ZIBELINE INTERNATIONAL™ PUBLISHING

Malaysian Journal of Sustainable Agriculture (MJSA)

DOI: http://doi.org/10.26480/mjsa.01.2024.45.52

ISSN: 2521-2931 (Print)
ISSN: 2521-293X (Online)
CODEN: MJSAEJ

CrossMark

RESEARCH ARTICLE

GERMINATION OF JUTE GENOTYPES UNDER SALINITY STRESS

K. Fatema[a*], S. S. U. Ahmed[a], M. M. Mukul[a], A. Sultana[b] and N. Akter[c]

[a]Breeding Division, Bangladesh Jute Research Institute, Ministry of Agriculture, Manik Mia Avenue, Dhaka-1207, Bangladesh.
[b]Agronomy Division, Bangladesh Jute Research Institute, Ministry of Agriculture, Manik Mia Avenue, Dhaka-1207, Bangladesh.
[c]Director (Agriculture), Bangladesh Jute Research Institute, Ministry of Agriculture, Manik Mia Avenue, Dhaka-1207, Bangladesh.
****Corresponding author E -mail: kanizbau1012@gmail.com***

ARTICLE DETAILS

Article History:

Received 15 April 2024
Revised 23 May 2024
Accepted 18 June 2024
Available online 21 June 2024

ABSTRACT

More than 20% of agricultural land around the world is suffering from salt stress which hampers plant growth and development. Jute is one of the most important fiber crops that stands second after cotton in the world. Since cultivable land in Bangladesh is decreasing day by day, jute cultivation needs to be moved to the coastal area. Therefore, the aim of our study was to investigate the response of five jute genotypes at different levels of salinity. Germination and seedling growth were focused on as the most critical stages of plant development. In this research, germination percentage (GP), germination index (GI), mean germination time (MGT), seedling vigor index (SVI), shoot & root lengths and fresh & dry seedling weight, and salinity tolerance indices were studied for two-way ANOVA and hierarchical agglomerative classification. Results showed that increasing salinity reduced GP, GI and SVI of the jute genotypes while MGT increased. Having no salt tolerant tossa jute genotype, salt tolerant white jute genotype BJRI Deshi pat 10 was grown simultaneously with four tossa jute genotypes to compare the growth parameters where results indicated that although not as tolerant as BJRI Deshi pat 10, tossa jute genotypes O-043-7-9 G and O-0512-6-2 G showed less salt sensitivity than the other two genotypes O-043-7-9 R and Acc. 4582 G.

KEYWORDS

Germination, Jute, Plant Selection, Salt stress, Seedling Vigor.

1. INTRODUCTION

Salinity is the major environmental stress that restricts agricultural productivity and sustainability in arid and semiarid regions (Foti et al., 2019). About 20% of irrigated land and 6% of world land is covered with salinity (Yang et al., 2020). Bangladesh has 710 km long coastline where 93 upazilas of 18 districts are found affected by different degrees of salinity (SRDI, 2010). Out of 2.86 million hectares of coastal and off-shore lands, about 1.056 million ha of arable lands (which is 63% of total cultivable land in the coastal region) are affected by varying degrees of salinity. A comparative study of the salt affected area between 1973 to 2009 also showed that about 0.223 million ha (26.7%) new land is affected by various degrees of salinity during the last four decades (SRDI, 2010). Moreover, about 2000 km^2 of the coastal areas of Bangladesh are likely to be inundated by the end of this century due to climate change-induced sea level rise, which will further increase the area affected by salinity deepening the salinity problem of the country (Hasan and Kumar, 2020). Since salinity and related saltwater intrusion are driven by climate-induced hazards, they adversely affect crop production in coastal zones of Bangladesh (Mazumder and Kabir, 2022).

Soil salinity is defined as the soluble salts' concentration in soil water which generally expressed by electrical conductivity (EC) of the saturation extract (ECe) and desi siemens per meter (1 dSm^{-1}) is used as its unit (Hasanuzzaman et al., 2013). When the ECe exceeds 4 dSm^{-1} and exchangeable sodium percentage is less than 15 with sodium adsorption ratio (SAR)< 13, the soil is saline (Uçarlı, 2020). The major problem with saline soils is the presence of soluble salts, primarily Cl^-, SO_4^{2-}, and sometimes NO_3^-. The pH of saline soils is usually below 8.5 (Uçarlı, 2020). USL Staff, 1954 described the type of saline soil as: non-saline soil (ECe ≤ 2 dSm^{-1}), very slightly saline soil (ECe = 2-4 dSm^{-1}), slightly saline soil (ECe = 4-8 dSm^{-1}), moderately saline soil (ECe = 8-16 dSm^{-1}) and strongly saline soil (ECe ≥ 16 dSm^{-1}).

99% of the world's flora are glycophytes which include most of the common crops e.g., rice, tomato, maize, bean, jute etc. and these are salinity sensitive or hypersensitive that are susceptible to even low levels of salinity (ECe < 4 dSm^{-1}) (Koyro et al., 2008; Flowers and Colmer, 2008). Seed germination in glycophytes is severely inhibited under salinity due to both osmotic stress and ionic toxicity stress, while halophytes (salt tolerant plants) are less affected by osmotic stress during germination (Llanes et al., 2016). In addition, high concentrations of sodium and chloride ions in the soil may be toxic to seeds (Khajeh-Hosseini et al., 2003).

Jute is a biodegradable and natural fiber with different inherent advantages like high tensile strength, low extensibility, moderate heat, fire resistance and long staple lengths which has advantages over synthetics and protects the environment as well as maintains the ecological balance (Sharna and Kamruzzaman, 2020). Jute fiber is extracted from the stem bark of an annual fiber plant namely Jute which belongs to the Malvaceae family under *Corchorus* genus. There are 100 species found in *Corchorus* genus in the world among which 40 species are available for cultivation and research purposes (Saunders, 2008.). Out of these, *Corchorous olitorius* and *C. capsularis* are the two species that are cultivated commercially in different parts of the world (Sarker et al., 2007). Jute is the second most important fiber crop in the world in terms of cultivation and usage (Saleem et al., 2019). It has been contributing to the economics of Bangladesh since a long time. With reference to agriculture wing of BBS,

Quick Response Code	Access this article online	
	Website: www.mjsa.com.my	**DOI:** 10.26480/mjsa.01.2024.45.52

Cite The Article: K. Fatema, S. S. U. Ahmed, M. M. Mukul, A. Sultana and N. Akter (2024). Germination of Jute Genotypes Under Salinity Stress. *Malaysian Journal of Sustainable Agricultures, 8(1): 45-52.*

in 2021-22, 0.72 million hectares area was cultivated for jute where 1.52 million tons jute were produced (BBS, 2022). These raw jutes are utilized for production of different materials like yarn, fabric, composites etc. According to Bangladesh Jute Mills Association (BJMA), a total of 310.06 thousand metric tons (MT) jute goods were produced during 2020-21, of which 242.492 thousand MT products were exported and 53.713 thousand MT were consumed internally. Export Bureau of Bangladesh (EPB) reported that in 2021-22, jute goods were exported to 128 countries from Bangladesh which had a total value of 1737.84 million USD (BBS, 2022).

