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Impact of Cold Plasma Treatments on Stored Wheat Quality and Field Emergence

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ABSTRACT

Eco-agricultural methods are necessary to enhance sustainable agricultural practices. The use of superior seeds is crucial for long-term improvement in agricultural yields. Wheat seeds are stated the key inputs for high crop yield. This study aimed to investigate the impact of cold plasma treatments on stored wheat seed germination, chlorophyll content, peroxidase activity, and field emergence of Misr 3 wheat variety. Both fresh and old wheat seed lots were subjected to atmospheric pressure cold plasma treatment using an argon gas mixture (flow rate; 1 L/min). Oxygen (0.2 L/min) into several groups of wheat seeds. The plasma treatment was conducted four times (0,30, 60, and 90 seconds). The results indicated that pre-sowing cold plasma treatment significantly improved germination, seedling vigor, and boost chlorophyll content, activities of superoxide dismutase (SOD), catalase (CAT), and ascorbate peroxidase (APX) compared to the control treatment. The most optimal germination and vitality were observed in seeds treated with plasma for 30 seconds. Results showed improvement in the studied traits when different bioactive seed lots undergo plasma treatment. Thus, this study recommends the use of cold plasma treatment as a novel and cost-effective method to enhance the quality of wheat seed lots and field emergence hence outstanding wheat yield.

Keywords: Wheat, Seed lots, Cold plasma, Catalase, Superoxide dismutase, APX, Field emergence.

INTRODUCTION

Wheat is the most important crops for increasing food security. Egypt has been producing about 9.0 million tons of wheat grains. Most of the production is consumed locally. The imports of wheat range between 10-12 million tons annually, reaching its peak at 12 million tons. Farmers must have access to suitable agricultural technologies in order to boost high production Abdalla *et al.* (2023). These technologies should include high-quality seed of climate smart varieties with high yield potential and traits like storability and seed quality. Generally speaking, there isn't extra land or water available to boost agricultural output. Enhancing productivity in a sustainable manner is actually the most sustainable way to achieve this goal (FAO, 2018). The use of cold plasma is considered safe for human health due to the absence of genotoxic effects. Furthermore, cold plasma is environmentally benign, efficient, simple to use, has a wide range of uses, and has a low influence on food quality (Liu et al., 2024). Plasma has been utilized for microbial inactivation and sterilizing for a long time. Electrons, excited atoms, ions, neutral atoms, free radicals, a large number of secondary electrons, UV photons, and UV visible light are all present in cold plasma, a partially ionized gas. These days, cold plasma is used to inactivate microorganisms, increase the rate at which seeds germinate, shorten the time that rice grains must be cooked, modify starch, decrease the production of aflatoxins, inactivate enzymes, change the hydrophilic/ hydrophobic characteristics, and etch or deposit thin films Sutar *et al.* (2021). Recently, substantial research has been conducted on the use of plasma technology in agriculture. Cold plasma plays a vital role in crop optimization, through activation of endogenous substances in seeds, innovation, promotion of crop growth, and increase crop yield. On the other hand, not much is known about how cold plasma affects plant disease prevention Konchekov *et al.* (2023). Bozhanova *et al.* (2024) identified the most appropriate combinations of the plasma source and duration of treatment positively affecting seed germination. In addition, the effect of cold plasma on the seedling growth. The treatment of seeds with cold plasma improves the osmoregulation ability of cells and therefore increases the drought resistance of genotypes (Nedyalkova, 2019) and Bozhanova *et al.* (2024). At the moment, cold plasma is essential for improving crops because it stimulates endogenous compounds in seeds, encourages growth, and increases crop yield (Pańka, 2022). However, little information is available on overcoming cold plasma in plant disease. Enhancing grain yield through the use of cold plasma technology in agriculture is a novel approach. A cutting-edge eco-agricultural high-tech technique called cold plasma seed treatment has the potential to boost crop yields and revitalize seeds Jiang *et al.* (2014); Hashizume *et al.* (2021); Cherif *et al.* (2023) and (Othman, 2024.) have demonstrated that cold air plasma pre-treatment could significantly improve seed germination. The thin films obtained by plasma polymerization could protect grains and enhance seed germination. This study highlights the potential of cold plasma technology as a viable and simple strategy for improving seed germination and plant growth in the long term, with important implications for the agricultural sector. The current study aims to investigate the

