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Improving Germination of Seeds Soaked GA3 by Electrostatic Field Treatment

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Abstract—Tree species with shallow dormancy are used for reforestation by airplane sowing in order to establish forest in mountain areas. To enhance germination and the quality of young seedling, an electrostatic field is used to treat pine seeds soaked with 100 ppm of gibberellic acid (GA3). The experimental results showed that the multiple factors treatment of the seeds is better than a single factor, and the treatment effect depended on the dosage, process and vigor index of the seeds. The optimal dosage was 500 kV/m 10 minutes for 50-100 ppm soaked seeds to improve germination, seedling height and root length during initial germination and middle and later stages of seedling development.

Index Terms—Electrostatic Field, Germination, 100 ppm GA3, Soaked Seed Treatment.

I. INTRODUCTION

After early researchers discovered the application of electricity in agro-forestry science, they used it for different purposes, such as for seed treatment, seedling growth, plant growth, insect control, and so on. Although their research aims were good, their apparatus, experimental design and methods, process, dosage, amplitude of voltage, and the treatment time were not scientific so that and they often got contradictory results as showed by Lund [1]. Probably the interaction between electrostatic field and seedling growth has not been fully understood. On the basis of this assumption, we have studied the application of electrostatic field in forestry science for many years in order to improve germination of tree seeds, using different electrical methods, single and multiple factor treatments. We know that most seeds germinate on the surface of the earth where strong magnetic fields exist in deep ground and strong electrostatic fields are present in the high atmosphere. Therefore, all forms of life live in an environment subject to the action of natural electromagnetic fields. However, these field forces on the surface of the earth appear too weak to influence seed germination and seedling development. Many studies have stimulated wider interest about the possible biological significance of naturally occurring electric fields and related phenomena.

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Murr [2-4] has shown that high intensity electric fields appear to inhibit development in grass seedling. Jorgenson and Priestley [5], and Shibusawa and Shibata [6], observed that electric field increases plant growth. The physiological effects of air ionization have been reported by Griffin and Kornblueh [7].

We think that in these experiments, the electrical field intensity was too weak and distance was too far; moreover the experimental designs were not standardized, because they did not solve insulation, dosage, experimental condition, and so on. Based on the above problems, it is difficult to get ideal results and conclusions. Therefore, we decided to investigate how the electrostatic treatment determines changes in seed vigor index through our apparatus and methods [8].

Several pine seeds including others are widely used as reforestation by airplane sowing. Each year, about millions of kilograms of seeds are sown directly in many mountain areas by airplane sowing for seedling. This technique of reforestation is fast and economical. After sowing seeds, if it rains 30-100 mm over 3 to 5 days and temperatures are suitable, 30 to 40% of the seeds germinated and became young tree seedlings. Otherwise, 50 to 70% of the seeds on the surface were quickly eaten by birds, insects, and rodents within 10 to 20 days. Therefore, pretreatment of seeds before sowing is the most important step to enhance germination and development of young seedlings.

II. EXPERIMENTAL PROCEDURE

Gibberellic acid (GA3) is a naturally occurring plant growth regulator. Presoaking seeds in GA3 cause rapid germination of many highly dormant seeds and are widely used in agro-forestry production. GA3 is highly stable in acidic solution and can break seed dormancy, improve quality and increase fruit production. In our study, we used 100 ppm GA3, 3 Kg solution, and soaked 0.5 kg *Pinus tabuliformis* Carr.

Seeds of pine, *Pinus tabuliformis* Carr., were selected and designated as the wet lot. It was placed into cold water containing 100 ppm GA3 for 24h, then removed from the water and drained for 5 minutes, and subsequently divided into four sublots. One sublot was retained as control and the other three were treated at 300 kV/m, 500 kV/m, and 700 kV/m, respectively. Treatment time was selected for these sublots as 10, 20, and 30 min., respectively. The electric field gradient E was calculated as same as Murr [4], but the circuit for high voltage generator was not the same, but such as those described in Fig.1 and Fig. 2.

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Treatment electrodes were two horizontal, circular metal plates of 300 mm in diameter and 4 mm thick, separated and maintained in parallel orientation by three insulating posts, 3 cm in length and 2 cm in diameter. The top one was the positive electrode; and the bottom one was the negative electrode as shown in Fig. 1.