During cultivation in field, jute faces several biotic and abiotic stresses (Mollah et al., 2021). Salinity is one of the major abiotic stresses that affects jute plant. Salt stress negatively affects jute growth and physiological parameters, which subsequently reduces yield quality (Naik et al., 2019). In Bangladesh, *C. capsularis* is somewhat tolerant to salt stress up to 8.0 dSm^{-1} (75.86 mM) in field condition (Islam et al., 2017). But there is no salt tolerant tossa jute variety developed in Bangladesh yet (Mukul et al., 2021). Although *C. olitorius* is very susceptible to stresses compared to *C. capsularis*; *C. olitorius* produces fiber with good qualities than *C. capsularis* (Ghosh, 1983; Keka, 2008; Samira, 2010). Developing jute varieties tolerant to salt stress can be useful for the coastal region. A significant proportion of agricultural land in the coastal region of Bangladesh remains unused because of salinity (Fatema et al., 2021). This fallow region can be utilized by cultivating salinity tolerant jute varieties which will increase the cropping intensity of that particular region. Seedling emergence in a saline environment provides a practical and convenient assay to investigate the extent of seed sensitivity to salt (Guo et al., 2020), that is why evaluation of jute seed germination responses to different NaCl concentrations in laboratories can be one of the common and rapid tests to identify salt tolerant jute genotypes (Bohnert et al., 1995). Therefore, an experiment was taken to study the effects of salt stress on the germination and seedling growth of some jute genotypes.

2. METHODS AND MATERIALS

In this experiment, jute seeds were grown to study their tolerance to salinity at germination and early seedling stage. To fulfill the objectives, jute seeds were germinated and data were recorded from 5 days old seedlings. Five jute genotypes were taken for this study.

2.1 Germination Experiment

Four advanced lines of tossa jute (*C. olitorius*) and one variety of white (*C. capsularis*) jute (Table 1) were used for this experiment. The experiment was conducted in laboratory condition in petri dishes following completely randomized design (CRD). Five salt treatments (control, 8, 10, 12 and 14 dSm^{-1} solutions of NaCl) were applied using three replications for each. Hundred seeds of each genotype were placed in each petri dish using double layer of Whitman No. 2 filter paper. The filter papers were moisted using different salt solutions with only water for the control treatment. Temperature and humidity were controlled in a range of 25±2 ^{0}C and 60-70 percent, respectively with a daylight of 14 hours. The petri dishes were observed for five days and watered with relevant salt solutions as and when necessary. Germination was observed for five days and germination data were recorded every day.

Table 1: Studied germplasms and their relevant information

Genotypes	Features of the genotypes	Source
O-043-7-9 G	Breeding line of tossa jute (*C. olitorius*); green stem, narrow lanceolate leaves	BJRI
O-043-7-9 R	Breeding line of tossa jute (*C. olitorius*); red stem, narrow lanceolate leaves	
O-0512-6-2 G	Breeding line of tossa jute (*C. olitorius*); green stem, lanceolate leaves	
Acc. 4582 G	Breeding line of tossa jute (*C. olitorius*); green stem, narrow lanceolate leaves	
BJRI Deshi pat 10 (BJC-12221)	Released variety of white jute (*C. capsularis*); green stem, ovate lanceolate leaves; can tolerate upto 12 dSm^{-1} salt stress (Breeding Division, 2023); used as control	

Note: BJRI-Bangladesh Jute Research Institute

2.2 Assessment of Germination

Seeds showing at least 0.5 mm of radicle through the seed coat were considered as germinated. Different germination parameters were assessed which are as follows:

1. Germination percentage (GP):

$$GP = \frac{\text{Number of normally germinated seeds}}{\text{Total number of seeds sown}} \times 100 \quad (1)$$

2. Germination index (GI):

$$GI = \sum \frac{G_t}{T_t} \quad (2)$$

where G_t is the number of seeds germinated on day t, and T_t is the number of days (Hakim *et al.,* 2010; Bijeh, 2012; Rajabi Dehnavi et al., 2020).

3. Mean germination time (MGT):

$$MGT = \frac{\sum (T_i \times N_i)}{\sum N_i} \quad (3)$$

where N_i is the number of newly germinated seeds at time T_i (Rajabi Dehnavi et al., 2020; Alvarado et al., 1987; Ruan et al., 2002).

4. Seedling vigor index (SVI):

$$SVI = \text{Mean germination percentage} \times \text{Mean seedling length} \quad (4)$$

(Rajabi Dehnavi et al., 2020; Mahender et al., 2015)

2.3 Assessment of Seedling Growth

To assess seedling growth, three seedlings were randomly selected from each petri dish at 5th day. After selection, shoot (SL) and root length (RL) were measured in centimeters (cm). Fresh and dry biomass were also assessed as seedling fresh weight (FW) and weight after drying the samples in an oven for 120 mins at 60 ^{0}C to obtain seedling dry weight (DW) and theses were measured in gram (g).

2.4 Salinity Tolerance Indices

To assess the tolerance to salinity of each genotype, stress susceptibility index (SSI) and stress tolerance index (STI) were adopted (Rajabi Dehnavi et al., 2020) using the following equations (Fischer and Maurer, 1978; Fernandez, 1992):

$$SSI = \frac{1 - \frac{Y_s}{Y_p}}{1 - \frac{\bar{Y}_s}{\bar{Y}_p}} \quad (5)$$

$$STI = \frac{Y_p \times Y_s}{(\bar{Y}_p)^2} \quad (6)$$

In both the above equations, Y_p and Y_s are the average seedling dry weight of a given genotype under non-stress and NaCl-stress conditions, respectively. $\bar{Y}_p$ and $\bar{Y}_s$ are the average seedling dry weights of all genotypes under non-stress and stress conditions, respectively.

2.5 Statistical Analysis

Overall, effects were assessed by two-way ANOVA (salinity and genotype as factors). To compare all treatments, we used analysis of variance (ANOVA), and for post-hoc comparisons, least significant difference (LSD, $p \leq 0.05$). To demonstrate similarity between genotypes, we applied hierarchical agglomerative cluster analysis with the unweighted pair group method for classification tree construction. R Software version 4.2.2, RStudio and Microsoft excel were used for calculations.

3. RESULTS

3.1 Overall Effects of Salinity and Genotypes

The main effects of genotypes were significant in all the measured parameters whereas effects of salinity were significant in all the parameters except GP and the effects of interaction between salinity and genotypes were significant in the parameters other than GP, GI and MGT (Table 2). Salinity affected germination percentage (GP), germination index (GI), seedling shoot length (SL), seedling root length (RL), seedling vigor index (SVI), seedling fresh weight (FW), seedling dry weight (DW), and mean germination time (MGT) in different jute genotypes at different salt treatments and the response to salinity was dependent on genotypes.

Table 2: Analysis of variance (mean squares) for different parameters of five jute genotypes in five salinity treatments

Traits	Sources of variation			
	S	G	S×G	Error
df	4	4	16	50
GP	342.25	1354.55***	127.56	180.69
GI	2283.3***	4493.9***	102.2	121.5
MGT	74.420***	99.753***	10.203	9.387
SL	4.2510***	2.1798***	0.2023***	0.0340
RL	12.4854***	2.3850***	0.7488***	0.1451
SVI	228416***	87307***	12392***	2283
FW	84.211***	293.692***	13.694***	1.619
DW	0.19539**	1.81887***	0.17248***	0.03776

GP = germination percentage; GI = germination index; MGT = mean germination time; SL = seedling shoot length; RL = seedling root length; SVI= seedling vigor index; FW = seedling fresh weight; DW= seedling dry weight; S = salinity; G = Jute genotypes; df = degrees of freedom; Error = within group variance

3.2 Germination Assessment

Jute genotypes showed variant results in terms of germination parameters, that is mean GP, GI, MGT and SVI in saline and non-saline conditions. Salinity did not affect the genotypes (interaction effect) significantly in case of GP, GI and MGT whereas SVI showed significant difference in different saline treatments. Salinity reduced GP, GI and SVI of the jute genotypes while MGT increased. The results showed that GP of the genotypes mostly decreased with increasing salinity, although some genotypes showed increased GP under some salt treatments compared to control. The percent reduction in GP increased with increasing salinity in Acc. 4582 G and this genotype showed the maximum reduction percentage in GP (-35.34%) followed by O-043-7-9 R (-27.82%) in 14 dSm^{-1} (Table 3). Whereas maximum percent increase was observed in O-043-7-9 G (6.85%) in 14 dSm^{-1} followed by O-0512-6-2 G (6.79%) in case of 8 dSm^{-1}. O-043-7-9 G showed decreased GP only in 10 dSm^{-1} salt treatment whereas BJRI Deshi pat 10 showed increased GP only in case of 10 dSm^{-1} salt treatment (Table 3).

