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Study of seedling Growth of Radish Seed Using Dielectric Barrier Discharge at Atmospheric Pressure

L. N. Mishra, R. K. Sapkota, A.K. Shah and R. Shrestha
Patan Multiple Campus, TU, Nepal.
Email: lekha.mishra@pmc.tu.edu.np
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Abstract

This work deals with the evaluation of effects of period of plasma treatment on radish seeds. The parameters such as germination rate (2nd to 9th day), shoot length (5th to 25th day), root length (8th to 12th day), and leaf area (measured for a duration of 12 days) were observed and analyzed. It is revealed that the untreated seeds exhibited the lowest values for all growth parameters whereas there was a significant improvement in germination rate, shoot length, root length, and leaf area after the increment of treatment duration. Experimentally, it is observed that those parameters such as germination rate, shoot length, root length, and leaf area become optimum at a treatment duration of 3 minutes and 30 seconds. This indicates that the plasma treatment using the DBD method has a positive impact on the seedling growth of radish plants, enhancing their overall development and vigor. This work could be useful in agriculture farming for the enhancement of the yielding growth.

Key Words: Plasma treatment, radish seeds, shoot length, root length and leaf area.

Introduction

Radishes are a type of root vegetables the member of the mustard family, or Cruciferae. They have a mildly sweet, peppery flavor, and their skins can be red, black, yellow, purple, or pink. From short and round to long and narrow, they come in a variety of shapes. The origin of radishes is probably in Southeast or Central Asia. They were also used by the Ancient Greeks and Romans as food and medicine. The wild radish was first domesticated several thousand years ago, and it eventually migrated to new regions.

Radish is mostly consumed in salads, vegetables, pickles, and juice around the world. The use of various parts of radish in treating jaundice, gastrointestinal issues, and liver [1, 2, 3]. Additionally, it contains a range of vitamins, carbohydrates, sugars, fibers, minerals, and secondary metabolites that have a range of intriguing biochemical activities in promoting human health.

In Nepal, radish is grown on approximately 18,250 hectares of land. With an average productivity of 13.74 metric tons/hectors, Nepal's overall production amounts to 2,87,200 metric tons [4]. According to reference [4], radish is grown in all 77 of Nepal's districts. It ranks fifth in Nepal for fresh vegetable cultivation and is one of the very few vegetables grown in all 77 districts. Radish cultivation is influenced by soil, climate, variety, season, and methods.

The increase in global population is driving up food consumption to record levels and contributing to environmental exploitation. Increased urbanization, infrastructure construction, and industrialization around the world are degrading the land, reducing productivity, and ultimately threatening food security. It is crucial to maintain and enhance crop and food production through sustainable, commercially successful, and socially acceptable modern agricultural practices in order to address the issues with food security.

Seed treatment is a method intended to lessen, control, or repel disease organisms, insects, or other pests that attack the seed or seedlings using plasma jets [5,6,7], dielectric barrier discharge [8,9,10], gliding arc [11,12], microwaves [13] and so on.

Literature Review and Problem of the Statement

Zhang et al. [14] investigated the efficacy of treating plant diseases using an atmospheric cold plasma jet. The primary emphasis of this study was the black mark on infected plants and leaves. A chilly plasma jet with a black spot was fired into the atmosphere on five different occasions. After three weeks, it was found that there were much fewer black areas. Additionally, plant-fungal cells were kept on a glass slide and then given plasma treatment.

Sharma et al. [15] investigated that reactive oxygen species (ROS) are produced as a normal product of plant cellular metabolism. Various environmental stresses lead to excessive production of ROS causing progressive oxidative damage and ultimately cell death. Despite their destructive activity, they are well-described second messengers in a variety of cellular processes, including conferment of tolerance to various environmental stresses. Whether ROS would serve as signaling molecules or could cause oxidative damage to the tissues depends on the delicate equilibrium between ROS production, and their scavenging. Efficient scavenging of ROS produced during various environmental stresses requires the action of several nonenzymatic as well as enzymatic antioxidants present in the tissues.

