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Content

Зміст

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EVALUATION OF THE ADAPTIVE POTENTIAL OF PROMISING SHALLOT ACCESSIONS

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Ecological stability and high adaptive potential are the main factors for stable performance and yield of agricultural crops under changing environmental conditions; therefore the selection of stress-resistant genotypes is relevant at all stages of breeding. **Purpose.** To evaluate and select promising breeding accession of shallots by adaptive potential for the "green leaf yield" trait and its components. **Methods.** Field, laboratory, computational and analytical methods were used in the study. The study was conducted in outdoors at the Institute of Vegetable and Melon Growing of NAAS in 2017–2020. Five breeding hybrid accessions were investigated. Lira was the check variety. **Results.** Having assessed the adaptive potentials of 5 breeding accessions of shallot, we selected a promising environmentally stable accession, D-57, which was noticeable for a high yield of green leaves (5.6 kg/m^2) in combination with the highest general adaptive capacity (GAC = 1.3), high stability (b_i = 0.4) and genomic breeding value (GBV = 2.7) for this trait. As to the adaptive potential for the "plant height" trait, the D-57 accessions also stood out; it was characterized by high general adaptive capacity (GAC = 1.3), relative stability (Sg_i = 10.9 %) and genomic breeding value (GBV = 23.4). This accession was also the best in terms of the "plant weight": trait with the genomic breeding value (GBV = 42.4), it had the largest plant weight including a bulb (75.4 g), combined high general (GAC = 17.3) and specific adaptive capacity (SAC= 129.3) with high plasticity (b_i = 2.6). **Conclusions.** The comprehensive study of the adaptive potential of 5 promising forms of shallots distinguished the D-57 accession, which was superior to the check variety, Lira, in terms of green leaf yield, plant height and weight (including a bulb) and had a high adaptive potential and genomic breeding value for these traits.

***Keywords**:* shallot, green leaves, yield, plant height, plant weight, adaptive potential

Introduction. Adaptability to environmental factors is one of the main requirements for new varieties, therefore studies and assessments of environmental plasticity of varieties, scopes of their application and adaptation to real natural and climatic conditions are urgent issues of the current agricultural production (*Prysiazhniuk O.*, 2015).

Yield depression occurs as a result of adverse environmental factors affecting plants. Here, the greater inconsistencies between growing conditions and adaptive potentials of plants are, the greater part of their assimilation products they spend not on yield, but on protective and compensatory reactions, resulting in a decline in the yield. Depression in the plant performance depends on an integral physiological indicator that characterizes the general stability of plants (environmental stability). Environmental stability and adaptive potential are the most important factors for the realization of the traits and features that are included in the high-yielding variety model (*Orliuk O.P.*, 1992).

Achieving environmental stability of the performance as an integral characteristic is not necessarily related to the stability of yield constituents or of other morpho-biological features. Often with stable yield, its constituents are unstable (*Kilchevskiy A.V.*, 1993).

Combination of high performance with environmental stability in intensive varieties, creation of varieties for large areas, and choice of optimal conditions for selection at all stages of breeding are major challenges in breeding for adaptability (*Kilchevskiy A.V.*, 1995).

Review of Recent Studies and Publications. The shallot is a species of the Cybulaceae family and its advantages are determined by several economic characteristics, such as a short growing period and early ripening of bulbs; high contents of dry matter (up to 22%) and sugars (up to 12%) in bulbs; tightly fitting husk, tightly arranged fleshy scale leaves; long storability (8–12 months) (*Novikova L.N*., 2021, *Yuryeva N., 1998, Grinberg Ye.G.,* 2009).

The ability to form not only primary but also secondary lateral shoots (and hence strong branching) is a feature of shallots and one of the main differences from onions. This makes it possible to obtain a nest with up to 30 bulbs weighing 10–50 g each from one planted bulb (*Pavlov A.V*., 2012)

Polyembryony and lots of leaves allow it to be successfully used to obtain early outdoor and indoor grown greenstuff (*Grinberg Ye.G.,* 2009).

Green leaves of shallots contain vitamins A, B, B_1, B_2, PP, mineral salts, phytoncides and other nutrients. Leaves contain a lot of sugars (4...6%) and vitamin C (20...90 mg/100 g) (*Kokareva V.,* 1991, *Bilenka O.M.,* 2009). The maximum amounts of sugars and ascorbic acid are accumulated 30 days after regrowth during the intensive growth of leaves (*Ahafonov A.F,* 1984).

Green leaves of shallots also contain up to 11 % of dry matter, up to 2.9 % of crude protein, and 28...34 mg% of essential oil (*Pavlov L.V.,* 2012). They are also noticeable for low levels of nitrates (4.3...132.0 mg/kg) (*Bilenka O.M.,* 2009).

There may be up to 73 leaves on a plant; the leaf number depends on the bud number in a bulb. First, leaves and roots are formed at the expense of reserve nutrients of the mother bulb (20–25 days), and then the plant continues feeding through its leaves and roots. In shallots, the root system is weak; roots do not grow around the entire basal plate, but only on one side. At a soil temperature of 8-10 ^{o}C, roots grow faster than leaves and bulbs take root better, and seedlings emerge in 11–14 days. Roots do not grow in dry soil at a depth of 5 cm when the temperature rises to 20 ^{o}C. Their growth is seen only 20–30 days after planting, when wet and cool weather sets in (*Grinberg Ye.G.,* 2009).

Leaves are 25–60 cm long and 0.5–0.8 cm wide, but can reach 2.0–2.4 cm. There are minimum 4.5 leaves on each shoot; the average number of leaves is 5.7; and some accessions have 11–12 leaves (*Shilyayeva Ye.A.,* 2019, *Klapotovskaya A.V.,* 2015). Shallot plants are characterized by rapid gain in green mass related to the weight of planted material – 70–250 % (*Kokareva V.,* 1991).

In the technical ripeness phase, the plant weight (including its bulb) is 53–85 g (*Grinberg Ye.G.,* 2009).

The shallot yield can exceed that of onions by 10–63 %, so its outdoor growing for leeks is more effective than onion growing (*Grinberg Ye.G.,* 2012).

Outdoor grown shallots can be harvested 35–45 days after planting. Short-season varieties are noticeable for even and intensive growth, and leaf tips turn yellow quite early. In later-ripening forms, leaves turn yellow much later and they maintain their marketable appearance for a long time (Y*ershov I.I.,* 1984).

According literature data, the yield of green shallot leaves is 1.1...5.5 kg/m^2 (but can amount to 11 kg/m^2 (Poldma P., 2006)) and depends on planting design, variety, harvesting time and planted bulb size (*Seredin T.M.,* 2021, *Grinberg Ye.G.,* 2009, *Kovalenko Ye.*M., 2010, *Bilenka O.M*., 2009, *Bilenka O.M*., 2018).

The genotypic variability of the performance quantitative traits, which characterize the leaf weight per plant and yellowing of leaf tips (which affect the marketability of products), is important (*Grinberg Ye.G.* 2009).

Some publications report a wide diversity of shallot forms and varieties in terms of environmental resilience (*Bilenka O.M*., 2009, *Aklilu S*., 2014, *Suzan V.G.*, 2009).

Materials and Methods. The study was conducted outdoors at the Institute of Vegetable and Melon Growing (IVMG) of NAAS in 2017–2020. Shallot bulbs were stored in boxes, in a layer of 5–12 cm thick, in a cold-warm way (in spring and autumn at 18–20^{o}C, in winter – at around 0^{o}C) from August to March (inclusive).

Bulbs were planted in the soil with 35-cm interrow spacing and 1-cm interplant distance in the row within the first 10 days of April. Leeks were harvested within the second 10 days of May; plants were dug out of the soil and cleaned of plant residues and roots. Green leaves were described and measured during the harvesting period. Twenty-five plants of each shallot accession were assessed.

The record plot was 2 m^2. Lira was taken as the check variety. The April–June weather in the study years differed. In 2017, this period was very wet and cool. In 2018 and 2019, there was insufficient amount of precipitation during the growing period with the average daily air temperature exceeding the long-term average by 0.7–3.3 ^{o}C. In 2020, it was also dry, and the average daily air temperature was below the long-term average by 1.1 ^{o}C. The April-May precipitation amount was 83.5 mm in 2017, 36.5 mm in 2018, and 52.0 mm in 2019, 31.5 mm in 2020 (the long-term average is 70.3 mm). The distribution of precipitation between 10-day periods was very uneven.

Five promising hybrid shallot accessions were investigated.

The study was carried out in accordance with the methodological recommendations " Methodical Approaches to Shallot Breeding and Seed Production" (*Korniyenko S.I., Bilenka O.M.*, 2013), "Guidelines for alliaceous crop breeding" (1989). Experimental data were processed by analysis of variance (*Dospekhov B.A.*, 1985). The adaptive potential and genomic breeding value were calculated in accordance with the methodical guidelines for environmental trials of vegetables (*Kilchevskiy A.V., Khotyleva L.V.*, 1985). The general adaptive capacity (GAC) was calculated as follows:

$$GAC_i = V_i = \overline{\chi - u},$$

where $\overline{\chi}$ – mean across the genotypes;

u – population mean.

To calculate the specific adaptive capacity (SAC), we used the following formulae:

$$d_R = \overline{\chi_R} - u,$$

$$(1\,\sigma^2 SAC = \frac{1}{m-1}\sum\left(d_R + vd_{iR}\right)^2 - \frac{m-1}{m}\times\sigma^2,$$

$$d_R + vd_{iR} = \chi_{iR} - \frac{1}{m}\times\chi_i,$$

where m – number of environments;

d_R – effect of the R^{th} environment;

vd_{iR} – effect of the 'i^{th} variety-R^{th} environment' interaction;

χ_{iR} – phenotypic value of the trait in the i^{th} variety grown in вирощеного в the R^{th} environment;

σ^2 – variance of random deviations.

The relative stability of an accession (Sg_i) was calculated as follows:

$$Sg_i = \frac{\sigma SAC_i}{u + GAC}\times 100\,\%.$$

The plasticity of an accessions (b_i) (response of an accession to improvement in environmental conditions) was determined by coefficient of regression:

$$b_i = \frac{\sum_R \chi_{iR}\times d_R}{\sum_R d_R^2},$$

To identify accessions that combine good values of a trait with its stable expression, we used the genomic breeding value (GBV):

$$GBV_i = u + GAC_i - p\times\sigma SAC_i,$$

$$p = \frac{100}{2\overline{Sg_i}}, \quad \overline{Sg} = \frac{Sg_1 + ...Sg_n}{n}.$$

The purpose of the study was to evaluate and select promising breeding lines of shallots by adaptive potential for "green leaf yield" trait and its components.

Results. In the sample under investigation, D-57 was the only accessions that was superior to the check variety, Lira, in terms of the green leaf yield (5.6 kg/m^2); the difference was 1.5 kg/m^2 (Table 1). D-93 and D-89 yielded similarly to the check variety; their green leaf yield was 4.3 kg/m^2 and 4.5 kg/m^2, respectively.

Table 1. Adaptive potential of the promising shallot accessions for the "green leaf yield" trait (mean for 2017–2020)

Accession	IVMG catalogue No	Green leaf yield, kg/m^2	Adaptive capacity		Stability (Sg_i), %	Plasticity (b_i)	GBV_i
			GAC (V_i)	SAC (σ^2)			
Lira (check variety)	37	4.1	-0.2	1.1	24.4	0.6	2.5
D-57	68	5.6	1.3	2.7	29.3	0.4	2.7
D-93	105	4.3	0	2.2	34.5	0.9	1.7
D-107	119	3.7	-0.6	0.4	17.0	2.0	2.7
D-89	101	4.5	0.2	0.5	9.8	0.0	3.4
D-83	95	3.3	-0.2	0.2	13.3	2.5	2.6
LSD_{05}		1.2					

The general adaptive capacity (GAC) for the "green leaf yield" in this group ranged -0.6 to 1.3. The highest GAC was recorded for D-57 (GAC = 1.3) and D-89 (GAC = 0.2).

The highest specific adaptive capacity (SAC) was intrinsic to D-57 (SAC = 2.7) and D-93 (SAC = 2.2). D-89, D-107 and D-83 more weakly responded to changes in vegetation conditions (SAC = 0.2-0.5). The relative stability of the trait (Sgi) additionally indicated these peculiarities. Thus, the relative stability of the green leaf yield in the last accessions was quite high and amounted to 9.8–17.0 %, while in D-57 and D-93 it was lower (29.3–34.5 %), that is, their yields were more variable and depended on growing conditions.

With improved vegetation conditions, the green leaf yield was significantly increased in D-107 (bi = 2.0) and D-83 (bi = 2.5), but it decreased when growing conditions worsened.

D-93 (bi = 0.9) was noted to show an optimal plasticity of the "green leaf yield" trait. D-89 was indifferent to growing conditions, as evidenced by the coefficient of regression on the environment (b_i = 0); this was also confirmed by the highest relative stability of the trait (Sgi=9.8%) and a low level of the specific adaptive capacity (SAC = 0.4).

The highest genomic breeding value (GBVi) was also recorded for D-89 (GBVi = 3.4); it was attributed to high stability of this trait over the years, as indicated by low specific adaptive capacity, high relative stability (Sgi) and coefficient of regression on environment (bi). The genomic breeding value of D-57, D-107 and D-83 was similar to that of Lira (check variety) (GBVi = 2.5) – 2.6–2.7.

The plant height and weight (including a bulb) are the main constituents of the green leaf yield in shallots. In our shallot accessions, the check variety, Lira, was taller than D-57 (43.9 cm) and D-89 (47.1 cm); the other accessions were similar to Lira (41.1-42, 6 cm) (Table 2).

The general adaptive capacity of the studied accessions for the "plant height" trait ranged -1.7 to 4.3. D-89 showed the highest general adaptive capacity (GAC = 4.3). D-57 GAC of 0.4 also stood out for its high general adaptability to growing conditions. The other accessions showed a rather low general adaptability of the train under investigation to the environmental conditions.

The specific adaptive capacity (SAC) varied widely - from 15.4 to 78.9. The highest SAC in D-89 indicated that, when growing conditions change, the height will vary widely. The check variety, Lira, was the least adapted to specific growing conditions (SAC = 5.6). This was also confirmed by the highest value of the relative stability of the plant height (Sgi = 5.8%), i.e., the plant height in Lira was hardly dependent on growing conditions.

Table 2. Adaptive potential of the promising shallot accessions for the "plant height" trait (mean for 2017–2020)

Accession	IVMG catalogue No	Plant height, cm	Adaptive capacity		Stability (Sg_i), %	Plasticity (b_i)	GBV_i
			GAC (V_i)	SAC (σ^2)			
Lira (check variety)	37	40.3	-2.5	5.6	5.8	-6.5	16.8
D-57	68	43.9	0.4	22.4	10.9	-3.1	23.4
D-93	105	42.2	-0.6	28.2	11.9	-3.2	19.7
D-107	119	42.6	-0.2	42.8	15.3	-2.4	15.3
D-89	101	47.1	4.3	78.9	18.8	-2.3	9.7
D-83	95	41.1	-1.7	15.4	9.5	-2.8	24.7
LSD_{05}		2.3					

Analyzing the relative stability of the plant height (Sgi) in this group of accessions, we should note its rather high level. The relative stability of the accessions’ plant height ranged 9.5% to 18.8%. The most variable plant height across the years was observed in D-89 (Sgi = 18.8%); D-57 (Sgi = 10.9%) and D-83 (Sgi = 9.5%) maintained their plant height more stably.

The coefficient of environmental plasticity (bi) in all the accessions under investigation studied was significantly below 1, indicating their low sensitivity of this characteristic to changes in vegetation conditions.

The genomic breeding value (GBVi) is a complex indicator of the adaptive potential of an accession, which depends on the GAC, SAC, stability (Sgi), and the population mean of a trait. By the genomic breeding value, the check variety, Lira, exceeded D-57 (GBV = 23.4) and D-83 (GBV = 24.7). The highest genomic breeding value in D-83 was attributed to its low specific adaptive capacity (SAC = 15.4) for the "plant height" trait and its insignificant variability (Sgi = 9.5%), which was confirmed by its stability across the years, although the plants of this accession were the shortest in the sample and - 41.1 cm tall. D-57 was superior to the check variety in terms of the general adaptive capacity (GAC = 0.4); its specific adaptive capacity was low (SAC = 22.4); and its plants were tall in all the study years.

As to the "plant weight" trait, the check variety was heavier than D-57 (75.4 g) by 20.6 g, the other accessions weighed similarly to the check variety or lighter (Table 3).

Table 3. Adaptive potential of the promising shallot accessions for the "plant weight" trait (mean for 2017–2020)

Accession	IVMG catalogue No	Plant weight, g	Adaptive capacity		Stability (Sg_i), %	Plasticity (b_i)	GBV_i
			GAC (V_i)	SAC (σ^2)			
Lira (check variety)	37	54.8	-3.3	80.7	16.4	1.3	28.6
D-57	68	75.4	17.3	129.3	15.1	2.6	42.4
D-93	105	59.4	1.2	173.3	22.2	2.4	21.1
D-107	119	48.1	-10.0	45.6	14.0	0.9	28.5
D-89	101	58.4	0.3	362.8	32.6	0.9	2.1
D-83	95	52.6	-5.5	12.0	4.7	0.5	45.1
LSD_{05}		9.1					

In terms of the general adaptability of the plant weight, D-57 (GAC = 17.3), D-93 (GAC = 1.2) and D-89 (GAC = 0.3) exceeded the check variety.

The plant weight depended the most on specific growing conditions in D-89, which showed the highest specific adaptive capacity (SAC = 362.8). Vegetation conditions had a weak effect on this characteristic in D-83 (SAC = 12.0). D-57 and D-93 were also characterized by a rather high SAC (129.3 and 173.3), indicating a considerable response of the "plant weight" trait to specific growing conditions.

The relative stability of the "plant weight" trait in the shallot accessions ranged 4.7 to 32.6 %. D-83 (Sgi = 4.7 %) showed the greatest stability of this trait. Over the years, the plant weight with bulb varied the most in D-89 (Sgi = 32.6 %). In Lira (check variety), this trait varied within 16.4 %.

In the studied sample, D-57 (bi = 2.6) and D-93 (bi = 2.4) were the most plastic in terms of the plant weight. D-107 and D-89 were optimally plastic (bi = 0.9) for this trait, and D-83 was the most stable (bi = 0.5).

As to the genomic breeding value for the "plant weight" trait, we selected D-57 (GBVi = 42.4), as its plant weight was the largest (75.4 g) in combination with high general (GAC = 17.3) and specific (SAC = 129.3) adaptive capacities as well as with high plasticity (bi=2.6). D-83 was also characterized by high genomic breeding value (GBV = 45.1), but it was due to high stability of the trait (SAC = 12.0, Sgi = 4.7 %, bi = 0.5); however, the plant weight was similar to that in the check variety (52.6 g).

