

CHAPTER 4

RESULTS AND DISCUSSION

CASE I: RESULTS AND DISCUSSIONS OF EFFECT OF PLASMA TREATMENT ON FENUGREEK SEEDS

4.1 EFFECT OF PLASMA TREATMENT ON FENUGREEK SEED GERMINATION AND EARLY GROWTH

Plasma treatment demonstrated a significant positive effect on the germination and early growth of **fenugreek seeds**. This enhancement is primarily due to the **modification of the seed coat**, making it more permeable and thus improving water and nutrient uptake. As a result, plasma-treated seeds exhibited **faster and more efficient germination**, especially under optimized treatment conditions.

During plasma exposure, **reactive oxygen species (ROS)** and **reactive nitrogen species (RNS)** are generated. These include compounds such as **hydroxyl radicals (OH•)**, **hydrogen peroxide (H₂O₂)**, **ozone (O₃)**, and **nitric oxide (NO)**, which interact with the seed surface to **increase permeability** and **stimulate biochemical processes** that promote seed vigor, root-shoot growth, and stress resilience.

Fenugreek seeds were treated using two plasma configurations: the **Volume Discharge (VD) Reactor** and the **Surface Discharge (SD) Reactor**. Treatments were conducted at **voltages of 12 kV and 15 kV** for **exposure durations of 10, 20, and 30 seconds**.

Parameters	Longest root (cm)	Shortest root (cm)	Longest shoot (cm)	Shortest shoot (cm)	Fungus (cm)	Non germinated (cm)	Total seeds germinated (cm)
Control	7.4	0.5	0.4	0.1	0	0	92
12kV 10sec (VD)	8.2	0.7	0.5	0.1	0	4	88
12kV 20sec (VD)	7.9	0.1	0.9	0.1	0	4	88
12kV 30sec (VD)	8.7	0.5	0.5	0.1	0	4	88

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15kV 10sec (VD)	7.2	0.3	0.6	0	0	2	90
15kV 20sec (VD)	7.8	1.5	0.5	0.1	1	1	90
15kV 30sec (VD)	7.2	0.7	0.5	0.2	0	3	89
12kV 10sec (SD)	9	0.8	0.3	0.1	0	0	92
12kV 20sec (SD)	7.2	0.8	0.2	0.1	1	2	90
12kV 30sec (SD)	7.2	0.2	0.4	0.1	0	4	88
15kV 10sec (SD)	8.5	0.6	0.6	0.2	0	2	90
15kV 20sec (SD)	7.1	0.6	0.6	0.1	0	3	89
15kV 30sec (SD)	9.2	0.4	0.4	0	0	6	86

Table 04: Day 1 Representation of Germination and Growth Data of Plasma-Treated Fenugreek Seeds

Parameters	Longest root (cm)	Shortest root (cm)	Longest shoot (cm)	Shortest shoot (cm)	Fungus (cm)	Non germinated (cm)	Total seeds germinated (cm)
Control	6.5	2.1	11.2	1.8	0	0	88
12kV 10sec (VD)	11	5	10.3	6.9	0	0	89
12kV 20sec (VD)	10.8	3.4	11	7.1	0	0	88
12kV 30sec (VD)	10.7	1.6	12	3.6	0	0	89
15kV 10sec (VD)	11.5	5	9.8	7	0	0	88
15kV 20sec (VD)	12.1	5.3	11.1	7.8	0	0	89
15kV 30sec (VD)	9.3	2.1	11.6	1.3	0	0	89
12kV 10sec (SD)	11.5	2.3	11.6	7	0	0	87
12kV 20sec (SD)	10.2	3	12.6	10.1	0	0	88
12kV 30sec (SD)	9.4	1.5	10.2	3.8	0	0	84
15kV 10sec (SD)	12	3.5	10.2	7.2	0	0	89
15kV 20sec (SD)	10.5	3	11.2	8.5	0	0	88
15kV 30sec (SD)	9.5	2.4	10.4	8.8	0	0	83

Table 05: Day 10 Representation of Germination and Growth Data of Plasma-Treated Fenugreek Seeds

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The data collected on **Day 1**(table 04) corresponds to the first observation made **three days after sowing**, when the germination sheets were initially opened. This early assessment captured the **initial seed response** to plasma treatment under different voltage-time combinations using both **Volume Discharge (VD)** and **Surface Discharge (SD)** reactors.

