cm and line- line: 30 cm distance (Fig. 1). After preparation of lands, jute seeds were sown on 15 March, 2019. Jute plants were grown in farmers' fields at Patuakhali. Agronomic practices like weeding, thinning, fertilization were done properly (41, 42). Plants were harvested at 120 days after sowing (15 July); then plants were heaped and allowed to fall off the green leaves for 3 days and finally the green plants or stems were kept under fresh water for 20-25 days and retting was done. Then well retted fibers were collected from outer region of stem and washed in fresh water. The collected fibers were dried using bamboo hanger. After harvesting, 30-35 days (up to mid-August) were required for data collection of jute fiber, stick yield data collection, compilation, analyses and reporting etc.

Data collection and analyses

The morphological parameters of jute plants (Table 2) were recorded according to the earlier researchers' reports (26, 43-45). The plant mortality rate (%) was observed and recorded at seedling, vegetative and harvesting stages (17). The plant mortality rate was calculated using the formula (Eqn. i).

$$\text{Plant mortality rate}\,(\%) = \frac{\text{Total number of plants died}}{\text{Total number of plants germinated}} \times 100$$

Standard agronomic practices were followed for uniform plant growth (41). Data were analyzed using Microsoft Excel Program (2016) and Statistical Software-Statistix10 (46). Soil salinity was recorded at 15 days interval from sowing to harvesting time using the direct soil pH/EC meter (HI993310).

Results

Soil salinity, seed germination (%) and plant mortality (%)

During crop growing period, the average soil salinity of the experimental field was 8.0-9.0 dSm^{-1}. Soil salinity was recorded at sowing time (15 March), vegetative stage (80-90 days) and harvesting stage (120 days) respectively (47). Among 24 genotypes of white jute, 22 were successfully germinated and survived; but two genotypes viz. Acc. 3020 and Acc. 3658 were germinated in very low rate and seedlings were died after 20 days of sowing (Fig. 2). It was observed that, the lowest plant or seedling mortality rate (2.50%) was found in Acc. 2750 followed by Acc. 1779 (6.24%), Acc. 1780 (7.50), Acc. 3556 (11.10%), Acc. 2589 (11.20%) etc (17, Fig. 5).

Yield and Contributing Characters

From the descriptive analyses of results, the mean performance for plant height, base diameter, fresh weight with leaves, dry fiber yield and dry stick yield of the studied germplasm were found statistically significant (Table 3).

Plant height

Plant height significantly contribute to the fiber yield in Jute crop (49). Considering all the genotypes, plant height was ranged from 0.95 to 2.84 m with a mean of 1.94 m (Table 3). The highest plant height (2.84 m) was observed in Acc. 2750 followed by Acc. 2589 (2.76 m) and Acc. 1779 (2.69 m).

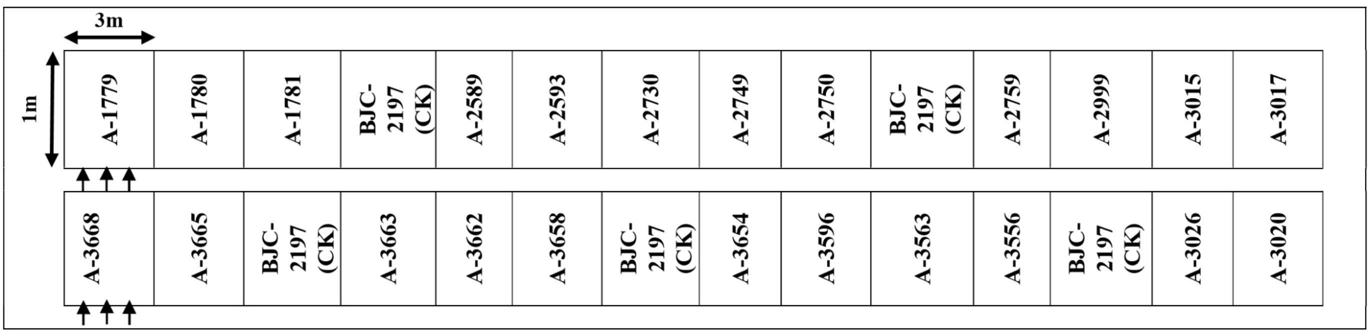

Fig 1. Field layout of the experiment.

