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SCREENING OF WATER STRESS TOLERANT SUGAR BEET (*Beta vulgaris* L.) GENOTYPES

R.K. GANAPATI[1*], M.M. RAHMAN[1], R.C. KABIRAJ[2], R. SEN[3] AND M.S. ISLAM[2]

[1]Breeding Division, Bangladesh Sugarcrop Research Institute, Bangladesh;
[2]Soil and Nutrition Division, Bangladesh Sugarcrop Research Institute, Bangladesh;
[3]Department of Agricultural and Industrial Engineering, Hajee Mohammad Danesh Science and Technology University, Bangladesh.

*Corresponding author & address: R.K. Ganapati, E-mail: rkganapati@hotmail.com
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ABSTRACT

Ganapati RK, Rahman MM, Kabiraj RC, Sen R, Islam MS (2016) Screening of water stress tolerant sugar beet (*Beta vulgaris* L.) genotypes. *Int. J. Sustain. Crop Prod.* 11(3), 29-35.

Crop production is severely affected by water stress in Bangladesh while irregular and limited precipitation is the major cause of drought. The use of drought-tolerant cultivars is one of the sustainable methods for coping with water deficiency in such regions. Prior to breeding and introduction of a cultivar, it is necessary to determine the relative drought tolerance of potential parental genotypes. Seventeen sugar beet populations were evaluated under moisture stress and non-stress conditions. Irrigation was conducted at one light and three deep furrow irrigation under stress and non-stress conditions respectively as well as permits natural evaporation. It was found that all of the studied traits were significantly different among the genotypes under stress and non-stress conditions. Cauvery and Srenada perform better in stress environment. The study of the relations among the stress and non-stress conditions revealed that increasing of brix percent lead to increasing of brown sugar yield whereas increasing of chlorophyll content under stress condition lead to decreased root yield. Beside this, stress influences the root length.

Key words: *G×E interaction, sugar beet, drought, brown sugar*

INTRODUCTION

Drought is the most significant environmental stress to crop productivity worldwide (Cattivelli *et al.* 2008; NCDC 2011) an effect that is likely to increase as global climate change progresses (Stern 2006; Keane *et al.* 2009). In the Europe, for instance, on average10% of potential yield is lost annually due to insufficient moisture and in particularly dry years, losses are considerably greater (Qi and Jaggard, 2006). In tropical and sub-tropical regions, sugar beet production depends on continuous irrigation over the growing period. Reduced precipitation and use of underground water resources together increase costs for pumping water from the well for water supply (Ober *et al.* 2005). Sugar beet has high water requirement (Fabeiro *et al*. 2003) and total water consumption for whole growing period is between 900 and 1200 mm (Vahidi *et al*. 2013). However, sugar beet is reputed to be a deep rooting crop and relatively insensitive to water stress (Salter and Goode, 1967). The water use efficiency can be improved through plant breeding and making new varieties less susceptible to water shortage (Blum 2009; Rajabi *et al*. 2009). To produce new cultivars, plant breeders must be able to identify germplasm with increased drought tolerance, and also able to select for this trait on a large scale cheaply and efficiently. In other crops where breeding for drought tolerance has been focused for many years, empirical breeding methods have been the most successful. That is breeders select for high yield in the target environments without necessarily knowing what mechanisms bring about greater yields. A drawback of this technique is that genotype × environment interactions hamper advances and low genetic variation for yield under drought condition contributes to low heritability for yield, making the process very time-consuming (Blum 1988). An alternative approach is physiology-based selection in which lines are selected on the basis of specific traits determined to be beneficial under water deficit condition (Bidinger and Witcombe, 1989). It has been shown that there is genetic diversity for drought tolerance and water use efficiency in sugar beet germplasm (Ober *et al*. 2005; Rajabi *et al.* 2009). Almost all agree, however, that breeding for difficult and complex traits such as drought tolerance could be vastly simplified by identifying morphological characters that are closely linked to yield in water-limited environments. For the indirect trait approach to be successful, the trait must have high genetic correlation with yield, high heritability, and selection method must be applicable (Richards *et al.* 2001). Rajabi *et al.* (2008) described the inheritance and genetic characteristics of carbon isotope discrimination (Δ), a measure of carbon isotope ratio in plant tissues, using a subset of the inbred breeding lines. However, some disadvantages of using as a selection tool, such as the cost of samples, time required to process the samples, and the need for access to expensive mass spectrometry instrumentation. Some traits such as chlorophyll content (Sheshshayee *et al.* 2006), was suggested as alternatives to discrimination. The main objective of the current study was to assess the effects of water stress on some important traits of sugar beet lines.

