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RESEARCH ARTICLE

Responses of seed germination, seedling growth under salinity stresses and variability for phenotypic traits in Tossa Jute (*Corchorus olitorius* L.)

Md. Mia Mukul[1*], SSU Ahmed[1], Nargis Akter[1], Md. Golam Mostofa[1], Md. Sohanur Rahman[2], Fakhar Uddin Talukder[2]

[1]Breeding Division, Bangladesh Jute Research Institute, Ministry of Agriculture, Manik Mia Avenue, Dhaka-1207, Bangladesh
[2]Pest Management Division, Bangladesh Jute Research Institute, Ministry of Agriculture, Manik Mia Avenue, Dhaka-1207, Bangladesh
*Email: mukulbjribreeding@gmail.com

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Salinity stress; Tossa jute; Stress tolerance; gene bank; salt tolerance index; relative salt harm rate

Abbreviations
BJRI-Bangladesh Jute Research Institute
FAO-Food and Agricultural Organization
SRDI-Soil Resource Development Institute

ABSTRACT

Salinity is a serious abiotic stress to Jute and other crop cultivation at saline regions in the world. No salt tolerant Tossa Jute (*Corchorus olitorius* L.) variety was developed in Bangladesh. Hence, six Tossa Jute accessions were investigated at germination stage against six concentration levels (0.00 or d.H_2O, 8.0, 10.0, 12.0, 14.0 and 16.0 dS m^{-1}) of salt (NaCl) using RCB design at Bangladesh Jute Research Institute (BJRI) during March-July, 2020. Jute seeds collected from Gene Bank of BJRI were allowed to germinate under laboratory condition. Seed germination rate was adversely affected as well as delay in germination was prolonged with increasing the salt concentration. In control, seeds were germinated up to 14.0 dS m^{-1} salt solution. Among six genotypes, Acc. 1141 and Acc. 3801 showed the highest germination rate (86.67 %); Acc. 3801 gave maximum root length (17.0 mm), dry biomass (6.37 mg); and Acc. 1089 showed higher shoot length (10.0 mm), fresh weight (43.93 mg) and salt tolerance index (60.69 %) under 14.0 dS m^{-1} level. Higher relative salt harm rate (7.14 %) was observed in both Acc. 1141 and Acc. 3801 under 14.0 dS m^{-1} salinity indicating highly tolerance to salinity. Acc. 3801 and Acc. 1141 were found good for germination under salt stresses; Acc. 3801, Acc. 1089 for fiber yield and salt tolerance; Acc. 3801 and Acc. 1407 for higher fiber yield. Acc. 3801 was found good for salt tolerance and fiber yield content. The genotypes with good desirable characters would be used as breeding materials to develop high yielding salt tolerant Tossa Jute variety.

Introduction

The abiotic stress salinity is a serious threat to crop cultivation in Bangladesh. Increase in salinity problem is expected to have devastating global effects predicting the 30 % lands will be lost in the next 25 years, and up to 50 % by the year 2050 (1). Drought and salinity cause water stress limiting plant germination and early seedling stage (2). Bangladesh is not exempt from salinity (soil & water) problem where, the soil of around 1.02 million ha of farmland is somewhat saline (3). The saline affected areas were categorized as moderate to high salinity (8-15 dS m^{-1}) or highly saline (>15 dS m^{-1}) which is increasing rapidly in Bangladesh due to changing of global climate (4). Soil salinity is the most alarming problem among abiotic and biotic stresses especially for Tossa jute cultivation in Bangladesh. The global rise in sea water level initiates the salinity problems where 20 % (45 million ha) of total globally irrigated area (230 million ha) affected by salinity problem (5). More than 1.02 million ha of land were saline affected in Bangladesh, which is marvellous potential for developing jute fiber yield (6). As different levels of salinity tolerances in various jute genotypes, it is necessary to isolate highly salt-tolerant genotypes for research and cultivation purposes. Researchers have adopted several strategies to overcome the adverse effect of salinity. Screening and identification of salt tolerant jute genotypes that maintain productivity under saline conditions is an effective approach for varietal improvement (7).

Jute plant is the world's second largest fiber crop after cotton grown for natural fiber content

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(8). In earlier a researcher reported (9) that, Jute is also used as vegetable; it is an annual crop belongs to the genus *Corchorus* and family Tiliaceae bearing chromosome number 2n = 2x = 14. Jute stem consist of xylem and phloem tissues where, the bark of the jute stem contain secondary phloem tissues and cambium cells (10). There are 100 species found under *Corchorus* genus in the world, where 40 species are available for cultivation and research purpose (11). Only two species namely *Corchorus olitorius* and *C. capsularis* are commercially cultivated in tropical and subtropical regions especially of Asia, Africa and Latin America for fiber production (12). *C. olitorius* is very susceptible to most biotic and abiotic stresses compared to *C. capsularis;* but *C. olitorius* produces fiber with good qualities than *C. capsularis* (13-15). In Bangladesh, *C. capsularis* is somewhat tolerant to salt stress up to 75.86 mM (8.0 dS m^{-1}) in field condition (16). Salinity inhibits plant growth by osmotic imbalance reducing the ability of plant to uptake water and by ion excess problem affecting the plant cells and saps (17).

Jute fiber is mainly used for manufacturing of cloth, cordage, carpets, bagging, wrapping materials, paper pulp etc. with an annual production of 2.65 million tons around the world (18, 19). Bangladesh, the second largest jute producer after India in the world (20); produces the best quality jute fiber; leading the export market and earning of a significant proportion of its foreign exchange annually from the export of jute products (21). Jute is an economic crop because many small families depend on the income from growing and selling jute in Bangladesh (22). Nearly 12-13% of total foreign currency of Bangladesh earned by exporting jute and jute products which is very important for fostering the national economy (23). In the total cultivable area, Jute covered 6.95% occupying 0.5 million hectares of land and producing 0.96 million metric tons jute fiber (24).

Among the statistics for Jute and allied fiber crop cultivation in Bangladesh, 80% are Tossa Jute and 10% are White jute and the rest 10% are Kenaf & Mesta (25). There is no salt tolerant Tossa jute variety developed in Bangladesh. Tossa jute is less tolerant to environmental stress conditions, and its distribution is dependent on its tolerance to some stresses such as salinity in water and soil (26); because its production of quality fiber is affected by several abiotic factors like salinity and drought stress (27). Salt stress is a complex physical-chemical process which may result from a combination of toxic, nutritional and osmotic factors and which affect plant growth and yield. Many biological macromolecules and small molecules such as nucleic acids (DNA, RNA, micro RNA), proteins, carbohydrates, lipids, hormones, ions, free radicals and mineral elements are involved in salinity stress condition (28-30).

Salinization seriously affects the growth and all the physiological steps of plants, and hence, plant production was significantly reduced (31). So, it is very necessary to increase the tolerance to salinity in order to increase Tossa jute fiber yield (27). In Jute plants, tolerance to salinity is a complex phenomenon that indicates specific morphological and developmental mechanisms with physiological and biochemical changes (32). Salt pressure causes decrease in leaf size, increase of leaf thickness, length of stomata and develop adaptation ability, i.e., succulence, osmotic adjustment, salt glands and ionic compartmentation to dilute or counter-balance the result of hyper-salinization (27, 31). Tossa Jute can't grow readily in saline soils (26). After increasing the salinity tolerance especially to the chlorine salt, the Tossa Jute varieties would be suggested as a promising natural fiber crops for cultivating in wetlands and saline soils in Bangladesh.

The wild Tossa jute species are prospective sources for abiotic and biotic stress lenient genes as well as significant genetic resources; and their cultivated species are globally important for fiber yield and their phenotypic traits (33). The two species indeed are distantly related and their maternal origins are different. On the contrary, genetic variability present at the intraspecific level is low than the interspecific level. To broaden the genetic base of new jute varieties, it is needed to improve the genetic architecture of jute cultivars. The breeders should explore the morphological characters of jute species on the basis of their needs (34). Jute is being pushed constantly to marginal and sub-marginal lands because, arable lands are decreased gradually due to high population pressure (35). The inhospitable terrains due to salinity problems will be allowed to cultivate through the development of salt tolerant Tossa jute varieties. It is very essential for the current situation to develop Tossa jute varieties with greater tolerance to environmental stresses. So, the jute genotypes should be evaluated at growth stages for salt tolerance capacity. Evaluation of jute seed germination responses to different NaCl concentrations in laboratories is one of the common and rapid tests (36).

In this regard, six Tossa Jute accessions were investigated i) to observe their response to salt (NaCl) stresses at germination stage; ii) to evaluate their seedling health status under different salt treatments and iii) to screen relatively better salt tolerant tossa jute genotype(s) having good fiber yield attributes which would be used as breeding materials for developing high yielding Tossa jute variety.

Materials and Methods

Plant materials

Six Tossa Jute (*C. olitorius* L.) genotypes were used in this investigation to evaluate their responses against salt stresses at germination stage along with their yield and yield attributing morphological characters at maturity and harvesting times (Table 1).

Time and Site of the experiment

The Jute accessions were investigated in both laboratory and field conditions during March-July'2020 under the Olitorius Department, Breeding

Table 1. Experimental Tossa Jute accessions with their identical traits, origin and sources of collection

SL. No.	Accession/ Genotype	Morphological characters	Country origin	Sources of collection
1	G_1=Acc. 1141	Ovate lanceolate leaves, horizontal leaf angle, full green plant, rudimentary branching habit	Bangladesh	Gene Bank of Bangladesh Jute Research Institute
2	G_2=Acc. 1089	Full green plant, ovate lanceolate leaves, horizontal leaf angle, no branching habit	Bangladesh	
3	G_3=Acc. 3801	Red stipule, coppery red petiole, light red stem, horizontal leaf angle, no branching habit	Kenya	
4	G_4=Acc. 4584	Ovate lanceolate leaves, horizontal leaf angle, full green plant, no branching habit	Nepal	
5	G_5=Acc. 1192	Ovate lanceolate leaves, Red stipule, coppery petiole, light red stem, horizontal leaf angle, no branching habit	Bangladesh	
6	G_6=Acc. 1407	Lanceolate leaves, horizontal leaf angle, full green plant, rudimentary branching habit	Bangladesh	

Division, Bangladesh Jute Research Institute, Dhaka (23°45'26"N, 90°22'47"E). The lab works were done for several times to enhance experimental accuracy.

