Improving Tree Seed Germination by Electrostatic Field

Zhi-bin Gui, Antonio Piras, Li-min Qiao

Abstract: Tree species with shallow dormancy are used for reforestation by airplane sowing in order to establish forest in mountain areas. To enhance germination, the quality of young seedling, an electrostatic field is used to treat pine seeds. Experiments found that treatment effect depended on the dosage, process and vigor index of seeds, and the optimal dosage was 500 kV/m 10 minutes for dry or wet seeds to improve germination, seedling height and root length during initial germination and middle and later stages of seedling development.

Index Terms: Dosage, Electrostatic Field, Germination, Tree Seed Pretreatment.

I. INTRODUCTION

Most seeds germinate on the surface of the earth where strong Magnetic Fields exist in deep ground and strong Electrostatic Fields exist in the high atmosphere. However, these field forces on the surface appear too weak to affect seed germination and seedling development. An electrostatic field was used as seed pretreatment in early work. Jorgensen and Priestly [1], and other researchers reported higher yields of plants under electric environments. Krueger et al. [2] reported that positively or negatively ionized air induced more rapid germination in *Avena sativa* seeds. Levengood [3], and Edwards [4] observed the influence of electric fields on pupation, oviposition and progeny of insects under weak electric fields. Murr [5]-[7] used 30-80 kV/m electrostatic field to stimulate grain sorghum seedlings and reported favorable results. Sidaway [8] used an electric field intensity of 180 V/cm to stimulate lettuce seeds and thought that a positive electric field inhibited plant development and the nature of plant responses depended on the sign of the electrostatic field. Yan et al. [9] reported effects on vegetable seeds by using metal line electrode treatment.

Many researchers demonstrated positive effects and negative influences on tree seeds by electrostatic field. From early reports, we think that experimental designs were not standardized, because they did not solve insulation, dosage, experimental condition and so on. Based on above problems, it is difficult to get ideal results and conclusions. Therefore, we decided to explore theoretical relationships between electrostatic treatment and changes in seed vigor index.

Revised Manuscript Received on 30 January 2013.
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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 which 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 eaten quickly by birds, insects, and rodents within 10 to 20 days. Therefore, pretreatment before sowing is a very important step to enhance germination and development of young seedlings.

II. EXPERIMENTAL PROCEDURE

Seeds of pine, *Pinus tabuliformis* Carr., was selected and divided into two lots. The first lot, designated as the dry lot, was mixed and divided into four sublots. One was the control. The other three were treated under an electric field intensity of 300 kV/m, 500 kV/m, and 700 kV/m, respectively, for a time of 10 min. The second lot, designated as the wet lot, was placed into cold water for 24h, then removed from the water and drained for 5 minutes, and then divided into four sublots in the same way as the dry lot. One sublot was retained as control and the other three were treated at 300 kV/m, 500 kV/m, and 700 kV/m respectively as same the dry sublots. 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 [7], but the circuit for high voltage generator was not the same. Treatment electrodes were two horizontal, circular metal plates 300 mm in diameter 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. Seeds were placed on the top surface of the bottom plate. The high voltage circuit was similar to Murr [7]. Positive and negative electrodes were connected to the positive and negative output terminals with insulating high-voltage line respectively, of a 1 to 30 kV high-voltage generator and adjusted output voltage with a knob. The negative electrode must ground. A kilovolt meter and a micro-ammeter were used as to measure the voltage between the electrodes and the electric current passed through respectively. For treatment, the seeds were placed in a single or more layer on top of the negative plate with 50 to 100g containing about 1000 to 2000 pine seeds at a time, (in airport test, 50 to 100kg pine seeds were treated in the box at a time). The distance between the surface of 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.

Both wet and dry control samples were not treated and were kept at a distance of 3 to 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, we used sensors to measure temperature. In the future, we can also use a wireless sensor network to measure the temperature. Research about wireless sensor networks can be found in [10]-[13].

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 Rules for Seed Testing (ISTA, 1996) [14]. For data analysis, a standard deviation was used as to express degree of variation and the F-test was used as to examine differences among tested samples.

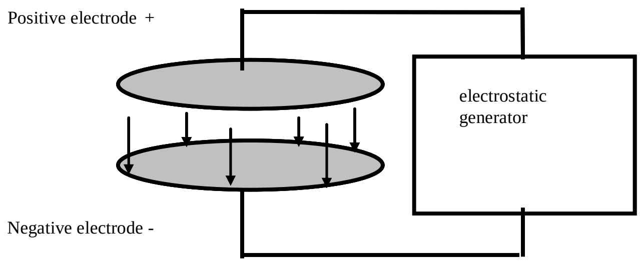

Fig. 1. Seed treatment principle

III. RESULTS AND DISCUSSION

Germination results at 10 days for the control and treated samples of the wet lot of pine seed are summarized in Table I.

The treatments at 300 kV/m for 10 min and 500 kV/m for 10 min improved germination from 49% to 55.3% and 55.0%, respectively, compared to the control sample. Because both LSD0.05=6.3 for the 300 kV/m, 10 min and LSD0.05=6.0 for the 500 kV/m, 10 min treatment surpassed LSD0.05=5.69, but were less than LSD0.01=7.90, these tests demonstrated that germination improvements for both treatments were significant ($p < 0.05$) at 10 days. Increasing the electric field intensity tended to reduced germination because stronger electric field restrains seeds and slows down the germination. Another test result of germination tests on the 500 kV/m with 10’ 20’ and 30’ wet sublot samples at 7 days are summarized in Table II.

The 10 min treatment improved 7-day germination from 35% to 42%. This demonstrated that treatment at 500 kV/m for 10 min was a suitable dosage. Even when exposure time was extended to 30 min, no reduction in germination was observed. Longer exposures would restrain germination at 500 kV/m, especially showing inhibition of root development of young seedlings. Effects of the electrostatic treatment wet lot seeds on root length of germinating seeds at 7 days are shown in Table III.