Table 2. Collection method of experimental data

SL. No.	Morphological parameters	Unit of measurement	Method of collection
1	Plant height	Meter (m)	The average stem height of plant (base-apex) was taken from 10 plants using measuring tape.
2	Girth or base diameter	Millimeter (mm)	The average diameter of the plant stem at base was taken from 10 plants using slide calipers.
3	Green weight of plants	g $plant^{-1}$	The average fresh or green weight of the plant was taken from 10 plants using digital balance or scale.
4	Dry fiber yield	g $plant^{-1}$	The average dry fiber yield of the plant was taken from 10 plants using digital balance or scale.
5	Dry stick yield	g $plant^{-1}$	The average stick yield of the plant was taken from 10 plants using digital balance or scale.
6	Soil salinity	dS m^{-1}	Soil salinity levels were recorded using direct EC/pH meter at 15 days interval from several locations of plot. The average salinity was calculated.

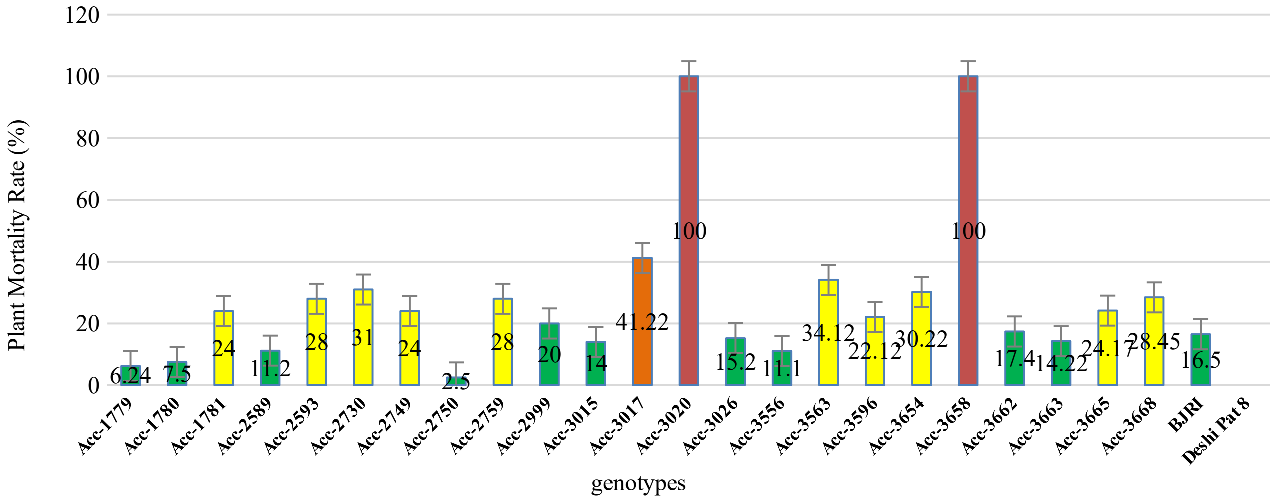

Fig. 2. Mortality percentage of different white jute accessions.

Note: Genotypes with green bar are salt tolerant (plant mortality rate ≤ 20%), yellow are moderately salt tolerant (plant mortality rate < 40%) and red are susceptible for soil salinity (plant mortality rate > 40%) (48).

