



Research Paper

Differential response of tossa jute (*Corchorus olitorius*) submitted to water deficit stress

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ABSTRACT

We aimed towards investigating the effects of water deficit stress (WDS) on phenotypic traits, leaf gas exchange, water relations, secondary metabolite profile and fibre properties of six tossa jute (*Corchorus olitorius*) genotypes grown under control or water withholding conditions. Root length, root weight, stem weight and whole biomass were reduced significantly ($p < 0.05$) in susceptible genotypes but remain unaltered in tolerant genotypes following WDS. The tolerant genotypes showed significantly higher ($p < 0.05$) photosynthetic carbon assimilation (PCA) and water use efficiency (WUE) along with significant reduction ($p < 0.05$) in stomatal conductance (SC), transpiration rate (TR) and vapour pressure deficit (VPD) as compared to susceptible genotypes after WDS. Tolerant genotypes exhibited significantly higher ($p < 0.05$) % RWC as compared to susceptible plants following WDS. Polyphenol and flavonoid content were significantly increased ($p < 0.05$) in tolerant and susceptible genotypes respectively following WDS. Susceptible plants exhibited significantly reduced ($p < 0.05$) proline content as compared to tolerant genotypes. Number of phytochemicals identified by GC–MS showed 46% and 81% increase in tolerant and susceptible groups respectively, after prolonged WDS. Major phytochemical groups in tolerant genotypes under WDS were ketone, acyclic diterpene alcohol, steroid/sterol, heterocyclic compound, alicyclic hydrocarbon, thiophenol and fatty acid ester. Whereas, the susceptible genotypes exhibited steroid/sterol, acyclic diterpene alcohol, alcohol and heterocyclic compound as the major phytochemical groups under WDS. Tolerant genotypes showed significantly higher ($p < 0.05$) fibre strength as compared to susceptible plants under stress. Our results show identifiable traits manifested by the tolerant and susceptible tossa jute genotypes under WDS which could therefore be utilized successfully for future selection and breeding programs, crop improvement initiatives and production of new varieties having optimum potential toward water deficit stress adaptation.

1. Introduction

Jute (*Corchorus* spp., family Malvaceae), also known as ‘golden fibre’, is an important ligno-cellulosic natural fibre-yielding industrial crop of tropics and subtropics with diversified economic and industrial uses. *Corchorus capsularis* (white jute) and *C. olitorius* (tossa jute) are the two commercially important cultivated species of *Corchorus* which are thought to originated in equatorial region of east Africa, but was domesticated in India or Indo Burma region (Kundu et al., 2013). They are vital cash crop with vast potential in multiple facets of industrial applications as well as social wellbeing. About 60% of the global production of jute goods is contributed by India with annual export earnings of about INR 1892.94 crore per annum (Annual Report, 2016–17, Ministry of Textile, Govt. of India). *C. olitorius* has also been largely produced in arid-region of Middle East and Africa, where it is used as an important vegetable for common cooking. *C. olitorius* also has medicinal

and health promoting properties (Tsukui et al., 2004; Islam, 2013). The current trends in research and development of this fibre crop in terms of genomic studies, molecular biotechnological approaches, metabolomics, nutrition, pharmacology and toxicology aspects are very promising and may usher novel research nodes in this sector (Sinha et al., 2011).

Global plant productivity is badly affected by limited water availability and the response of plants subjected to water deficit stress (WDS) is still a grey area of investigation. The composite response of plant towards WDS differs strongly among plant species (Neto et al., 2010; Gallé et al., 2011; Barigah et al., 2013) and populations within species (Zhang et al., 1997; Monclus et al., 2009; Granda et al., 2014). Aside from causing changes in photosynthetic metabolism, WDS is well reported to play key role to induce additional cellular and molecular cascades that are evident in altered whole plant transcriptome and metabolome (Ramakrishna and Ravishankar, 2011; Arbona et al., 2013;

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Granda et al., 2014; Zhang et al., 2014). These altered responses ultimately result into main changes in the chemical composition of the plant under stress. In the current context of global climatic change, WDS is a major problem limiting production and productivity of jute. It causes 20–30% loss of fibre yield and also deteriorates the quality which eventually results in huge loss in global economy of the fibre industry. Plenty of water is required for the normal growth of jute, particularly for the later stage of its vegetative growth (Gupta and Dargan, 1970; Kundu et al., 2013). Studies by Chowdhury and Choudhuri (1985, 1986) on the mechanism of WDS tolerance in jute clearly demonstrated that *C. olitorius* is more susceptible than *C. capsularis* to water-deficit stress. The plant height of both *C. capsularis* and *C. olitorius* grown under different water regimes was studied by Prodhan et al. (2001) and they found shorter height in all water stressed cultivars as compared to their corresponding control plants. On the contrary to these reports, *C. olitorius* has also revealed tolerance response to soil moisture and salt stress (Fawusi et al., 1984; Ayodele and Fawusi, 1989, 1990; Chaudhuri and Choudhuri, 1997; Shiwachi et al., 2008). In recent time, Yakoub et al. (2016) investigated the effect of water deficit on physiological and agro-morphological parameters related to water deficit tolerance of *C. olitorius* from Tunisian oasis. It is also hypothesized that the distribution of *C. olitorius* in arid-region is attributed to its tolerance to WDS. However, lack of in-depth investigation to describe the response of prolonged WDS of *C. olitorius* demands new research initiatives to mitigate future obstacles in this area.

