Effects of Corona Discharge Treatment on Enhancement of Seed Germination

Takayuki Watanabe, Eiji Kumano* and Atsushi Kanzawa

Department of Chemical Engineering, Tokyo Institute of Technology
O-okayama, Meguro-ku, Tokyo 152, Japan
*Present address: Dai Nippon Printing Co. Ltd.
Enoki-cho, Shinjuku-ku, Tokyo 162, Japan

ABSTRACT The purpose of this research is to enhance seed germination of *Grand Rapids* by corona discharge and to investigate the enhancement mechanism. The seeds were treated by corona discharge in the first experiments, while the cultivation water without the seeds were treated in the second experiments. Both experiments have shown that the corona discharge treatment is very effective for the germination enhancement. The enhancement is attributed to NO_3^- which penetrates into the seed and promote some biochemical reactions related to the germination; nitric ion in the cultivation water is formed from NO_2 produced by the corona discharge.

1. INTRODUCTION

Plant growth and seed germination are affected by environmental conditions such as moisture, temperature, light and similar functions. These effects of environmental conditions on plant growth and seed germination have been investigated extensively. However the influence of electric field environment on plant growth and seed germination is little known. Plant growth enhanced by atmospheric electricity at the early experiments were reviewed by Sidaway [1]. The acceleration of plant growth by various electrical treatment has been attempted for 200 years. For example, positive discharge from the overhead conductors was applied to crops in 1885. Murr has shown that high intensity electric fields inhibit the development of grass seedlings [2].

Seed germination affected by electrostatic fields were reported by Sidaway [3]. He has presented the polarity-dependent influence of electrostatic fields on production rate of carbon dioxide in germinating seeds. Wheaton *et al.* [4] have shown that the seed germination of corn and soybean have a direct relationship with electric field intensity. Smith [5] has shown that the gemination of mustard seed was enhanced by nitrogen ion bombardment because of an etching of the seed coating by the ion bombardment. Xingyu *et al.* [6] have shown that the frost-resistant ability of wheat seeds was improved by a plasma treatment. However the mechanism of the influence of electric fields on seed germination has not been studied. The purpose of this research is to enhance the seed germination of *Grand Rapids* by a corona discharge and to investigate the enhancement mechanism. The first experiments are corona discharge treatments for the seeds of *Grand Rapids*, and the second experiments are the corona discharge treatments for cultivation water without the seeds.

2. CORONA DISCHARGE TREATMENT FOR SEEDS

2.1 Experimental Procedures

The seeds of *Grand Rapids* were treated by the corona discharge between two parallel electrodes as shown in Fig. 1. The each electrode consists of a copper plate (55 mm in diameter) and a glass plate (75 mm in diameter) as dielectrics. The corona discharge was generated between the parallel glass plates which distance is 1.5 mm, and is capable of the treatment for 500 seeds. The seeds were treated with high voltage (12 kV, 50 Hz) and with the current from 50 to 250 μA under the pressure of 700 torr.

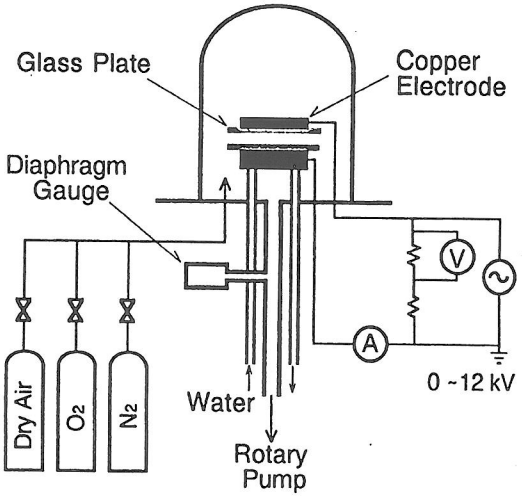

Fig. 1 Experimental set-up.

The *Grand Rapids* seeds after the corona discharge treatment

were cultivated in a dark room at 25 °C in cultivation water. The seeds without the corona discharge treatment (control seeds) can not germinate under these conditions. Gibberellin (GA_3) has been used for the enhancement of the germination of *Grand Rapids* seeds. The seeds can germinate by GA_3 with high concentration (> 30 μM) in cultivation water even under such conditions. The fraction of the seed germination was measured after 48 hours for 3 sets of sample which contains 20 seeds at every conditions. The same procedures were repeated several times after a few days.

