Effects of Cold Plasma Treatment on the Growth Rate of Corn and Eggplant Plants

Muhammad Abu Bakar Sidik[1], Zolkafle Buntat[2]*, Zainuddin Nawawi[1], Muhammad Irfan Jambak[1], Yahya Buntat[3] and Fatin Nabilah Musa[2]

[1] Department of Electrical Engineering, Faculty of Engineering, Sriwijaya University, Ogan Ilir, South Sumatera, Indonesia.
[2] Institute of High Voltage and High Current, Faculty of Electrical Engineering, Universiti Teknologi Malaysia, 81310, Skudai, Johor, Malaysia, zolkafle@utm.my *
[3]Faculty of Education, Universiti Teknologi Malaysia, 81310, Skudai, Johor, Malaysia.

***Abstract*— This paper investigates the effect of cold plasma on the germination, growth, and yield of corn plant. The effect of plasma plume was applied to the corn seeds to kill the bacteria on the outer surface of the seeds to investigate the effects of cold plasma towards the germination and growth rate of the seeds. The time of treatment was varied from 3, 5 and 10 minutes to identify the optimum treatment time. The result showed that the seeds that treated with 3 minutes plasma treatment germinates faster and show excellent growth rate compared to the untreated seed. This revealed that cold plasma treatment as an alternative method to promote seed germination and enhance seed growth of the corn plant.**

Keywords—cold plasma; germination; growth

I. INTRODUCTION

Corn also is known as maize (*Zea mays convar. saccharata var. rugosa*) is a staple food that the total production exceeds the wheat and rice. Usually, it is produced as corn ethanol, animal feed, corn syrup and starch. However, the production of the corn was insufficient to meet the worldwide demand. This is because of corn seed germinates in 10 to 14 days due to its thick and impermeable pericarp (seed coat). Then, the corn plant took 60 to 100 days to fully grown before can be harvest, hence affect the yield of the corn. Also, eggplant also known as brinjal or aubergine (*Solanum melongena L*) usually has an egg-like shape and a vibrant purple color. The germination of eggplant usually took 7 to 14 days to germination and 110 to 160 days to be harvest after sowing. The time taken to harvest the plant may affect the production of the vegetables.

One of the proposed methods to increase the corn and eggplant production is by enhancing seed germination. The conventional method of enhancing seed germination such as physical scratching, heat treatment as well as chemical treatment showed good results [1]. For the corn plant, the seed scratching, and UV light treatment are commonly technique for the seed germination. While, eggplant seed usually using NaCl salinity to increase the germination as well as growth of the plant. However, all these methods are non-uniform and resulted in environmental pollution. Therefore, the introduction of cold plasma to treat the seed improved the seed performance.

Cold (also known as non-thermal) plasma had shown great interest in industrial, biotechnology and medical treatment due to its low cost and flexible operation. Recently, the innovation of cold plasma for agriculture promoted as an alternative to the traditional seed treatment as it is pollution-free, low-temperature and the most important, it does not cause any damage to biological materials [1, 2]. Cold plasma modifies the chemical and physical properties of seed that is capable of bacteria inactivation as well as stimulate seed germination and growth [3, 4].

Previous research on the plasma treatment had a positive effect on seed germination and plant development. Zivkovic *et al.* [5] demonstrated that cold plasma pre-treatment significantly improved the germination of *Paulownia tomentosa* significantly 5 to 30% higher compared to untreated seed. Zhou *et al.* [6] investigated the effect of the voltage of the plasma treatment and result showed that the tomato yields of any plasma voltage treated groups were increased than the untreated seed. Also, Matra reported that plasma treatment using plasma jet improved the growth rate of the radish seed by 9 to 12% compared to the untreated seed [7]. However, Dobrin *et al.* [3] found that non-thermal plasma had little effect on the growth of the germination rate but influenced growth parameter of *Triticum aestivum.*While Pradeep *et al.* [8] claimed that 2 min plasma treatment is sufficient to promote the seeds germination rates and seedling growth without affecting the physicochemical and sensory characteristics of their rapeseed sprouts.

In addition, plasma treatment also improved the seed performance and development of the plant by adjusting seed coat structure, stimulating seed germination, increase the seed growth and improve immunization of the seed [4]. Selcuk *et al.* [2] reported a drastic reduction of pathogenic fungi, *Aspergillus spp*. and *Penicillum spp.* on the grain and legume yields. The anti-fungal efficacy against *Aspergillus spp* on various nut samples using cold plasma also reported in [9, 10]. After all, the plasma treatment also increased the plant yield. The cold plasma treatment increase the grain and legumes yields [2] as well as significantly increases wheat yield as reported by Jiang *et. al* [11].