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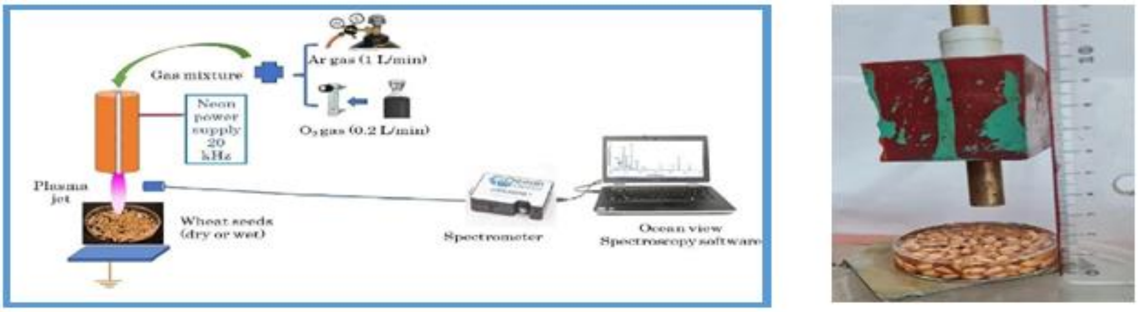
effect of cold plasma jet on pre-sowing stored wheat seed treatment, which includes: investigating the effect of different cold plasma treatment durations on wheat seedling parameters and seedling establishment, chlorophyll content, activities of superoxide dismutase (SOD), catalase (CAT), and ascorbate peroxidase (APX) compared to the control treatment and field emergence. In addition, we attempted to determine the effect and mode of action of cold plasma on the viability of stored wheat seed lots.

MATERIALS AND METHODS

Seed source : Wheat seeds were obtained from the Wheat Research Department, Field Crops Research Institute (FCRI), Agricultural Research Center (ARC), and plasma treatment pre-sowing at the Plasma and Nuclear Fusion Dept. Nuclear Research Center- Egyptian Atomic Energy Authority, Cairo, Egypt.

Plasma Jet Setup: Figure 1 showed the process of treating wheat seedlings with an atmospheric-pressure cold plasma jet. A neon sign transformer (Model Neon Pro NP-10000-30, Hyrite Lighting Co.) is utilized to ignite the plasma jet discharge. It has outputs of 10 kV, 30 mA, and 20 kHz. A 12A, 220/220V Variac (Yokoyama, Japan, Type SB-10 2 kVA) controls its input. The plasma jet apparatus is built from a 10 cm-long copper tube with a 12 mm outer and a 1 mm inner diameter. This tube is connected to the neon power supply terminal and is fed by the gas input. A 7 cm-diameter glass Petri plate filled with wheat seeds. Attaching a copper plate to the bottom of the petri dish creates a 25 mm gap between it and the ground. From the tube, the plasma jet is pushed into the wheat seed interfaces. This setup involves the use of a mixture of Ar feeding gas (at a flow rate of 1 L/min) and a small percentage of oxygen gas (0.2 L/min). The plasma spectrum released by the cold plasma jet is collected using an optical fiber cable and a Flame-S-UV-VIS spectrometer that has been commercially calibrated.



(a) **(b)**

Fig. 1. (a) A schematic (b) photo of atmospheric-pressure cold plasma jet setup used for wheat seeds treats.

With a signaltonoise ratio of 250/1 and a minimum integration period of 1 minute, its spectra cover a wavelength range of 200 to 850 nm. Its detector is a 2048-pixel Sony ILX511B linear silicon CCD array with a resolution of 1.5 nm and a standard slit of 25 µm. With the use of the NIST Atomic Spectra Database Lines, the plasma spectrum lines (retrieved via the Spectra Suite program) are examined. Wheat Groups: The wheat seeds are divided into six groups as illustrated in Figure 2 as follows: Three old wheat seed groups were produced in 2020: control, dry, and wet (the wheat seeds are immersed in water in the petri dish). Three Fresh wheat seed groups were produced in 2022 and 2023: control, dry, and wet (the wheat seeds are immersed in water in the petri dish). Four wheat seed groups were treated with a cold plasma jet for different durations: 30,60, or 90 seconds, respectively while the two control groups were left untreated.