Conclusions. Thus, having assessed the adaptive potential of the 5 best forms of shallots, we selected D-57, which was superior to the check variety, Lira, in terms of the green leaf yield (5.6 kg/m2), plant height and weight with bulb (43.9 cm and 75.4 g, respectively) as well as in terms of high adaptive potential and genomic breeding value for these traits. The selected accession is promising for use in breeding programs to create shallot varieties with high adaptive potentials.

References

Agafonov, A.F. (1984). Development of a varietal farming technique for cultivation of shallots and forcing it on greens in the open and protected ground: Author’s synopsis the thesis for the academic degree of Candidate of Agricultural Sciences. 06.01.06. "Breeding and Seed Production" Moscow. 17 p.

Aklilu Shimeles. (2014). The performance of true seed shallot lines under different environments of Ethiopia. *Journal of Agricultural Sciences.* V. 59, No. 2. P. 129-139.

Awale Degevione. (2011). Genetic Variability and Association of Bulb Yield and Related Traits in Shallot (*Allium cepa var. aggregatum DON.*) in Ethiopia.

Bilenka, O.M. (2009). Starting material to create onion and shallot varieties adapted to the Forest-Steppe of Ukraine: Author's synopsis the thesis for the academic degree of Candidate of Agricultural Sciernces: 06.01.05. "Plant Breeding". Kharkiv. 20 p.

Bilenka, O.M. (2018). Assessment of shallot collection accessions in breeding for yield capacity. *Genetičnì Resursi Roslin*. Kharkiv. Issue 23. P. 58-66.

Dospekhov, B.A. (1985). Methods of field experimentation. M.: Agropromizdat. 351 p.

Yershov, I.I.., Ahafonov, A.F., Dubova, M.V. (1984). Shallot breeding for the central regions of the Non-Chernozem zone of the RSFSR. *Selektsiya Ovoshchnykh Kultur. Collection of scientific papers of the All-Russian Scientific Research Institute of Vegetable Breeding and Seed Production*. M. Issue. 18. P. 61-66.

Grinberg, Ye. G., Vanina, L. A. Zharkova, S. V. et al. (2009). Scientific basics of introduction, breeding and field management of shallots in Western Siberia. Novosibirsk: Rosselkhozakademiya. Siberian department. 208 p.

Grinberg, Ye.G., Suzan, V.G. (2012). Shallot. Chelyabinsk-Yekaterinburg. *Sad i Ogorod*. 36 p.

Klapotovskaya, A.V. Suzan, V.G. (2015). Yield and quality of shallot varieties in the Southern Forest-Steppe of the Omsk Region. *Omskiy Nauchnyy Vestnik*. No 5. P. 136.

Kokareva, V. (1991). Aristocratic shallot. *Priusadebnoye Khozyaystvo*. No 5. P. 28.

Kilchevskiy, A.V. (1993). Mainstreams of ecological plant breeding. *Selektsiya i Semenovodstvo*. No 3. P.5.

Kilchevskiy, A.V. (1995). Studying genotype-environment interactions in vegetable breeding. *Geneticheskiye Osnovy Selektsii Selskohozyaystvennykh Rasteniy*. M. P. 169.

Kilchevskiy, A.V., Khotyleva, L.V. (1985). Guidelines for environmental trials of outdoor grown vegetables. M. VNIISSOK. 53 p.

Kovalenko, Ye. (2005). Shallot to mach onion. *Ogorodnik*. No 7. P. 10.

Kovalenko, Ye.M. (2010). Starting material of shallot in breeding of varieties for different purposes in the Northern Steppe of Ukraine: Author's synopsis the thesis for the academic degree of Candidate of Agricultural Sciences: 06.01.05. Kharkiv. 17 p.

Korniienko, S.I., Bilenka, O.M. Chernyshenko, T.V., Kovalenko, Ye.M. (2013). Methodical approaches to shallot breeding and seed production. Kharkiv: VP «Pleiada LLC. IVMG NAAS. 27 p.

Guidelines for alliaceous crop breeding. (1989). M.: VNYYSSOK. 64 p.

CMEA's extended harmonized classifier and CMEA's international classifier of onions. (1980). Olomouts. 42 p.

Novikova, L.N., Novikov, B.N. (2021). Shallot variety Blondin as starting material in breeding for early ripening, storability, performance and yield. *Ovoshchi Rossii*. No 3. P. 49.

Orliuk, O.P., Korchynskyi, A.A. (1992). Challenges in adaptive breeding of winter wheat. Ecology and Agricultural Production: Collection of scientific papers. Kyiv. 1992. P. 96.

Pavlov, A.V., Paraskova, O.T., Agafonov, A.F., Kanonykhina, V.M. (2012). Shallot seeds - a new object of standardization. *Vestnik Ovoshchevoda*. No 2. P. 31.

Poldma, P., Merivee, A., Jarvsoo, T. (2006). Inelvence of bulb size on the yield and quality of forced shallot (Allium cepa L., Aggregatum group). *Vegetable Crops Research Bulletin*. V. 64, P. 117–122.

Prysiazhniuk, O., Korovko, I. (2015). Parameters of environmental plasticity and stability of new sugar beet hybrids. Varietal Plant Resources: Status and Prospects of Development (Abstracts of the International Scientific and Practical Conference dedicated to the 20th anniversary of Ukraine's membership in the International Union for the Protection of New Varieties of Plants (UPOV) (November 3, 2015, Kyiv). / Ministry of Agrarian Policy and Food of Ukraine, Ukr. Institute for Plant Variety Examination. K. "Nilan-LTD" LLC. P.86.

Seredin, T.M., Shumilina, V.V., Zharkova, S.V. (2021). Lines and results of work on shallots (*Allium ascalonicum* L.) in the Moscow region]. *Vestnik Altayskogo Gosudarstvennogo Universiteta*. No 12. P. 28.

Suzan, V.G. (2009). Creation of varieties and improvement of cultivation of alliaceous crops in the Middle Urals. Author's synopsis the thesis for the academic degree of Candidate of Agricultural Sciences. 06.01.05 "Breeding and Seed Production". Tyumen. 20 p.

Shilyayeva, Ye.A. (2019) Peculiarities of shallot breeding in the Kirov region. Abstracts of the Interuniversity Congress (Moscow, October 25, 2019). Part 1. M. Publishing House Infiniti. P. 152. http://doi.org/10.25630/PAV.2021.43.66.007

Yuryeva N. (1998). Leek all year round. *Nauka i Tekhnika*. No 4. P. 120.

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ОЦІНКА АДАПТИВНОГО ПОТЕНЦІАЛУ ПЕРСПЕКТИВНИХ ЗРАЗКІВ ЦИБУЛІ ШАЛОТ

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Екологічна стійкість і високий адаптивний потенціал є головними факторами формування стабільної продуктивності і урожайності сільськогосподарських культур в мінливих умовах навколишнього середовища, тому добір стійких до стресів генотипів є актуальним на усіх етапах селекційного процесу. **Мета.** Оцінка і виділення перспективних селекційних зразків цибулі шалот за рівнем адаптивного потенціалу за ознакою «урожайність зелених листків» та її складових. **Методи.** В дослідженнях використовували польові, лабораторні, розрахунково-аналітичні методи. Дослідження проводились у Інституті овочівництва і баштанництва НААН у 2017-2020 рр. у відкритому ґрунті. Об'єкт досліджень – 5 селекційних форм гібридного походження.. Стандарт сорт – Ліра.. **Результати.** В результаті оцінки адаптивного потенціалу 5 селекційних форм цибулі шалот виділено перспективний екологічно стабільний зразок Д-57, який відзначається високою урожайністю зелених листків (5,6 кг/ м^2), найвищою загальною адаптивною здатністю ($ЗАЗ_i$ =1,3), високою стабільністю (b_i= 0,4) і селекційною цінністю генотипу ($СЦГ_i$=2,7) за даною ознакою. За ознакою «висота рослин» за адаптивним потенціалом теж виділився зразок Д-57, який характеризується високими показниками загальної адаптивної здатності ($ЗАЗ_i$ =1,3), відносної стабільності (Sg_i=10,9 %) і селекційної цінності генотипу ($СЦГ_i$=23,4). Даний зразок був кращим і за ознакою «вага рослини» з показником селекційної цінності генотипу ($СЦГ_i$=42,4), він мав найбільшу вагу рослини з цибулиною (75,4 г), поєднував високу загальну ($ЗАЗ_i$=17,3) і специфічну адаптивну здатність ($САЗ_i$ =129,3) та високу пластичність (b_i=2,6). **Висновки.** В результаті проведеного комплексного дослідження адаптивного потенціалу 5 перспективних форм цибулі шалот виділено зразок Д-57, який перевищував стандарт сорт Ліра за урожайністю зелених листків, висотою та вагою рослини з цибулиною і мав високий адаптивний потенціал і селекційну цінність генотипу за даними ознаками.

Ключові слова: цибуля шалот, зелені листки, урожайність, висота рослини, вага рослини, адаптивний потенціал

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SELENIUM-CONTAINING BIOLOGICALLY ACTIVE COMPOSITE FORMULATIONS AS EFFECTIVE GROWTH REGULATORS FOR IMPROVING SOWING QUALITY OF SEEDS AND MORPHO-BIOLOGICAL PARAMETERS OF WHITE AND PURPLE CABBAGE HEADS

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Abstract. Purpose. To analyze regulatory effects of selenium-containing biologically active formulations manufactured in Ukraine on the sowing quality of seeds and on morpho-biological parameters (level and uniformity) of productive organs (heads) in varietal populations of cabbage plants. **Methods: G**eneral scientific, measuring, weighing, and variation statistics. **Results.** The regulatory effects of selenium-containing composite formulations, D-8SE and D-AMSSE, were tested on three white cabbage varieties (Kharkivska Zymova, Ukrainska Osin, and Bilosnizhka) and one purple cabbage variety (Paleta). D-AMSSE was more effective; the cabbage varieties differently responded to its application, depending on genotypes, however they similarly increased the head weight (by 22–23 %). An analogous pattern was observed for head density (it increased by 13-22 %). In the control, there was a medium or strong correlation between the head weight and head volume. Depending on treatment with the studied formulations, a stable increase in the Pearson's pairwise correlation coefficient (r_p) was noted for the four cabbage varieties (r_p = 0.55...0.95). D-8SE and D-AMSSE positively affected the sowing qualities of cabbage. A statistically significant increase in the seed germination energy by 8.99–15.64 %, laboratory (by 10.25–19.18 %) and field (by 13.05–23.24 %) germination abilities was observed in the four varieties. **Conclusion.** Tests of D-8SE and D-AMSSE confirmed their high efficiency as growth regulators to optimize the growth of apical meristems of cabbage plants, making formation and maturation of heads more even and uniform within the varietal populations. D-8SE and D-AMSSE beneficially affected the sowing quality of cabbage compared to the standard growth regulator - gibberellic acid (GA_3). In particular, for Kharkivska Zymova, there was 0.80- to 1.23-fold advantage of the composite formulations in the field germination ability. In Ukrainska Osin, this there was a 1.38- to 2.05-fold increase in in the field germination ability; in Bilosnizhka – 2.60- to 2.77-fold; in Paleta – 3.12- to 3.38-fold.

Key words: white cabbage, purple cabbage, selenium-containing composite formulations, morpho-biological parameters of heads, sowing quality of seeds, growth regulators.

Introduction. The Institute of Vegetable and Melon Growing of NAAS breeds late-ripening cabbage varieties, namely white cabbage (*Brassica oleraceae* L. convar. *capitata* (L.) *Alef. var. alba* DC) and purple cabbage (*Brassica oleracea* L. var. *capitata* L. *subvar. rubra*). Cabbage is a biennial vegetable, in which the vegetative phase of development (the first year of life) plays an important role in ontogenesis, since during this period the main productive organ (head) is formed; in the reproductive period (the second year of life), it will determine the seed productivity of plants. During the head formation, one should take into account morpho-biological parameters of heads, which ensure better storability of foundation stock in vegetable storehouses in autumn and winter and improve the quality of heads used for commercial purposes. Appropriate weight, volume and density are especially important for heads. Hence, depending on growing conditions, it is desirable to reduce percentages of plants with underdeveloped apical zones and with incompletely formed heads without desirable density and weight. Cabbage is characterized by wide polymorphism of morphological features, especially in the vegetative phase of development. In many countries worldwide, it is a mass consumption product, as it is capable of producing high yields of up to 80–100 t/ha with intensive cultivation technologies. Harvesting, which accounts for more than 40% of labor costs, remains a problematic issue. In almost all varieties, heads do not ripen simultaneously; their weight, size and density vary a lot, which makes mechanized harvesting significantly more complicated. It is extremely difficult to achieve complete uniformity of heads, as varieties are populations that combine heterozygous biotypes differing to a greater or lesser extent one from another by several quantitative traits (*Zhuk, O. Ya., 2008*). To ensure the effective operation of cabbage harvesters, varieties must have stable indicators of their growth and development, among which yield, maturation evenness, resistance to diseases and splitting, biological and morphological uniformity of plants are especially important (*Balkaya, A. et al, 2005; Cervenski, J. et al, 2011b*). Thus, the model of white cabbage varieties suitable for mechanized harvesting provides the following intervals of variations for morphostatistical parameters of plants: the leaf rosette diameter is ≤ 70 cm, not many leaves; identical height of the outer head –15-20 cm; uniform weight and size of heads (weight 1.5–2.5 kg, diameter 15–20 cm) (*Krutskikh, B.N. & Horoshikh, N.N., 1978*). Since quantitative traits in cabbage plants are controlled by numerous genes, they considerably vary in ontogenesis, depending on growing conditions. Foreign researchers reported that the head weight significantly varied both in varieties and F_1 hybrids. The coefficient of variation was 41.0% in the varieties and 8.8-26.0% in the F_1 hybrids. The greatest variability of the outer head height was recorded for the varieties (CV = 14.4...27.4%). Bulgarian hybrids were also heterogeneous according to this parameter (CV = 7.2...25.8%). Dutch hybrids with a coefficient of variation ranging 7.4% to 8.4% were more uniform (*Popkov, Yu. D. & Stozharova, I. A., 1989*). To achieve plant homogeneity in new cabbage varieties, it is also important to study the variability of morphological and economic-biological traits in new lines as starting materials for breeding (*Kibar, B. et al, 2016; Özer, M.Ö., 2021*).

Application of growth regulators, which can actively influenc physiological processes of growth and development, especially with regard to the uniformity and synchronicity of productive organ maturation, is a way to overcome the negative phenomenon of asynchronous growth and development of cabbage plants of some varietal populations (*Kotecha, A. V. et al, 2011 ; Puzik L.M. & Haiova, L.O., 2018*). In any vegetable species, all processes in ontogenesis are mainly regulated by three important systems: genetic, hormonal and trophic (*Shevelukha, S. V., 1990*). Studies of interactions between these three important autoregulation systems are of primary importance for breeding and require solving several problems. The first and main objective is in-depth studying biologically active substances that can act as growth regulators and affect those growth processes in vegetable species that are important through the lens of breeding and seed production (*Ponomarenko, S. P., 2005; Tkachuk, O.O., 2014*). Use of selenium-containing biologically active compounds or composite formulations based on biological forms of selenium is a promising trend in this sphere. From literature, it is known that adequate nutrition of plants must include this trace mineral, which is able to many-fold increase their resistance to various negative environmental stressors (*Brown, T. A. & Shift, A., 1982; Vihreva, V. A. et al , 2001*). Selenium has high restorative and regenerating potentials, allowing for significant boost in the plant performance (*Mechora, Š. et al., 2012; Sharma, V. K. et al, 2015*). Elimination of selenium deficit, i.e. achievement of high stress tolerance of vegetable seedlings, is possible by timely application of selenium-containing growth regulators.

Analysis of Recent Studies and Publications. Selenium is a vital (essential) trace mineral for all higher plants, as it directly participates in numerous intracellular processes that ensure the vital activity of cells. The main mechanism of biological action of selenium-containing compounds is their participation in antioxidant processes (*Davydova, O. Ye. et al, 2009; Pilon-Smits, E. A. & Quinn, C. F., 2010*). Selenium-containing compounds are also involved in the regulation and activation of syntheses of polyunsaturated fatty acids, pigments and carotenoids (*Lu, J., & Holmgren, A., 2009*). In plant cells, selenium is actively bound by organic substances - amino acids, proteins, nucleic acids, and polysaccharides. Chloroplast proteins contain selenocysteine and selenomethionine (*Davydova, O. Ye. et al, 2009*). Selenium is also required for synthesis of selenocysteine-linked tRNA. It is metabolyzed by replacing sulfur in sulfur-containing compounds (*Řezanka, T. & Sigler, K., 2008*). Thus, plants produce organic selenium-containing compounds, primarily selenocysteine and selenomethionine, from inorganic ones (*Whanger, P. D., 2002*).

In view of natural/climatic changes, the development of approaches and methods that facilitate adaptation of vegetable species, which are affected by various biotic and abiotic stressors of the environment, to new growing conditions has been intensified recently. In this aspect, development of phytohormonal agents and growth regulators as well as of selenium-containing formulations is a promising trend (*Ibatullin, I. I. et al, 2004*). Recent studies of the biological role of selenium have confirmed its active role in the growth and development of higher plants. It was revealed that this trace mineral was necessary in small doses (0.05–0.10 mg/kg of dry matter (dm)) and toxic in large doses (2–5 mg/kg dm) (*Mirza, H. et al, 2020*). In plants, selenium is found as selenate (Se^{6+}), selenite (Se^{4+}), selenide and thioselenite (Se^{2+}) and as dimethyl selenide (DM Se) and dimethyl diselenide (DMD Se) as part of some compounds etc. (*Davydova, O. Ye. et al, 2009*). Numerous studies proved the stress-protective activity of selenium and its ability to neutralize the negative impact of various environmental stressors on plants. In particular, the amounts of free radicals (which cause peroxide stress) in tissues of six plant species of the *Fabaceae* family decreased due to selenium during intensive growth (*Alford, É. R. et al, 2014; Philip, J. W., 2016*). Chinese scientists confirmed the influence of selenium on the redox balance in cabbage plants (*Brassica campestris* cv. Chiba), which were treated with aqueous solutions of selenium-containing compounds. Inorganic forms of selenium were discovered to beneficially affect redox enzymes, increasing their activities, hence minimizing detrimental impact of different stressors on cabbage plants (*Han-Chul, K. et al, 2004*). It was demonstrated that selenium preserved hydration of plant tissues during droughts, without reducing transpiration intensity. Upon water deficit, the protective effect of this trace mineral was manifested as intensive inflow of water from soil due to stimulation of the water-absorbing capacity of roots (*Kuznetsov, V. V. et al, 2003*). Selenium, which is detected in seed coats of some vegetable species, also performs a protective function due to the fact that its content in the coat can be 2-20 times greater than that in the pericarp, depending on plant species. Studies on 7 perennial *Allium* L. species (10 varieties) and 15 *Brassica* L. varieties proved the positive effect of selenium on seed germination, which is attributed to specific endogenous regulation of the physiological process by this trace mineral (*Golubkina, N. A. et al, 2005*).