Table 3: Germination parameters of five jute genotypes in five salt treatments (means)

Traits	Salt levels (dSm^{-1})									
	Genotypes	Control	8 dSm^{-1}	% Change	10 dSm^{-1}	% Change	12 dSm^{-1}	% Change	14 dSm^{-1}	% Change
GP	O-043-7-9 G	73.00^{abc}	76.00^{abc}	4.11	71.00^{abc}	-2.74	73.67^{abc}	0.92	78.00^{abc}	6.85
	O-043-7-9 R	88.67^{ab}	89.67^{ab}	1.13	84.00^{ab}	-5.27	91.00^{a}	2.63	64.00^{bc}	-27.82
	O-0512-6-2 G	73.67^{abc}	78.67^{abc}	6.79	75.33^{abc}	2.25	75.00^{abc}	1.81	70.33^{abc}	-4.53
	Acc. 4582 G	83.00^{ab}	81.33^{ab}	-2.01	78.33^{abc}	-5.63	74.00^{abc}	-10.84	53.67^{c}	-35.34
	BJRI Deshi pat 10	96.33^{a}	95.67^{a}	-0.69	97.00^{a}	0.70	95.67^{a}	-0.69	95.00^{a}	-1.38
GI	O-043-7-9 G	56.58^{c-g}	41.73^{f-i}	-26.24	40.38^{f-i}	-28.63	37.11^{ghi}	-34.42	35.60^{ghi}	-37.08
	O-043-7-9 R	81.58^{ab}	68.18^{b-e}	-16.43	58.64^{c-f}	-28.12	60.51^{c-f}	-25.83	31.56^{hi}	-61.32
	O-0512-6-2 G	50.33^{e-h}	45.14^{f-i}	-10.31	33.09^{hi}	-34.26	31.28^{hi}	-37.85	27.18^{i}	-45.99
	Acc. 4582 G	71.53^{bcd}	51.73^{d-h}	-27.67	42.81^{f-i}	-40.15	41.89^{f-i}	-41.43	24.92^{i}	-65.17
	BJRI Deshi pat 10	95.06^{a}	81.28^{ab}	-14.49	82.97^{ab}	-12.71	75.49^{abc}	-20.58	67.07^{b-e}	-29.44
MGT	O-043-7-9 G	7.33^{cde}	13.67^{ab}	86.36	10.33^{a-d}	40.91	15.00^{a}	104.55	12.67^{abc}	72.73
	O-043-7-9 R	6.33^{de}	7.67^{cde}	21.05	6.33^{de}	0.00	10.33^{a-d}	63.16	6.67^{cde}	5.26
	O-0512-6-2 G	7.33^{cde}	12.00^{abcd}	63.64	15.00^{a}	104.55	14.67^{a}	100.00	14.00^{a}	90.91
	Acc. 4582 G	6.33^{de}	10.33^{abcd}	63.16	9.00^{a-e}	42.11	10.67^{a-d}	68.42	11.67^{a-d}	84.21
	BJRI Deshi pat 10	3.33^{e}	4.00^{e}	20.00	6.33^{de}	90.00	8.00^{bcde}	140.00	12.00^{a-d}	260.00
SVI	O-043-7-9 G	309.07^{efg}	160.87^{hij}	-47.95	243.89^{fgh}	-21.09	173.04^{hij}	-44.01	131.56^{ij}	-57.43
	O-043-7-9 R	404.74^{bcd}	358.48^{cde}	-11.43	224.00^{gh}	-44.66	251.04^{fgh}	-37.97	31.77^{kl}	-92.15
	O-0512-6-2 G	406.78^{bcd}	322.33^{def}	-20.76	234.36^{gh}	-42.39	162.88^{hij}	-59.96	111.18^{jk}	-72.67
	Acc. 4582 G	355.29^{cde}	231.54^{gh}	-34.83	211.13^{hi}	-40.57	96.67^{jk}	-72.79	4.29^{l}	-98.79
	BJRI Deshi pat 10	617.60^{a}	466.04^{b}	-24.54	416.91^{bc}	-32.49	162.43^{hij}	-73.70	223.69^{gh}	-63.78

Note: GP = germination percentage; GI = germination index; MGT = mean germination time; SVI= seedling vigor index. Values within a group in a row bearing different superscripts are significantly different at $p \leq 0.05$.

Mean GI, on the other hand, decreased under all salt treatments. Maximum decrease percentage in GI for all the genotypes was observed in 14 dSm^{-1} salt treatment and the maximum reduction was observed in Acc. 4582 G (-65.17%) followed by O-043-7-9 R (-61.32%). Decrease percentage also increased gradually with increasing salinity except for O-043-7-9 R (in 12 dSm^{-1}) and BJRI Deshi pat 10 (in 10 dSm^{-1}) where GI was slightly higher than 10 dSm^{-1} and 8 dSm^{-1} salt treatments, respectively (Table 3).

MGT also increased in all salt treatments. Percent increase in MGT ranged from 0-260% with 0% increase found in O-043-7-9 R (in 10 dSm^{-1}) and 260% in BJRI Deshi pat 10 (in 14 dSm^{-1}). In 8 dSm^{-1} salinity, maximum increase in MGT was recorded in O-043-7-9 G (86.36%) followed by O-0512-6-2 G (63.64%) and Acc. 4582 G (63.16%). In 10 dSm^{-1}, maximum increase was found in O-0512-6-2 G (104.55%) and BJRI Deshi pat 10 showed maximum increase in 12 dSm^{-1} (140%) and 14 dSm^{-1} (260%) salt treatments (Table 3).

Regarding vitality of seedlings assessed as the seedling vigor index, salinity significantly reduced SVI of all jute genotypes. The highest decrease was observed in genotype Acc. 4582 G (-98.79%) followed by O-043-7-9 R (-92.15%) in case of 14 dSm^{-1} and the lowest decreases were obtained in genotype O-043-7-9 R (-11.43%) followed by O-0512-6-2 G (-20.76%) in 8 dSm^{-1} salinity (Table 3).

3.3 Seedling Growth Assessment

Salinity significantly reduced SL of the investigated tossa jute genotypes (Table 4). In case of SL, BJRI Deshi pat 10 had the maximum mean results in all the salt doses compared to other genotypes (Figure 1). The highest decrease in SL was observed in 14 dSm^{-1} treatment in Acc. 4582 G (-100%) followed by O-043-7-9 R (-75%) and O-0512-6-2 G (-73.63%). In 12 dSm^{-1}, maximum decrease was in O-0512-6-2 G (-72.53%) followed by Acc. 4582 G (-65.98%). In 10 and 8 dSm^{-1} treatments, highest decrease was observed in O-0512-6-2 G (-48.35%) and O-043-7-9 G (-49.71%), respectively. Some genotypes showed lower decrease of SL in higher salt treatments. For example, O-043-7-9 G had 34.68% reduction at 10 dSm^{-1} whereas at 8 dSm^{-1} it showed 49.71% reduction. Similarly, BJRI Deshi pat 10 showed maximum SL in 10 dSm^{-1} (2.15% increase) compared to control and 8 dSm^{-1} treatment (0.43% reduction). In all the treatments, lowest decrease was recorded in BJRI Deshi pat 10 (Table 4).