The main challenge of fibre industry production sector is to produce high quality fibre with stability across different cultivation areas. The WDS is one of the most prevailing limiting factors for jute productivity as well as yield stability. It causes around 20–30% loss of fibre yield in rainfed production systems along with deterioration of fibre quality. At present, under perceived climate change, the extent of damage will increase many fold. Therefore, jute improvement programs have been formulated with a prime focus of developing jute cultivars with enhanced WDS tolerance and improved fibre quality. In this endeavour, evaluation and subsequent utilization of jute germplasm is of great importance. In India, there is no systematic evaluation of jute germplasm for WDS tolerance and fibre quality. In our institute, 300 tossa jute genotypes were assessed for fibre fineness and wide range of variability was observed. Fibre fineness in tossa jute varied from 2.07–3.89 tex. Researchers also evaluated different tossa jute accessions of exotic and indigenous origin for moisture stress tolerance. Parameters like relative turgidity and chlorophyll disintegration (CD) were used for such evaluation. Relative turgidity of the genotypes varied between 45%–85% over control and CD varied between 0.33 mg–1.60 mg. These accessions could be classified into susceptible, moderately susceptible and moderately tolerant categories. Such preliminary work highlights degree of diversity exists in tossa jute germplasm for the trait which can be effectively utilized for enhancing WDS tolerance and fibre quality of tossa jute cultivars.

Previously, a total of 600 germplasm along with 15 varieties of tossa jute in our institute were evaluated under field condition as well as under poly ethylene glycol (PEG) treatment. Frequency distribution of germination% under PEG reveals that majority of accession was found to be susceptible to WDS condition and 20 lines were found to be tolerant to WDS. Therefore, determination of the visible traits for water stress tolerance among tossa jute genotypes would help us in screening and selection of jute germplasm for WDS environment. We should follow an integrated approach to find out the phenotypic, physiological, biochemical and metabolomic traits along with physical and mechanical properties to unravel the differential response of tossa jute genotypes under prolonged WDS and these traits could be used for production of new stress-tolerant jute varieties. In this backdrop, the present research was focused towards investigating the differential response of both WDS tolerant and susceptible genotypes of *C. olitorius* subjected to prolonged WDS treatment. To achieve this, we here studied

the phenotypic traits, physiological measures, biochemical attributes, secondary metabolite profile, physical and mechanical properties of tossa jute genotypes following prolonged WDS with an objective to identify and register genotypes with improved stress tolerance as well as fibre quality.

2. Materials and methods

2.1. Chemicals

Sulphosalicylic acid, proline, ninhydrin, acetic acid, orthophosphate, ethanol, methanol and toluene were purchased from Sigma-Aldrich (St. Louis, MO, USA). Folin-Ciocalteu's phenol reagent, sodium carbonate, aluminium chloride, gallic acid and quercetin were purchased from Merck Chemical Supplies (Merck KGaA, Darmstadt, Germany).

2.2. Experimental condition for WDS treatment

All experiments were designed in glass house condition. Based on previous germplasm screening of 600 tossa jute genotypes for germination percentage following field performance, a total of six jute genotypes were selected for our experiment. Amongst these, the WDS tolerant genotypes were OIN 631, OIN 632 and OIN 633 and the susceptible genotypes were OIN 694, OIN 873 and OIN 875. All experiments were conducted for the consecutive two years time period during the months of April to July 2014 and 2015. For each year's experiment, twenty days old tossa jute plants were subjected to progressive water deficit stress (WDS group) by leaving them under water withholding condition for 10 days and then provided recovery irrigation. The control (C group) plants were watered daily to maintain soil water content near to field capacity. The soil type was clay-loam with pH around 6.5–7.5. Recommended agronomic practices were followed to grow the crop (CRIJAF Annual Report, 2013–14). The growing season of *C. olitorius* as a fibre crop is pre-wet season i.e. during March to July. The crop often encounters drought stress, particularly at the early growth stage, i.e. upto 30–40 days after sowing due to the prevailing hot and dry weather condition. However, the jute crop receives high rainfall and humid condition thereafter during its growth period in the South-East Asian region. Keeping this growing condition of the crop, the temperature of glass house was maintained at 32–37 °C with 70–80% relative humidity. After 120 days of experiment in the glass house, plants were examined for different experimental parameters viz. phenotypic traits, physiological measures, biochemical profile and secondary metabolite content, physical and mechanical properties. Ten plants were maintained for each replications of each treatment assigned randomly to ridged plots with water controlling facility (both drainage and irrigation) as per factorial Randomized Complete Block Design (RCBD) with three replications. Each genotype of *C. olitorius* was grown in a plot of six rows of three meter length with 30 cm space between two rows. Three plants from each experimental group were uprooted carefully to record data on morphological and biochemical parameters. Fibre properties of plants were noted after harvesting. For mechanical properties i.e. fibre strength and fineness, five plants from each treatment were retted in retting tank for 21 days. Fibres were extracted and sundried till constant weight and moisture content were achieved.

2.3. Morphological phenotypic traits

We performed analysis of the morphological phenotypic traits by measuring plant height (cm), basal diameter (mm), root length (cm), number of leaves, root weight (gm), stem weight (gm) and whole biomass (gm) of plants under WDS and control condition.

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