Nevertheless, the reports about the effect of cold plasma on the corn and eggplant plant are limited. This study investigated the effect of the cold plasma plume treatment on the germination and growth of the corn plant. The plasma plume device is developed in order to treat numbers of seeds at the same time. The cold plasma plume for the plant treatment with different treatment time to observe the optimum time as different plants have different sensitivity and endurance to the treatment.

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II. METHODOLOGY

A. Plasma Plume System

Plasma plume system is used for the treatment of the corn seed. Figure 1 showed the design of the plasma plume system. It consists of 7 high voltage electrode, 1 ground electrode and also 7 glass tubes. The high voltage electrode welded to a plate to ensure that the high voltage applied can be connected equally. Both electrode and plate are made of stainless steel. The electrodes were a 2 mm diameter and 61 mm length. The plate made up of diameter of a 25.5 mm.On the other hand, the dielectric glass tube has an outer diameter of 6 mm and the inner diameter of 4.8 mm which is 5 cm long. The ground electrode was an aluminum tape with adhesive that stuck around the outer of the glass tube. Helium gas injected from the side of the plasma jet and 20 kHz AC high voltage is applied to the electrodes. This resulted in the generation of 7 homogenous plasma plume.

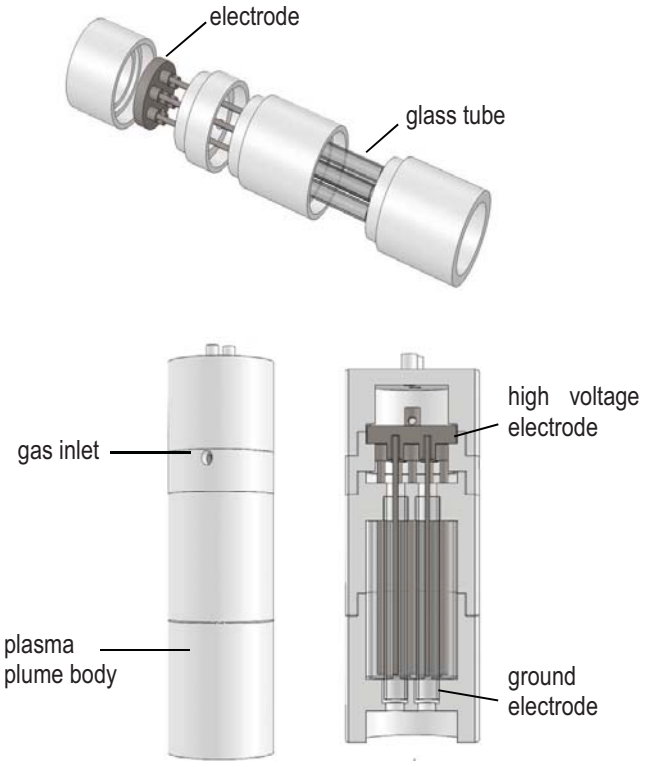

Fig. 1. Design of Plasma Plume Device

B. Experimental Procedure

The experiment was conducted to observe the germination and growth of the corn seed of 3, 5 and 10 min of plasma plume treatment. The setup of the experiment is as shown in Figure 2. The plasma plumes were generated by connecting a high voltage circuit to 240 V, 50 Hz input, which produces 6 kV_{rms}, and a frequency of 20 kHz. The output of high voltage circuit is connected to the high voltage electrode of the plasma plume system. Helium with a gas flow of 6 L/min was inserted into the plasma plume device. The inlet A of Figure 2 shows the plasma plume discharge and inlet B show the plasma treatment of the seed. The tip of glass tubes was set to be 10 mm away from the petri dish.