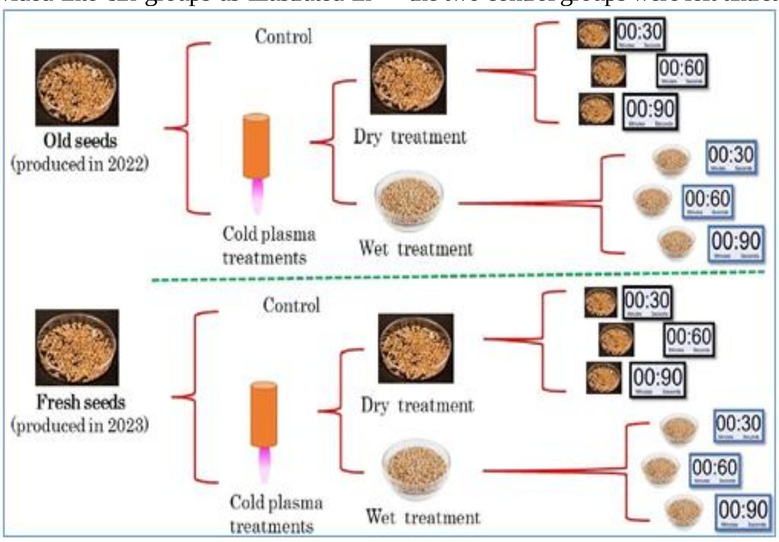


Fig. 2. An illustration of experimental design and experimental procedures for wheat seed treatments through cold plasma.

Fluid simulation: The gas flow is described by incompressible momentum conservation and the continuity equations Terebun *et al.* (2021).

$$\rho\frac{\partial u}{\partial t} + \rho(u.\nabla)u = \nabla.[-pI + k] + F \qquad (1)$$

$$\nabla. \qquad = 0 \qquad (2)$$

Where is ρe gas density, is the gas velocity, p is the pressure, I is the identity tensor, and F is the resultant force.

Figure 3 shows the simulated geometry with the velocity field, gas inlet, and outlet position of the substrate.

The vertical y-axis is the symmetry axis and the gas channel (~plasma) is located in the region from 0 to 20 mm on the y axis, while the gap between the jet nozzle and the bottom of the wheat seed lies in the region from -20–0 mm on the y-axis. Figure 4 shows the gas velocity simulation (streamline view) above wheat seed during plasma treatment, where it was found that the streamlines (direction and density) were highly dependent on the orientation of wheat seed on the treatment plate as reported by Guragain *et al.* (2024).

Germination test: wheat seed germination test was based according to (ISTA, 1999). Each culture dish was lined with two layers of filter paper, and 10 mL of distilled water was added. Each culture dish contained 50 seeds, distributed uniformly. The dish was cultivated in a light incubator at 20-25 ºC for 8 days, with daily observations and recording of seed germination. The criteria for determining seed germination are when the germ length equals half of the seed length.

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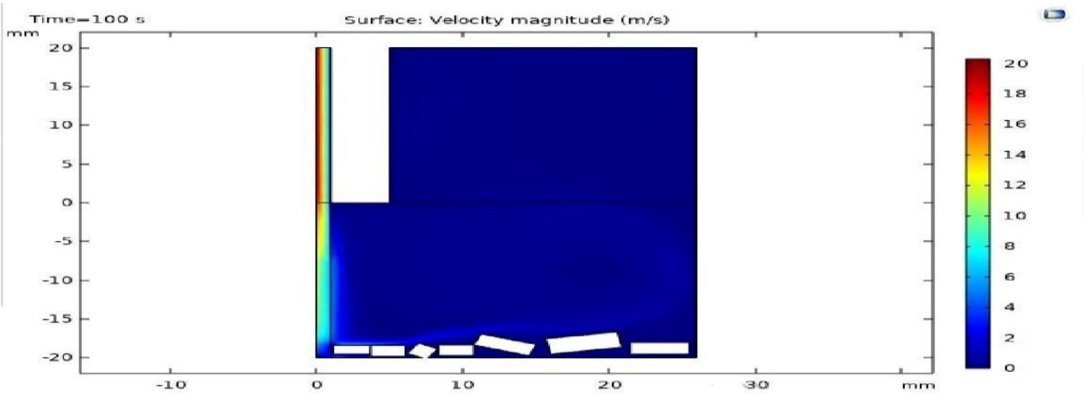

Fig. 3. Gas velocity simulation (surface view) above wheat seed during plasma treatment.

