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MODERN TRENDS IN AGRICULTURE SCIENCE: PROBLEMS AND SOLUTIONS

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Reviewers:
Mykola DOLYA, Ph.D., Prof., Head Department of Integrated Plant Protection and Quarantine of National University of Bioresources and Nature Management;
Oleksandr KUTS, Ph.D., leading of science collaboration, Director of the Institute of Vegetable Growing and melon growing of NAAS of Ukraine.

The monograph is a collection of the results of actual achievements of domestic agricultural scientists, obtained directly in real conditions. The authors are recognized experts in their fields, as well as young scientists and postgraduate students of Ukraine. Research is conceptually grouped at 7 sections: Plants protection and quarantine; vegetable growing in open and closed ground; horticulture, fruit growing, viticulture; breeding and seed production; agrochemistry and soil science; agriculture and modern agricultural technologies; management and strategies for future development. The monograph will be interesting for experts in plant breeding, economics, plant protection, selection, agrochemistry, soil science, scientific workers, teachers, graduate students and students of agricultural specialties of higher education institutions, and for all those who are interested in increasing the quantity and quality of agricultural products.

Keywords: agriculture, modern technologies, plants protection, quarantine, vegetable growing, horticulture, fruit growing, viticulture, breeding and seed production, agrochemistry, soil, management, strategies, development.

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INTEGRITY OF WINTER GARLIC DEPENDING ON VARIETAL CHARACTERISTICS, PACKAGING AND ANTIMICROBIAL TREATMENT

Ludmila PUSIK
Doctor of Agricultural Sciences, Professor Department of Horticulture and Storage of Crop Products, State Biotechnological University
ludmilap@gmail.com
Veronika BONDARENKO
PhD of Agricultural Sciences, Assistant Professor, Department of Horticulture and Storage of Crop Products, State Biotechnological University
Vladimir PUSIK
Doctor of Agricultural Sciences, Professor of the Department ecology and biotechnology in crop production, State Biotechnological University
Hryhorii YAROVYI
Doctor of Agricultural Sciences, Professor, Head of the Department of Horticulture and Storage of Crop Products, State Biotechnological University
Nataliya DIDUKH
PhD of Agricultural Sciences, Lecturer, Department of Horticulture and Storage of Crop Products,State Biotechnological University

Pre-storage treatment of garlic bulbs with Trichodermin and Gaupsin reduced the number of damaged and sprouted bulbs, indicatinge antimicrobial and fungicidal effects of these bioprotectors of plants. Polyethylene inserts in boxes decreased the weight loss of garlic bulbs by 2–3.2%, depending on varietal characteristics. The weight loss of winter garlic bulbs depended on varietal characteristics and storage methods. The dry matter loss ranged 23.3 to 69.7% of the weight loss, while water evaporation accounted for 30.2–76.7%. The commercial output was 80.1% after six months of storage of garlic at –3... –1±0.5°C.

***Key words**: garlic, biologicals, integrity, packaging.*

Garlic is a very common vegetable all over the world. It is one of the main suppliers of natural vitamins, sugars, organic acids, dietary fibers, minerals and other valuable substances, which ensure adequate nutrition, to the human body. It is the best antiseptic with strong bactericidal and phytoncidal effects, enhancing its significance, especially during virus epidemics (Bobos I.M., 2011). However, production offers significantly lag behind growing demand for products.

Long-term storage of garlic from harvest to harvest is a pre-requisite for its continuous supply to the population. However, widespread introduction of winter garlic is held back by few varieties adapted to certain growing conditions and storage technologies. During storage, garlic suffers from downy mildew, Fusarium basal rot, bacteria and two species of stem nematodes. Diseases of garlic bulbs are caused by fungi *(Botrytris allii Munu, Fusarium sp.),* bacteria *(Erwinia carotovora subsp. Carotovora Bergey et al., Burkholderia cepacia ex Burkholder Yabuuchi et al., Pseudomonas syringae pv. Porri),* and nematodes *(Dytilenchus dipsaci, Dytilenchus allii)* (Mohylna O.M., 2018).