Root lengths of young seedling from seeds treated at 500 kV/m for 10 min, and 20 min were improved from 4.7 cm to 5.9 cm ($p < 0.01$) and 5.5 cm ($p < 0.05$), respectively, at 7 days. These tests demonstrated that treatments gave highly significant increases in root length (1.2 cm) and significant increases (0.8 cm) for 10 min and 20 min exposures, respectively, when soaked pine seeds were treated at 500 kV/m. Treatment for 10 min was the best ($p < 0.01$).

Results of electrostatic electric field treatments of dry pine seeds are summarized in Table IV.

Treatments at 500 and 700 kV/m accelerated germination percentage. Treatment of the dry pine seeds at field intensities greater than 700 kV/m decreased germination. An effective improvement of germination index was close to that of treatment of presoaked seeds, but germination was later for the dry pine seed. As earlier airplane sowing reforestation tests were successful, we conducted reforestation tests in 1989- 1994 in the south and northern mountains of Shaanxi Province of China at 700 to 1700 meters above sea level.

Seed treatment has many methods, such as low and high frequency electric fields, magnetic field, x-ray, microwave, infrared ray and electrostatic field and so on. According to recently year observation, electrostatic field is better to pre-treat thin coat seed with shallow dormancy comparing with normal methods. The direction and magnitude of electrostatic field does not change during the exposure. Seeds being treated were in contact with only one electrode. Seed vigor was apparently changed by electrostatic field force. The temperature of seeds is not changed during and after seed treatment. The percentages of germination of seeds were improved by the field because each seed has some electrical nature with electric potential differences existing in all tissue cells. Thus, polarization phenomenon occurs in the seed tissue when there is an external electric field. Thus, positive and negative ions in the seed tissue would move and be concentrated on top and bottom surfaces of each seed during electrostatic field exposure. Positive ions would concentrate from original positions toward the negatively polarized electrode, and negative ions in the seed tissue would concentrate from original positions toward the positively polarized electrode. Therefore, an inner electric field induced by the external electric field would form in the seed, and its direction is the reverse of 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. Another most important discovery is bioelectricity in seed, its magnitude and direction change with external electric field, such as properties of electromagnetic, direction and so on. When seeds exposure under an electrostatic field environment, bioelectricity in seed tissue must change, and direction and magnitude of seed bioelectricity also must change with external electrostatic field direction and magnitude according to the theory of conducting electricity and electrical interactions of matter. Comparing the works of Jorgensen et al [1], Krueger et al. [2], Edwards [4], Sidaway [8] and Murr [5]-[7], 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.

Table I. Comparison of 10-day germination of treated and control sample of *Pinus tab.* Carr. Seeds

Test samples	Average germination (%)	Difference of treatment and control
300 kV/m, 10min	55.3	6.3*
500 kV/m , 10min	55.0	6.0*
700 kV/m , 10min	38.0	-11.0
Control sample	49.0	---

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Table II. Comparison of 7-day germination of treated and control samples of soaked pine seed

Test samples	Average germination (%)	Difference of treatment and control
500kV/m 10min	42.0	7.0*
500kV/m 20min	39.7	4.7
500kV/m 30min	39.7	4.7
Control	35.0	—

Table III. Comparison of 7-day root growth of treated and control samples of soaked pine seed

Test groups	Average young seedling root length (cm)	Difference of treatment and control
500kV/m 10 min	5.9	1.2**
500kV/m 20 min	5.5	0.8*
500kV/m 30 min	5.4	0.6
Control	4.7	—

Table IV. Germination effects of electrostatic field treatment on dry pine seeds

Samples	Germination 10 days	GI
300kV/m 10’	29.3±5.2	3.3±0.6
500kV/m 10’	35.0±4.2	4.1±1.0
700kV/m 10’	34.0±3.5	3.9±0.3
Control	26.3±2.9	2.9±0.4

Selecting a single treatment dosage provides only limited information. Electrical plates of control electrodes that were connected together with an electrical line increased errors, and also did not insulate testing samples (control sample also was affected by electric field). Thus, accuracy is affected, and this raises questions about the reliability of comparisons with our results. We know that seed vigor is defined as the potential capacity of seed germination and seedling growing speed.

IV. CONCLUSION

The quick germination of seeds, uniform germination of seeds, and robust growth of seedlings indicate high vigor of seeds. Considering changes of the electric conductivity, respiratory intensity, and dehydrogenase activity of seeds, we have concluded that the structure of seed cell membranes being repaired by electrostatic field treatment, and the hydrolysis of fat has been accelerated. β-oxidation of seeds has been speeded up, 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 are beneficial to seed germination and seedling growth. after using electrostatic field treatment Other analyses, such as changes of physiology, biochemistry and bioelectricity of seeds will be discussed in separate articles.

ACKNOWLEDGMENT

We thank Professor Hu Jing-jiang, and Mr. Liu Jian-chao, Physiological and Biochemical Laboratory of Northwest Forestry College for their assistance in the seed testing, and part of the analyses. The work was supported by the National Natural Science Foundation of China.

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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.

Antonio Piras holds a Master’s degree in Biological Sciences at the University of Cagliari, Cagliari, Italy. Currently he’s third-year doctoral student at the Doctorate School in Morphological and Functional Sciences, University of Cagliari. His research interests are in the field of Metabolomics and Nutrition. Actually is conducting his studies on extraction and measurement of lipid molecules through HPLC-MS methods. He has been working for two years on Krebs Cycle intermediates and enzymes research on isolated rat mammary gland mitochondria at the University of Alabama at Birmingham, USA.

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