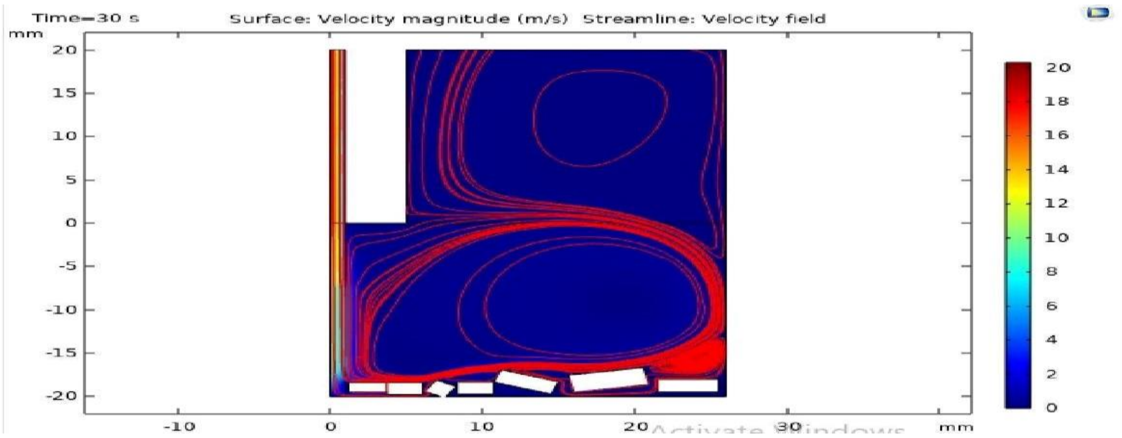

Fig. 4. Gas velocity simulation (Streamline view) above wheat seed during plasma treatment.

Eexperiment repeats 4 times. Seedling length (shoot and root length cm): Ten normal seedlings 8 days after planting after then, the seedlings were dried in a hot-air oven at 85 ^{0}C for 12 hours according to obtain the seedling dry weight (g). Seedling dry weight (g): Ten normal seedlings were weighed 8 days after planting according to (ISTA, 1999). Chlorophyll (a & b): were determined using fresh samples according to Krishnasamy and Seshu (1990). Accurately (0.5 g) of fresh cutting parts were weighted and homogenized with 10 ml of methanol extracting solvent at 4°C in the presence traces of sodium bicarbonate in the test tube covered by aluminium foil. Green colour tincture concentration was spectrophotometrically measured at (665.2nm) Chlorophyll a and (652.4nm) Chlorophyll b wavelength. The contents of total chlorophyll, chlorophyll a and chlorophyll b were calculated by the following equations:

Chlorophyll a (μg/ml) = (16.72 X A665.2) - (9.16 X A652.4)
Chlorophyll b (μg/ml) = (34.09 X A652.4) - (15.28 X A665.2) As, A= Absorbance.

Chlorophyll content (mg/g fresh weight) =

$$\frac{\text{chlorophyll content} \times \text{volume of methanol}}{1000 \times \text{weight of sample (gm)}}$$

Superoxide dismutase (SOD), catalase (CAT), ascorbate peroxidase (APX): were determined using fresh samples according to Henselová et al. (2012) and Sumanta *et al.* (2014). Field experiment: One hundred seeds of the Misr 3 variety were planted in three replications using a Randomized Complete Block Design (RCBD) in the experimental field at the Tag El-Ezz Agricultural Research Station in the Dakahlia governorate. The total number of seedlings in the field was counted when the emergence was complete or when there was no further addition in total emergence. Ten seedlings were selected randomly and were analyzed for shoot length, root length, fresh weight, dry weight, germination percentage, seedling vigor index 1and 2, chlorophyll a, b and total chlorophyll and catalase, pod and APX activities.

Statistical analysis: Data was statistically analysed according to Gomez and Gomez (1984). At the 5% level of significance, the means of the treatments were compared using the least significant difference (LSD).

RESULTS AND DISCUSSION

Table 1exhibits the impact of different cold plasma treats and wheat seed lots on germination percentage, seedling fresh and dry weight. Highly significant differences among cold plasma teats were observed except for fresh weight in first season and seedling dry weight in both seasons. Cold plasma treats enhanced the seed lots for dry and wet types. On the other hand, the variation between the two lots was highly significant. Treatment wet 90 seconds of fresh lot gave the highest seedling fresh and dry weight.

Table 1. Germination percentage, fresh weight and dry weight as affected by cold plasma treatments

Cold Plasma treats	Germination percentage		Fresh weight (gm)		Dry weight (gm)	
	2022	2023	2022	2023	2022	2023
Fresh dry control	100	97	0.397	0.400	0.066	0.060
Fresh dry 30 Sec	100	97	0.512	0.500	0.059	0.053
Fresh dry 60 Sec	100	98	0.340	0.400	0.060	0.056
Fresh dry 90 Sec	90	94	0.316	0.300	0.053	0.050
Fresh wet control	100	97	0.502	0.533	0.068	0.063
Fresh wet 30 Sec	93	92	0.482	0.500	0.062	0.056
Fresh wet 60 Sec	100	97	0.244	0.400	0.048	0.043
Fresh wet 90 Sec	86	88	0.842	0.566	0.696	0.693
Old dry control	93	94	0.440	0.500	0.058	0.053
Old dry 30 Sec	80	86	0.336	0.400	0.055	0.050
Old dry 60 Sec	90	94	0.354	0.400	0.065	0.060
Old dry 90 Sec	93	94	0.285	0.400	0.043	0.040
Old wet control	100	97	0.507	0.566	0.064	0.060
Old wet 30 Sec	77	82	0.384	0.466	0.052	0.050
Old wet 60 Sec	80	85	0.308	0.400	0.053	0.050
Old wet 90 Sec	90	91	0.391	0.500	0.045	0.040
F. test.	**	**	NS	**	NS	NS
LSD. 0.05.	11.81	7.31	-	0.049	-	-

