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Research Article

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Growth Performance of Tossa Jute (*Corchorus olitorius*) under Waterlog Stress in Tropical Monsoon Climate Region

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ABSTRACT

Waterlogging is a serious abiotic stress for Tossa jute cultivation in flood-prone areas or haor areas of Bangladesh. There is no waterlog-tolerant variety in Bangladesh, and hence it is essential to study the growth performance of Tossa jute genotypes under waterlogged stress. Two previously selected lines, Accession (Acc.) 1306 and Acc. 1318, an exotic variety JRO-524 and three popular varieties, e.g., BJRI Tossa pat 5, BJRI Tossa pat 8 and BJRI Tossa pat 9, were grown at Jute Agricultural Experiment Station, Manikganj in 2022. Jute genotypes were grown in three different blocks in which two plots were inundated at 65- and 80-day age, respectively and one plot was used as a control without inundation. Artificially, waterlog condition was maintained for 30 days. Survivability status and other agronomic characteristics (plant height, stem diameter, fresh weight, root length, fiber yield) were observed closely after the submergence condition. There was a difference in the plant survivability percentage. Maximum plants (97.1%) of Acc. 1306 were survived under waterlog conditions at 65 days after sowing (DAS) but in case of inundation at 80 DAS, JRO-524 had maximum survivability (92.9%) than other genotypes followed by Acc. 1318(91.6%) and BJRI Tossa pat 8 (90.2%) Among all jute genotypes, BJRI Tossa pat 5 gave highest fiber yield (3.05 t/ha) when inundated after 80 days followed by inundated after 65 days (2.75 t/ha) in this variety compared to the control. Correlation study reveals that fiber yield and stick yield of Tossa jute are strongly correlated; root length and adventitious root length have negative correlation with green weight with leaf, fiber and stick yield. BJRI Tossa pat 5 showed robust adaptive responses with notable increases in both root length and adventitious root length in case of inundation at 65 and 80 DAS. BJRI Tossa pat 5 may be considered as a relatively waterlog tolerant Tossa jute variety which can be used for cultivation in flood-prone areas of Bangladesh.

Keywords: Abiotic stress; Adventitious root; *Corchorus olitorius*; Mortality rate; Natural fiber; Waterlog stress

INTRODUCTION

Corchorus olitorius (Tossa jute) is a vital crop for producing natural fibers, especially in regions like South Asia where it holds economic and industrial significance (Islam et al., 2017). Known for its strength, biodegradability, and versatility, Tossa jute is integral to the manufacture of textiles, ropes, and various packaging materials (Islam, 2019; Kumari et al., 2020). However, its cultivation is highly susceptible to environmental stress, particularly waterlogged conditions, which can significantly impact both yield and fiber quality (Dhar et al., 2018).

Plants grow normally by balancing water absorption through their roots with transpiration from their leaves. Adequate water is essential for healthy plant growth, but excessive soil moisture, whether at or above the soil's water-holding capacity, can cause waterlogged stress. This stress hampers root respiration and leads to the buildup of harmful substances, negatively impacting both vegetative and reproductive growth, which can ultimately result in reduced yields or even total crop failure (Xu et al., 2014; Herzog et al., 2016; Tian et al., 2019; Ding et al., 2020; Zhou et al., 2020).

Waterlogged stress occurs when excess water saturates the soil, creating an anaerobic environment that hampers root respiration and overall plant health. This condition often results from heavy rainfall, inadequate drainage, or over-irrigation (Pan et al., 2021). For Tossa jute, which requires well-drained soils for optimal growth, waterlogging can be particularly detrimental (Bhattacharyya & Palit, 1982).

The yield of *Corchorus olitorius* L. (Tossa jute) is directly influenced by waterlogged stress. Prolonged saturation of the soil leads to oxygen deficiency in the root zone, disrupting nutrient uptake and root function. This stress manifests in stunted growth, reduced leaf area, and diminished stem biomass, all of which contribute to lower fiber yield (Bhattacharyya & Palit, 1984). Additionally, waterlogged conditions can delay the maturation process, resulting in an uneven and less productive harvest (Rahman et al., 2021; Manghwar et al., 2024).

