

ELECTRONICS AND HARDWARE FOR STUDYING THE IMPACT OF ELECTROSTATIC FIELDS ON GERMINATION, GROWTH, AND DEVELOPMENT OF PLANTS

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Abstract: This research focuses on the design and development of electronic and mechanical components for a hardware system aimed at investigating the effects of electrostatic fields on plant germination, growth, and development. The study contributes to a deeper understanding of plant biology by exploring the relatively under-researched influence of electrostatic fields on key physiological processes. The hardware system includes a high-voltage source for generating electrostatic fields, utilizing a diode-based high-voltage cascade, rectangular perforated metal electrodes arranged in a parallel plate capacitor configuration, and a germination chamber made of insulating plastic. The chamber is larger than the electrodes and equipped with mechanisms to maintain stable environmental conditions, such as temperature and humidity. The construction of the system was successfully completed, and the intended experiments were conducted using this setup, providing valuable insights into the interaction between electrostatic fields and plant growth dynamics.

Key words: germination and plant development, electrostatic field

1. INTRODUCTION

Electrostatic fields, though often overlooked in the context of biological research, represent a significant factor in understanding plant germination, growth, and development. This phenomenon can influence various physiological processes within plant organisms, including nutrient transport, metabolism, and stress responses. In modern agronomic practices, understanding how electrostatics affects plant development could open new avenues for improving crop yields and quality. Investigating the interaction between electrostatics and plants not only enhances scientific knowledge of plant processes but also holds practical applications in agriculture [1], [2], [3]. This study focuses on the design of a device capable of providing suitable conditions for examining these effects.

Initially, the basic principles of electrostatics, including the nature of the electrostatic field, voltage, and other critical characteristics, will be explored. Subsequently, the construction of the apparatus for generating electrostatic fields for experimental purposes will be described in detail.

Understanding the relationship between fields and plant development could contribute to the development of innovative techniques that may enhance the efficiency of plant cultivation in the future.

2. ELECTROSTATIC FIELD

2.1. Characteristics and Shape

An electrostatic field is a physical field created around charged particles or objects. It represents the space in which the influence of the electric field E can be felt. While the electrostatic field is invisible, its effects can be observed. For instance, when combing hair with a plastic comb, the comb becomes charged and attracts small dust particles. Similarly, removing a wool sweater in the dark can produce small sparks due to static electricity discharge.

An electrostatic field is generated when electrons within an atom of a material move from one location to another. This displacement of electrons creates an imbalance between positive and negative charges within the body, leading to the generation of electric potential. A charged object then creates an electric field in its surroundings.

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The electrostatic field is graphically represented using electric field vector lines EE . These lines are conceptual representations showing the direction and magnitude of the electric force at each point in space, as illustrated in Figure 1 [4].