Chinese researchers found that selenium-containing yeast as a source of selenium had a considerable effect on the growth and quality of white cabbage. The results showed that initial treatment of juvenile cabbage plants with selenium-containing yeast at an effective concentration of 16 mg/kg increased the total plant weight, head weight and size by 48.4%, 88.3% and 25.4%, respectively, compared to the control values. The main sources of selenium in white cabbage heads were its organic forms - selenocysteine and methylselenocysteine. Selenium-containing yeast at a dose of 8 mg/kg increased the contents of amino acids, soluble sugars, vitamin C, phenolic acids, and glucosinolates in productive organs by 12.3–81.6% (*Liao, X. et al, 2021*).

Another team of foreign researchers also investigated effects of different concentrations of selenite (0.1–0.4 mmol/L) on the growth and nutritional quality of white cabbage. They found that selenite concentrations of 0.1–0.2 mmol/L induced the accumulation of primary (soluble proteins, sugars, and free amino acids) and secondary (vitamin C, glucosinolates, flavonoids, anthocyanins, and phenolic acids) metabolites and enhanced the activities of antioxidant enzymes (glutathione peroxidase, catalase, and superoxide dismutase) (*Yu, L. et al, 2023*).

The Scientific and Engineering Center "AKSO" of NAS of Ukraine investigated the protective potentials of plant growth regulators, antioxidants, and trace minerals, including selenium compounds, on Smuhlianka and Syrena Odeska wheat varieties grown on artificially created acute deficit of phosphorus, which is a stress factor, no less dangerous than drought. Pre-sowing treatment of grain with 10^{-4}% aqueous solution of sodium selenate (Na_2SeO_4) intensified root growth, increased the total length of roots by 45-70% and enhanced root exudation of acids by 53-65%. It was experimentally established that sodium selenate had complex properties of a growth and development stimulator of wheat plants, improving their phosphorus nutrition, as well as an antioxidant and anti-stressor (*Davydova, O. Ye. et al*, 2009).

Thus, despite a great number of foreign studies on regulatory effects of selenium on the growth and development of agricultural plant species, there have been very few studies of this trace mineral or its organic forms in vegetable species in Ukraine. Therefore, there is an urgent need to expand such exploratory studies, especially in respect to optimization of the creation of initial forms for breeding.

Purpose. To analyze regulatory effects of selenium-containing biologically active formulations manufactured in Ukraine on the sowing quality of seeds and on morpho-biological parameters (level and uniformity) of productive organs (heads) in varietal populations of cabbage plants during the vegetative phase of development.

Method and Materials. In accordance with the objective, we studied two new selenium-containing composite formulations - D-8SE and D-AMSSE produced by *Vysokyi Vrozhai* LLC (Kyiv, Ukraine). For biotests of these formulations on cabbage, the well-known regulator Mars-1 (the closest prototype of D-8SE and D-AMSSE), which had been was previously studied on growing white cabbage plants at the Institute of Vegetable and Melon Growing of NAAS, was chosen as a reference (standard). Mars-1 was established to have a double function: it can act as a fungicide against pathogens (viruses and fungi) and as a growth regulator for economically valuable plant species (*Mazalova, I. V. et al, 2000*).

To carry out biotests of D-8SE and D-AMSSE, white and purple cabbage plants, which were grown in the field, were used during the vegetative phase of their development. In particular, we used 3 white cabbage varieties (Bilosnizhka, Ukrainska Osin, and Kharkivska Zymova) and 1 purple cabbage variety (Paleta) bred by the Institute of Vegetable and Melon Growing of NAAS. The white and purple cabbage varieties were grown at the experimental base of the Institute of Vegetable and Melon Growing, which is located in the Kharkivska Oblast (Selektsiine village). The agro-climatic zone of the study site is the Eastern Forest Steppe of Ukraine. Seeds were planted in the field within the first 10 days of May. The seedling arrangement was 70x70 cm. Cabbage was grown in compliance with the traditional farming technique without artificial irrigation (*Horova, T. K. & Yakovenko, K. I. (Eds.), 2001*). The first treatment of seedlings with regulators was carried out in early June. During the vegetation period, plants were treated four times with a month interval. Twenty plants were used in each experimental variant. Aqueous solutions of regulators at a concentration of 2 ml/L were used for treatment. This concentration was selected in agreement with the manufacturers' recommendations, both for the test formulations and for the reference, Mars-1 *(Mazalova, I. V. et al, 2000*). Plants that were treated with water were taken as the absolute control. Each treatment was carried out with a knapsack sprayer in the afternoon, between 4.00 p.m. 5.00 p.m. For the morphometric analysis of cabbage plants, the following parameters were measured: weight, volume and density of cabbage heads at the end of the growing period. To calculate the head volume (V), we approximated heads to the ellipsoid of rotation and used the following formula: $V = 1/6 * \pi * a * b^2$, where *a* - diameter of the shorter axis of the ellipsoid, b^2 - diameter of the longer axis. Biometric measurements of heads were conducted at the end of the vegetation period of cabbage plants within the first 10 days of October before putting them into a storehouse for winter. Arithmetic mean values of statistical parameters and their standard errors were used to analyze the obtained data (*Dospekhov, B. A., 1985*). The regulators were tested on cabbage in 2020–2022.

The composite formulations were tested on cabbage seeds both in the laboratory and in the field. For this purpose, 100 seeds of each cabbage variety were placed in gauze bags and incubated in aqueous solutions of the studied substances (2 ml/L) without illumination in a thermostat at 25°C for 1 day. The experiments were replicated 5 times. Control seeds were soaked in distilled water. Gibberellic acid (GK_3) was used as reference solution; seeds were soaked in water-diluted GK_3 (phytohormonal control, 2 mg/L).

When conducting biotests of substances, we followed the requirements for assessing the sowing and varietal qualities of vegetable seeds, which are specified in DSTU 7160:2010 (DSTU 7160:2020, 2021). The sowing quality of seeds was determined by such indicators as germination energy (at day 3), laboratory (at day 8) and field (at day 10) germination abilities, which were calculated as the portion of germinated seeds at days 3, 8 and 10 related to the total number of sown seeds (expressed as a percentage). After treatment, seeds were washed three times with distilled water and germinated in Petri dishes on wetted filter paper sheets without illumination in a thermostat at 25°C. The energy of seed germination and laboratory germination ability of seeds were determined in laboratory experiments. To calculate the field germination ability of seeds, seeds that had been pretreated with tested biologically active substances in the laboratory were sampled, washed three times with distilled water and sown outdoors. All the above parameters were expressed as percentages. To analyzed data, we used variation statistics (*Dospekhov, B. A., 1985*).

Results. Results on treatment of vegetating cabbage plants with three selected composite formulations and regulators (D-8SE, D-AMSSE and Mars-1) are summarized in Table 1. The statistically significant values are in bold and underlined; the parameters with a clear upward trend but within the standard error of the control value are in bold.

By head weight, D-AMSSE is the leader. When the four cabbage varieties were treated with D-AMSSE, there was a statistically significant increase in the head weight compared to the control (untreated plants). In particular, the head weight increased by 23%in Kharkivska Zymova and Bilosnizhka and by 22% in Ukrainska Osin and Paleta. Considering the actions of the other investigated biologically active agents, we should note, first of all, rather wide variations in their influence on growth processes in certain cabbage genotypes. In particular, Mars-1 proved to be the most effective agent of the tested compounds in stimulating the head weight growth in Bilosnizhka white cabbage (36% increase in weight). When Paleta purple cabbage plants were treated, its efficiency was lower than that of D-8SE, but with a statistically significant increase in the head weight by 20%. D-8SE was less efficient than D-AMSSE and Mars-1, because when plants were treated with this agent, we observed a clear upward trend in the head weight, but within the margins of the standard error of the control. Bilosnizhka's response to this regulator turned out to be an exception: there was a statistically significant increase in the head weight by 28%.

Head volume and density are other important indicators. Increased weight in combination with increased density and optimal volume, which would not go beyond the accepted limits of variations of these parameters according to the developed variety model, is especially valuable for improving quality. The best ratio of the head weight and volume was recorded for D-AMSSE on Kharkivska Zymova plants. D-8SE and Mars-1 gave the best ratios on Bilosnizhka plants. When Ukrainska Osin white cabbage plants were treated with any of the test formulations, we observed a specific varietal response: a statistically significant decrease in the head volume compared to the control. D-AMSCE treatment resulted in a statistically significant increase in the head weight in this variety with a clear upward trend in the head density, but with overlapping standard errors with the control (Table 1).

Table 1. Effects of the selenium-containing formulations, D-8SE and D-AMSSE, on white and purple cabbage heads, mean for 2020–2022

Regulator	**Head weight (m), kg**	**Heat volume (*V*), • 10^{-3} m^3**	**Head density ($\rho = m/V$), kg/m^3**	**Correlation between the head weight and volume, r_p ***
		Kharkivska Zymova white cabbage		
Control	1.77±0.17	2.93±0.45	666.02±47.73	0.63
Mars-1	1.77±0.19	2.58±0.23	**672.25±42.28**	0.86
D-AMSSE	**2.17±0.18**	2.87±0.16	**726.39±64.10**	0.55
D-8SE	**1.89±0.17**	2.36±0.22	**717.53±46.27**	0.86
$LSD_{0.05}$	0.18	0.27	50.10	–
		Ukrainska Osin white cabbage		
Control	2.10±0.17	3.04±0.23	695.92±36.71	0.77
Mars-1	1.98±0.95	**2.46±0.24**	**786.23±32.64**	0.95
D-AMSSE	**2.56±0.20**	**2.41±0.22**	**699.00±37.74**	0.93
D-8SE	**2.31±0.18**	**2.46±0.21**	**764.83±49.12**	0.84
$LSD_{0.05}$	0.16	0.23	38.9	–
		Bilosnizhka white cabbage		
Control	2.18±0.20	2.74±0.24	800.80±55.12	0.69
Mars-1	**2.97±0.13**	**3.6±0.24**	**862±42.48**	0.59
D-AMSSE	**2.67±0.22**	**3.0±0.24**	**880.26±41.72**	0.87
D-8SE	**2.80±0.23**	**3.07±0.22**	**903.62±34.48**	0.91
$LSD_{0.05}$	0.20	0.23	43.5	–
		Paleta purple cabbage		
Control	1.23±0.10	1.88±0.12	650.19±42.44	0.89
Mars-1	**1.48±0.12**	**2.21±0.17**	**695.38±56.86**	0.92
D-AMSSE	**1.50±0.13**	1.77±0.16	**795.20±56.43**	0.92
D-8SE	**1.35±0.12**	**1.89±0.15**	**700.36±40.84**	0.81
$LSD_{0.05}$	0.12	0.15	49.2	–

Note: * statistical significance of the Pearson pair correlation coefficient (r_p) at $p < 0.05$.

The increase in the head weight in the four treated cabbage varieties was associated with changes in the head density. This is a beneficial point in the physiological reaction of treated plants, because internal tissues of denser cabbage heads will be less prone to damage by fungal and bacterial infections when put to winter storage. A statistically significant increase in the Paleta head density compared to the control (by 22%) was observed after its plants had been treated with D-AMSSE, in Bilosnizhka after D-8SE treatment (by 13%) and in Mars-1-treated Ukrainska Osin (by 13%).

There was a strong linear correlation between the head weight and volume (Table 1). Depending on treatment, the Pearson pairwise correlation coefficient (r_p) ranged 0.55 to 0.95 in the four selected cabbage varieties. In the control, there was a medium (r_p = 0.3...0.7) or strong correlation (r_p > 0.7) between these parameters. Kharkivska Zymova (r_p = 0.63) and Bilosnizhka (r_p = 0.69) showed a medium correlation, while a strong correlation was noted for Ukrainska Osin (r_p = 0.77) and Paleta (r_p = 0.89). With some exceptions, treatment with the tested agents changed the correlation strength almost to the functional level (r_p = 1.0). This experimental fact indicates the direct effects of D-8SE and D-AMSSE and their closest prototype, Mars-1, on the apical meristems of cabbage plants, as the regulators influence the evenness of formation and maturation of heads in some varietal populations.

In particular, Mars-1 and D-8SE strengthened the correlation compared to the control in Kharkivska Zymova white cabbage (r_p = 0.86 vs r_p = 0.63). D-AMSSE was an exception, as it, on the contrary, weakened the correlation to medium (r_p = 0.55) (Table 1). The composite formulations had the greatest effects when tested on Ukrainska Osin; they strengthened the relationship (r_p = 0.84...0.95) compared to the control (r_p = 0.77). D-8SE and D-AMSSE proved to be more effective than Mars-1 in strengthening the relationship on Bilosnizhka white cabbage. With D-8SE and D-AMSSE, the correlation coefficient increased (r_p = 0.87...0.91) compared to the control (r_p = 0.69). Mars-1 weakened the correlation to medium (r_p = 0.59) in this variety. In Paleta purple cabbage, there was a strong correlation between the head weight and volume (r_p = 0.89) in the control, therefore D-8SE, D- AMSSE and Mars-1 did not significantly strengthen this correlation (r_p = 0.81...0.92).

Cabbage seeds that are grown for sowing must meet the requirements of state standards. DSTU 7160:2010 stipulates the following requirements for varietal qualities of seeds: varietal purity of original seeds – 99%; of elite seeds – 98%; of reproductive seeds – 97%. The germination ability should be at least 80% for original and elite seeds and 75% for reproduction seeds. The water content in seeds should not exceed 9%. Under compliance with the technological regulations for storage, seeds retain their commercial germination ability for 5–6 years. According to the requirements of DSTU 7160:2010, pre-sowing treatment with growth regulators is an effective measure to ensure high quality of seeds. In order to select the most effective regulators, it is advisable to test them preliminary for initiation of seed germination in the laboratory. This technique helps to find the best regulators with beneficial effects on seed germination in less expensive laboratory experiments and then to use them in large-scale field tests. Other researchers noted that selenium and its biological forms had strong regulatory effects on the germination of seeds of agricultural plant species (*Golubkina, N. A. et al., 2005*). Taking into account the above, we evaluated D-8SE and D-AMSSE first in the laboratory and then in the field for their potential to improve the sowing quality of cabbage seeds. Data from these experiments are summarized in Table 2. In terms of energy of seed germination, all the tested formulations were more effective than the control (distilled water). Depending on treatment, there was a statistically significant increase in the energy of seed germination by 8.96–15.64% in Kharkivska Zymova, by 7.35–13.24% in Ukrainska Osin, by 3.95–12.96% in Bilosnizhka and by 4.46–11.01% in Paleta. The control energy of seed germination was 65.15% in Kharkivska Zymova, 62.12% in Ukrainska Osin, 65.37% in Bilosnizhka, and 68.19% in Paleta. Of the tested agents, gibberellic acid was less effective than D-8SE or D-AMSSE. After GA_3 application, the energy of seed germination increased by 3.95–8.96% in the four cabbage varieties. A similar variation range of the energy of seed germination was observed for D-AMSE (11.01–15.64%); for D-8CE, the energy of seed germination varied between 8.69% and 13.24%.

Similar patterns were observed for the laboratory germination ability of seeds. Compared to the distilled water control, all the tested agents resulted in a statistically significant increase in the laboratory germination ability of seeds of all the cabbage varieties (Table 2). The difference in the laboratory germination ability between the treated and control variants was 12.01–16.98% in Kharkivska Zymova. A similar difference was detected in Ukrainska Osin (5.78 - 12.77%), Bilosnizhka (4.27 - 15.02%), and Paleta (4.97 - 19.18%). Of the tested agents, gibberellic acid was less effective than D-8SE or D-AMSSE; its regulatory effect was manifested as a rise in the laboratory germination ability of seeds of the four cabbage varieties by 4.27–12.01%. A similar variation range of the laboratory germination ability was noted for D-AMSSE (10.57–19.18%) and D-8SE (10.25–15.04%). The control laboratory germination ability was 72.37% for Kharkivska Zymova seeds, 67.55% for Ukrainska Osin seeds, 70.12% for Bilosnizhka seeds, and 74.28% for Paleta seeds (Table 2).

Field germination ability of seeds is a rather important indicator for cabbage seeds. If an agent is able to increase the number of germinated seeds, it is possible to increase the sowing quality of seeds to the level required by DSTU 7160:2010. Like in the in laboratory tests, a positive upward dynamics in seed germination was traced in the field experiments with pre-sowing treatment. Compared with the control (soaking of seeds in distilled water prior to sowing), the field ability increased up to 70.24 - 77.31% for Kharkivska Zymova seeds (control - 57.19%), to 61.55–73.45% for Ukrainska Osin seeds (control – 50.21%), to 65.15–75.38% for Bilosnizhla seeds (control – 59.37%), and to 71.36 –86.14% for Paleta seeds (control – 65.15%). The increase in the absolute values of the field germination ability was statistically significant in the D-8SE, D-AMSSE and GA_3 experiments. The field germination ability of seeds increased by 13.05–20.12% in Kharkivska Zymova, by 11.33–23.24% in Ukrainska Osin, by 5.78– 16.01% in Bilosnizhka, and by 6.21–20.99% in Paleta. Thus, summarizing the results of tests of D-8SE and D-AMSSE, we should emphasize their positive effects on the germination energy, laboratory and field germination abilities of seeds of the four cabbage varieties.