The quality of jute fiber, characterized by its strength, fineness, and color, is also compromised under waterlogged conditions. Oxygen-deprived roots lead to poor cell wall development, producing weaker fibers. Nutrient deficiencies during critical growth periods can result in coarser, less lustrous fibers (Viégas et al., 2018). Consequently, the market value and industrial utility of the fiber are diminished.

The southwest coast of Bangladesh, including some other lowland areas of the country, is very vulnerable to the effect of regular and flash flooding during the rainy season (Wang et al., 2021). Therefore, in the context of global warming, with predictions of more frequent and intense rainfall and increased flood disasters, it is crucial to study plant waterlogged tolerance and its mechanisms. This research is essential for sustaining successful agriculture and developing effective adaptations to the changing climate (Bailey-Serres et al., 2012; Nishiuchi et al., 2012; Mondal et al., 2020).

Understanding and mitigating the effects of waterlogged stress on Tossa jute are crucial for maintaining its yield and quality (Prodhan et al., 2001). Effective management practices, including improved drainage systems, the development of resistant varieties, and strategic planting schedules, are essential for sustaining the productivity and economic viability of this important crop. Therefore, a study was designed to select jute germplasm tolerant to submergence that can help to develop a variety to be released for waterlogged-affected areas of Bangladesh.

MATERIALS AND METHODS

Plant materials

There are six Tossa jute genotypes including accessions, advanced lines, and pre-released varieties were used in this study to observe their yield and yield attributing traits contributing to fiber and stick production followed by identifying superior genotype(s) for further water log tolerant Tossa jute variety development (Table 1).

Location and timing of the experiment

In 2022, experimental plants were cultivated, and morphological assessments were carried out at the Jute Agriculture Experimental Station (JAES) of BJRI, located in the Manikganj District of Bangladesh [coordinates: 23°52′56.1″N 90°01′53.0″E]. Manikganj district in Bangladesh experiences a tropical monsoon climate, characterized by hot and rainy summers and a cooler, drier winter. The average annual temperature ranges from 12.7°C to 36°C, and the annual rainfall totals around 2,376 mm.

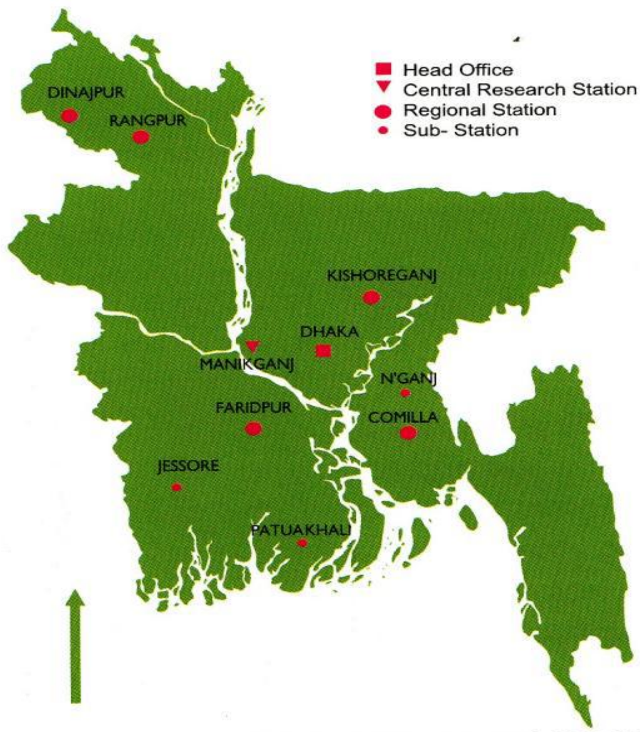

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Table 1. List of plant materials, type of plants, sources of collection and country of origin.

