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THE EFFECT OF OZONE TREATMENT VIA ION PLASMA METHOD AND MINERAL FERTILIZER APPLICATION RATES ON WHEAT FIELD GERMINABILITY (BASED ON LYSIMETER EXPERIMENTS)

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Abstract

Today, wheat is not only of vital importance for human nutrition but is also the most widely cultivated crop globally, providing approximately 20% of daily protein and caloric intake. After rice, wheat serves as the second most important staple food crop in developing countries (Asseng S.; Guarin J., 2020). As global food demand continues to rise, there is a pressing need to increase food production, which cannot be achieved solely by expanding agricultural land (Lawlor D.W.; Mitchell R.A., 2001).

Introduction

The Development Strategy of Uzbekistan highlights the importance of “Implementing a program for the development of the food industry” under the agenda of “Rapid economic development and ensuring high growth rates.” Given the high national demand for wheat grain, it is crucial to select varieties adapted to irrigated land conditions and to further improve optimal agrotechnological practices for wheat cultivation through scientific research.

Amidst a variety of environmental challenges, it is necessary to enhance seed germination and early plant development in agriculture while simultaneously reducing reliance on pesticides and other environmentally hazardous chemicals. To this end, the development of novel, environmentally friendly technologies is essential. One such innovative method is seed treatment using ion plasma (Rashid, A.; Harris, D.; Hollington, P.A.; Khattak, R.A., D.A., 2002).

Ion plasma represents a state of matter in which gases are ionized. It is a physicochemical process whereby gas becomes ionized under high temperature or in an electric field. A growing body of research is investigating the potential impacts of ion plasma treatment on plant development. Plasma-based methods can supply additional nutrients and create favorable growth conditions for plants, offering significant applications in modern agriculture.

In recent years, scientific studies have increasingly focused on the pre-sowing treatment of seeds using ion plasma technology to improve germination rates, growth parameters, crop productivity, and resistance to abiotic stress factors (Starič, P.; Grobelnik Mlakar, S.; Junkar, I.; Los, A.; Ziuzina, D.; Boehm, D.; Cullen, P.J.; Bourke, P.; Mehrotra, R.; Tyagi, G.; Jangir, D.K., 2021;

Zhang, W.; Xu, L.L.; Ober, E.S.; Alahmad, S.; Cockram, J.; Forestan, C.; Hickey, L.T.; Kant, J.; Maccaferri, M.; Marr, E.; Milner, M.; Pinto, F., 2021). Among the various crops studied, wheat remains a focal species, being a primary source of calories and non-animal protein (Sharma, K.K.; Singh, U.S.; Sharma, P.; Kumar, A.; Sharma, L., 2015).

The Alekseevich wheat cultivar is highly attractive for agricultural production due to its high yield potential, resistance to cold stress, tolerance to diseases and pests, and its suitability for high-quality bread production. Although its cultivation is officially approved in the Central Black Earth and North Caucasus regions of the Russian Federation, Alekseevich is also well-adapted to the diverse agro-ecological zones of Uzbekistan, making it viable for widespread cultivation (State Register of Agricultural Crops Recommended for Cultivation in the Republic of Uzbekistan, 2022). Its pronounced cold resistance allows it to quickly adapt to various climatic conditions, rendering it a versatile cultivar for different regions (https://agronom.expert/posadka/ogorod/zlaki/pshenitsa/sort-alekseevich. html, accessed 27.04.2024)

Research Methodology

The experiment investigated the effect of ion plasma (O_3-based) seed treatment on the germinability of winter wheat (Alekseevich cultivar) under conditions of irrigated typical sierozem (grey) soils. Initial germination studies were carried out in a laboratory setting using Petri dishes, followed by field-scale lysimetric experiments.

The field trials were conducted from March to August 2024 at the lysimetric facility located on the experimental farm of the Botanical Research and Education Center of the National University of Uzbekistan named after Mirzo Ulugbek. In total, 55 lysimetric experimental containers were prepared and installed as part of the study. A two-factor experimental design was implemented to evaluate the interaction between ion plasma treatment and mineral fertilizer application.

