Agricultural Water Management 201 (2018) 144–151

Contents lists available at ScienceDirect

Agricultural Water Management

journal homepage: www.elsevier.com/locate/agwat

Tolerance of some sugar beet varieties to water stress

El-Sayed A. Mahmoud[a], Mahmoud A. Hassanin[a], Taha I. Borham[b], Eman I.R. Emara[a,*]

[a] Agronomy Department, Faculty of Agriculture, Cairo University, Giza, Egypt
[b] Soil Department, Faculty of Agriculture, Cairo University, Giza, Egypt

ARTICLE INFO

Keywords:
Drought stress
Root yield
Quality
Sugar yield
Varietal tolerance

ABSTRACT

Tolerance of three of sugar beet multigerm varieties: Zwanpoly, England; Halawa, Germany and Heba, Denmark, and two monogerm varieties: Xanadu and Marathon, Denmark to water stress levels of 30, 50 and 70% of field capacity (F.C) which were studied during 2013/2014 and 2014/2015 seasons in the experimental station, Faculty of Agriculture, Cairo Univ., Giza, Egypt. The variety Xanadu produced the highest values of the studied growth traits as dry matter accumulation, chlorophyll content, leaf area index (LAI), relative growth rate (RGR) and net assimilation rate (NAR) at 125, 150, 175 and 200 days post planting as well as root, top and sugar yield, and were of the most tolerant variety according to stress tolerance index (STI), followed by Zwanpoly, Halawa, Heba and Marathon variety in a descending order. Whereas, Marathon was of the highest variety in sucrose, purity and sugar recovery (SR) percentages. Increasing water stress level from 30 up to 70% from F.C was significantly decreased beet growth throughout the growing season. Juice quality (sucrose, purity and SR%) significantly increased as water stress increased up to 70%, while juice impurities and sucrose loss to molasses% (SLM) decreased. A reduction in root yield of 13.6 and 15.6%, sugar yield was obtained by 7.5 and 11.5% and top yield by 14.9 and 36.5% in the 1st and 2nd seasons, respectively which were recorded as water stress levels increased from 30 up to 70%. The highest value of WUE for root and sugar yield where obtained for Xanadu variety at 70% of water stress level.

1. Introduction

Irrigated agriculture is considered the main source of the fresh water resources. About 70% of the total water withdrawals and 60–80% of total consumptive water use are consumed in irrigation (Huffaker and Hamilton, 2007).

Water shortage is of a vital importance in agriculture according to the prevailing arid and semi-arid climate condition. Agricultural production is impossible without optimizing water resources (Kheirabi et al., 1996). In Egypt, sugar production depends mainly on sugar cane and sugar beet crops. Sugar beet share with about 57.61% of total sugar production (2.2 million tons annually), 42.39% being for sugar cane (Sugar Crop CouncilReport, 2017).

Sugar beet (*Beta vulgaris* L.) is a field crop which could be tolerant to drought (Vamerali et al., 2009), however drought stress have an adverse effect on morpho-physiological traits as root, leaves and plant dry weight, leaf chlorophyll and stomatal conductance; root yield of sugar beet genotypes (Moosavi et al., 2017). In this respect, Gharib and El-Henawy (2011) used three irrigation regimes of 40, 55 and 70% soil water depletion on sugar beet yield and quality. They found that increasing water stress significantly decreased leaf area index and net assimilation rate. Other studies reported a reduction in root and sugar yields in water stress conditions. Besheit et al. (1996) used 20%, 40% and 60% of soil water depletion, in root and sugar yields significantly increased when sugar beet was grown constantly under 40% water depletion from the field capacity. They noticed a reduction in sugar yield under the higher level of water depletion which may be attributed to the reduction in root yield and/or metabolic products translocated from leaves to roots. The highest WUE was obtained for 60%. While Mohamed et al. (2000) used 50%, 65% and 80% soil water depletion of field capacity, where they reported the maximum root and sugar yields as well as WUE from 65% soil water depletion. Kiziloglu et al. (2006) and Topak et al. (2011) found that root, leaf and sugar yields were significantly decreased with increasing water deficit in the semi arid regions. The relationship between evapotranspiration and root yield was linear. The WUE was the highest at the lowest irrigation conditions. Masri et al. (2015), Bahmani et al. (2017) and Zare Abyaneh et al. (2017) investigated the effects of water stress levels from 50 up to 100% of the crop water requirement. They found that increasing the amount of irrigated water increased LAI and root and white sugar yields; however sugar content, purity and extractable sugar% were reduced. other studies reported that drought stress decreased Na and K content in