Genotypes	Ancestors or method of development	Plant type	Source of collection	Country of origin
Acc. 1306	Pure line selection (PLS)	Accession	Gene Bank of BJRI	Bangladesh
Acc. 1318	Pure line selection (PLS)	Accession	Gene Bank of BJRI	Bangladesh
BJRI Tossa pat 5	Uganda red × O-4	Pre-released variety	Breeding division, BJRI	Bangladesh
BJRI Tossa pat 8	PLS of mutants	Pre-released variety	Breeding division, BJRI	Bangladesh
BJRI Tossa pat 9	JRO-524 × Acc. 1749	Pre-released variety	Breeding division, BJRI	
JRO-524	African (cv. Sudan Green) × indigenous (cv. JRO-632)	Pre-released variety	Breeding division, BJRI	India

Experimental design, seeding and plants growing

The experiment was conducted following a randomized complete block design keeping individual plot size 3.0 m^2 (1.5m × 2m) with three replications. These six genotypes were grown in three different blocks in which two blocks were inundated at 65 and 80 days after sowing, respectively and one block was used as control without inundation. Artificially, water logging condition was maintained for 30 days.

Data collection and data analysis

Survivability status and other agronomic characteristics such as plant height (PH), base diameter (BD), green leaves weight (GLW), and stick yield (SY) were observed closely after the submergence condition. Plants were harvested at 120 DAS and different morphological characters as well as fiber and stick yield were recorded. The morphological data were collected and compiled carefully using Microsoft Excel (Windows 10 Pro, MS Office 2016). The analysis of variance, descriptive analyses, correlation coefficient, and Tukey's comparison tests (DMRT) were done using **Minitab 19** statistical analysis software (Minitab, 2019).

RESULTS AND DISCUSSION

Plants were investigated carefully for survivability rate and morphological traits after applying waterlogging stresses. There was a difference in the plant survivability percentage. Acc. 1306 survived in higher number (97.1%) in water-logged conditions at 65 days after sowing (DAS), but in the case of inundation at 80 DAS, JRO-524 had maximum survivability (92.9%) than other genotypes, followed by Acc. 1318 and BJRI Tossa pat 8 (Table 2). BJRI Tossa pat 9 showed highest mortality percentage (35%) in case of inundation after 80 days followed by BJRI Tossa pat 8(31.5%) (Fig. 1). Treatment effects are highly significant for base diameter (BD), green leaves weight (GLW), and stick yield (SY), indicating that different treatments lead to statistically significant differences in these variables. Genotype effects are significant for BD, GLW, FY, and SY, showing that different genotypes result in significant differences in these variables. Interaction effects (Time× Genotype) are significant only for PH and SY, suggesting that the combination of treatment and genotype significantly affects these variables (Table 3). Both treatment and genotype have substantial effects on most response variables, with notable interaction effects in specific cases. The significant results highlight the importance of both treatment and genotype in influencing these agricultural or biological variables.

The data reveal significant variation in the response of different genotypes to inundation stress. Genotypes like Acc. 1318 and JRO-524 demonstrate strong resilience across all conditions, making them potentially more suitable for environments prone to flooding. On the other hand, BJRI Tossa pat 8 and BJRI Tossa pat 9 are more susceptible to prolonged inundation, indicating a need for careful management in such conditions. The analysis highlights the importance of genotype selection based on environmental stress factors for optimal crop survival and yield.

Inundation negatively impacts the fiber yield and yield-contributing characteristics of jute plants. Inundation after 80 days generally results in more significant reductions in plant height, base diameter, plant weight with leaves, fiber yield, and stick yield compared to inundation after 65 days. This suggests that stem development is adversely affected by waterlogging stress. There was a marked decrease in GLW under inundation, with the most significant reduction observed after 80 days. This indicates that inundation affects the overall biomass production. Among the genotypes, BJRI Tossa pat 5 gave the highest fiber yield (3.7 t/ha) when inundated after 80 days, followed by inundated after 65 days (3.2 t/ha) compared to the control. (Table 4).

Fiber and stick yield decreased with inundation, particularly after 80 days, suggesting that waterlogging at a comparatively mature stage negatively impacts fiber and stick production, which is crucial for jute cultivation. The highest fiber yield was found in BJRI Tossa pat 8 (3.31 t/ha) in the control condition. BJRI Tossa pat 5 had the highest fiber yield (3.05 t/ha) at 65 days after inundation. At 80 days after inundation, Acc. 1318 had the lowest fiber yield (1.53 t/ha), significantly different from the others (Table 4).

