Growth of Radish Sprouts Cultivated in Electrolyzed and Non-Electrolyzed Solutions with Different Strengths

Masahiko TAMAKI, Tosifumi UEDA and Seiichiro ISOBE*

School of Bioresources, Hiroshima Prefectural University, Shobara, Hiroshima 727-0023, Japan
* National Food Research Institute, Tsukuba, Ibaraki 305-8642, Japan

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This study was conducted to determine the effects of electrolyzed solution (alkaline solution and mixed solution, mixed with the same volume of alkaline and acid solution) and non-electrolyzed solution (KCl solution), with different strengths, on the growth of radish (Raphanus sativus L.) sprouts. The electrolyzed solution was generated by dissolving KCl as an electrolyte. The 1/1 (247 mg L⁻¹ of K⁺ concentration) and 1/2 (124 mg L⁻¹ of K⁺ concentration) strength alkaline solutions promoted the plant growth. Among the 1/1 strength solutions, the plant growth was most superior in alkaline solution, followed by mixed solution (176 mg L⁻¹ of K⁺ concentration), and less superior in KCl solution (175 mg L⁻¹ of K⁺ concentration). One of the reasons of the accelerated plant growth in 1/1 strength alkaline solution may be due to higher K⁺ concentration in the solution, because K⁺ acts as a fertilizer. However, in spite of the K⁺ concentration in 1/2 strength alkaline solution was lower than that in 1/1 strength mixed and KCl solutions, the plant growth was more promoted in 1/2 strength alkaline solution. Therefore, the superior plant growth in alkaline solutions may concern not only K⁺ concentration but another factors, for example, lower oxidation-reduction potential (ORP) in the solution and/or easiness of mineral absorption by electrolysis.

Keywords : fertilizer, K⁺ concentration, ORP

INTRODUCTION

An electrolyzed solution is the one generated by electrolyzing a solution containing dissolved electrolytes such as NaCl and KCl. In medical and food science, NaCl is used as an electrolyte in the generation of an electrolyzed solution, and in agriculture, KCl is used. Matsuo and Sima (1994a, b) reported that the alkaline solution, which is generated at the cathode, promoted the growth of Komatsuna (Brassica rapa L. (Peruviridis group) ). Ohyama et al. (1996) also reported that the growth of rice (Oryza sativa L.) seedlings was promoted in alkaline solution. However, there are limited studies why the plant growth is promoted in alkaline solution. The KCl, an electrolyte, is ionized in solutions and increased K⁺ at the cathode may affect as a fertilizer.

The purpose of this experiment was to determine the effect of electrolyzed and non-electrolyzed solutions on the growth of radish sprouts, in relation to K⁺ in solutions.
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MATERIALS AND METHODS

Culture conditions
Six urethane chips (each 30 mm × 22 mm × 25 mm) were placed in a plastic container (500 mL), and 30 radish seeds were sown on urethane chips. They were germinated in a controlled environment chamber at 25 ± 1°C and 80% RH under dark conditions for 4 days, thinned to 20 uniform plants on each of urethane chip, and grown at 25 ± 1°C and 80% RH under 14-h day/10-h night cycle for additional 4 days. The plants were illuminated with fluorescent lamps (FLR40S•W, National Co., Ltd., Japan) at 300 μmol m⁻² s⁻¹ PPFD on the top of them.

Experimental solutions
An electrolyzed solution was generated by dissolving 2 g of KCl, as an electrolyte, in 4 L of distilled water and electrolyzing for 15 min using the electrolyzed solution generation apparatus (Disapppear, PBM Co., Ltd., Sendai, Japan). The apparatus consists of two wells separated by a septum with anode and cathode electrodes installed in either well. The alkaline solution was generated from the well with the cathode, and the acid solution was generated from the well with the anode. Experimental solutions were 1/1 strength alkaline solution, 1/1 strength mixed solution, which was mixed with the same volume of alkaline and acid solution, and 1/1 strength solution dissolving the electrolyte (2 g) which was not electrolyzed. Solutions were diluted with distilled water at 1/2, 1/5, 1/10, 1/50, 1/100, and 1/1,000 strengths of the above mentioned three 1/1 strength solutions. One hundred mL of each solution was infused in the container with six urethane chips at sowing, and 50 mL of each solution was added after 4 days from sowing.