The current research came as a direct response to improving the quality of the wheat crop and improving germination levels, especially in light of the climate change crisis, which has become a major threat to the Egyptian agricultural production process. Also, this study focused on measuring and estimating a set of tests, physiological parameters, and measurements of growth strength, quality degree besides, and seed vitality for using both old and fresh lots.

Table 2 shows highly positive significance on the studied traits i.e.; shoot length, root length, and seedling length in both seasons respectively. Also, cold plasma treatments fresh wet for 30 seconds recorded the highest values for the studied traits comparing other traits followed by the treatment old wet 60 seconds.

Table 3 elucidated the cold plasma treats of wheat variety Misr 3, seed lots and durations on the following parameters i.e. seedlings vigor index 1 and 2, field emergence percentage Misr 3 wheat variety recorded the highest seedling length, and seedling dry weight, seedlings vigor index 2 with fresh lots. Fresh lots recorded the highest values in seedling parameters comparing old lots.

Table 2. Shoot, root length, and seedling length as affected by cold plasma treatments

Cold plasma treats	Shoot length cm		Root length cm		Seedling length cm	
	2022	2023	2022	2023	2022	2023
Fresh dry control	7.9	8.0	4.4	5.0	12.3	13.0
Fresh dry 30 Sec	7.8	7.7	4.9	5.0	11.7	12.6
Fresh dry 60 Sec	6.5	7.0	4.8	5.0	10.3	12.0
Fresh dry 90 Sec	6.8	7.3	5.6	6.0	11.4	13.3
Fresh wet control	7.4	7.5	4.4	6.0	11.6	13.5
Fresh wet 30 Sec	8.2	8.0	5.8	7.0	13.9	15.0
Fresh wet 60 Sec	5.9	6.7	5.1	6.0	8.6	12.6
Fresh wet 90 Sec	3.0	7.0	5.6	6.0	4.4	13.0
Old dry control	7.4	7.7	5.1	6.0	10.5	13.6
Old dry 30 Sec	6.5	7.7	5.4	6.0	9.0	13.6
Old dry 60 Sec	7.3	8.0	5.1	6.0	8.3	14.0
Old dry 90 Sec	6.9	7.3	4.5	6.0	7.5	13.3
Old wet control	5.2	7.0	5.5	6.0	6.8	13.0
Old wet 30 Sec	5.8	7.0	5.2	6.0	7.6	13.0
Old wet 60 Sec	7.1	7.2	5.7	6.3	13.1	14.8
Old wet 90 Sec	5.1	7.0	5.4	6.0	7.50	13.0
F test	**	**	**	**	**	**
LSD 0.05	1.442	0.73	0.533	0.241	1.85	0.81

Table 3. Seedling vigor index1, seedling vigor index2, field emergence as affected by cold plasma treatments

Cold plasma treats	Seedling vigor index 1		Seedling vigor index 2		Field emergence%	
	2022	2023	2022	2023	2022	2023
Fresh dry control	1225.0	1269.7	6.65	5.86	88.6	92.6
Fresh dry 30 Sec	1165.0	1228.7	5.95	5.17	90.0	92.0
Fresh dry 60 Sec	1030.0	1180.0	6.00	5.57	93.3	93.3
Fresh dry 90 Sec	1031.0	1254.3	4.77	4.70	92.0	89.0
Fresh wet control	1100.5	1247.8	5.84	5.24	89.6	87.3
Fresh wet 30 Sec	1395.0	1465.3	6.80	6.29	92.7	93.6
Fresh wet 60 Sec	855.0	1233.0	4.85	4.21	87.0	92.3
Fresh wet 90 Sec	334.3	1144.0	6.53	6.28	86.6	83.0
Old dry control	987.5	1283.7	5.39	5.01	83.3	89.0
Old dry 30 Sec	781.5	1177.3	4.43	4.30	85.0	81.0
Old dry 60 Sec	747.0	1325.3	5.85	5.68	82.0	89.6
Old dry 90 Sec	701.0	1257.3	4.06	3.77	78.6	89.3
Old wet control	1305.0	1438.8	6.45	5.82	77.0	92.0
Old wet 30 Sec	574.5	1066.0	4.02	4.10	80.0	77.0
Old wet 60 Sec	540.0	1105.0	4.24	4.26	79.0	80.0
Old wet 90 Sec	675.0	1191.7	4.09	3.66	80.7	86.6
F test	**	**	NS	NS	**	**
LSD 0.05	230.73	131.22	-	-	2.1266	7.31

