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Effects of water stress on total biomass, tuber yield, harvest index and water use efficiency in Jerusalem artichoke

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ABSTRACT

The objectives of this study were to determine the effects of drought on tuber yield, total biomass, harvest index, water use efficiency of tuber yield (WUEt) and water use efficiency of biomass (WUEb), and to evaluate the differential responses of Jerusalem artichoke (JA) varieties under drought stress. The 3 × 5 factorial combinations of three water regimes (Field capacity (FC), 50% available soil water (50%AW) and 25%AW), and five JA varieties (JA 60, JA 125, JA 5, JA 89 and HEL 65) were arranged in a pot experiment in a randomized complete block design with four replications for two years. Data were recorded for tuber dry weight, total biomass, harvest index, WUEt and WUEb at harvest. Drought reduced tuber dry weight, total biomass, harvest index, WUEt and WUEb, and reductions were more severe under the severe drought stress of 25%AW. Varieties were significantly different for all traits under drought and well-watered conditions. The JA varieties were classified into three groups. The first category was comprised of the JA 5 variety with high tuber yield potential and low drought tolerance, the second category consisted of JA 60 and JA 125 varieties with low tuber yield potential and high drought tolerance, and the third group included JA 89 and HEL 65 varieties with low tuber yield potential and low drought tolerance. The multiple regression analysis showed that tuber yield, total biomass and harvest index at 50%AW and 25%AW depended largely on the reductions of tuber yield, total biomass and harvest index under drought. Therefore, the results of this study recommend that the selection of JA genotypes with low reduction in yield under drought stress could be a criterion in drought resistance breeding programs for development of JA varieties with high tuber yield under drought stress. JA with drought tolerance in this study means high tuber yield under drought conditions. JA 5 had high yield and WUEt across water regimes and could be used as parental source for drought tolerance breeding programs in further research.

1. Introduction

Jerusalem artichoke (*Helianthus tuberosus* L.) is an important crop native to North America (Kays and Nottingham, 2008). Inulin containing tubers of Jerusalem artichoke with anti-cancer and immune enhancing properties can be consumed directly either as a vegetable or processed food to make several value-added products that are beneficial to health such as pharmaceutical products, food additive (Barclay et al., 2010) and feed additive (Sritiawthai et al., 2013). It is also used as an energy crop for bioethanol production (Sachs et al., 1981). As gasoline price have increased, the crop has received more attention for use as raw material for biofuel production (Li et al., 2013; Kim et al., 2013).

Temperature increase in certain seasons around the world is the result of global warming leading to increased rates of water evaporation and thus surface drying, thereby increasing intensity and duration of drought (Trenberth, 2011). Drought is increasingly an important factor affecting crop production worldwide, and it also reduces tuber yield of Jerusalem artichoke (Conde et al., 1991; Losavio et al., 1997; Schittenhelm, 1999; Monti et al., 2005; Liu et al., 2012; Ruttanaprasert et al., 2014). Although effective irrigation scheduling may help in water saving for an irrigated crop in the short-term, breeding and selection of varieties that are more

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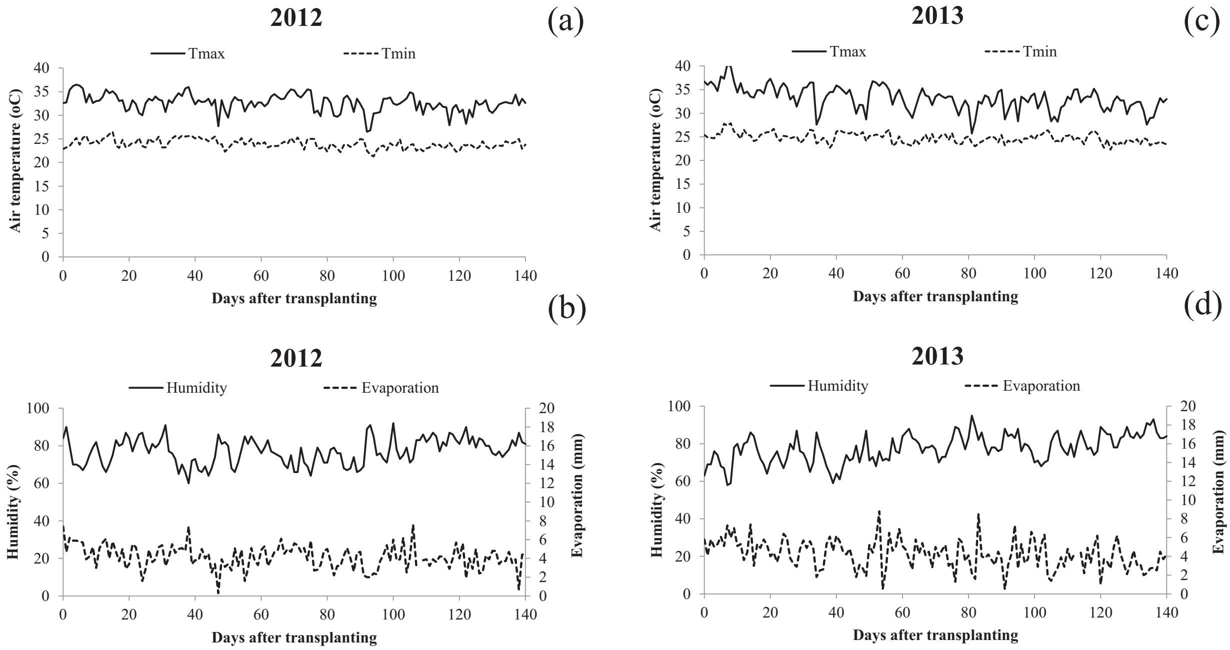

