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APPLICATION OF OZONE FOR THE TREATMENT OF SHALLOT PLANTING MATERIAL

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The paper presents studies of the effect of ozone-air treatment on the preservation, yield, fungal disease damage and chemical composition of shallots of the Lira variety. The effect of concentrations of 10, 50 and 100 ppm O_3 and exposure times of 10, 60 and 180 min was studied. The positive effect of ozone on reducing losses from diseases during storage and during the growing season was established, an increase in the productivity and marketability of shallots was achieved, as well as an improvement in a number of chemical indicators of the product.

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INTRODUCTION

The use of gas-discharge technologies in agriculture has become widespread mainly due to the high oxidizing properties of ozone generated during this process [1, 2]. Its antiseptic properties significantly exceed chemical analogues (chlorine, fluorine, etc.) [3]. At the same time, the antibacterial and fungicidal effect does not cause resistance of harmful objects [4]. In some cases, an antiviral effect is observed, which indicates not only its surface action, but also an indirect influence on the viral spreading inside cells [5].

Ozonation of agricultural products, premises and tools is of applied importance. It is economically feasible and environmentally safe [6, 7]. The ozone molecule dissociates to form oxygen naturally. No additional measures are required for its formation, storage and disposal [8].

Disinfection of the surface of fruit and vegetable products allows to reduce losses during storage and transportation, keep and improve quality, improve durability and shelf life [9, 10]. The use of ozone is of particular importance for the treatment of planting and sowing material [11]. Plant species that reproduce vegetatively (potatoes, garlic, shallots, sweet potatoes, and others) can be affected by a large number of diseases and pests through seed material [12]. This subsequently leads to crop losses and deterioration of their quality. Currently, a number of methods of pre-planting treatment have been developed using an ozone-air mixture for blowing through the mass of products or creating a uniform ozone concentration field in chambers of different volumes [13].

Shallots ("bush") are characterized by their high taste and high content of nutrients. They have a relatively low reproduction rate, which significantly limits their spreading [14]. Bulbs used for propagation contain a large amount of water and sugars, so under certain conditions they can be affected by fungal or bacterial infections [15]. As a rule, harmful microorganisms are found in the soil, so infection occurs in the field. Under the influence of weather conditions or violation of growing technology, such planting material is subject to rotting and infects unaffected products. Due to the fact that shallot bulbs need to be stored for a long time (from August to April), there is an urgent need to regulate the storage process, especially in unequipped storage facilities with natural cooling and ventilation [16]. In this case, the critical periods for exposure to pathogens are dispatch of products for storage and pre-planting preparation.

MATERIALS AND METHODS

The research program was intended to substantiate the effect of abiotic factors (ozonation) during the preparation of planting material in alternative technologies for growing onion vegetable plants on the development and prevalence of harmful organisms.

In accordance with the set goal, the following tasks were under solving:

- to determine the disinfecting effect of ozone on shallot planting material;
- to study the effect of ozonation modes on the dynamics of the biochemical composition of products and their preservation;
- to study the effect of ozone on the growth and development of shallot;
- to determine the effect of ozonation on the formation of shallot yield, crop structure and adaptive properties;
- to evaluate the phytopathological state of shallot samples by types of diseases depending on the effect of ozone.

Research work was carried out by conducting field experiments and storage experiments.

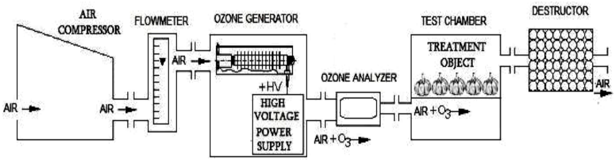
Field experiments were conducted on shallots according to Methods of research in vegetable growing and melon growing (2001). Designing and conducting of storage experiments were carried out according to Guidelines for storing fruits, vegetables and grapes (1998). The technology of growing shallots is recommended for the Forest-Steppe of Ukraine, except for the studied elements (DSTU 6012:2008, 2009). The predecessors of shallots were cucumbers. The shallot of the Lyra variety was used in the experiment.