Table 4 presents the cold plasma treats of wheat variety Misr 3, seed lots and durations on the following parameters i.e. chlorophyll a, chlorophyll b and total chlorophylls. Fresh wet 30 Seconds recorded the highest values. On the other hand, Fresh dry control recorded the lowest values. Cold plasma treats with 90 seconds also improvement the chlorophyll comparing control without treatment for fresh and old wheat lots in both seasons.

With respect to superoxide dismutase (SOD), catalase (CAT), ascorbate peroxidase (APX) as affected by cold plasma treatments Table 5 presents the cold plasma treats of wheat variety Misr 3, seed lots and durations. Fresh wet 90 Seconds recorded the highest values of SOD and APX. On the other hand, CAT recorded high values when treated seed with 90 sec of fresh wet compared to control. Cold plasma treats for 90 seconds also improve the enzyme activities for both lots fresh and old comparing control in both seasons.

Table 4. Chlorophyll content as affected by cold plasma treatments

Cold plasma treats	Chlorophyll a		Chlorophyll b		Chlorophyll total	
	2022	2023	2022	2023	2022	2023
Fresh dry control	2.359	2.333	1.796	1.733	2.079	2.033
Fresh dry 30 Sec	2.713	2.700	2.409	2.400	2.554	2.500
Fresh dry 60 Sec	2.777	2.700	2.316	2.300	2.522	2.466
Fresh dry 90 Sec	2.229	2.20	2.106	2.100	2.163	2.100
Fresh wet control	2.719	2.70	1.869	1.833	2.324	2.300
Fresh wet 30 Sec	3.113	3.10	2.378	2.300	2.746	2.700
Fresh wet 60 Sec	3.204	3.20	2.610	2.600	2.857	2.833
Fresh wet 90 Sec	2.937	2.900	2.601	2.600	2.694	2.633
Old dry control	2.631	2.600	2.206	2.200	2.419	2.400
Old dry 30 Sec	2.830	2.800	2.505	2.500	2.643	2.600
Old dry 60 Sec	2.902	2.900	2.421	2.400	2.637	2.600
Old dry 90 Sec	2.432	2.400	2.229	2.200	2.331	2.300
Old wet control	2.936	2.900	2.101	2.100	2.519	2.500
Old wet 30 Sec	3.431	3.400	2.334	2.300	2.908	2.900
Old wet 60 Sec	3.513	3.500	2.607	2.600	3.045	3.000
Old wet 90 Sec	3.058	3.030	2.647	2.600	2.838	2.767
F test	**	**	**	**	**	**
LSD 0.05	0.024	0.027	0.0315	0.0329	0.0374	0.049

Table 6 revealed the correlation coefficient of different measures of two lots of wheat variety Misr 3 and cold plasma treats studied 1. germination%, 2. shoot length, 3. root length, 4. seedling length, 5. fresh weight, 6. seedling dry weight, 7. seedling vigor index1, 8. seedling vigor index 2, 9. chlorophyll a, 10. chlorophyll b, 11. chlorophyll total, 12. field emergence, 13.SOD, 14.CAT as well as 15.APX were highly significant positively correlated with studied parameters. Along the germination percentage and field emergence. shoot length with seedling length and seedling vigor index1. Root length with seedling length and seedling vigor index 1. Fresh weight with seedling vigor index 2. Seedling dry weight with seedling vigor index 2. Seedling vigor index, as well as seedling length were significant and highly significantly positively correlated with field emergence. Significant and highly significant negative correlations were found with shoot length, root length, seedling length seedling vigor index 1, total chlorophylls and field emergence, respectively. Fresh lots have recorded progress in genetic enhancement related to standard germination, seedling length, seedling dry weight, seedlings vigour index 1, seedlings vigour index 2, as well as field emergence.

Table 5. Superoxide dismutase, catalase, ascorbate peroxidase as affected by cold plasma treatments.

