INVESTIGATION OF COLD PLASMA INTERACTION WITH POACEAE SEEDS: ANALYTICAL APPROACHES AND AGRICULTURAL IMPLEMENTATION FOR SUSTAINABLE DEVELOPMENT

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Keywords:

Cold Plasma Technology, High Voltage, Dielectric Barrier Discharge, Non- thermal Plasma, Sustainable Agriculture.

Introduction:

Agriculture is essential for supporting the growing global population, but it faces challenges from limited resources, environmental damage, and excessive use of chemical fertilizers and pesticides. Traditional seed treatment methods are effective for improving germination and protecting crops, but they can harm the environment and reduce soil fertility over time. This situation creates a strong need for sustainable, eco-friendly alternatives that can boost crop productivity without harming the environment.

In this circumstance, cold plasma technology has emerged as an development in modern agriculture. Plasma, the fourth state of matter, consists of highly energetic charged particles that can interact with biological materials without causing thermal damage when used in its non-thermal (cold) form. Among various plasma generation methods, Dielectric Barrier Discharge (DBD) plasma is popular because it operates at atmospheric pressure.

When seeds are treated with cold plasma, their surface properties change due to physical and chemical interactions. This leads to increased surface roughness, better water absorption, and improved gas exchange. These factors contribute to faster and more uniform germination. Additionally, plasma generates reactive oxygen and nitrogen species that help with microbial decontamination and stimulate internal biochemical processes within the seed.

Cereal crops like maize and jowar heavily rely on strong early growth for higher yields. Improving seed quality and germination efficiency in these crops can greatly affect agricultural productivity. Therefore, exploring plasma-based seed treatment provides a

sustainable and chemical-free way to enhance seed performance, plant growth, and stress tolerance.
This project aims to investigate how DBD cold plasma affects the germination, growth, and biochemical characteristics of maize and jowar seeds. By examining both laboratory and field conditions, the study seeks to assess the effectiveness of plasma treatment as a new solution for sustainable agricultural development.

Objectives:

1. To examine the effect of Dielectric Barrier Discharge (DBD) cold plasma treatment at different voltage levels on the germination behavior of seeds.
2. To track the growth cycle of plasma-treated Poaceae seeds under both laboratory and field conditions and measure various growth parameters.
3. To conduct biochemical analysis to evaluate differences between treated and untreated seeds.

Methodology:

The project aimed to study how Dielectric Barrier Discharge (DBD) cold plasma affects the germination, growth, and biochemical traits of maize and jowar seeds. We conducted the experiment in controlled lab conditions to maintain consistency in our observations.
We selected healthy, uniformly sized maize (Zea mays) and jowar (Sorghum bicolor) seeds. We cleaned them to remove dust and impurities, ensuring that any observed effects were solely from plasma exposure. We divided the seeds into three groups: control (untreated), 15 kV plasma-treated, and 18 kV plasma-treated.
A DBD cold plasma system treated the seeds. The setup included a step-up transformer to create high voltage, a rectifier to convert AC to DC, a filter and voltage divider for regulation, and a rotary spark gap to produce controlled high-voltage pulses. These pulses were sent to a surface discharge reactor where we generated plasma and placed seeds for treatment.

Here is a simplified view of the system:
We arranged the seeds uniformly in the reactor to ensure equal exposure. Plasma treatment occurred at two voltage levels, 15 kV and 18 kV, while keeping the exposure time the same. We monitored the seeds during treatment to prevent overheating or damage. Right after exposure, we transferred the seeds for germination testing to preserve the effects from the plasma.
For germination analysis, we placed seeds on moist germination sheets and kept them under controlled conditions. We recorded observations over 14 days. We measured key growth parameters such as germination rate, root length, shoot length, and overall seedling vigor, comparing these across all groups.