At this stage, parameters such as **root length, shoot length, presence of fungal infection, number of non-germinated seeds, and total germinated seeds** were recorded. While germination had already begun, the full extent of root and shoot development was still in its early stages. For instance, shoot lengths ranged between **0.2 to 0.9 cm**, and the longest root observed was **9.0 cm** under 12kV 10s (SD). Interestingly, the highest number of germinated seeds on Day 1 was seen in **control and 12kV 10s (SD)** conditions, both reaching **92 out of 100** seeds. Over the next **10 to 14 days**(table 05), regular daily observations were conducted to monitor progress in each of the recorded parameters. By **Day 10**, significant **growth and development** were observed across all plasma-treated groups:

- ✓ **Root lengths** improved notably, with some treatments reaching **over 12 cm**, especially under **15kV 20s (VD)** and **15kV 10s (SD)**.
- ✓ **Shoot growth** showed substantial improvement, with shoot lengths extending up to **12.6 cm** under **12kV 20s (SD)**.
- ✓ All treated groups showed **zero fungal contamination** and **zero non-germinated seeds** by Day 10, indicating improved seed health and uniform development.
- ✓ **he germination rate improved or remained consistent**, with most treatments maintaining a total germination of **88–90 seeds** out of 100.

Following the plasma treatment using the **Volume Discharge (VD) reactor**, seed growth was monitored daily for a period of **10 days**. The sum of **Longest Shoot + Longest Root (LS+LR)** was recorded as a combined growth parameter to assess overall seedling development.

The initial observation on **Day 1** showed modest differences among treatments. However, from **Day 2 onwards**, clear distinctions in growth trends emerged between treated and untreated (control) groups. Notably:

Seeds treated with **15kV for 20 seconds (VD)** showed a consistent and substantial increase in LS+LR values, reaching the **highest combined growth of 23.2 cm by Day 10**. Seeds treated at

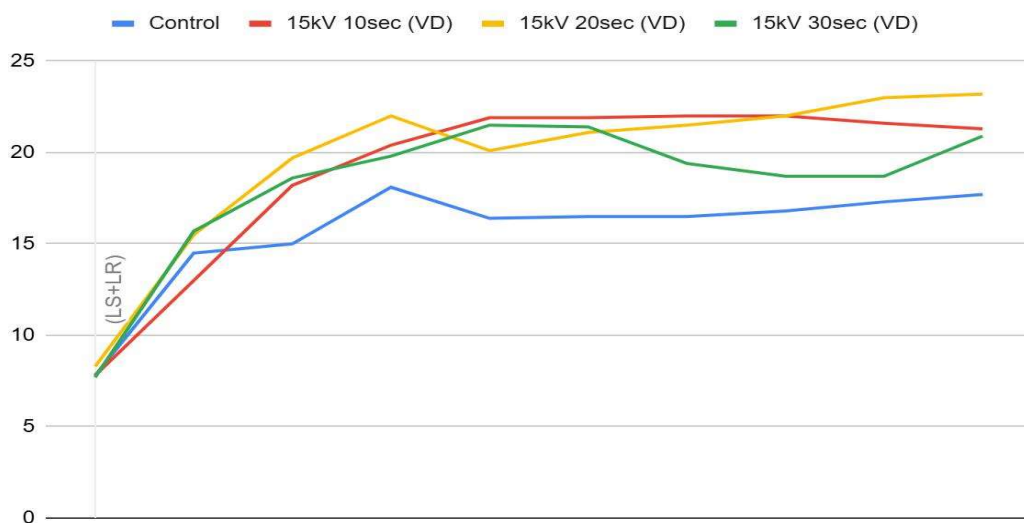
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12kV for 30 seconds (VD) also performed well, peaking at **22.7 cm** by Day 10. The **control group** remained behind, with a Day 10 LS+LR value of **17.7 cm**, highlighting the effectiveness of plasma treatment.

This dataset confirms that VD plasma treatment significantly improves seedling growth when optimized voltage and duration are applied. The **optimal condition for VD-treated fenugreek seeds** was found to be **15kV for 20 seconds**, yielding the most favorable growth performance.