Scholtz et al. [16] investigated that the nonthermal plasma (NTP) usage expanded to new biological areas of application like plasma microorganisms' inactivation, ready-to-eat food preparation, biofilm degradation or in healthcare, where it seems to be important for the treatment of cancer cells and in the initiation of apoptosis, prion inactivation, prevention of nosocomial infections or in the therapy of infected wounds.

Guragain et al. [17] looked into how plasma water affected the germination and growth of radish, fenugreek, and pea seedlings. Local gliding arc discharge plasma generated at atmospheric pressure is used for a range of time periods to treat deionized water. Plasma treatment changed the physical characteristics of the water. Furthermore, it has been discovered that watering of seeds with PAW rather than deionized water increases the germination rate of the seeds. Not only has the germination rate grown, but so too have growth factors like shoot length and other germination metrics like the germination index and mean germination rate.

Aim and Objectives of the Study

The aim of this research is to investigate the impact of dielectric barrier discharge on radish seeds. The study aims to provide valuable insights into the alterations in germination and seedling growth with or without plasma treatment on the seeds. To achieve this aim, the following objectives are accomplished:

- Investigate the alterations in germination and seedling growth with or without plasma treatment on the seeds.
- Assess the impact of the improvement in germination rate, shoot length, root length, and leaf area.

Materials and Methods

Experimental Setup

Figure 1 depicts the experimental setup for a dielectric barrier discharge. It consists of two parallel disc of diameter 5.05 cm. The glass sheet 1.5 mm thick was used as dielectric barrier to limit the current and to prevent the formation of spark and arc discharge. The plasma is generated in gap space 2 mm using argon gas at flow rate 2 lit/min by applying AC source of (0-20) kV and frequency (20-50) kHz. The current and voltage signals of discharge were fed to storable digital oscilloscope through current and voltage probe respectively and recorded in the personal computer coupled with oscilloscope.

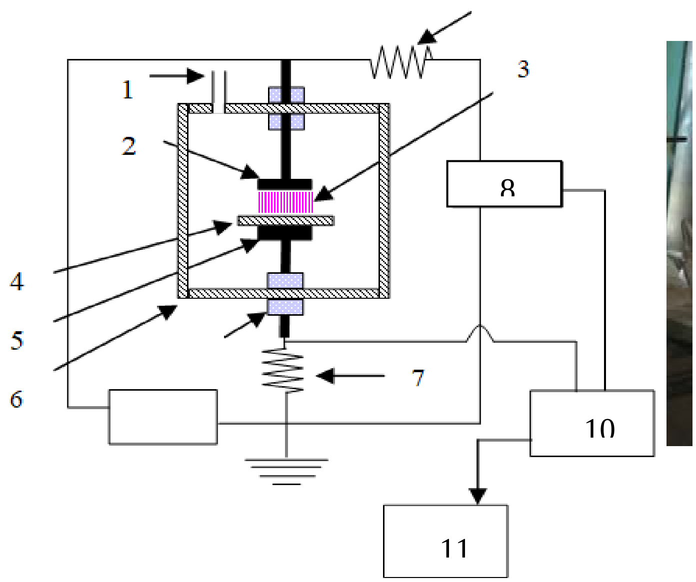

Fig. 1: Schematic diagram of experimental arrangement of DBD: 1. Gas inlet, 2. Parallel disc electrode, 3. Plasma, 4. Glass plate, 5. Grounded disc electrode, 6. Quartz glass chamber, 7. Resistance 10 kΩ, 8. Voltage probe, 9. AC power supply, 10. Oscilloscope, 11. Computer, 12. Resistance 10 MΩ, 13. Teflon screw.

