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Effects of Nutrient Solution Electrical Conductivity and pH on the Productivity of the Medicinal Plant *Pinellia ternata* Breit.

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Medicinal plants (*Pinellia ternata* Breit.) were cultivated under four nutrient solution conditions, namely a pH of 4 and electrical conductivity (EC) of 2.2 mS cm^{−1}, pH of 4 and EC of 1.2 mS cm^{−1}, pH of 6 and EC of 2.2 mS cm^{−1}, and pH of 6 and EC of 1.2 mS cm^{−1}. Plants were grown for 15 weeks in phytotron glass rooms controlled at an air temperature of 25°C and a relative humidity of 70%. The leaf number per plant was measured every week, the leaf chlorophyll content (SPAD) was measured at 100 d after planting, and the corm yield and the effective ingredient, namely araban, content in the corm were evaluated after 15 weeks of cultivation. No clear effects of the nutrient solution EC and pH on the corm growth, the corm quality, and leaf chlorophyll content were not observed in this experiment. The EC and pH of the nutrient solution will not affect the productivity of the *P. ternata* in the ranges of EC 1.2–2.2 mS cm^{−1} and pH 4–6, respectively.

Keywords : *Pinellia ternata*, corm yield, nutrient solution, electrical conductivity, pH

INTRODUCTION

The electrical conductivity (EC) and pH of nutrient solutions appear to affect the growth of some crops (e. g., Wu et al., 2004; Dewir et al., 2005; Samarakoon et al., 2006; Zhao et al., 2013; Singh et al., 2019). With regard to environmental effects, we already have shown that the medicinal plant *Pinellia ternata* Breit. is affected by the hydraulic conditions surrounding the corm (Eguchi et al., 2014), and the temperature surrounding the plant (Eguchi et al., 2016, 2019, 2020). In this study, we examined the effects of the nutrient conditions, EC, and pH on the yield and the quality of *P. ternata*.

MATERIALS AND METHODS

Plant material

Bulbils of *P. ternata* native to the Kyoto Prefecture, which showed the highest corm yield and the highest effective ingredient content in the corm among plants collected from Japan (not published), were used for this experiment. This plant is in the process of plant variety registration with the Ministry of Agriculture, Forestry and Fisheries. This strain has already been proven to have high anti-emetic activity (Tanaka et al., 2020).

Cultural conditions

The porous solid material PUMICE® (grain size: 0.5–2.4 mm; porosity: 0.58; OhE Chemicals Inc., Osaka, Japan) was used as the root medium. A square cultivation

box (inner size: width, 300 mm; length, 150 mm; height, 210 mm) was filled with the medium at a thickness of 180 mm. A drainage tube was connected to the bottom of the box. Four boxes were installed in three phytotron glass rooms of Kyushu University and controlled at an air temperature of 25±1°C and a relative humidity of 70±5%. Standard and half-strength of OAT agrio A solution (OAT Agrio Co., Ltd., Tokyo, Japan) was used, and the nutrient solution was adjusted to 4.0 or 6.0 with 0.5 M KOH solution (Nacalai Tesque Inc., Kyoto, Japan). The root medium was moistened well, and five bulbils were transplanted into each box. In each box, the bulbils were equally placed in a line at intervals of approximately 6 cm in line, with the bulbil base located 3 cm below the surface of the medium. The ground water level in the root medium was adjusted by controlling the nutrient solution level within the tank using drainage tube. The ground water levels were maintained at approximately 4 cm below the bulbil base, which is favorable for the plant growth (Eguchi et al., 2014). During the cultivation using this box, the water content of the root medium around the bulbils was kept almost constant, regardless of the irradiation to the box (Eguchi et al., 2009). Plants were grown for 15 weeks (from November 16, 2016 to March 1, 2017) under four nutrient solution conditions, namely a pH of 4 and EC of 2.2 mS cm^{−1}, pH of 4 and EC of 1.2 mS cm^{−1}, pH of 6 and EC of 2.2 mS cm^{−1}, and pH of 6 and EC of 1.2 mS cm^{−1}. The number of leaves per plant was measured weekly (every Wednesday), and the chlorophyll content in the leaves was measured at 100 d after planting using an

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SPAD meter (SPAD-502 Plus, Konica Minolta Inc., Tokyo, Japan). Corms grown from bulbils were harvested after cultivation and weighed. The harvested corms were peeled and washed well with distilled water. Washed corms were dried at room temperature for 2 weeks, and then their dry weights were measured.

Effective ingredient content

The major effective ingredient is a water-soluble polysaccharide that mainly consisted of arabinose, namely araban (Maki et al., 1987). Dried corms were used to determine the effective ingredient content by using the enzyme-linked immunosorbent assay (ELISA). Each sample (50 mg) was pulverized and extracted with water (1 mL per 100 mg powder) three times and then heated at 95°C for 10 min. The sample solutions were diluted 4,000 or 20,000 times with 50 mM carbonate buffer (pH of 9.6) absorbed on the wells of a 96-well immunoplate (100 µL). The solutions were then treated with 300 µL of 5% skimmed milk in PBS for 1 h to reduce non-specific adsorption. The plate was washed with a washing buffer and then treated with a monoclonal antibody (MAb) against the polysaccharide fraction of *P. ternata*. The MAb was combined with 100 µL of a 1:1000 dilution of peroxidase-labeled anti-mouse IgG for 1 h. After washing the plate, 100 µL of the substrate solution [2,2'-azino-bis (3-ethylbenzothiazoline-6-sulfonic acid) diammonium salt (ABTS) solution] was added to each well and incubated for 10 min. The absorbance was measured at 405 nm using a microplate reader.