The Lira variety is early maturing, the vegetation period is 72-74 days. Spicy. The bulb is elliptical, weighing 40…50 g. Universal purpose. The yield of bulbs is

15.0…16.4 t/ha, green feathers – 28 t/ha. It is characterized by friendly growing of green leaves. (*State register of plant varieties suitable for distribution in Ukraine*, 2024).

Shallots were treated on a laboratory stand "Ozone-agro-1L" (Figure). The stand is composed of the following functional units: Secoh sangyo (Japan) air compressor of capacity up to 50 l/min and of a maximum pressure of up to 12.7 kPa, a gas flow meter (type SM-4 GUZ), OzW Stream Ozone laboratory ozone generator, Teledyne instruments (USA) ozone concentration meters (model 454H) of ozone concentration measurement range of 0.1…100 g/m³, Ozone Solutions (USA) (model ES-600) of ozone concentration measurement range of 0.01…0.1 g/m³ and StreamOzone-1000 ozone concentration meters of ozone concentration measurement range up to 1000 ppm, a laboratory chamber for samples and an ozone destructor.

We used barrierless ozone generators based on a streamer discharge of atmospheric pressure for ozone synthesis [11]. They have clear advantages over barrier ozone generators in agricultural industry. First of all, their low sensitivity to water vapor in the feeding gas, no need for precision assembly of the electrode system, no need for water cooling of electrodes, low resistance to pumping the gas mixture through the ozone generator module. They can steadily and durably produce ozone from ambient atmospheric air (without using a special air preparation system) of ozone-air mixture parameters required for onion treatment.



Block diagram of the laboratory stand "Ozone-agro 1L" functional units

Pre-planting treatment of planting material was carried out 3 days before planting by blowing an ozone-air mixture through the mass of products. The area of the registration plot was 5 m^2, fivefold repetition, the placement-systematic.

Shallots were planted in the second decade of April, the planting pattern – 70×15 cm. Soil preparation and crop care – common for this growing area except for the studied elements. Shallots were harvested when the bulbs were fully formed (dry neck and outer scales) in the third decade of July.

After harvesting the marketable bulbs were treated with ozone before drying according to the experimental options (Table 1). The final drying was carried out for 20 days in a dry, well-ventilated room. After final drying, 100 bulbs were placed for long-term storage in fivefold repetition in numbered mesh bags. The samples were stored in a natural-cooled onion storage room. During storage the temperature and humidity of the air were monitored using August psychrometers, as well as the state of the products was observed.

At the end of storage (180 days), natural weight loss and yield of marketable bulbs, losses due to germination and disease damage were determined. The pathogen was identified. To determine the quality of the products, the chemical composition was determined using the indicators and methods described above.

Table 1

Experimental options

№	Option	
	C[O$_3$], ppm	exposure, min
1	without treatment (reference sample)	
2	10	10
3		60
4		180
5	50	10
6		60
7		180
8	100	10
9		60
10		180

To compare the results of the chemical composition at the beginning and at the end of storage, the content of substances in the bulbs at the end of storage was recalculated with a correction for weight loss according to the formula:

$$X = \frac{A(100 - B)}{100},$$

where X – content of substances reduced to the initial mass, %; A – substance content determined at the end of storage, %; B – mass loss during storage, %.

Natural mass loss is determined by the formula:

$$X = \frac{A - B}{A} \times 100,$$

where X – mass loss, %; A – product mass at the beginning of storage, g; B – product mass after storage, g.

