Agricultural Water Management 188 (2017) 29–35

Contents lists available at ScienceDirect

Agricultural Water Management

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

Association of photosynthetic traits with water use efficiency and SPAD chlorophyll meter reading of Jerusalem artichoke under drought conditions

Darunee Puangbut[a,b], Sanun Jogloy[a,b,*], Nimitr Vorasoot[a]

[a] Department of Plant Science and Agricultural Resources, Faculty of Agriculture, Khon Kaen University, Khon Kaen, 40002, Thailand
[b] Peanut and Jerusalem Artichoke Improvement for Functional Food Research Group, Khon Kaen University, Khon Kaen, Thailand

ARTICLE INFO

Article history:
Received 27 November 2016
Received in revised form 19 March 2017
Accepted 1 April 2017
Available online 11 April 2017

Keywords:
Gas exchange
SCMR
Water stress
Helianthus tuberosus L.

ABSTRACT

The impact of water stress on plant growth, tuber yield and inulin content has been widely studied but there is limited information on the effect of drought on photosynthetic characteristics. Therefore, this study was to investigate the effect of water stress on photosynthetic characteristics in Jerusalem artichoke genotypes with different levels of drought tolerance. Two experiments were conducted in rhizobox under greenhouse conditions during August to October in 2015 and 2016. A factorial experiment in randomized complete block design with three replications was used. Factor A were two water regimes (irrigated = field capacity; (FC) and water stress) and factor B were three Jerusalem artichoke genotypes. Data were recorded for relative water content, SPAD chlorophyll meter reading (SCMR), photosynthetic characteristics and water use efficiency (WUE) at 7 and 30 days after imposing drought. Leaf area and dry matter was recorded at 30 days after imposing drought. Our results revealed that drought caused a greater reduction in stomatal conductance (g_s), net photosynthetic rate (P_n), leaf area and biomass production than in other traits measured. In contrast, WUE and SCMR were increased under drought conditions. However, g_s and P_n decreases were less in resistant Jerusalem artichoke genotypes than in susceptible genotypes. Also, resistant genotypes had higher WUE increases than susceptible genotypes. Improved P_n combined with high WUE could contribute to higher biomass production. Interestingly, SCMR was associated with P_n and this trait could be used as surrogate trait for improved P_n under drought conditions.

1. Introduction

Jerusalem artichoke is used for many purposes such as human food, animal feedstock, and ethanol production (Yang et al., 2015). Recently Jerusalem artichoke tuber has also been reported as functional food high in inulin (Radovanovic et al., 2015) and other traits thought to reduce the risk of diabetes, cardiovascular diseases, obesity, stroke and cancer (Watzl et al., 2005; Roberfroid, 2007).

Large areas of Jerusalem artichoke are grown under rain-fed conditions. The crop is grown successfully under rain-fed conditions in the semi-arid tropics in Thailand, where drought is a major contributor to production losses. Although Jerusalem artichoke has been reported as hardy plant, drought causes severe yield loss. Irrigation is still necessary for commercial production (Pimsaen et al., 2010; Ruttanaprasert et al., 2016a).

Drought is expected to increase in frequency and severity in the future as a result of climate change, mainly as a consequence of decreases in regional precipitation but also because of increasing evaporation driven by global warming. Drought stress not only reduces yield and quality, it also may reduce inulin accumulation in tubers (Monti et al., 2005a; Gao et al., 2011; Ruttanaprasert et al., 2014; Puangbut et al., 2015). While drought induced yield reductions of 20–98% had been reported (Conde et al., 1991; Ruttanaprasert et al., 2014, 2016a), drought's effect on inulin content varies dependent on severity and length of the drought, with some studies showing increased inulin content when grown under mild water stress (Monti et al., 2005b; Vandoorne et al., 2012; Puangbut et al., 2015).

Most previous research on effects of drought has been focused on growth, yield and inulin content, with few studies of drought effects on photosynthetic characteristics. Monti et al. (2005a)

* Corresponding author at: Department of Plant Science and Agricultural Resources, Faculty of Agriculture, Khon Kaen University, Khon Kaen, 40002, Thailand.
E-mail address: sjogloy@gmail.com (S. Jogloy).

http://dx.doi.org/10.1016/j.agwat.2017.04.001
0378-3774/

reported that leaf net photosynthesis was slightly reduced by moderate water stress under rain-fed conditions. Studies on the effect of severe water stress on photosynthesis and on genotypic variation under water-limited control environments are lacking.

Water use efficiency (WUE) and chlorophyll density have been identified as drought resistant traits and could be used as selection criteria for drought resistance trait in peanut (Arunyanark et al., 2008; Songsri et al., 2009; Puangbut et al., 2009). SPAD chlorophyll meter reading (SCMR) is a tool for rapid assessment of chlorophyll density in several crops (Songsri et al., 2009; Jangpromma et al., 2010; Darkwa et al., 2015). Therefore, SCMR can be used as a screening tool for drought resistant traits in many plant species. However, there were a few studies in Jerusalem artichoke. Recent report has demonstrated that SCMR could be used as a selection tool for harvest index and tuber yield in Jerusalem artichoke (Ruttanaprasert et al., 2016b). Very limited information has been available for the relationships between drought resistant traits and photosynthetic rate under drought conditions.

