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Variation of inulin content, inulin yield and water use efficiency for inulin yield in Jerusalem artichoke genotypes under different water regimes

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ABSTRACT

The information on genotypic variation for inulin content, inulin yield and water use efficiency of inulin yield (WUEi) in response to drought is limited. This study was to investigate the genetic variability in inulin content, inulin yield and WUEi of Jerusalem artichoke (*Helianthus tuberosus* L.) under different water regimes. A field experiment was conducted for two years during September to January 2010/2011 and 2011/2012. A strip plot design with four replications was used in both years. Horizontal factors were three irrigation levels (W1 = 100% evapotranspiration (ET), W2 = 75% ET and W3 = 45% ET) and vertical factors were 12 Jerusalem artichoke genotypes. Data were recorded for inulin content, inulin yield and WUEi at harvest. Significant differences among Jerusalem artichoke genotypes were observed for inulin content, inulin yield and WUEi under W1, W2 and W3 in both years. There were five genotypes (HEL 253, HEL 53, HEL 256, HEL 65 and CN 52867) that exhibited consistently high inulin content and inulin yield across water regimes in both years. Inulin content was increased under W2 conditions but not inulin yield, while WUEi was increased under both W2 and W3 conditions. CN 52867 and HEL 65 were the genotypes with the highest inulin content and inulin yield under limited water conditions in both years. Furthermore, these genotypes showed high WUEi and drought tolerance indices under drought conditions in both years. Improvement of inulin content combined with high WUEi could have contributed to higher inulin yield under limited water conditions. The information on genotypic variation in inulin content and WUEi under drought conditions may have application in genetic improvement of drought resistance in Jerusalem artichoke.

1. Introduction

Jerusalem artichoke (*Helianthus tuberosus* L.) originated in North America, and has been introduced to many countries for immediate uses and further development particularly in relation to lower production cost and drought tolerance (Denoroy, 1996). Jerusalem artichoke is used for many purposes such as human food, animal feedstock and ethanol production. Currently, it is important as a source of inulin.

Inulin is a polydispers fructan, which has a degree of polymerization between 4-150 (Baldini et al., 2011). The fructans can be used as dietary fiber in the food industry, and fructose resulting from fructan hydrolysis can be used as a low calorie sweetener and has several uses in the non-food medical and pharmaceutical industries (Frese, 1993). Due to these properties, inulin is considered a functional food ingredient.

However, inulin or fructan is dependent upon on many factors such as photosynthesis and temperature (Schubert and Feuerle, 1997; Kocsis et al., 2008). Moreover, low temperature is an important factor affecting growth, tuber yield and inulin yield of Jerusalem artichoke (Kocsis et al., 2008; Puangbut et al., 2012; Ruttanaprasert et al., 2013). Although inulin content responses to low temperature have been extensively studied in this species, the impact of water stress has received little attention.

Drought is a major abiotic stress affecting yield and quality of Jerusalem artichoke as it reduces inulin accumulation in tubers (Gao et al., 2011; Conde et al., 1991; Schittenhelm, 1999; Monti et al., 2005a). Previous study showed that the severity of

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drought strongly influenced tuber yield and inulin content (Monti et al., 2005b). Severe water stress decreased inulin accumulation (Monti et al., 2005a), while moderate stress increased inulin content (Monti et al., 2005b; Vandoorne et al., 2012). Although inulin content benefits of mild stress conditions have been demonstrated, the studies involved a limited number of genotypes and inulin yield responses are not fully understood.

In addition, Losavio et al. (1997) reported that water use efficiency for tuber yield (WUEy) was increased with drought conditions. Recently, Yang et al. (2010) reported that WUEy was increased under limited water conditions and this could be due to the increasing in tuber yield. However, there is limited information on genotypic variation for water use efficiency for inulin yield (WUEi) under drought conditions.

Jerusalem artichoke has been reported as a hardy plant that can be grown at low cost with low input techniques and less desirable soils (Kays and Nottingham, 2008). Jerusalem artichoke has been reported non-tolerant to water stress conditions because drought may strongly influence its dry matter production (Monti et al., 2005a; Schittenhelm, 1999; Conde et al., 1991), but the impact of water stress on inulin yield and WUEi remains poorly documented.