MATERIALS AND METHODS

The study was carried out at Bangladesh Sugarcrop Research Institute (BSRI) Sub-station, Barisal in December to April, 2015-16 cropping season. Seventeen sugar beet genotypes (Cauvery, Shubhra, HI 0044, HI 0473, SZ 35, PAC 60008, SV 887, SV 889, SV891, SV 892, SV 893, SV 894, Danicia, Aranka, Serenada, Natura and Bellaza) were evaluated under stress and non stress conditions in a split plot experiment on the basis of a randomized complete block design (RCBD) with three replications. The main plots were irrigation treatment with two levels (stress and non-stress) and sub plots were genotypes. The Subhra was used as check. The planting rows were spaced 50 cm apart and the plants were spaced 20 cm apart after thinning. There was one meter spacing between replications and one row on both sides of the replications was left as margin. The plots were irrigated by furrow irrigation method. Under non-stress conditions, the irrigation was carried out under three heavy irrigation and natural evaporation, whereas under stress conditions, one light irrigation after seven days of sowing is applied and permit natural evaporation. Permitting natural evaporation in both the environment the average moisture conservation in stress and non-stress field condition were respectively 19.39% and 34.52%. The soil moisture were measured in gravimetric method. The plots were fertilized with 260 kg urea, 120 kg TSP, 225 kg MoP 100 kg Gypsum, 10 kg Zinc Sulphet, 20 kg Borax and 1.5 ton Cowdung. The traits were recorded during the growing season and at harvest time as follows: to measure leaf chlorophyll content in stress and non-stress conditions, three leaf samples were taken from the randomly selected plants of each plot and their chlorophyll contents were measured by chlorophyll-meter SPAD-502Plus (Konika Minolta, Japan) considering their average as the leaf chlorophyll content of each replication. After harvest, the beet roots were transferred to sub-station laboratory and the weight and length of the roots of each plot was measured after washing them. Then, sucrose content (brix%) was measured by refractometer ATAGO Manual. Other traits brown sugar Yield (BSY) were measured by slicing the beet from a plot and diffuse the slices for sucrose harvest as juice. Then boil the juice to obtain brown sugar (Goor) according to Abdollahian Noghabi *et al.* (2011). Completely randomized experimental block design was used in all experiments and all data were statistically analyzed using STAR Nebula (2013).

RESULTS AND DISCUSSION

Assumptions of ANOVA were met by verifying that the data was normally distributed and homogenous in its variance. The effect of irrigation was significant on root yield (P<0.01) and also on brix%, chlorophyll content and root length (P<0.05) (Table 1). There were significant differences among genotypes for all the traits (Table 1). The interaction effect of genotype and irrigation levels was significant for root yield, chlorophyll content, root length (P<0.01), and for brown sugar yield and brix% (P<0.05) (Table 1).

Table 1. Analysis of Variance (ANOVA) of yield contributing traits under study

Source of Variation	df	Root Yield	Brix%	Brown Sugar Yield	Chlorophyll Content	Root Length
Replication	2	8.44 ^{ns}	0.08^{ns}	0.11^{ns}	7.08^{ns}	2.28^{ns}
Genotype (G)	16	1428.21**	4.98**	15.43**	49.33**	28.21**
Error (a)	32	2.01	0.36	0.121	2.45	1.58
Block (E)	1	7552.53**	171.86*	3.14^{ns}	505.19*	250.98*
G X E	16	6896.68**	2.77*	3.11*	67.95**	11.73**
Error (b)	34	82.95	0.38	0.19	0.82	0.83
CV%		16.26	12.13	18.16	21.73	16.22

Root Yield

Water stress reduced root yield at significance level of 0.01 (Fig. 1). Interaction effect of genotype × irrigation level showed that root yield of genotypes was significantly different (P<0.01) under stress and irrigated conditions (Table 1), with the highest root yield belonging to Cauvery and Serenada genotypes, and the lowest one belonging to HI 0044 and PAC 60008, under non-stress and stress conditions, respectively (Table 2). Such root yield response to water stress was also reported by Mahmoodi *et al.* (2008), and Ober and Rajabi (2011).