Pre-storage treatment of products with biologicals containing active strains, which are able to inhibit plant disease development, is a way to increase the shelf life of vegetables for food purposes and simultaneously reduce the disease percentage (Pusik L.M., 2011). Through the lens of the above, the need to improve measures to extend the consumption period of winter garlic determines the topicality of our work. For this purpose, we evaluated effects of antimicrobial bioagents on the contents of some chemicals and integrity of winter garlic varieties. The study was carried out on Diushes, Liubasha, and Uhorskyi varieties. Bioagents Gaupsin and Trichodermin were investigated. Treatment was conducted by spraying plants during the growing period in accordance with the manufacturers' recommendations.

It was proven that the pre-storage treatments of garlic bulbs with Trichodermin and Gaupsin influenced the weight loss of bulbs during storage. We found that the winter garlic bulb weight decreased by 11.6% after five-month storage at 0±0.5°C compared to the storage start value. After four-month storage, the number of microorganism-affected and sprouted bulbs was 5.33 (2.87%) and it increased by 62 (39%) after five-month storage (Table 1).

Trichodermin and Gaupsin treatments of garlic bulbs were shown to reduce the total loss of weight by 30% after four-month storage; after five-month storage, the garlic bulb weight loss was additionally reduced by 10%. At the same time, a decrease in the number of microorganism-affected and sprouted garlic bulbs after antimicrobial treatments was observed: Trichodermin significantly influenced the number of microorganism-affected bulbs after four-month storage and the number of sprouted bulbs after five-month storage, while the Gaupsin effects on these

Table 1

Integrity of Liubasha winter garlic bulbs depending on antimicrobial treatments, % (T = 0±0.5ºC)

Treatment of bulbs	Natural loss,%	Disease-induced loss, %	Sprouted bulbs,%	Total loss, %	Commercial output, %
After four-month storage					
No treatment (control)	7.89	5.33	2.87	16.09	83.91
Trichodermin	2.34	2.17	1.43	5.94	94.06
Gaupsin	2.56	0.82	2.41	5.79	94.21
LSD_{05}	1.07	–	–	–	–
After five-month storage					
No treatment (control)	11.59	8.53	7.22	27.34	72.66
Trichodermin	11.67	2.89	4.35	18.91	81.09
Gaupsin	6.48	6.28	5.26	18.02	81.98
LSD_{05}	0.86	–	–	–	–

parameters were different. Pre-storage treatments of garlic bulbs with Trichodermin and Gaupsin reduced the number of damaged and sprouted bulbs, indicating antimicrobial and fungicidal effects of these plant bioprotectors. The output of standard products, loss amount and shelf life are preservation indicators. The output of standard products and losses are inversely proportional, that is, the greater the loss is, the smaller the output of standard products is. Both of the preservation indicators depend on storage conditions and terms. As a storage object, a bulb is a fruit with a shortened stem (basal plate), fleshy clove specialized leaf sheaths and tunics, which are attached to the plate (tunics protect the bulb from drying out). Bulbs of the annual or biennial crop have a well-defined state of deep dormancy. Bulbs become dormant as the photoperiod shortens, the sunlight spectrum changes and the air temperature drops at the end of summer. Dormancy is considered as blocking of cell division caused by decreased intensity of physiological and biochemical processes and altered state of protoplasm and metabolism in cells leading to a sharp decrease in the content of nucleic acids, amino acids, auxins, and B vitamins involved in cell division. During dormancy, physiological and morphological processes occur and the formation of generative organs in apices is completed (2...10°C). At temperatures above 10°C, cell differentiation is slow, and at 18°C it does not occur. Therefore, the best temperatures for garlic storage are -1...0°C. Storability is the ability or biological property of vegetables to be stored for a certain period of time under optimal storage conditions without significant weight loss, damage by phytopathogenic microorganisms or by physiological disorders, deterioration of commercial, nutritional and seed qualities (Pusik L.M., 2011).

