Hydroponics Culture of Edible Opuntia ‘Maya’: Drought Stress Affects the Development of Spines on Daughter Cladodes

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This study aimed to investigate the effects of hydroponics culture involving deep flow technique (DFT) on the growth of edible Opuntia, and drought stress on spine occurrence on daughter cladodes. Edible Opuntia cladodes were grown by hydroponic and pot culture. In pot culture experiments, plants were watered at different frequencies (once a week, once every 2 weeks, and once every 4 weeks). The total fresh weight of cladodes grown by DFT increased and daughter cladodes appeared, thus indicating that edible Opuntia can be grown by DFT. The number of daughter cladodes did not significantly differ between hydroponic and pot culture, but the growth rate of first daughter cladodes under DFT and high drought stress became slower than that with other treatments. We counted the number of spines on daughter cladodes, which is one of the most undesirable characteristics in edible cacti, and it was the greatest on cladodes under high drought stress and lowest on cladodes under DFT. Our results suggest that drought stress affects daughter cladode growth and the number of spines on daughter cladodes. Thus, controlling water availability is important for improving edible cactus quality.

Keywords : Edible Opuntia, hydroponics culture, deep flow technique, drought stress, growth, spines

INTRODUCTION

The stem of the cactus Opuntia (genus Opuntia, sub-family Opuntioideae, family Cactaceae) is widely consumed as a vegetable in Mexico and Mediterranean countries (Stintzing and Carle, 2005; Cruz-Hernández and Paredes-López, 2010). With respect to its growth behavior, daughter cladodes develop from the areole of the mother cladode and this process is repeated (Pimienta-Barrios et al., 2005). In Japan, edible Opuntia plants are also produced as vegetables, mainly in Kasugai city, Aichi Prefecture. However, cladodes have a characteristic that diminishes their acceptance by the consumer; the presence of spines on the areole. A number of beneficial functions have been ascribed to spines, including participation in zoochorous dispersal (Frego and Staniforth, 1985; Bobich and Nobel, 2001), mechanical protection from herbivores (Norman and Martin, 1986), shading of the stem (Nobel et al., 1986), reflection of light (Loik, 2008), and thus a reduction in water loss (Stintzing and Carle, 2005). In addition to the above, a further report shows that cactus spines also function as a fog collection system (Ju et al., 2012). Therefore, drought stress on cladodes might be related to the appearance and number of spines. Reducing the number of spines will lead to an improvement in the edible quality of Opuntia and thus increase consumer acceptance.

Opuntia plants are commonly produced through soil or pot culture. Major problems in growing vegetables, including edible Opuntia, using soil are soil-borne disease, salt accumulation, and difficulty in fertilizer management (Lakkireddy et al., 2012). Hydroponics culture is a method of growing plants using nutrient solution (water and fertilizer) with or without the use of an artificial medium. No soil means absence of weeds or soil-borne disease, and precise fertilizer management is possible (Lakkireddy et al., 2012). Thus, hydroponics culture conveys many advantages for edible Opuntia production, although there is no report investigating the effects of hydroponics culture on edible cactus growth as far as we searched.

In this study, we attempted to investigate the effects of hydroponics culture with a deep flow technique (DFT) on the growth of edible cacti and to assess the effect of drought stress on the spine frequency of daughter cladodes.

MATERIALS AND METHODS

Plant materials

Edible Opuntia cladodes (Opuntia ‘Maya’) averaging 16 cm long, 7.5 cm wide, and 1 cm thick were harvested at a commercial cactus farm (Goto saboten) in Aichi Prefecture, Japan, in October, 2014. Cladodes were transported in a dry condition to our laboratory within 1 h, and were then trimmed to a length of 15 cm.

Treatments

In the hydroponics culture treatments (DFT), cladodes were fixed in a container with 5.6 L filled with deionized water using bubble wrap (Fig. 1). Aeration was conducted using an air pump (Silent β-30, Nisso, Japan). We added deionized water to the container once a week to refill evaporated water. In pot culture treatments, cladodes were planted in plastic pots (1.2 L), filled with Akadama soil.
(loamy soil). Cladodes in pots were watered with 500 mL/pot water at the following frequencies to evaluate the effect of different levels of drought stress on the growth of daughter cladodes: once a week (low drought stress), once every 2 weeks (middle drought stress), and once every 4 weeks (high drought stress). Cladodes under hydroponics and pot culture were maintained at 25°C for a 14-h light period (220–240 μmol m⁻² s⁻¹), and 15°C for an 10-h dark period. Relative humidity was maintained at 70% during light and dark periods. We did not use any fertilizer in both hydroponics and pot culture treatments. The number of daughter cladodes and length of first daughter cladodes were measured every 2 weeks; the thickness was also measured 12 weeks after planting. In hydroponics culture, the fresh weight (FW) of cladodes was measured every 2 weeks. We also measured the number of areoles which had spines to calculate spine occurrence on daughter cladodes: spine occurrence = the total number of areoles which had spines longer than 1 mm/the total number of areoles. When a mother cladode had multiple daughter cladodes, the mean spine occurrence was calculated.