Analyses of plant growth and K⁺ concentration in solutions
The plant height, above-ground fresh weight, and above-ground dry weight were measured after the harvest. The above-ground dry weight was measured after 2-day drying at 80°C. The K⁺ concentration in solutions was determined using the ion analyzer (IA-100, TOA Co., Ltd., Japan).

Statistics
A randomized complete block design was used, and three replicates were performed. The data were subjected to analysis of variance (ANOVA) and the Least Significant Differences (LSD) test (P < 0.05).

RESULTS

PH of solutions
The pH of 1/1 strength alkaline and mixed solutions, electrolyzed with the KCl electrolyte, and 1/1 strength KCl solution, and of their diluted solutions are shown in Table 1. Distilled water was of pH 6.9. The pH of 1/1 strength alkaline solution was the highest (pH 11.5) and that of 1/1 strength KCl solution was the lowest (pH 5.5) among all solutions. The pH of 1/1 strength mixed solution and its diluted solutions was close to that of distilled water.

Plant growth
Figure 1 shows the fresh weights of radish sprouts cultivated in 1/1 strength alkaline and

Table 1 The pH of 1/1 strength alkaline and mixed solutions, electrolyzed with the KCl electrolyte, and 1/1 strength KCl solution, and of their diluted solutions with distilled water.

<table>
<thead>
<tr>
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<th>1/1 strength</th>
<th>1/2 strength</th>
<th>1/5 strength</th>
<th>1/10 strength</th>
<th>1/50 strength</th>
<th>1/100 strength</th>
<th>1/1,000 strength</th>
</tr>
</thead>
<tbody>
<tr>
<td>Alkaline solution</td>
<td>11.5</td>
<td>11.3</td>
<td>11.1</td>
<td>10.7</td>
<td>9.5</td>
<td>8.6</td>
<td>7.4</td>
</tr>
<tr>
<td>Mixed solution</td>
<td>7.1</td>
<td>7.0</td>
<td>7.0</td>
<td>6.9</td>
<td>6.9</td>
<td>6.9</td>
<td>6.9</td>
</tr>
<tr>
<td>KCl solution</td>
<td>5.5</td>
<td>5.6</td>
<td>5.8</td>
<td>5.9</td>
<td>5.9</td>
<td>6.1</td>
<td>6.3</td>
</tr>
</tbody>
</table>
GROWTH OF RADISH SPROUTS

![Bar graph showing growth of radish sprouts](image)

**Fig. 1** The fresh weights of radish sprouts cultivated in 1/1 strength alkaline and mixed solutions, electrolyzed with the KCl electrolyte, and 1/1 strength KCl solution, and in their diluted solutions with distilled water. Values with same letters are not significantly different (P< 0.05 by LSD test).

The growth of radish sprouts was superior in 1/1 and 1/2 strength alkaline solutions and decreased with increasing dilution degree in all the solutions. Among the 1/1 strength solutions, the plant growth was most superior in alkaline solution, followed by mixed solution, and less superior in KCl solution. However, there were no significant differences between the 1/1 strength mixed and KCl solutions, and between their diluted solutions. The plant growth in 1/100 and 1/1,000 strength solutions was similar to that in distilled water, in all solutions.

**K⁺ concentrations in solutions**

The K⁺ concentrations were 247, 176, and 175 mg L⁻¹ in 1/1 strength alkaline, mixed, and KCl solutions, respectively.

**DISCUSSION**

The 1/1 and 1/2 strength alkaline solutions promoted the growth of radish sprouts. Since K⁺ is well known as an essential nutrient, higher K⁺ concentration in 1/1 strength alkaline solution may be one of important factors for the acceleration of the plant growth.

However, in spite of lower K⁺ concentration in 1/2 strength alkaline solution than that in 1/1 strength mixed and KCl solutions, the plant growth was more promoted in 1/2 strength alkaline solution. Matsuo and Sima (1994a, b) suggested the relation of superior plant growth and lower ORP of alkaline solution. Therefore, it is reasonable that the superior growth of the plant in 1/2 strength alkali solution than 1/1 strength mixed and KCl solutions is concerned not only higher K⁺ concentration but lower ORP in the solution.

The plant growth in mixed solution was superior in comparison with that in KCl solution. Levengood (1985) reported that the ion transport in the seed coat tissues was promoted by the application of a pulse, since the cell wall structure of the seed coat altered in response to induced in electrical change. This suggests that minerals are easily absorbed by plants cultivated in solutions with the electrical activity, and plant growth is accelerated by electrolysis.

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REFERENCES