During storage, disease-induced losses of vegetables can be significant, and changes in the biology of pathogens that are manifested as increased resistance, plasticity, adaptability and pathogenicity, play an important role (Kulyeshov A.V., 2011; Harman G.E., 1998). *Trichoderma spp.* isolates were demonstrated to induce resistance of plants to *Fusarium oxysporum* Schlecht, a common pathogen on garlic plants. In experiments with 1% Trichodermin solution, there was a 1.7–3.6-fold increase in the sugar beet yield and, when beetroots were stored, the development of fungal and bacterial rots was delayed by 1.6 times compared to untreated variants. Trichodermin was also revealed to have a fungicidal effect; this agent is used to dress vegetable seedlings and seeds, because all biologicals ensure on average 2–3-fold reduction in saprophytic and pathogenic fungal infections, although their effectiveness is somewhat inferior to that of chemical dressers (Vinale F., 2008).

The active substance of Gaupsyn is phenazine, an antibiotic. Gaupsin also contains two strains of pseudomonads: *Pseudomonas aureofaciens* 2186 and *Pseudomonas aureofaciens* 2387. *Pseudomonas aureofaciens* 2186 has a conspicuous reducing effect on root rot, while *Pseudomonas aureofaciens* 2387 is effective against Phytophthora. On average, Gaupsin can inhibit 92% of fungal, 70% of bacterial and 15% of viral diseases of garlic; the action of *Pseudomonas aureofaciens* is attributed to its ability to tissue colonization and synthesis of antifungal compounds as well as complex enzymatic activity (Grondona J., 1997). Measures that reduce the development of diseases during the growing period potentially allow obtaining a larger number of healthy garlic bulbs, which are more tolerant to phytopathogens during storage. It was experimentally proven (Kravchenko N.O., 2014) that pre-sowing treatment of planting material and subsequent spraying of garlic plants with Trichodermin and Gaupsin could reduce the population density of exogenous and endogenous contamination of bulbs of the new harvest. We found that during storage of winter garlic bulbs pre-treated with antimicrobial bioagents, Trichodermin or Gaupsin, the number of bulbs with disease signs decreased. The basal plate rots were recorded as the most frequent diseases (Table 2). The optimal activity of a bioagent against pathogens of vegetables is determined by many factors. For example, soil temperature is one of the environmental factors that can limit *Trichoderma* activity.

Table 2

The number of Liubasha winter garlic bulbs affected by diseases during storage depending on antimicrobial treatment, % (after five-month storage at 0 ± 0.5ºC)

Treatment	Bacterial diseases	Fusarium basal rot	White rot	Neck rot
No treatment (control)	7.1	2.0	6.3	8.4
Trichodermin	4.0	0.7	2.2	2.7
Gaupsin	–	2.8	3.5	5.3

The maximum temperature for the *Trichoderma viride* (fungus component of Trichodermin) activity was found to be 28...34°C and the minimum – 2...5°C; the maximum temperature for the *Pseudomonas aureafaciens* IMB 2617 (bacterium component of Gaupsin) was determined to be 22... 25°C (Popova L., 2013). Literature data on the minimum temperature for the development and action of active ingredients of biologicals vary. It should be noted that biologicals are ineffective against very high loads of phytopathogens. Therefore, Trichodermin and Gaupsin may exert fungicidal and probably adaptogenic effects on garlic plants.

Storage as a stage of movement of goods from the producer to the consumer is supposed to ensure quantitative and qualitative preservation of products with minimal losses, as well as continuous supply of products to the population. The final result of efficient storage of products is their preservation without losses or with minimal losses during a specified period.

