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Research paper

Root responses of Jerusalem artichoke genotypes to different water regimes

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ABSTRACT

The objective of this study was to determine effects of drought on selected root growth parameters and develop relationships between root parameters and tuber yield for selected Jerusalem artichoke (JA) genotypes. Three water regimes (Field capacity, 50% available soil water (AW) and 25% AW) and five JA varieties (JA 60, JA 125, JA 5, JA 89 and HEL 65) were planted with factorial treatments in a randomized complete block design with four replications. Data on root dry weight (RDW) and root: shoot ratios (RSR) were measured manually. Root diameter (RD), root length (RL), root surface area (RSA) and root volume (RV) were collected at harvest. Drought tolerance indices (DTI) were calculated for all root parameters. Drought reduced all root parameters and DTI but increased RSR in JA 60, JA 125, JA 5, and HEL 65. JA 125 had high values for all root traits and DTI of these traits under drought stress. JA 60 had high DTI of RDW, RD and RSR under mild and severe water stress. JA 5 had high DTI of RDW, RD, RL, RSR and RV under drought conditions. JA 89 and HEL 65 performed well for RDW, RD, RL and low DTI of all root characteristics. DTI for root parameters were positively correlated with tuber dry weight under mild and severe water stress. The JA 5, JA 60 and JA 125 varieties showed high DTI for some root traits, indicating that better root parameters contributed to higher tuber yield under drought stress.

1. Introduction

Jerusalem artichoke (*Helianthus tuberosus* L.) is a tuber crop containing inulin that can be used as raw material in many industries. Inulin can be used as soluble dietary fiber or sugar replacement for diabetes disease in the medicine industry, as a stabilizer in the pharmaceutical industry [1] and as raw material for biofuels [2,3]. Jerusalem artichoke is a new crop that has the potential to be grown in temperate and tropical regions of the world.

Global warming may cause more severe and frequent droughts due to either decreased precipitation and/or increased evaporation [4]. Drought reduces productivity of agricultural crops including Jerusalem artichoke [5–10]. Yield loss of 20% under mild water stress has been reported [5,6] and yield loss higher than 90% has been reported under severe drought stress [11]. Although drought problems can be alleviated by irrigation, management of irrigation systems is sometimes difficult in those geographical areas of the world where water resource are not either readily available or too expensive to maintain. The development and utilization of drought tolerant varieties would be ideal in these drought prone areas of the world.

The selection of Jerusalem artichoke for drought tolerance has primary been based on biomass production and tuber dry weight under drought stress conditions. In tropical regions of the world, JA 5 was reported as a drought tolerant variety with high tuber yield under drought stress conditions [11]. The progress in breeding for drought tolerance varieties has been slow because yield and related traits vary greatly, depending on ecological environmental conditions. A better understanding of some physiological mechanisms of drought resistance varieties should accelerate the progress in breeding for high tuber productivity under drought stress.

Drought tolerance may be enhanced by exploiting drought

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avoidance mechanisms such as the ability of roots to extract water from the soil. Root dry weight, root length, root: shoot ratio [12], deep root and root length density [13–16] have been identified as drought-adaptive traits and they could be used as selection criteria for drought resistance traits. However, root characteristics of Jerusalem artichoke in responses to drought have not been clearly investigated. Therefore, the objective of this study was to determine the effects of drought on selected root growth parameters of Jerusalem artichoke and develop relationships between root growth parameters (characters) and tuber yield for selected drought resistance varieties of Jerusalem artichoke genotypes. The new scientific information from this research on the ability of root traits of selected Jerusalem artichoke genotypes contributing to high tuber yield under water stress are likely to reveal the avoidance mechanism and could result in the development of improved breeding strategies for drought tolerance in Jerusalem artichoke.

2. Materials and methods

2.1. Experimental design and treatments

Pot experiments were conducted 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). The experimental treatments were arranged in a 3×5 factorial experiment in randomized complete block design with four replications for each treatment and experiments were conducted for two years during May to September 2012 and May to September 2013. Factor A consisted of three water regimes including field capacity (FC), 50% available soil water (50% AW) and 25% available soil water (25% AW) and factor B included five Jerusalem artichoke varieties with different drought tolerance levels based on tuber yield under drought stress. The experimental unit consisted of 5 pots requiring a total of 300 pots for each experiment. The varieties JA 60 and JA 125 had low tuber yield, JA 5 had intermediate tuber yield and JA 89 and HEL 65 had high tuber dry weight under drought stress conditions [11].