A better understanding of drought resistant traits associated with photosynthesis should be useful in improving yield under drought conditions. Selection of superior Jerusalem artichoke genotypes for their ability to maintain high photosynthesis under water stress may help breeders to identify Jerusalem artichoke genotypes with drought tolerance. The objective of this study was to investigate the effect of water stress on photosynthetic characteristics in three Jerusalem artichoke genotypes.

2. Materials and methods

2.1. Experiment conditions and plant materials

Two experiments were conducted in rhizobox under greenhouse conditions during August to October 2015 and August to October 2016 at the Field Crop Research Station of Khon Kaen University located in Khon Kaen province, Thailand.

The experimental treatments were arranged in a 2 × 3 factorial experiment in randomized complete block design with three replications. Factor A consisted of two water regimes including irrigated (field capacity; FC) and water stressed, and factor B included three Jerusalem artichoke genotypes (JA 5, JA 60 and HEL 65) with differences in their drought tolerant index (DTI) and tuber yield reduction (Ruttanaprasert et al., 2014, 2015). JA 5 is drought resistant genotype with high DTI for root traits and high reduction in tuber yield under drought conditions. JA 60 was identified as a drought resistant genotype with high DTI for root traits coupled with low reduction in tuber yield under drought conditions. HEL 65 is susceptible genotype with low DTI for root traits combined with high reduction in tuber yield under drought conditions.

2.2. Rhizobox preparation and crop management

Rhizobox with the dimension of 10 cm in thickness, 50 cm in width and 120 cm in height was used. Rhizoboxs were filled with 92 kg of dry soil up to a height of 115 cm. The soil was uniformly packed from the top to the bottom of the box. Seedlings were transplanted into a rhizobox at the V4 stage (4th leaf sprouted, Paungbut et al., 2015). Seedlings were grown at the center of rhizobox. Fertilizer (15-15-15) was applied at 15 days after transplanting (DAT) at a rate of 1.56 g per rhizobox.

Before planting, each rhizobox was watered to FC to a depth of 35 cm for crop establishment and continued until 15 DAT. At 16 DAT, the water stress treatment was imposed by withholding water for 30 days. The irrigated treatment was maintained at FC throughout the crop growth cycle at 1-day intervals. Soil moisture contents at FC and permanent wilting point (PWP) were determined to be 14.08% and 4.66%, respectively, using the pressure plate method. The amount of water applied was based on crop water requirements using the Doorenbos and Pruitt (1992) methodology along with water loss from surface evaporation as described by Singh and Russell (1981).

Crop water requirement was calculated using the methods described by Doorenbos and Pruitt (1992):

$$\text{ET crop} = \text{ETo} \times \text{Kc}$$

where ET crop = crop water requirement (mm/day), ETo = evapotranspiration of a reference plant under specified conditions calculated by pan evaporation method, Kc = the crop water requirement coefficient for sunflower, which varies with genotype and growth stage. As crop coefficient for Jerusalem artichoke is not available in the literature, the crop coefficient for sunflower (Monti et al., 2005a) was used because sunflower and Jerusalem artichoke are closely related species and their morphological characters are similar.

Soil evaporation (Es) was calculated as (Singh and Russell, 1981):

$$Es = \beta \times \left(\text{Eo}/\text{t}\right)$$

where Es = soil evaporation (mm), β = light transmission coefficient measured depending on crop cover, Eo = evaporation from class A pan (mm/day), t = days from the last irrigation

2.3. Soil moisture content

Soil moisture content was measured by gravimetric method using micro auger at 30 days after imposing drought at 10, 25, 45, 65, and 85 cm of soil depths as 10 cm in thick-ness of rhizobox. The soil samples were collected and soil fresh weights were taken immediately. The soil samples were oven dried at 105 °C until for 72 h or until weights were constant and soil dry weight was determined. Soil moisture content for each rhizobox was calculated as:

$$\text{Soil moisture content} = \left[\frac{\text{wet weight} - \text{dry weight}}{\text{dry weight}}\right] \times 100$$

2.4. Relative water content (RWC)

Relative water content (RWC) was measured at was measured at 7 and 30 days after imposing drought. The third fully-expanded leaf from the top of the main stem was sampled between 10:00 h to 12:00 h. After recording the fresh weight, turgid weight was measured by placing the leaf sample in water for 8 h, blotting dry and weighing. Leaf dry weight was measured after oven-drying at 80 °C for 48 h. RWC was computed by the following formula:

$$\text{RWC} = \left[\frac{\text{fresh weight} - \text{dry weight}}{\text{turgid weight} - \text{dry weight}}\right] \times 100$$

2.5. Leaf gas exchange

Leaf gas exchange was measured at 7 and 30 days after imposing drought by using a LI-6400XT portable measuring system (LiCor, Inc., Lincoln, NE, USA) with a 6400-02B LED source providing a PPFD of 1500 μmol m^{-2} s^{-1} and temperature was set at 25 °C. CO_2 concentration was set at 400 μmol m^{-2} s^{-1} and relative humidity at 70%. Net photosynthetic rate (P_n), transpiration rate (E), and stomatal conductance (g_s) were collected from six plants per treatment. Water use efficiency (WUE) was computed as net photosynthetic rate divided by transpiration rate.