We assessed effects of packaging and characteristics of a variety on winter garlic integrity. Prior to packaging, garlic was cooled to storage temperature to prevent condensation. Garlic was stored as follows: 1) in boxes without packaging (control); 2) in boxes lined with 40-micron polyethylene (PE) film. Polyethylene film is waterproof, has high chemical resistance, is a relatively cheap packaging material, is strong and light, and protects against negative effects of the environment due to tight packaging. The film edges were tightly envelope-like folded. Garlic was monitored every 30 days.

The integrity of products is a manifestation of vegetable storability under conditions of specific seasons, growing locations, farming techniques, storage technologies and modes; it is characterized by loss amount and degree of changes in quality indicators during storage periods. We established that the winter garlic integrity depended on varietal characteristics and storage method. Over the study years, the weight loss of winter garlic bulbs ranged 4.9% to 7.6% after six-month storage in open boxes. The weight loss in Uhorskyi variety was 2.8% lower than the control value, amounting to 4.88%, while in Liubasha variety, it was 5.50%, which was 2.1% lower than the control (Fig. 1).

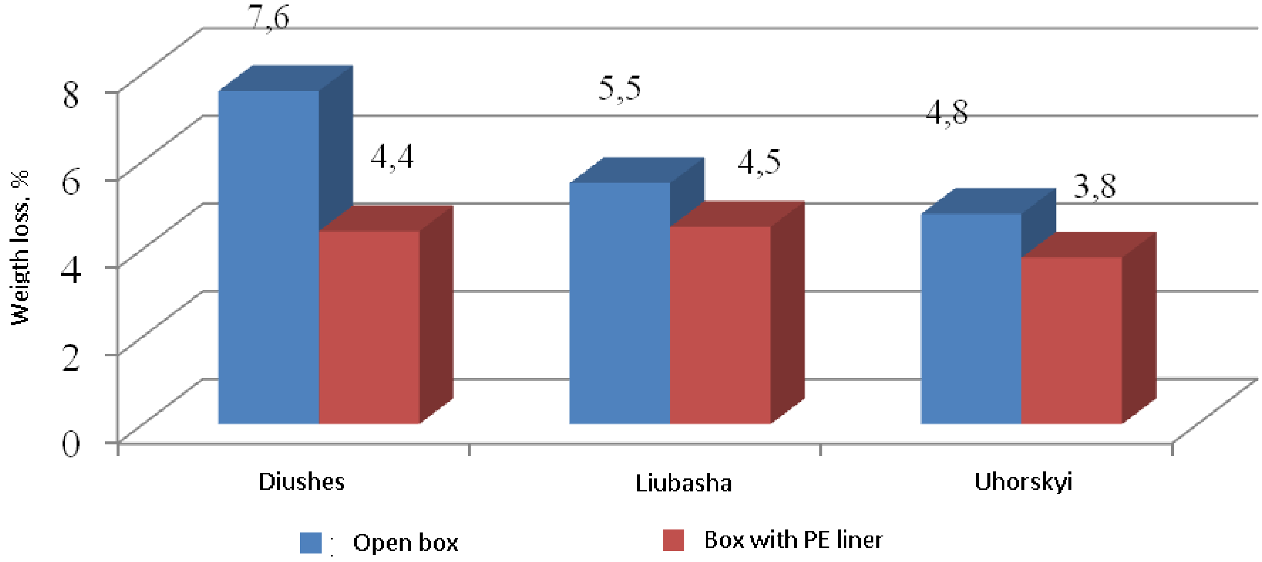

Fig. 1. Weight loss of winter garlic bulbs depending on varietal characteristics and storage method, % (average for 2020–2022)

In order to inhibit vital processes and water evaporation during storage, it is recommended to use polyethylene liners in storage containers. The results showed that polyethylene inserts in boxes reduced the weight loss of garlic bulbs by 2.0–3.2%, depending on varietal characteristics. After six-month storage of garlic in polyethylene-lined boxes, the weight loss ranged from 4.4% in the control to 3.8% in Uhorskyi variety. The weight loss in Liubasha variety was similar to the control.

