Study of Air Radio-Frequency (RF) Plasma Treatment Effect on Wheat Seed for Improvement of Germination and Crop Yield

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Abstract: Effect of air RF plasma treatments on wheat seeds have been investigated in present detail study. Plasma treatments of seeds resulted in drastic reduction of apparent contact angle, which resulted in enhancement of water uptake during germination. Lab germination experiments for plasma treated seeds demonstrated much higher growth of seedlings as compare to untreated wheat seeds. While, field experiments showed enhancement of grain yield by 9.8 % for plasma treated in comparison to untreated seeds.

Keywords: Air RF plasma treatment, Wheat seed, Seed germination, Field experiments.

1. Introduction

Our food security depends on increase of crop production in order to realize future demands of our growing population [1]. As a result, huge amount of fertilizers are practiced nowadays to enhance crop production. This leads to in general soil degradation and percolation of toxic chemicals in food chain and water bodies, and hence finding of an alternative ways for increment of crop yield are extremely essential. The use of low-temperature plasma is fastest emerging field in areas of bio-medical, food processing and agricultural applications [2 - 4]. Moreover, plasma treatment of seeds for various types of crops represents a promising technology for enhancement of agriculture production. In recent days, plasma treatment has been explored world-wide for seed germination improvement of various plants seeds such as Maize, Rice, Mung, Soybean, Cucumber, Pepper, Radish and Tomato etc [5-10]. In particular, plasma treatment can also be an impressive alternative to traditional pre-sowing seed treatment which uses expensive and/or harmful chemical for environment as well as human health.

In this study, we have attempted a detail study of air Radio Frequency (RF) plasma treatment effect on wheat (Triticum aestivum) seeds for improvement of germination and crop yield in collaboration with G. B. Pant University of Agriculture and Technology (GBPUAT), Pantnagar (Uttarakhand, India). Wettability and water uptake of plasma treated wheat seeds were characterized by sessile drop method using optical Goniometer setup and time dependent imbibition study at ambient condition, respectively. The lab experiments were performed for vigour and plant growth indices of plasma treated wheat seeds; whereas field experiments were carried out for grain and biological yield data measurements along with untreated seeds at Norman E. Borlaug crop research centre of GBPUAT, Pantnagar (Uttarakhand, India).

2. Experimental

Wheat seeds (Variety: HD 2967, supplied by GBPUAT, Pantnagar) were used for plasma treatment experiments, as wheat represent one of the most important crop all over the world. The seeds were visually scanned and only healthy seeds without any visible defects were selected for plasma treatments. Capacitively coupled RF plasma operated between two parallel plates of Stainless Steel (SS) electrodes with diameter 120 mm placed in vacuum chamber were used in this study (Fig. 1). A Petri dish with wheat seeds was put on the grounded lower electrode for plasma treatment with time duration of 2, 4, 6, 8 and 15 minutes (Fig. 1). The experimental conditions for RF plasma treatment were following: Supply operating frequency = 13.56 MHz, Gas used for discharge = Air, Fixed coupled RF power = 50 watts, Fixed treatment pressure = 7 x 10^{-1} mbar and Distance between electrodes: 20 mm. All treatments for all experimental conditions were replicated three times in this study.

The effect of plasma treatment on wheat seeds were examined by means of laboratory germination and biometric characteristics analysis of treated and controlled wheat seeds. Plasma treated and controlled wheat seeds were placed in Petri dishes (200 mm diameter), each dish containing 50 seeds. The seeds were placed on a layer of filter paper wetted with 10 ml of deionised water and regular watering was done at 2 days interval during experiments. These Petri dishes were placed in an incubator and temperature was maintained at 21.5° C for 15 days. The observation of germination percentage was recorded at 7th day of experiment and other observation such as root and shoot length were taken at 15th day of experiment.

The apparent contact angles of plasma treated and untreated or controlled wheat seeds were measured by sessile drop method using optical Goniometer (model no. OCA15 EC, supplied by Dataphysics Instruments GmbH, Germany). The field experiments of treated and untreated wheat seeds were conducted during December 2017 to April 2018 at Norman E. Borlaug crop research centre of GBPUAT, Pantnagar (Uttarakhand, India), situated at 29°N latitude, 79.5°E longitude and altitude of 243.83m above mean sea level in the foot hills of a *Shivalik Range* of Himalaya. The grain yield and biological yield were calculated after harvesting of crop grown from plasma treated and untreated wheat seeds to see the effect of plasma treatment.