Similarly, salinity significantly affected all the other assessed seedling parameters. Mean performance of the jute genotypes for RL varied in different treatments. Although BJRI Deshi pat 10 had the highest mean RL in control, this varied greatly under the salt treatments (Figure 1). The highest decrease (-96.14%) in RL was observed in the genotype Acc. 4582 G at 14 dSm^{-1} followed by O-043-7-9 R (-93.71%). O-0512-6-2G and Acc. 4582 G showed gradual increase in decrease percentage with the rise of salinity. O-043-7-9 G showed higher decrease at 8 dSm^{-1} (-50.00%) compared to 10 dSm^{-1} (-6.05%) and 12 dSm^{-1} (-33.87%). O-043-7-9 R showed higher decrease at 10 dSm^{-1} (-49.67%) compared to 12 dSm^{-1} (-40.73%) and BJRI Deshi pat 10 showed maximum decrease at 12 dSm^{-1} (-85.29%) compared to other treatments (Table 4).

In case of fresh weight (FW), best performance was recorded in BJRI Deshi pat 10 which had mean FW almost twice the values of other genotypes for all the treatments (Figure 1). Maximum decrease (-59.33%) was observed in O-0512-6-2 G at 14 dSm^{-1}. But O-043-7-9 R showed increase in FW at 8 dSm^{-1} (24.45%) and 10 dSm^{-1} (26.66%) where O-043-7-9 G showed maximum decrease (-20.75%) at 10 dSm^{-1} and BJRI Deshi pat 10 had maximum decrease (-49.88%) at 12 dSm^{-1}. While Acc. 4582 G had minimum decrease in FW at 10 dSm^{-1} (-1.53%) (Table 4).

BJRI Deshi pat 10 had highest DW in all the treatments followed by Acc. 4582 G at 10 and 14 dSm^{-1} (Figure 1). In this case though most of the genotypes showed an increase compared to control. Among the genotypes, O-0512-6-2 G had increased DW at all the salt treatments compared to control and the percent increase of DW decreased with increasing salt doses. O-043-7-9 R however showed increased percentage of DW with increasing salt treatment except 14 dSm^{-1}. Maximum decrease in DW (-32.97%) was observed in O-043-7-9 G at 14 dSm^{-1} while maximum increase (109.64%) was found in Acc. 4582 G at 10 dSm^{-1}. Only BJRI Deshi pat 10 showed decreased DW in all the salt treatments compared to control (Table 4).

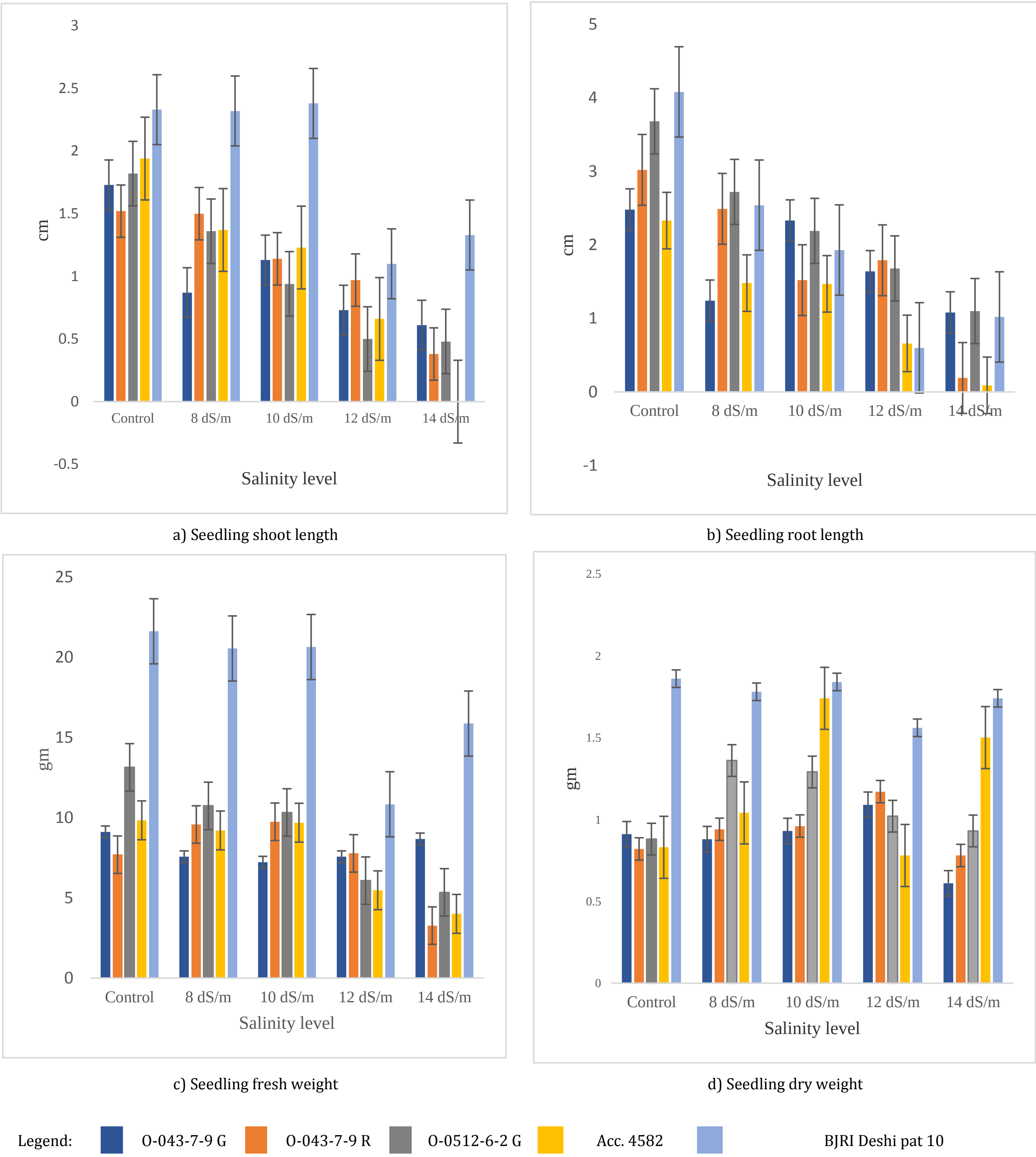

Figure 1: Seedling growth parameters (mean) of five jute genotypes under different salt treatments

Table 4: Percent change of seedling growth parameters of five jute genotypes in four salt treatments compared to control					
Traits	**Genotypes**	**% Change at 8 dSm^{-1}**	**% Change at 10 dSm^{-1}**	**% Change at 12 dSm^{-1}**	**% Change at 14 dSm^{-1}**
SL	O-043-7-9 G	-49.71	-34.68	-57.80	-64.74
	O-043-7-9 R	-1.32	-25	-36.18	-75
	O-0512-6-2 G	-25.27	-48.35	-72.53	-73.63
	Acc. 4582 G	-29.38	-36.60	-65.98	-100
	BJRI Deshi pat 10	-0.43	2.15	-52.80	-42.92
RL	O-043-7-9 G	-50	-6.05	-33.87	-56.45
	O-043-7-9 R	-17.55	-49.67	-40.73	-93.71
	O-0512-6-2 G	-26.09	-40.50	-54.35	-70.11
	Acc. 4582 G	-36.48	-36.91	-71.67	-96.14
	BJRI Deshi pat 10	-37.75	-52.70	-85.29	-75.00
FW	O-043-7-9 G	-17.01	-20.75	-17.01	-4.83
	O-043-7-9 R	24.45	26.66	1.04	-57.48
	O-0512-6-2 G	-18.28	-21.40	-53.77	-59.33
	Acc. 4582 G	-6.41	-1.53	-44.35	-59.31
	BJRI Deshi pat 10	-4.95	-4.53	-49.88	-26.61
DW	O-043-7-9 G	-3.30	2.20	19.78	-32.97
	O-043-7-9 R	14.63	17.07	42.68	-4.88
	O-0512-6-2 G	54.55	46.59	15.91	5.68
	Acc. 4582 G	25.30	109.64	-6.02	80.72
	BJRI Deshi pat 10	-4.30	-1.08	-16.13	-6.45