Three cladodes were used in hydroponics for each pot culture treatment (low drought stress, middle drought stress, and high drought stress). All experiments were repeated three times. The data underwent analysis of variance, and the significance of the differences across means were defined using Tukey’s test at a significance level of P < 0.05.

RESULTS AND DISCUSSION

Hydroponics culture involves growing plants without soil. This system can avoid the costly and time-consuming task of soil sterilization to prevent soil-borne disease and enable precise fertilizer management (Lakkireddy et al., 2012). Daughter cladodes and roots appeared from mother cladodes under DFT treatment, and total FW of cladodes also increased after treatment, showing that edible Opuntia can be grown by DFT (Figs. 2 and 3). DFT is also a basic method for plant production in plant factories. Stable production of edible Opuntia and increasing its nutritive value through environment control in a plant factory is can be studied in future.

The number of daughter cladodes did not significantly differ among treatments (Fig. 4), although growth of the first daughter cladodes were affected by drought stress and growth conditions (Fig. 5). The length of the first daughter cladodes under low and middle drought stress rapidly increased until 4 weeks after treatment and showed very little change after 6 weeks of treatment. In cladodes under high drought stress and DFT, length also rapidly increased until 4 weeks after treatment and gradually increased until approximately 8 or 10 weeks after treatment; however, their growth rate became slower than that with other treatments (Fig. 5). When given the drought stress for edible Opuntia, the length of first daughter cladodes in low
drought stress was longest, followed by middle drought stress, high drought stress (Fig. 5). Thus, drought stress seemed to suppress the elongation growth of first daughter cladodes. However, the length of first daughter cladodes became shortest among treatments (Fig. 5). Some reasons are conceivable as to why growth first daughter cladodes in DFT became short compared with other treatments. The first probable reason is that the soil in pot culture contained organic and inorganic matter and it promoted cladodes elongation in pot culture. The second probable reason is that relatively low temperature around root area and low dissolved oxygen concentration in DFT affected the growth of daughter cladodes and resulted in short length of first daughter cladode. Figure 6 shows the thickness of the first daughter cladodes in each treatment, and it became significantly thinner in cladodes under high drought stress than those under other treatments. Daughter cladodes in the early stages of development absorb significant volumes of water from mother cladodes (Pimienta-Barrios et al., 2005). It seems that high drought stress affected the water content in cladodes and the growth of daughter cladodes, resulting in a slow growth rate and relatively thin cladodes.

Next, we compared spine occurrence on daughter cladodes in each treatment (Fig. 7). It was the highest in cladodes under high drought stress and the lowest under DFT. Among pot culture, cladodes under low and middle drought stress had fewer spines than those under high drought stress. This result suggests that water availability for mother cladodes affects the development of spines on daughter cladodes. Ju et al. (2012) report that cactus spines also function as a fog collection system in addition to other functions such as protection from herbivores. Thus, drought stress on cladodes might promote the development of spines to facilitate efficient fog collection. Spines on cladodes are one of the most undesirable characteristics in edible Opuntia. Opuntia ‘Maya’ has fewer spines than other cultivars, but their spines are very sharp, which flaws their commercial value. Therefore, cultivation techniques that can reduce the number of spines can contribute to improving the commercial value of Opuntia ‘Maya’ and that of other edible Opuntia cultivars. However, other cultivation conditions, including fertilizer, growth temperature, humidity, and light intensity, might also affect the development of spines. Thus, further research is needed to further understand the effects of hydroponics culture and cultivation conditions on the development of spines on cladodes.

In the present study, we showed that edible cacti can be grown using DFT, and that drought stress affects the growth of daughter cladodes and the number of spines on them. This is the first report to describe the hydroponics culture of edible Opuntia using DFT, and its use for improving cladode quality.

REFERENCES