Film creates a modified atmosphere (MA) around products, allowing for preservation of the product appearance and extension of the storage duration due to a decreased intensity of respiration and moisture evaporation. Similar studies were conducted on onions in a MA, which was formed when onions were placed in hermetically sealed polyethylene bags with inserts made of a gas-selective membrane at the rate of 4.5-6.0 cm^2/kg of product. In such bags, there was an atmosphere with a reduced oxygen content of 6–8% and an increased carbon dioxide content of 3–5%, which extended the storage period and preserved high-quality bulbs (Gilman S., 1989). However, packaging makes it impossible to timely remove excess moisture by ventilation; hence, long-term storage favors the development of microorganisms and physiological disorders. We investigated the weight loss structure in winter garlic bulbs depending on varietal characteristics and storage method (Table 3). The weigh loss consists of dry matter mass loss, which is spent on respiration, and water evaporation loss. After six-month storage, the dry matter loss ranged 23.3% to 69.7% of the weight losses. Based on this, the lowest respiration intensity was recorded for Uhorskyi winter garlic bulbs. The respiration-attributed loss was 23.3%, which was 2.9 and 40.4% lower in comparison with Liubasha and Diushes varieties, respectively. The water evaporation-attributed loss ranged 30.2% to 76.7% with the average across the varieties of 60.4%.

Table 3

Weight loss structure in winter garlic bulbs depending on varietal characteristics and storage method, %

Variety	Dry matter loss		Water evaporation-attributed loss	
	Open box	Box + PE liner	Open box	Box + PE liner
Diushes	69.7	54.8	30.2	45.2
Liubasha	26.2	68.0	73.8	42.0
Uhorskyi	23.3	51.0	76.7	49.0
Average across the varieties	39.6	57.9	60.4	45.4

Polyethylene inserts reduce the weight loss. This is explained by the fact that a MA is formed in the insert environment, bulbs switch to anaerobic respiration, the intensity of which is almost 20-fold as low as that of aerobic respiration. In parallel, dry matter consumption because of respiration and water evaporation decreases. Our calculations demonstrated that, when garlic was stored in boxes with PE inserts, the weight loss structure altered. On average across the varieties, the dry matter loss accounted for 59.7% and the water evaporation-attributed loss was 45.4%. During storage, the weight loss of winter garlic bulbs occurred unevenly (Figs. 2, 3). At the beginning of storage (August–September), the average weight loss across the varieties was 1.1%; in September–October it increased to 1.49%. Starting from November to February, it was 0.7%, then again grew to 0.75%. The uneven weight loss of garlic bulbs can be explained by forced dormancy. Physiological processes during this period occur slowly. The peculiarity of bulb vegetables lies in the fact that they have sprouts – so-called growth points, which slowly prepare for further reproductive development during storage.

From biological ripeness until vegetation onset (that is, during storage), bulb vegetables are deeply dormant, not germinating for a long period, even when the environment is ideal for germination.