Related observations in the field experiment:

1) observation and recording of meteorological conditions of the shallot growing season (according to the meteorological post of the IVMG NAAS);

2) recording and registration the main phases of growth and development of shallots (date of planting bulbs, emergence of seedlings, bulb formation, feather lodging, harvesting) – the beginning of the phase (10%) and its mass coming (75%);

3) recording bulb survival and density during the period of full germination and before harvesting (counting germinated plants and comparing their number with the number of planted plants);

4) biometric measurements were performed before the beginning of feather lodging. The number of leaves on the plant, the number of bulbs in the nest were counted, the plant height was measured by the length of the largest leaf, and the average bulb weight (at harvesting) was measured on 10 plants of each variant;

5) harvesting was carried out during feather lodging of 70…90% of plants. During harvesting the yield was recorded by weighing the plants on a plot-by-plot basis and determining the marketable and non-marketable share;

6) determination of chemical composition of bulbs depending on ozonation options: dry matter content (*DSTU 7804:2015 Fruit and vegetable processing*

products. Methods of determining dry substances or moisture), sugars (monosaccharides and diaccharides) (*DSTU 4954:2008 Products of fruit and vegetable processing. Methods of determination of sugars*), vitamin C (*DSTU 7803:2008 Fruit and vegetable processing products. Methods of determination of vitamin C*), nitrate (*DSTU 4948:2008 Fruits, vegetables and their processing products. Methods of determination of nitrate content*).

The obtained experimental data were processed by the method of correlation and variance analysis according to the existing methodology [17].

RESULTS AND DISCUSSION

The most important indicator of the effectiveness of techniques and measures in storage experiments is the safety of marketable products. According to the results of the conducted experiment it has been found that using ozone leads to increasing the number of preserved bulbs. Regardless of the ozone concentration during treatment before storage only a slight increase in this indicator by 0.5…1.2% was noted at exposure for 10 min. A significant increase in this indicator was noted during exposure at 60 and 180 min, where the increase in the number of bulbs yield was 2.6…4.6%, which is significantly higher than $HIP_{0,05}$=2.5. The highest yield of bulbs was provided by the maximum exposure of 180 min at ozone concentrations of 50 and 100 ppm – 94.5 and 94.2% respectively. The increase in preservation occurs due to reduction of bulb losses due to rot damage (Table 2).

According to the results of long-term storage during September-April a positive effect of ozone on reducing onion losses due to rot damage was found. It was found that an obvious effect at the minimum ozone concentration (10 ppm) can be achieved only with longer exposures – 60 and 180 min. Bulb losses in these variants were 7.5 and 7.0%, respectively, which is 25.7 and 30.1% lower than the reference sample. A similar pattern was observed when using higher ozone concentrations – 50 and 100 ppm. A significant effect was observed with longer treatment exposures. The best result was obtained when treating bulbs with an ozone-air mixture with an O_3 concentration of 50 ppm and an exposure of 60 min – 5.5%, and 100 ppm with an exposure of 180 min – 5.8%. Under these conditions, losses were reduced almost twice as compared to the reference sample. According to the results of phytopathological monitoring of diseases it was founded that bulb losses occur as a result of bulb damage by gray neck rot (*Botrytis allii* Munn).

The higher efficiency of long-term ozone exposures can be explained by the limited air permeability of the bulb, as a result of which ozone penetration into the gaps between the integumentary scales and gas interaction with pathogens requires more time.

The destruction of surface infection that occurs during short-term treatment (exposure 10 min) is obviously insufficient and provides only a slight reduction in losses from damage. The expected effect can be achieved only by increasing the exposure of the treatment – which is confirmed by the results of our studies.

Table 2

Losses of shallot bulbs during long-term storage, Lira variety (2020-2021)

Option		Natural mass loss, %	Output of marketable bulbs by quantity, %	Losses due to rot damage by quantity, %
$C[O_3]$, ppm	Exposure, min			
without treatment (reference sample)		18.3	89.9	10.1
10	10	16.8	90.5	9.6
	60	18.3	92.5	7.5
	180	18.6	93.0	7.0
50	10	19.7	90.4	9.6
	60	20.7	90.5	5.5
	180	19.8	94.5	5.5
100	10	20.7	91.1	8.9
	60	19.4	93.4	6.6
	180	18.6	94.2	5.8
$LSD_{0.5}$		1.8	2.5	1.3

According to the experimental design after the completion of storage, pre-planting treatment of bulbs with ozone was carried out 3 days before planting the bulbs. It should be noted that no difference was visually observed in the passage of phenological phases of growth and development depending on the experimental options. Thus, it can be concluded that ozonation does not affect the onset of phenological phases of growth and development in shallots of the Lira variety.