Cold plasma treats	SSOD		CAT		APX	
	2022	2023	2022	2023	2022	2023
Fresh dry control	14.47	14.40	11.553	11.467	10.453	10.400
Fresh dry 30 Sec	9.38	9.30	12.774	12.733	8.645	8.733
Fresh dry 60 Sec	10.45	10.40	14.543	14.537	11.838	11.880
Fresh dry 90 Sec	16.61	16.60	11.614	11.583	12.631	12.610
Fresh wet control	13.47	13.40	13.872	13.843	10.663	10.833
Fresh wet 30 Sec	15.28	15.20	15.092	15.090	10.693	10.663
Fresh wet 60 Sec	11.55	11.50	15.286	15.290	10.14	10.333
Fresh wet 90 Sec	19.78	19.70	18.733	18.710	14.014	14.200
Old dry control	22.42	22.40	11.818	11.820	13.733	13.800
Old dry 30 Sec	18.68	18.60	13.109	13.107	12.672	12.700
Old dry 60 Sec	20.50	20.50	16.628	16.637	14.03	14.500
Old dry 90 Sec	20.94	20.57	15.682	15.667	15.00	15.000
Old wet control	14.59	14.50	10.017	10.070	11.065	11.267
Old wet 30 Sec	18.80	18.67	16.109	16.113	14.306	14.327
Old wet 60 Sec	20.27	20.13	15.723	15.713	12.020	12.010
Old wet 90 Sec	22.50	22.27	13.496	13.500	14.375	14.667
F test	**	**	**	**	**	**
LSD 0.05	1.23	0.240	5.471	0.1007	0.139	0.175

SOD: Superoxide dismutase CAT: Catalase APX: Ascorbate peroxidase

Table 6. A correlation coefficient of different measures of wheat lots and plasma treatments.

Mean	1	2	3	4	5	6	7	8	9	10	11	12	13	14	15
1	1														
2	0.479	1													
3	0.354	0.509	1												
4	0.501	0.943	0.751	1											
5	0.138	0.121	0.021	0.026	1										
6	-0.009	-0.276	-0.167	-0.354	0.826	1									
7	0.734	0.903	0.699	0.952	0.031	-0.319	1								
8	0.00633	-0.268	-0.161	-0.346	0.829	0.999	-0.306	1							
9	-0.416	-0.365	-0.309	-0.382	0.070	0.025	-0.442	0.018	1						
10	-0.391	-0.640	-0.633	-0.721	-0.048	0.150	-0.691	0.143	0.633	1					
11	-0.472	-0.487	-0.449	-0.527	0.015	0.038	-0.571	0.030	0.955	0.817	1				
12	0.828	0.403	0.375	0.437	0.123	0.067	0.621	0.081	-0.530	-0.348	-0.539	1			
13	-0.514	-0.393	-0.350	-0.429	-0.029	0.092	-0.518	0.083	0.124	0.264	0.203	-0.694	1		
14	-0.351	-0.744	-0.314	-0.687	0.021	0.295	-0.657	0.289	0.476	0.550	0.532	-0.292	0.252	1	
15	-0.457	-0.511	-0.381	-0.528	-0.085	0.124	-0.577	0.116	0.034	0.254	0.137	-0.592	0.864	0.390	1

1.Germination%, 2. Shoot length, 3. Root length, 4. Seedling length, 5. Fresh weight, 6. Seedling dry weight, 7. Seedling vigor index1, 8. Seedling vigor index 2, 9. Chlorophyll a, 10. Chlorophyll b, 11. Chlorophyll total, 12. Field emergence% 13.SOD 14.CAT 15.APX