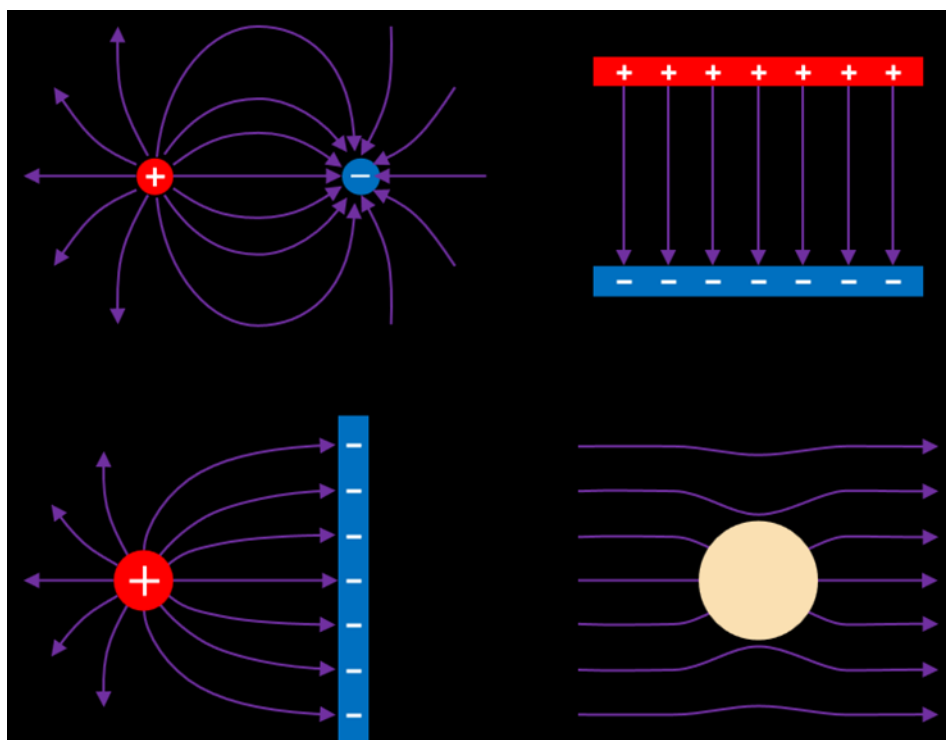


Figure 1 - Electrostatic Field Vector Lines EE

- a) Electric field vector lines EE between two point charges.
- b) Electric field vector lines EE between a point charge and a charged plate.
- c) Electric field vector lines EE between two plates of a capacitor.
- d) Electric field vector lines EE around a conductive body.

It is important to note that in this study, we use the configuration under (c).

Properties of the Electrostatic Field:

Field intensity: The intensity of the electrostatic field is strongest in the immediate vicinity of the charged object and decreases with distance, specifically as the square of the distance. **Field direction:** The direction of the electrostatic field is defined by the direction of the electric vector EE , which acts on a positively or negatively charged particle at a given point in the field. **Superposition principle:** The total electric field at any point in space is equal to the vector sum of the electric fields from all charges present in that space. **Applications:** Electrostatic fields have numerous applications in daily life and various industries. Some of the most notable include: Electrostatic precipitators, Lasers, Photocopiers, Spray painting and Potential applications in agriculture.

3. EXPERIMENT

3.1. Detailed Description of the Experiment

This research analyzes the impact of electromagnetic radiation on the germination and early growth of corn, bean, sunflower, and wheat seeds. The experiment is designed to allow precise control

over the intensity and duration of exposure to the radiation. The seeds are placed in specially designed containers and exposed to radiation under controlled conditions. A parallel control group of seeds is kept that is not exposed to radiation. Regular visual inspection and photography are used to monitor all changes during germination and early growth.

The study focuses on determining how different intensities and durations of electromagnetic radiation affect physiological processes during germination and early development of selected agricultural crops. The experiment is designed to enable systematic variation of these parameters and accurate measurement of seed response to the application of electrostatic voltage.

The exposure to the field lasted for a period of 7 days. The applied electrostatic field was **350 V** on the different types of crops.

After two days from the start of the experiment (see Figures 2, 3 and 4), the control samples showed only the initial signs of germination, with a small number of seedlings emerging. In contrast, the seeds exposed to electromagnetic radiation had already germinated to a greater extent and developed visible sprouts. This significant difference in germination speed was observed across all four types of seeds under investigation, indicating a strong influence of electromagnetic radiation on the germination process.

The results of this experiment clearly demonstrate that electromagnetic radiation can have a stimulating effect on seed germination. These findings open new perspectives for investigating the potential application of electromagnetic radiation in agriculture, aimed at improving crop production and plant resilience. However, since the focus of this paper is not on the experiment results, a detailed discussion of the achieved outcomes will not be provided.

It is also worth noting that other forms of electrical phenomena have been investigated for their impact on plant development. These include experiments attempting to determine the effect on germination and plant development using: Plasma [5], Exposure of seeds to magnetic fields before sowing [6], Using $\text{IrO}_2\text{-Ta}_2\text{O}_5\text{-Ti}$ electrodes [7], The effect of electrical discharge on seeds [8], The impact of magnetic field exposure on seeds during growth and development [9], The influence of microwaves [10], and so on.