3.4 Salinity Tolerance

Tolerance indices SSI and STI are shown in Table 5. The results demonstrate that the highest values of the SSI index were observed in genotype Acc. 4582 G in 14 dSm^{-1} salt treatment followed by O-043-7-9 R in 12 dSm^{-1}, and the lowest values of the SSI index were obtained in genotype O-043-7-9 R in 14 dSm^{-1} salinity followed by O-043-7-9 G also in 14 dSm^{-1} (Table 5). Among all the genotypes, BJRI Deshi pat 10 had lower SSI values in all the salt treatments. Values of the STI index revealed that they were highest in genotype BJRI Deshi pat 10 in 10 dSm^{-1} and in 8 dSm^{-1} salinity, and lowest in genotype O-043-7-9 R in 14 dSm^{-1} salt treatment followed by Acc. 4582 G in 12 dSm^{-1} (Table 5).

The classification tree, which takes into account all germination and growth parameters, shows that the most salt sensitive genotypes were O-043-7-9 R and Acc. 4582 G (Figure 2). Whereas the most salt tolerant genotype was BJRI Deshi pat 10. This genotype showed similar response as control when grown in 8 and 10 dSm^{-1} salt treatments which were grouped in cluster I. The response of this genotype declined in 12 and 14 dSm^{-1} which were grouped with the sensitive genotypes O-043-7-9 R and Acc. 4582 G (cluster IV). All the other genotypes except BJRI Deshi pat 10 were grouped in same cluster (cluster III) when grown in control along with O-043-7-9 R in 8 dSm^{-1}. O-043-7-9 R and Acc. 4582 G were together in cluster II at 14 dSm^{-1} salt treatment. The other two genotypes (O-043-7-9 G and O-0512-6-2 G) were grouped together in cluster V and VI which shows their similarity in performance in different salt treatments (Figure 2).

Table 5: Tolerance indices of five jute genotypes under four salt levels					
Tolerance Indices	**Genotypes**	**8 dSm^{-1}**	**10 dSm^{-1}**	**12 dSm^{-1}**	**14 dSm^{-1}**
Stress susceptibility index (SSI)	O-043-7-9 G	-0.28	0.09	3.32	-2.91
	O-043-7-9 R	1.13	0.59	7.14	-5.10
	O-0512-6-2 G	4.12	1.69	2.80	1.26
	Acc. 4582 G	1.92	3.95	-1.14	15.90
	BJRI Deshi pat 10	-0.32	-0.02	-2.75	-1.19
Stress tolerance index (STI)	O-043-7-9 G	0.71	0.76	0.88	0.63
	O-043-7-9 R	0.69	0.70	0.85	0.45
	O-0512-6-2 G	1.06	1.01	0.80	0.73
	Acc. 4582 G	0.77	1.29	0.58	1.11
	BJRI Deshi pat 10	2.94	3.05	2.57	2.88

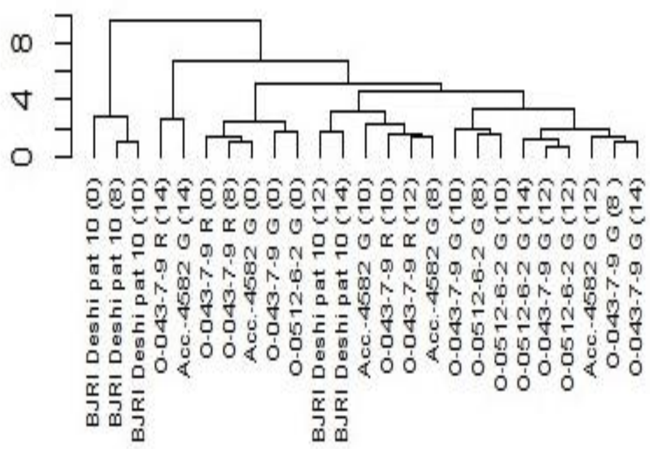

Figure 2: Results of hierarchical agglomerative cluster analysis based on 10 morphological traits at five salt treatments. The numbers in parenthesis indicate the salinity level (dSm^{-1}).

4. Discussions

The main aim of this study was to recognize salt tolerant and sensitive genotypes of jute during germination and at the early seedling stages to determine their potential for salt tolerance. Since effect of salinity on plant growth depends on different genotypes of different species, studying genetic variability of different plant species to understand the salt tolerance mechanism is an important step for developing salt tolerant genotypes (Rajabi Dehnavi et al., 2020; Ashraf et al., 2006; Ranjbar et al., 2008; Ates and Tekeli, 2007). Studies suggest that germination and seedling features are the most viable principles that affect the ultimate performance of the plants (Krishnamurthy et al., 2007; Bybordi and Tabatabaei, 2009). Considering this, early stages of plant development were studied in this experiment.

This study shows that the jute genotypes varied in their response to salt treatments in germination and seedling characteristics. Results show that increased salinity noticeably reduced GP, GI and SVI of the jute genotypes while MGT increased. But GP of certain genotypes also increased at high salt doses. This could be because of the criteria that was used to study the GP of the genotypes in this experiment since the seeds showing only 0.5 mm of radicle were considered as germinated. But eventually the growth of these germinated seeds was stunted due to high salinity. However, the change in the germination parameter varied depending on the genotypes. These results coincide with previous study that shows negative correlation between salinity and germination parameters GP, GI and SVI (Rehman et al., 2000).

Moreover, this negative correlation varies depending on the salt concentration, with low concentrations of NaCl inducing seed dormancy, and high concentrations of NaCl inhibiting seed germination due to the effects of high osmotic potential and specific ion toxicity (accumulation of Na^+ and Cl^- ions) (Khan and Weber, 2006.). In this study salinity did not significantly affect GP while other germination parameters such as GI, SVI and MGT were significantly affected. Similarly, non-significant reduction in GP of tossa jute was also reported (Naik et al., 2015). Water absorption by plant tissue under salinity stress is also reduced due to high accumulation of Na^+ ions in medium that causes osmotic and pseudo-drought stress (Farhoudi and Tafti, 2011; Misra and Gupta, 2005).

Salinity can also change enzymatic activities by the toxic effects of ions that can bring about huge alterations in plants e.g., changed metabolism of nucleic acid and protein (Gomes-Filho et al., 2008; Dantas et al., 2007), disturbed hormonal balance (Ryu and Cho, 2015). Reduced utilization of seed reserves (Promila and Kumar, 2000; Othman et al., 2006), increased phenolic compounds etc (Ayaz et al., 2000). All of these contribute to reduced germination. Moreover, different internal factors of seed i.e., coat proteins, age, polymorphism, dormancy, seedling vigor, and external factors i.e., temperature, light, moisture content etc. can also affect seed germination under saline conditions (Wahid et al., 2016).