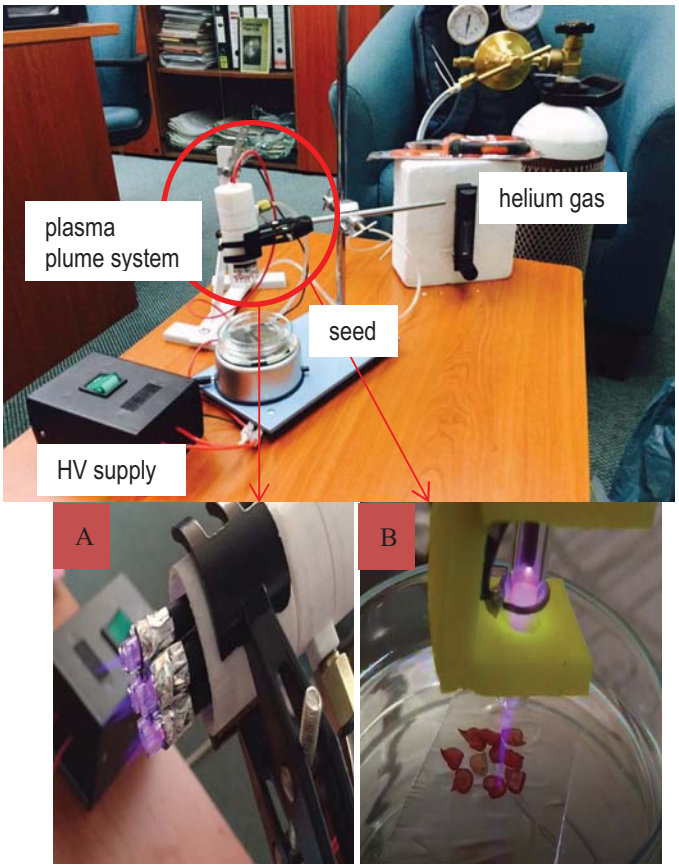

Fig. 2. Experimental Setup

The plasma treatment is exposed to the 7 seeds for 3, 5 and 10 min of corn and eggplant seed respectively. Then, the seed is planted and exposed to 20±5 ºC of soil temperature and 82% relative humidity of environmental condition in Universiti Teknologi Malaysia, Johor, Malaysia. The germination and growth of the corn and eggplant seeds are observed continuously and the height of the plant is measured and recorded.

III. RESULT AND DISCUSSION

A. Corn Plant

The effect of cold plasma on seed germination of the corn is varied with different treatment time. The germination and growth of the corn seed that treated for 3, 5 and 10 min as well as untreated are observed for 6 weeks. The first seeds to germinate is recorded and the height is taken every week. The germination rate of the corn seeds to germinate over one week as shown in Figure 3. It is shown that the germination rate for all conditions is 86%, which that one out of the 7 seed failed to germinate.

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Fig. 3. Germination of Corn Seed

Nonetheless, the first seed to grow is on the third day after planting is the seed of 3 min plasma treatment. The untreated corn seed took about 1 week to germinate. This study showed that germination was effectively promoted and germination time was shortened by cold plasma treatment. This result agreed with numerous studies that found that cold plasma significantly increases the seed germination [1, 2, 4, 12].

Then, the effect of the cold plasma on corn seedling growth is recorded based on the first seed to germinate. Table 1 and Fig. 4 show the average height of the growth of corn seeds. It can be seen that the first to grow is the seeds that are treated for 3 min. The next seed to grow is untreated seeds followed by 5 min and 10 min. However, as the week passed by, the growth rate of 5 min treated seeds was not as rapid as the rest of the seeds. The final growth of 6th week of the corn is as shown in Fig. 5.

TABLE I. AVERAGE HEIGHT OF THE CORN PER WEEK

Week	Treatment Time			
	NT (cm)	3 min (cm)	5 min (cm)	10 min (cm)
1	6	8.9	4.9	4.2
2	24.5	28	17.1	21.9
3	30.7	35.4	20.2	27.9
4	47.0	50.8	33.5	41.2
5	64.9	67.1	39.8	55.8
6	98.9	102.8	60	82.2