Stick yield significantly reduced at waterlogged conditions, ranging from 3.25-7.7 t/ha. In case of stick yield, BJRI Tossa pat 5 performed best at 65 days after inundation, and BJRI Tossa pat 8 gave similar result at 80 days after inundation (Table 4).

Prodhan et *al*. (2001) investigated the effects of different standing water levels on four genotypes of jute, specifically *C. capsularis* (cv. D-154 and CVL-1) and *C. olitorius* (cv. O-4 and R-26). They found significant reductions in plant height, 45%, 39%, 59%, and 61% for CVL-1, D-154, O-4, and R-26, respectively, when 30-day-old plants were subjected to 5 cm of standing water. However, when mature 90-day-old plants were exposed to 30 cm of standing water, the height reductions were much smaller at 3%, 3%, 9%, and 12%. In a subsequent experiment, Prodhan *et al.*reported similar trends in stem base diameter reduction under various water levels, with 37%, 30%, 40%, and 36% reductions for D-154, CVL-1, O-4, and R-26, respectively, in 30-day-old plants under 5 cm of water. At the mature stage with 30 cm of water, the reductions were much lower at 0.6%, 3%, 9%, and 8%, indicating that mature jute plants exhibit greater tolerance to waterlogging.

In another study, Chang et *al*. 2009 examined the effects of different durations of waterlogged (45, 60, 75, 90, and 105 days) on *C. olitorius*, observing significant reductions in growth and yield parameters with longer waterlogged durations. Specifically, at 105 days of waterlogged, there were reductions of 53% in plant height, 36% in stem diameter, 73% in leaf area, 71% in taproot length, and 75% in yield, although adventitious root formation increased with longer waterlogged.

Prodhan *et al*. 2021, also reported that *C. olitorius* genotypes showed greater height reductions (59% and 61%) compared to *C. capsularis* (45% and 39%) when exposed to a 5 cm water level. Additionally, *C. olitorius* genotypes experienced more significant reductions in stem diameter across various water levels compared to *C. capsularis*. Ghorai *et al*. subjected three jute cultivars (*C. olitorius* cv. JRO-524 and *C. capsularis*cvs. Hybrid-C and JRC-212) to waterlogged stress, noting a reduction in reed length (fiber length) by 19-24% under different water levels compared to a control group grown on a 40 cm raised bed. They also observed that waterlogged caused the basal region of jute plants to become hard and dark, thereby reducing fiber quality.

In this experiment, BJRI Tossa pat 5 exhibited strong adaptive responses with significant increases in root length and adventitious root length under both inundations (at 65 and 80 DAS). This suggests good tolerance and adaptability to moderate to prolonged waterlogging (Changdee et al., 2009; Ghorai et al., 2001; Mukul et al., 2021).

BJRI Tossa pat 8 showed high root weight under control and 80 DAS inundation, indicating strong resilience and potential for waterlogged conditions. Acc. 1318 demonstrated the longest root length under 65 DAS inundation, suggesting an initial strong adaptive response, but the root weight decreases significantly, indicating some vulnerability to prolonged stress.

The correlation study revealed that out of 28 associations, 11 were significant and 17 were non-significant. Four associations had strong positive correlation— (FY, SY); (GLW, FY); (GLW, RGW); (RL, ADV RT)—and three had strong negative correlation— (GLW, ADV RT); (GLW, RL); (ADV RT, RGW) (see Table 5). Green weight with leaf and stick yield is strongly correlated with fiber yield. In contrast, green weight with leaf is negatively correlated with adventitious root and root length (Prodhan et al., 2001).