Table 2. Effects of the selenium-containing formulations, D-8SE and D-AMSSE, on germination energy, laboratory and field germination abilities of cabbage seeds, mean for 2020–2022

Treatment	Germination energy, %	Laboratory germination ability, %	Field genimation ability, %
Kharkivska Zymova white cabbage			
Control	69.15±0.43	72.37±2.15	57.19±2.36
Mars-1	78.11±0.59	84.38±1.27	73.55±2.79
D-AMSSE	84.79±0.38	89.35±1.07	77.31±1.85
D-8SE	82.14±0.45	85.14±1.36	70.24±2.57
$LSD_{0.05}$	1.15	1.84	2.71
Ukrainska Osin white cabbage			
Control	62.12±2.17	67.55±0.69	50.21±2.48
Mars-1	69.47±1.57	73.33±0.38	61.54±1.30
D-AMSSE	73.35±1.38	78.12±0.55	65.88±0.93
D-8SE	75.36±2.06	80.32±1.28	73.45±1.48
$LSD_{0.05}$	1.35	2.26	2.48
Bilosnizhka white cabbage			
Control	65.37±2.11	70.12±0.55	59.37±2.06
Mars-1	69.32±1.35	74.39±1.06	65.15±1.48
D-AMSSE	78.06±1.32	85.14±2.35	74.39±1.27
D-8SE	74.23±1.58	80.37±1.92	75.38±0.99
$LSD_{0.05}$	1.29	2.02	2.95
Paleta purple cabbage			
Control	68.19±1.73	74.28±1.64	65.15±1.47
Mars-1	72.65±1.39	79.25±1.26	71.36±1.55
D-AMSSE	79.20±0.95	93.46±1.59	84.54±1.48
D-8SE	76.88±2.05	89.32±1.48	86.14±0.70
$LSD_{0.05}$	1.75	1.22	2.30

Conclusions. Tests of the composite formulations, D-8SE and D-AMSSE, confirmed their high biological activity as growth regulators capable of increasing the qualitative and quantitative parameters of cabbage plants in the vegetative phase of development. D-AMSSE turned out to be the most effective agent; different cabbage genotypes responded differently to its application, but their head weight increased similarly (by 22–23%). An analogous pattern was observed for such an important quantitative indicator as the head density (13-22% increase). D-8SE treatment was only effective in Bilosnizhka; as to the other cabbage varieties, there was a steady upward trend in all morphometric parameters, but within the standard error limits of the control values. The effect Mars-1 was selective: it was more effective in Bilosnizhka and Paleta. It was found that there was a medium (r_p = 0.3...0.7) or strong (r_p > 0.7) linear correlation between the head weight and volume in the control. Depending on treatment, we observed a stable increase in the Pearson correlation coefficient (r_p) (r_p = 0.55...0.95) in the four cabbage varieties. This experimental fact attests to the direct effects of D-8SE, D-AMSSE and Mars-1 on the apical meristems of cabbage plants, as the agents improve the evenness of the head formation and maturation within the varietal populations. Summarizing our results on the composite formulations, D-8SE and D-AMSSE, we should emphasize their beneficial effects on the germination energy, laboratory and field germination abilities of seeds of the four cabbage varieties. Both formulations statistically significantly increased the germination energy by 8.99–15.64%, the laboratory germination ability by 10.25–19.18%, and field germination ability by 13.05–23.24%. At the same time, the reference regulator, gibberellic acid (GA_3), was significantly inferior or equal to the tested agents in terms of effectiveness. In particular, in Kharkivska Zymova, we recorded a 1.45- to 1.75-fold superiority of the composite formulations in terms of energy of seed germination. As to laboratory germination ability, there was a 1.06-to 1.41-fold advantage of D-8SE and D-AMSSE over GA_3. For field germination ability, we observed a 0.80- to 1.23- fold advantage of D-8SE and D-AMSSE over GA_3. Corresponding values for Ukrainska Osin were 1.53- to 1.80-fold, 1.83- to 2.21-fold and 1.38- to 2.05-fold; for Bilosnizhka – 2.24- to 3.21-fold, 2.40- to 3.52-fold and 2.60- to 2.77-fold; for Paleta – 1.95- to 2.47-fold, 3.03- to 3.86-fold and 3.12- to 3.38-fold.

References

Alford, É.R., Lindblom, S.D., Pittarello, M., Freeman, J.L., Fakra, S.C., Marcus, M.A., Broeckling, C., Pilon-Smits, E.A., Paschke, M.W. (2014). Roles of rhizobial symbionts in selenium hyperaccumulation in Astragalus (*Fabaceae*). *American journal of botany*. **101(11):**1895–1905. https://doi.org/10.3732/ajb.1400223

Balkaya, A., Yanmaz, R., Apaydin, A., Kar H. (2005). Morphological characterization of white head cabbage (*Brassica oleracea* var. *capitata* subvar. *alba*) genotypes in Turkey. *New Zealand Journal of Crop and Horticultural Science.* **33**:333–341.

Brown, T.A., Shift, A. (1982). Selenium: toxicity and tolerance in higher plants. *Biol. Rev*. 57:59–84.

Cervenski, J., Gvozdanovic-Varga, J., Glogovac, S. (2011b). Local cabbage (*Brassica oleracea* var. *capitata* L.) populations from Serbian Province of Vojvodina. *African Journal of Biotechnology.* **10(27):**5281–5285. https://doi.org/10.5897/AJB10.2686

Davydova, O.Ye., Veshytskyi, V.A., Yavorovskyi P.P. (2009). Physiological-biochemical and stress-protective functions of selenium in plants. *Fiziologii͡a i Biokhimii͡a Kulturnykh Rasteniĭ.* **41(2):**109–123.

Dospekhov, B.A. (1985) Methods of field experimentation. Moscow: Agropromizdat. 350 p.

State Standard of Ukraine DSTU 7160:2020. “Seeds of vegetables, melons, fodder and aromatic crops. Varietal and sowing qualities. Specifications”. Valid from 01/09/2021]. Official edition. Kyiv: Derzhstandart Ukrainy. 20 p.

Golubkina, N.A., Golubev, F.V., Temichev, A.A. (2005). Protective function of selenium in the seed coat of plants. *Vestnik RASKhN*. **4:**54–57.

Han-Chul, K., Jung-Bong, K., Young-Sang, K., Seok-Cheol, S. (2004). Seleno compounds-included bimodal function as measured for oxidoreductive potentials in *Brassica campestris* cv. Chiba. *Journal of Applied Biological Chemistry*. **47(4):**167–172.

Horova, T.K. & Yakovenko, K.I. (Eds.) (2001). State-of-art methods of vegetable and melon breeding. Kharkiv: Osnova. 369 p.

Ibatullin, I.I., Veshytskyi V.A., Otchenashko V.V. (2004). Use of selenium in crop production and animal husbandry. Kyiv: Feniks, 208 p.

Kibar, B., Karaağaç, O., & Kar, H. (2016). Determination of morphological variability among cabbage (*Brassica oleracea* var. *capitata* L.) hybrids and their parents. *Journal of the Institute of Science and Technology*. **6:**31–44. http://dx.doi.org/10.21597/jist.2016119273

Kotecha, A.V., Dhruve, J.J., Vohol, N.J. (2011). Effect of foliar application of micronutrients and growth regulators on growth and yield of cabbage

(*Brasicca oleracea* L. var. *capitata*) cv. GOLDEN ACRE. *Asian Journal of Horticulture*. **6(2):**381–384. http://dx.doi.org/10.22271/chemi.2021.v9.i1z.11485

Krutskikh, B.N., Khoroshikh, N.N. (1978). White cabbage cultivation technology. *Kartofel i Ovoshchi*. **12:**28–31.

Kuznetsov, V.V., Kholodova, V.P., Kuznetsov, Vl.V., Yagodin, B.A. (2003). Selenium regulates the water status of plants during drought. *Doklady RAN*. **390(5):**713–715. [in Russian]

Liao, X., Rao, S., Yu, T., Zhu, Z., Yang, X., Xue, H., Gou, Y., Cheng, S., Xu, F. (2021). Selenium yeast promoted the Se accumulation, nutrient quality and antioxidant system of cabbage (*Brassica oleracea* var. *capitata* L.). *Plant Signaling & Behavior*, **16(6):**1907042. https://doi.org/10.1080/15592324.2021.1907042

Lu, J., Holmgren, A. (2009). Selenoproteins. *Journal of Biological Chemistry*, **284(2):**723–727. https://doi.org/10.1074/jbc.R800045200

Mazalova, I.V., Dindorokho, V.H., Halushko, V.P., Mazalov, V.K., Artomov, A.F., Chernyshov, S.I., Syromolot, Ye.A. (2000). Mars-1 formulation for pre-sowing treatment of agricultural crops (Ukrainian invention patent No. 27093). “Scientific-Technological Institute of Transcription, Translation and Replication” Joint-stock company. https://uapatents.com/10-27093-sklad-mars-1-dlya-peredposivno-obrobki-nasinnya-silskogospodarskikh-kultur.html

Mechora, Š., Germ, M. & Stibilj, V. (2012). Selenium compounds in selenium-enriched cabbage. *Pure and Applied Chemistry*, 84(2):259–268. https://doi.org/10.1351/PAC-CON-11-07-19

Mirza, H., M. H. M., Bhuyan B., Raza A., Hawrylak-Nowak, B., Matraszek-Gawron R., Nahar K., Fujita, M. (2020). Selenium Toxicity in Plants and Environment: Biogeochemistry and Remediation Possibilities. *Plants*. **9(12):**1711. https://doi.org/10.3390/plants9121711

Özer, M.Ö. (2021). Morphological variability of red head cabbage (*Brassica oleracea* L. var. *capitata* L. subvar. *rubra*) populations. *Genet Resour Crop Evol*. **68:**1033–1043. https://doi.org/10.1007/s10722-020-01046-8

Philip, J. W. (2016). Selenium accumulation by plants, *Annals of Botany*. 117(2):217–235. https://doi.org/10.1093/aob/mcv180

Pilon-Smits, E.A., Quinn, C.F. (2010). Selenium metabolism in plants. In Cell Biology of Metals and Nutrients. Springer: Berlin/Heidelberg, Germany, P. 225–241.

Ponomarenko, S.P. (2005). High technologies in agriculture. *AhroSvit*. **4:**16–21.

Popkov, Yu.D., Stozharova, I.A. (1989). Comparative characteristics of white cabbage hybrids and varieties of different origins. Breeding and seed production of vegetables and melons. Moscow: NIIOKh, 40–45 p.

Puzik L.M., Haiova, L.O. (2018). Effects of plant growth regulators on the growth, development and yield of cauliflower hybrids. *Tavriiskyi Naukovyi Visnyk. Series: Ahrarni Nauky*. **103:**105–112.

Řezanka, T., Sigler, K. (2008). Biologically active compounds of semi-metals. *Studies in Natural Products Chemistry*. **35:**835–921. http://dx.doi.org/10.1016/S1572-5995(08)80018-X

Sharma, V.K., McDonald, T.J., Sohn, M., Anquandah, G.A.K., Pettine M., Zboril R. (2015). Biogeochemistry of selenium. *A review. Environ Chem Lett*. 13:49–58. https://doi.org/10.1007/s10311-014-0487-x

Shevelukha, S.V. (ed.) (1990). Plant growth regulators. Moscow: Agropromizdat, 185 p.

Tkachuk, O.O. (2014). Environmental safety and prospects for plant growth regulators. *Visnyk Vinnytskoho Politekhnichnoho Instytutu*. **3:**41–44

Vikhreva, V.A., Gryanin, V.N., Gnis, V.K., Blinokhvatov, A.F. (2001). Adaptogenic role of selenium in higher plants. *Byulleten Bashkirskogo Gosudarstvennogo Universiteta*. **2(II):**65–66.

Whanger, P.D. (2002). Selenocompounds in plants and animals and their biological significance. *Journal of the American College of Nutrition*. **21(3):**223–232. https://doi.org/10.1080/07315724.2002.10719214

Yu, L., Chen, Q., Liao, X., Yang, X., Chao, W., Cong, X., Zhang, W., Liao, Y., Ye, J., Qian, H., Zhao, Y., Cheng, S., Xu, F. (2023). Exploring effects of exogenous selenium on the growth and nutritional quality of cabbage (*Brassica oleracea* var. *capitata* L.). *Horticulturae*. **9:**330. https://doi.org/10.3390/horticulturae9030330

Zhuk, O.Ya. (2008). Morphological characteristics of white cabbage (*Brassica oleraceae* L. convar. *capitata* (L.) Alef. var. aiba DC) plants and their variability depending on the variety. *Sortovyvchennia ta Okhorona Prav na Sorty Roslyn*. **2(8):**34–39.

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СЕЛЕНОВМІСНІ БІОЛОГІЧНО-АКТИВНІ КОМПОЗИЦІЙНІ ПРЕПАРАТИ ЯК ЕФЕКТИВНІ РЕГУЛЯТОРИ РОСТУ ДЛЯ ПОКРАЩЕННЯ ПОСІВНИХ ЯКОСТЕЙ НАСІННЯ ТА МОРФО-БІОЛОГІЧНИХ ПОКАЗНИКІВ ГОЛОВОК КАПУСТИ БІЛО- і ЧЕРВОНОГОЛОВОЇ

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Мета – провести аналіз регуляторного впливу селеновмісних біологічно-активних препаратів вітчизняного виробництва на посівні якості насіння та на формування і вирівняність в межах сортових популяцій морфобіологічних показників продуктивних органів (головок) рослин капусти головчастої. **Методи.** Загальнонаукові, вимірювальні, зважувально-вагові, варіаційної статистики. **Результати.** Випробування регуляторної дії селеновмісних композиційних препаратів Д-8СЕ і Д-АМССЕ проводилося на трьох сортах капусти білоголової сортів Харківська зимова, Українська осінь, Білосніжка та одному сорті капусти червоноголової Палета. Найбільш ефективним виявився препарат Д-АМССЕ, при застосуванні якого сортові генотипи капусти реагували з різною сортовою реакцією, збільшуючи масу головок на приблизно однаковому рівні (на 22–23 %). Теж саме стосується такого показника, як щільність головок (збільшення на 13–22 %). У контрольному варіанті досліду між рівнями прояву двох кількісних ознак “Маса головок” і “Об’єм головок” існував середній і сильний кореляційний зв’язок. Залежно від варіанту обробки досліджуваними засобами, у чотирьох сортів капусти головчастої відмічено стабільне зростання коефіцієнту парної кореляції Пірсона (r_p) (r_p = 0,55…0,95). Препарати Д-8СЕ і Д-АМССЕ виявили позитивний вплив на посівні якості капусти головчастої. У чотирьох сортів відмічено статистично достовірне збільшення енергії проростання насіння на 8,99–15,64 %, лабораторної (на 10,25–19,18 %) та польової (на 13,05–23,24 %) схожості насіння. **Висновки.** Проведені випробування препаратів Д-8СЕ і Д-АМССЕ підтвердили їх високу ефективність, як регуляторів росту в аспекті оптимізації росту апікальних меристематичних зон росту рослин капусти головчастої, впливаючи на дружність формування і визрівання головок в межах певних сортових популяцій. Препарати Д-8СЕ і Д-АМССЕ позитивно вплинули на посівні якості капусти головчастої порівняно із еталонним регулятором росту – гібереловою кислотою (ГК$_3$). Зокрема, для сорту Харківська зимова перевага композиційних препаратів за показником “Польова схожість насіння” становила 0,80–1,23 рази. Для сорту Українська осінь – 1,38–2,05 разів. Для сорту Білосніжка – 2,60–2,77 рази. Для сорту Палета – 3,12–3,38 рази.

Ключові слова: капуста білоголова, капуста червоноголова, селеновмісні композиційні препарати, морфобіологічні показники головок, посівні якості насіння, регулятори росту.

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MAIN PERIODS OF GROWTH AND DEVELOPMENT OF F_1 CUCUMBER HYBRIDS AND THEIR YIELDS DEPENDING ON WEATHER

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Purpose. To evaluate effects of weather on growth and development of cucumber plants, lengths of the main interphase periods, and cucumber yield the Left-Bank Forest-Steppe of Ukraine; to select breeding-valuable genotypes for heterosis breeding under climatic changes. **Methods**. Field, analytical, measuring, statistical. **Results**. The study was conducted outdoors at the Institute of Vegetable and Melon Growing of NAAS in 2019–2020. The weather in the study years varied significantly, allowing us to assess its influence on phenological processes of growth and development of cucumber plants. Summarizing the results, we established that sufficiently high average daily air temperature (25.3–25.8 °C), a large amount of unevenly distributed precipitation (0–104 mm), with little or no precipitation during certain phases of cucumber development, significantly affected the growing period length and yield of the cucumber hybrids under investigation. We found that the onset of mass anthesis of female flowers did not vary significantly across the years, averaging 33–36 days. (35 days in the check accession). Fructification started on day 37–40 in 2019 and on day 42–45 in 2020, which was 4–6 days later. Fructification lasted 32–40 days in 2019 and 20–24 days in 2020, which was 12–16 days longer. Analysis of the cucumber yield dynamics over the study years showed that the weather in 2019 was more favorable for the growth and development of cucumber plants. Thus, in 2019, the total yields of hybrids ranged 20.8 t/ha to 64.9 t/ha. In 2020, at high temperatures and low air humidity, the total yield was 12.7–26.9 t/ha, which was significantly lower (by 41.4–61.0 %). **Conclusions.** The weather in the study years reflected the climate instability in the Forest-Steppe of Ukraine. The lengths the main periods of the growth and development of cucumber hybrid plants and their yields were revealed to vary significantly under variable growing conditions. We selected hybrids with annual parameters that would be valuable for further breeding: by early ripeness – F_1 'BD 96-18' / 'Tsezar', F_1 'RD 96 2-95'/ 'Dzherelo', F_1 'RD 96 2-95' / 'Heim' and F_1 'Mah-62' / 'Toma-18' (42 days); by fructification length – F_1 'RD 96 2-95'/ 'Dzherelo' (35 days), F_1 'Mah-62' / 'Toma-18', F_1 'BD 96-18'/ 'Heim' and F_1 'RD 96 2-95/ 'Heim' (32 days); by yield capacity – F_1 'Mah-62' / 'Toma-18' (45,9 t/ha), F_1 'BD 96-18'/ 'Toma-18' (39,3 t/ha), F_1 'Krak' / 'RD-96 2-95' (36,8 t/ha), F_1 'RD 96 2-95'/ 'Heim' (35,8 t/ha), F_1 'BD 96-18'/ 'Heim' (34,6 t/ha), and F_1 'RD 96 2-95'/ 'Dzherelo' (34.2 t/ha). The selected hybrids yielded significantly more than the check F_1 hybrid 'Ajax' (by 80-142 % or by 19.0 t/ha).

Key words: F_1 hybrid, cucumber, temperature, precipitation, anthesis, fructification, yield.

Introduction. Today, the agricultural production problem has been significantly aggravated because of intense pace of global and regional climatic changes, which are manifested as an increase in average annual air temperatures, frequent droughts, which cover up to 50–70 % of the territory of Ukraine (*Basok B.I. & Bazieiev Ye.T., 2020*). Global changes in the climate in recent years have made an important objective – creation of new genotypes with powerful genetic potentials of high performance and adaptability– more urgent in order to harvest stable yields.

Review of Resent Studies and Publications. Cucumber is one of the most common vegetables. It has been very popular among the population for a long time. Both fresh and canned cucumbers are eaten. Cucumber fruits are rich in biologically active substances; contain aromatic substances, enzymes that facilitate assimilation of proteins and vitamins B and C, carbohydrates, Ca and P ions (*Deepa S.K. et al., 2018; Murri I.K., 1961*).

Today, drastic climatic changes pose a big challenge for agricultural production. It was documented that the average annual air temperature in the territory of Ukraine started rising by 1.5 times faster than in the world as a whole. The difference between the initial and final temperatures for the period of 1991–2020 increased from 0.5 ºC to 1.2 ºC (*Basok B.I. & Bazieiev Ye.T., 2020*). A rapid increase in the sum of temperatures in March and a considerable increase in the average daily temperatures in July-August are inherent in these changes. In addition, water supply is getting worse due to insufficient precipitation; its seasonal distribution has become irregular: May. September and October amounts are similar to or higher than the multiyear averages. but there is a great precipitation deficit in other months. Reduced precipitation in July-August, when anthesis and fructification occur, is especially negative (*Vdovenko S.A. & Palamarchuk I.I., 2021*). There are very high risks that intense droughts could increase in number. Water deficit and high temperatures disrupt most of metabolic processes in plants, impairing hormonal balance and causing alterations in subcellular structures. The degree of damage largely depends on plants' resistance to heat and drought as well as on hydrothermal stress duration and intensity (*Parkash V. et al., 2021*).