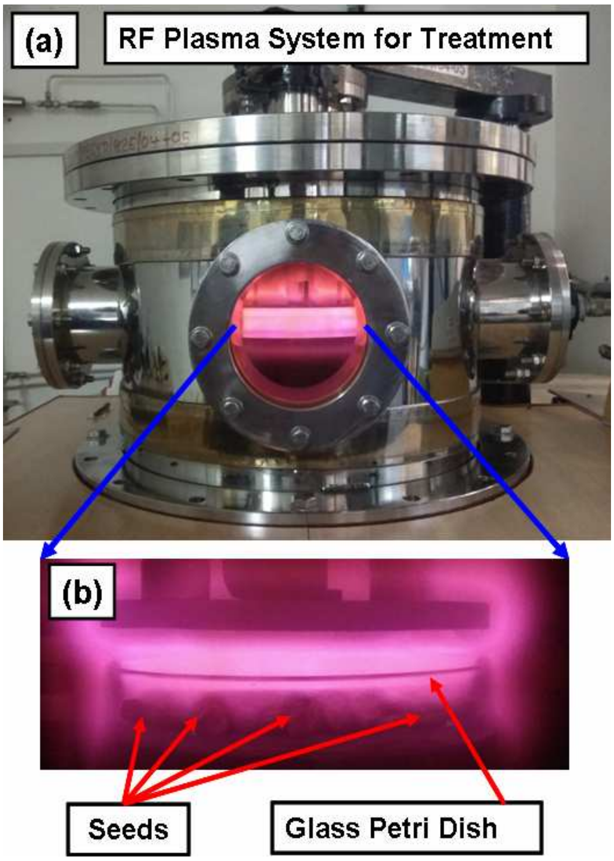

Fig. 1. (A) RF air plasma system for wheat seed treatment with plasma glow and (B) Closer view of plasma glow

3. Results and discussion

It has been observed that plasma surface treatment of seeds positively influenced their germination and biometric characteristics of seedling. In fact, many studies found that plasma treatment significantly improved seed germination [5-7,9]. At same time, a number of studies have also proposed that plasma treatment enhance seedling growth and plant growth [8,10]. In present study, plasma treatment of wheat seeds were performed using capacitively coupled air RF plasma with fixed coupled power of 50 watts and pressure of 7 x 10^{-1} mbar for treatment time duration of 2, 4, 6, 8 and 15 minutes. All plasma treatment experiments were conducted at least three replicates in order to minimize errors in experiments.

The apparent contact angle obtained using Goniometer setup for plasma treated and without treated wheat seeds are shown in Figure 2. The apparent contact angle of the untreated or controlled wheat seed was 121.6°, which was very high and represented essentially hydrophobic nature of wheat seed surface. The plasma treatment of wheat seeds dramatically decreased the apparent contact angle to 83.3°, 73.9°, 56.4°, 50.2° and 34.9° for 2, 4, 6, 8, and 15 minutes treatment time, respectively. Here, seeds subjected to plasma treatment were bombarded with ionized species resulted in seed coat erosion made-up of very thin lipid layer responsible for water-repellent properties of seed surfaces. Such modification of seed coat could increase the hydrophilic properties of plasma treated seeds and hence reduction in apparent contact angle observed for plasma treated seeds. It was obvious from the measured apparent contact angles that 2 minutes (83.3°) and 4 minutes (73.9°) plasma treatment time duration were not enough to get good hydrophilic properties of wheat seeds (Fig. 2). Inset images in Figure 2 are shown typical photos for water droplets on (a) untreated and (b) 6 minutes plasma treated wheat seeds, indicated clear change of wettability of seed surface.

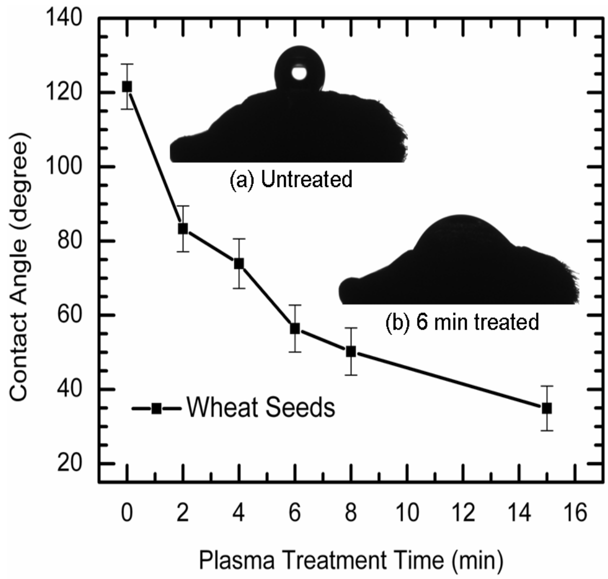

Fig. 2. Measured apparent contact angle of plasma treated and untreated wheat seeds by Goniometer. Inset images: photos taken for contact angle measurement (a) untreated and (b) 6 minutes treated wheat seeds