Irrigation was carried out according to plant water requirements throughout the experiment. Key parameters monitored included seed germination rate, seedling emergence, and tillering density.

The ion plasma treatment was performed as illustrated in Figure 1, following a controlled sequence. Seeds (excluding the control treatment) were exposed to ozone (O_3) at approximately 15,1 Watts for durations ranging from 10 to 100 seconds using a conveyor-based plasma treatment unit. This exposure is intended to enhance seed metabolic activity and positively influence germination performance.

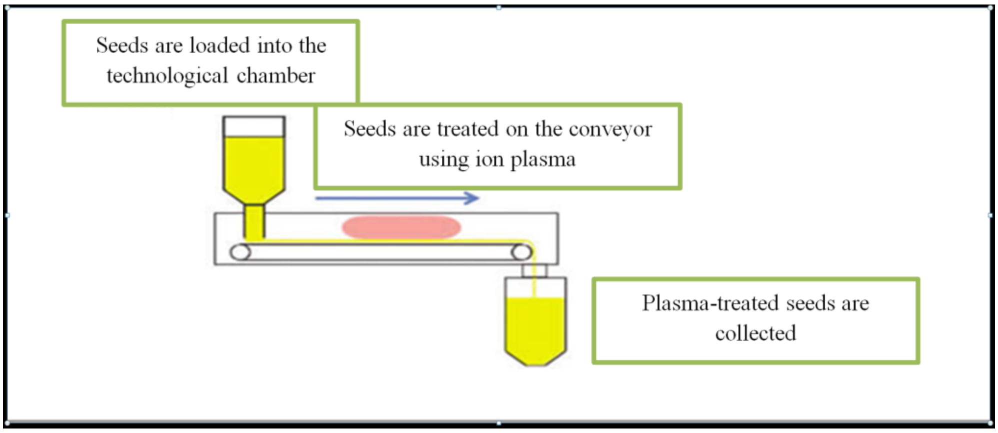

Figure 1. Mechanism of seed treatment via ion plasma

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Figure 2 presents a schematic layout of the lysimetric experimental design. The experimental matrix consisted of 11 treatments, ranging from a control (no plasma treatment) to 10–100 seconds of plasma exposure. Each treatment included combinations of control (no fertilizer), full recommended NPK rates ($N_{200}P_{140}K_{60}$ kg/ha, replicated twice), and moderate NPK rates ($N_{150}P_{105}K_{45}$ kg/ha) supplemented with two foliar nutrient suspensions (also replicated twice).

The control treatment was completely devoid of fertilizers and plasma exposure, serving as a baseline to evaluate the effects of the treatments. All NPK fertilizers were applied pre-sowing. The first foliar suspension consisted of UAN-32 (urea ammonium nitrate, 32% nitrogen) applied at 5 L/ha during the tillering stage in variant V-x.3. The second suspension involved “Kalifos” (10% phosphorus, 25% potassium), applied at 2 L/ha during the stem elongation phase, also in variant V-x.3.