Preparation of salt solutions

The measurement of dissolved salt concentration in water is known as salinity estimation. The commonly used units of measurement of salt solution are EC (Electrical conductivity) or dSm^{-1} (Decisiemens per meter), ppm or mgL^{-1} (milligram per liter), mM (Millimolar) etc.

Calculation

1. Surface water salinity is described by units of “electrical conductivity (EC)”.
2. Ground water salinity is described by units of “parts per million (ppm)”.
3. Scientific reports use “DeciSimense per metre (dSm^{-1})” as the main unit of measurement.

The relationship among these calculation units are as follows (42):

1 dS m^{-1}= 1 mS/cm=1000 EC (µS/cm) = (1000×0.55) ppm=550 ppm

1 L 1 mM NaCl solution= (58.44g× 1 × 10^{-3}) or 0.058 g NaCl diluted and volume up to 1 L dH_2O

1 ppm NaCl solution= 1 mg or 0.001 g NaCl diluted and volume up to 1 L dH_2O

The treatment solutions were prepared as follows:

T_0= 0.0 mM or dS m^{-1}; distilled water with no salt content

T_1= 8.0 dS m^{-1} or 75.86 mM; 4.40 gm NaCl was added and diluted in 1000 ml of stock sample.

T_2= 10.0 dS m^{-1}or 94.83 mM; 5.50 gm NaCl was added and diluted in 1000 ml of stock sample.

T_3= 12.0 dS m^{-1} or 113.79 mM; 6.60 gm NaCl was added and diluted in 1 L of stock sample.

T_4= 14.0 dS m^{-1} or 132.76 mM; 7.70 gm NaCl was added and diluted in 1 L of stock sample.

T_5= 16.0 dS m^{-1} or 151.72 mM; 8.80 gm NaCl was added and diluted in 1 L of stock sample.

Salt application and seed germination

After collection, seeds were exposed to sunshine for 5 hrs to enhance germination capacity (37). At first, seeds were placed on filter paper (two layers) in the Petri dishes followed by soaking in distilled water for five minutes and then seeds were washed repeatedly with distilled water to remove surfactants. The sterilized seeds were placed on doubled filter paper in petri-dishes (Fig. 1) and allowed to germinate in a growth chamber at room temperature (27 °C ± 2). For this, 20 viable seeds were arranged on double filter paper (Whatman, 150 mm) into 9 cm kept in petri dishes, and wetted each with 8.0 ml of distilled water containing 0.0, 8.0, 10.0, 12.0, 14.0 and 16.0 dS m^{-1} NaCl concentrations (T_0, T_1, T_2, T_3, T_4 and T_5, respectively) for each genotype and five replications for each treatment were applied. The treatment solutions were used from the stock solutions of salt prepared earlier for each dose.

Data collection

At germination stage

It was considered to germinate the seeds when there was radical protrusion occurred through the seed coat (38). The seed germination (Fig. 2) was

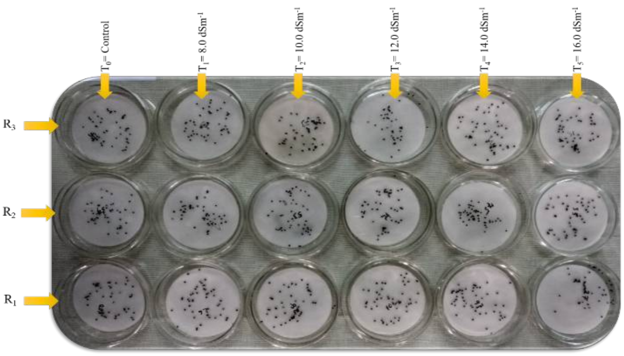

Fig. 1. Seeds of a Jute genotype placed on blotting paper in petri-dishes and treated with different salt doses.

investigated daily and recorded for 3 days at 3rd, 4th, 5th day with an interval of 24 hrs. The root length, shoot length, fresh weight or biomass of the seedlings were taken on 5th day. The root and shoot lengths of the seedlings were recorded carefully by using centimeter scale. Fresh weight of the roots and shoots of seedlings were taken carefully using Electronic Precision Analytical Weighing Balance (RS232). Then, the samples were oven dried at 60 °C for 24 hrs and dry weights were taken using the same balance (39).

Growing of plants and morphological data collection

Soil samples were prepared through mixing of fertilizers (Cowdung: Urea: TSP: MoP= 1 kg: 100 gm:

80 gm: 40 gm per 10 kg soil); then earthen pots (Height: Width= 30: 25 cm) were filled with these soils and ready for seed sowing. Jute seeds were treated with Vitavex 200@ 0.5 % to remove seed

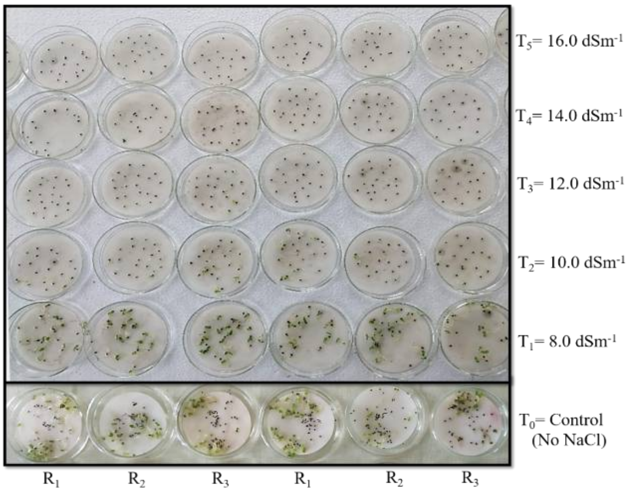

Fig. 2. Effects of salt stresses on seed germination of two jute genotypes at 3rd day.

borne pathogens and treated seeds were sown in earthen pots (Fig. 3) keeping proper labelling in pot for identity during 25 March' 2020 at their critical day length (>12.5 hr). Agronomic practices (weeding, thinning, fertilization, irrigation etc.) were done carefully as and when necessary. There are 20 plants for each genotype were kept in earthen pot. After 120 days of sowing, matured plants were harvested and morphological parameters like plant height (m), stem base diameter (mm), total diameter of plant (mm), leaf length (cm), leaf width (cm), length breadth ratio, leaf area (cm^2), petiole length (mm), number node, inter-nodal length (cm), days to flowering (day), weight of 1000 seeds (gm), dry jute stick weight (gm plant^{-1}), dry jute fiber weight (gm plant^{-1}), germination rate (%) of jute genotypes were recorded very carefully. Plants were grown in 3 replications and data were recorded respectively (40).

Fig. 3. Experimental Jute genotypes grown in earthen pots at research field.

Calculation of germination rate (GR)

According to an earlier researcher (41), the seed germination rate in Jute crop were estimated using the following formula:

Rate of seed germination,

$$GR=\{(n1\times t1)+(n2\times t2)+(n3+t3).ni\times ti\}\div T\ ......(i)$$

Here, n: Number of days for each counting of germinated seeds, t: Number of germinated seeds in each counting day and T: Number of total germinated seeds.

Relative salt harm rate (RSHR)

The relative salt harm rate (RSHR) and salt tolerance grade was measured carefully according to an earlier researcher (42) with some modification. Seeds of each jute genotype were placed on soaked filter paper. One group was added with dd.H_2O as control, the other groups were supplied with NaCl as treatment doses. These groups were kept under 30 °C for 5 days. The filter papers were changed every day maintaining with respective salt doses and then the germination rate of each group was recorded. This experiment was conducted in triplicates. The relative salt harm rate (RSHR) of each genotype was calculated carefully as follows according to an earlier researcher's method (43).

$$RSHR(\%)=\frac{\frac{(CK1+CK2+CK3)}{3}\times 100-\frac{(T1+T2+T3)}{3}\times 100}{\frac{(CK1+CK2+CK3)}{3}\times 100}\times 100..(ii)$$

Where, *CK*= Germination rate of control and *T*= Germination rate of treatment.

Estimation of salinity tolerance grade

The salt tolerance grade of each genotype at germination stage was calculated carefully using the grade (Table 2) (43).

Salt tolerance index (STI)

The salt tolerance index was calculated as total dry weight of the plant obtained from 5 seeds grown under different salt treatments compared to the plants grown normal concentration as control (44).

Table 2. Grade standard of salt tolerance of Tossa Jute (43)

Relative salt harm rate (%)	Average index salt harm (%)	Salt tolerance	
		Level	Grade
≤20.0	≤20.0	Highly tolerant	1
20.10-40.0	20.10-40.0	Tolerant	2
40.10-60.0	40.10-60.0	Middle tolerant	3
60.10-80.0	60.10-80.0	Salt susceptible	4
80.1-100.0	80.1-100.0	Highly susceptible	5

Salt tolerance index, $STI=[(\frac{TDW(S_x)}{TDW(S_0)})\times 100]$.....(iii)

Here, TDW (S_0) = Total dry weight of pants under no salt and TDW (Sx) = Total dry weight of plants under salt treatments.

Statistical Procedures

Statistical analyses were performed according to a completely randomized design using Microsoft Excel Program and Statistical Analysis Software (OriginPro 2020) software program (45). Analysis of variances (ANOVA) were estimated to test the differences among the genotypes treated under different salt concentrations at germination stage and lowest standard deviations (LSD) tests were done to estimate the mean differences among all genotypes. Significant differences were considered at 5% probability level (P< 0.05).