In the current study, the germination parameters were affected differently in different salt treatments. But amidst all, it was noticed that of the five genotypes, Acc. 4582 G showed the highest reduction in GP, GI and SVI followed by O-043-7-9 R. The lowest reduction values differed for different genotypes. Besides, increase in some parameters at increased salt dose was recorded in some cases. While the highest MGT was recorded for BJRI Deshi pat 10. Results of this study coincide with the results by researchers in 2021 (Mukul et al., 2021). Decreased GP with increasing salinity in tossa jute was also reported by some researchers (Yakoub et al. 2019; Bhuyan et al. 2018; Naik et al. 2015). While increased germination time was found by others (Yakoub et al. 2019 and Naik et al. 2015). The differences in germination parameters of the studied jute genotypes may be due to the genetic factors and inheritance variation among them.

The effect of salinity on the jute genotypes was more prominent from the results of the growth parameters studied compared to the germination parameters. Different growth parameters (SL, RL and FW) of jute seedlings at the very early stage showed decreased results for each studied genotypes with increasing salinity except for DW which showed increased results for most of the genotypes in most salt treatments. But the degree of reduction varied depending on the genotypes.

Since roots are the first to come in contact with salinity and also remain in direct contact with the soil, reduction of root length is a very common happening in many plants and since the roots absorb water and nutrients from soil to supply to the shoots, damage of roots also cause damage in shoots (Asaadi, 2009). Salinity can negatively affect the ultrastructures of cells, tissues and organs as well (Koyro, 2002; Rasheed, 2009). In addition, earlier studies show that causing osmotic and specific ion toxic effects, salinity can inhibit the maintenance of necessary nutrient levels that are essential for plant growth which on the other hand limit root emergence and seedling growth (Krishnamurthy et al., 2007, Abari, et al., 2011; Bilgili et al., 2011). In this study, both the SL and RL were drastically affected by salinity. The reduction of FW could be the result of toxic effect of Na^+ on photosynthesis rate at higher concentrations (Carlos Torres and Bingham, 1973; Kawasaki et al., 1983).

Earlier it has been found that salinity reduces photosynthesis rate by reducing intercellular CO_2 concentration by stomatal closure (Kaymakanova and Stoeva, 2008). Moreover, Na^+ can lower transportation rate of vital ions such as NO_3^- and inhibit plant growth and biomass accumulation by limiting N-containing compounds (Mohsina Hamid et al., 2008; Chien et al., 2009). According to this study, highest decrease in SL was observed in Acc. 4582 G followed by O-043-7-9 R while lowest decrease was found in BJRI Deshi pat 10. In RL, highest decrease was also recorded in Acc. 4582 G followed by O-043-7-9 R and BJRI Deshi pat 10 whereas lowest decrease was observed in O-043-7-9 G. In case of FW, no particular pattern was observed. With few exceptions, FW decreased with salinity where O-043-7-9 G and BJRI Deshi pat 10 had lowest decrease. In case of DW, most of them showed increased result. The alteration of SL, RL and FW of the studied jute genotypes of this experiment are in line with a few study by a group of researchers (Mukul et al., 2021; Naik et al., 2015; Ghosh et al., 2013). Although no previous result of increased DW with increasing salinity could be found, in a study of tossa jute, Naik et al., 2015 recorded an unchanged DW of JRO 632 at 10 DAS in control, 100 and 160 mM NaCl whereas the same happening was found in JRO 8432 in control and 100 mM NaCl.

To assess the salt tolerance capacity of the studied genotypes, two tolerance indices (SSI and STI) were also applied in this study. According to the result of the SSI, Acc. 4582 G showed susceptibility towards salinity while BJRI Deshi pat 10 showed better performance against salinity. The result of STI showed the results that were in accordance with the SSI values where BJRI Deshi pat 10 had higher STI values indicating higher tolerance against salinity and Acc. 4582 G showed lower STI indicating lower tolerance towards salinity. The SSI and STI indices are applied to assess salt tolerance based on quantitative criteria proposed for selection of genotypes based on their yield performances in stress and non-stress conditions (Rajabi Dehnavi et al., 2020). Salt tolerant genotypes can be determined by SSI index according to the rate of yield changes compared to non-stress conditions which indicates higher stability in yield (Fernandez, 1992).

Higher STI indicates highest yield and highest tolerance to stress (Rajabi Dehnavi et al., 2020). Different studies reported that better performance and higher effectiveness for STI compared to SSI distinguish higher yielding genotypes across different environments (Fernandez, 1992). Besides, the lower values for SSI demonstrate the lower difference in the yield between the stress and normal conditions, which means higher stability in yield (Rajabi Dehnavi et al., 2020). Although this stability may not indicate better performance of the genotypes under saline conditions in this study since these indices were determined using the dry biomass of seedlings, not real yield, they still coincide with the findings of germination and growth parameters of this study.

It is difficult to discuss salt tolerance of the studied genotypes based on the individual parameters because of problems interpreting the statistical significance of differences (Tables 3 and 4). So, cluster analysis was applied to compare all the studied parameters in all treatments simultaneously. Based on the shown results, we can define BJRI Deshi pat 10 as salt tolerant genotype. Results also indicate that O-043-7-9 R and Acc. 4582 G are the most salt sensitive genotypes. But no clear indication about the other two genotypes (O-043-7-9 G and O-0512-6-2 G) can be done. These genotypes were not as sensitive as O-043-7-9 R and Acc. 4582 G, they did not even show tolerance as BJRI Deshi pat 10. The different results found in different genotypes may be because of their differences in genetic potentiality. Besides, the more tolerance of BJRI Deshi pat 10 against salinity could be because of its species since it was reported that capsularis showed more tolerance than tossa jute (Ghosh et al., 2013).

5. Conclusions

Significant differences among jute genotypes under saline conditions at germination and seedling stages were proved in the present study. In agriculture variety development is a major step and to fulfill this purpose identification and selection of the most salt tolerant genotypes of species is very important. Jute has huge potential for genetic variability in saline conditions. Studied genetic differences are a good basis for providing information about jute genotypes that can be grown in areas affected by salt, and may be useful for better crop production and for determining the degree of salt tolerance in different genotypes for their further use in breeding programs. Seedling traits can be used as valid attribute for the selection of genotypes with a better tolerance to salinity stress.

References

Abari, A.K., Nasr, M.H., Hojjati, M. and Bayat, D., 2011. Salt effects on seed germination and seedling emergence of two Acacia species. African Journal of Plant Science, 5 (1), Pp.52-56.

Alvarado, A.D., Bradford, K.J. and Hewitt, J.D., 1987. Osmotic priming of tomato seeds: effects on germination, field emergence, seedling growth, and fruit yield. Journal of the American Society for Horticultural Science, 112 (3), Pp.427-432.

Asaadi, A.M., 2009. Investigation of salinity stress on seed germination of Trigonella foenum-graecum. Research Journal of Biological Sciences, 4, Pp. 1152-1155.

Ashraf, M.Y., Akhtar, K., Hussain, F. and Iqbal, J., 2006. Screening of different accessions of three potential grass species from Cholistan desert for salt tolerance. Pakistan Journal of Botany, 38 (5), Pp.1589-1597.

Ates, E. and Tekeli, A.S., 2007. Salinity tolerance of Persian clover (*Trifolium resupinatum* var. Majus Boiss.) lines at germination and seedling stage. World Journal of Agricultural Sciences, 3, Pp. 71–79.

Ayaz, F.A., Kadioglu, A.S.I.M. and Turgut, R.A.B.İ.Y.E., 2000. Water stress effects on the content of low molecular weight carbohydrates and phenolic acids in Ctenanthe setosa (Rosc.) Eichler. Canadian Journal of Plant Science, 80 (2), Pp. 373-378.