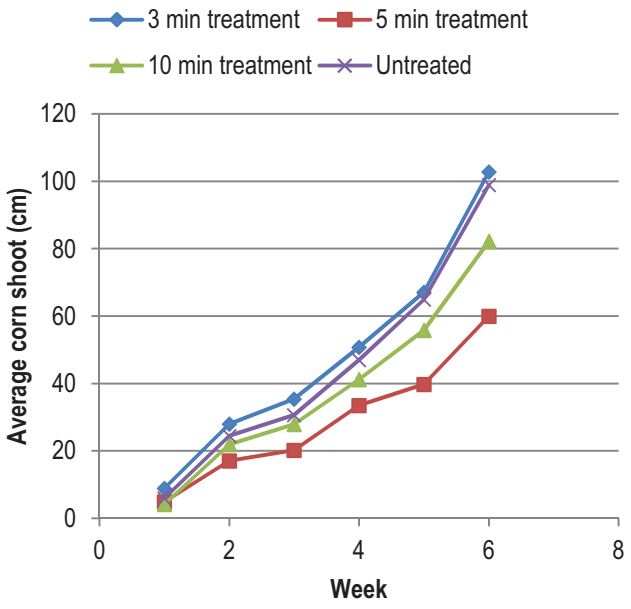

Fig. 4. Average height of the corn plant

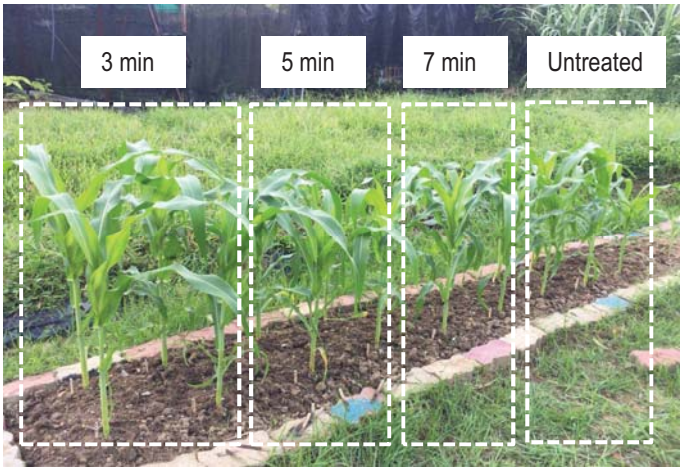

Fig. 5. Corn Plant

Figure 6 shows the growth pattern of the corn plant. The rate of growth is the percentage of increment in height each week. It can be seen that a very fast increase in growth is shown from 1st to 2nd week. The growth reaches its peak at 2nd week for all the treatment time. Then, the growth of the corn plant is maintained until the 6th week. It showed that the height of the 3 min plasma treated plant is about 4 cm longer every week compared to the untreated seed.

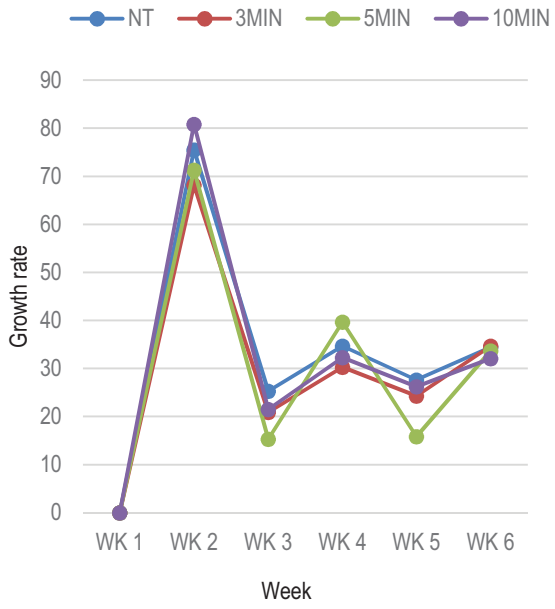

Fig. 6 Growth rate of the corn plant

The 3 min plasma treated plant showed an excellent seed growth every week compared to the untreated plant. This result agreed with other researches that plasma treatment promoted seedling growth and development of the plant [2, 4, 6, 12]. However, it is found that the longer treatment time used had no significant effect on the seed growth. The 5 min and 10 min of plasma treatment showed a diminishment compared to the untreated plant. Therefore, it can be concluded that the optimum time of the cold plasma treatment is 3 min plasma treatment.

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B. *Eggplant Plant*

The germination and growth of the eggplant seed that treated for 3, 5 and 10 min as well as untreated are observed for 5 weeks. The first seeds to germinate is recorded and the height is taken every week. The germination rate of the eggplant seeds to germinate over one week as shown in Figure 7. It is shown that the germination rate for all conditions is 71%, which that 2 out of the 7 seed failed to germinate.