Theory Regarding Experiment

According to electrical properties, instantaneous power consumption can be calculated by multiplying the current-voltage signals on the DBD

$$P_i = V_i I_i \quad \ldots\ldots\ldots\ldots\ldots\ldots \quad (1)$$

where V_i denoted the instantaneous applied voltage on the discharge, I_i represented the instantaneous current, and P_i referred to the instantaneous power.
The time averaged electrical power consumption P can be obtained from equation (2) [18]

$$P = \frac{1}{T}\int_{t=0}^{T} V(t) * i(t)dt$$

$$P = f\int_{t=0}^{T} V(t) * i(t)dt \quad \ldots\ldots\ldots\ldots\ldots \quad (2)$$

T is the waveform period and f the frequency of applied field.
The electron density formula is given by

$$n_e = P/(2A v_b E_{lost}) \quad \ldots\ldots\ldots\ldots\ldots\ldots\ldots\ldots\ldots\ldots (3)$$

where,
n_e = electron density
A= area of disk = $\pi d^2/4$
v_b = Bohm velocity
E_{lost} = the energy lost by the system per electron - ion pair
P = The total power absorbed by capacitive coupled plasma = IV

Results and Discussions

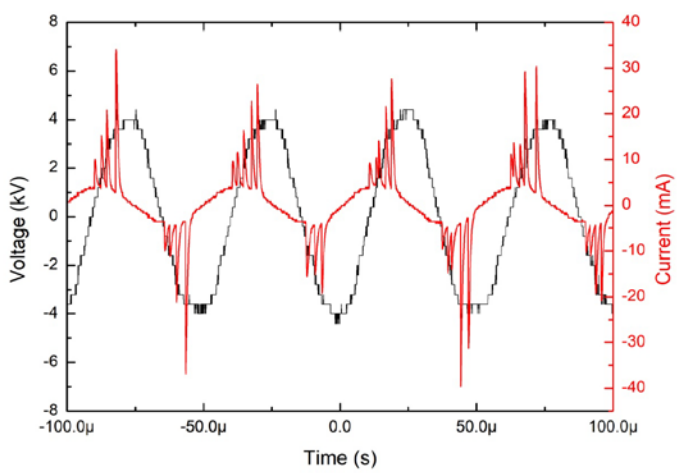

Fig. 2: Current and voltage with time graph

As a function of time, Fig. 2 displays typical waveforms for applied voltage and discharge current, maintaining an input voltage of 2 kV at a frequency of 20 kHz. It is shown that the waveforms nature was determined to be sinusoidal in properties. On the other hand, there were several sporadic, large-amplitude spikes in the current. The presence of spikes was caused by the many filament channels (micro-discharges) in the atmospheric pressure DBD, which were constantly forming and extinguishing.

Fig.3: A typical glimpse of tray where radish seeds are germinated

For the preparation of germination of seeds, the tray which is shown as in Fig. 4 was filled with the mixture of dry soil and rakuichi fertilizer in the ratio 3:1. Fifty seeds of radish were planting of each treatment in a tray after treatment different time interval i.e 30 seconds, 1 minute, 1minute 30 seconds, 2 minutes, 2 minutes 30 seconds, 3 minutes, 3 minutes 30 seconds, 4 minutes, 4 minutes 30 seconds, 5 minutes. On the other hand, untreated seeds are placed on the tray for the comparison with treated one. Water was supplied alternative day by syringe of 10 ml for each hole. Each hole consists of two seeds.

Five days following planting, three radish plants were randomly selected from each treatment, and the length of each plant's shoots was measured using a scale. The typical shoot length for each treatment was also determined. This process was performed every day. Moreover, after 13 days, the shoot length did not considerably increase, so data collecting was halted. The branch length of treated plants increased for 3 minutes and 30 seconds before decreasing in comparison to untreated plants. The plants that received treatment for three minutes and thirty seconds had the longest shoot length, while those that received no treatment had the shortest. The bar diagram as in Fig.4, which spans days 5 through 15, displays the shoot length for each treatment duration.