2.2 Results and Discussions

Effects of the discharge time for the seeds on the germination are shown in Fig. 2. The corona was generated under dry air with 200 μA. Both of the germination with 5 μM GA_3 and without GA_3 increase with the discharge time. The corona discharge treatment during 120 min has the same effect as GA_3 with 5 μM has on the germination.

The current of the corona discharge for the seed treatment has strong effects on the germination as shown in Fig. 3. The germination with 200 μA is about 2.4 times that without the corona discharge.

Effects of the corona discharge environment on the germination are shown in Fig. 4. The corona discharge with dry air has strong enhancement on the germination, while the corona discharge with oxygen or with nitrogen has no effect on the germination. The concentration of oxygen in mixed gas with oxygen and nitrogen controls the germination as shown in Fig. 5. The germination has the maximum at 20 % in the oxygen concentration.

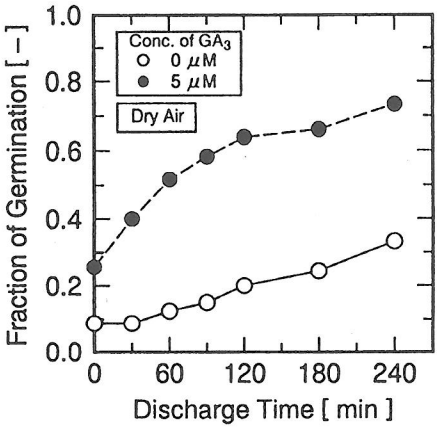

Fig. 2 Effects of discharge time for the seeds on the germination.

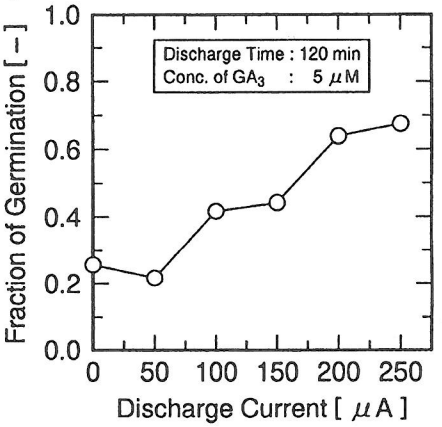

Fig. 3 Effects of discharge current for the seeds on the germination.

3. CORONA DISCHARGE TREATMENT FOR CULTIVATION WATER

3.1 Experimental Procedures

The cultivation water (30 ml) in a glass container was treated by the corona discharge on the lower copper electrode, while the upper electrode was the same as Fig. 1. The cultivation water were treated with high voltage (12 kV, 50 Hz) under the pressure of 760 torr. After the corona discharge treatment for the cultivation water, the seeds were dipped into the cultivation water. The cultivation conditions were the same as Sec. 2.

3.2 Results and Discussions

Effects of the discharge time for the cultivation water on the germination are shown in Fig. 6. The seeds used in these experiments are as follows; without treatment, the corona discharge treatment for 120 min and 240 min, and punctured treatment by a fine needle. The germination of all the seeds increases with the discharge time, even the germination of the untreated seeds are increased by the cultivation water treated by the corona discharge. These results indicate that the corona treated water has similar functions as GA_3 has.

The results of chemical analysis for the corona treated water is presented in Fig. 7. The chemical analysis for NO_2^-, NO_3^- and NH_4^+ was performed. The concentration of NO_3^- is much higher than that of NO_2^- or NH_4^+. Moreover the concentration of NO_3^- increases with the discharge time for the water, while NO_2^- and NH_4^+ were unstable especially at the long discharge time. The effects of NO_3^- is expected to be important in the mechanism of the seed germination.

4. MECHANISM OF THE ENHANCEMENT OF SEED GERNIMATION

Effects of NO_3^- in the cultivation water on the seeds germination are shown in Fig. 8. The cultivation water was prepared from nitric acid without the corona discharge treatment. The germination increases with NO_3^- concentration, presenting the similar results in Fig. 6. These results indicate that the enhancement by the corona discharge treatment is attributed to NO_3^- produced indirectly from the corona discharge.

Mechanism of the enhancement of the seed germination is illustrated in Fig. 9. Nitrogen dioxide produced by the corona discharge absorbs on the seed surface. Nitric ion is produced in the cultivation water from the absorbed NO_2, then NO_3^- penetrates into the seed. Some biochemical reactions related to the germination are promoted by NO_3^- in the seed. Nitric ion is expected to be a mediator of signal transduction for the germination, however the biochemical reaction in the seeds has not been identified.