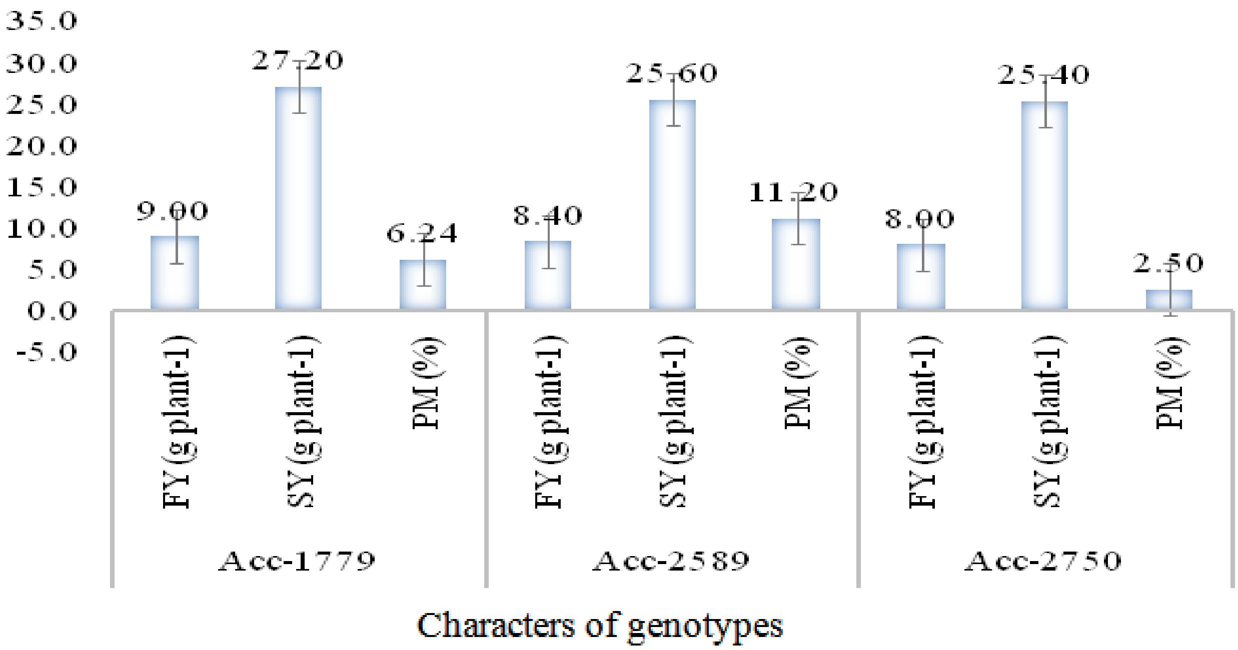

Fig. 5. Graphical view of fiber yield, stick yield and plant mortality rate of Acc. 1779, Acc. 2589 and Acc. 2750
Note: FY-Fiber yield, SY-Stick yield, PM-Plant mortality.

Base diameter

The highest girth or plant base diameter (20.0 mm) was recorded in Acc. 2589 followed by Acc. 2750 (19.60 mm), Acc. 1779 (19.40 mm), Acc. 2999 (18.80 mm), Acc. 2730 (18.20 mm), Acc. 3596 (18.20 mm), Acc. 1781 (18.20 mm), Acc. 1780 (18.0 mm) (Table 3).

Table 3. Statistical analyses for studied morphological characters of 24 white jute genotypes

Sl. No.	Acc./Var.	PH (m)	BD (mm)	GW (g plant^{-1})	FY (g plant $^{-1}$)	SY (g plant $^{-1}$)
1	Acc-1779	2.69	19.40	398.00	9.00	27.20
2	Acc-1780	2.54	18.00	238.40	7.45	19.22
3	Acc-1781	2.44	18.20	304.00	5.80	17.00
4	Acc-2589	2.76	20.00	384.00	8.40	25.60
5	Acc-2593	2.44	17.90	186.00	7.20	19.40
6	Acc-2730	2.43	18.20	224.00	7.20	22.40
7	Acc-2749	2.10	15.40	192.00	5.80	16.60
8	Acc-2750	2.84	19.60	330.00	8.00	25.40
9	Acc-2759	2.29	17.80	198.00	6.80	22.20
10	Acc-2999	2.21	18.80	286.00	7.20	23.00
11	Acc-3015	1.76	15.61	140.00	5.20	15.40
12	Acc-3017	1.71	16.80	154.00	3.80	15.40
13	Acc-3020	-	-	-	-	-
14	Acc-3026	1.76	15.80	122.00	4.20	14.00
15	Acc-3556	1.72	17.40	134.00	5.60	18.40
16	Acc-3563	1.59	16.00	48.00	2.00	4.60
17	Acc-3596	1.67	18.20	124.00	5.40	14.80
18	Acc-3654	1.42	16.00	82.00	2.40	4.60
19	Acc-3658	-	-	-	-	-
20	Acc-3662	1.01	13.20	70.00	1.60	4.40
21	Acc-3663	1.17	12.60	82.00	1.40	5.40
22	Acc-3665	0.97	13.50	49.00	1.44	4.42
23	Acc-3668	0.95	13.00	34.00	1.40	4.25
24	BJRI Deshi Pat-8	2.24	16.80	356.00	7.10	17.40
Maximum		2.84	20.00	398.00	9.00	27.20
Mean		1.94	16.74	187.97	5.20	15.50
Range		1.89	7.40	364.00	7.60	22.95
CV (%)		30.71	13.05	48.52	49.66	60.52

Note: PH= Plant height (m), BD= Base diameter (mm), GW= Green weight with leaves (g plant^{-1}), FY= Dry fiber yield (g plant^{-1}), SY= Dry stick yield (g plant^{-1}), CV (%) = Coefficient of variation in percentage, Comparison among the genotypes for morphological traits based on non-replicated individual data.