Information on genetic variability for economically important traits is important for plant breeding. Screening for water use efficiency for inulin yield in a large number of germplasm accessions has not been reported in the literature. Studies on the effects of drought on inulin content and inulin yield conducted so far have been limited to a small number of accessions (Gao et al., 2011; Zhang et al., 2010; Monti et al., 2005a), and information on genotypic variation in inulin content and inulin yield under drought conditions is lacking. Knowledge on the responses of Jerusalem artichoke genotypes to drought is important for selection of Jerusalem artichoke genotypes with good performance under drought conditions. The objectives of this study were to investigate the genetic variability in inulin content, inulin yield and WUEi of Jerusalem artichoke subjected to different water regimes.

2. Materials and methods

2.1. Plant material and experimental design

Twelve Jerusalem artichoke genotypes were studied during two growing seasons. They included seven genotypes (JA 1, JA 3, JA 16, JA 38, JA 60, JA 89 and CN 52867) from the Plant Gene Resources of Canada (PGRC), four genotypes (HEL 256, HEL 65, HEL 53 and HEL 253) from the Leibniz Institute of Plant Genetics and Crop Plant Research (IPK) of Germany and [JA 102 × JA 89] − 8 a hybrid clone of Khon Kaen University, Thailand.

A field experiment was conducted during two years at the Field Crop Research Station of Khon Kaen University located in Khon Kaen province, Thailand (16°28′N, 102°48′E, 200 masl) during September 2010 to January 2011 and September 2011 to January 2012. The soil type was a Yasothon series (Yt: fine-loamy; siliceous, isohypothermic, Oxic Paleustults). A strip plot design with four replications was used in both years. Horizontal factors were three irrigation levels (W1 = 100% evapotranspiration (ET), W2 = 75% ET and W3 = 45% ET)) and vertical factors were 12 Jerusalem artichoke genotypes. Plot size was 2 × 4 m with a spacing of 50 cm between rows and 30 cm between hills in a row.

2.2. Crop management

Pre-sprouted seed tubers were used as planting materials. To prepare the sprouted seed tubers, the tubers were cut into small pieces each of which had 2–3 buds/piece. The tuber pieces were incubated in plastic bags containing moist coconut peat at the bottom and the top of the bags for 7 days. The plastic bags were kept opened for good aeration. The tuber pieces with active buds and roots were further transferred to plug plastic trays containing a mixture 1:1 soil:burnt rice husk medium about 7 days for germination. The two leaf-sprouted seedlings were then suitable for transplanting in the plot. One seedling was transplanted per hill. Fertilizer formula 15–15–15 of $N–P_2O_5–K_2O$ was applied at 30 days after transplanting at a rate of 156 kg ha^{-1}. A Terraclor (quintozene 24% W/V EC) was applied monthly for 3 months after transplanting at the rate 25 mL/20 L of water for the control of stem rot (*Sclerotium rolfsii*).

2.3. Water regimes

A drip-irrigation system (Super Typhoon®, Netafim Irrigation equipment & Drip systems, Israel) was installed with a distance of 20 cm between emitters and a spacing of 50 cm between drip lines on the soil surface mid way between Jerusalem artichoke rows and fitted with a pressure valve and water meter to supply a uniform measured amount of water. Before transplanting, water was supplied uniformly to the experiment field to field capacity (FC) to a depth of 10 cm using the drip irrigation system for crop establishment until 14 days after transplanting (DAT).

Different water gradients were supplied by the line source sprinkler to the crop at 14 DAT until harvest. The line-source sprinkler system provided three water gradients, which hereafter are referred to as W1 (100% ET), W2 (75% ET) and W3 (45% ET), respectively. The water gradients were dependent on the distances from the line source, which was installed at the center of the field. The water supplied to W1 was expected to be equivalent to the crop water requirement (ET crop). Water supplied to W2 was estimated as 75% of that supplied to W1, and water supplied to W3 was 45% of that supplied to W1.

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).

Total crop water use for W1 was calculated as the sum of transpiration and soil evaporation. Crop water requirement was calculated using the methods described by Doorenbos and Pruitt (1992):

$$ET_{crop} = ET_o \times K_c$$

where ET_{crop} = crop water requirement (mm/day), ET_o = evapotranspiration of a reference plant under specified conditions calculated by pan evaporation method, K_c = the crop water requirement coefficient for sunflower, which varies with genotype and growth stage. Soil evaporation (E_s) was calculated as (Singh and Russell, 1981):

$$E_s = \beta \times \left(\frac{E_o}{t}\right)$$

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

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.

2.4. Soil moisture status

Soil moisture content was measured by gravimetric methods at the depths of 30, 60 and 90 cm at planting and harvesting. Soil moisture content at planting was used for calculating the correct amount of water to be applied to the crop, and soil moisture at harvest was