Studying peculiarities of yield formation and developing special technology models in order to prevent risks and predict possible losses of yields are the main ways to overcome the negative impact of climatic changes on yield (*Surhan O.V., 2020*). Successful breeding of hybrids for resistance to biotic and abiotic stressors depends on the availability of starting materials with high levels of valuable morphological and biological characteristics, including heat and drought resistance. Creation of such genotypes (lines. varieties and hybrids) requires the improvement of existing methods of evaluation and selection of valuable cucumber starting materials, development of new methods and their effective application, which will allow for significant acceleration of breeding and synthesis of genotypes with high adaptive potentials *(Serhiienko O.V. et al., 2022*).

Onset dates of some phases of growth and development and lengths of both the growing period as a whole and its parts are informative breeding traits, which determine the adaptability of a genotype to growing conditions (*Serhiienko O.V., 2016*). Growing period length is determined by genotype. However, both the entire vegetation period of cucumber plants and interphase periods depend on weather and technological factors *(Kharkina T.G. & Morkovskaya Ye.F., 1999*). Soil and climatic conditions of cucumber cultivation were also demonstrated to have a significant impact on yield (*Polovyi A.M. et al., 2021*).

Cucumber is a temperature and water-demanding crop. Growth stops when temperature drops below 14.5 ºC or rises above 42 ºC. Extended periods at temperature of below 10 ºC are harmful for plants. Short frosts (below 1.5 ºC) kill cucumber plants. The most intensive growth is observed at 28-32 ºC (*Kuperman F.M.. 1982; Singh M.C. et al,. 2017*). Cucumber does not tolerate soil or air droughts. The highest yields are harvested at a relative air humidity of >90 % and a water content of 85–95 % related to the full moisture content of the soil. It was shown than insufficient air humidity could be to some extent compensated by moistening the soil (*Rahil M.H. & Qanadillo A., 2015*).

A drastic rise in temperature, large fluctuations in daily temperature maxima and minima, prolonged high temperature without sufficient soil moisture are extremely unfavorable for cucumber. A drop in temperature below 20 °C leads to a sharp reduction in the ability of plants to absorb nutrients. Even average daily air temperatures, slight daily temperature fluctuations, a slow decrease in temperature at the end of the growing period are most favorable for cucumbers (*Vashchenko S.F., 1956; Bolotskykh A.S., 2001, 2002*).

Environmental requirements of cucumber are closely associated with its origin. Its homeland is tropical regions of Southeast Asia, which are characterized by high temperatures, frequent precipitations and high sunlight intensity. However, the cultivation of cucumber for thousands of years in different climatic zones has left its mark and to a certain extent changed the ecological nature of the crop. This made it possible to create varieties and hybrids adapted to cultivation in areas with a temperate climate.

Nevertheless, an upward trend in the average daily air temperatures and uneven distribution of precipitation in the last decades are the main causes of deterioration of conditions during cucumber plants' growth and development phases, including key ones. Many scientists reported that the same variety grown under different weather conditions differed both in the entire growing period length and in its parts. Given the need of the population for sufficient amounts of vitamin-rich vegetables, the creation of new, more productive F_1 cucumber hybrids is a priority line to increase the efficiency of agricultural production and is of great social, scientific and practical importance.

Hence, the purpose of our study was to describe weather effects on the growth and development of cucumber plants of different breeding genotypes, lengths the main interphase periods, and yield in the eastern Forest-Steppe of Ukraine and to select breeding-valuable genotypes for heterosis breeding under of sharp climatic changes.

Material and Methods. The influence of agrometeorological conditions on the cucumber growth. development and yield was studies outdoors at the experimental base of the Institute of Vegetable and Melon Growing of NAAS located in the Left-Bank Forest-Steppe of Ukraine (central mid-humid area of the Kharkivska Oblast; the climate of the zone is temperate-continental) in 2019-2020.

The soil is a typical low-humus heavy loamy chernozem. The humus content in the arable layer was 4.0–4.5 %; the P_2O_5 content was 11–15 mg/100 g of soil; the K_2O content was 8–10 mg/100 g of soil; pH of salt extract was 7.0–7.5.

In 2019–2020, the weather was characterized by insufficient rainfall; air temperatures during the cucumber growing period were higher than the multi-year averages. Figures 1–3 illustrate the agrometeorological parameters (precipitation. air temperature) during the growing period in the study years.

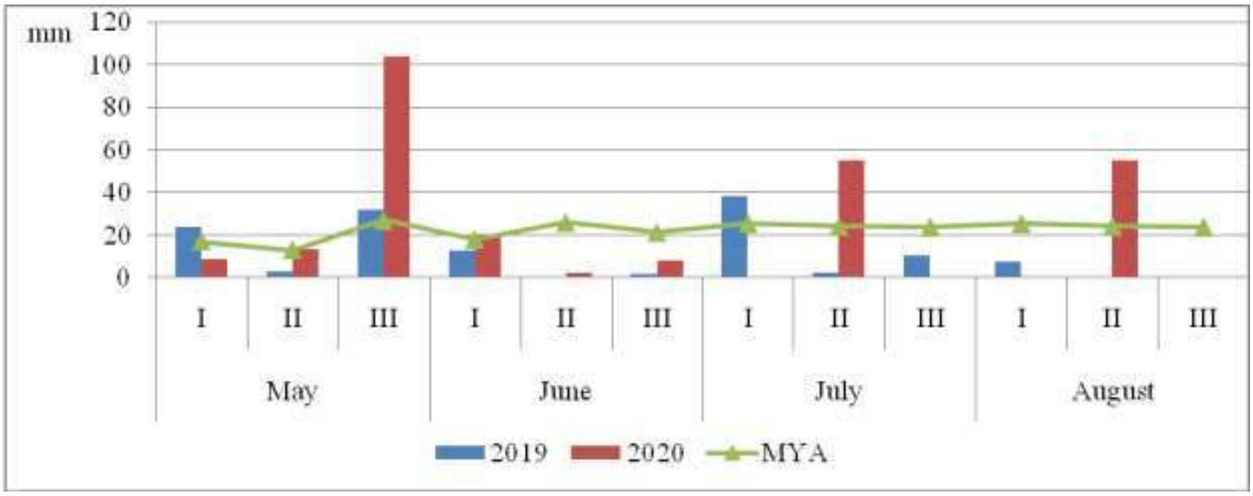

Figure 1. Precipitation (mm) profile during the cucumber growing period, 2019–2020 (MYA = multi-year average)

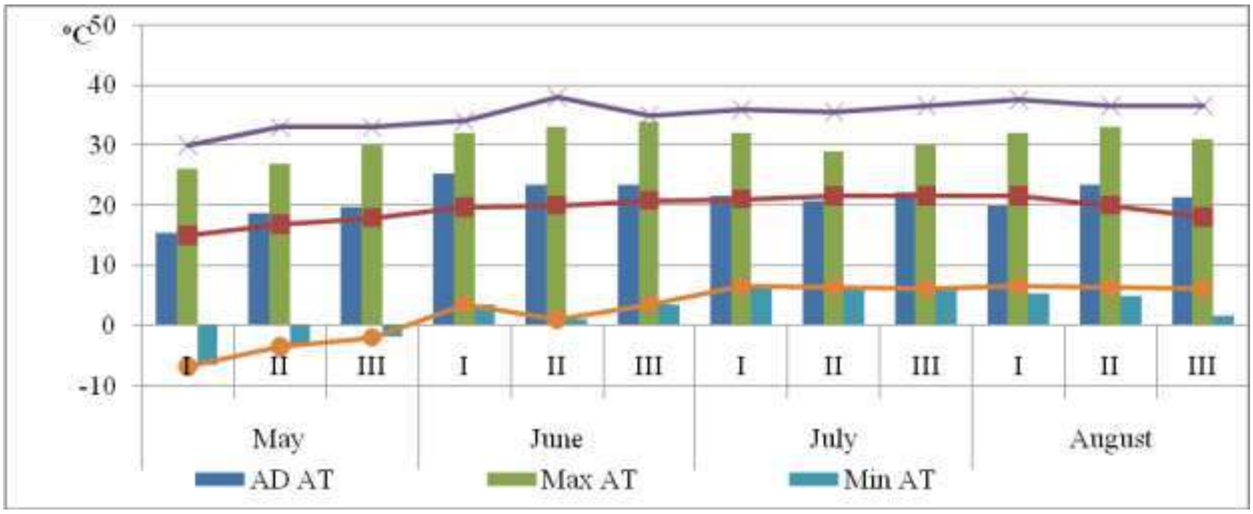

Figure 2. Air temperature profile during the cucumber growing period in 2019 (AD AT = average daily air temperature; Max AT = maximum air temperature; Min AT = minimum air temperature; MY DA AT = multi-year daily average air temperature; MYA Max AT = multi-year average maximum air temperature; MYA Min AT = multi-year average minimum air temperature)

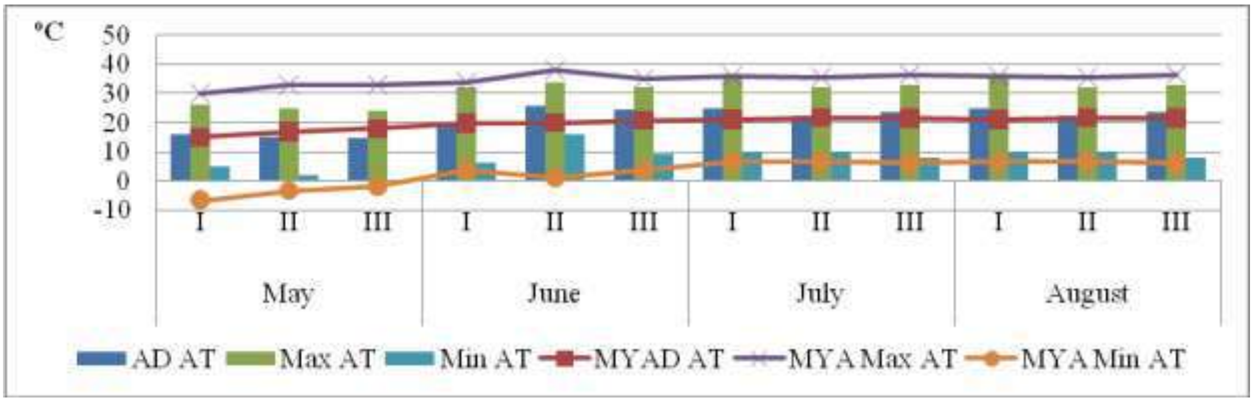

Figure. 3 Air temperature profile during the cucumber growing period in 2020 (AD AT = average daily air temperature; Max AT = maximum air temperature; Min AT = minimum air temperature; MY DA AT = multi-year daily average air temperature; MYA Max AT = multi-year average maximum air temperature; MYA Min AT = multi-year average minimum air temperature)

Breeding material in the amount of 10 F_1 hybrids obtained by synthetic selection was studied. F_1 hybrid 'Ajax' (Netherlands) was taken as the check hybrid. Phenological observations of the main periods of the growth and development of cucumber plants were done: "emergence – anthesis of female flowers", "emergence – fructification" and fructification length (*CMEA's extended harmonized classifier, 1980; Methods of state trials of agricultural crop varieties, 2001*). Fruits were harvested in accordance with the requirements of the state standard (*DSTU 3247-95, 1996*). Mathematical and statistical methods were used to process experimental data and test significance of differences (*Dospekhov B.A., 1985*). The farming techniques were conventional for the Forest-Steppe of Ukraine (*Yakovenko K.I., 2001*).

Results. The weather variability during plant growing has a considerable impact on quantitative and qualitative parameters of agricultural plant products, which significantly depend on water availability and temperature, i.e. on precipitation amount and frequency and air temperature (*Serhiienko O.V., 2016*). Different genotypes differently respond to environmental changes; therefore studies were focused on identifying cucumber hybrid combinations with high resistance to adverse environmental conditions, mainly to fluctuations in daily temperatures and soil moisture.

The temperature profile is known to have the greatest effect on the cucumber growth, development and performance. It is known that 12–13 °C is the most favorable temperature for cucumber seed germination; 22–24 °C is optimal for plant growth; at 40–45 °C physiological processes stop, so such temperatures are detrimental. The optimal temperature for cucumber plant growth is closely associated with sunlight intensity and carbon dioxide concentration *(Kuperman F.M., 1982; Singh M.C. et al., 2017; Bolotskykh. A.S., 2002*).

In 2019, the weather was favorable for the growth and development of cucumbers. Giving plants a chance to fulfill their potentials (Fig. 2). Analyzing the temperature profile, we noted that cucumber plants were exposed to significant temperature fluctuations during the growing period. In the hot summer months, plants were exposed to high temperatures (higher than 33.0 °C), which had a negative impact on the cucumber growth, development and yield. In June-August, the minimum temperature (6.0–9.0 °C) exceeded the multi-year average by 1–6.5 °C. The strongest deviations towards increasing daytime temperatures were observed starting from the 10th of June to the end of the month. On some days, the temperature reached 33–34 °C or even higher. The peak of the maximum daily air temperature was recorded at 37 °C (within the third 10 days of June). During the growing period, precipitation was not abundant, but wetting was sufficient during the crucial periods of the plant growth and development, contributing to high yields of the cucumber hybrids. The highest amount of precipitation was recorded during the third 10 days of May, which was 5.1 mm more than the multi-year average and contributed to the intensive development of plants. At the fructification onset (the first 10 days of July; a crucial period), the precipitation amount was 38 mm with the multi-year average of 25.4 mm, which ensured even fructification.

However, the weather in 2020 was less favorable for cucumber. During the cucumber emergence within the second 10 days and third 10 days of May, there were big fluctuations in the average daily (15.0–14.7 ºC) and minimum (0.0–2.0 ºC) air temperatures, significantly delaying the emergence. The traditional inflow of cold air masses during the second 10 days and third 10 days of May combined with a large amount of precipitation, which was almost five-fold compared to the multi-year average, negatively affected the emergence of seedlings, delaying (on average by 14 days) further growth and development of plants as well as harvest of marketable young cucumbers. Reproductive organs were formed during the second-third 10 days of June at high air temperature (32–34 °C) and water deficit (2.5–8.0 mm. with the multi-year average for this period of 21.2–25.9 mm). These factors slowed down the growth and development of plants, considerably reducing the number of female flowers (by 25–40 %), which is known to impair the outflow of macronutrients, to raise energy costs for evaporation, to reduce plants' resistance to diseases, and to disrupt fructification. Abundant precipitation during the third 10 days of May (104 mm. which is 77.1 mm more than the multi-year average) and the first 10 days of June (20 mm vs. the multi-year average of 17.9 mm) contributed to the intensive growth of the vegetative mass, which was ensured by the optimal temperature mode (20.2–25.8 °C). At the same time, the second 10 days and third 10 days of June were characterized by low air humidity and soil moisture because of a small amount of precipitation (2.5 and 8.0 mm. respectively. with its irregular distribution) and high average daily air temperature (24.4–25.8 °C, with the maximum of 32.0–34.0 °C). There was no precipitation at all (0.0 mm) during the first 10 days of July. At the same time, the second 10 days of July had a big (55 mm) amount of precipitation, which, combined with low average daily temperatures (22.2 °C, with the minimum of 10°C), caused intensive development of *Peronospora brassicae* and damage to cucumber plants, decreasing young cucumber yields and marketability.

We noted that the weather during the cucumber growing period significantly influenced the growth period lengths and development of promising F_1 hybrids. Lengths of phenological phases outdoors are an integrated indicator of hybrids' responses to environmental changes (Table 1).

All hybrids under investigation were grown under identical weather conditions and we found that growth and development phases did not differ significantly between genotypes within a year unlike year-to-year variations.

Data show that the "emergence – anthesis of female flowers" lasted on average 33–36 days (35 days in the check hybrid), with weather-induced 2- to 3-day differences: 30 - 35 days in 2019 and 33–37 days in 2020. Hybrids with the shortest mean periods (33 days) were selected: F_1 'SD 96-18' / 'RD 96 2-95', F_1 'BD 96-18' / 'Tsezar', F_1 'Mah-62' / 'Toma-18', F_1 'RD 96 2-95'/ 'Heim' and F_1 'SD 96-18' / 'RD 96 2-95' (*Am* = 1); F_1 'Mah-62' / 'Toma-18' and F_1 'BD 96-18' / 'Tsezar' (*Am* = 0) were most stable cross the years.

F_1 hybrids under investigation are classed as early-ripening or mid-early; their the "emergence – fructification onset" periods lasted on average 40–43 days, with weather-induced 4- to 5-day differences: 37–41 days in 2019 and 42–45 days in 2020. Hybrids that began to bear fruits earlier than the others were selected: in 2019 – F_1 'RD 96 2-95' / 'Heim' (37 days); in 2020 – F_1 'SD 96-18' / 'RD 96 2-95', F_1 'BD 96-18' / 'Tsezar' and F_1 'Mah-62' / 'Toma-18' (42 days). Analysis of the averaged data distinguished the following early-ripening F_1 hybrids: F_1 'BD 96-18' / 'Tsezar' (40 days); F_1 'Ivol D 96' / 'RD 96 2-95', F_1 'SD 96-18' / 'RD 96 2-95', F_1 'Mah-62' / 'Toma-18', and F_1 'RD 96 2-95'/ 'Heim' (41 days). F_1 'SD 96-18' / 'RD 96 2-95' (*Am* = 2 days) and F_1 'Mah-62' / 'Toma-18' (*Am* = 3 days) were most stable cross the years.

Fructification in hybrids lasted on average 26–35 days, with significant (12–16 days) weather-induced differences: 32–40 days in 2019 and 20–24 days in 2020. Long fructification (32–35 days) was intrinsic to F_1 'Mah-62' / 'Toma-18', F_1 'RD 96 2-95'/ 'Dzherelo', F_1 'BD 96-18'/ 'Heim' and F_1 'RD 96 2-95' / 'Heim'. The longest fructification was recorded for F_1 'RD 96 2-95' / 'Dzherelo' (35 days), with a variation amplitude of 16 days between the years with variation limits of 24–40 days, which was 8 days longer than in the check hybrid (27 days) or 4.5-fold compared to the sample mean. Besides the check hybrid, the smallest variation amplitude of this trait between the years was observed in F_1 'Ivol D 96' / 'RD 96 2-95' (*Am* = 13 days) and F_1 'SD 96-18' / 'RD 96 2-95' (*Am = 12* days), with the sample mean of 16.1 days.