Results

A. Lab experiment

Effects of salt (NaCl) stresses on seed germination speed

Analysis of variance explored that, significant differences were observed in seed germination speed under different salt concentrations. Seeds of all genotypes were germinated/emerged under all salt treatments (Fig. 4-9) except the last treatment (16 dS m^{-1}). No seeds were germinated under 16 dS m^{-1} salt treatment. The seed germination speed was decreased proportionally with increasing the salt levels. Jute seeds were germinated after 24 hr (9) rapidly in salt solutions within 0.0 and 12.0 dS m^{-1} NaCl (Fig. 4-9). The highest seed germination (%) was found under controls, followed by 8.0, 10.0, 12.0 dS m^{-1} for Acc. 1141 (Fig. 4), Acc. 1089 (Fig. 5), Acc. 1192 (Fig. 8) and Acc. 1407 (Fig. 9) salt solutions; and the highest germination speed was recorded from 0.0 to 14.0 dS m^{-1} for Acc. 3801 (Fig. 6, 10); and from 0.0 to 10.0 dS m^{-1} for Acc. 4584 (Fig. 7).

Maximum seed germination was reached after three days for T_0, T_1, T_2 and T_3 treatments in Acc. 1141 (Fig. 4), Acc. 1089 (Fig. 5), Acc. 1192 (Fig. 8), Acc. 1407 (Fig. 9); for T_0, T_1, T_2, T_3 and T_4 treatments in Acc. 3801 (Fig. 6); after two days for T_0, T_1 and T_2 treatments in Acc. 4584 (Fig. 7). However, a significant reduction in speed and rate of germination was marked after 14.0 dS m^{-1} salt dose which was severely limited at T_5 (16.0 dS m^{-1}) (Fig. 4; P<0.05).

After 5 days of salt applications, the final percentage of seed germination was decreased by 6.67, 6.67, 13.33, 13.33 and 100 % in Acc. 1141 (Fig. 4); by 13.33, 13.33, 13.33, 40.0 and 100 % in Acc. 1089 (Fig. 5); by 6.67, 6.67, 13.33, 13.33 and 100 % in Acc. 3801 (Fig. 6); by 13.33, 13.33, 53.33, 60.0 and 100 % in Acc. 4584 (Fig. 7); by 33.33, 6.67, 13.33, 60.0 and 100 % in Acc. 1192 (Fig. 8); by 6.67, 20.0, 23.33, 56.67 and 100 % in Acc. 1407 (Fig. 9) under T_1, T_2, T_3, T_4 and T_5, respectively, compared to control treatment (T_0).

Seed germination ability

Seeds of all genotypes were germinated in controls followed by 8.0, 10.0, 12.0 and 14.0 dS m^{-1} salt stress condition; no seeds were germinated in 16 dS m^{-1} salt solution (Fig. 10). Under control or no salt stress condition, the highest germination (96.67 %) was recorded in Acc. 1407 followed by Acc. 1141, Acc. 1089, Acc. 3801, Acc. 4584 (Fig. 10). Similar results were described in a study (46). In 8.0 dSm^{-1} salt stress, the highest germination (93.33 %) was found in Acc. 1141, Acc. 1407, Acc. 3801 followed by Acc. 1089, Acc. 4584 and Acc. 1192. The Acc. 1141, Acc. 3801 and Acc. 1192 gave the highest germination (93.33 %) followed by Acc. 1089, Acc. 4584 and Acc. 1407 under 10.0 dS m^{-1} salt treatment. Under 12 dS m^{-1} salt treatment, Acc. 1141, Acc. 1089, Acc. 3801 and Acc. 1192 gave the highest germination (86.67 %) followed by Acc. 1407 and Acc. 4584. Under 14.0 dS m^{-1} salt treatment, Acc. 1141 and Acc. 3801 showed the highest germination (86.67 %) ability followed by Acc. 1089, Acc. 1407, Acc. 1192 and Acc. 4584. There is no genotypes were germinated under 16.0 dS m^{-1} salt stress condition.

Seed germination (%)

From the analysis, it was revealed that, the Acc. 1141 and Acc. 3801 showed the highest seed germination ability under all salt treatments compared to other salt stresses. On the other hand, the Acc. 4584 and Acc. 1192 gave the lowest seed germination ability under 8.0 and 14.0 dS m^{-1} salt solutions including control. The lowest seed germination capacity under 10.0 and 12.0 dS m^{-1} salt treatments was found in Acc. 4584. Seeds were not germinated under 16.0 dS m^{-1} salt treatment (Table 3).

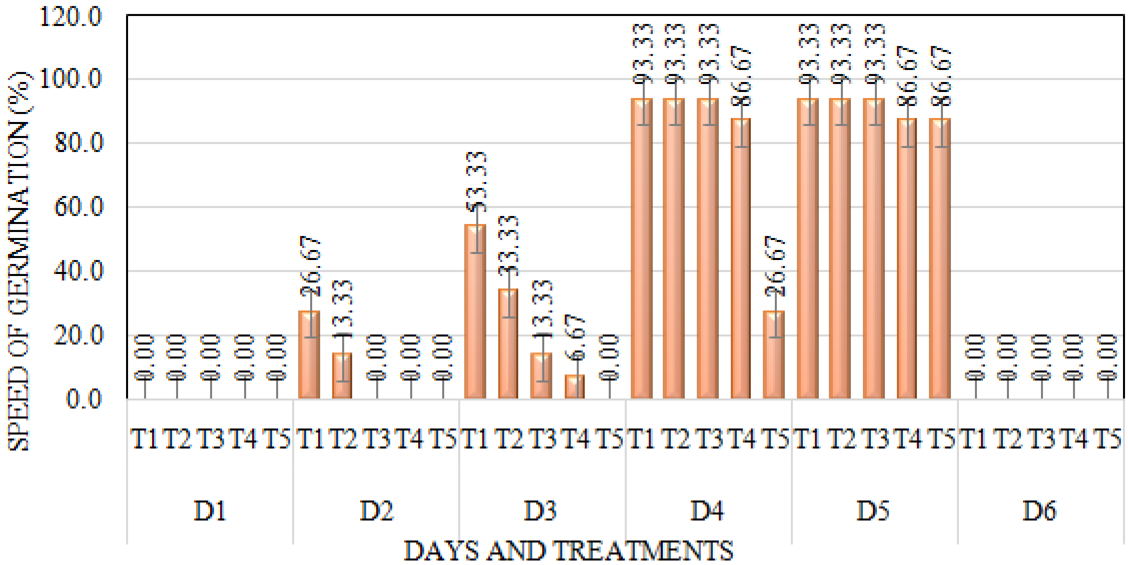

Fig. 4. Graphical view of seed germination speed of Acc. 1141 under different NaCl treatments.

Note: T_0=Control or 0.0 dS m^{-1}, T_1=8.0 dS m^{-1}, T_2=10.0 dS m^{-1}, T_3=12.0 dS m^{-1}, T_4=14.0 dS m^{-1} and T_5=16.0 dS m^{-1}

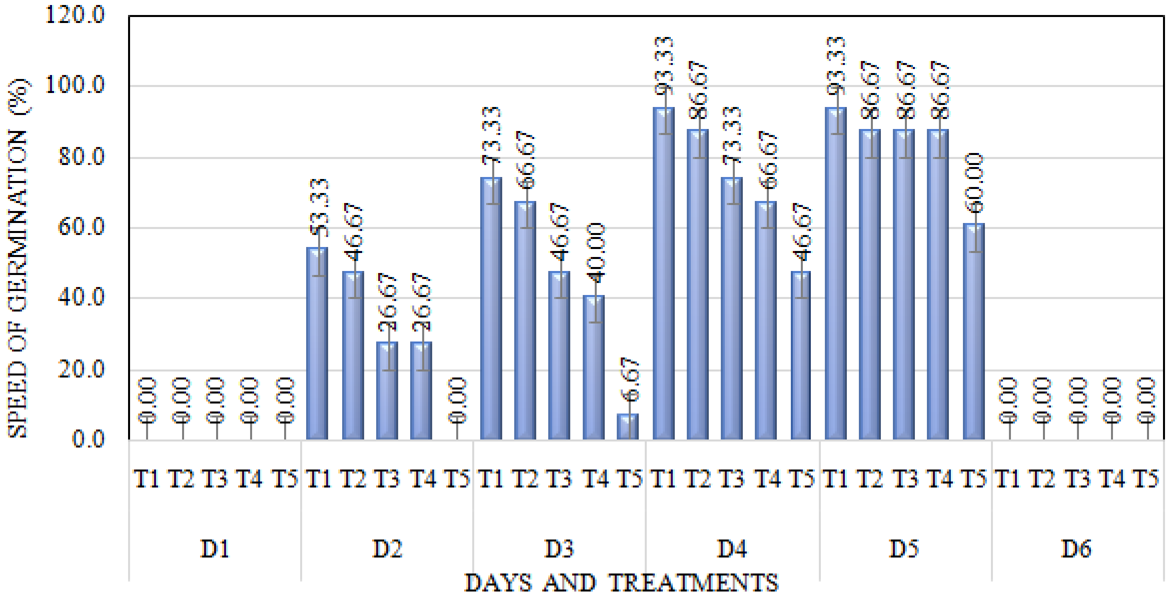

Fig. 5. Graphical view of seed germination speed of Acc. 1089 under different NaCl treatments.