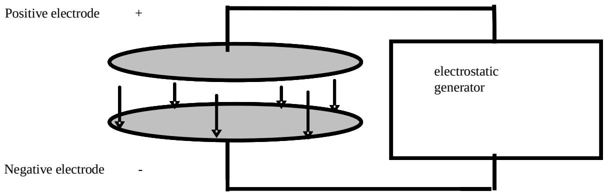

Fig. 1. Seed treatment principle

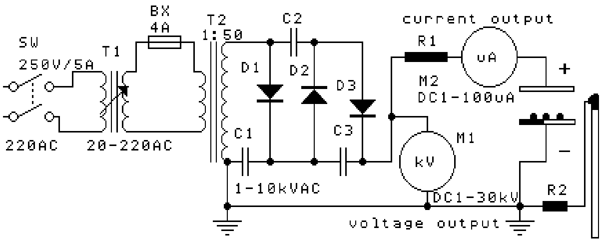

Fig. 2. Circuit for high voltage generator

Seeds were placed on the top surface of the bottom plate. The high voltage circuit was not the same as that used by Murr [4]. Positive and negative electrodes were connected to the positive and negative output terminals with insulating high-voltage line respectively, of 1 to 10 kV high-voltage generator and adjusted output voltage with a knob. The negative electrode must ground when use a positive electrostatic treatment. A kilovolt meter and a microammeter were used to measure the voltage between the electrodes and the electric current passed through seeds, respectively. For the treatment, the seeds were placed in a single or more layers on the top of the negative plate with 50 to 100 g containing about 1000 to 2000 pine seeds at a time, (in airport test, 50 to 100 kg pine seeds were treated in the box at a time by positive electrostatic field treatment). The distance between the surface of the seeds and the positive electrode is decided by electrical field intensity. When treatment was over, the plates were then discharged with an insulated conducting rod for safety before removing the treated seeds. Wet GA3 control sample was not treated and was kept at a distance of 3-4 meters away from the treatment equipment.

After finishing treatment, four replicates of 100 seeds each of treated and control sublots were randomly selected and placed into glass culture containers with sandy medium. They were watered in timely fashion and germinated at 25 ºC constant temperature with full photoperiod. The temperature of the seeds was not changed during and after the seed treatment. We used a temperature sensor to measure temperature. In the future, sensor networks can also be used to measure temperature. Sensor networks can measure temperature from different points. Therefore, using sensor networks to acquire temperature is a more accurate method. Research about sensor networks can be found in [9-12]. The percentages of germination of seeds were improved by the field because in all tissue cells of the seed there are electric potential differences. Seeds were considered to have germinated when the length of the radical was equal to the length of the seed. Germination percentage was calculated according to the rules for seed testing (ISTA, 1996) [13]. For data analysis, a standard deviation was used as to express the degree of variation and the F-test was used as to examine differences among tested samples.

III. RESULTS AND DISCUSSION

The germination results at 10 days for the control and treated samples of the GA3 wet lot of pine seeds are summarized in Table I, where are shown the effects of the positive electrostatic field treatment on germination percentage of pine seeds soaked 100 ppm GA3. The results showed that treatments of 500 kV/m 10 min., 500 kV/m 20 min., and 500 kV/m 30 min. have markedly improved germination percentage from 28.3% to 49.0%, 42.3%, and 40.3% comparing with control, and the three treatments have surpassed $LSD_{0.05}$=11.78, ($P<0.01$). The percentage differences between treatments and control are significance during germination at 10 days. The increase of the treatment time determines damage to seeds and as a consequence the germination percentage slowly reduces. If continuously extending the treatment time, the temperature does not increase. The range of the temperature variation in the seeds before and after the treatment was a little.

In Table II are shown the effects of the positive electrical treatment on root length of young seedling after germinated at 10 days. Pine seeds treated with 500 kV/m 10 min., 500 kV/m 20 min. and 500 kV/m 30 min. germinated and grown quickly within 10 days germination period, especially the difference of seedling heights ranging from 5.0 cm to 7.8 cm, 10.9 cm and 8.7 cm comparing with the control one. All the root length differences were statistically significant ($P < 0.01$), and the 500 kV/m 10 min. treatment was a suitable dosage. If treatment time lasted continuously, the germination percentage decreased because prolonging of the treatment time would restrain germination, especially appearing inhibition in height of young seedlings. Maintaining the same electric field intensity but lasting the treatment time would determine excessive energy exposure to seeds.