Table 1. Interphase periods of the growth and development of F_1 cucumber hybrids (F_1 cucumber hybrid nursery. 2019-2020)

Hybrid	Number of days from emergence to						Fructification length. days		
	anthesis of female flowers			fructification onset					
	2019	2020	Mean	2019	2020	Mean	2019	2020	Mean
F_1 'Ajax' (check hybrid)	34	36	35	40	44	42	34	20	27
F_1 'Ivol D 96' / 'RD 96 2-95'	35	37	36	39	45	41	33	20	27
F_1 'SD 96-18' / 'RD 96 2-95'	33	34	33	40	42	41	32	20	26
F_1 'Krak' / 'RD-96 2-95'	32	36	34	39	45	42	40	21	31
F_1 'Mah-62' / 'Fora-18'	35	36	35	38	45	42	40	22	31
F_1 'BD 96-18' / 'Tsezar'	33	33	33	38	42	40	40	22	31
F_1 'BD 96-18'/ 'Toma-18'	32	35	34	38	45	42	40	22	31
F_1 'Mah-62' / 'Toma-18'	33	33	33	39	42	41	40	23	32
F_1 'RD 96 2-95'/ 'Dzherelo'	33	36	35	39	45	42	40	24	35
F_1 'BD 96-18'/ 'Heim'	32	36	34	41	45	43	40	24	32
F_1 'RD 96 2-95'/ 'Heim'	30	36	33	37	45	41	40	24	32
$\bar{X}$	32.9	35.3	34.1	38.9	44.1	41.5	38.1	22.0	30.5
Lim	30-35	33-37	33-36	37-41	42-45	40-42	32-40	20-24	26-35
Am	5	4	3	4	3	2	8	4	9

So, our study demonstrated that the weather in the study years had different effects on the hybrids, that is, the genotypes differently responded to changes in the environment. Three hybrids were most stable in terms of the onsets and lengths of growth and development phases: F_1 'SD 96-18' / 'RD 96 2-95', F_1 'BD 96-18' / 'Tsezar', and F_1 'Mah-62' / 'Toma-18'; their averaged data were vary similar to yearly data, with the smallest variation amplitude of the "emergence – onset of anthesis of female flowers" (*Am* = 0-1 day) and "emergence – fructification onset" (*Am* = 2–4 days) periods. F_1 'SD 96-18' / 'RD 96 2-95' should also be highlighted, as its variation amplitude for the "fructification length" trait was the smallest (12 days).

Genetic improvement to increase and maximize the performance of varieties as the ultimate indicator characterizing their economic value is a mainstream in cucumber breeding. Cucumber yield stability and amount are determined by values and ratio of quantitative traits that are formed during certain stages of organogenesis and, in turn, depend on how optimal or intensive factors that support the plant life are.

During the growing period, cucumber plants absorb water unevenly. Cucumber plants require the largest amounts of water in the phase of 2–4 true leaves, during anthesis and fructification (*Bolotskykh A.S., 2002*). Water deficit during these periods has a negative effect on the development of plants. leading to a significant decrease in the yield, especially at elevated temperature of the air.

Yield is a complex characteristic that significantly depends on growing conditions: the more favorable growing conditions are, the higher chances for genotypes to fulfill their potentials are. The yields of the hybrids under variable growing conditions, along with averaged data, are summarized in Table 2.

Table 2. Characterization of F_1 cucumber hybrids in terms of the "total yield" trait. 2019-2020

Hybrid	Total yield					
	2019		2020		Mean	
	t/ha	% to the check hybrid	t/ha	% to the check hybrid	t/ha	% to the check hybrid
F_1 'Ajax' (check hybrid)	20.8	100	17.1	100	19.0	100
F_1 'Ivol D 96' / 'RD 96 2-95'	30.3	146	24.5	143	27.4	144
F_1 'SD 96-18' / 'RD 96 2-95'	33.3	160	14.0	82	23.7	125
F_1 'Krak' / 'RD-96 2-95'	51.2	246	22.3	131	36.8	194
F_1 'Mah-62' / 'Fora-18'	40.2	193	21.1	124	30.7	162
F_1 'BD 96-18' / 'Tsezar'	45.2	217	12.7	74	29.0	153
F_1 'BD 96-18'/ 'Toma-18'	57.2	275	21.4	125	39.3	207
F_1 'Mah-62' / 'Toma-18'	64.9	312	26.9	157	45.9	242
F_1 'RD 96 2-95'/ 'Dzherelo'	44.0	212	24.3	142	34.2	180
F_1 'BD 96-18'/ 'Heim'	44.0	212	25.2	148	34.6	182
F_1 'RD 96 2-95'/ 'Heim'	46.5	224	25.1	147	35.8	189
LSD_{05}	2.61	-	3.32	-	-	-
$\bar{X}$	43.4	209	21.3	125	32.4	171
Lim	20.8-64.9	212-312	14.0-26.9	74-157	19.0-45.9	125-242
Am	44.1	100	12.9	83	26.9	117

Analysis of the obtained data made it possible to distinguish a number of F_1 hybrids by mean yield. Thus, the highest yield (45.9 t/ha) was harvested from F_1 'Mah-62' / 'Toma-18'. It should be noted that this hybrid yielded the most by years: 64.9 t/ha under the favorable weather conditions in 2019 and 26.9 t/ha in the unfavorable year of 2020, which by 2.4–fold or by 58.5 % less; it was superior to the check hybrid by 212 % or by 57 %, respectively. F_1 'BD 96-18'/ 'Toma-18' was also noticeable for its high yield (the mean yield was 39.3 t/ha; 57.2 t/ha under the favorable weather conditions in 2019 and 21.4 t/ha in the unfavorable year of 2020, which is by 2.7–fold or by 63 % less; it yielded by 175 % and 25 % more than the check hybrid, respectively.

In general, all studied hybrids tended to decrease their yields in 2020 by 1.2–3.6 times or by 19.1–71.9 %, with the sample mean of 2.1 times or 47.8 %, respectively, which again confirmed the dependence of this characteristic on weather conditions. The smallest variation amplitude of this characteristic was recorded for the check hybrid, F1 'Ajax' (*Am* = 3.7 t/ha), and F_1 'Ivol D 96' / 'RD 96 2-95' (*Am* = 5.8 t/ha), which gave low mean yields: 19.0 t/ha, 27.4 t/ha, respectively. Of the hybrids that significantly exceeded the check hybrid and yielded a lot, the following hybrids should be noted, as they were the most stable combinations with smaller variation amplitudes of this parameter: F_1 'Mah-62' / 'Fora-18' (*Am* = 19.1 t/ha), F_1 'RD 96 2-95'/ 'Dzherelo' (*Am* = 19.7 t/ha), F_1 'BD 96-18'/ 'Heim' (*Am* = 18.8 t/ha), and F_1 'RD 96 2-95'/ 'Heim' (*Am* = 21.4 t/ha), which corresponded to a decrease in this indicator by 1.7–1.9 times or by 42.7–48.0 %. The largest variation amplitude of this parameter was observed in F_1 'BD 96-18' / 'Tsezar' (32.5 t/ha, which corresponds to a decrease in this parameter by 72 % or by 3.6–fold). F_1 'SD 96-18' / 'RD 96 2-95', F_1 'Krak' / 'RD-96 2-95', F_1 'BD 96-18' / 'Toma-18' and F_1 'Mah-62' / 'Toma-18' also had wide variation amplitudes of this parameter, depending on growing conditions (*Am*=19.3-38.0 t/ha), which corresponded to a decrease in yield by 2.3 2.7 times or by 58.0–63.0 % and characterizes the these hybrids as intensive genotypes.

Conclusions. The weather in the study years reflected the climatic instability of the Forest-Steppe of Ukraine. The variability of the lengths of the main periods of the growth and development of hybrid cucumber plants and their significant variability in terms of yield under variable growing conditions were demonstrated for the genotypes under investigation. The hybrids that are valuable for further breeding were selected by average annual parameters: F_1 'BD 96-18' / 'Tsezar', F_1 'RD 96 2-95'/ 'Dzherelo', F_1 'RD 96 2-95' / 'Heim' and F_1 'Mah-62' / 'Toma-18' by early ripeness (42 days); F_1 'RD 96 2-95'/ 'Dzherelo' (35 days); F_1 'Mah-62' / 'Toma-18', F_1 'BD 96-18'/ 'Heim' and F_1 'RD 96 2-95'/ 'Heim' (32 days) by fructification length; and F_1 'Mah-62' / 'Toma-18' (45.9 t/ha), F_1 'BD 96-18'/ 'Toma-18' (39.3 t/ha), F_1 'Krak' / 'RD-96 2-95' (36.8 t/ha), F_1 'RD 96 2-95'/ 'Heim' (35.8 t/ha), F_1 'BD 96-18'/ 'Heim' (34.6 t/ha) and F_1 'RD 96 2-95'/ 'Dzherelo' (34.2 t/ha) by yield, as they yielded significantly more (by 80–142 % or by 19.0 t/ha) than the check hybrid, F_1 'Ajax'.

References

Basok, B.I., Bazieiev, Ye.T. (2020). Global warming: problems, debates and projections. *Svitohliad*. Vol. 6 (86). P. 4–15.

Deepa, S.K., Hadimani, H.P., Hanchinamani, C.N., Shet, R., Koulgi, S., Ashok, O. (2018). Studies on character association in cucumber (Cucumis sativus L.). *International Journal of Current Microbiology and Applied Sciences*. Vol. 7 (11). P. 1977–1982.
http://doi.org/10.20546/ijcmas.2018.711.224

Murri, I.K. (1961). Cucumber biochemistry. *Biokhimiya Ovoshchnykh kultur*. P. 173-205.

Vdovenko, S.A., Palamarchuk, I.I. (2021). Innovations in the technology of outdoor growing of vegetables of the gourd family: Monograph. Vinnytsia: VNAU. 184 p.

Parkash, V., Singh, S., Deb, S.K., Ritchie, G.L., Wallace, R.W. (2021). Effect of deficit irrigation on physiology, plant growth, and fruit yield of cucumber cultivars. *Plant Stress*. Vol. 1. P. 100004.
http://doi.org/10.1016/j.stress.2021.100004

Surhan, O.V. (2020). Adaptation of crop cultivation technologies to climatic changes in Ukraine. *Climatic Changes and Agriculture. Challenges to Agrarian Science and Education*: Abstracts of the 3rd International Scientific and Practical Conference (Kyiv, June 2020). P. 25–28.

Serhiienko, O.V., Harbovska, T.M., Solodovnyk, L.D., Radchenko, L.D. (2022). Breeding for resistance of cucumbers to abiotic and biotic stressors. *Agricultural Plant Breeding, Genetics and Biotechnology: Achievements, Innovations and Prospects*: International Scientific Internet-Conference dedicated to the 110th anniversary of the Plant Breeding and Genetics Institute – National Center of Seed and Cultivar Investigation (Odesa, October 26, 2022). P. 150–151.

Serhiienko, O.V. (2016). Ways of obtaining high-quality cucumbers. *Plantator*. Vol. 4 (28). P. 24–29.

Kharkina, T.G., Morkovskaya, Ye.F. (1999). Effect of fruiting on the growth and functional activity of vegetative organs of cucumber. *Fiziologiya Rasteniy*. Vol. 46 (4). P. 586–591.

Polovyi, A.M., Barsukova, O.A., Bozhko, L.Yu., Tolmachova, A.V. (2021). Influence of weather conditions on cucumber yield in the Forest-Steppe of Ukraine. P. 216–221.

Kuperman, F.M. (1982). Biology of the development of domestic plants. Moscow: Vysshaya Shkola. 342 p.

Singh, M.C., Singh, J.P., Pandey, S.K., Mahay, D., Srivastava, V. (2017). Factors affecting the performance of greenhouse cucumber cultivation-a review. *International Journal of Current Microbiology and Applied Sciences*. Vol. 6 (10). P. 2304–2323.
http://doi.org/10.20546/ijcmas.2017.610.273

Rahil, M.H., Qanadillo, A. (2015). Effects of different irrigation regimes on yield and water use efficiency of cucumber crop. *Agricultural Water Management*. Vol. 148. P. 10–15.

Vashchenko, S.F. (1956). On staged development of cucumbers. *Agrobiologiya*. Vol. 5. P. 149–150.

Bolotskykh, A.S. (2001). Vegetables of Ukraine. Kharkív: Orbita. P. 400–432.

Bolotskykh, A.S. (2002). Cucumbers. Kharkiv: Folio. 285 p.

CMEA's extended harmonized classifier and CMEA's International classifier of *Cucumis sativus* L. (1980). Leningrad. 28 p.

Methods of the state trials of agricultural crop varieties. (2001). Kyiv. Vol. 2. 68 p.

State Standard of Ukraine DSTU 3247-95 (1996). Fresh cucumbers. Specifications. Valid from 01/01/1997. Official edition. Kyiv: Derzhstandart Ukrainy. 17 p.

Dospekhov, B.A. (1985). Methods of field experimentation. Moscow: Agropromizdat. 335 p.

Yakovenko, K.I. (2001). State-of-art technologies in vegetable growing. Kharkiv. 127 p.

Serhiienko, O.V. (2016). Cucumber's stresses. *Plantator*. 3 (27). P. 25–28.

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ТРИВАЛІСТЬ ОСНОВНИХ ПЕРІОДІВ РОСТУ І РОЗВИТКУ ГІБРИДІВ F_1ОГІРКА ТА РІВЕНЬ УРОЖАЙНОСТІ В ЗАЛЕЖНОСТІ ВІД ДІЇ ПОГОДНИХ УМОВ

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Мета досліджень – виявлення впливу погодних умов на темпи росту і розвитку рослин огірка, тривалості основних міжфазних періодів, формування врожаю огірка в Лівобережному Лісостепу України та виділення селекційно-цінних генотипів для гетерозисної селекції в умовах змін клімату. **Методи.** Польові, аналітично-вимірювальні, статистичні. **Результати.** Дослідження проводилось впродовж 2019-2020 рр. в Інституті овочівництва і баштанництва НААН в умовах відкритого грунту. Погодні умови в роки проведення досліджень значно різнились, що дозволило нам оцінити їх вплив на фенологічні процеси росту і розвитку рослин огірка. Узагальнюючи результати спостережень дослідженнями встановлено, що достатньо високі показники середньодобової температури повітря (25,3-25,8°С), велика кількість опадів з нерівномірним їх розподілом (від 0 до 104 мм) та значним їх дефіцитом у окремі фази розвитку огірка мали істотний вплив на тривалість вегетаційного періоду та формування урожайності досліджуваних гібридних комбінацій огірка. Встановлено, що настання масового цвітіння жіночих квіток за роками різнилося не істотно і, в середньому, спостерігалось на 33-36 добу, у стандарту на 35 добу. Початок плодоношення у 2019 р. відбувся на 37-40 добу, у 2020 р. на 42-45 добу, що на 4-6 діб пізніше. Період плодоношення у 2019 р. тривав 32-40 діб, у 2020 р. – 20-24 доби., що на 12-16 діб довше. Аналіз динаміки формування урожайності огірка за роки досліджень показав, що погодні умови 2019 р. були більш сприятливіші для росту і розвитку рослин огірка. Так у 2019 р. загальна урожайність гібридів знаходилася в межах 20,8-64,9 т/га. У 2020 р. на тлі високих температур і низької вологості повітря загальна врожайність становила 12,7-26,9 т/га, що на 41,4-61,0 % істотно менше. **Висновки.** Погодні умови в роки досліджень відобразили кліматичну нестабільність Лісостепу України. Виявлено мінливість рівня прояву ознак тривалості основних періодів росту і розвитку рослин гібридних комбінацій огірка та значну його мінливість за врожайністю за змінних умов вирощування досліджуваних генотипів. Виділено за середньорічними показниками цінні для подальшої селекційної роботи гібридні комбінації: за ранньостиглістю – F_1 БД 96-18 / Цезар, F_1 РД 96 2-95/ Джерело, F_1 РД 96 2-95 / Гейм, F_1 Маг-62 / Тома-18 (42 доби); за тривалістю періоду плодоношення – F_1 РД 96 2-95/ Джерело (35 діб); F_1 Маг-62 / Тома-18, F_1 БД 96-18/ Гейм, F_1 РД 96 2-95/ Гейм (32 доби); за урожайністю – F_1 Маг-62 / Тома-18 (45,9 т/га), F_1 БД 96-18/ Тома-18 (39,3 т/га), F_1 Крак / РД-96 2-95 (36,8 т/га), F_1 РД 96 2-95/ Гейм (35,8 т/га), F_1 БД 96-18/ Гейм (34,6 т/га), F_1 РД 96 2-95/ Джерело (34,2 %), що істотно на 80-142 % перевищувало стандарт Аякс F_1 (19,0 т/га).

Ключові слова: гібрид, огірок, температура, опади, цвітіння, плодоношення, урожайність

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DOMINANCE AND HETEROSIS IN F_1 WATERMELON HYBRIDS

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Purpose. To evaluate heterosis in new F_1 hybrids and to select the best ones with the greatest dominance and heterosis for the "growing period length", "yield", "marketability" and "mean marketable fruit weight" traits for further use in breeding for heterosis. **Object.** Twenty-seven F_1 watermelon hybrids and 22 parents. **Methods.** General scientific, measuring and weighing, computational and statistical. **Results.** F_1 watermelon hybrids and their parents were screened for the following characteristics: lengths of interphase periods, total yield, marketability, and mean marketable fruit weight. Analysis of the growing period and its parts showed that in the hybrids the "emergence - ripening" period ranged 71 to 80 days in 2021 and 60 to 84 days in 2022. The variation limits were from 6 to 24 days. The "anthesis of male flowers - anthesis of female flowers" and "anthesis of female flowers – fruit setting" were the most stable interphase periods across the years both in the hybrids and in the parents. Eleven hybrids were classed as ultra-early, as their "emergence - ripening" period did not last longer than 63 days in 2022 or 72 days in 2021. On average in the hybrids across the study years, the variation amplitude (Am) of the "total yield" trait was 30.9 t/ha; of the "marketability" trait – 16%; of the "mean marketable fruit weight" trait – 2.9 kg. In the parents, *Am* was 43.1 t/ha, 20% and 2.8 kg for the 'total yield', 'marketability" and "mean marketable fruit weight" traits, respectively. The variation limits (*Lim*) of the "yield" and "marketability" traits in the parents were wider than those in the hybrids. On the opposite, the variation limits of the "% to the check accession" and "mean marketable fruit weight" traits in the study years were wider in the hybrids. In breeding for yield, 10 F_1 hybrids, which were significantly superior to the check F_1 hybrid, 'Kazka', (130-166% to the check hybrid), are of practical value. Analysis of dominance and heterosis in the F_1 hybrids allowed us to select the best combinations with the greatest dominance and heterosis for yield (*hp*=0.39-3.94; *X*=101-136), marketability (*hp*=0.11-7.00; *X*=101-106) and mean marketable fruit weight (*hp*=0.26-99.00; *X*=100-164). Based on high indicators of dominance and heterosis, 10 F_1 hybrids were selected for further breeding; they were also noticeable for a set of economically valuable characteristics: early ripening, high yield, marketability, evenness, resistance to biotic factors, etc. Fruits of the selected hybrids are attractive in appearance and have excellent palatability. The selected F_1 hybrids are valuable for breeding to create competitive first-generation watermelon hybrids. **Conclusions.** The interphase periods that were most stable across the years were determined. Eleven ultra-early hybrids were selected. Ten F_1 hybrids, which in two study years were significantly superior to the check F_1 hybrid, 'Kazka', (130-166% to the check hybrid), are of practical value. High marketability was noted in 6 hybrids. Analysis of dominance and heterosis in the F_1 hybrids allowed us to select 10 combinations with the greatest dominance and heterosis for yield (*hp*=0.39-3.94; *X*=101-136), marketability (*hp*=0.11-7.00; *X*=101-106) and mean marketable fruit weight (*hp*=0.26-99.00; *X*=100-164) for further breeding, as they are of practical value for heterosis breeding

Key words: watermelon, breeding, F_1 hybrid, breeding trait, dominance, heterosis, breeding value.