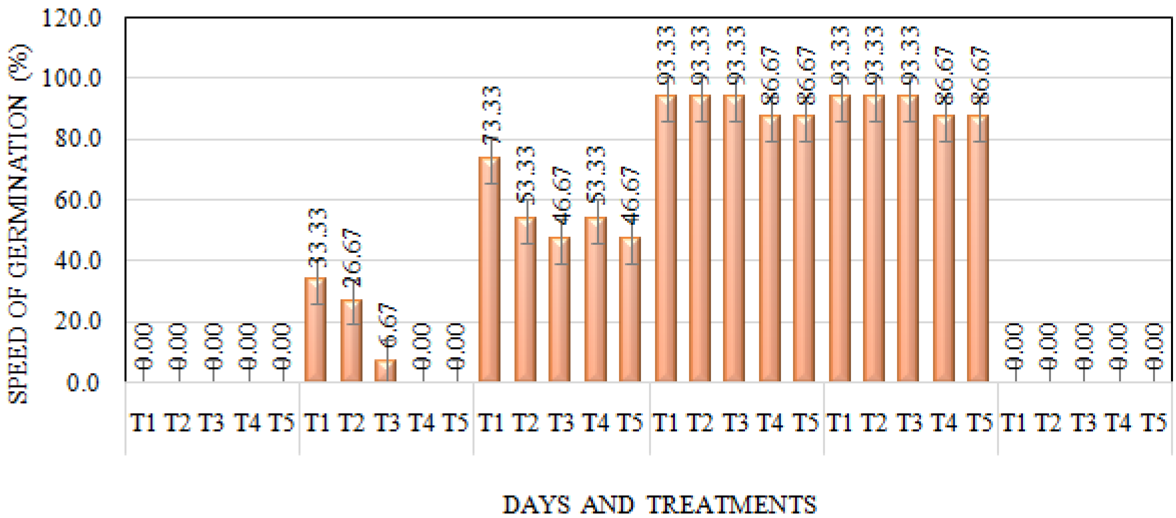

Fig. 6. Graphical view of seed germination speed of Acc. 3801 under different NaCl treatments.

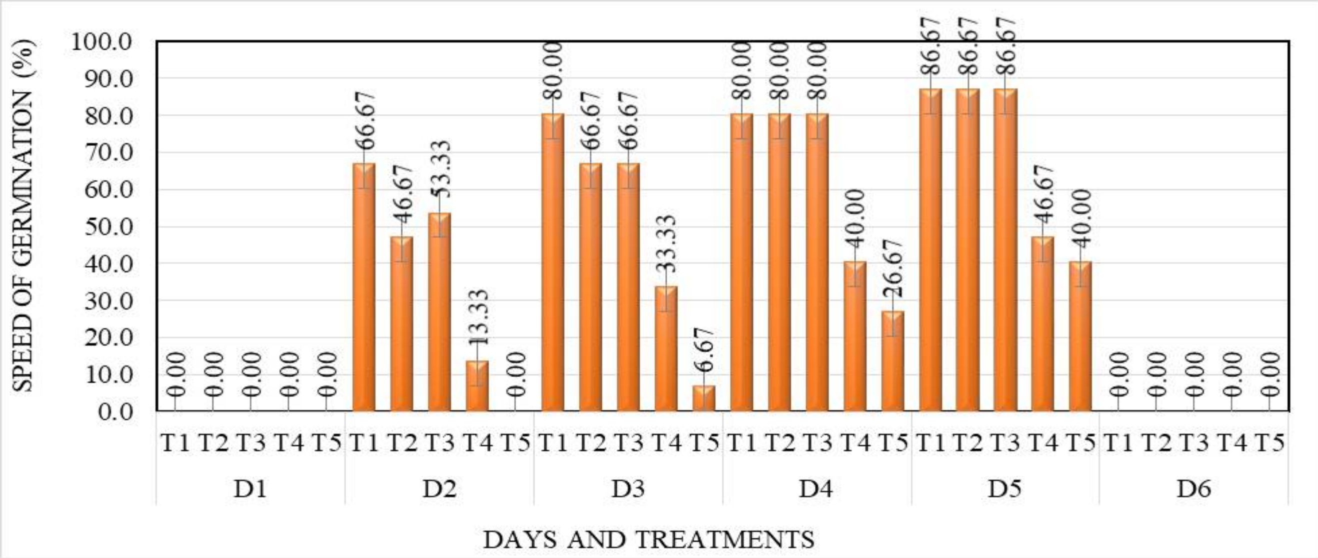

Fig. 7. Graphical view of seed germination speed of Acc. 4584 under different NaCl treatments.

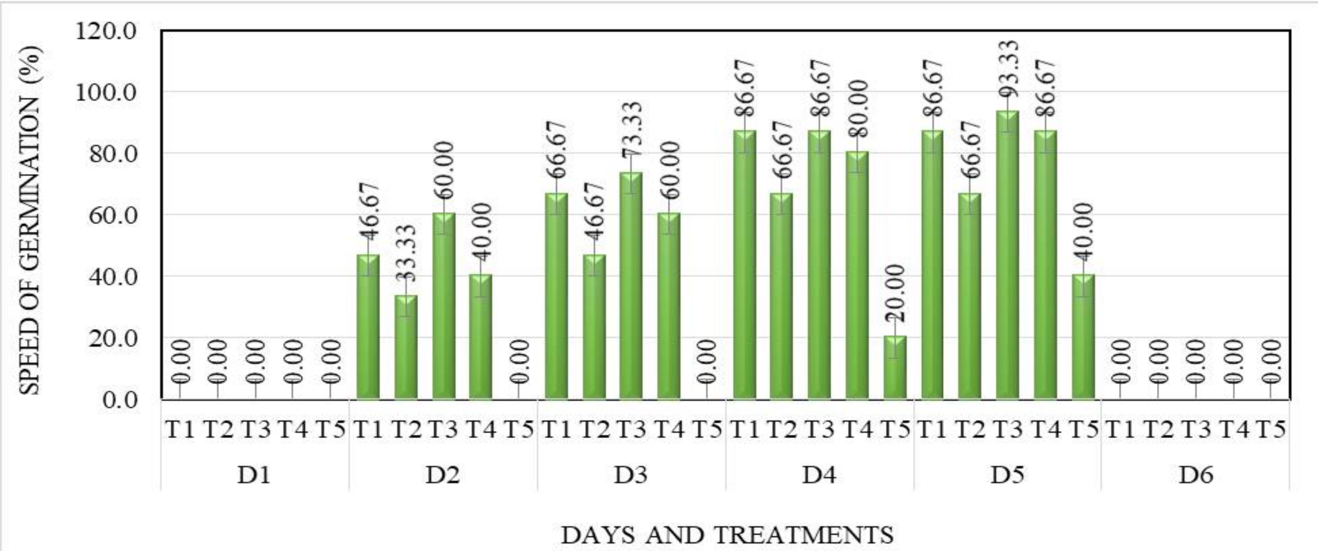

Fig. 8. Graphical view of seed germination speed of Acc. 1192 under different NaCl treatments.

Note: T_0=Control or 0.0 dS m^{-1}, T_1=8.0 dS m^{-1}, T_2=10.0 dS m^{-1}, T_3=12.0 dS m^{-1}, T_4=14.0 dS m^{-1} and T_5=16.0 dS m^{-1}

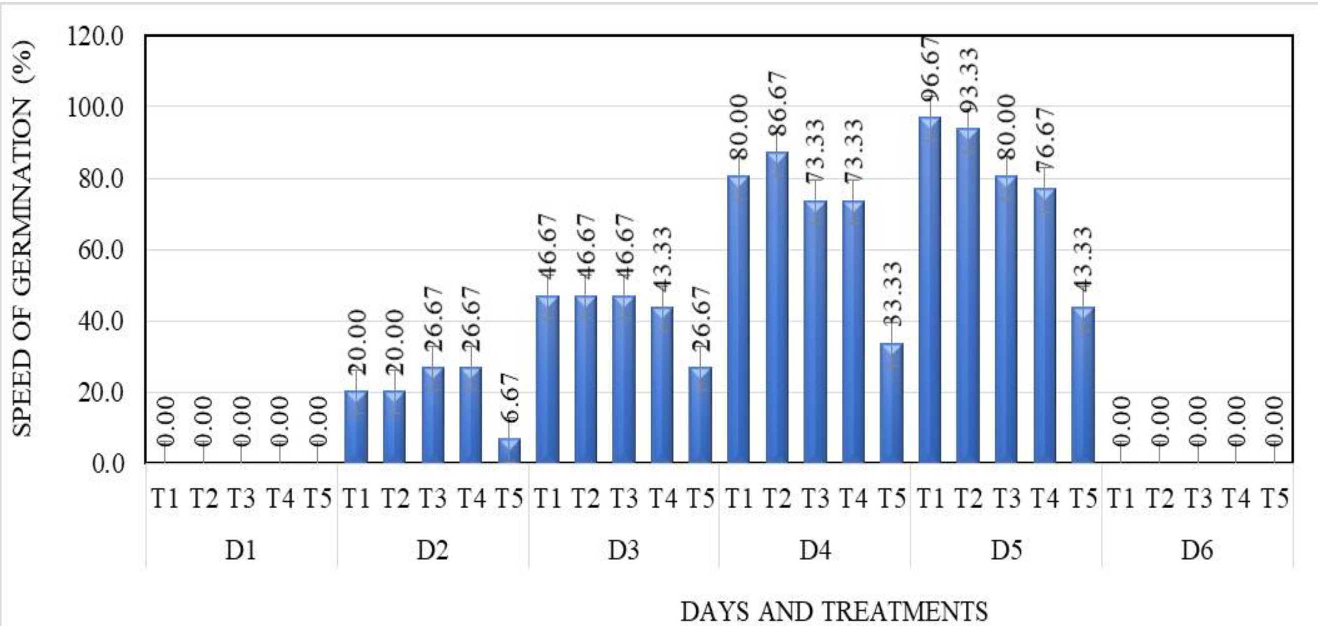

Fig. 9. Graphical view of seed germination speed of Acc. 1407 under different NaCl treatments.