BBS., 2022. Statistical yearbook of Bangladesh. 42nd edition. Bangladesh Bureau of Statistics. Statistics & Informatics Division (Sid), Ministry of Planning, Government of The People's Republic of Bangladesh, Dhaka, Bangladesh.www.bbs.gov.bd

Bilgili, U., Çarpıcı, E.B., Aşık, B.B. and Celik, N., 2011. Root and shoot response of common vetch (*Vicia sativa* L.), forage pea (*Pisum sativum* L.) and canola (*Brassica napus* L.) to salt stress during early se. Turkish Journal of Field Crops, 16 (1), Pp. 33-38.

Bhuyan, M.I., Hassan, K.M., Lipi, N.J., Uddin, M.R., Islam, M.M., Ferdous, M., Antor, N.H. and Das, P., 2018. Screening of jute and kenaf varieties for salinity tolerance. International Journal of Advanced Geosciences 6 (2), Pp. 214-218.

Bijeh, K.M.H., 2012. Studying the effects of different levels of salinity which caused by NaCl on early growth and germination of *Lactuca sativa* L. seedling. Journal of Stress Physiology & Biochemistry, 8 (1), Pp.203-208.

Bohnert, H.J., Nelson, D.E. and Jensen, R.G., 1995. Adaptations to environmental stresses. The plant cell, 7 (7), Pp. 1099.

Breeding Division, 2023. Technologies on Jute, Kenaf and Mesta Varieties. Bangladesh Jute Research Institute, Ministry of Agriculture, Government of The People's Republic of Bangladesh, Dhaka, Bangladesh.; https://bjri.gov.bd/site/page/e6d669a0-b9a0-4369-aebf-82ed33e13bb7/Jute-Variety

Bybordi, A. and Tabatabaei, J., 2009. Effect of salinity stress on germination and seedling properties in canola cultivars (*Brassica napus* L.). Notulae Botanicae Horti Agrobotanici Cluj-Napoca, 37 (2), pp.71-76.

Carlos Torres, B. and Bingham, F.T., 1973. Salt Tolerance of Mexican Wheat: I. Effect of NO3 and NaCl on Mineral Nutrition, Growth, and Grain Production of Four Wheats1. Soil Science Society of America Journal, 37 (5), Pp.711.

Chien, S.W.C., Liao, J.H., Wang, M.C. and Mannepalli, M.R., 2009. Effect of Cl−, SO42−, and fulvate anions on Cd2+ free ion concentrations in simulated rhizosphere soil solutions. Journal of hazardous materials, 172 (2-3), Pp.809-817.

Dantas, B.F., Ribeiro, L.D.S. and Aragão, C.A., 2007. Germination, initial growth and cotyledon protein content of bean cultivars under salinity stress. Revista Brasileira de Sementes, 29, Pp.106-110.

Farhoudi, R. and Tafti, M.M., 2011. Effect of salt stress on seedlings growth and ions homeostasis of soybean (*Glysin max*) cultivars. Advanced environmental biology, 5 (8), Pp. 2522-2526.

Fatema, K., Rasel, M., Islam, M.M., Begum, S.N., Azam, M.G., Hossain, M.A., Hassan, L., 2021. Evaluation of rice (*Oryza sativa* L.) genotypes grown under combined salinity and submergence stresses based on vegetative stage phenotyping. *Acta Biologica Szegediensis,* 65 (2), Pp. 145-162, DOI:10.14232/abs.2021.2.145-162.

Fernandez, G.C., 1992. Effective selection criteria for assessing plant stress tolerance. In proceedings of the international symposium on adaptation of vegetables and other food crops in temperature and water stress; Kuo, C.G., Ed.; AVRDC Publication: Shanhua, Taiwan. Pp.257–270.

Fischer, R.A. and Maurer, R., 1978. Drought resistance in spring wheat cultivars. I. Grain yield responses. Australian Journal of Agricultural Research, 29 (5), Pp.897-912.

Flowers, T.J. and Colmer, T.D., 2008. Salinity tolerance in halophytes. New phytologist, Pp. 945-963.

Foti, C., Khah, E.M. and Pavli, O.I., 2019. Germination profiling of lentil genotypes subjected to salinity stress. Plant Biology, 21 (3), Pp. 480-486.

Ghosh, T., 1983. Hand book on Jute. Food and Agriculture Organization of the United Nations (FAO), Pp. 115–16. https://books.google.com.bd/books?id=vnBNtQEACAAJ&redir_esc=y

Ghosh, R.K., Thitaporn Phumichai, T.P., Tanee Sreewongchai, T.S., Sutkhet Nakasathien, S.N. and Chalermpol Phumichai, C.P., 2013. Evaluation of salt tolerance of jute (*Corchorus spp.*) genotypes in hydroponics using physiological parameters. Asian Journal of Plant Sciences,12, Pp. 149-158.

Gomes-Filho, E., Lima, C.R.F.M., Costa, J.H., da Silva, A.C.M., da Guia Silva Lima, M., de Lacerda, C.F. and Prisco, J.T., 2008. Cowpea ribonuclease: properties and effect of NaCl-salinity on its activation during seed germination and seedling establishment. Plant Cell Reports, 27, Pp.147-157.

Guo, J., Du, M., Tian, H. and Wang, B., 2020. Exposure to high salinity during seed development markedly enhances seedling emergence and fitness of the progeny of the extreme halophyte Suaeda salsa. Frontiers in Plant Science, 11, Pp. 1291.

Hakim, M.A., Juraimi, A.S., Begum, M., Hanafi, M.M., Ismail, M.R. and Selamat, A., 2010. Effect of salt stress on germination and early seedling growth of rice (*Oryza sativa* L.). African journal of biotechnology, 9 (13), Pp.1911-1918.

Hasan, M.K. and Kumar, L., 2020. Meteorological data and farmers' perception of coastal climate in Bangladesh. Science of the total environment, 704, Pp.135384.

Hasanuzzaman, M., Nahar, K. and Fujita, M., 2013. Plant response to salt stress and role of exogenous protectants to mitigate salt-induced damages. Ecophysiology and responses of plants under salt stress, Pp. 25-87.

Islam, M.S., Saito, J.A., Emdad, E.M., Ahmed, B., Islam, M.M., Halim, A., Hossen, Q.M.M., Hossain, M.Z., Ahmed, R., Hossain, M.S. and Kabir, S.M.T., 2017. Comparative genomics of two jute species and insight into fibre biogenesis. Nature plants, 3 (2), Pp.1-7.

Kawasaki, T., Akiba, T. and Moritsugu, M., 1983. Effects of high concentrations of sodium chloride and polyethylene glycol on the growth and ion absorption in plants: I. Water culture experiments in a greenhouse. Plant and Soil, 75, Pp.75-85.

Kaymakanova, M. and Stoeva, N., 2008. Physiological reaction of bean plants (*Phaseolus vulg*. L.) to salt stress. General and Applied Plant Physiology, 34, Pp.177-188.

Keka, S.I., Shamsuzzaman, M., Pahloan, M.U., Pervin, S., Rahman, M.M. and Khan, H., 2008. Identifying simple sequence repeat (SSR) marker linked to mite tolerance in jute species. Bangladesh Journal of Botany, 37 (2), Pp.161-171.

Khan, M.A. and Weber, D.J. eds., 2006. Ecophysiology of high salinity tolerant plants (Vol. 40). Springer Science & Business Media.

Khajeh-Hosseini, M., Powell, A.A. and Bingham, I.J., 2003. The interaction between salinity stress and seed vigour during germination of soyabean seeds. Seed Science and technology, 31 (3), Pp. 715-725.