Introduction. Watermelon (*Citrullus lanatus* (Thumb.) Matsum. Et Nakai) is a valuable food product; it is a source of vitamins and medicinal ingredients, which are important for health. Watermelons are grown for ripe juicy fruits that are rich in sugars. Depending on growing conditions, the sugar content can vary from 4 to 12%. Watermelon is rich in vitamin B9 some essential amino acids and mineral salts (*Kravchenko V.O., Prylipko O.V.*, 2002). Watermelons contain easily digestible calcium and iron salts and are used as a remedy for various diseases. Fruits are used mainly fresh, but can be processed. Expansion of the assortment of highly adaptable watermelons is very important.

New gourd varieties and hybrids allow for a 15-20% increase in yields without significant additional costs. Hybrids are obtained via hybridization of two specially created and well-selected initial parent forms. F_1 hybrid plants are more homogeneous and uniform in their biological and morphological characteristics than conventional varieties. However, one should take into account that as the yield capacities varieties and hybrids grow, their demand for cultivation technologies increases considerably and the yield amount and quality becomes more dependent both on biotic and abiotic factors.

The global approach to fulfillment of the biological potential of watermelons consists in the use of various genetic methods to change the heredity of plants, among which heterosis breeding holds a special place. In the context of agriculture intensification, new requirements are put forward to new genotypes; the main of them are high uniformity of traits and features, stability of their expression, high yield, and top quality of products. These objectives can be solved by using heterosis, a genetic phenomenon, which has been widely used in vegetable and gourd breeding over the past fifty years.

Analyzing successes in the breeding of commercial hybrids, we should note that they depend on the availability of a wide assortment of specific lines, which allows for a quicker response to changes of the current market. In addition, with heterozygous hybrids, it is easier to protect copyright and conduct effective controlled seed production.

Review of Recent Studies and Publications. As of today, there are 127 watermelon varieties and hybrids in the Register of Plant Varieties Suitable for Dissemination in Ukraine. Most of them are varieties and only 22.8% of the watermelons in the Register are hybrids (4.7% of them were bred in Ukraine). For today's conditions, the Register comprises too few hybrids, as due to heterosis, it is possible to increase yields by 15-30% (State Register of Plant Varieties Suitable for Dissemination in Ukraine in 2022).

Today, hybrid breeding is much more promising than variety breeding, which is almost at the end of its resources, having reached the biological limit of performance. In hybrids, it is no problem to combine important features such as yield, resistance, fruit quality, adaptability, etc. significantly increasing the efficiency of heterosis breeding. Varieties of any crop have a common genetic basis and are highly related, and it is genetically regulated heterosis that can give new opportunities for increasing the efficiency of breeding and for providing the population with high-quality vegetable and gourd products in scientifically justified quantities. Most breeders came to the conclusion that stable heterosis in watermelons could be only achieved in interline hybrids from homogeneous lines. Heterosis is manifested when environmentally and geographically distant forms are crossed, especially if the female line is a local form, and the male form is distant in origin (*Kravchenko V., Prylypko O.*, 2002).

As above mentioned, new high-yielding varieties and hybrids with high fruit quality and resistance to biotic and abiotic factors are an important factor in achieving high yields (*Umbertayev I., Makhmadzhanov S. (Eds.), 2015; Zhou, X.G., Everts, K.L., 2004; Serhiienko O.V., 2017*). Cultivation of varieties and hybrids with complex resistance are ecologically safe, meaning no pollution of the environment or residual amounts of pesticides in products. Identification of new sources of valuable traits, including those with a strong heterosis effect, is a very important area in gourd studies, as it can solve the problem of competitive hybrids with desirable parameters.

50% of the foreign market is represented by watermelon hybrids. The Dutch company Nunhems Zaden is the world's leader in creating heterotic watermelon hybrids; every year it offers new competitive hybrids, for example: 'Crisby', 'Trophy', 'Lady', 'Dumara', 'Red Comet', 'Red Star', etc. Seminis Vegetable Seeds, Inc, which created hybrids 'Crimson Glory', 'Madera', 'Pata Negra', 'Royal Majesty', 'Royal Sweet', 'Red Sweet', etc., was an active player in this field. Russian, Hungarian, Chinese, Japanese, and American breeders are intensively working to create heterotic watermelon hybrids (*Global market of watermelons and melons, 2019*).

The leading countries worldwide refuse to grow varieties and massively introduce heterotic hybrids into agricultural production, which characterizes the current policy. The main advantage of hybrids is not only heterosis in terms of performance (30%), but also their ability to combine traits that are difficult to combine in varieties. (*Orliuk A.P., Didenko V.P., 2009; Sokolov S.D., 2003*). As gourd cultivation becomes more popular in the private sector, the demand for attractively looking, high-yielding, short-season, top-quality, intensive, simultaneously ripening, heterotic hybrids has increased. Consumers need delicious, disease-resistant, early-ripening, cold-resistant, cheap, new hybrids with long shelf lives. Success in the breeding of commercial hybrids depends on the availability of a wide assortment of specific lines, which allows for a quicker response to changes in the current market. It is hybrids that can yield more, combining several economically valuable traits in one genotype and additionally facilitating copyright protection of completed scientific innovations. Hybrid breeding promotes close interactions between seed producers and originators, positively affecting the entire production process of vegetables and fruits and introduction of domestic developments at agrarian enterprises of various forms of ownership.

Hence, the study was focused on evaluating dominance degrees and heterosis effects in new watermelon hybrids (in comparison with their parents) versus the check accessions for further use in breeding for heterosis.

Purpose. To evaluate heterosis in new F_1 hybrids and to select the best ones with the greatest dominance and heterosis for the "growing period length", "yield", "marketability" and "mean marketable fruit weight" traits for further use in breeding for heterosis.

Materials and methods. The experiments were carried out in the experimental breeding crop rotation fields of the Institute of Vegetable and Melon Growing of NAAS located in the Left-Bank Forest-Steppe of Ukraine (central moderately humid area of the Kharkivkyi District of the Kharkivska Oblast) in 2021-2022. The climate of the study site is temperate-continental. The experiments were carried out outdoors on a natural background of infections. Twenty-seven F_1 watermelon hybrids and 22 parents were studied. F_1 hybrid 'Kazka' (Ukraine) and variety 'Max Plus' (Ukraine) were taken as check accessions. The record plot was 19.6 m^2. The experiments were conducted in two replications. Economically valuable characteristics in the hybrids were evaluated in comparison with those in their parents. Dominance degree and heterosis in the F_1 watermelon hybrids were determined. The study was conducted in accordance with conventional methods (*Horova T.K., Yakovenko K.I. (Eds.), 2001; Yakovenko, K. I. (Eds.), 2001; Korniienko S. I., Serhiienko O. V., Krutko R. V., 2016; Lymar A.O. et al. , 2001*). Data were statistically processed, as BA Dospekhov described (*Dospekhov V.A., 1985*). Data were mathematically processed in Statistica. Dominance degree and heterosis effect were determined, as it is recommended in the guidebook "Genetics of Quantitative Traits. Genetic Crossings and Genetic Analysis" (*Litun P.P., Proskurnin N.V., 1992*). The farming techniques were traditional for watermelon growing in this soil/climate zone (Yakovenko, K. I. (Eds.), 2001; DSTU5045:2008, 2008).

Results. The F_1 watermelon hybrids and their parents were screened for the following characteristics: lengths of interphase periods, total yield, marketability, and mean marketable fruit weight.

Analysis of the growing period and its parts showed that the "emergence - ripening" period in the hybrid ranged 71 to 80 days in 2021 and 60 to 84 days in 2022. In the parent, this period was 75-82 days (2021) and 67-84 days (2022). The variation amplitude of the growing period parts was 6 - 24 days. On average across the study years, the variation limits (*Lim*) were 66-82 days in the hybrids and 71-83 days in the parent; the variation amplitude (A_m) of the "emergence - ripening" period was 16 days in the hybrids and 12 days in the parents (Table 1).

All hybrids and parents were classed as early-ripening by growing period and its parts. The maximum variation range was recorded for the "emergence - stem formation" and "emergence - ripening" interphase periods. The "anthesis of male flowers – anthesis of female flowers" and "anthesis of female flowers – fruit setting" were the most stable interphase periods across the years both in the hybrids and in the parents.

The following F_1 hybrids were categorized as ultra-early: F_1 'Limono 2/Mak', F_1 'Leshchyna/Mak', F_1 'Mak'/'Lypa', F_1 'Limono 2'/'Pershyi', F_1 'Shar'/'Leshchyna', F_1 'Mak/'No. 543', F_1 'No. 543'/'Mak', F_1 'Pershyi'/'Chorna', F_1 'Chorna'/'Pershyi', F_1 'Ohoniok'/'Chorna', and F_1 'Br-19'/'Shar'. The "emergence - ripening" period in these hybrids was not longer than 63 days in 2022 or 72 days in 2021.

The variation amplitude (A_m) of the total yield in the F_1 hybrids was 28.6 t/ha and 47.2 t/ha in 2021 and 2022, respectively; the variation limits (*Lim*) were 15.4-43.0 t/ha and 32.0-79.2 t/ha, respectively (Table 2).

On average in the hybrids across the study years, the variation amplitude (A_m) of the "total yield" trait was 30.9 t/ha; of the "marketability" trait – 16%; of the "mean marketable fruit weight" trait – 2.9 kg. In the parents, A_m was 43.1 t/ha, 20% and 2.8 kg for the 'total yield', 'marketability" and "mean marketable fruit weight" traits, respectively. The variation ranges (*Lim*) of the "yield" and "marketability" traits in the parents were wider than those in the hybrids. On the opposite, the variation ranges of the "% to the check accession" and "mean marketable fruit weight" traits were wider in the hybrids.

Table 1. Variation ranges and limits of the growing period parts in the F_1 hybrids and parent, days (2021-2022)

Variation range and amplitude of the interphase period		Interphase period							
		Emergence – stem formation	Emergence – anthesis of female flowers	Emergence – fruit setting	Shooting – anthesis of female flowers	Shooting – fruit setting	Anthesis of male flowers – anthesis of female flowersві-	Aanthesis of female flowers – fruit setting	Emergence – ripening
F_1 hybrids									
2021	*Lim*	22 - 30	37-43	38-47	7-17	11-19	1 - 7	1-10	71-80
	A_m	8	6	9	10	8	6	9	9
2022	*Lim*	20 - 34	32-43	35-47	6-21	11-22	1 - 8	1-9	60-84
	A_m	14	11	12	15	11	7	8	24
Mean ($\bar{X}$)	*Lim*	21-32	35-43	37-47	7-19	11-21	1-8	1-9	66-82
	A_m	11	8	10	12	10	7	8	16
Parents									
2021	*Lim*	21-44	38-42	38-47	5-19	3-21	1-7	1-10	75-82
	A_m	23	14	9	14	18	6	9	7
2022	*Lim*	14 - 30	26-41	34-46	6-17	10-22	2 - 8	2-9	67-84
	A_m	16	15	12	11	12	6	7	17
Mean ($\bar{X}$)	*Lim*	18-37	32-	36-47	6-18	7-22	2-8	2-10	71-83
	A_m	19	10	11	12	15	6	8	12

The following F_1 hybrids, which in two years of research significantly (130-166% to the check accession) outperformed the F_1 check hybrid, ‘Kazka’, are valuable in breeding for yield: F_1 ‘Br-19’/‘Rada’, F_1 ‘Harna’/‘K 605’, F_1 ‘Lypa’/‘Harna’, F_1 ‘Limono 2’/‘Mak’, F_1 ‘Leshchyna’/‘Mak’, F_1 ‘Mak’/‘Lypa’, F_1 ‘Mak’/‘No. 543’, F_1 ‘Lypa’/‘Mak’, F_1 ‘Harna’/‘Mak’, and F_1 ‘No. 543’/‘Mak’. High marketability was noted in F_1 ‘Lypa’/‘Mak’, F_1 ‘No. 543’/‘Mak’, F_1 ‘Shar’/’Br-19’, F_1 ‘Lypa’/ ‘Harna’, F_1 ‘K 605’/ ‘Harna’, and F_1 ‘Limono 2’/ ‘Pershyi’.

In 2021-2022, the dominance degree and heterosis were determined (Table 3).

The variation amplitude (*Am*) of the dominance degree (*hp*) for the “yield” trait was 4.56, with *Lim* of -0.62-3.94 in 2021; in 2022, *Am* was 16.93 and *Lim* was - 15.54-1.39. The variation amplitude (A_m) for the heterosis effect (*X*) for the “yield” trait was 37, with the variation range of 99-136 in 2021; in 2022, the corresponding indicators were 93 and 49-170.

Having determined the dominance degree and heterosis effect in the F_1 hybrids, we selected combinations with the highest degree of dominance and strongest effect of heterosis for the "yield", "marketability" and "mean marketable fruit weight" traits. Ten best F_1 hybrids were selected for further breeding due to their high degree of dominance and strong effect of heterosis.

The selected F_1 hybrids were also noticeable for a set of economically valuable characteristics (high yield, marketability, uniformity, resistance to biotic factors, etc) in comparison with the check hybrid (Table 4).

Table 2. Variation ranges and limits of yield constituents in the F_1 hybrids and parent, 2021-2022

Variation range and amplitude of yield constituents		Total yield, t/ha	Total yield, % to the check accession	Marketability, %	Mean marketable fruit weight, kg
F_1 hybrids					
2021	*LSD₀₅*	2.19			
	Lim	15.4-43.0	59-166	57-65	1.8-3.7
	A_m	28.6	106	8	1.9
2022	LSD_{05}	3.5			
	Lim	32.0-79.2	74-181	75-99	0.9-4.9
	A_m	47.2	107	24	4.0
Mean ($\bar{X}$)	*Lim*	23.7-54.6	67-173	66-82	1.4-4.3
	A_m	30.9	106	16	2.9
Parents					
2021	LSD_{05}	2.7			
	Lim	15.4-40.1	59-155	57-65	1.9-3.1
	A_m	24.7	96	8	1.2
2022	LSD_{05}	7.7			
	Lim	18.5-60.1	38-125	60-92	1.4-5.9
	A_m	51.6	87	32	4.5
Mean ($\bar{X}$)	*Lim*	17.0-50.1	49-140	59-79	1.7-4.5
	A_m	43.1	91	20	2.8

Table 3. Dominance degree (hp) and heterosis effect (X) in the best F_1 watermelon hybrid, mean for 2021-2022

Hybrid		Yield *hp*	Yield *X*	Marketability *hp*	Marketability *X*	Mean marketable fruit weight *hp*	Mean marketable fruit weight *X*
F_1 ‘Lypa’/‘Mak’		2.82	128	7.00	106	2.60	125
F_1 ‘Leshchyna’/‘Mak’		2.06	101	0.50	102	99.00	122
F_1 ‘Limono 2’/‘Pershyi’		1.70	115	1.00	104	3.67	126
F_1 ‘Shar’/‘Leshchyna’		1.24	121	1.00	105	3.67	126
F_1 ‘No. 543’/‘Mak’		2.25	136	1.00	102	0.26	100
F_1 ‘Limono 2’/‘Mak’		0.39	105	0.40	101	1.40	112
F_1 ‘Skarbnytsia’/‘Such’		3.94	136	5.00	118	4.00	106
F_1 ‘Mak’/‘No. 543’		0.61	118	0.11	101	1.9	133
F_1 ‘Lypa’/‘Harna’		0.98	124	1.00	102	19.00	106
F_1 ‘Br-19’/‘Rada’		1.39	170	0.60	105	5.80	164
In the entire sample (27 accessions):							
2021	*Lim*	-0.62-3.94	99-136	-3.00-7.00	98-118	-0.67-5.80	91-133
	A_m	4.56	37	10	20	6.47	42
2022	*Lim*	-15.54-1.39	49-170	-19.0-1.33	79-118	-0.6-89.0	72-133
	A_m	16.93	93	20.33	39	89.6	61

Table 4. Characterization of the best F_1 watermelon hybrids in terms of economically valuable characteristics, mean for 2021-2022

Hybrid	Economic characteristics				
	"Emergence – ripening" period, days	Yield		Marketability, %	Mean marketable fruit weight, kg
		Total yield, t/ha	% to the check accession		
F_1 'Kazka' (check hybrid)	79	31.5	100	87	3.0
F_1 'Lypa'/'Max Plus'	73	43.0	137	82	3.1
F_1 'Leshchyna'/'Maks Plus'	71	54.6	173	93	2.9
F_1 'Limono 2'/'Pershyi'	74	40.7	129	84	2.7
F_1 'Shar'/'Leshchyna'	76	37.5	119	96	2.4
F_1 'No. 543'/'Maks Plus'	76	41.3	131	90	2.3
F_1 'Limono 2'/'Maks Plus'	73	41.1	130	81	2.6
F_1 'Skarbnytsia'/'Sich'	75	33.8	107	84	2.4
F_1 'Maks Plus'/'No. 543'	73	41.6	132	89	2.6
F_1 'Lypa'/'Harna'	78	50.6	161	81	3.0
F_1 Bryz'/'Radost'	75	39.2	124	82	3.0
Mean ($\bar{X}$) for the entire sample (27 accessions):					
Lim	66-82	23.7-54.6	67-173	66-82	1.4-4.3
A_m	16	30.9	106	16	2.9

Fruits of the selected F_1 hybrids were attractive in appearance, had excellent palatability, ripened early and are valuable in breeding to create competitive F_1 watermelon hybrids.

Conclusions. The F_1 watermelon hybrids and their parents were screened for lengths of interphase periods, yield, marketability and mean marketable fruit weight. The "anthesis of male flowers - anthesis of female flowers" "anthesis of female flowers - fruit setting" interphase periods were found to be most stable across the years both in the F_1 hybrids and in the parents. Eleven ultra-early hybrids were identified; their "emergence - ripening" periods were not longer than 63 days in 2022 or 72 days in 2021. In breeding for yield, 10 F_1 hybrids are of the practical value, because in two years of research they were significantly superior (130-166% to the check hybrid) to 'Kazka' (F_1 check hybrid). High marketability was noted in 6 hybrids. Having determined the dominance degree and heterosis effect in the F_1 hybrids, we selected combinations with the highest degree of dominance and strongest effect of heterosis for the "yield" (hp = 0.39-3.94; X = 101-136), "marketability" (hp = 0.11-7.00; X = 101-106) and "mean marketable fruit weight" (hp = 0.26-99.00; X = 100-164) traits. Based on high degrees of dominance and strong effect of heterosis, the following 10 F_1 hybrids were selected for further heterosis breeding; they were also noticeable for a set of economically valuable characteristics (early ripening, high yield, good marketability): F_1 'Lypa'/'Mak', F_1 'Leshchyna'/'Mak', F_1 'Limono 2'/'Pershyi', F_1 'Shar'/'Leshchyna', F_1 'No. 543'/'Mak', F_1 'Limono 2'/'Mak', F_1 'Skarbnytsia'/'Sich', F_1 'Mak'/'No. 543', F_1 'Lypa'/'Harna', and F_1 'Br-19'/''Rada'.