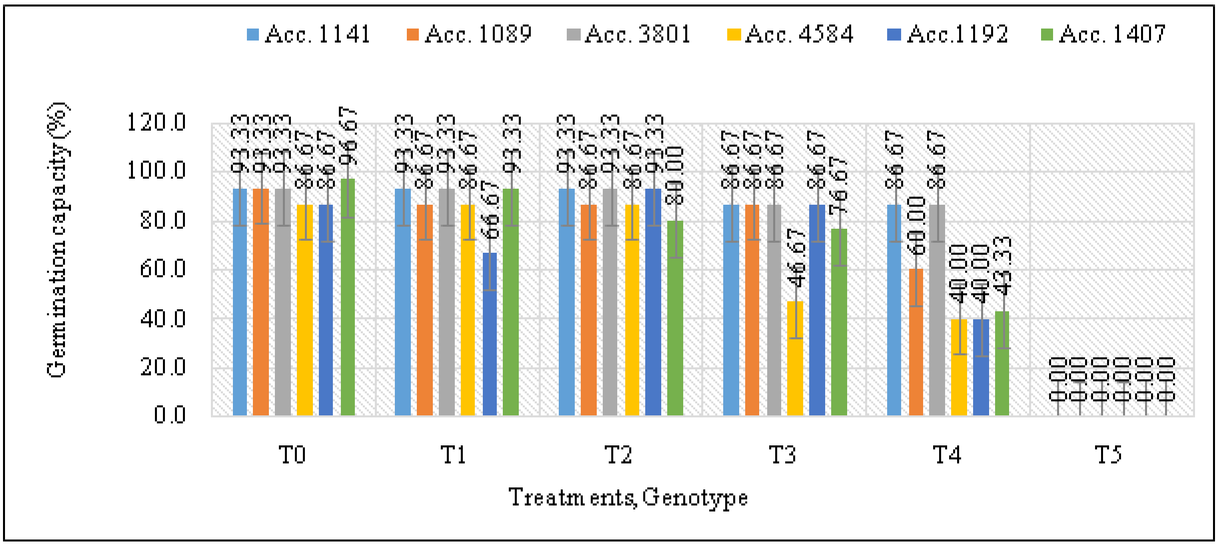

Fig. 10. Seed germination capacity of six Tossa jute genotpes under NaCl treatments up to to 16.0 dSm^{-1}

Note: T_0=Control or 0.0 dSm^{-1}, T_1=8.0 dSm^{-1}, T_2=10.0 dSm^{-1}, T_3=12.0 dSm^{-1}, T_4=14.0 dSm^{-1} and T_5=16.0 dSm^{-1}

Seed germination rate (days)

In case of seed germination rate (days), the Acc. 1141 showed the highest value under all salt treatments compared to other genotypes (Table 3). Acc. 1407 gave the highest germination rate under no salt stress but the lowest rate under 14.0 dS m^{-1} salt treatment. Acc. 4584 gave the lowest germination rate under 8.0 dS m^{-1} and no salt treatments. The lowest germination rates were recorded in Acc. 1192 under 10.0 and 12.0 dS m^{-1} salt treatments. Under the salt dose (16.0 dS m^{-1}), no seed germination rate was recorded.

Root length of the seedlings

Effects of salt treatments on the root length of all genotypes were observed carefully. At 3rd day of seed germination, maximum root lengths were recorded in Acc. 3801 under 0.0, 8.0, 10.0 and 14.0 dS m^{-1} salt treatments; and in Acc. 1089 under 12.0 dS m^{-1} salt treatment (Table 4). At 4th day of seed germination, maximum root lengths were recorded in Acc. 1407 under 0.0 and 8.0 dS m^{-1}; in Acc. 3801 (Fig. 11 a-e) and Acc. 4584 under 10.0 dS m^{-1}; in Acc. 1192 under 12.0 dSm^{-1}; and in Acc. 3801 under 14.0 dS m^{-1} salt solutions (Fig. 11 a-e; Table 4). At 5th day of seed germination, maximum root lengths were recorded in Acc. 1407 under 0.0 dS m^{-1}; in Acc. 1192 under 8.0, 10.0 and 12.0 dS m^{-1}; in Acc. 1089 under 14.0 dS m^{-1}

Table 3. Effects of NaCl treatments on seed germination capacity of six Tossa jute genotypes.

Genotypes	Germination (%)						Germination rate (days)					
	NaCl (dS m^{-1})						NaCl (dS m^{-1})					
	T_0	T_1	T_2	T_3	T_4	T_5	T_0	T_1	T_2	T_3	T_4	T_5
Acc. 1141	93.33	93.33	93.33	86.67	86.67	0.00	3.96	4.15	4.41	4.45	4.77	0.00
Acc. 1089	93.33	86.67	86.67	86.67	60.00	0.00	3.73	3.75	3.95	3.97	4.53	0.00
Acc. 3801	93.33	93.33	93.33	86.67	86.67	0.00	3.84	3.94	4.15	4.15	4.18	0.00
Acc. 4584	86.67	86.67	86.67	46.67	40.00	0.00	3.60	3.74	3.70	3.92	4.65	0.00
Acc.1192	86.67	66.67	93.33	86.67	40.00	0.00	3.75	3.79	3.68	3.83	4.64	0.00
Acc. 1407	96.67	93.33	80.00	76.67	43.33	0.00	4.04	4.03	3.92	3.95	4.03	0.00
	S.E.m = (± 9.77) CV (%)= 17.72 LSD (P=0.05)=19.48*						S.E.m = (± 0.12) CV (%)= 4.34 LSD (P=0.05)= 0.24*					

Note: T_0=Control or 0.0 dS m^{-1}, T_1=8.0 dS m^{-1}, T_2=10.0 dS m^{-1}, T_3=12.0 dS m^{-1}, T_4=14.0 dS m^{-1} and T_5=16.0 dS m^{-1}; S.E.m- Standard error mean; CV-Coefficient of variation; * Denotes statistically significant at 0.05 level of probability; LSD= Least significance difference

Table 4. Effects of NaCl treatments on root length of six Tossa jute genotypes at seedling stage.

Geno types	Root length (mm) at 3rd, 4th & 5th day of seed germination under 0.0, 8.0, 10.0, 12.0, 14.0 & 16.0 dS m^{-1} NaCl treatments																	
	3rd day						4th day						5th day					
	T_0	T_1	T_2	T_3	T_4	T_5	T_0	T_1	T_2	T_3	T_4	T_5	T_0	T_1	T_2	T_3	T_4	T_5
Acc. 1141	21.00	12.00	12.00	2.33	0.00	0.00	28.67	19.67	18.67	7.33	6.33	0.00	31.67	26.00	25.00	13.00	13.00	0.00
Acc. 1089	20.33	20.33	16.33	12.33	3.67	0.00	29.00	29.00	22.00	15.00	13.33	0.00	43.67	34.00	24.33	15.67	17.00	0.00
Acc. 3801	22.67	21.33	21.00	10.33	7.00	0.00	32.33	25.67	23.67	12.33	10.00	0.00	38.33	30.00	27.67	15.67	12.00	0.00
Acc. 4584	19.33	19.33	14.00	6.00	2.33	0.00	30.67	27.67	23.67	10.67	6.00	0.00	43.67	37.33	26.67	16.00	12.00	0.00
Acc.1192	9.33	8.67	8.33	8.33	0.00	0.00	22.00	20.67	21.67	20.33	3.67	0.00	39.33	34.33	31.33	34.33	6.33	0.00
Acc. 1407	21.00	20.67	14.33	6.00	4.00	0.00	33.00	29.67	16.67	10.00	6.33	0.00	44.00	31.00	21.67	13.33	10.00	0.00
	S.E.m = (± 1.96) CV (%)= 23.70 LSD (P=0.05)= 3.91*						S.E.m= (± 2.26) CV (%)= 17.33 LSD (P=0.05)= 4.51*						S.E.m = (± 2.34) CV (%)= 13.42 LSD (P=0.05)= 4.66*					