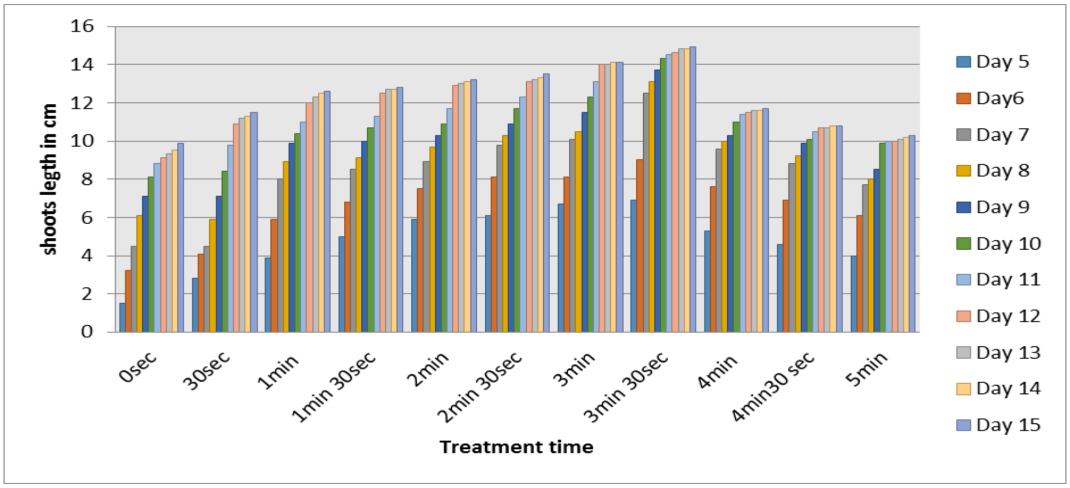

Fig. 4: Shoot length diagram

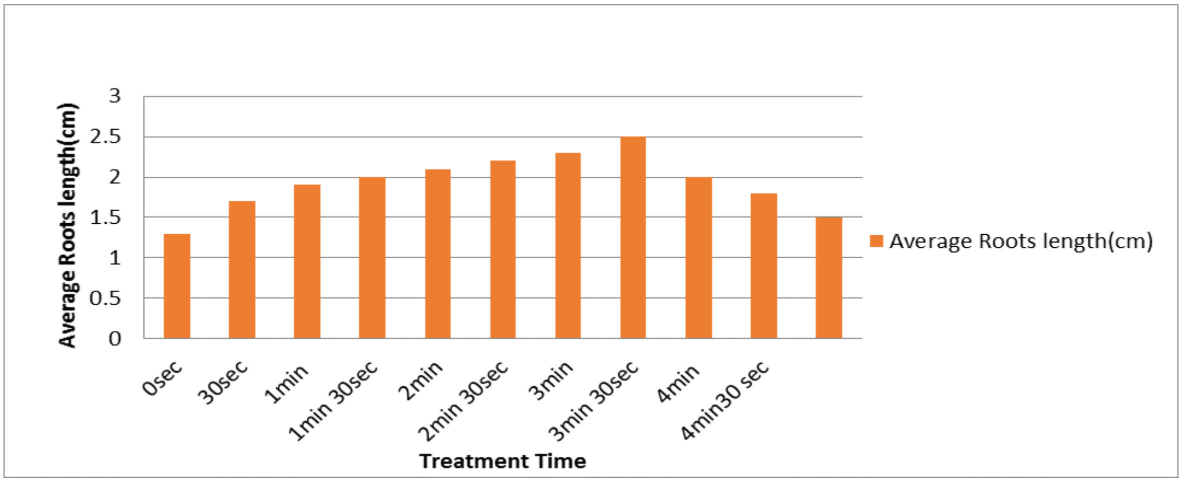

Fig. 5: Average roots length

From day 8 to day 12 after germination, every day, the roots of four radish plants that were selected at random were measured in the same way that the shoot length was. The graph was drawn using a calculation of the average root length as shown in Fig.5. In comparison to seeds in other categories, the results showed that seeds treated for 3 minutes and 30 seconds had the largest root length. The root length of the untreated seeds, on the other hand, was noticeably shorter.

The formula, $germinated\ seeds\ \% = \frac{number\ of\ germinated\ seeds}{total\ number\ of\ seeds} \times 100\%$ can be used to determine germination rate. On the sixth and ninth days, germination rate was calculated.

The germination rate of radish seeds on the sixth and ninth days is shown in Fig. 6. It demonstrates that, on the sixth day, seeds treated for 2 minutes and for 8 minutes have higher germination rates than other seeds. On the other hand, seeds that were treated for 8 minutes had a higher germination rate on day 9 than any other category. On the ninth day, it is also seen that seed treated for 10 minutes has a lower germination rate than other seeds. Until 22nd day, untreated seeds did not germinate. The rate of germination was the same for seeds treated for 2, 3, and 5 minutes. On the 29th day, it was also noted that seeds treated for 10 minutes had a high germination rate.