Discussion

Fast-acting, economically effective, and ecologically acceptable solutions are required to boost crop productivity during agricultural activities. Currently, cold plasma stimulation plays an essential role in crop optimization by activating endogenous chemicals in seeds, rejuvenating them, promoting plant growth, and increasing yield. However, nothing is known about the effect of cold plasma on wheat seed pre-sowing and storability. In this study, we looked at how a cold plasma pre-treatment affected germination, wheat seedling establishment, and physiological responses like as chlorophyll concentration and POD activity. Furthermore, we sought to understand the effect and mechanism of action of cold plasma on the improvement and enhancement of wheat seed lots, including fresh lots and old lots with high and low vigor, respectively. Plasma therapy produced UV light, radicals, and chemical processes, all of which contributed significantly to dormancy breaking. According to Karimi et al. (2024) cold helium plasma may play a role in breaking dormancy. Šerá *et al.* (2012) found a considerable delay in seed germination after treatment with fluorocarbon plasmas. Their findings are exactly opposite to ours. When they used fluorocarbon plasmas, the seed coat properties were altered by plasma deposition of hydrophobic compounds, resulting in decreased water absorption and delayed germination. In our tests, we used helium plasma, which may improve seed wettability and ultimately alter germination speed. Liu *et al.* (2024) also reported comparable findings. The effect of plasma treatment at various intensities (output power) was variable Bormashenko *et al.* (2015). Plasma treatment with low energy may be insufficient to have noticeable effects on seeds. Meanwhile, the high-energy plasma treatment may have an overpowering influence on seeds, causing inappropriate results. Thus, each type of seed has its own optimal processing power. On this premise, we conducted seed germination tests for wheat treated for various durations (30, 60, and 90 s), and it was discovered that 30 s was the most appropriate power of treatment for wheat seeds. Previous research has shown that cold plasma treatment can boost wheat development, increasing the weight of shoots substantially. The present experiment revealed that the plant height, root length, and fresh weight of wheat seedlings treated with cold helium plasma were significantly higher. Because cold plasma therapy improved the hydrophilicity of seeds, plants' ability to absorb water and nutrition was increased, resulting in better growth. Our results demonstrated that the treated plant grew faster than the control at the booting stage. Compared to the control, the treated wheat seedlings developed longer roots, higher heights, and heavier weights, allowing them to absorb more water and nourishment and get more light for photosynthesis. Cold plasma treatment has the potential to boost wheat growth not only at the seedling stage but also during the booting stage. At the same time, we discovered that the chlorophyll content of the treated wheat was larger than that of the control, showing that cold plasma treatment could improve wheat's physiological activities. This is consistent with Sayahi et al. (2024). The yield remains the most important problem. Our study found that treated wheat yielded 7.55 $t \cdot ha^{-1}$, which is 5.89% more than the control. At the booting stage, the treated wheat had longer roots, making it easier to absorb water and nutrients. Furthermore, the plant's height allowed it to receive more sunlight. Furthermore, the treated wheat has increased leaf area, thickness, and chlorophyll content, resulting in increased photosynthesis. All of the beneficial qualities of treated wheat pointed to an increase in production.

CONCLUSION

The initial result that we reported in this study was that the pre-sowing seed of the wheat variety Misr 3 may be improved by using a cold plasma jet that was operated with a mixture of argon and oxygen gases at atmospheric pressure. Germination may be improved, growth could be promoted, and the physiological level of chlorophyll in wheat could be enhanced by the use of cold plasma treatment, which would ultimately result in an increase in yield. Our research not only demonstrates that the application of cold plasma to pre-seed treatment is feasible and advantageous, but it additionally provides a theoretical foundation for the use and widespread adoption of that method.

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تأثير استخدام البلازما الباردة في تحسين جودة تقاوي القمح المخزنة والتكشف الحقلي

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الملخص

إن الأساليب الزارعية البيئية ضرورية لتحسين الزرعة المستدامة. كما يعد استخدام البذور المحسنة من الأهمية لتحسين إنتاجية المحاصيل على المدى الطويل. وتعتبر تقاوي القمح من المدخلات الرئيسية لزيادة إنتاجية المحصول. هدفت هذه الدارسة إلى معرفة تأثير معاملات البلازما الباردة على إنبات تقاوي القمح المخزنة (القديمة والحديثة) ومحتوى الكلوروفيل ونشاط البيروكسيديز وفوق أكسيد الديسموتيز والكتاليز واسكوربات البيروكسيديز والتكشف الحقلي لصنف القمح مصر٣ . تم تعريض كل من تقاوي القمح الحديثة والقديمة لمعالجة البلازما الباردة بالضغط الجوي باستخدام خليط غاز الأرجون (معدل التدفق؛ ١ لتر/دقيقة). الأكسجين (٠،٢ لتر/دقيقة) إلى عدة مجموعات من تقاوي القمح. تم إجراء المعاملة بالبلازما أربع فترات هي (٩٠،٦٠،٣٠،٠ ثانية). أشارت النتائج إلى أن معاملة التقاوي بالبلازما الباردة قبل الزارعة أدت إلى تحسن معنوي في إنبات وحيوية البادارت وزيادة محتوي الكلوروفيل والنشاط الإنزيمي لفوق اكسيد الديسموتيز والكتاليز ونشاط انزيم اسكوربات البيروكسيديز مقارنة بمعاملة الكنترول. وقد لوحظ أفضل إنبات وحيوية في البذور المعالجة بالبلازما لمدة ٣٠ ثانية. أظهرت النتائج تحسنا ملحوظا في الصفات المدروسة عند المعاملة بجرعات مختلفة من البلازما. ولذلك، توصي هذه الدارسة باستخدام المعالجة بالبلازما الباردة كوسيلة جديدة وفعالة من حيث التكلفة لتعزيز جودة لوطات تقاوي القمح والتكشف الحقلي.

الكلمات الدالة: القمح، لوطات التقاوي ، البلازما الباردة، انزيم الكتاليز، وفوق اكسيدالديسموتيز ، البيروكسيديز والتكشف الحقلي.