Fig. 1. Maximum temperature ($T_{\max}$), minimum air temperature ($T_{\min}$) (°C), evaporation (mm) and humidity (%) in 2012 (a), (b) and 2013 (c), (d).

tolerant to drought should be the best long-term solution to the problem.

Effects of drought stress on tuber dry weight, biomass (Conde et al., 1991; Losavio et al., 1997; Schittenhelm, 1999; Monti et al., 2005; Liu et al., 2012; Ruttanaprasert et al., 2014) harvest index (Conde et al., 1991; Ruttanaprasert et al., 2015) and water use efficiency (Conde et al., 1991; Janket et al., 2013) of Jerusalem artichoke has been reported in several studies. In temperate regions, drought stress reduced Jerusalem artichoke tuber yield by 20% (Conde et al., 1991; Losavio et al., 1997) but increased water use efficiency by 7–35% and harvest index by 21% (Conde et al., 1991). In potato, terminal drought slightly reduced harvest index by 17% (Schafleitner et al., 2007). In tropical regions, drought stress with heat stress can cause tuber yield loss of 29% and biomass loss of 53%, however, some Jerusalem artichoke varieties can sustain yield to some extent under drought (Ruttanaprasert et al., 2014). Meanwhile, mild water stress caused 7.1% and 9.6% reductions in water use efficiency of biomass and tubers, respectively, but severe drought stress caused slight increases in water use efficiency of biomass (4.2%) and tubers (5.4%) (Janket et al., 2013). Drought also increased water use efficiency in cassava (Olanrewaju et al., 2009). Genotypic variations in tuber dry weight, biomass (without root mass) (Ruttanaprasert et al., 2014), harvest index (Ruttanaprasert et al., 2015) and water use efficiency (Janket et al., 2013) were found and used as selection criterion for Jerusalem artichoke productivity under drought stress.

The physiological basis for achieving higher yields under drought stress might indicate or show an underlying mechanism from where improved strategies could be developed to enhance the effectiveness and progress in breeding programs for drought resistance in Jerusalem artichoke. In one of the recently conducted studies, drought resistant varieties had higher tuber dry weight and biomass compared to drought-sensitive varieties (Ruttanaprasert et al., 2014). Higher crop productivity under drought stress of resistant varieties could be due to their ability to produce higher yield under well-watered conditions, i.e. higher productivity potential, or its ability to maintain high production, i.e. less yield reduction under drought stress (Pimratch et al., 2008). However, the relative contributions of these two attributes to high crop yield of Jerusalem artichoke under drought conditions of resistant varieties have not been studied.

Therefore, the objectives of this study were to determine the effects of drought on tuber yield, total biomass, harvest index, water use efficiency of tuber (WUEt) and water use efficiency of biomass (WUEb), and to evaluate the differential responses of Jerusalem artichoke varieties under drought stress.

2. Materials and methods

2.1. Experimental design and treatments

A 3 × 5 factorial experiment was conducted for two years (May–September in 2012 and May–September in 2013) in the greenhouse and all the 15 treatments were replicated 4 times and arranged in a randomized complete block design (RCBD) at the Field Crop Research Station of Khon Kaen University located in Khon Kaen province, Thailand (16°28′N, 102°48′E, 200 m above mean sea level). There were 5 pots in each experimental unit with one plant in each pot. Three water regimes (defined as field capacity (FC), 50% available soil water (50%AW) and 25% available soil water (25%AW)) were assigned in factor A, and five varieties of Jerusalem artichoke (JA 60, JA 125, JA 5, JA 89 and HEL 65) were assigned in factor B. Five Jerusalem artichoke varieties with different drought tolerance levels based on tuber yield under drought stress were selected (Ruttanaprasert et al., 2014). JA 60 and JA 125 had low tuber yield, JA 5 gave intermediate tuber yield, and JA 89 and HEL 65 gave highest tuber yield under drought stress (Ruttanaprasert et al., 2014).

2.2. Pots and plant preparation

Prior to planting, 20 kg of dry soil was loaded into 300 plastic pots with a diameter of 35 cm and height of 25 cm. The soil was equally divided into two layers to create uniform bulk density (of 1.61 g cm^{-3}) in each pot. The pots were first filled with 10 kg of dry soil taken from a depth of 10 cm below the soil surface to create