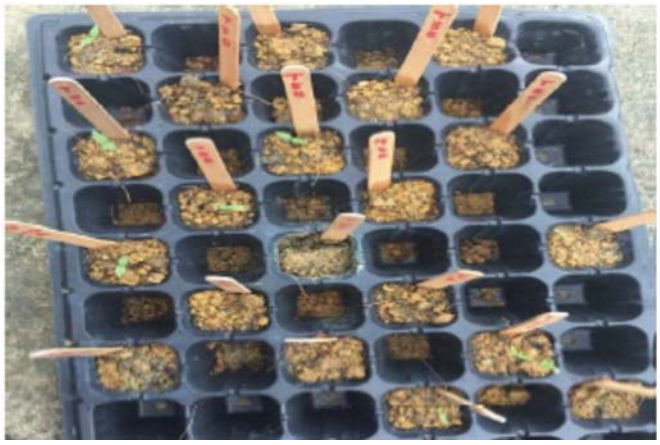

Fig. 7 Germination of eggplant seed

At 1st week, none of the seeds germinated. This may be due to the fact that, for eggplant to germinate a hot and sunny weather is required. However, during the first week, it has been raining all week. Also, this is considered normal as for eggplant to germinate took around 7 to 14 days. While at 2nd week, the first eggplant seeds have germinated. The first seed to germinate is non-treated seeds, followed by 5 minute treatment seed the next day, 3 minutes and 10 minutes.

TABLE II. AVERAGE HEIGHT OF THE EGGPLANT PER WEEK

Week	Treatment Time			
	NT (cm)	3 min (cm)	5 min (cm)	10 min (cm)
1	0.00	0.00	0.00	0.00
2	1.20	0.50	1.00	0.40
3	1.66	0.66	2.00	0.80
4	2.00	0.66	2.60	1.00
5	2.40	0.66	3.30	1.30

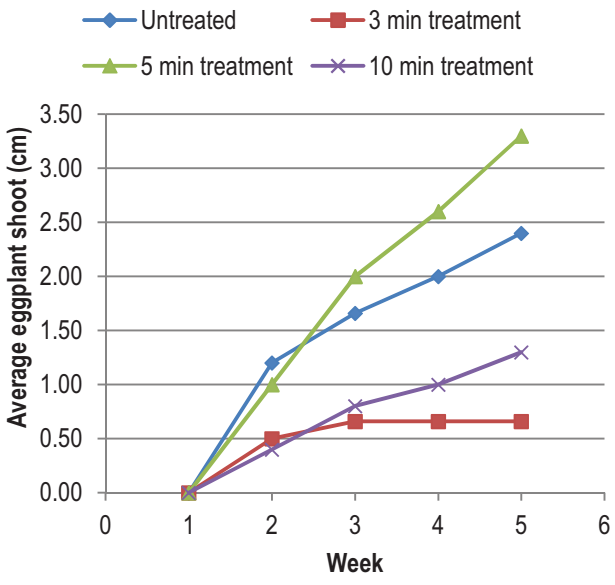

Fig. 8. Average height of the eggplant plant

Table 2 and Figure 8 shows the average height of eggplant per week. The height of eggplants shoot was recorded in 5 weeks. In week 1, none of the eggplants start to germinate. In week 2, some of the seeds start to germinate. However, the tallest seeds are non-treated, followed by 5 minutes, 10 minutes and 3 minutes. In week 3, the 5 minute treatment seed had bypassed the height of non-treated seeds, but the height for 3 minute treatment and 10 minute treatment decreases. In week 4, the tallest shoot is 5 minute treatment.

In week 5, the tallest and healthiest shoot is again at 5 minutes, which is then followed by non-treated seeds and 10 minute treatment. The final growth of 5th week of the corn is as shown in Fig. 9. However, the growth of the eggplant seed should continually observe until 16 to 24 week until the eggplant harvested.

Fig. 9. Eggplant Plant

Figure 10 shows the growth pattern of the eggplant plant. The seed reaches its peak during 2nd week. Then, the rate of growth decreased for all kinds of treatment during 3rd week. However, 10 minutes and 3 minute treatment have the lowest drop which is at 34% and also 40%. At week 3, the seeds for non-treated and 5 minutes continue to drop but for 10 minutes and 3 minutes the growth rate increased. Finally, the growth rate for untreated and 5 minute treatment had come to a constant whilst for 3 minutes the growth rate had stopped.