2.2. Preparation of plants and pot materials

Tubers with uniform size were cut into small pieces with 2–3 buds per piece. The tuber pieces were then pre-sprouted in charred rice husk with mixed trichoderma in the ratio of 3:1 by volume under ambient conditions for 4–7 days to control *Sclerotium rolfsii*. The sprouted tuber pieces were then transferred to germinating plug trays with mixed medium containing soil, charred rice husk and trichoderma (3:2:2) for 7 days to complete sprouting. Healthy and uniform seedlings were then transplanted to plastic pot containers (1 plant pot^{-1}).

The plastic containers with 35 cm in diameters and 25 cm in height were then filled with 20 kg of dry soil which was separated into two layers to create uniform bulk density. The first soil fraction of 10 kg of dry soil was filled in the bottom of the container at 10 cm below the soil surface, and the second soil fraction of remaining 10 kg was filled to 5 cm below the top of the pot. The water tubes were installed at the middle of these soil fractions. One seedling was transplanted into each container. Wood vinegar obtained from slow pyrolysis of wood was sprayed on Jerusalem artichoke plants two times per week at the dilution of 5 cm^3 wood vinegar in a liter of water to control insects in the pots. Weeds were controlled manually after transplanting and fertilizer grade 15-15-15 was applied to each pot at the rate of 2 g per pot or 265 kg ha^{-1} at 15 days after transplanting (DAT).

2.3. Water management

Water was applied to each pot as per each water treatment and based on crop water requirements (ETcrop) [17] plus to meet the daily surface evaporation (S.E.) needs of pots [18]. Crop water requirements for each pot were calculated as per the requirements of experimental treatments and using the methods described by Ref. [17]:

$$\mathrm{ETcrop} = \mathrm{kc} \times \mathrm{ETo},$$

where ETcrop is the crop water requirement (mm day^{-1}), ETo is evapotranspiration of reference crop and kc is the coefficient of the crop at different growth stages. The crop coefficient (kc) of the Jerusalem artichoke was not found in literature, therefore, kc of sunflower was used [8,10].

Surface evaporation (S.E.) was calculated as [18]:

$$\mathrm{S.E.} = \beta(\mathrm{E_o}/\mathrm{t}),$$

where S.E. is the soil evaporation (mm), β is the light transmission coefficient measured depending on crop cover, E_o is the evaporation from class A pan (mm day^{-1}), t is the days from the last irrigation.

To maintain a uniform water supply in the whole pot, the irrigation was divided into two fractions. Water was supplied to the soil fractions through the plastic tubes previously installed to the containers. At pre-transplanting, water was supplied to all pots and moisture level was maintained at FC (20.5% of soil moisture content) until 10 DAT for uniform establishment of the plants. Water treatments (20.5% of soil moisture content in FC, 13.9% of soil moisture content in 50% AW and 10.6% of soil moisture content in 25% AW) were imposed to the crop after 14 DAT and maintained uniformly with no more than 1% fluctuation until harvest.

The irrigation supplied to each pot was equal to the sum of water used by the crop and to meet the daily soil surface evaporation needs. The soil water status was also monitored by gravimetric method for soil moisture collection at 7-days interval. The added water irrigation was applied to each pot once a week for maintaining the level of soil moisture treatment.

2.4. Data collection

2.4.1. Meteorology conditions

Weather data for two years were recorded daily from transplanting until crop harvest by a weather station located 100 m away from the experimental field. Maximum temperatures, minimum temperature, daily pan evaporation and daily relative humidity were recorded at this experiment station (Fig. 1).

2.4.2. Soil data

The data on soil texture and chemical properties were collected using ten randomly selected points in the field from where the whole soil was collected and mixed to create two sets of soil samples. The first set was analyzed for field capacity and permanent wilting percentage of soil for irrigation management. The second set was analyzed for the soil texture and the soil chemical properties including total N and available P, pH, organic matter, exchangeable K and Ca and cation exchange capacity.

Soil moisture contents were recorded by gravimetric method at 30, 60 and 90 DAT at the depth of 0–20 cm (Fig. 2).

2.4.3. Plant data

Relative water content (RWC) in each experimental unit was measured at 30, 60 and 90 DAT to estimate plant water status. The