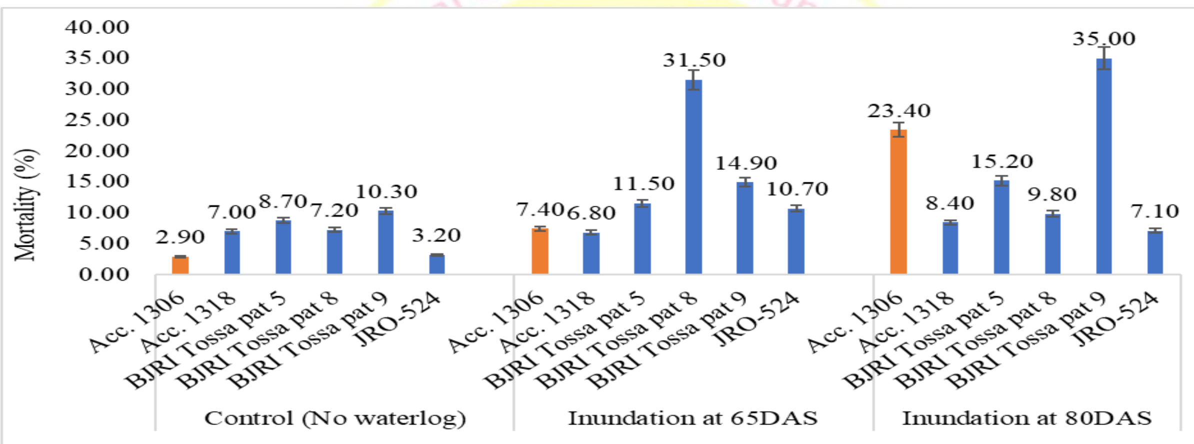

Figure 1. Mortality percentage of Tossa jute genotypes under waterlogged conditions.

Table2. Survivability (%) of tested germplasm at harvesting time (120 DAS).

Genotypes	Control (No inundation)			Inundation after 65 Days			Inundation after 80 Days		
	PP before watering	Death plants	Survivability (%)	Before watering	Death plants	Survivability (%)	Before watering	Death plants	Survivability (%)
Acc. 1306	215.0	16.0	92.6	173.0	5.0	97.1	184.0	43.0	76.6
Acc. 1318	201.0	14.0	93.0	192.0	13.0	93.2	215.0	18.0	91.6
BJRI Tossa pat 5	183.0	16.0	91.3	200.0	23.0	88.5	171.0	26.0	84.8
BJRI Tossa pat 8	181.0	13.0	92.8	184.0	58.0	68.5	205.0	20.0	90.2
BJRI Tossa pat 9	175.0	18.0	89.7	201.0	30.0	85.1	160.0	56.0	65.0
JRO-524	188.0	6.0	96.8	168.0	18.0	89.3	156.0	11.0	92.9

DAS = Days after sowing; PP=Plant population

Table 3. Analysis of variance (MS) for yield and contributing morphological characters of six Tossa jute genotypes under inundated condition.

Sources of variation	df	PH	BD	GLW	RL(cm)	ARL(cm)	RGW(gm)	FY	SY
Treatment(T)	2	0.47^{**}	14.36^{***}	1237.56^{***}	102.43^{***}	376.70^{***}	4910.7^{***}	1.12^{**}	7.59^{**}
Genotype(G)	5	0.085ns	4.987^{**}	188.10^{**}	6.97^{**}	3.27ns	158.26^{***}	1.14^{***}	6.45^{***}
T *G	10	0.222^{*}	1.632ns	28.89ns	5.95^{***}	3.68ns	327.74^{***}	0.17ns	6.52^{***}
Error	36	0.102	1.266	48.02	1.47	3.36	17.59	0.16	1.19

*, **, and *** indicate significant at 0.05, 0.01, and 0.001 levels of probability; ns indicate non- significant.

Table 4. Mean performance of yield and yield contributing characters of six Tossa jute germplasms at harvesting time.