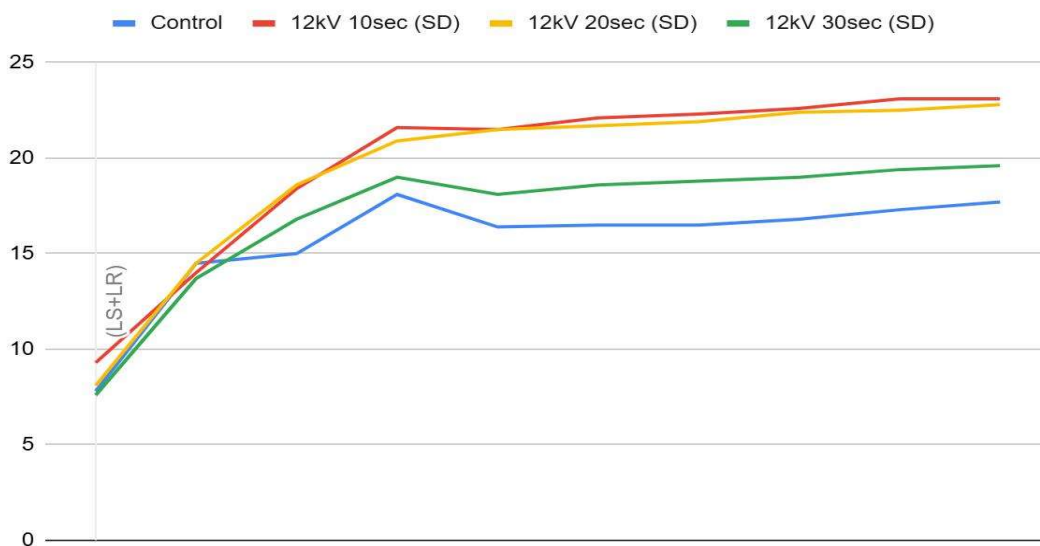
	D 1	D 2	D3	D4	D5	D6	D7	D8	D9	D10
Control	7.8	14.5	15	18.1	16.4	16.5	16.5	16.8	17.3	17.7
12kV,10sec (VD)	8.7	13.5	16	18.7	17.4	17.8	19.3	20	20.7	21.3
12kV ,20sec (VD)	8.8	14.5	18	20.5	20.8	20.9	21	21.2	21.7	21.8
12kV, 30sec (VD)	9.2	14.4	18.6	21	21.3	21.5	21.7	22	22.2	22.7
15kV, 10sec (VD)	7.8	13	18.2	20.4	21.9	21.9	22	22	21.6	21.3
15kV ,20sec (VD)	8.3	15.5	19.7	22	20.1	21.1	21.5	22	23	23.2
15kV, 30sec (VD)	7.7	15.7	18.6	19.8	21.5	21.4	19.4	18.7	18.7	20.9

Table 06:Representation of Total Germination rate and Growth of Plasma-Treated Fenugreek Seeds under volume discharge (VD) reactor over 10 days



Graph 03: Graphical representation of the total germination rate of seeds treated under volume discharge (VD) reactor over 10 days

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Graph 04: Graphical representation of the total germination rate of seeds treated under surface discharge (SD) reactor over 10 days

This data clearly indicates that **plasma treatment not only initiated early germination but also supported consistent and enhanced seedling development** over time. After analyzing performance across all conditions, the following were identified as the **optimal plasma treatment parameters** for the seeds by the end of the study:

Name of the seed	Optimal Voltage (VD)	Optimal Voltage (SD)
Fenugreek	15kV, 20sec	12kV, 10sec

Table 06 :Optimal Voltage-Time Combinations for Seed Plasma Treatment for fenugreek seed

These optimal parameters achieved the best balance of **germination rate, root and shoot growth, and overall plant health**, confirming the effectiveness of the selected plasma parameters.

4.1.1 SEED VIABILITY AND HEALTH ASSESSMENT

A comprehensive analysis of seed germination must account for challenges such as fungal infections and the presence of non-germinated seeds. Plasma treatment showed significant improvements in mitigating these issues, as evidenced by the graphs illustrating reductions in fungus-infected seeds and non-germinated seeds. This highlights the additional benefits of plasma treatment in promoting healthier seed germination conditions.

4.2 FENUGREEK SEED GROWTH MONITORING FOR MORPHOLOGICAL ANALYSIS ON GERMINATION SHEET AND GROWTH RATE MONITORING OF SEED SOWN ON GROUND



Fig 4.2:Fenugreek Seed Growth Monitoring for Morphological Analysis on Germination Sheet and Growth Rate Monitoring of Seed Sowed on Ground