* Corresponding author.
E-mail address: emanemara@agr.cu.edu.eg (E.I.R. Emara).

https://doi.org/10.1016/j.agwat.2018.01.024
Received 23 October 2017; Received in revised form 23 January 2018; Accepted 26 January 2018

beet roots (Mahmoodi et al., 2008; Abd El-Wahab and Nemeat Alla, 2002; while Baigy et al. (2012) and Hoffmann (2014) used water stress from 30% up to 100% of water holding capacity, which they found that Na and K content were not affected by water stress, whereas amino-N content was increased. Last et al. (1983) found that the concentration of K and Na were considered as impurities in the extracted root sap which have been shown to be inversely related to the amount of extractable sugar.

Regarding tolerance variety of sugar beet to water stress, Shehata et al. (2000) evaluated four sugar beet varieties (Top, M9340, Del. 1939 and Raspoly) under different levels of available soil water (100, 75 and 25%). They found that growth and yield of sugar beet shoot were affected by water deficit more than the roots. Sucrose and purity% increased, but sugar yield decreased under water stress. Raspoly and Del 1939 varieties were not affected by water stress level but M9340 was highly sensitive and top was moderately sensitive. Ober et al. (2005) evaluated 46 sugar beet genotypes with diverse genetic backgrounds. They found significant genotypic differences for their stomatal conductance, succulence index, specific leaf weight and osmotic adjustment, but not for photosynthetic rate, relative water content or total water use. Droughted sugar yield was positively correlated with soil water extraction and negatively correlated with relative leaf expansion rate. There was high positive correlation between transpiration rate and sugar yield under the irrigated conditions. Tsialtas et al. (2012) tested 3 sugar beet varieties (Europa, Corsica and Rival) under drought for a month for WUE and defoliation. They found significant differences among varieties in WUE, but there were of no significant differences in defoliation. Hussein et al. (2008) compared two varieties (FD99 and Cardova) under 40, 60 and 80% of the maximum water holding capacity (WHC) of the soil. They found that the interaction between varieties and WHC was significant for total chlorophyll. Farshdfar et al. (2012) and Hesadi et al. (2015) evaluated different sugar beet genotypes to drought stress, stress tolerance index (STI), stress susceptibility index (SSI), tolerance index (Tol), yield stability index (YSI), drought resistance index (DI), yield index (YI) and abiotic tolerance index (ATI). They indicated that STI, DI and YSI can be used as most suitable indicators for screening of the drought tolerance genotypes.

The target of this investigation was to study and evaluate varietal tolerance of sugar beet to water stress through determining growth performance for root and sugar yields and juice quality traits as well.

2. Materials and method

2.1. Experimental site and soil properties

Two field experiments were designed and carried out in the experimental station, faculty of Agriculture, Cairo University, Giza, Egypt during 2013/2014 and 2014/2015 seasons. Mechanical and chemical analysis of the upper soil of 40 cm of the experimental sites revealed that soil type was clay loam with sand of 41.5 and 42.5%, silt 24.9 and 26.2%, clay 33.6 and 31.3%, available N 0.095 and 0.095%, P 0.08 and 0.09%, K 0.66 and 0.68%, pH 8.47 and 8.68 and Ec (dS m^{-1}) 0.52 and 0.57 in the first and second seasons, respectively.