For the study of time dependent of water absorption (uptake), treated and untreated seeds were placed on humid cotton batting at ambient conditions. The time dependent water uptake of wheat seeds are shown in Figure 3 in terms of weight gain. The water uptake of wheat seeds were measured by weight gain using analytical balance and weight gain was obtained at regular time intervals. In the first 2 hr (120 minutes), the water uptake of the seeds slowly increased and hence weight gain for seeds were also slow, so there was no significant difference noticed between plasma treated and controlled seeds. Between 3 hr (180 minutes) to 5 hr (300 minutes), 6, 8 and 15 minutes treated seeds continued to raise more weight by taking more water in comparison to 2 minutes, 4 minutes and controlled seeds (Fig. 3). This behaviour was very well matched with apparent contact angle measurement data as 2 and 4 minutes treatment time were not sufficient to get hydrophilic properties of wheat seeds (Fig. 2). The 6, 8, and 15 minutes treatment times had the best weight gain and hence water uptake promoting effect, which was about ~ 8% higher than the 2 minutes and controlled seeds.

The effect of air RF plasma treatments by varying treatment time duration 2, 4, 6, 8 and 15 minutes on seed germination were shown in Table 1. Germination rate of all plasma treated wheat seeds (2 minutes = 89%, 4 minutes = 94%, 6 minutes = 96%, 8 minutes = 92% and 15 minutes = 91%) were much higher in comparison to the controlled seeds (54%). The maximum germination rate (96%) was obtained for 6 minutes plasma treatment time among all treatment time durations. Similarly, root length and shoot length were also higher for 6 minutes plasma treatment time among all, which were 15.1 and 11.1 cm, respectively (Table-1). Here, the superior water uptake ability was accompanied with increased ability to in-take nutrients, which could promote the growth of plant seedlings. However, for longer treatment time (8 and 15 minutes) the percentage germination, root length and shoot length decreased, this was most probably due to the damage of seed coat due to longer treatment time. Hence, field experiments were performed for 6 minutes plasma treatment and controlled wheat seeds to get crop yield data.

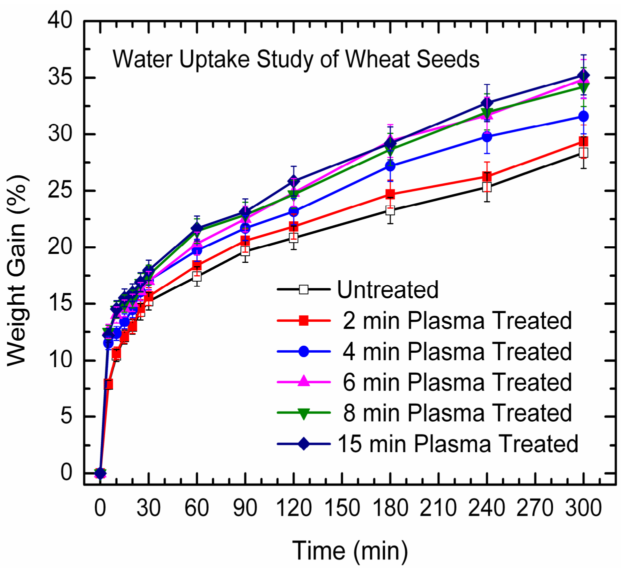

Fig. 3. Effect of RF air plasma treatment on water uptake of plasma treated and untreated wheat seeds.

Plant growth height taken at 30, 60 and 90 days after sowing were presented in Table-2 during field experiment at GBPUAT, Pantnagar (Uttarakhand, India). Here, sowing was done in field area of plot size 1 m x 7 m in triplicate for 6 minutes plasma treated and controlled wheat seeds to minimize errors, and required dose of fertilizer with regular irrigation in fields were done during experiments. Plant height of 6 minutes plasma treated wheat seedling was 16.0 (30 days), 46.7 (60 days) and 98.0 (90 days), significantly higher than that of controlled wheat seeds, which were 10.1 (30 days), 39.0 (60 days) and 94.3 (90 days) (Table-2). It confirmed that plasma treatment had positive effect on plant growth during field experiment in comparison to untreated wheat seeds.

Table 1. Seedling vigour indices influenced by plasma seed treatment.