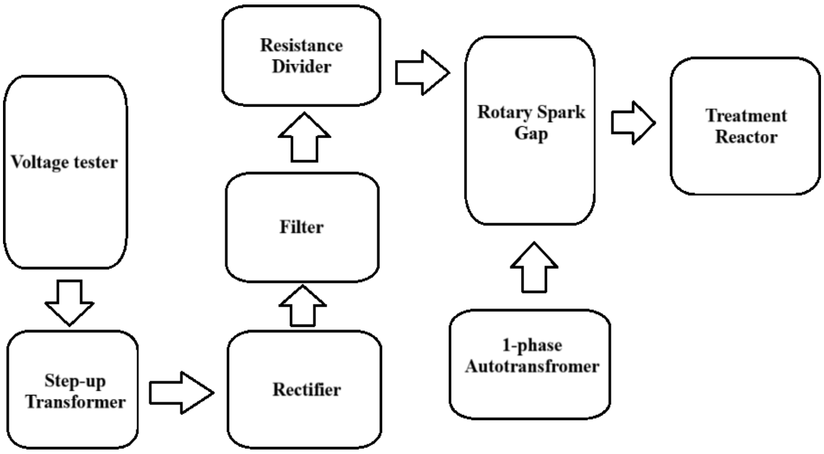

Fig1: Block Diagram

In addition to physical growth, we performed biochemical analysis on maize leaves. We dried the samples and tested them for total phenolic content (TPC), total flavonoid content (TFC), and antioxidant activity. These parameters helped us examine internal metabolic changes from plasma treatment.
We compared the data from control and treated samples to assess how effective the plasma treatment was. This systematic approach helped us identify the best plasma conditions for improving seed performance and supporting sustainable farming practices.

Result and Conclusion:

In conclusion, the study showed that Dielectric Barrier Discharge (DBD) plasma treatment significantly improves the germination and growth of maize seeds compared to untreated control samples.
In laboratory tests, plasma-treated seeds germinated faster and had better seedling vigor. Growth began uniformly from Day 3. Among the different treatments, 15 kV with short

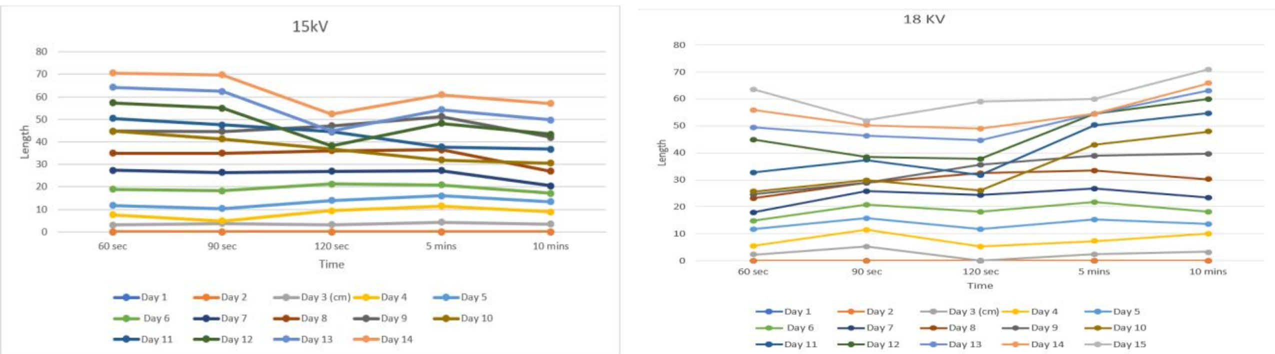

Fig 2: Growth Curve for 15 kV and 18kV Treatments

exposure times (60 to 90 seconds) resulted in the most consistent and sustained growth, with a maximum height of 70.6 cm, which is about 47% higher than the control at 48.0 cm.
In contrast, the 18 kV treatment led to quick initial growth but somewhat lower final heights in the lab, suggesting possible stress from the higher plasma intensity. These results imply that moderate plasma exposure is more effective than high intensity in controlled settings.