To establish the effect of pre-planting ozonation, biometric measurements of plants in the bulb formation phase were carried out. According to their results it was noted that the use of ozone for the treatment of planting material contributes to the improvement of plant growth and development, which is reflected in their height – a tendency towards increasing the height by 1.4…5.3 cm relative to the reference sample was noted. At the same time, the average mass of bulbs in the variants was 21.4…25.0 g, in the reference sample – 20.5 g (Table 3).

As it is known, plant development has a direct impact on formation of crop yield. In addition, yield is an integral part of assessing the effectiveness of agricultural practices. According to the plot accounting of this indicator (Table 4), in the options of applying pre-planting ozone treatment, it increased relative to the reference sample by 1.0…2.1 t/ha.

The highest marketable yield of shallots was provided by the use of treatment of bulbs with an ozone-air mixture with an O_3 concentration of 10 and 100 ppm and an exposure of 180 min – 12.3 t/ha, on the reference sample (without treatment) – 10.2 t/ha. On these variants the highest indicators of the standard share of the harvest were noted – 11.2…11.5 t/ha. Due to ozone using an increase in the marketability of the harvest by 1.2…3.3% was noted, while on the control this indicator was 94.6%.

Table 3

The effect of pre-planting ozone treatment on plant development before feather lodging, Lira variety (2021)

Option		Number of bulbs in the nest, pcs.	Plant height, cm	Number of leaves on the stem, pcs.	Bulb mass, g
$C[O_3]$, ppm	Exposure, min				
without treatment (reference sample)		4.8	55.3	8.1	20.5
10	10	4.7	56.5	6.9	21.4
	60	5.5	58.5	11.0	22.7
	180	5.0	58.3	7.3	22.8
50	10	4.5	57.9	6.6	21.4
	60	4.9	58.9	7.5	23.1
	180	4.7	60.2	6.4	24.9
100	10	5.0	59.5	8.2	21.5
	60	5.3	60.7	6.9	21.5
	180	5.3	61.8	7.0	25.0

The effect of pre-planting ozone treatment on the biochemical composition of shallots was studied (Table 5). It was noted that its use increased the content of monosaccharides total sugar and vitamin C. The content of monosaccharides in the reference sample was 1.19% in variants with treatment of bulbs with an ozone-air mixture with an O_3 concentration of 50 and 100 ppm and exposure for 60 and 180 min – 1.22…1.55%.

Table 4

Marketable yield and marketability of shallots depending on pre-plant ozone treatment, Lira variety (2021)

Option		Bulb yield, t/ha		Marketability, %
$C[O_3]$, ppm	Exposure, min	Marketable	Standard	
without treatment (reference sample)		10.2	9.3	94.6
10	10	11.2	10.5	96.1
	60	11.6	10.8	95.8
	180	12.3	11.2	97.0
50	10	11.3	10.4	96.7
	60	11.8	10.9	97.4
	180	12.1	11.3	97.4
100	10	11.3	10.5	96.7
	60	11.9	11.0	97.8
	180	12.3	11.5	97.9
$LSD_{0.5}$		0.91	0.88	1.45

The total sugar content was 1.49…5.08% higher than in the reference sample, which was 12.02%. The vitamin C content was 11.49…13.04 mg/100 g, in the reference sample – 9.39 mg/100 g.

Table 5

The effect of pre-plant ozone treatment on the chemical composition of bulbs, Lira variety (2021)

Option		Dry matter, %	Monosaccharides, %	Disaccharides, %	Total sugar, %	Vitamin C, mg/100 g
$C[O_3]$, ppm	Exposure, min					
without treatment (reference sample)		18.68	1.19	10.29	12.02	9.39
50	60	18.00	1.22	11.68	13.51	11.49
	180	19.84	1.23	14.85	16.86	13.04
100	60	22.42	1.52	14.80	17.1	9.67
	180	19.98	1.55	14.06	16.35	11.22
$LSD_{0.5}$		1.81	0.12	1.01	1.12	0.82

The inspection of diseases in Lira shallot crops found that onion downy mildew and viral mosaic were most prevalent in 2021 (Table 6).

