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Growth of sweetpotato cultured in the newly designed hydroponic system for space farming

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Abstract

Life support of crews in long-duration space missions for other planets will be highly dependent on amounts of food, atmospheric O_2 and clean water produced by plants. Therefore, the space farming system with scheduling of crop production, obtaining high yields with a rapid turnover rate, converting atmospheric CO_2 to O_2 and purifying water should be established with employing suitable plant species and cultivars and precisely controlling environmental variables around plants grown at a high density in a limited space. In this study, we developed a new hydroponic method for producing tuberous roots and fresh edible leaves and stems of sweetpotato. In the first experiment, we examined the effects of water contents in the rooting substrate on growth and tuberous root development of sweetpotato. The rooting substrates made with rockwool slabs were inclined in a culture container and absorbed nutrient solution from the lower end of the slabs by capillary action. Tuberous roots developed on the lower surface of the rockwool slabs. The tuberous roots showed better growth and development at locations farther from the water surface on the rockwool slabs, which had lower water content. In the second experiment, three sweetpotato cultivars were cultured in a hydroponic system for five months from June to November under the sun light in Osaka, Japan as a fundamental study for establishing the space farming system. The cultivars employed were 'Elegant summer', 'Kokei-14' and 'Beniazuma'. The hydroponic system mainly consisted of culture containers and rockwool slabs. Dry weights of tuberous roots developed in the aerial space between the rockwool slab and the nutrient solution filled at the bottom of the culture container were 0.34, 0.45 and 0.23 kg/plant and dry weights of the top portion (leaves, petioles and stems) were 0.42, 0.29 and 0.61 kg/plant for 'Elegant summer', 'Kokei-14' and 'Beniazuma', respectively. Young stems and leaves as well as tuberous roots of 'Elegant summer' are edible and palatable. Therefore 'Elegant summer' would be a promising crop to produce large amounts of food with high nutritional values in the present hydroponic system in space farming.

Keywords: Aeration; Hydroponic culture; Space farming; Sweetpotato

1. Introduction

Plant growth in space has recently been of greater concern as the possibility of realizing manned space flight over a long duration increases. The feasibility of achieving long-duration manned space missions for other planets will be highly dependent on crops in bioregenerative life support systems (BLSS) or space farming that will play important roles in food production, CO_2/O_2 conversion and water purification (e.g., Nitta, 1987; Salisbury, 1991; Gitelson, 1992). In space farming, scheduling of crop production and obtaining high yields with a rapid turnover rate are important.

Sweetpotato is a candidate food crop for crews and an important feed for domestic animals in space. Sweetpotato culture has many advantages over the culture of other crops, i.e., it grows more rapidly, has a high yield, and requires less fertilizer (Kozai et al., 1996). Recirculating hydroponic systems were recommended in space farming

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to allow efficient crop production and conservation of nutrients and water (Bugbee, 1995; Wheeler et al., 1999). However, the tuberous root growth of sweetpotato in hydroponic systems is generally poor mainly due to poor aeration in the root zone because of waterlogging or excess moisture content in the rooting substrate.

Hydroponic techniques for sweetpotato production have been developed by Loretan et al. (1989), Uewada (1990), Mortley et al., 1991, Uewada et al. (1992) and Hill et al. (1992) as well as for potato production (Wheeler et al., 1990) and peanut production (Mackowiak et al., 1998) in bioregenerative life support systems. Although the growth rate of sweetpotato in hydroponic systems was greatly fluctuated by environmental conditions (e.g., Loretan et al., 1989, 1994; Uewada et al., 1992; Bonsi et al., 1994; Eguchi et al., 2003), the yields were generally less than those under conventional field conditions. We are developing a new hydroponic method for culturing sweetpotato with a fibrous rooting substrate in order to ensure high yield with a simple system compared with previous studies. We employed rockwool slabs as the rooting substrate.