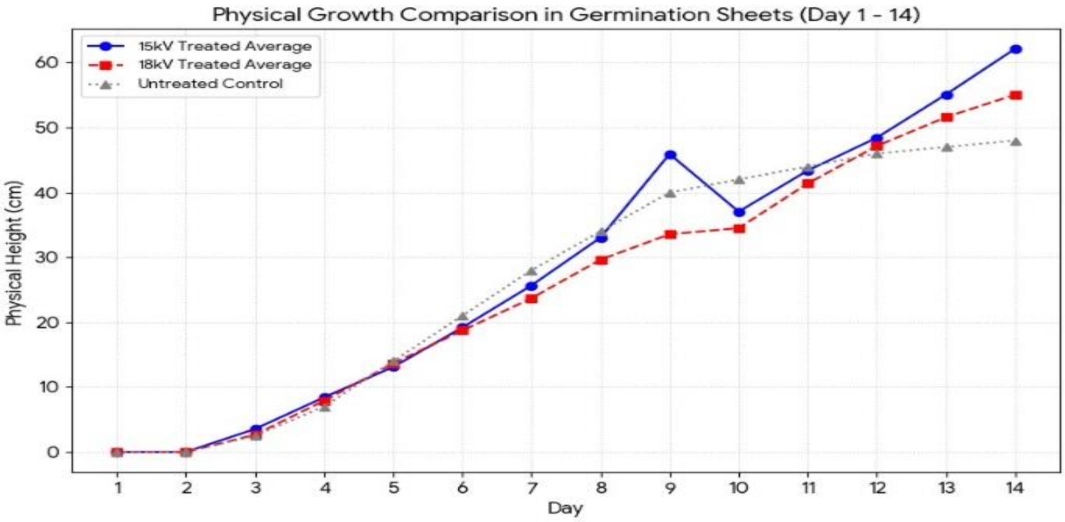

Fig 3: Growth Curve Comparison – Control, 15 kV and 18 kV

In field tests, both 15 kV and 18 kV treatments significantly surpassed the control. The 15 kV group showed steady growth, reaching up to 103 cm,

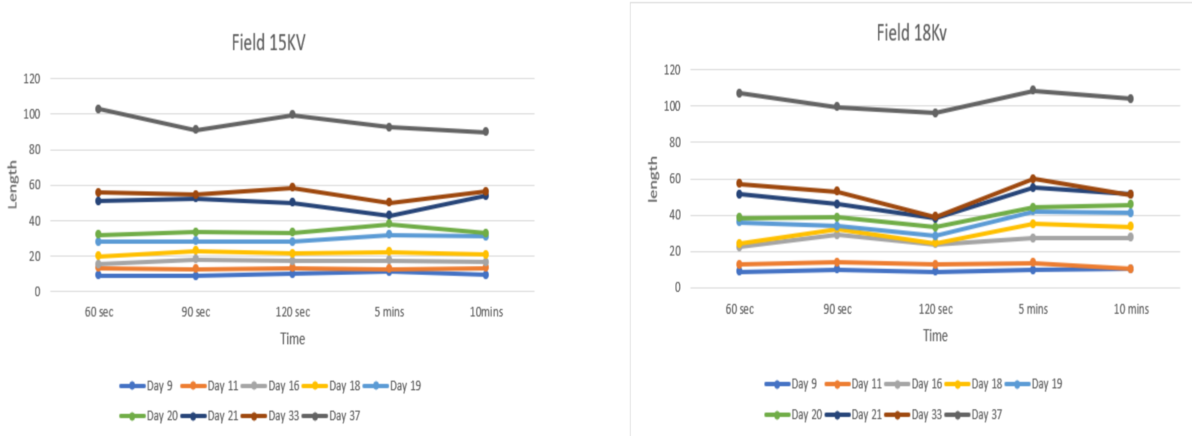

Fig 4: Field Growth Curve – 15 kV and 18kV

while the 18 kV group performed the best, achieving a maximum height of 108.5 cm. This indicates that higher plasma intensity benefits plants more in natural environments where they encounter stress factors like soil variability and climate changes.

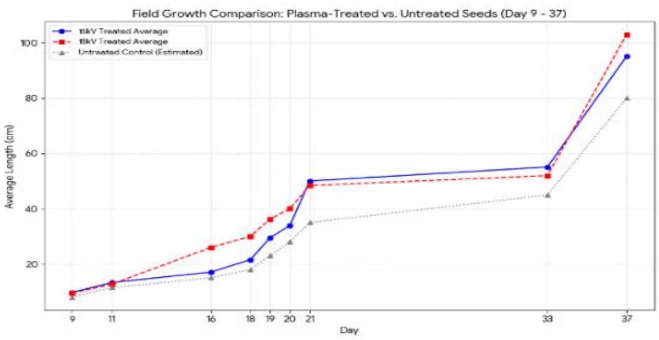

Fig 5: Field Growth Curve Comparison – Control, 15 kV and 18 kV

Storage analysis showed that plasma-treated seeds had better resistance to fungal contamination than untreated seeds. The 15 kV treatment for 15 minutes had the least microbial growth even after three months, confirming improved storage stability and seed preservation.