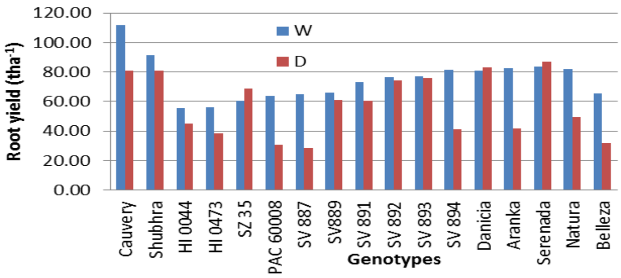

Fig. 1. Root yield of sugar beet genotypes under normal and water stress condition (W- Irrigated, D-Moisture stress)

Brown Sugar Yield (BSY)

Water stress decreased BSY significantly (Fig. 3). Interaction effect of genotype × irrigation level showed that brown sugar yield of genotypes was significantly different under stress and non-stress conditions (P<0.01) (Table 1). The highest BSY belonged to Cauvery and SZ 35 under normal and water stress conditions respectively, whereas the lowest one belonged to SV 887 in both (Table 2). According to Mehdikhani (2011), the highest positive correlation was observed between gross sugar yield and brown sugar yield. Also, the increased sugar content reported earlier by others Kirda (2002), which can indirectly lead to higher sugar yield

(Rajabi *et al.* 2013). Last *et al.* (1983) stated that increasing root yield will result in higher sugar yield, provided that there is no severe reduction in sugar percentage. As shown in Table 2, genotype Cuvery produced high root yield which resulted in high sugar yield, because of no reduction in sugar content and root yield.

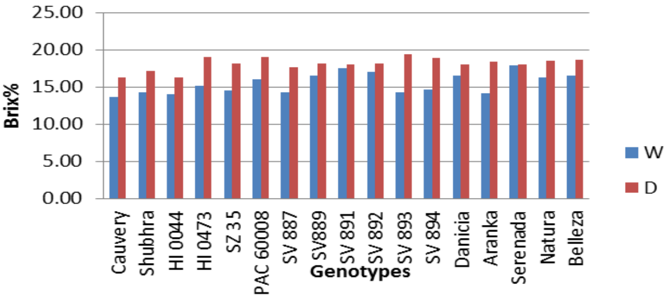

Fig. 2. Brix percent of Sugar beet Genotypes under normal and water stress condition (W- Irrigated, D-Moisture stress)

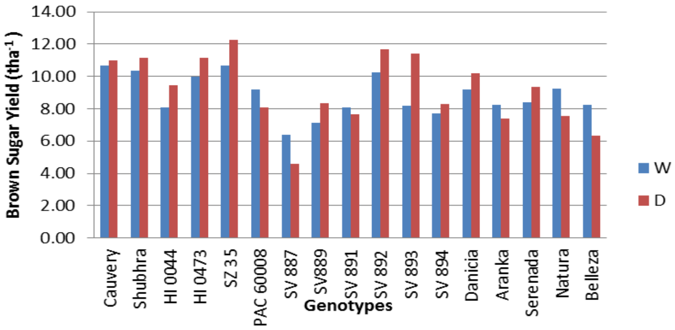

Fig. 3. Brown sugar yield of sugar beet genotypes under normal and water stress condition (W- Irrigated, D-Moisture stress)

Brix Percent (Brix%)

Water stress increases the sugar content in beet (Fig. 2). Effect of genotypes per irrigation level showed significant differences among genotypes (Table 1). The highest brix percentage belonged to Serenada and SV 893, whereas the lowest one belonged to Cuvery and HI 0044 under non-stress and stress conditions, respectively (Table 2). Bloch and Hoffman (2005) reported that water stress leads to increased sucrose concentration in fresh root weight and decreased dry matter. Loomis and Haddock (1967) and Hills *et al.* (1990) stated that such sucrose concentration increase is related to slower water accumulation relative to sucrose and other root dry matter under water stress. Similar results were found by Rytter (2005).