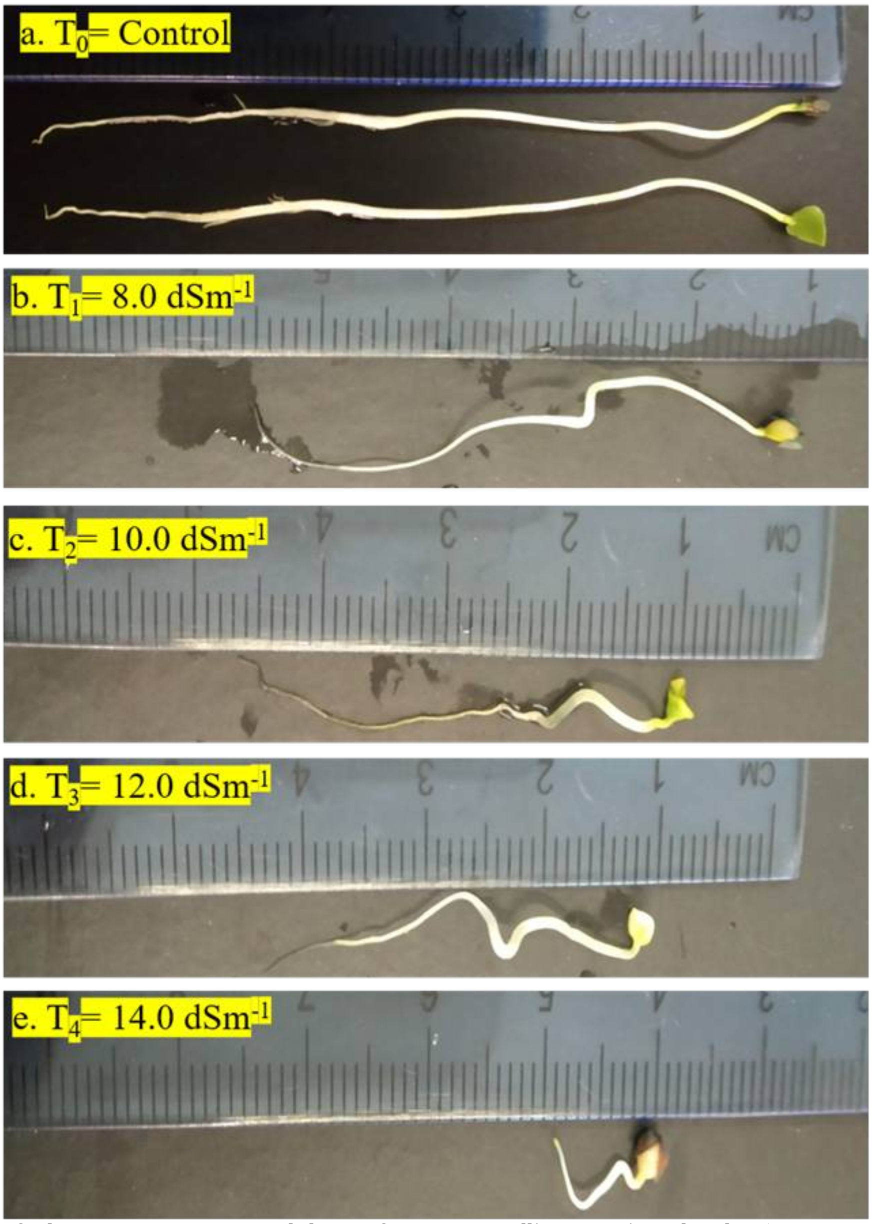

Fig. 11 (a-e). Effects of salt treatments on roots and shoots of Acc. 3801 seedlings germinated under a) T_0= Control, b) T_1= 8.0 dSm^{-1}, c) T_2= 10.0 dSm^{-1}, d) T_3= 12.0 dSm^{-1}, e) T_4= 14.0 dSm^{-1} and no seeds were germinated under T_5= 16.0 dSm^{-1} NaCl treatment.

salt solutions (Table 4). On an average, the Acc. 1089, Acc. 1141, Acc. 3801, Acc. 4584 and Acc. 1407 showed comparatively more root lengths at 14.0 dS m^{-1}.

Shoot length of the seedlings

Effects of salt treatments on the shoot length of all genotypes were observed carefully. At 3rd day of seed germination, maximum shoot lengths were recorded in Acc. 3801 under 0.0, 10.0, 12.0 and 14.0 dS m^{-1} salt treatments; and in Acc. 1089 under 8.0 dS m^{-1} salt treatment (Table 5). At 4th day of seed germination, maximum shoot lengths were recorded in Acc. 1407 under 0.0 and 8.0 dS m^{-1}; in Acc. 1192 under 10.0 and 12.0 dS m^{-1}; in Acc. 1089 under 14.0 dS m^{-1}. Comparatively, the Acc. 1141, Acc. 1089 and Acc. 3801 showed good results for shoot lengths under 14.0 dS m^{-1} salt solution (Fig. 11 a-e; Table 5). At 5th day of seed germination, the highest shoot lengths were recorded in Acc. 1192 under 0.0, 8.0, 10.0 and 12.0 dSm^{-1}; in Acc. 1089 under 14.0 dS m^{-1}. Comparatively, all genotypes showed good results for shoot lengths under all salt solution at 5th day (Table 5).

Fresh weight of the germinated seedlings

The highest value for fresh weight of 5 days old seedling under 14 dS m^{-1} salt treatment was recorded in Acc. 1089 followed by Acc. 3801, Acc. 1407, Acc. 4584, Acc. 1141 and Acc. 1192 (Table 6). The Acc. 1141 gave the lowest fresh weight under all salt treatments. The Acc. 1089 gave higher fresh weight under 8.0, 12.0 and 14.0 dS m^{-1} salinity levels. Acc. 3801 gave the highest fresh weight under 10.0 dS m^{-1} salt treatment (Table 6). No seedling was found under 16.0 dS m^{-1} salt dose.

Dry weight of the germinated seedlings

The Acc. 3801 gave the highest weight of the dried seedling under all salt treatments (Table 6). At 14.0 dS m^{-1} salt stress, both the Acc. 3801 and Acc. 1089 gave maximum dry weight. The Acc. 3801, Acc. 1192 and Acc. 1089 showed good results for dry weight under 12.0 dS m^{-1} salt treatment. Comparatively, the Acc. 3801 gave good results for dry weight under different salinity levels (Table 6). No seedlings were found under 16.0 dS m^{-1}.

Salt Tolerance Index (STI)

The Acc. 1089 gave the highest STI under 8.0 and 14.0 dS m^{-1} salt treatments. At 14.0 dS m^{-1} salt solution, Acc. 1089 showed maximum STI followed by Acc. 1141, Acc. 3801, Acc. 4584, Acc. 1192 and Acc. 1407 (Table 7). Under 12.0 dS m^{-1} salt solution, Acc. 1192 gave the highest STI followed by Acc. 1089, Acc. 1141, Acc. 1407, Acc. 4584, Acc. 3801. No STI was recorded at 16.0 dS m^{-1}. On an average, all the genotypes showed good results for STI under 12.0 dS m^{-1}; and Acc. 1141 and Acc. 1089 under 14.0 dS m^{-1} salt treatments (Table 7).

Relative salt harm rate

In respect of relative salt harm rate for seed germination under salt treatments (Table 8), Acc. 1141 and Acc. 3801 were highly tolerant to salinity up to 14.0 dS m^{-1}, and highly sensitive under 16.0 dS m^{-1}. Acc. 1089 and Acc. 1192 were highly tolerant up to 12.0 dS m^{-1} and sensitive under 16.0 dS m^{-1}; Acc. 1089 was tolerant and Acc. 1192 was middle tolerant under 14.0 dS m^{-1} salt solution. In this study, both the Acc. 1407 and Acc. 4584 were highly salt tolerant up to 10.0 dS m^{-1}, and sensitive to highly sensitive for salinity under 14.0 and 16.0 dS m^{-1} salt treatments, respectively. Acc. 1407 was tolerant and Acc. 4584 was middle tolerant to salinity under 12.0 dS m^{-1}. Both the Acc. 1141 and Acc. 3801 were considered as good genotypes in respect of seed germination under 14.0 dS m^{-1} salt stress (Table 8).

Table 5. Effects of NaCl treatments on shoot length of six tossa jute genotypes at seedling stage.

Geno types	Shoot length (mm) at 3rd, 4th & 5th day of seed germination under 0.0, 8.0, 10.0, 12.0, 14.0 & 16.0 dS m^{-1} NaCl treatments																	
	3rd day						4th day						5th day					
	T_0	T_1	T_2	T_3	T_4	T_5	T_0	T_1	T_2	T_3	T_4	T_5	T_0	T_1	T_2	T_3	T_4	T_5
Acc. 1141	13.67	5.33	5.00	1.33	0.00	0.00	19.00	10.33	8.33	7.33	7.00	0.00	23.00	15.33	10.33	9.00	8.00	0.00
Acc. 1089	16.00	15.67	7.00	9.00	2.33	0.00	20.00	16.67	13.00	10.00	9.67	0.00	22.00	17.67	16.00	12.00	10.00	0.00
Acc. 3801	20.00	14.67	13.00	9.00	5.00	0.00	20.67	15.67	14.67	10.00	7.67	0.00	21.00	20.00	16.67	13.33	8.00	0.00
Acc. 4584	14.33	11.00	10.33	4.00	2.00	0.00	19.33	14.00	12.33	6.33	4.33	0.00	19.67	21.00	14.33	11.00	8.33	0.00
Acc.1192	9.33	7.00	6.00	4.67	0.00	0.00	12.67	16.33	17.33	15.33	4.67	0.00	26.67	21.00	19.00	18.67	8.00	0.00
Acc. 1407	19.67	15.67	10.00	4.67	4.00	0.00	22.33	18.33	13.00	8.00	5.33	0.00	23.67	20.67	15.00	12.33	8.67	0.00
	S.E.m = (± 2.06) CV (%)= 34.90 LSD (P=0.05)= 4.10*						S.E.m = (± 1.82) CV (%)= 21.09 LSD (P=0.05)= 3.62*						S.E.m = (± 1.83) CV (%)= 17.14 LSD (P=0.05)= 3.65*					

Table 6. Effects of NaCl treatments on fresh weight and dry weight at seedling stage.

Genotypes	Fresh weight (mg)						Dry weight (mg)					
	NaCl (dS m^{-1})						NaCl (dS m^{-1})					
	T_0	T_1	T_2	T_3	T_4	T_5	T_0	T_1	T_2	T_3	T_4	T_5
Acc. 1141	40.00	38.33	28.67	26.67	21.33	0.00	7.67	6.50	5.50	3.00	2.13	0.00
Acc. 1089	73.00	72.23	57.33	52.47	43.93	0.00	7.50	7.00	6.50	6.21	5.23	0.00
Acc. 3801	78.67	66.33	65.00	43.33	36.00	0.00	8.37	8.10	7.20	6.87	6.37	0.00
Acc. 4584	56.40	46.03	43.43	34.37	22.53	0.00	7.33	5.73	4.77	2.97	2.60	0.00
Acc.1192	65.90	56.93	50.17	47.83	21.00	0.00	8.87	7.57	6.77	6.57	1.23	0.00
Acc. 1407	71.33	65.67	61.67	44.67	22.67	0.00	7.07	6.13	5.40	4.30	1.63	0.00
	S.E.m ± 5.53 CV (%)= 16.78 LSD (P=0.05)= 11.03*						S.E.m ± 0.92 CV (%)= 23.54 LSD (P=0.05)= 1.84*					

B. Field Experiment

ANOVA (mean square values) for morphological characters

Analyses of variances revealed highly significant (**, P≤0.01) differences among the selected Tossa jute accessions for the mean square values of plant height, base diameter, total diameter, leaf length, leaf width, leaf length breadth ratio, leaf area, petiole length, node number, intermodal length, days to flowering, 1000 seed weight, dry stick weight, dry fiber weight, plant mortality rate (Table 9).