Seed treatment includes many methods, such as low and high frequency electrical fields, magnetic field, X-ray, microwave field, infrared ray, and electrostatic field. According to our recent observations, compared to other methods, electrostatic field represents a fast, effective and economic method for the pretreatment of thin coat seeds with shallow dormancy. The direction and magnitude of electrostatic field does not change during the exposure. Treated seeds were in contact with two electrodes. Seed vigor was apparently changed by electrostatic field force.

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Table I. Germination percentage of positive electrostatic field treated and control samples of *Pinus tab.* Carr. seeds soaked 100 ppm GA3 at 10 days germination

Test samples	Germination percentage (%)	Percentage difference
+500 kV/m 10'	49.0	20.7**
+500 kV/m 20'	42.3	14.0**
+500 kV/m 30'	40.3	12.0*
Control	28.3	0

Table II. Root length of positive electrostatic field treated and control samples of *Pinus tab.* Carr. seeds soaked 100 ppm GA3 at 10 days germination

Test samples	Mean of root length (cm)	Root length difference
+500kV/m 10'	7.8	2.8**
+500kV/m 20'	10.9	5.9**
+500kV/m 30'	8.7	3.7**
Control	5.0	0

Germination at 10 days, F=14.89, $LSD_{0.05}$=2.06, $LSD_{0.01}$=3.0 and S_{x1-x2}=0.89

The temperature of the seeds was not changed during and after the seed treatment. The percentages of germination of seeds were improved by the field because in all tissue cells of the seed there are electric potential differences. During electrostatic field exposure, positive ions in the seed tissue would move and be concentrated on the surfaces of each seed. Positive ions would move from original positions toward the negatively polarized electrode. The external electric field induces an inner electric field in the seed, with a opposite direction of that the external electric field. Therefore the magnitude of the inner electric field in the seed tissue will depend on the magnitude of the external electric field.

Comparing the works of Jorgensen and Priestley [5], Krueger et al. [14], Edwards [15], Murr [2-4], Sidaway [16], we think that they used weaker electric fields and longer times for the stimulation period. They placed samples into a small space that was formed by plate electrodes in a higher moisture condition. Pammenter et al. [17] used a lower electrostatic gradient, as that of 140 V existing in the earth's surface. The voltage here is measured by a voltage-meter. Positive electrostatic field treatment of +500 kV/m 10 min., and +500 kV/m 20 min. on *Pinus tab.* Carr. seeds soaked 100 ppm GA3, were the best dosage and treatment time to improve germination and seedling growth, respectively. The experiments performed by us in the laboratory were also confirmed in mountain areas using 0.5% Ca(OH)2 powder for protection coat of seeds (data not shown), and all results have provided strong evidences for application of the electrostatic field treatment for forestry production, particularly for old seeds, where the action of the positive electric field can counteract more effectively the attack of free radical species on cellular structures [17].

IV. CONCLUSION

The quick and uniform, germination of seeds, and the robust growth of seedlings indicate high vigor of seeds. Considering changes of the electric conductivity, respiratory intensity, and dehydrogenase activity of cellular enzymes of seeds, the electrostatic field treatment determined the repair of seed cell membranes and the acceleration of hydrolysis of fats. Also, the supply of sugar has been ensured for seed respiration and germination, and the speed of germination and seed vigor have been raised. Therefore, all electrical and biochemical changes are beneficial for seed germination and seedling growth, after using positive electrostatic field treatment.

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Prof. Zhi-bin Gui. Associate professor, graduated in 1976, with B.Sc. Radio Elements & Materials, Technical Physical Department of Xidian University. Supervisor postgraduate students at Microelectronics School of Xidian University. Research interests are development application on electronics in forestry science, such as tree seed pretreatment by electrical methods, seedling growth, tree's protection by electrical methods. He published 20 research papers in Chinese. He received a researcher paper award on germination mechanism of pine seeds treated with electrostatic field, also he got an invention patent award on equipment & method of pretreatment tree seeds using direct current field. He finished 10 research projects from national, province, and university during 20 years.

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