

# Multi-Spark Discharge System for Preparation of Nutritious Water

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**Abstract.** The nitrogen compound concentration in water is increased by atmospheric-pressure plasma discharge treatment. A rod-to-water electrode discharge treatment system using plasma discharge has been developed by our group to obtain water with a high concentration of nitrogen compounds, and this plasma-treated water improves the growth of chrysanthemum roots. However, it is difficult to apply the system to the agriculture because the amount of treated water obtained by using the system too small. In this study, a multi-spark discharge system (MSDS) equipped multiple spark plugs is presented to obtain a large amount of plasma-treated water. The MSDS consisted of inexpensive parts in order to reduce the system introduction cost for agriculture. To suppress the temperature increase of the spark plugs, the 9 spark plugs were divided into 3 groups, which were discharged in order. The plasma-treated water with a  $\text{NO}_3^-$  concentration of 50 mg/L was prepared using the MSDS for 90 min, and the treatment efficiency was about 6 times higher than that of our previous system. It was confirmed that the  $\text{NO}_2^-$ ,  $\text{O}_3$ , and  $\text{H}_2\text{O}_2$  concentrations in the water were also increased by treating the water using the MSDS.

## INTRODUCTION

In protected horticulture which is a field of agriculture, the control of growth environments, including water, nutrition, temperature, and light, is important to plant growth. The crop yield increases by improving plant growth. There are several techniques to promote plant growth<sup>1</sup>. In the control of light, effective lights for the photosynthesis of plants are provided efficiently<sup>2,3</sup>. In temperature control, the optimum temperature is maintained for plant growth<sup>4,5</sup>. One of the nutrient control methods in protected horticulture is nutriculture<sup>6-8</sup>, is a cultivation method using a liquid nutrient that does not use soil. Nitrogen, phosphorus, and potassium are three major elements necessary for plant growth<sup>9</sup>. Nitrogen is an integral element for proteins, and promotes leaf growth of plants<sup>10-12</sup>. Phosphorus promotes the growth of flowers and fruits<sup>13,14</sup>, potassium also helps leaf growth<sup>15,16</sup>.

An atmospheric-pressure plasma discharge has been widely used as an easy and low-cost plasma treatment methods<sup>17</sup>. Nitrite ( $\text{NO}_2^-$ ) and nitrate ions ( $\text{NO}_3^-$ ) are produced and increased in water by plasma discharge treatment<sup>18-20</sup>. In addition, the concentration of components such as ozone ( $\text{O}_3$ ), hydrogen peroxide ( $\text{H}_2\text{O}_2$ ), and hydroxide ( $\text{OH}$ ) radicals also changes by water plasma discharge treatment<sup>21-24</sup>.  $\text{O}_3$  and  $\text{H}_2\text{O}_2$  have bactericidal action in water<sup>23-25</sup>.

Plasma-treated water with an improved nitrogen compound concentration promotes the growth of plants on soil cultivation and nutriculture<sup>19,20,26,27</sup>. In our group, a rod-to-water electrode discharge treatment system has been developed to obtain plasma-treated water<sup>26,27</sup>. In the system, a tungsten rod and aluminum ribbon were used as a high-voltage electrode and a ground electrode, respectively. The aluminum ribbon was placed in water. The distance between the high-voltage electrode and the water surface was 5 mm. It was possible to treat 200 mL of tap water at