Statistical analysis

Data on the SPAD, corm yield, and effective ingredient content in the corm were analyzed using analysis of variance ($n = 5$). Significant differences between conditions were tested using Tukey's test at $P < 0.05$.

RESULTS AND DISCUSSION

Terrestrial part

The changes in the number of leaves in the plant are shown in Fig. 1. The number of leaves plateaued at approximately 6 weeks after planting under all four nutrient conditions. The leaf number under the nutrient solution condition with an EC of 1.2 mS cm⁻¹ and pH of 6 appeared to be lower than that of the other nutrient conditions, but there were no significant differences among the

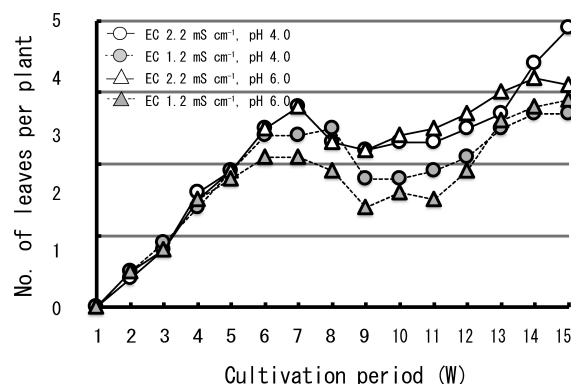


Fig. 1 Changes in the number of leaves in a *P. ternata* plant grown under different nutrient solution conditions. Mean values are indicated. No significant difference was observed among the four nutrient conditions ($n = 5$, $P > 0.05$, Tukey's test).

nutrient solution conditions. The chlorophyll content in the leaves, which was assumed from the SPAD values, was almost the same among the different nutrient conditions (Fig. 2). The EC and pH of the nutrient solution will not affect the leaf growth of the *P. ternate*, in the ranges of

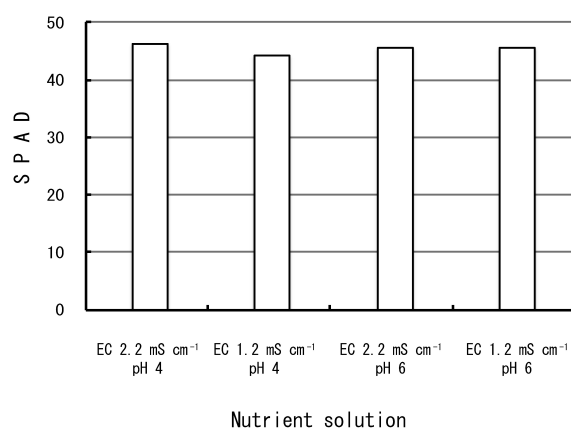


Fig. 2 Leaf SPAD value measured in *P. ternata* plants grown 100 d under different nutrient solution conditions. Mean values are indicated. No significant difference was observed among the four nutrient conditions ($n = 5$, $P > 0.05$, Tukey's test).

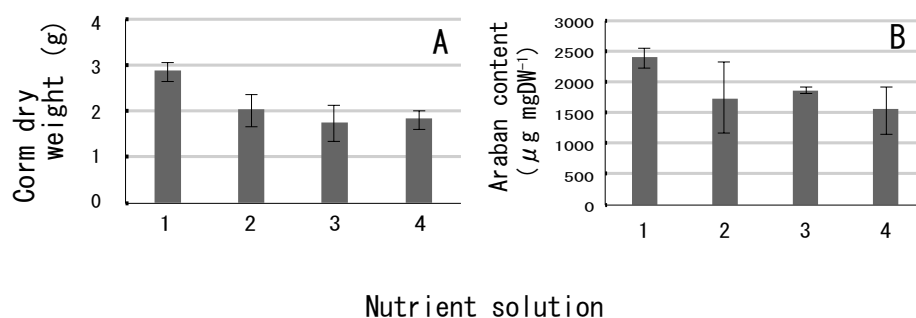


Fig. 3 Corm dry weight (A) and content of the effective ingredient, namely araban, in the corm (B) in *P. ternata* plants grown under different nutrient solution conditions (1: EC of 2.2 mS cm⁻¹, pH of 4.0; 2: EC of 1.2 mS cm⁻¹, pH of 4.0; 3: EC of 2.2 mS cm⁻¹, pH of 6.0; 4: EC of 1.2 mS cm⁻¹, pH of 6.0). Mean values are indicated with standard error. No significant difference was observed among four nutrient conditions ($n = 5$, $P > 0.05$, Tukey's test).

1.2–2.2 mS cm⁻¹ and 4–6, respectively.

Subterranean part

The corm yield seemed to be highest under the nutrient solution condition with an EC of 2.2 mS cm⁻¹ and pH of 4, but the yields were not significantly different among the four nutrient conditions (Fig. 3A). Significant differences in the effective ingredient content, araban content, in the corm were not observed among the four nutrient solution conditions (Fig. 3B). The EC and pH of the nutrient solution also did not affect the corm growth and the corm quality of the *P. ternate* significantly in the ranges of 1.2–2.2 mS cm⁻¹ and 4–6, respectively.

Thus, the nutrient solution EC and pH within the ranges of 1.2–2.2 mS cm⁻¹ and 4–6, respectively, seemed to have no obvious effect on leaf growth, corm growth, and corm quality of a *P. ternate* strain collected from Kyoto.

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