In this study, we developed a method for producing large amount of sweetpotato tuberous roots in a hydroponic system. In the first experiment, we examined the effects of water contents in the rooting substrate on growth and tuberous root development of sweetpotato as a preliminary experiment. After deciding the appropriate planting location on the rockwool slabs, three sweetpotato cultivars were cultured in a newly developed hydroponic system and the yield and growth performance of the cultivars were compared in the second experiment.

2. Materials and methods

Plastic containers containing rooting substrates were used to culture sweetpotato (*Ipomoea batatas* (L.) Lam.) hydroponically. The rooting substrates made with rockwool slabs were inclined in the container and absorbed nutrient solution from the lower end by capillary action. Sweetpotato plants were cultured using stem cuttings, which were inserted into the rooting substrate. Cuttings were 0.25–0.28 m long and had 9–11 nodes with 7–9 leaves each. Tuberous roots of sweetpotato were developed in the aerial space between the rockwool slab and the nutrient solution filled at the bottom of the culture container. The nutrient solution used was modified Hoagland solution. Water depth was kept at 0.05 m throughout the experimental period.

Dry weights of leaves, stems and tuberous roots were determined after drying each plant part for more than 48 h at 80 °C in an oven. The tuberous root biomass ratio was evaluated from the expression, (tuberous root dry weight)/(whole plant dry weight). All the data were analyzed statistically and differences in mean values were evaluated by Fisher's t test at a 5% level of significance, and showed with means and least significant differences.

2.1. Experiment 1: Growth of sweetpotato planted on the rooting substrate at different distances from the water surface

A sweetpotato cultivar, 'Elegant summer', was employed for this experiment. The rockwool slabs were inclined in the culture container ($0.6 \times 0.45 \times 0.35$ m high) (Fig. 1). The stem cuttings were located at 0.05, 0.15 and 0.25 m above the water surface. We focused on tuberous root formation at different locations on the substrate in this experiment. Terminal and lateral buds of each cutting were, then, removed for suppressing top growth and promoting tuberous root growth. Plants were cultured under greenhouse conditions without CO_2 enrichment in a summer season. Six plants were cultured for 32 days in each location.

Temperatures of the ambient air, the aerial space between the rooting substrate and the nutrient solution layer were measured every hour for the growing period. Temperatures of rooting substrates were also measured at 0.05, 0.15 and 0.25 m above the water surface. Relative humidity was measured in the ambient air and the aerial space between the rooting substrate and the nutrient solution layer. Temperatures and relative humidity in the air were measured with thermo-hygrometer (TR-72, T&D Inc., Japan) and temperatures in the substrate and the solution were measured with thermocouples. The water content at each location in the rooting substrates was measured with a soil moisture meter (HYDRO SENSE, Decagon Devices Inc., USA) at a depth of 5 cm in the substrate after making calibration with a weighing method.

2.2. Experiment 2: Growth characteristics of three sweetpotato cultivars in a hydroponic system

Three sweetpotato cultivars, 'Beniazuma', 'Elegant summer' and 'Kokei-14' were cultured in the hydroponic system mainly consisted of culture containers ($1.9 \times 0.55 \times 0.25$ m high, each) (Fig. 2a) and rockwool substrates. A growing space for tuberous roots was made

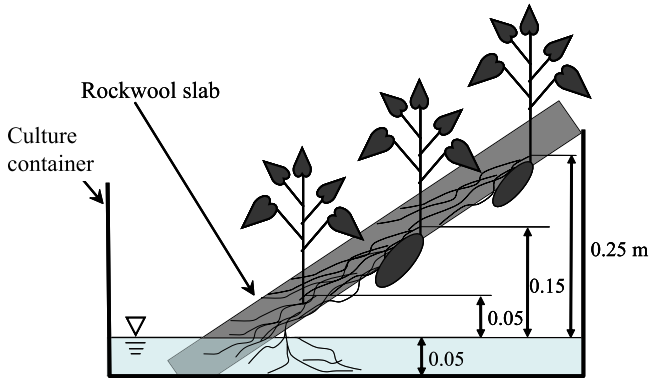

Fig. 1. Cross-section of the hydroponic system mainly consisted of a culture container and a rockwool slab in the first experiment.