Plasma Treatment Time (minutes)	Germination (%)	Root Length (cm)	Shoot Length (cm)
0	54	6.2	4.6
2	89	10.8	7.9
4	94	11.5	9.4
6	96	15.1	11.1
8	92	14.2	10.9
15	91	13.1	9.3

The Figure 4 shows, wheat crop plot images of field experiments images taken at 90 days after sowing for 6 minutes plasma treated (Fig. 4 (A)) and controlled seeds (Fig. 4 (B)). Images clearly show that the higher and uniform growth of wheat crop for plasma treated wheat seeds were obtained compare to untreated wheat seeds. Here in the initial stage, the treated wheat seed had longer roots, making it more convenient to absorb water and other nutrients from soil in comparison to controlled seeds, could play role for higher plant growth in this case. Correspondingly, the grain and biological yields were also achieved much elevated for 6 minutes plasma treated wheat seeds, 53.8 and 143.27 compare to controlled 49.0 and 137.17, respectively (Table-3). Over all in present study, we got 9.8% and 4.4% enhancement in grain yield and biological yield for 6 minutes plasma treated wheat seeds with respect to controlled seeds for field experiments performed at GBPUAT, Pantnagar (Uttarakhand, India).

Table 2. Plant growth indices of wheat seeds: without treatment /controlled and 6 minutes plasma treatment.

Plasma Treatment Time (minutes)	Plant Height (cm) at 30 Days	Plant Height (cm) at 60 Days	Plant Height (cm) at 90 Days
0	10.1	39.0	94.3
6	16..0	46.7	98.0

4. Conclusion

In this study, we have investigated the effect of air RF plasma treatment on wheat seeds for improvement of germination and crop yield. Plasma treatment of wheat seeds were contributed for the alteration of seed surface properties from hydrophobic to hydrophilic as evident from apparent contact angle measurements, which were essentially resulted in higher water uptake. Plasma treatment of wheat seed for 6 minutes showed enhancement of germination, root and shoot length for laboratory experiments. It was also found that grain yield and biological yield increased by 9.8% and 4.4% for 6 minutes plasma treated wheat seeds, respectively. The present experiments confirmed that the air RF plasma pre-treatment of important crop seeds is useful method for improvement of seed germination and crop yield.

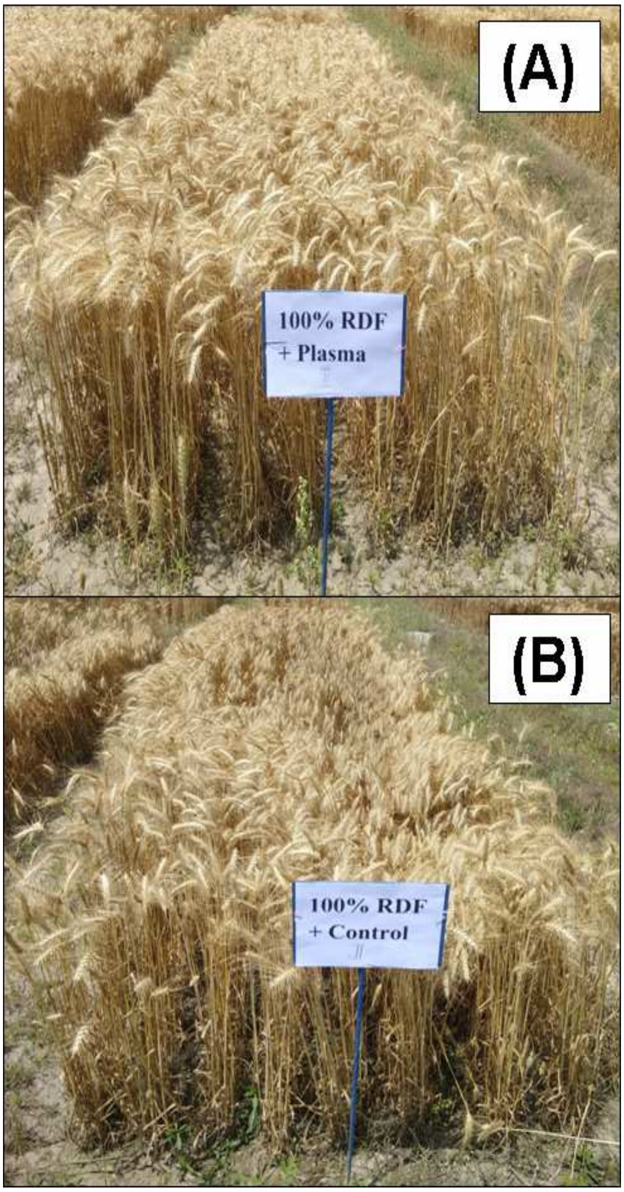

Fig. 4. Photographs taken at 90 days after sowing for wheat crop plots of (A) 6 minutes plasma treated and (B) controlled seeds (RDF in photos correspond to Required Dose of Fertilizer as per soil testing)

Table 3. Grain yield and Biological yield data of: without treatment /controlled and 6 minutes plasma treatment wheat seeds

Plasma Treatment Time (minutes)	Grain yield (q/ha)	Biological yield (q/ha)
0	49.0	137.17
6	53.8	143.27

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5. References

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