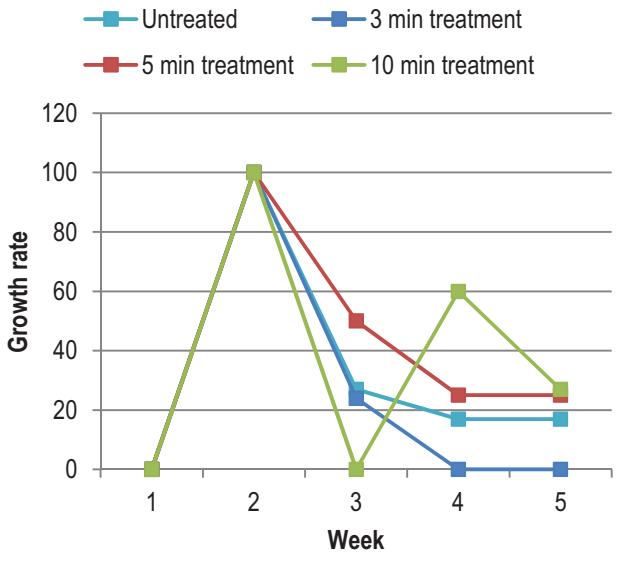

Fig. 10 Growth rate of the eggplant plant

IV. Conclusion

The cold plasma plumes for the treatment of the corn seed was successfully developed. Results showed that the plasma with 3 min treatment showed an excellent result of the germination and growth of the corn seed. The germination rate for both plasma treated and untreated is maintained at 86%, but it is found that with plasma, the seed germinates faster. The average root length of the plasma treated seed was longer than that of the controlled case by almost 4 cm. On the other hand, the cold plasma treatment of the eggplant seed showed that 5 min treatment is the optimum treatment time. The plasma does not promote the germination rate of the eggplant seed but it does improve the growth of the seed.

This concluded that the cold plasma gave an excellent result in improved seed performance and may have a positive effect on corn and eggplant yield and thus, could be used in future other vegetable production.

Acknowledgement

This work was supported by the Universiti Teknologi Malaysia and Ministry of Higher Education (MoHE) under Research University Grant (Q.J130000.2523.13H14).

References

[1] M. Dhayal, S.-Y. Lee, and S.-U. Park, "Using low-pressure plasma for Carthamus tinctorium L. seed surface modification," *Vacuum,* vol. 80, pp. 499-506, 2006.

[2] M. Selcuk, L. Oksuz, and P. Basaran, "Decontamination of grains and legumes infected with Aspergillus spp. and Penicillum spp. by cold plasma treatment," *Bioresour Technol,* vol. 99, pp. 5104-9, Jul 2008.

[3] D. Dobrin, M. Magureanu, N. B. Mandache, and M.-D. Ionita, "The effect of non-thermal plasma treatment on wheat germination and early growth," *Innovative Food Science & Emerging Technologies,* vol. 29, pp. 255-260, 2015.

[4] L. Ling, J. Jiafeng, L. Jiangang, S. Minchong, H. Xin, S. Hanliang*, et al.*, "Effects of cold plasma treatment on seed germination and seedling growth of soybean," *Sci Rep,* vol. 4, p. 5859, Jul 31 2014.

[5] S. Živković, N. Puač, Z. Giba, D. Grubišić, and Z. L. Petrović, "The stimulatory effect of non-equilibrium (low temperature) air plasma pretreatment on light-induced germination of Paulownia tomentosa seeds," *Seed Science and Technology,* vol. 32, pp. 693-701, 2004.

[6] Z. Zhou, Y. Huang, S. Yang, and W. Chen, "Introduction of a new atmospheric pressure plasma device and application on tomato seeds," *Agricultural Sciences,* vol. 2, pp. 23-27, 2011.

[7] K. Matra, "Non-thermal Plasma for Germination Enhancement of Radish Seeds," *Procedia Computer Science,* vol. 86, pp. 132-135, 2016.

[8] P. Puligundla, J.-W. Kim, and C. Mok, "Effect of corona discharge plasma jet treatment on decontamination and sprouting of rapeseed (Brassica napus L.) seeds," *Food Control,* vol. 71, pp. 376-382, 2017.

[9] P. Basaran and Ü. Akhan, "Microwave irradiation of hazelnuts for the control of aflatoxin producing Aspergillus parasiticus," *Innovative food science & emerging technologies,* vol. 11, pp. 113-117, 2010.

[10] P. Basaran, N. Basaran-Akgul, and L. Oksuz, "Elimination of Aspergillus parasiticus from nut surface with low pressure cold plasma (LPCP) treatment," *Food Microbiology,* vol. 25, pp. 626-632, 2008.

[11] J. Jiafeng, H. Xin, L. Ling, L. Jiangang, S. Hanliang, X. Qilai*, et al.*, "Effect of cold plasma treatment on seed germination and growth of wheat," *Plasma Science and Technology,* vol. 16, p. 54, 2014.

[12] B. Sera, P. Spatenka, M. Sery, N. Vrchotova, and I. Hruskova, "Influence of Plasma Treatment on Wheat and Oat Germination and Early Growth," *IEEE Transactions on Plasma Science,* vol. 38, pp. 2963-2968, 2010.

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