Table 2. Comparison of means sugar beet genotype (G) under moisture stress (D) and irrigated (W) condition and their interaction of sugar beet genotypes. root yield; brown sugar yield; brix percent; chlorophyll content and root length index

Genotypes	Root Yield (t ha^{-1})		Brix%		Brown Sugar Yield (t ha^{-1})		Chlorophyll Content		Root Length (cm)	
	W	D	W	D	W	D	W	D	W	D
Cauvery	111.67 a	81.00 b	13.67 f	16.33 c	10.67 a	11.00 bc	50.67 b-g	46.33 gh	24.33 a	29.67 a
Shubhra	91.33 b	81.00 b	14.33 ef	17.17 bc	10.33 ab	11.17 a-c	52.00 a-d	50.00 fg	23.33 a-d	29.00 a
HI 0044	55.33 j	45.33 fg	14.00 f	16.23 c	8.10 d-f	9.43 de	47.67 e-h	50.67 ef	18.33 f	23.67 cd
HI 0473	56.00 ij	38.67 h	15.17 c-f	19.00 a	10.00 ab	11.17 a-c	47.00 gh	61.33 a	18.83 ef	25.33 c
SZ 35	60.33 hi	68.67 d	14.50 ef	18.17 ab	10.60 a	12.27 a	45.67 h	57.33 bc	20.33 d-f	28.67 ab
PAC 60008	64.00 gh	31.00 i	16.00 b-e	19.00 a	9.20 b-d	8.07 g	47.33 f-h	62.67 a	21.00 b-f	18.67 e
SV 887	65.00 g	28.33 i	14.33 ef	17.67 a-c	6.40 g	4.57 i	48.33 d-h	54.17 c-e	19.50 ef	18.50 e
SV889	66.00 g	61.00 e	16.50 a-c	18.17 ab	7.10 gf	8.37 e-g	48.50 d-h	61.67 a	20.67 c-f	24.33 cd
SV 891	73.00 f	60.67 e	17.50 ab	18.00 a-c	8.10 d-f	7.67 g	49.00 e-h	52.00 d-f	21.00 b-f	25.00 cd
SV 892	76.67 ef	74.33 c	17.00 ab	18.17 ab	10.23 ab	11.70 ab	50.67 b-g	60.33 ab	20.33 d-f	24.67 cd
SV 893	77.17 d-f	76.00 c	14.33 ef	19.33 a	8.17 c-f	11.43 ab	51.00 b-f	46.00 h	21.00 b-f	22.83 cd
SV 894	81.33 cd	41.33 gh	14.67 d-f	18.83 ab	7.70 ef	8.27 fg	51.33 a-e	50.00 fg	22.00 a-e	25.67 bc
Danicia	81.00 c-e	83.00 ab	16.50 a-c	18.00 a-c	9.20 bd	10.20 cd	52.67 a-c	55.67 cd	23.67 a-c	24.67 cd
Aranka	82.50 c	41.67 gh	14.17 f	18.33 ab	8.23 c-f	7.40 gh	52.00 a-d	54.00 c-e	24.00 ab	26.00 bc
Serenada	89.67 c	87.00 a	17.93 a	18.00 a-c	8.40 c-e	11.65 ab	55.00 a	62.00 a	21.33 a-f	22.00 d
Natura	82.23 c	49.33 f	16.33 a-d	18.50 ab	9.27 bc	7.57 g	54.00 ab	57.33 bc	23.00 a-d	24.67 cd
Belleza	65.67 g	32.00 i	16.50 a-c	18.67 ab	8.23 c-f	6.33 h	55.00 a	51.00 ef	24.00 ab	26.00 bc
LSD	2.59		1.02		0.72		1.51		1.50	