Figure 2 - Container with samples for the experiment



Figure 3 - Samples without the effect of the electrostatic field

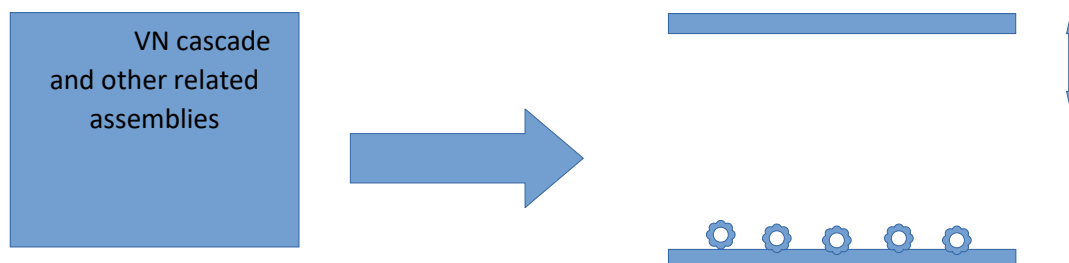


Figure 4 - Samples with the effect of the electrostatic field

4. HARDWARE CONSTRUCTION

4.1. Block Diagram

The block diagram (in Figure 5.) consists, in principle, of two parts. Electronics and mechanical engineering. The electronics are used to generate the voltage needed to affect the plant, while the mechanical part contains the housing, electrodes, sample containers, etc.



Electronics mechanical part with samples

Figure 5 - Block Diagram of the Device for Testing the Impact of Electrostatic Field on Germination, Growth, and Development of Plants

4.2. Detailed Description of the Manufacture of Individual Components and Material Selection for the Mechanical Part of the Device

Electrodes

- **Material:** Metals such as aluminum, brass, or stainless steel can be used due to their good electrical conductivity. In our experiment, we used perforated galvanized sheets. The dimensions of the sheets are 30 x 40 cm. The perforations are made to ensure that the plant, which is placed between the electrodes, has satisfactory conditions for development. This includes uniform distribution of temperature, oxygen supply, light, and humidity. The perforations have a diameter of approximately 4 mm.
- **Processing:** The electrodes are **cut** from larger sheets of galvanized steel. The shape of the electrodes is designed to be either parallel plates or cylindrical electrodes, depending on the experiment setup.
- **Connection:** The electrodes are connected to the high-voltage source using flexible, high-voltage insulated conductors. This ensures safe and efficient transmission of electrical current to the electrodes.
- **Standoffs (spacers):** The spacers are made from insulating material, in our case, PVC tubing. PVC is flexible and easy to work with, and its dielectric strength is satisfactory for this application. The standoffs are equipped with a system for adjusting the distance between the plates, allowing for precise control over the spacing during the experiment.

Plant Chamber

Material: PVC was used in the form of a closed box. PVC was chosen for its transparency, moisture resistance, and ease of processing.

4.3. Assembly and Connection

- **Assembly:** All elements are carefully assembled and secured to ensure the stability of the structure.
- **Connection:** High-voltage conductors are carefully connected to the electrodes and the power source. All connections must be firm and well-insulated.
- **Grounding:** All metal parts that are not under voltage must be reliably grounded.

4.4. Electronics

Diode cascades, shown in Figure 6, represent a simple yet efficient method for generating high voltage from a low-voltage source, which is essential for creating the electrostatic field required for such research [11]. This type of electronics enables precise control of voltage and current, which is crucial for optimizing experimental conditions.

Components and Function

1. Low-Voltage Source:

- Typically, main voltage is used to provide a stable power supply for the diodes.

2. Diodes:

- High-voltage diodes with a high voltage rating are used. Diodes are connected in series to increase the overall voltage.

3. Resistors:

- Serve to limit the current through the diodes and protect the circuit from overload. The resistor value is determined based on the diode characteristics and the desired voltage.

4. Capacitors:

- Used to filter the output voltage and reduce noise.