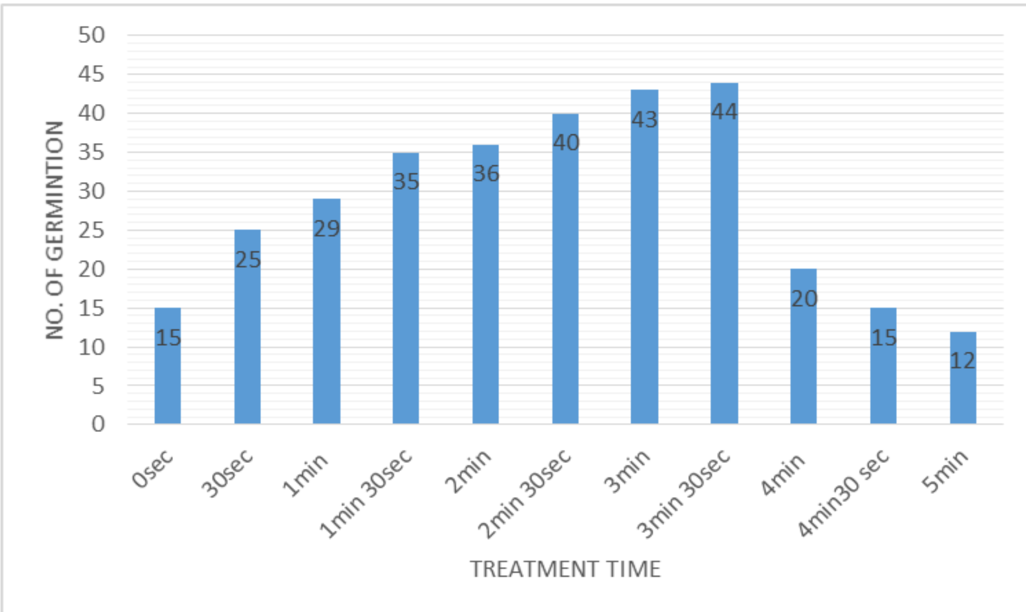

Fig. 6: Germination Rate in Days 4

As mentioned before, 50 seeds were sowed for each treatment. Germination was observed two days after planting and was monitored until day 9. No further germination was observed beyond the 9th day. These results indicate that the germination rate of untreated (0-second) seeds was lower than that of the treated seeds. Additionally, it was observed that the germination rate increases from untreated (0-second) seeds to those treated for 3 minutes and 30 seconds, but then decreases as the treatment time increases. The untreated seeds exhibited the lowest germination rate, while the seeds treated for 3 minutes and 30 seconds had the highest germination rate. The Fig.7 illustrates the germination rate of seeds for different treatment durations.