Table 6

The effect of pre-plant ozone treatment on the prevalence of diseases on shallots of Lira variety and damage by onion thrips during the growing season (2021)

Option		Disease prevalence, %		Plant damage by onion thrips, %
$C[O_3]$, ppm	Exposure, min	Downy mildew	Viral diseases	
without treatment (reference sample)		13.0	10.5	26.5
10	10	8.0	7.0	23
	60	6.0	10.0	28.5
	180	5.0	11.6	26
50	10	5.0	10.0	29
	60	5.0	10.0	30
	180	4.0	11.0	25.5
100	10	6.0	9.0	22
	60	5.0	5.0	22.5
	180	2.5	7.5	22.5

A steady deficit of precipitation and elevated temperature conditions due to soil drought led to suppression of the prevalence and development of downy mildew. Downy mildew was the most common in the option with the lowest dose of ozone and amounted to 13%, in other variants the prevalence was less than 8%. Viral mosaic was spread almost uniformly in all options (5…11.6%), this may be due to the fact that the plants were damaged by thrips – a carrier of viral disease pathogens.

Thus, it was established that pre-planting ozone treatment reduces shallot damage with downy mildew by 38.4…80.8%, and viral diseases when using a maximum concentration of 100 ppm – by 14.3…52.4% compared to the reference sample.

CONCLUSIONS

1. Treatment of bulbs with an ozone-air mixture at O_3 concentration of 50 and 100 ppm and exposure for 60 and 180 min, respectively, tends to reducing the loss of shallot planting material due to gray neck rot infection by almost twofold compared to the reference sample (without treatment) to the level of 5.5…5.8%.

2. The effect of pre-planting treatment of shallot bulbs on the course and duration of phenological phases of plant development was not observed.

3. Ozonation of planting material contributes to improvement of plant growth and development, which is reflected in their height – a tendency towards increasing the height by 1.4…5.3 cm relative to the reference sample and the average bulb mass by 0.9…4.5 g was noted.

4. Pre-planting treatment of bulbs with ozone provides a reliable increase in marketable yield compared to the reference sample by 1.0…2.1 t/ha and an increase in crop marketability by 1.2…3.3% to the level of 95.8…97.9%.

5. An improvement in chemical composition of bulbs was noted due to the use of pre-planting treatment with an ozone-air mixture. The dry matter content increased by 1.16…3.74%, disaccharides by 1.39…4.56%, total sugar by 1.49…5.08%, and vitamin C by 0.28…3.65 mg/100 g.

6. Pre-planting ozone treatment reduces shallot damage with downy mildew by 38.4…80.8%, and viral diseases by 14.3…52.4% when using a maximum concentration of 100 ppm compared to the reference sample.