Treat.	Genotypes	PH(m)	BD(mm)	GLW(t/ha)	RL(cm)	ARL(cm)	RGW(gm)	FY(t/ha)	SY(t/ha)
Control (No inundation)	Acc. 1306	2.65ab	12.35abc	24.8a-d	3.46cde	6.87e	85bcd	2.15abc	5.1bcd
	Acc. 1318	2.55ab	12.65abc	29.48a-d	2.93de	6.8e	81.33cde	2.5abc	6.3a-d
	BJRI Tossa pat 5	2.1ab	12.55abc	35.8ab	2.33e	7.33de	74.67def	3.05a	6.85abc
	BJRI Tossa pat 8	1.995ab	11.9abc	42.65a	3de	8.07cde	88.67bc	3.31a	9.25a
	BJRI Tossa pat 9	2.6ab	13.8a	30.45ab	3.4cde	7.33de	95.33ab	2.44abc	5.2bcd
	JRO-524	2.75ab	12.15abc	33abc	4.67b-d	8.13cde	104.33a	2.6abc	5.6bcd
Inundation after 65 Days	Acc. 1306	2.65ab	14.1a	17.25bcd	11.6a	12.33ab	70.33efg	2.08abc	5.9bcd
	Acc. 1318	2.35ab	11.35abc	21.62a-d	13.6a	13.27ab	61.67ghi	2.1abc	5.35bcd
	BJRI Tossa pat 5	2.4ab	12.65abc	25.85a-d	12.4a	11.53abc	55hij	2.9ab	6.45a-d
	BJRI Tossa pat 8	2.45ab	12.7abc	28.02a-d	11.93a	10.4b-e	73.33d-g	2.28abc	3.25d
	BJRI Tossa pat 9	2.36ab	13.05ab	17.7bcd	11.13a	8.13cde	48.67j	2.1abc	4.95bcd
	JRO-524	2.2ab	12abc	14.1cd	11.67a	10.73bcd	53hij	2.4abc	4.95bcd
Inundation after 80 Days	Acc. 1306	2.05ab	12.55abc	18.13bcd	12.67a	12.6a	55.33hij	2.1abc	4.75bcd
	Acc. 1318	2.35ab	11.15abc	13.62cd	9.53ab	11.4bc	52hij	1.53c	3.3d
	BJRI Tossa pat 5	2.25ab	10.95abc	21.33bcd	9abc	11.4bc	62f-i	2.75abc	6.4a-d
	BJRI Tossa pat 8	2.25ab	12.15abc	19.35bcd	10ab	14.93a	63.33f-h	2.4abc	7.7ab
	BJRI Tossa pat 9	1.7b	9.3c	10.6d	8.4a-d	10.2b-e	71rfg	1.8bc	3.8cd
	JRO-524	2.25ab	10.25bc	17.53bcd	10.27ab	10.93bcd	50ij	2.35abc	5.1bcd

PH=Plant height; BD=base diameter; GLW= Plant weight with leaves; RL= Root Length; ARL=Adventitious root length; RW= Root weight; FY=Fiber yield; SY=Stick yield.Means that do not share a letter are significantly different.

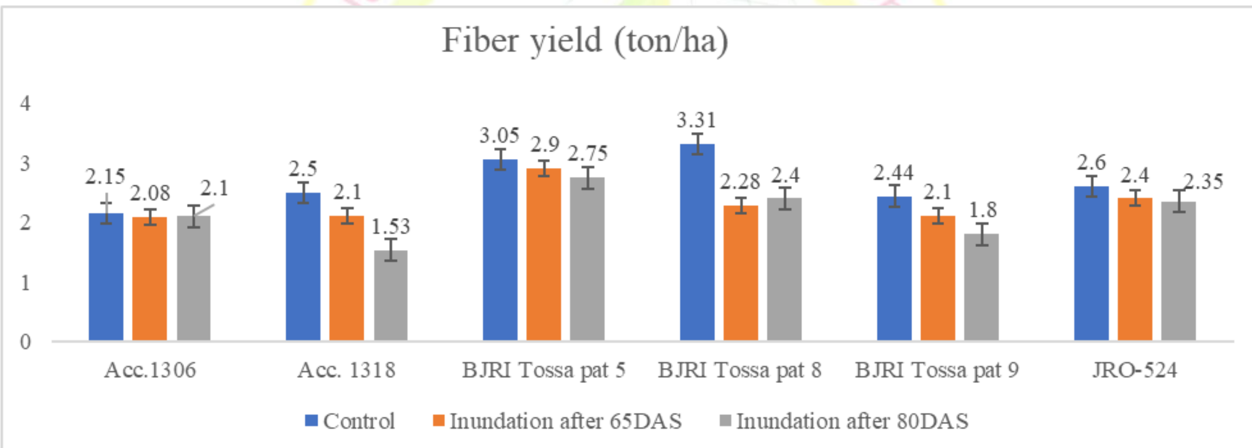

Fig. 2. Mean performance of treatment and variety for fiber yield (ton/ha) of six Tossa jute genotypes under control, inundation after 65 days and inundation after 80 days treatments.