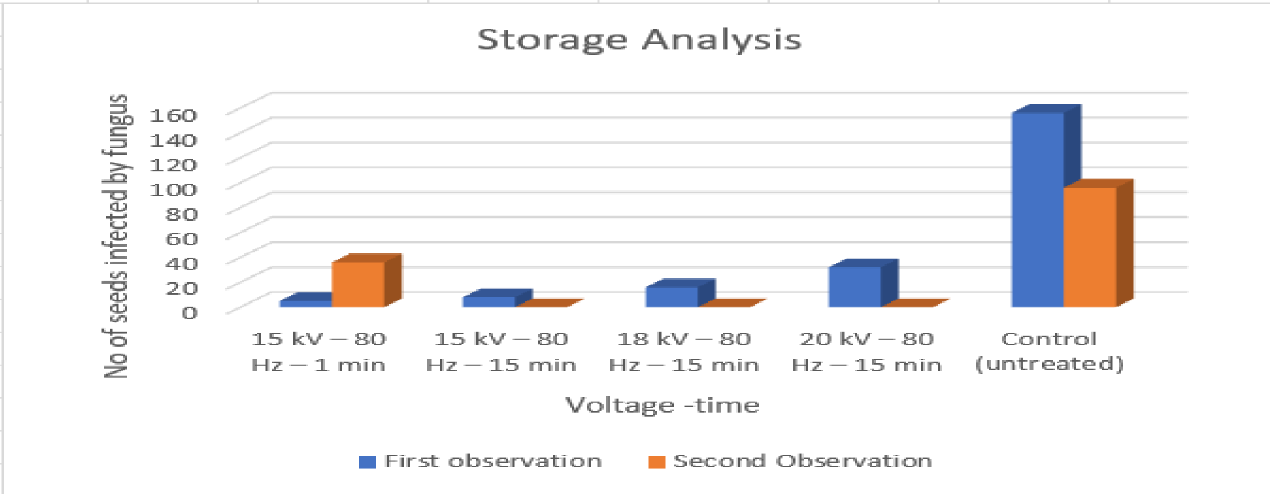

Fig 8: Storage Analysis (Two Observation)

The biochemical analysis showed that plasma treated seeds had higher total phenolic and flavonoid content, indicating enhanced antioxidant activity and metabolic processes. This confirms that DBD plasma treatment improves plant health, stress tolerance and overall biochemical performance compared to untreated seeds.

Project Outcome & Industry Relevance:

The project showed that Dielectric Barrier Discharge (DBD) cold plasma treatment is an effective and sustainable way to improve seed germination, plant growth, and storage stability. The results confirmed that optimized plasma exposure boosts seed vigor, speeds up early growth, and increases resistance to microbial contamination without using harmful chemicals.

This work adds to agricultural engineering and biotechnology by providing experimental proof of a non-chemical seed treatment method that supports sustainable farming practices. It connects electrical engineering concepts with agricultural uses, demonstrating how plasma systems can be used for biological improvements. In real-world applications, this technology can be used in seed processing industries to enhance seed quality before distribution to farmers. It can also fit into large-scale agricultural practices to lessen the reliance on chemical fertilizers and pesticides, which reduces environmental impact and lowers production costs. Furthermore, agri-tech companies and research institutions can adopt plasma treatment systems to develop better seed enhancement technologies. The improved storage stability makes it valuable for seed banks and supply chains, ensuring longer shelf life and fewer post-harvest losses. Overall, the project highlights the potential of cold plasma technology as an innovative, eco-friendly, and scalable solution for modern agriculture and sustainable food production.

Project Outcomes and Learnings:

Key Outcomes

The project showed that using Dielectric Barrier Discharge plasma is a good way to help seeds grow better. Seeds that were treated with plasma started growing and did better than seeds that were not treated. They had roots and shoots and grew taller. The people doing the project found out that using 15 kilovolts for a time worked best in a lab and 18 kilovolts worked better in a field. They also saw that the plasma treatment helped keep fungus from growing on the seeds, which means the seeds can be stored for longer.

Key Learnings

This project taught us how to combine electricity with farming. We learned how to make plasma using machines like transformers and spark gaps. We found out how different settings can affect the results. We got to try setting up experiments looking at data and checking how well plants are growing. We also learned how to work solve problems and use methods that are good for the earth, in real life situations. The Dielectric Barrier Discharge cold plasma project was a way to learn about the cold plasma and how it can help with seed germination and plant growth. The cold plasma was used to treat seeds. It helped them grow better.

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Future Scope:

The future scope of this project includes:

1. Expansion to Multiple Crop Varieties: The treatment can be tested on additional crops such as wheat, rice, millet, and pulses to evaluate its broader agricultural applicability
2. Long-Term Field Trials: Extended multi-season and multi-location studies are needed to understand how plasma-treated seeds perform under different climate conditions, soil types, and farming practices.

3. Detailed Biochemical and Molecular Analysis: Future studies may investigate gene expression, enzyme activity, and metabolic pathway changes induced by plasma to understand the underlying mechanisms more deeply.
4. Development of a Portable Plasma Seed-Treatment Device: A compact, farmer-friendly DBD plasma unit can be designed for on-field use, making the technology accessible to rural communities.