Fresh or green weight

The more biomass of jute plant indicate the higher yield content of fiber and/or stick (30, 50). Among all the genotypes, Acc. 1779 showed higher fresh weight (398.0 gm plant^{-1}) followed Acc. 2589 (384.0 gm plant^{-1}), BJRI Deshi Pat 8 (356.0 gm plant^{-1}), Acc. 2750 (330.0 gm plant^{-1}), Acc. 1781 (304.0 gm plant^{-1}) (Table 3).

Yield components

Dry fiber yield was ranged from 1.4 to 9.0 gm plant^{-1}with a mean of 5.2 gm plant^{-1}. The highest fiber yield was recorded in Acc. 1779 (9.0 gm plant^{-1}) followed by Acc. 2589 (8.4 gm plant^{-1}) and Acc. 2750 (8.0 gm plant^{-1}). Therefore, Acc. 1779, Acc. 2589, Acc. 2750 would be considered as good for selection and hybridization purposes regarding their fiber yield, stick yield and mortality rate (Fig. 5; Table 3).

Hierarchical Cluster Analysis

Cluster analysis of morphological traits grouped all genotypes into five major clusters at the genetic distance of 180.0 (Fig. 4) and indicates that 24 white jute genotypes shown remarkable genetic divergence in case of phenotypic traits. It was also observed that, among the five clusters, cluster I and V were larger and each of them consisted of 6 genotypes (25%). The control variety BJRI Deshi pat-8 was found in cluster I, and the other cluster were consisted of accessions. Intra and inter cluster distances for similar and dissimilar white Jute genotypes were assessed by using ward's method (Fig. 3, 4). Six genotypes of cluster I (Acc. 1779, Acc. 2589, Acc. 1781, Acc. 2999, Acc. 2750 and BJRI Deshi pat-8) showed higher intra-cluster distance and mean values for all studied morphological characters (Fig. 3, 4). The cluster II and V showed almost similar values at intra level of distance; cluster III gave lowest intra-cluster distance; while there is no intra-cluster distance in cluster IV. Maximum inter-cluster distance (344.35) was observed between cluster I and IV indicating the higher possibility of variations between the genotypes of these cluster. The two genotypes (Acc. 3020 and Acc. 3658) of cluster IV were not germinated in the field and no data were found. These were found susceptible to salt stress.

Discussion

Soil salinity causes serious damage to the plant root system; hampers the nutrient recycling from soil to plant body and ultimately crop production is drastically decreased (17). A large saline area remains unused due to salinity problem in southern parts of Bangladesh. Hence, development of salinity tolerant white jute variety is a crying need to cultivate these saline areas to benefit the farmers' as well as the national economy (51). From this study, the salt tolerant jute genotypes would be used as breeding parents leading to development of high yielding salt tolerant varieties in Bangladesh (52).

According to one study (53), plant height and base diameter are significantly associated with each other directly contributing to fiber yield in jute crops. The increase in plant height and/or base diameter results the increase in fiber and/or stick yield (49). So, the jute genotypes with higher stem height and base diameter would be selected and used as parent(s) in hybridization programme for developing high yielding stress tolerant variety (54).

The fresh weight or green weight of jute plants without leaves contribute to fiber and stick yield

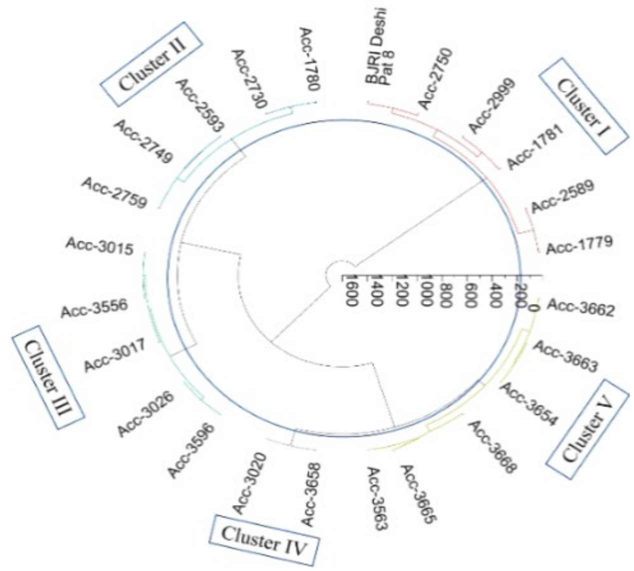

Fig. 3. Euclidean cluster Dendrogram showing the relationships among 24 White Jute genotypes for five morphological characters.