Mean performance of the genotypes

The analyses results for the mean performances of all accessions (Table 10) showed the highest plant height (3.53 m) was observed in Acc. 1089 followed by Acc. 3801; while the shortest plant was found in Acc. 1141 (3.11 m) followed by Acc. 4584. The highest value was found for stem base diameter (19.78 mm) in Acc. 1407; leaf length breadth ratio (2.66) in Acc. 4584; leaf area (62.63 cm^2) in Acc. 1192; highest inter-nodal length (5.48 cm) in Acc. 1089; days to flowering (141.67 days) in Acc. 1407; 1000 seed weight (1.92 gm) in Acc. 4584; dry fiber weight (22.60 gm p^{-1}) and germination rate (86.22 %) in Acc. 3801 and Acc. 1141 under 14 dS m^{-1} salinity level (Fig. 4, 6, 10; Table 10).

Euclidean Cluster Analysis based on morphological traits

Clustering was done using all variables. The six Tossa jute genotypes were grouped into three major clusters at the genetic distance of 48.0 in cluster

Table 7. Effects of NaCl treatments on six tossa jute genotypes for salt tolerance index at seed germination stage.

Genotypes	Salt tolerance index-STI (%)					
	NaCl (dS m^{-1})					
	T_0	T_1	T_2	T_3	T_4	T_5
Acc. 1141	100.00	95.83	76.17	62.78	52.22	0.00
Acc. 1089	100.00	97.95	76.92	71.32	60.69	0.00
Acc. 3801	100.00	84.43	82.68	55.04	45.83	0.00
Acc. 4584	100.00	81.67	77.70	61.16	39.68	0.00
Acc.1192	100.00	87.33	75.47	73.67	32.18	0.00
Acc. 1407	100.00	92.27	86.81	62.65	31.99	0.00
	S.E.m ± 9.02 CV (%)= 17.57 LSD (P=0.05)= 17.99*					

Table 8. Relative salt harm rate and salt tolerance grade at seed germination stage.

Genotypes	NaCl (dS m^{-1})	RSHR (%)	Grade	Genotypes	NaCl (dS m^{-1})	RSHR (%)	Grade
Acc. 1141	T_0=Control	0.00	1	Acc. 4584	T_0=Control	0.00	1
	T_1=8.0	0.00	1		T_1=8.0	0.00	1
	T_2=10.0	0.00	1		T_2=10.0	0.00	1
	T_3=12.0	7.14	1		T_3=12.0	46.15	3
	T_4=14.0	7.14	1		T_4=14.0	53.85	3
	T_5=16.0	100.0	5		T_5=16.0	100.0	5
Acc. 1089	T_0=Control	0.00	1	Acc.1192	T_0=Control	0.00	1
	T_1=8.0	7.14	1		T_1=8.0	20.00	1
	T_2=10.0	7.14	1		T_2=10.0	-7.69	1
	T_3=12.0	7.14	1		T_3=12.0	0.00	1
	T_4=14.0	35.71	2		T_4=14.0	53.85	3
	T_5=16.0	100.0	5		T_5=16.0	100.0	5
Acc. 3801	T_0=Control	0.00	1	Acc. 1407	T_0=Control	0.00	1
	T_1=8.0	0.00	1		T_1=8.0	3.45	1
	T_2=10.0	0.00	1		T_2=10.0	17.24	1
	T_3=12.0	7.14	1		T_3=12.0	20.69	2
	T_4=14.0	7.14	1		T_4=14.0	55.17	3
	T_5=16.0	100.0	5		T_5=16.0	100.0	5

Dendrogram indicating the notable genetic divergence among all genotypes for their morphological traits (Fig. 12). The jute genotypes having similar morphological characters were laid in the same cluster. Each of the cluster consists of two accessions. The genotypes Acc. 3801, Acc. 1141 were included in cluster I; Acc. 1089 and Acc. 1407 in cluster II; and Acc. 4584 and Acc. 1192 in cluster III. In this investigation, the accessions of cluster II and I were good for all desirable characters; and genotypes of cluster III were also good performer for days to flowering, leaf area, leaf length breadth ratio, petiole length and except the other traits (Fig. 12). The genotypes Acc. 3801, Acc. 1141, Acc. 1089, Acc. 1407 were good for their studied morphological desired characters.

Cluster mean values for studied morphological characters

The mean values of three different clusters for different morphological traits of six Tossa jute genotypes were estimated (Table 11) where, the cluster II recorded the highest mean values for plant height, base diameter, leaf length, leaf width, leaf area, intermodal length, days to flowering, dry seed weight, dry fiber weight and rate of plant survivability. These characters are important and contribute to jute fiber yield. The genotypes of cluster II and I were good for fiber yield and yield attributing characters.

Cluster distances (D^2)

Analyses of Euclidean cluster distances (Fig. 13) revealed that the higher inter-cluster distance (50.64) was recorded between cluster I and III; while minimum distance (33.03) was between cluster II and III. The intra cluster distances 10.57, 14.62 and 16.46 were recorded for cluster I, II and III respectively.

Discussion

A researcher (9) reported in earlier that, the increase in *NaCl* concentrations prolonged the lag time before the jute seed germination and the germination rate was delayed (47) (Fig. 2; P<0.05). From one to four days, lag time was prolonged mostly for the 12.0 dS m^{-1}, 14.0 dS m^{-1} and 16.0 dS m^{-1} salt treatments compared to other salt doses in five jute accessions except Acc. 4584. The delay of seed germination prolonged with increasing salt stresses (9). However, the germination rate (44) was delayed for three days for the treatments within 0.0 dS m^{-1} and 12.0 dS m^{-1} to five days for 14.0 dS m^{-1}. Above 14.0 dS m^{-1} salt concentration, the germination rate was 0.0 %. Tossa jute seeds were germinated in controls followed by 8.0, 10.0, 12.0 and 14.0 dS m^{-1} salt stress condition; and no seeds were emerged in 16 dS m^{-1} salinity level. The highest seed germination (96.67 %) was recorded in Acc. 1407 followed by Acc. 1141, Acc. 1089, Acc. 3801, Acc. 4584 under no salt stress condition. Similar results were also described (46).

Table 9. Analysis of variance (ANOVA) for studied 15 variables (Mean square values).

S.V.	d.f.	PH (m)	BD (mm)	TD (mm)	LL (cm)	LW (cm)	LBR	LA (cm^2)
Replication	2	0.015	0.018	0.001	0.011	0.004	0.007	1.941
Genotype	5	0.103**	7.079**	0.491**	5.658**	1.188**	0.016**	318.32**
Error	10	0.002	0.006	0.004	0.001	0.005	0.001	0.032
Total	17							

Table 9. Continued.

S.V.	d.f.	PTL (mm)	NN	INL (cm)	DF (Days)	TSW (g)	DSW (g p^{-1})	DFW (g p^{-1})	MR (%)
Replication	2	4.155	0.134	0.012	6.500	0.000	0.212	0.387	2.343
Genotype	5	33.27**	323.39**	0.80**	509.97**	0.048**	87.98**	2.93**	911.97**
Error	10	3.132	0.187	0.110	12.767	0.001	1.014	0.281	3.088
Total	17								

Note: S.V.= Sources of variation, d.f.= Degree of freedom, PH= Plant height, BD= Stem base diameter, TD= Total diameter, LL= Leaf length, LW= Leaf width, LBR= Length breadth ratio, LA= Leaf area, PTL= Patiole length, NN= Number node, INL=Inter-nodal length, DF= Days to flowering, TSW= Weight of thousand seeds, DSW= Dry jute stick weight, DFW= Dry jute fiber weight, MR= Mortality rate of jute plants; ** denote statistically significant at 0.01 probability level

Table 10. Performance of six Tossa Jute genotypes for studied 15 morphological traits.

SL. No.	Accession	PH (m)	BD (mm)	TD (mm)	LL (cm)	LW (cm)	LBR	LA (cm^2)
1	Acc. 1141	3.11c	15.16e	4.06c	13.75c	5.55b	2.51bc	50.44c
2	Acc. 1089	3.53a	17.22b	3.95c	13.34d	5.12c	2.63a	45.30d
3	Acc. 3801	3.48ab	16.41d	4.85a	12.69e	5.06c	2.54b	42.60e
4	Acc. 4584	3.16c	16.89c	4.62b	12.25f	4.60d	2.66a	37.41f
5	Acc. 1192	3.43b	16.49d	4.92a	15.67a	6.13a	2.56b	62.63a
6	Acc. 1407	3.50ab	19.78a	4.61b	15.25b	6.18a	2.47c	61.65b
CV (%)		1.45	0.45	1.37	0.25	1.35	1.19	0.36
Mean ± SE		3.37 ±0.04	16.99 ±0.06	4.50 ±0.05	13.82 ±0.03	5.44 ±0.06	2.56 ±0.03	50.00 ±0.15
LSD $_{(0.05)}$		0.09	0.14	0.11	0.06	0.13	0.06	0.33

Table 10. Continued.

SL. No.	Accession	PTL (mm)	NN	INL (cm)	DF (Days)	TSW (g)	DSW (g p^{-1})	DFW (g p^{-1})	Germination (%)
1	Acc. 1141	61.53a	63.87e	4.92ab	126.00b	1.91a	41.24d	19.60c	86.22a
2	Acc. 1089	57.33b	65.87d	5.48a	125.67b	1.76c	57.00a	21.33b	60.00b
3	Acc. 3801	55.33b	80.00b	4.39bc	123.33bc	1.67d	49.41c	22.60a	86.22a
4	Acc. 4584	63.47a	87.07a	4.07c	119.00c	1.92a	49.97c	21.48b	50.02c
5	Acc. 1192	61.60a	76.93c	4.30c	101.33d	1.84b	53.87b	21.77ab	50.03c
6	Acc. 1407	56.43b	61.00f	4.40bc	141.67a	1.61e	53.00b	21.87b	52.78c
CV (%)		2.99	0.60	7.23	2.91	1.37	1.98	2.49	2.74
Mean ± SE		59.28 ±1.45	72.46 ±0.35	4.59 ±0.27	122.83 ±2.92	1.79 ±0.02	50.75 ±0.82	21.31 ±0.43	64.21 ±1.43
LSD $_{(0.05)}$		3.22	0.79	0.60	6.50	0.04	1.83	0.96	3.20

Finally, among all the genotypes, the Acc. 1141 and Acc. 3801 showed the highest germination ability under all salt treatments viz. 8.0, 10.0, 12.0, 14.0, 16.0 dS m^{-1}. Similar results were described (9). The Acc. 4584 gave the lowest seed germination capacity under 10.0 and 12.0 dS m^{-1} salt treatments. There is no seed germination occur under 16.0 dS m^{-1} salt treatment. A significant differences for the seed germination (%) under salt treatments were found among the genotypes and salt treatments (9).