2.2. Studied treatments

2.2.1. Water regimes

Three levels of water stress (30, 50 and 70% of field capacity) which were used. The TDR 300 was used to measure the available soil water, and quantify their amount;

$$Q_w = [D_p(Q_f - Q_w)*R_l]*areaperplot$$

Where: $\mathbf{Q_w}$: Amount of requested water per plot (m^3 $plot^{-1}$), $\mathbf{D_p}$: Level of depletion (as 0.3 or 0.5 or 0.7), $\mathbf{Q_f}$: Field capacity (41%), $\mathbf{Q_w}$: Wilting point (20%) and $\mathbf{R_l}$: Root length (cm) as reported by Blaney and Criddle (1962).

2.2.2. Sugar beet varieties

Three multigerm varieties: Zwanpoly, England; Halawa, Germany and Heba, Denmark, and two monogerm varieties: Xanadu and Marathon, Denmark which were obtained from the Sugar Crops Research Institute, Agriculture Research Center, Egypt.

2.3. Experimental design, sugar beet plantation and some agricultural practice

A split plot design with four replicates was used, where water regimes were randomly arranged in the main plots whereas varieties in the sub plot. The sub plot area was 15 m^2 and consisted of five ridges of 5 m in length and 60 cm apart and 17.5 cm between hills. Sowing was on 23th and 9th of October in 2013/2014 and 2014/2015 seasons. Field was immediately irrigated post planting. Seedlings were thinned at 4–6 leaf stage (40 days from sowing) to ensure simple plant per hill. Amount of 30 kg P_2O_5 fed^{-1}[1] in the form of superphosphate (15.5%P_2O_5) was applied at sowing. Nitrogen fertilizer at a rate of 100 kg N fed^{-1} in the form of ammonium nitrate (33.5% N) was added in two doses after thinning and 4 weeks later using 48 kg K_2O fed^{-1} in the form of Potassium Sulphate (48%K_2O) was applied with the first dose of Nitrogen fertilizer. Other cultural practices were carried out as recommended. Harvest of sugar beet plants took place at 200 days from sowing in each season.

2.4. Studied traits

2.4.1. Growth traits

Root, top and plant dry weight (g) were determined using a sample of 5 plants (at 125, 150, 175and 200 days from sowing) from each plot after drying in an air farced oven at 70° C till constant weight. Leaf area per plant (LA-cm^2) and leaf area index (LAI) at sampling dates using digital area meter model U3100 (Watson, 1947).

$$\boldsymbol{LAI = \frac{LA}{P}}$$

= Chlorophyll content (mg m^{-2}) at sampling dates was measured using chlorophyll meter (SPAD 502 value); these units were transformed to mg m^{-2} according to Monje and Bugbee (1992) as follows;

$$Chlorophyllcontent = 80.05 + (10.4*SPADvalue)$$

Relative growth rate (RGR- g g^{-1} $week^{-1}$) (Watson, 1947);

$$RGR = \frac{\ln W_2 - \ln W_1}{T_2 - T_1} =$$

Net assimilation rate (NAR- g cm^{-2} $week^{-1}$) (Radfords, 1967);

$$NAR = \frac{(W_2 - W_1)(\ln LA_2 - \ln LA_1)}{(T_2 - T_1)(LA_2 - LA_1)}$$

2.4.2. Juice quality

At harvest a random sample of 10 plants from each sub plot was taken randomly and the following traits were determined according to the Delta Sugar Company, Kafr El-Sheikh, Egypt.

Total soluble solids (T.S.S)% was determined by using digital refractometer, model PRI (ATAGO). Sucrose percentage was determined by using sacharometer on lead acetate extract of fresh macerated roots (Carruthers and Oldfield, 1960). Potassium and sodium were determined in the digested solution using flame photometer (Brown and Lilleland, 1964). Amino nitrogen percentage was determined using Hydrogenation method (Pregel and Grant, 2018). Juice impurities according to Carruthers and Oldfield (1960);

$$Impurities\% = ((K + Na)*0.0343) + (alphaamino - N*0.094) + 0.29$$

[1] Feddan = 0.42 ha.