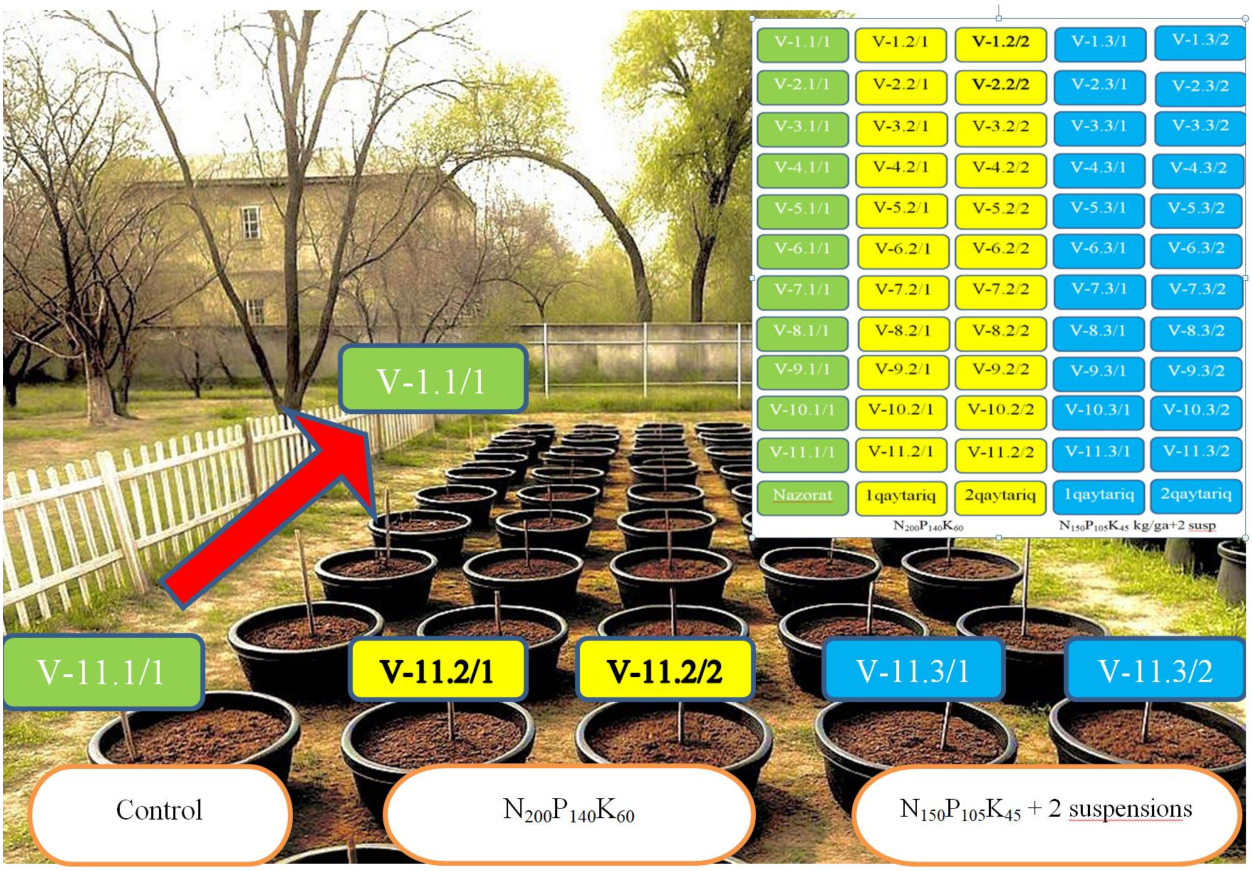

Figure 2. Schematic Layout of the Lysimetric Experiment

Seed germination under field conditions is a critical indicator reflecting the actual biological viability of seeds. In this experiment, seeds were sown at a density of 500 seeds per 1 m², based on the surface area of each lysimetric container, and the number of germinated seedlings was counted to determine germination percentage.

Research Findings

The results of the study revealed that ozone-based ion plasma treatment, in combination with mineral fertilizers, had a significantly positive effect on seed germination. In the control treatment (V-1.1), where neither plasma treatment nor fertilizers were applied, the germination rate was only 83%, corresponding to 415 germinated seeds per m². This low figure indicates weak germination vigor in the absence of any stimulatory treatment.

However, when fertilizers were applied without plasma treatment (V-1.2 and V-1.3), germination increased slightly to 84%, demonstrating a modest 1–2% improvement. Plasma treatment for just 10 seconds (V-2.1) led to a noticeable increase in germination, reaching 87%, which is 4% higher than the untreated control. This suggests that even a brief exposure to ion plasma positively stimulates seed metabolic activity. Moreover, when the 10-second plasma treatment was combined with fertilizer application (V-2.2 and V-2.3), germination reached 88%, or 440 seeds per m².

As the duration of plasma exposure increased, germination continued to improve. At 20, 30, and 40 seconds, germination rose to 89% and 90%, corresponding to 445–450 germinated seeds per m², respectively.

The highest germination rates were observed in the 50-second treatment variants (V-6.1 to V-6.3), where germination peaked at 92% (460 seeds per m²). This finding indicates that a 50-second plasma treatment may represent the optimal exposure time for maximizing germination. Plasma treatments of 60 and 70 seconds also maintained high germination levels of 90–92%, corresponding to 450–460 seeds per m². However, treatments beyond this duration-specifically 80, 90, and 100 seconds (V-9.1 to V-11.3)-resulted in a slight decline or stabilization of germination rates at around 88% (440 seeds per m²). This trend suggests that excessively long plasma exposure may exert a detrimental effect on seed physiological integrity.