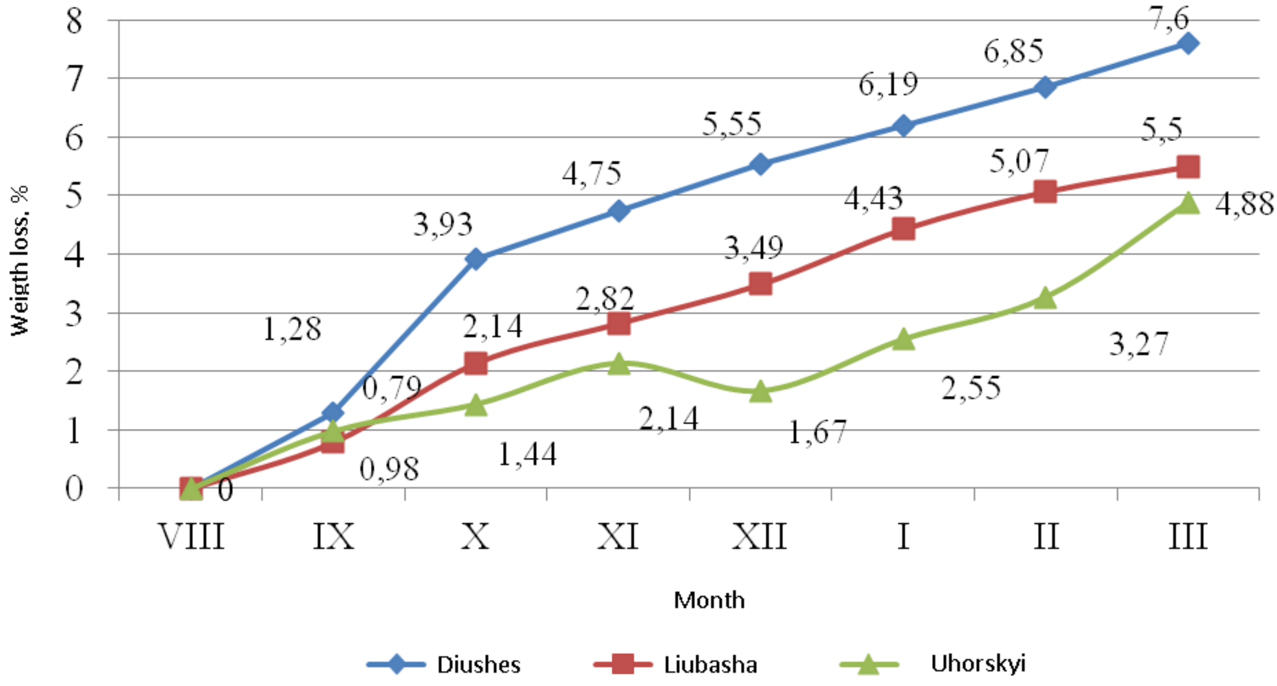

Fig. 2. Weigh loss dynamics in winter garlic bulbs depending on varietal characteristics and storage length in open boxes, % (2020–2022)