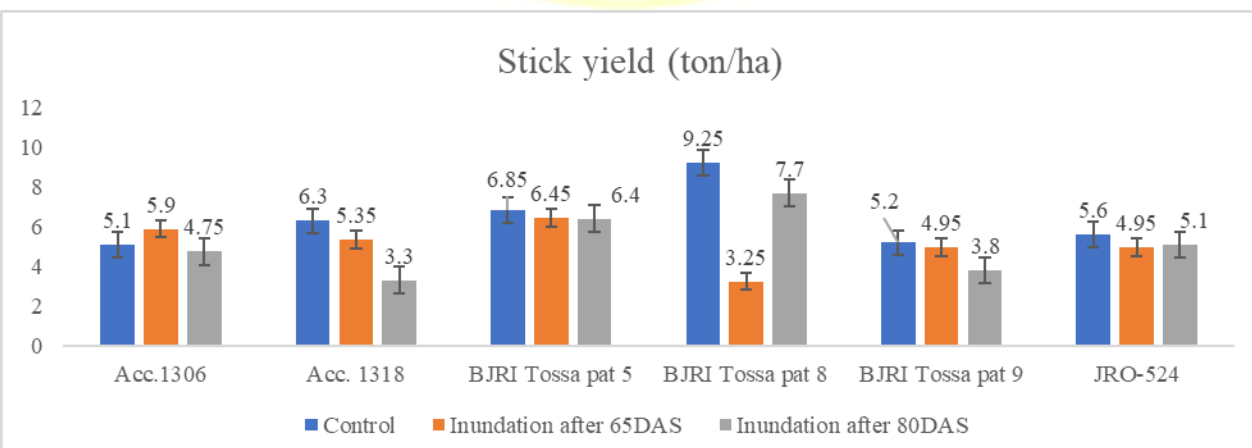

Fig. 3. Mean performance of treatment and variety for stick yield(ton/ha) of six Tossa jute genotypes under control, inundation after 65 days and inundation after 80 days treatments.

Table 5. Correlation coefficient of yield and yield contributing characters of six Tossa jute germplasms.

Traits	PH	BD	GLW	FY	SY	RL	ADV RT
BD	0.620**						
GLW	0.223	0.370					
FY	-0.046	0.202	0.796***				
SY	-0.124	0.157	0.598**	0.799***			
RL	-0.383	-0.501*	-0.632**	-0.440	-0.167		
ADV RT	-0.167	-0.159	-0.689**	-0.462	-0.417	0.754***	
RGW	0.344	0.408	0.718***	0.364	0.266	-0.524*	-0.670**

*, **, and *** indicate significant at 0.05, 0.01, and 0.001 levels of probability; PH=Plant height; BD=base diameter; GLW= Plant weight with leaves; RL= Root Length; ARL=Adventitious root length; RW= Root weight; FY=Fiber yield; SY=Stick yield

CNCLUSION

BJRI Tossa pat 8 performed well under control conditions with the highest GLW, FY, and SY, but shows a decline under inundation. Conversely, Acc. 1306 and BJRI Tossa pat 5 showed relatively better performance under inundation conditions, indicating potential resilience traits valuable for breeding programs targeting water-stress environments. BJRI Tossa pat 5 and BJRI Tossa pat 8 are recommended for areas prone to moderate to prolonged waterlogged due to their robust adaptive responses and resilience.

CONFLICT OF INTEREST

The author here declares that there is no conflict of interest in the publication of this article.

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AUTHORS' CONTRIBUTIONS

SSUAH[1] conceived, designed and performed the experiment; MMM[1] helped in analysis and interpretation of data; NT[1] wrotes the manuscript. NA[5], MGM[1], RKG[3] supervised the experiment and guided the study; OA[3] & NA[4] helped in data collection. MH[2], KF[1], and MMM[1] helped in writing the manuscript; MMM[1] reviewed the article for publication, prepared and submitted it to the journal, and communicated for publication. All authors contributed to the article and approved the submitted version for publication.

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