Table 1. Germination rate of winter wheat seeds (day 16) depending on ozone-based ion plasma treatment and mineral fertilizers (2023–2024)

Variant numbers	The treatment duration of seeds with ozone using the ion plasma method (15.1 watt voltage)	Annual norm of mineral fertilizers	The number of germinated plants (planted at 500 seeds per 1 m²)	
			plants per square meter	%
V-1.1	Control	Control	415	83
V-1.2.		$N_{200}P_{140}K_{60}$ kg/ha	420	84
V-1.3.		$N_{150}P_{105}K_{45}$ kg/ha+2 times suspension*	420	84
V-2.1	10 second	Control	435	87
V-2.2.		$N_{200}P_{140}K_{60}$ kg/ha	440	88
V-2.3.		$N_{150}P_{105}K_{45}$ kg/ha+2 times suspension*	440	88
V-3.1.	20 second	Control	445	89
V-3.2.		$N_{200}P_{140}K_{60}$ kg/ha	445	89
V-3.3.		$N_{150}P_{105}K_{45}$ kg/ha+2 times suspension*	445	89
V-4.1.	30 second	Control	445	89
V-4.2.		$N_{200}P_{140}K_{60}$ kg/ha	445	89
V-4.3.		$N_{150}P_{105}K_{45}$ kg/ha+2 times suspension*	445	89
V-5.1.	40 second	Control	450	90
V-5.2.		$N_{200}P_{140}K_{60}$ kg/ha	450	90
V-5.3.		$N_{150}P_{105}K_{45}$ kg/ha+2 times suspension*	455	91
V-6.1.	50 second	Control	460	92
V-6.2.		$N_{200}P_{140}K_{60}$ kg/ha	460	92
V-6.3.		$N_{150}P_{105}K_{45}$ kg/ha+2 times suspension*	460	92
V-7.1.	60 second	Control	450	90
V-7.2.		$N_{200}P_{140}K_{60}$ kg/ha	455	91
V-7.3.		$N_{150}P_{105}K_{45}$ kg/ha+2 times suspension*	455	91
V-8.1.	70 second	Control	460	92
V-8.2.		$N_{200}P_{140}K_{60}$ kg/ha	460	92
V-8.3.		$N_{150}P_{105}K_{45}$ kg/ha+2 times suspension*	460	92
V-9.1.	80 second	Control	440	88
V-9.2.		$N_{200}P_{140}K_{60}$ kg/ha	440	88
V-9.3.		$N_{150}P_{105}K_{45}$ kg/ha+2 times suspension*	440	88
V-10.1.	90 second	Control	435	87
V-10.2.		$N_{200}P_{140}K_{60}$ kg/ha	435	87
M-10.3		$N_{150}P_{105}K_{45}$ kg/ha+2 times suspension*	440	88
V-11.1.	100 second	Control	455	91
V-11.2.		$N_{200}P_{140}K_{60}$ kg/ha	455	91
V-11.3.		$N_{150}P_{105}K_{45}$ kg/ha+2 times suspension*	460	92

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During the experiment, wheat seeds were treated with ozone using the ion plasma method for varying durations (from 0 to 100 seconds). Additionally, two fertilization regimes were applied: the full standard rate - $N_{200}P_{140}K_{60}$ kg/ha, and a 25% reduced rate supplemented with two applications of a microbial suspension -$N_{150}P_{105}K_{45}$ kg/ha + 2x suspension treatment. Under these conditions, germination rate, plant population density, tillering coefficient, and plant height were analyzed.

When analyzing the treatment groups by variant, the control group (V-1.1 to V-1.3, untreated with plasma) showed relatively low germination rates (415–420 plants/m²). The plant population ranged between 525–545 plants/m². The tillering coefficient was 1.3. The tallest plants were observed in the untreated control (23,4 cm), but plant height decreased (down to 16,8 cm) when fertilizers were applied, suggesting that excessive fertilizer rates may sometimes inhibit plant growth.