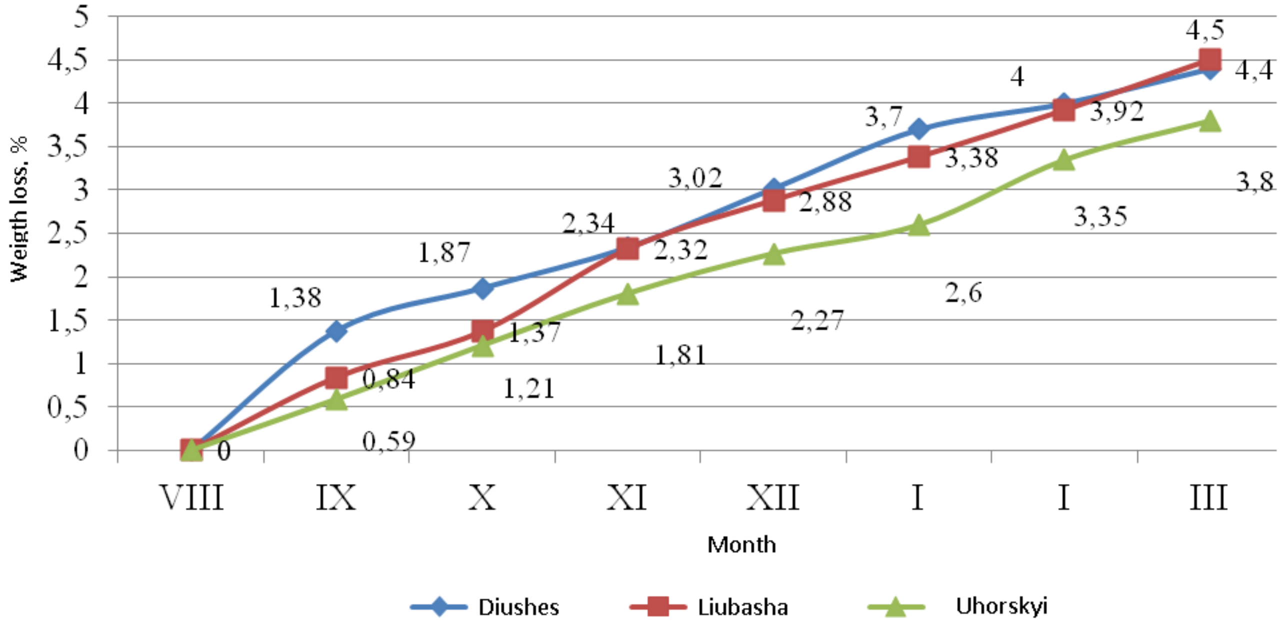

Fig. 3. Weight loss dynamics in winter garlic bulbs depending on varietal characteristics and storage length in boxes with PE inserts, % (2020–2022)

Biochemical processes are only activated after a certain period of storage, which is specific for each species and variety. Completion of dormancy is characterized by a sharp rise in the intensity of respiration and redox processes, movement of nutrients to apices, and biosynthesis of new physiologically active substances. Moisture evaporation is another, no less important process occurring in bulb vegetables after harvesting. Drying out of garlic bulbs reduces the clove volume; as a result, tunics loosely wrap clove buds, facilitating penetration of mold fungi. In addition, cloves fall from basal plates and bulbs break into individual cloves. All these lead to a decrease in the output of standard products and an increase in the output of non-standard ones after storage. Correlation analysis of the data was done and linear relationships of the weight loss of winter garlic bulbs with varietal characteristics and storage method were established (Table 4).

Table 4

Correlations between weight loss of winter garlic bulbs and varietal characteristics and between weight loss and storage method

Variety	Open box		Box + PE insert	
	Linear relationship	Coefficient of determination	Linear relationship	Coefficient of determinatio n
Diushes	Y= 1.055x – 0.229	R^2 = 0.933	Y = 0.596x – 0.093	R^2= 0.966
Liubasha	Y= 0.802x – 0.582	R^2 = 0.985	Y = 0.636x – 0.466	R^2 = 0.991
Uhorskyi	Y= 0.577x – 0.479	R^2 = 0.898	Y= 0.536x – 0.458	R^2 =0.995

Note: Y – weight loss, %, x – storage length, months.

There was a clear functional relationship between dormancy of bulbs and resistance to phytopathogenic microflora. The earlier and more intensively the growth and development of buds begin, the faster the flow of macronutrients and physiologically active substances to meristems of apical cones is. At the same time, the main mass of storage tissues (garlic cloves) are depreciated from nutritional and commodity perspectives and lose their natural resistance to phytopathogenic microflora. Lowered temperatures, air humidity, and gaseous environment can prolong forced dormancy and maintain resistance of bulb vegetables to diseases.

We observed the first signs of microorganism development after four months of storage (Table 5). The greatest number of affected garlic bulbs was recorded for Diushes (2.1%); in Liubasha, this parameter was 0.3% lower than the control value; and in Uhorskyi, it was 0.2% higher compared to the control. After further storage, the loss from microorganism-induced damage rose to 5.1% in Uhorskyi and 4.8% in Diushes. After four-month storage, bulbs come out of dormancy and begin to germinate.