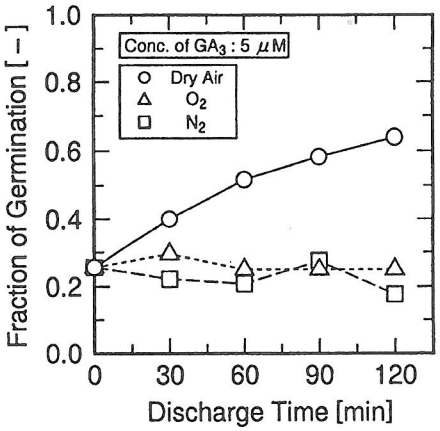

Fig. 4 Effects of discharge environments on the germination.

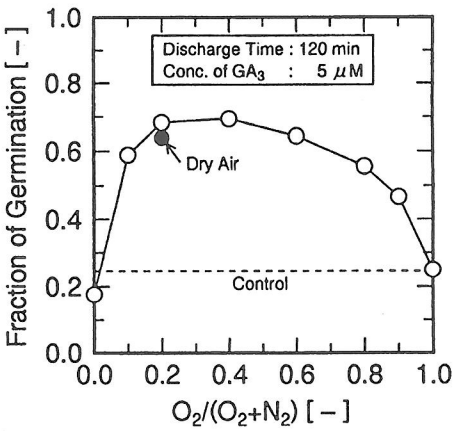

Fig. 5 Effects of oxygen concentration on the germination.

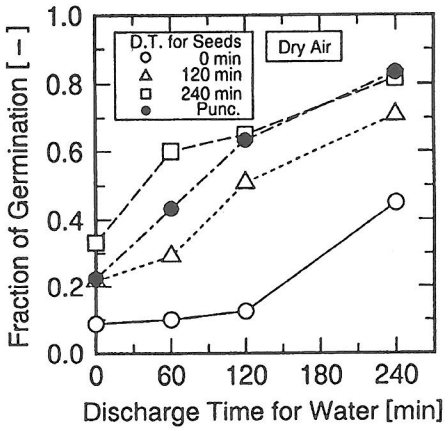

Fig. 6 Effects of discharge time for the cultivation water on the germination.

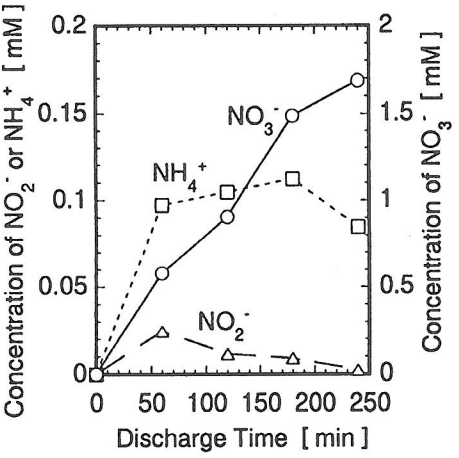

Fig. 7 Chemical analysis of NO_3^-, NO_2^- and NH_4^+ in the corona treated water.

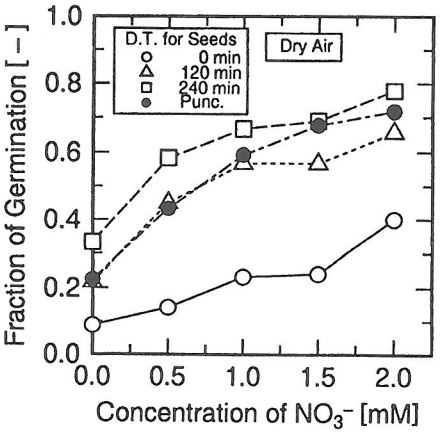

Fig. 8 Effects of NO_3^- in the cultivation water on the germination.

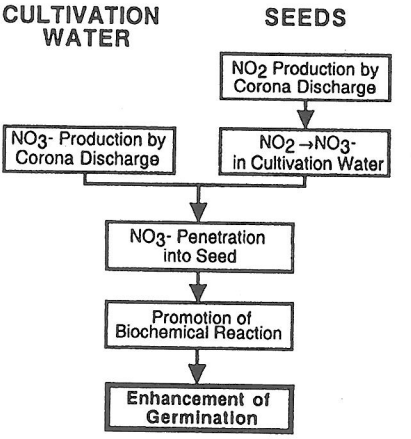

Fig. 9 Mechanism of seed germination enhancement by the corona discharge.

5. CONCULUSIONS

The corona discharge is capable of enhancing the germination of *Grand Rapids* seeds. The treatment is effective for the germination enhancement of low-germination seeds such as *Grand Rapids*. The enhancement is attributed to NO_3^- produced in the cultivation water from NO_2 which is formed by the corona discharge.

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