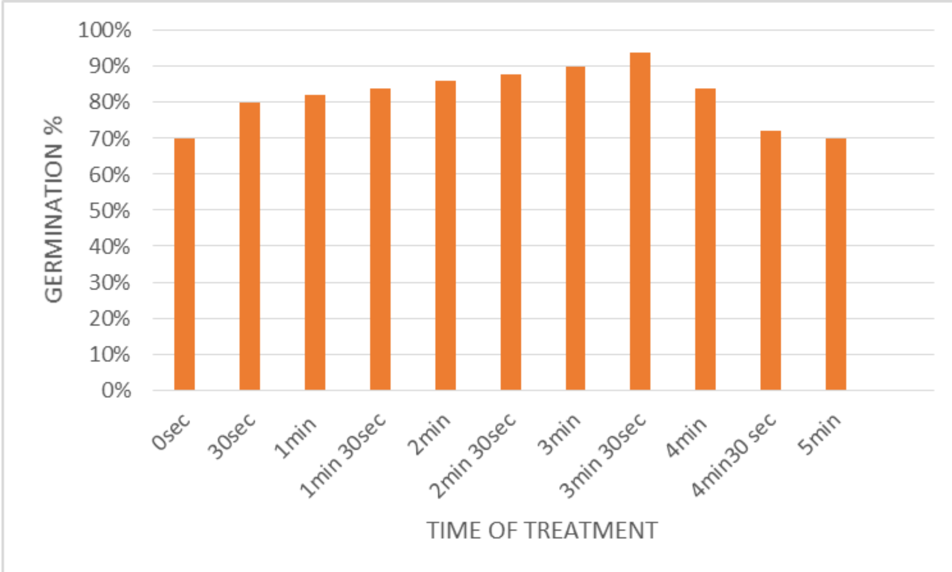

Fig. 7: Total % of germination rate

It is also calculated germination percent after all germination seeds up to 9 days. The germination percent can be calculated as,

$$Germination\ \% = \frac{total\ no.\ of\ Germination}{total\ no\ of\ Cultivation\ (i.e.50)} \times 100\%$$

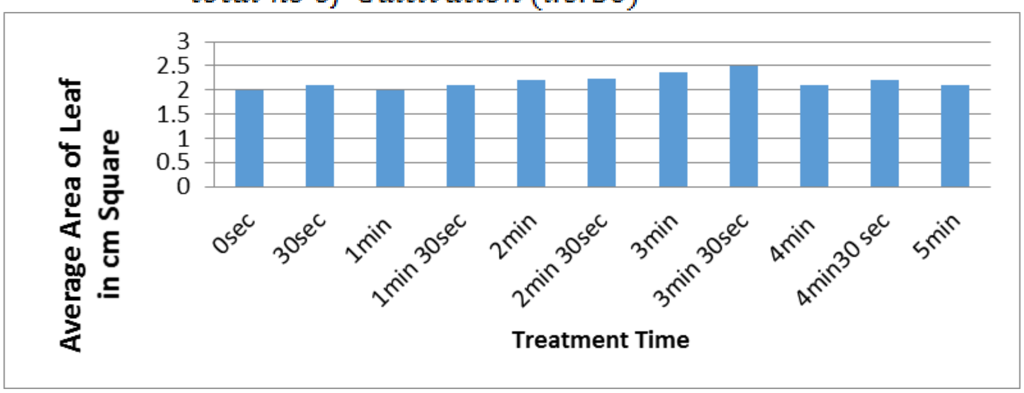

Fig. 8: Average area of leaf

After 12 days, 5 to 7 leaves of each treatment seed were selected randomly. The leaf is sketched on the graph with help of pencil to calculate its area. It was observed that untreated seed had minimum area of leaf but leaf area is found to maximum when treatment time is 3 min 30 sec. The area of leaf for different treatment time is shown in Fig.8.

6. Conclusion

The research of the impact of plasma creation utilizing the Dielectric Barrier Discharge (DBD) method on the radish plant seedling growth was the primary subject of this research. The goal of the study was to assess the effects of various treatment lengths on important growth characteristics, such as germination rate, shoot length, root length, and leaf area. Results of this study show a distinct pattern in the growth traits of radish seedlings exposed to various treatment durations. At first, the untreated seed had the lowest germination rates, shoot lengths, root lengths, and leaf area measurements. However, there was a steady and increasing improvement in these growth indices as the plasma treatment time rose. At treatment duration of 3 minutes 30 seconds, the maximum values for germination rate, shoot length, root length, and leaf area were noted. This shows that the DBD method plasma therapy considerably improves the seedling growth of radish plants, promoting their general development and vigor. Interesting, the growth parameter gradually decreased as treatment time was increased beyond the 3 minutes 30 seconds ideal treatment period. It is possible that there is a saturation point beyond which the benefits of plasma therapy start to wane and may even start to harm seedling growth. This study offers insightful information on the usage of plasma synthesis via the DBD method to enhance radish plant seedling growth. Researchers and agricultural professionals can maximize the growth parameters of radish seedlings and possibly extend this information to other crops by knowing the effects of various treatment durations. To fully comprehend this unique technology, subsequent study should concentrate on illuminating the underlying mechanisms driving the plasma-plant interaction and investigating additional growth characteristics. In summary, this research improved our knowledge of plasma therapy and seedling development using dielectric electric barrier discharge technique.

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