Table 5

Integrity of winter garlic depending on varietal characteristics, %

Variety	Natural weight loss, %	Disease-attributed loss, %	Sprouted bulbs, %	Shrunken bulbs, %	Marketable output, %
After 4-month storage					
Diushes	5.55	2.1	2.9	4.3	85.1
Liubasha	3.49	1.8	2.8	4.0	87.9
Uhorskyi	2.68	2.3	2.7	4.1	88.2
After 6-month storage					
Diushes	6.87	4.8	4.2	6.7	77.4
Liubasha	5.54	4.3	3.9	6.2	80.1
Uhorskyi	4.88	5.1	4.0	7.0	79.0

The number of sprouted bulbs was 2.7–2.9%, while after six-month storage it was 3.9–4.2%. The marketable output was reduced because of shrunken (partially empty) bulbs, the number of which at the end of storage was 6.2–7.0%. On average across the study years, the highest marketable output after six-month storage of garlic in open boxes at -3...-1±0.5^{o}C was recorded for Liubasha (80.1%), as it exceeded the control value and Uhorskyi’s value by 2.7 and 1.1%, respectively.

Our results are confirmed by other researchers. In some EU countries (Switzerland, Austria, the Czech Republic, Finland), microbial agents have become complementary components of organic farming techniques. Trichodermin was proven to be efficient against verticillium wilt on celeries and eggplants, fusarium wilt on watermelons, and black scurf of potatoes, as well as against various rots (Grondona J., 1997).

In experiments with 1% Trichodermin solution, sugar beets yielded 1.7–3.6 times as much as in the untreated control and, when they were put into storage, the development of fungal and bacterial rots was delayed by 1.6 times compared to untreated variants (Shailbala S., 2017).

There were differences in resistance of bioagent-treated tomato varieties to major infections during storage. Pre-storage treatment of seeds and fruits with biologicals caused no disorders in the biological oxidation cascade and reduced the intensity of fruit respiration during storage (Alsufiev MA, 2017).

Conclusions

1. Pre-storage treatment of garlic bulbs with Trichodermin and Gaupsin reduced the number of damaged and sprouted bulbs, indicating antimicrobial and fungicidal effects of these plant bioprotectors.

2. After four-month storage, the number of microorganism-affected and germinated bulbs was 5.33 and 2.87%, respectively; and after five-month storage, these parameters increased by 62 and 39%, respectively.

3. We established that winter garlic integrity depended on varietal characteristics and storage method. Over the study years, the weight loss of winter garlic bulbs ranged 4.9 to 7.6% after six-month storage in open boxes. The weight loss in Uhorskyi variety was 4.88%, which was 2.8% lower than the control value, while in Liubasha variety, it was 5.50% or by 2.1% lower than the control.

4. Polyethylene inserts in boxes reduced the weight loss of garlic bulbs by 2–3.2%, depending on varietal characteristics. After six-month storage of garlic in boxes with polyethylene liners, the weight loss ranged 4.4% in the control to 3.8% in Uhorskyi. The weight loss in Liubasha was similar to the control.

6. We determined the weight loss structure in winter garlic bulbs depending on varietal characteristics and storage method. After six-month storage, the dry matter loss ranged 23.3 to 69.7% of the total weight loss, while the water evaporation-attributed loss ranged 30.2 to 76.7% (the average across the varieties was 60.4%). In boxes with PE inserts, the weight loss structure changed. On average across the varieties, the dry matter loss accounted for 59.7% and water evaporation – for 45.4% of the total weight loss.

7. During storage, winter garlic bulbs lose their weight unevenly. At the storage start (August–September), the average across the varieties was 1.1%; in September–October, it amounted to 1.49%. Starting from November to February, this parameter was 0.7%, and then it began to grow (0.75%). Correlation analysis of the data was done and linear relationships of the weight loss of winter garlic bulbs with varietal characteristics and storage method were established.

8. On average across the study years, the highest marketable output after six-month storage of garlic in open boxes at –3... –1±0.5^{o}C was recorded for Liubasha (80.1%). It exceeded the control value and Uhorskyi's value by 2.7 and 1.1%, respectively.

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