The Acc. 1141 would be considered a good genotype regarding seed germination rate (days). No seed germination rate was recorded under 16.0 dS m^{-1} salt treatment. Significant differences for the seed germination rate (days) under salt treatments were found among the genotypes and salt treatments. In this investigation, the Acc. 1089, Acc. 1141, Acc. 3801, Acc. 4584 and Acc. 1407 gave relatively more root lengths at 14.0 dS m^{-1}. It was reported that significant differences were found for the root lengths among the genotypes and salt treatments (38).

All genotypes recorded good results for shoot lengths under all salt solutions at 5th day (Table 5). It was reported that for the shoot lengths, significant differences were found among the genotypes and salt treatments (38). Among six tossa jute genotypes, Acc. 3801 showed the highest fresh weight under 10.0 dS m^{-1} salt treatment. At 16.0 dS m^{-1} salt stress, no seedling was found. Significant differences for the fresh weight of the seedlings were found among the genotypes and salt treatments (38). In this experiment, Acc. 3801 showed good results for dry weight under the salt treatments. No seedlings were found under 16.0 dS m^{-1}. According to the studies (38), significant differences for the dry weight of the seedlings were found among the genotypes and salt treatments.

Acc. 1089 showed maximum salt tolerance index (STI) under 14.0 dS m^{-1} salt solution followed by Acc. 1141, Acc. 3801, Acc. 4584, Acc. 1192 and Acc. 1407. Under 12.0 dS m^{-1}, all the accessions gave good results for STI; and Acc. 1141 and Acc. 1089 under 14.0 dS m^{-1} salt treatments. Similar results revealed that

Table 11. Mean values of three clusters for 15 morphological traits of all jute genotypes.

Variables	Cluster I	Cluster II	Cluster III	Grand Centroids
PH (cm)	3.30	5.52	3.30	3.37
BD (mm)	15.79	18.50	16.69	16.99
TD (mm)	4.46	4.28	4.77	4.50
LL (cm)	13.22	14.30	13.96	13.83
LW (cm)	5.31	5.65	5.37	5.44
LBR	2.53	2.55	2.61	2.56
LA (sq.cm)	46.52	53.48	50.02	50.01
PTL (mm)	58.43	56.88	62.54	59.28
NN	71.94	63.44	82.00	72.46
INL (cm)	4.66	4.94	4.19	4.59
DF (Days)	124.67	133.67	110.17	122.83
TSW (g)	1.79	1.69	1.88	1.79
DSW (g p^{-1})	45.33	55.00	51.92	50.75
DFW (g p^{-1})	21.10	21.200	21.63	21.31
Seed germination (%) at 14.0 dS m^{-1} NaCl	86.67	51.67	40.00	59.45

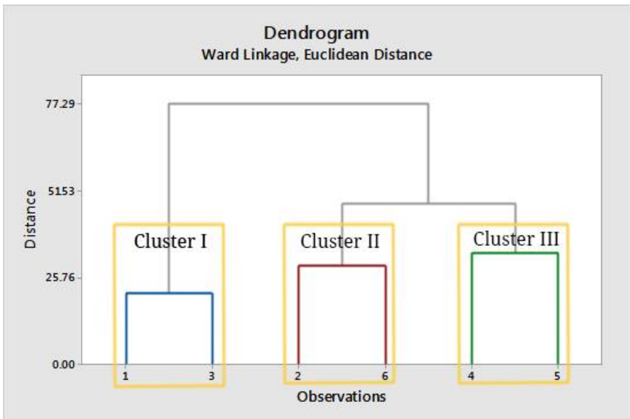

Fig. 12. Dendrogram showing the relationships among six observations of Tossa Jute accession for fifteen morphological traits.

Note: Observation- 1. Acc. 1141; 2. Acc. 1089; 3. Acc. 3801; 4. Acc. 4584; 5. Acc. 1192; 6. Acc. 1407

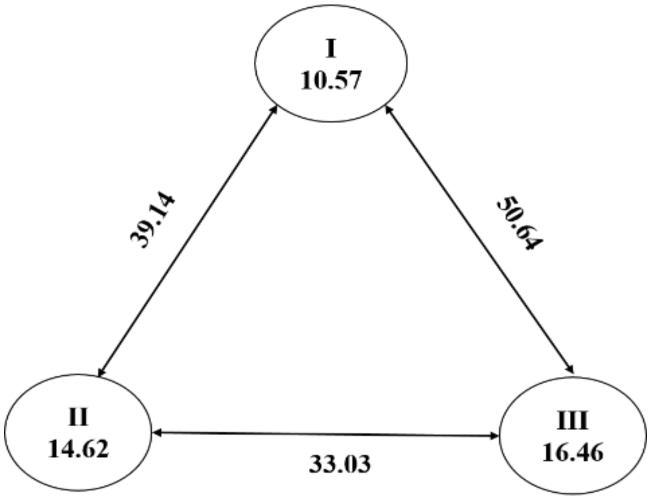

Fig. 13. Average intra and inter-cluster distances for fifteen morphological traits of six Tossa Jute genotypes.

significant differences for the salt tolerance index of the seedlings were found among the genotypes and salt treatments (38, 48).

Here, Acc. 1407 and Acc. 4584 were highly salt tolerant up to 10.0 dS m^{-1}, and sensitive to highly sensitive to 14.0 and 16.0 dS m^{-1} salinity stresses, respectively. Acc. 1407 was salt tolerant and Acc. 4584 was middle tolerant to salinity under 12.0 dS m^{-1}. On an average, both the Acc. 1141 and Acc. 3801 were good genotypes in respect of seed germination under 14.0 dS m^{-1} salinity stress. Selection of salt tolerant tossa jute genotypes based on relative salt harm rate at germination stage was also reported (9, 26).

Significant differences among the genotypes were described for morphological traits and physiological response to salinity. Similar findings were described in an earlier investigation in *C. olitorius* (10). Among all genotypes, Acc. 1089 gave the maximum plant height (3.53 m); while the shortest plant was found in Acc. 1141 (3.11 m). The highest value for stem base diameter (19.78 mm) was found in Acc. 1407; total diameter (4.92 mm) in Acc. 1192; leaf length breadth ratio (2.66) in Acc. 4584; leaf area (62.63 cm^2) in Acc. 1192; petiole length (63.47 mm) in Acc. Acc. 4584; lowest node number (61.0) in Acc. 1407; highest inter-nodal length (5.48 cm) in Acc. 1089; days to flowering (141.67 days) in Acc. 1407; 1000 seed weight (1.92 gm) in Acc. 4584; dry fiber weight (22.60 gm p^{-1}) and germination rate (86.22%) in Acc. 3801 and Acc. 1141 under 14 dS m^{-1} salinity level. In an earlier research investigation, it was described for Tossa jute morpho-anatomical character analyses (10).

The six Tossa jute genotypes were grouped into three major clusters in Euclidean Dendrogram. The jute genotypes having similar morphological characters were laid in the same cluster. The genotypes Acc. 3801, Acc. 1141, Acc. 1089 and Acc. 1407 were good for their morphological performances. Similar findings were reported in Tossa jute (10). The genotypes of cluster II gave the highest mean values for studied and desired morphological traits. These characters are important and contribute to jute fiber yield. Considering the mean values, the genotypes of cluster II and I were good for fiber yield and yield attributing characters. Similar results were described for *C. olitorius* in earlier (10). The cluster showing the higher inter-cluster distance with the other clusters depict the higher differences among the genotypes of the respective clusters. The minimum intra-cluster distance indicate the lower differences among the genotypes (47).

Conclusion

The seed germination ability of all *C. olitorius* were decreased with increasing the NaCl concentration; germination was completely inhibited at higher salt concentration (16.0 dS m^{-1} NaCl) in all genotypes. Among all the genotypes, Acc. 1141 and Acc. 3801 showed the highest germination rate (86.67%) under 14.0 dS m^{-1} salt concentration. At last or 5^{th} day of observation, Acc. 1089 recorded the higher root and shoot length under 14.0 dS m^{-1} salt solution. Salt tolerance index were observed higher in genotype Acc. 1141 and Acc. 3801 under 14.0 dS m^{-1} salt level; and while Acc. 4584 gave lower salt tolerance index. Among six Tossa Jute genotypes, Acc. 1141 and Acc. 3801 were relatively more tolerant to the salt stress; Acc. 3801, Acc. 1089 performed well for fiber yield and salt tolerance; Acc. 3801 and Acc. 1407 showed higher fiber yield compared to others. Hence, the genotypes namely Acc. 3801, Acc. 1407, Acc. 1089 and Acc. 1141 having desirable characters would be used as breeding materials to develop high yielding salt tolerant *C. olitorius* variety through hybridization approaches in Bangladesh.

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Authors' contributions

MMM carried out the investigation with the help of all co-authors. He has designed and observed the study and took data regularly; compiled, analyzed the data and reported. SSUA observed the experiment during seeding and helped in watering period. NA has provided lab facilities, seed materials and guided the experiments. MGM has helped during the planning and monitoring of experiment. MSR and FUT had helped during the observation of seedlings. MMM has drafted, edited, submitted and corrected the article; all authors read and approved the final manuscript.

Conflict of interests

Authors do not have any conflict of interests to declare.

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