REFERENCES

1. L.P. de Souza, L.R.D.A. Faroni, F.F. Heleno, P.R. Cecon, T.D.C. Gonçalves, G.J. da Silva, L.H.F. Prates. Effects of ozone treatment on postharvest carrot quality // *Lwt*. 2018, v. 90, p. 53-60.
2. E. Sarron, P. Gadonna-Widehem, T. Aussenac. Ozone treatments for preserving fresh vegetables quality: A critical review // *Foods*. 2021, v. 10(3), p. 605.
3. N. Tzortzakis, A. Chrysargyris. Postharvest ozone application for the preservation of fruits and vegetables // *Food Reviews International*. 2017, v. 33(3), p. 270-315.
4. Skog, CL Chu. Effect of ozone on qualities of fruits and vegetables in cold storage // *Canadian Journal of Plant Science*. 2001, v. 81(4), p. 773-778.
5. S. Shezi, L.S. Magwaza, A.Mditshwa, S.Z. Tesfay. Changes in biochemistry of fresh produce in response to ozone postharvest treatment // *Scientia Horticulturae*. 2020, v. 269, p. 109397.
6. S. Horvitz, M.J. Cantalejo. Application of ozone for the postharvest treatment of fruits and vegetables // *Critical reviews in food science and nutrition*. 2014, v. 54(3), p. 312-339.
7. R. Botondi, M. Barone, C. Grasso. A review into the effectiveness of ozone technology for improving the safety and preserving the quality of fresh-cut fruits and vegetables // *Foods*. 2021, v. 10(4), p. 748.
8. H. Karaca, Y.S. Velioglu. Ozone applications in fruit and vegetable processing // *Food Reviews International*. 2007, v. 23(1), p. 91-106.
9. B.K. Tiwari, K. Muthukumarappan. Ozone in fruit and vegetable processing // *Ozone in food processing*. 2012, p. 55-80.
10. M. Glowacz, D. Rees. The practicality of using ozone with fruit and vegetables // *Journal of the Science of Food and Agriculture*. 2016, v. 96(14), p. 4637-4643.
11. V.I. Golota, G.V. Taran, A.A. Zamuriev, P.O. Opalev, S.G. Pugach, S.M. Mankovskiy, V.P. Petrenkova, I.N. Nyska. The use of ozone technologies in grain storage // *Problems of Atomic Science and Technology. Series "Plasma Electronics and New Methods of Acceleration".* 2018, № 4, p. 185-188.
12. S.G. Pugach, L.M. Zavada, O.O. Zamuriev, D.V.Kudin, P.O. Opalev, O.V.Melnyk, S.A. Scherbina, O.L. Semenchenko. Determination of the optimal ozonation mode for winter garlic planting material // *Problems of Atomic Science and Technology. Series "Plasma Electronics and New Methods of Acceleration".* 2021, № 4, p. 204-206.
13. G.V. Taran, V.A. Breslavets, A.A. Zamuriev, et al. Plasma-chemical methods for control of biotic contaminants // *Problems of Atomic Science and Technology. Series "Plasma Electronics and New Methods of Acceleration"*. 2019, № 4, p. 198-202.
14. O.D. Vitanov, V.P. Rud, O.V. Kuts, O.V. Melnyk, N.V. Chefonova, S.O. Shcherbyna, S.M. Datsenko, D.V. Ivanin. *Modern systems of vegetable production*. Vinnytsia: "Tvory", 2022.
15. O. Melnyk, I. Mytenko, N. Dukhina, O. Semenchenko, O. Vitanov, S. Shcherbina, S. Datsenko, Y. Zelendin, N. Chefonova, D. Ivanin. Efficiency of potato and garlic virus control by interferon use // *Ukrainian Journal of Ecology*. 2020, v. 10(2), p. 50-54.
16. L. Carletti, R. Botondi, R. Moscetti, E. Stella, D. Monarca, M. Cecchini, R. Massantini. Use of ozone in sanitation and storage of fresh fruits and vegetables // *Journal of Food, Agriculture and Environment*. 2013, v. 11(3-4), p. 585-589.
17. V.A. Dospekhov. *Field experiment methodology*. M.: "Agropromizdat", 1985, p. 286.

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ЗАСТОСУВАННЯ ОЗОНУ ДЛЯ ОБРОБКИ САДИВНОГО МАТЕРІАЛУ ШАЛОТУ

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Представлено дослідження впливу озоноповітряної обробки на збереженість, урожайність, ураження грибними хворобами та хімічний склад цибулі шалот сорту Ліра. Досліджено вплив концентрацій 10, 50 та 100 ppm O_3 та часу експозиції – 10, 60 та 180 хв. Встановлено позитивний вплив озону на зменшення втрат від хвороб при зберіганні та під час вегетації, досягнуто збільшення продуктивності і товарності цибулі шалот, а також покращення низки хімічних показників продукції.