Operating Principle

1. The low-voltage source powers the first diode in the cascade.
2. The diode rectifies the alternating voltage component, allowing only the direct current portion to pass.
3. The output voltage of the first diode becomes the input voltage for the second diode, and so on.
4. Each additional diode in the cascade increases the output voltage by the voltage drop across one diode.
5. Capacitors filter the output voltage and reduce voltage ripple.

It is important to note that this circuit must be well-insulated and protected from short circuits. A high-voltage voltmeter is used to set the voltage to the desired value. The assembled circuit can be compact in size, as shown in Figure 7 [12]. For safety when working with high voltages, all safety precautions must be followed.

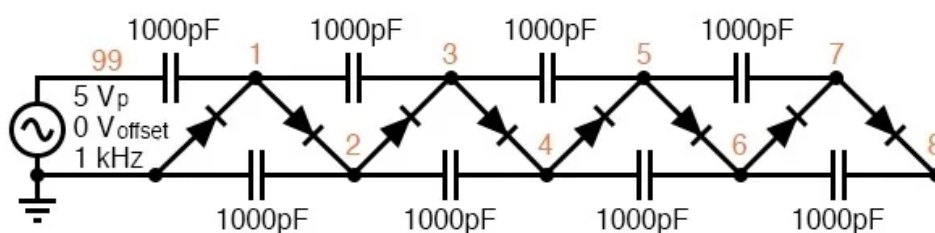


Figure 6 – Construction of HV diode cascade

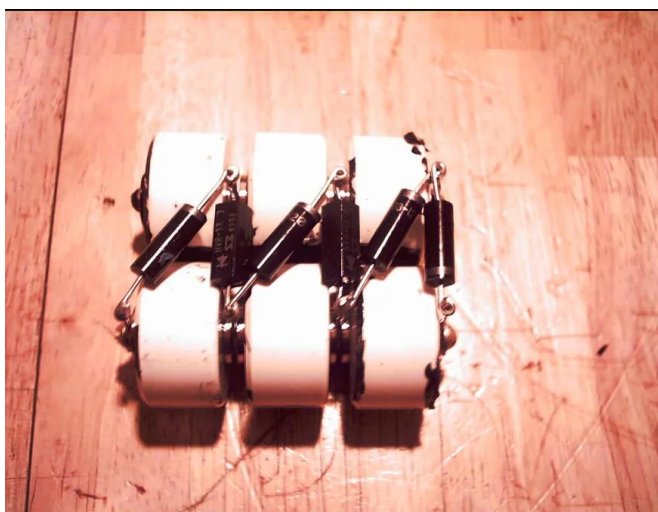


Figure 7- Hardware version of one HV diode cascade

5. CONCLUSION

This research has demonstrated that an electrostatic field can significantly impact the early stages of plant development. The results suggest that it is possible to manipulate physiological processes in plants through the application of controlled electrostatic fields. These findings open new perspectives for the development of innovative agricultural techniques.

However, it is important to emphasize that these results were obtained under controlled laboratory conditions, and their applicability in field conditions remains unclear. Additionally, the mechanisms underlying the observed effects are not yet fully understood. Future research should focus on isolating and characterizing the molecular mechanisms underlying these responses. It would also be interesting to investigate the impact of electrostatic fields on other plant processes, such as photosynthesis, water and nutrient transport, and stress resistance.

The hardware aspect of this research was the primary focus of this paper. Hardware is essential for achieving precise and reproducible results. The constructed device for generating an electrostatic field enabled precise control of field intensity and exposure duration. The use of a diode cascade, perforated growth chamber plates, and the device's housing ensured a stable and homogeneous electric field within the plant growth chamber.

The diode cascade, as a key element of the electronics, proved to be a reliable and straightforward method for generating the high voltage required to create the electrostatic field. However, it should be noted that the efficiency of the diode cascade is relatively low, with a significant portion of energy lost as heat. Therefore, the current approach is suitable only for laboratory applications. Future research could explore the use of alternative technologies for high-voltage generation, such as high-voltage transformers or piezoelectric converters.

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