In variants V-2.1 to V-2.3 (10-second plasma exposure), germination and plant population significantly increased compared to the control, reaching 610–643 plants/m². The tillering coefficient improved to 1,4–1,5, reflecting a positive plasma effect. Plant height reached up to 24,5 cm, particularly under the reduced NPK + suspension treatment.

In variants V-3.1 to V-3.3 (20-second plasma exposure), germination remained high (up to 645 plants/m²), and plant height ranged from 17,0 to 19,6 cm. Although slightly lower than the 10-second treatment, these results were stable and consistent.

In V-4.1 to V-4.3 (30-second plasma exposure), similar germination levels were recorded. Plant density ranged between 578–640 plants/m². While the highest plant height (23,5 cm) was observed in the untreated subvariant, fertilization reduced it to 13,4 cm, indicating a mismatch between plasma treatment and fertilizer dose.

Variants V-5.1 to V-5.3 (40-second plasma exposure) showed germination rates of 450–455 plants/m², with total plant density reaching up to 690 plants/m². Plant height ranged between 16,2–23,6 cm, and the tillering coefficient varied between 1,3–1,5, indicating good but slightly unstable results.

In V-6.1 to V-6.3 (50 seconds), the highest plant density was observed, reaching 760 plants/m² in V-6.2. Tillering coefficient was notably high (1,7), and plant height ranged from 21,3–23,1 cm. This treatment represents the optimal combination of plasma exposure duration and fertilizer rate.

Variants V-7.1 to V-7.3 (60 seconds) displayed moderate and stable results, with plant height ranging from 20,1–23,8 cm. However, total plant density declined slightly compared to previous high-performing variants. The tillering coefficient remained stable at 1,4.

In V-8.1 to V-8.3 (70-second plasma treatment), germination reached 460 plants/m², and plant population ranged from 470 to 693 plants/m². The tallest plants were recorded in V-8.3 (27,4 cm) when the suspension was applied, highlighting the synergistic effect of plasma treatment and microbial stimulation.

In V-9.1 to V-9.3 (80 seconds), plant density stabilized at 440 plants/m², with a tillering coefficient between 1,3–1,4. Plant height ranged from 20,8 to 27,6 cm, showing some decline in the fertilizer variants compared to the control.

In V-10.1 to V-10.3 (90 seconds), the highest plant height of 29,8 cm was observed in V-10.1 (control), although plant population slightly decreased. These results suggest that longer plasma treatment may enhance growth when matched with the correct fertilization background.

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In V-11.1 to V-11.3 (100 seconds), a significant reduction in plant density (435–480 plants/m²) and the lowest tillering coefficient (0,9–1,1) were recorded, indicating that excessive plasma exposure suppresses plant development.

Overall, ozone treatment using ion plasma within the 50–70 second range produced the most favorable agronomic results. In particular, treatments using the reduced fertilizer rate ($N_{150}P_{105}K_{45}$) supplemented with two microbial suspension applications led to high and stable germination rates, increased plant population, and improved plant height.

Conclusion

The study demonstrated that ion plasma treatment of seeds, in combination with nutrient background, positively influences seed germination and plant development. Plasma-treated winter wheat exhibited improved nitrogen and phosphorus assimilation and enhanced utilization of other soil nutrients.

The highest plant density (760 plants/m² in V-6.2) and tillering coefficient (1,7) were observed in the 50-second treatment group, confirming this duration as optimal. Notably, combining plasma treatment with mineral fertilizers and microbial suspensions significantly boosted germination, with a maximum rate of 92% recorded in V-6.3 (50 seconds + suspension).

The most pronounced positive effects of ion plasma treatment on seed germination occurred between 50–70 seconds. In particular, 50-second treatment resulted in up to 92% germination. When plasma is combined with fertilizers and biostimulant suspensions, outcomes are significantly enhanced.

This technology can be considered a modern, eco-safe, and highly effective agro-technique for improving seed germination, metabolic energy, and disease resistance. Integrating ion plasma technology with resource-efficient fertilization systems enables high agrobiological efficiency and sustainable crop production.

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