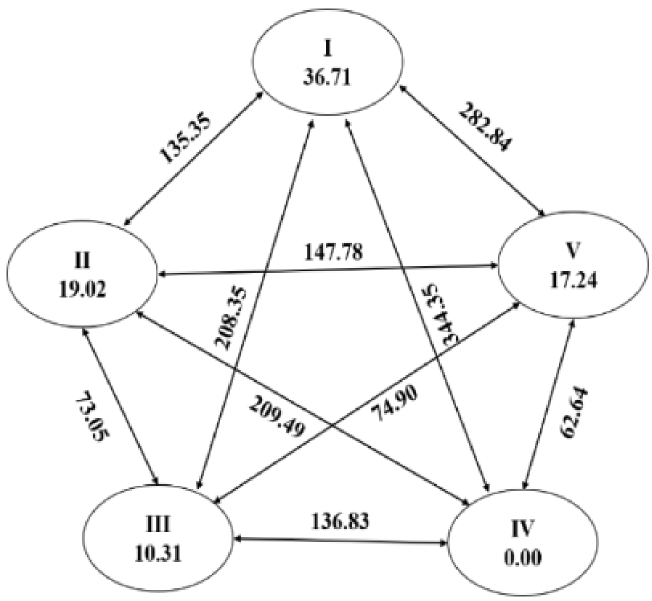

Fig. 4. Average intra and inter cluster distances among five clusters with respective White Jute genotypes.

contents (41). Jute leaves are also important as green manure used in soil (50). Fiber yield is the main criteria of jute crops to consider as a good genotype (55).

Along with stem height and base diameter; fresh weight of jute plants contribute to its fiber and stick yield (56). Plant mortality means the number of plants died in proportion to the number of total plants after germination expressed as percentage (57). Plant population is an important factor contributing the fiber and stick yield in jute crops (41).

The jute genotypes having good germination as well as survivability rate, higher plant height, girth of stem, fiber yield even after growing under salinity stresses would be selected as salinity tolerant genotype; and would be used as breeding materials (49). So, among all the experimental genotypes, Acc. 1779, Acc. 2589, Acc. 2750 were superior for selection and hybridization purpose regarding their fiber yield, stick yield and mortality rate (Fig. 5). White Jute genotypes showed remarkable genetic divergence in case of phenotypic traits (47). The dendrogram tends to group some of the genotypes with similar morphological traits into the same cluster (58).

The genotypes of cluster I showed higher diversity but the cluster II, III, V showed almost similar type diversity. The higher inter cluster distances reveals the presence of high genetic divergence between the clusters, while estimating genetic diversity of jute identical result was reported (59). Selecting the jute genotypes from high inter cluster distances with high mean values for fiber yielding characters will help in developing high heterotypic hybrids and also useful in selecting better recombinants in the segregating generations for higher fiber yield (10). The average inter cluster distances were higher than the average intra cluster distances, which indicates the presence of wide genetic diversity among the genotypes of different clusters than those of same cluster (60). Salinity is a serious abiotic stress to Jute and other crop cultivation at saline regions in the world (61).

So, the three white jute genotypes (Acc. 1779, Acc. 2589, Acc. 2750) from cluster I were superior for selection and hybridization purpose which was corroborated with an earlier study in *C. olitorius* (47, 61).

Conclusion

Salinity is a serious abiotic stress to Jute and other crop cultivation at saline regions in the world. There are 23 white jute accessions and one moderately salt tolerant white jute variety were investigated to isolate the salt tolerant accession(s) and to study the morphological performances contributing to fiber yield. The experimental results revealed that the genotypes were varied for the studied traits under salinity stresses. Among all the genotypes, Acc. 1779, Acc. 2589 and Acc. 2750 were relatively more salt tolerant compared to control variety and showed good performances for morphological traits i.e. fiber yield, plant height, base diameter, fresh weight and plant mortality rate etc. which contribute to fiber yield. These genotypes would be considered as good in respect of salinity tolerance and these are need to grow again in the area having more salt stressed environment for the confirmation. These good genotypes would be used as breeding materials or parents to transfer or incorporate the genes for respective desired traits in one existing cultivar for salt stress tolerance or higher fiber yield potentialities.

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Authors' contributions

NA, RKG, MGM and MMM planned the experiment and NA sanctioned all facilities required. They also helped to set up the experiment. SAJ and IJN were sown the seed materials in field. The morphological and soil salinity data were recorded by MHR, MMM and TS at vegetative phase, and by RKG, MGM and TS at maturity or final harvesting stage of jute plants. Finally, SAJ, MHR and MMM compiled the data, analyzed, reported for presentation. MMM conceptualized the experimental design, experimental set up, article writing, submission and corrections. All authors provided critical feedback and helped to shape the research system.

Conflict of interests

The authors do not have any conflict of interests to declare.

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