Chlorophyll Content

The highest chlorophyll content was observed in Serenada and PAC 60008 and lowest chlorophyll content was seen in SZ 35 and SV 893 under irrigated and water stress conditions, respectively (Table 2 and Fig. 4). Interaction effect of genotype × irrigation level showed significant differences among genotypes (Table 1). Leaf chlorophyll content increases owing to the larger cells per unit leaf weight at water stress. Taize and Zeiger (2001) stated that under mild stress, chlorophyll content per unit leaf area was likely to be increased with the loss of leaf area and in total, the effect of water stress on chlorophyll content widely varies depending on environmental conditions and genotype. In semi-arid regions, drought stress can be followed by salinity and osmotic stress (Chaves *et al.* 2002; Munns 2002) through enhancing leaf salinity level of plants growing under normal conditions (Martinez *et al*. 2003; Tsialtas and Maslaris, 2006). Chlorophyll breakdown under stress is a typical response for limiting photo-inhibition, which increases leaf salinity and chlorophyll accumulation under stress (Niazi *et al.* 2004; Garcia-Valenzuela *et al.* 2005). This increase is due to the higher Mg level as a component of central structure of chlorophyll (Hermans *et al.* 2004). In addition, as a result of the interruption in electron transport pathway and the deterioration of photosynthesis-related tissues under stress, plants cannot optimally use substrate and energy. For the same reason, substrate use efficiency sharply decreases under these conditions (Paknejad *et al.* 2007). Mirakhori *et al.* (2010) mentioned such conditions as the cause of the loss of soybean grain yield. Also, Cook and Scott (1993) observed variations in sugar beet leaves under drought stress including delayed emergence, slow development, loss of assimilates and accelerated senescence. Hydrocarbon delivery from leaves to roots is regarded as a main factor in determining root growth. When stress reduces their delivery, root growth inevitably decreases resulting in the loss of sugar and white sugar yield as the ultimate product of sugar beet. Thus, irrigation withdrawal at more than one stage, irrespective of the growth stage in which it happens, imposes moisture stress to the plants interrupting their physiological growth and causing irreversible injuries to them. In our study, PAC 60008 had the highest chlorophyll content, while showing the lower root yield and BSY under water stress condition.

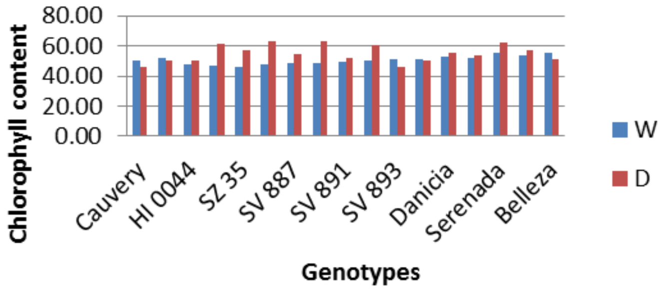

Fig. 4. Chlorophyll content sugar beet genotypes under normal and water stress condition (W- Irrigated, D-Moisture stress)

Root Length

Drought caused considerable morphological changes in root, such as increased root length (Fig. 5). The highest root length was observed in Cuvery both under water stress and normal conditions. Ganapati *et al.* (2015) stated that stated that under light stress, root length have significantly higher compare to non stress one and beet yield insignificantly increase due to increase of root length and that have significant in respect of genotype. Mild water stress affected the shoot dry weight, while shoot dry weight was greater than root dry weight loss under severe stress in sugar beet genotypes (Mohammadian *et al.* 2005).

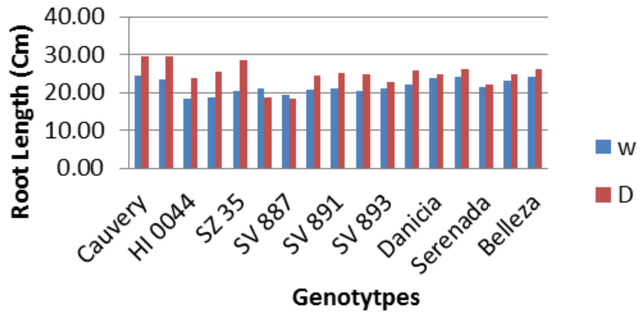

Fig. 5. Root length of sugar beet genotypes under normal and water stress condition (W- Irrigated, D-Moisture stress)

CONCLUSION

Evaluating all seventeen genotypes Cauvery and Srenada perform better in all environments. Although there were differences among the sugar beet genotypes for some plant characteristics under stress conditions, the genotypes' yield performance cannot be predicted from a single trait. Each trait represents a specific reaction of the sugar beet plant to drought stress. Therefore, it is recommended that several criteria be considered to select the suitable sugar beet variety for drought prone area.

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