Koyro, H.W., 2002. Ultrastructural effects of salinity in higher plants. In Salinity: Environment-Plants-Molecules (Pp. 139-157). Dordrecht: Springer Netherlands.

Koyro, H.W., Lieth, H. and Eisa, S.S., 2008. Salt tolerance of Chenopodium quinoa willd., grains of the Andes: Influence of salinity on biomass production, yield, composition of reserves in the seeds, water and solute relations. Mangroves and halophytes: Restoration and utilisation, Pp.133-145.

Krishnamurthy, L., Serraj, R., Hash, C.T., Dakheel, A.J. and Reddy, B.V., 2007. Screening sorghum genotypes for salinity tolerant biomass production. Euphytica, 156, Pp.15-24.

Llanes, A., Andrade, A., Masciarelli, O., Alemano, S. and Luna, V., 2016. Drought and salinity alter endogenous hormonal profiles at the seed germination phase. Seed Science Research, 26 (1), Pp.1-13.

Mahender, A., Anandan, A. and Pradhan, S.K., 2015. Early seedling vigour, an imperative trait for direct-seeded rice: an overview on physiomorphological parameters and molecular markers. Planta, 241, Pp. 1027-1050.

Mazumder, M.S.U. and Kabir, M.H., 2022. Farmers' adaptations strategies towards soil salinity effects in agriculture: the interior coast of Bangladesh. Climate Policy, 22 (4), Pp. 464-479.

Misra, N. and Gupta, A.K., 2005. Effect of salt stress on proline metabolism in two high yielding genotypes of green gram. Plant science, 169 (2), Pp. 331-339.

Mohsina Hamid, M.H., Ashraf, M.Y., Khalil-ur-Rehman, K.U.R. and Arashad, M., 2008. Influence of salicylic acid seed priming on growth and some biochemical attributes in wheat grown under saline conditions. Pakistan Journal of Botany, 40, Pp. 361-367.

Mollah, M.A.F., Al Rafiq, M.Z., Hossain, A.S., Rony, M.N.H., Fatema, K. and Sadat, M.A., 2021. Effect of different weed management techniques for jute seed production. Asian Journal of Crop, Soil Science and Plant Nutrition.5 (1), Pp.187-192.

Mukul, M.M., Ahmed, S.S.U., Akter, N., Mostofa, M.G., Rahman, M.S. and Talukder, F.U., 2021. Responses of seed germination, seedling growth under salinity stresses and variability for phenotypic traits in Tossa Jute (*Corchorus olitorius* L.). Plant Science Today, 8 (1), Pp.166-180.

Naik, M.R., Barman, D., Maruthi, R.T., Mandal, U.K. and Kundu, D.K., 2015. Screening of tossa jute (*Corchorus olitrius* L.) varieties against salt stress. Ecoscan, 9, Pp.815-819.

Naik, M.R., Barman, D., Maruthi, R.T., Babu, V.R., Mandal, U.K. and Kundu, D.K., 2019. Assessment of salinity tolerance based upon morpho-physiological attributes in white jute (*Corchorus capsularis* L.). Journal of Environmental Biology, 40 (3), Pp. 377-383.

Othman, Y., Al-Karaki, G., Al-Tawaha, A.R. and Al-Horani, A., 2006. Variation in germination and ion uptake in barley genotypes under salinity conditions. World Journal of Agricultural Sciences, 2 (1), Pp. 11-15.

Promila, K. and Kumar, S., 2000. Vigna radiata seed germination under salinity. Biologia Plantarum, 43, Pp.423-426.

Rajabi Dehnavi, A., Zahedi, M., Ludwiczak, A., Cardenas Perez, S. and Piernik, A., 2020. Effect of salinity on seed germination and seedling development of sorghum (Sorghum bicolor (L.) Moench) genotypes. Agronomy, 10 (6), p.859.

Ranjbar, G.H., Cheraghi, S.A.M. and Banakar, M.H., 2008. Salt sensitivity of wheat at germination stage. Crop and Forage Production using Saline Waters in Dry Areas. New Delhi: Daya Publishing.

Rasheed, R., 2009. Salinity and extreme temperature effects on sprouting buds of sugarcane (Saccharum officinarum L.): some histological and biochemical studies (Doctoral dissertation, University of Agriculture, Faisalabad, Pakistan).

Rehman, S., Harris, P.J., Bourne, W.F. and Wilkin, J., 2000. The relationship between ions, vigour and salinity tolerance of Acacia seeds. Plant and Soil, 220, Pp. 229-233.

Ruan, S., Xue, Q. and Tylkowska, K., 2002. The influence of priming on germination of rice (Oryza sativa L.) seeds and seedling emergence and performance in flooded soil.

Ryu, H. and Cho, Y.G., 2015. Plant hormones in salt stress tolerance. Journal of Plant Biology, 58, Pp. 147-155.

Saleem, M.H., Rehman, M., Zahid, M., Imran, M., Xiang, W. and Liu, L., 2019. Morphological changes and antioxidative capacity of jute (*Corchorus capsularis*, Malvaceae) under different color light-emitting diodes. Brazilian Journal of Botany, 42, Pp.581-590.

Samira, R., Moosa, M.M., Alam, M.M., Keka, S.I. and Khan, H., 2010. 'In silico' analysis of jute SSR library and experimental verification of assembly. Plant Omics, 3 (2), Pp. 57-65.

Sarker, R.H., Al-Amin, G.M. and Hoque, M.I., 2007. In vitro regeneration in three varieties of white jute (*Corchorus capsularis* L.). Plant tissue culture and biotechnology, 17 (1), Pp.11-18.

Saunders, M., 2008. Recovery plan for the endangered native jute species, Corchorus cunninghamii F. Muell. in Queensland (2001-2006). Rainforest Ecotone Recovery Team (RERT)-2001. Australia, Pp. 1-5. https://www.environment.gov.au/system/files/resources/2f058095-1de7-4601-b70d-720db03f22d7/files/corchoruscunninghamii.pdf

Sharna, S.C. and Kamruzzaman, M., 2020. Comparative Advantages of Jute Export in Bangladesh, China and India. Research in Agriculture Livestock and Fisheries, 7 (2), Pp.183-190.

SRDI, 2010. Saline Soils of Bangladesh. Soil Resource Development Institute SRMAF Project, Ministry of Agriculture. https://srdi.portal.gov.bd/sites/default/files/files/srdi.portal.gov.bd/publications/bc598e7a_df21_49ee_882e_0302c974015f/Soil%20salinity%20report-Nov%202010.pdf.

Staff, U.S.L., 1954. Diagnosis and improvement of saline and alkali soils. Agriculture Handbook, 60, Pp.83-100.

Uçarlı, C., 2020. Effects of salinity on seed germination and early seedling stage. Abiotic stress in plants, 211, Pp.211-231.

Wahid, A., Farooq, M., Basra, S.M., Rasul, E. and Siddique, K.H., 2016. Germination of seeds and propagules under salt stress. In Handbook of Plant and Crop Stress, Third Edition, Pp. 321-337. CRC Press.

Yakoub, A.R.B., Tlahig, S. and Ferchichi, A., 2019. Germination, growth, photosynthesis, and osmotic adjustment of Tossa jute (*Corchorus olitrius* L.) seeds under saline irrigation. Polish Journal of Environmental Studies, 28 (2).

Yang, Z., Li, J.L., Liu, L.N., Xie, Q. and Sui, N., 2020. Photosynthetic regulation under salt stress and salt-tolerance mechanism of sweet sorghum. Frontiers in plant science, 10, Pp.487808.