References

State register of plant varieties suitable for dissemination in Ukraine in 2022. (extract as of 10/21/2022) URL: https://sops.gov.ua/reestr-sortiv-roslin (cited on 10/26/2022).

Dospekhov, B.A. (1985) *Methods of field experimentation*. Moscow: Agropromizdat. 351 p.

Horova, T.K., Yakovenko, K.I. et al. (2001). *Current methods of vegetable and melon breeding.* Kharkiv: Osnova. 369 p.

Jalal, A.A. (2012) Genetic variation, heritability, phenotypic and genotypic correlation studies for yield and yield components in promising barley genotypes. *Journal of Agricultural Science*. 4 (3). 194–210.

Korniienko, S.I., Serhiienko, O.V., Krutko, R.V. Methodical approaches to the selection and creation of watermelon starting material in heterosis breeding: monograph. Kharkiv, 2016. 106 p.

Kravchenko, V.O., Prylypko, O.V. (2002). Vegetable breeding and seed production indoors. Kyiv: Ahrarna Nauka. 262 p.

Litun, P.P., Proskurnin, N.V. Genetics of quantitative traits. Genetic crossings and genetic analysis: Manual. Kyiv: UMK VO, 1992. 100 p.

Lymar, A.O. et al. Methods of breeding and field experiments with gourds: methodical recommendations. Kyiv: Ahrarna Nauka, 2001. 132 p.

Mazur, V.A., Palamarchuk, V.D., Polinchak, I.S. et al. (2017). *Novel farming techniques in plant production*. Vinnytsia 588 p.

Nunhems Ukraine http://www.nunhems.ua/www/nunhemsinternet.nsf /id/ UA_UK_Watermelon-WMW (cited on 02/03/2019).

Orliuk, A.P., Didenko, V.P. Theoretical and practical aspects of gourd breeding: monograph. Kherson: Ailant, 2009. 320 p.

Serhiienko, O.V. Watermelon diseases. Plantator, Kyiv, 2017. No. 4 (34), P. 108-110.

Sokolov, S.D. Fundamentals of hybrid gourd seed growing. Melon growing in Russia (problems and solutions): Abstracts of the Scientific and Practical Conference within the framework of the "Russian Watermelon" festival (Astrakhan, August 23-24, 2002). Astrakhan, 2003. P. 20–26.

Global market of watermelons and melons. https://www.profihort.com/2019/06/svitovij-rinok-kavuna-ta-dini-2/ (cited on 03/04/2019).

Umbertayev, I., Makhmadzhanov, S., Dzhunusova, M. Disease resistance in gourd cultivars in the south of Kazakhstan. *Scientific journal on agriculture "Manas*". Almaty, 2015. No. 5 (1), P. 7–12.

Yakovenko, K.I. (2001) *State-of-art technologies in vegetable production*. Kharkiv: IOBNAAN. 369 p.

Zhou, X.G., Everts, K.L. (2004) Quantification of root and stem colonization of watermelon by Fusarium oxysporum f. sp. niveum and its use in evaluating resistance. *Phytopathology*, 94:832-841.

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СТУПІНЬ ДОМІНАНТНОСТІ ТА ЕФЕКТ ГЕТЕРОЗИСУ ГІБРИДНИХ КОМБІНАЦІЙ F_1 КАВУНА

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Мета. Визначити рівень прояву гетерозису в нових гібридних комбінацій F_1 та виділити кращі з найвищими показниками ступеня домінантності та ефекту гетерозису за ознаками «тривалість вегетаційного періоду», «урожайність», «товарність» та «середня маса товарного плоду» для подальшого використання у селекції на гетерозис. **Об'єкт.** 27 гібридних комбінацій F_1 кавуна та 22 батьківські форми. **Методи.** Загальнонаукові, вимірювально-вагові, розрахункові, статистичні. **Результати.** Проведено скринінг гібридних комбінацій F_1 та батьківських форм кавуна за ознаками: «тривалість міжфазових періодів», «загальна урожайність», «товарність» та «середня маса товарного плоду». Аналіз тривалості вегетаційного періоду та його складових показав, що розмах варіювання періоду «сходи – достигання» у гібридних комбінацій у 2021 році складав 71-80 діб, у 2022 році – 60-84 доби. Ліміт варіювання рівня показників складав від 6 до 24 діб. Найбільш стабільна за роками досліджень тривалість міжфазових періодів «цвітіння чоловічих квіток – цвітіння жіночих квіток» та «цвітіння жіночих. квіток – зав'язування плодів», як у гібридних комбінацій, так й батьківських форм. До надранніх гібридних комбінацій було віднесено 11 форм, у яких період «сходи – достигання» гібридних комбінацій не перевищував 63 доби у 2022 р. та 72 доби у 2021 р. У середньому за роки досліджень амплітуда варіювання (A_m) гібридних комбінацій ознаки «загальна урожайність» дорівнювала 30,9; товарності – 16; ознаки «середня маса товарного плоду» - 2,9. У батьківських форм (A_m) ознаки «загальна урожайність» дорівнювала 43,1; товарності – 20; ознаки «середня маса товарного плоду» - 2,8. Розмах варіювання (*Lim*) батьківських форм був більшим за гібридних комбінацій для ознак «урожайність» і «товарність», розмах варіювання ознак «відсоток до стандарту» та «середня маса товарного плоду» за роки досліджень був більше навпаки у гібридних комбінацій. Для селекційної роботи на ознаку "урожайність" практичну цінність становлять 10 гібридних комбінації F_1, які за два роки досліджень істотно (130 – 166 % відносно стандарту) перевищували стандарт Казка F_1. У результаті визначення ступеня домінантності й ефекту гетерозису гібридних комбінацій F_1 виділено кращі гібридні комбінації з найвищими показниками ступеня домінантності та ефекту гетерозису за ознаками «урожайність» (hp=0,39-3,94; X=101-136), «товарність» (hp=0,11-7,0; X=101-106) та «середня маса товарного плоду» (hp=0,26-99,00; X=100-164). За високими показниками ступеня домінантності та ефекту гетерозису для подальшої селекційної роботи виділено 10 гібридних комбінацій F_1, які відрізняються також за комплексом господарсько-цінних показників – ранньостиглістю, високою врожайністю, товарністю, вирівняністю, стійкістю до біотичних чинників та ін. Плоди, виділених гібридних комбінацій, мають привабливий зовнішній вигляд та високі смакові якості. Виділені гібридні комбінації F_1 мають цінність для селекційної роботи зі створення конкурентоздатних гібридів кавуна першого покоління. **Висновки.** Визначено найбільш стабільні за роками складові вегетаційного періоду. Виділено 11 надранніх гібридних комбінацій. Практичну цінність становлять 10 гібридних комбінації F_1, які за два роки досліджень істотно (130 – 166 % відносно стандарту) перевищили стандарт Казка F_1. Високу товарність було відмічено у 6 гібридних комбінацій. У результаті визначення ступеня домінантності й ефекту гетерозису гібридних комбінацій F_1 виділено 10 гібридних комбінацій F_1 з найвищими показниками ступеня домінантності та ефекту гетерозису за ознаками «урожайність» (hp=0,39-3,94; X=101-136), «товарність» (hp=0,11-7,00; X=101-106) та «середня маса товарного плоду» (hp=0,26-99,00; X=100-164) для подальшої селекційної роботи, які становлять практичну цінність для гетерозисної селекції.

Ключові слова: кавун, селекція, гібридна комбінація F_1, селекційна ознака, ступень домінантності, ефект гетерозису, селекційна цінність.

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BREEDING VALUE OF SHALLOT CULTIVARS AND LOCAL FORMS IN TERMS OF ECONOMIC CHARACTERS FOR THE RIGHT-BANK FOREST-STEPPE OF UKRAINE

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Purpose. To indentify the best shallot cultivars and local forms by growing period length, bulb yield, leaf productivity, and bulb weight and number per clump in the Right-Bank Forest-Steppe of Ukraine. **Methods.** Statistical processing, field assessments, computational and analytical methods. **Results.** Collection shallot accessions were evaluated for growing period lengthand, bulb weight, number and performance. Early-ripening accession 'Sh-8' with a vegetation period of 74 days was selected. Local form 'Sh-1' from the Kyivska Oblast region turned out to be the best in terms of the mean bulb weight per clump (26.7 g). Accessions from Kyivska ('Sh-1', 'Sh-2'), Dnipropetrovska ('Sh-6', 'Sh-9'), and Chernihivska ('Sh-10') Oblasts yielded the most (30.5, 25.4, 18.9, 18.1, and 19.4 t/ha, respectively). The check cultivar, 'Lira', yielded 15.5 t/ha. The smallest yields were harvested from the following accessions: 'Sh-4' (12.2 t/ha), 'Sh-7' (12.0 t/ha), 'Sh-11' (11.9 t/ha), 'Sh-12' (13.8 t/ha ha), 'Sh-13 (13.2 t/ha), and 'Sh-14' (13.0 t/ha). Two accessions, which came from the Kyivska ('Sh-3)' and Dnipropetrovska ('Sh-6') Oblasts were found to be best adapted to the environmental conditions of the Right-Bank Forest-Steppe of Ukraine. Their Lewis's phenotypic stability factors were close to 1. A local form from the Dnipropetrovska Oblast, 'Sh 9' was the worst adapted accessions, as its Lewis's phenotypic stability factor was as high as 1.2. The maximum leaf length was recorded for accessions from the Kyivska ('Sh-1', 'Sh-2'; 38.0 and 35.8 cm, respectively) and Chernihivska ('Sh-10'; 36.2 cm) Oblasts. **Conclusions.** Due to this study, shallot accessions with short growing periods, great weights and numbers of bulbs and yield were selected for the conditions in the Right-Bank Forest-Steppe of Ukraine. 'Sh-1' sample originating from the Kyivska Oblast showed the best results in terms of the bulb weight (26.7 g) and yield (30.5 t/ha). However, it turned out to be late-ripening (86 days), and only formed on average 4 bulbs per clump. The maximum leaf length was 38 cm was. 'Sh-8', a local form from the Dnipropetrovska Oblast, was the most early-ripening (74 days).

***Key words**:* shallots, yield, growing period, cultivars, local forms, bulb weight, leaf traits.

Introduction. Shallot (*Allium sera var. aggregatum* G.Don.) is a vegetable that is commonly grown in tropical countries, including Indonesia, and used as a spice for daily cooking, medicine, cosmetics, and dietary supplements (*Stanley J. Kays, 2011*). It is a valuable and indispensable consumer product in Indonesia, which is confirmed by annually increasing product consumption and price fluctuations (*Herlina L. et al., 2019*). Shallot production reaches 7.21% of the total vegetable production in Indonesia and ranks third after cabbages and potatoes (*Rahmawati A. et al., 2018, Arifin B. et al., 2019*). Its pungent aroma and unique palatability are indispensable for cooking (*Tabor G., 2018*). Shallots are used to treat some diseases in folk medicine, as the plant contains antiseptic compounds with antimicrobial activities (*Askari-Khorasgani & Pessarakli M., 2019; Wulaisfan R., Musdalipah, & Nurhadiah, 2018*). The first positions in the annual production of bulbs are occupied by China and Japan - more than 500,000 tons, followed by New Zealand, Mexico, Iran, Iraq, Cambodia and Cameroon (*FAOSTAT, 2018*).

Recently, the demand for shallots in the globalproduction has risen significantly, resulting in intensification of the breeding of this crop, which requires searching for and studying local forms that are widespread in Ukraine (*Korniienko S. I. et al., 2013; Bilenka O. M., 2015; Bilenka O.M., 2018*). Creation of new cultivars is a long and expensive process. However, screening of existing local forms for adaptation to production in certain environmental conditions and their use as starting materials in breeding can accelerate this process. Development and evaluation of available shallot cultivars is a sustainable strategy to boost performance and production. Tolerant local forms is one of the most effective and inexpensive options.

Review of Recent Studies and Publications. Shallot is a close relative of onion. Shallot, despite some differences in anthesis time, easily crosses with onion and gives fertile offspring, and these two varieties show a strong cytological and morphological similarity (*Rabinowitch & Kamenetsky, 2002*).

Since shallot reproduce itself mainly vegetatively, pathogens (fungi, bacteria and viruses) are accumulated in bulbs, worsening performance and quality. Use of bulbs as planting material poses several problems: a large amount (1.2 t/ha) of bulbs is required, which is expensive and requires long storage with significant post-harvest losses. Bulbs also pass fungal diseases, such as *Fusarium* spp., and latent viruses (*SLV*) from generation to generation (*Kotlinska T., 1995*). Great damage is caused by sucking pests (nematodes, thrips, mites, and onion sucker), which overwinter between dry and juicy scales during storage, and move to leaves in spring. They, in addition to direct damage to plants, are vectors of many viral and bacterial diseases.

In Ukraine, local forms and cultivars do not yield much (0.5–1.4 kg/m^2), with the mean bulb weight per clump of 7.9–18.3 g and bulb number per clump of 4.4–7.4 (*Bilenka O. M., 2018*). Strong branching of shallot plants makes it possible to obtain a clump containing 4-10 bulbs of different sizes from one planted bulb, allowing for simultaneous segregation of large (commercial) and small (intended for planting) bulbs. Each bulb, after rooting and growing, forms up to 10 shoots, which bear 5-7 leaves in compacted tufts. The length of the maximally developed leaf is 25–54 cm, and the plant weight in the technical ripeness phase is 53–85 g. Green shallot leaves are rich in total sugar (4–5%), at the level of perennial onion species (*Kovalenko Ye., 2005; Bilenka O. M., 2018*).

Farmers consider several factors, including production potential, market demand, environmental adaptability, seed availability, and price, when they select cultivars for planting (*Sych Z.D. & Kubrak S.M., 2023*).

Shallot cultivars and local forms grown in Ukraine have not yet been enough studied regarding their response to environmental factors. At the same time, they occupy an important position in production and home gardening. Shallots can be grown for bulbs and leek forcing both outdoors and indoors. Shallot is a multigerm plant; hence, it is most suitable for leek growing (*Sych, Z.D. & Kovalenko Ye. M., 2007*).

Shallot is a crop that is propagated mainly vegetatively, but foreign breeders have already created cultivars and hybrids that are also suitable for generative reproduction in industrial conditions *(Aklilu S., 2014*).

Onion business is considered profitable and has been quite popular recently. Some farmers continue to grow local forms, which they bred themselves, as such forms are well adapted to regional conditions. There are few high-yielding cultivars suitable for dissemination in Ukraine in the State Register (*Melnyk S.I., 2019; Melnyk S.I., 2020; Hriunvald N.V., 2021; Hriunvald N.V., 2022*). Foe example, 3 and 4 cultivars were included in the State Register in 2022 and 2021, respectively.

Cultivation of shallots obtained from another region, without proper growing of planting material and rehabilitation, leads to rapid degeneration and decreased yields after 2-3 generations. Therefore, the problem of selecting the best shallot cultivars by growing season length, the number and weight of underground bulbs, leaf productivity, resistance to diseases and pests, and yield requires constant investigation.

Our **purpose** was to indentify the best shallot cultivars and local forms by growing period length, bulb yield, leaf traits, and bulb weight and number per clump in the Right-Bank Forest-Steppe of Ukraine.

Materials and Methods. The study was conducted in the Right-Bank Forest-Steppe of Ukraine, in an experimental field of Bela Tserkva National University, in 2019–2020. The shallot collection comprised 30 cultivars and local forms from different regions of Ukraine: Kyivska, Dnipropetrovska, Kirovohradska, Chernihivska, and Cherkaska Oblasts. The accessions were evaluated in compliance with "Experimantation Methods in Vegetable and Melon Growing" (*Yakovenko K. I. (Eds., 2001*). Cultivar ‘Lira’ bred by the Institute of Vegetable and Melon Growing of NAAS was used as a control. The soil in the experimental site is typical low-humus mid-loamy chernozem. No irrigation was used. Cultivation was carried out by conventional technology (*Bondarenko H.L. & Yakovenko K.I., 2001*). Shallot cultivars were planted by tape method according to a 50+20+20x10 cm design (the density was 286,000 plants/ha). The record plot was 3 m^2. Bulb harvest was started when signs of leaf drying appeared in the first half of July ("Distinction, Uniformity and Stability Tests on Vegetable, Potato and Mushroom Cultivars", 2021).

Shallot bulbs were stored in boxes, packed in layers of 5–12 cm thick, by cold-warm method under uncontrolled conditions (in spring and autumn at 18–20 °C, in winter at around 0°C) from August to March (inclusive).

Lewis’s phenotypic stability factor (SF) was calculated using the following formula: SF = HE / LE, where HE and LE - high and low yields in different years, respectively (*Yakovenko K. I. (Eds), 2001*). Its closeness to 1 indicated high stability, and moving away from 1, on the contrary, meant instability. Data were statistically processed by analysis of variance in Statistica 7 (*Sych Z.D., 1993*).

Results. The study showed that, in 2019, accession 'Sh-1', which came from the Kyivska Oblast, had the longest growing period (as long as 85 days) (Table 1). The shortest period of 73 days was recorded for the control shallot cultivar, 'Lira'. The growing periods in 'Sh-7', 'Sh-8' (Dnipropetrovska Oblast; 74 and 73 days, respectively), 'Sh-11', and 'Sh-12' (Chernihivska Oblast; 75 days each), 'Sh-13', 'Sh-14' (Cherkaska Oblast; 75 days each).

In 2020, the growing season of different local shallot forms ranged from 74 days ('Sh-8') to 86 days ('Sh-1'). In the control cultivar, 'Lira', it was 75 days. The growing periods were one to two days longer than that in 'Lira' in the following accessions: 'Sh-4', 'Sh-7', 'Sh-14' (77 days), 'Sh-11', 'Sh-12', and 'Sh-13' (76 days). However, the growing periods of 'Sh-2', 'Sh-6', 'Sh-9', and 'Ш-10' were 5-7 days longer than that in 'Lira'.

Table 1. Growing periods of shallot cultivars and local forms

Accession	Origin	Growing period, days		
		2019	2020	Mean for 2019-2020
Lira (control cultivar)	Kharkivska Oblast, UKR	73	75	74
Sh-1	Kyivska Oblast, UKR	85	86	86
Sh-2	Kyivska Oblast, UKR	79	82	81
Sh-3	Kyivska Oblast, UKR	77	79	78
Sh-4	Kyivska Oblast, UKR	76	77	77
Sh-5	Kyivska Oblast, UKR	75	78	77
Sh-6	Dnipropetrovska Oblast, UKR	78	80	79
Sh-7	Dnipropetrovska Oblast, UKR	74	77	76
Sh-8	Dnipropetrovska Oblast, UKR	73	74	74
Sh-9	Dnipropetrovska Oblast, UKR	79	81	80
Sh-10	Chernihivska Oblast, UKR	79	82	81
Sh-11	Chernihivska Oblast, UKR	75	76	76
Sh-12	Chernihivska Oblast, UKR	75	76	76
Sh-13	Cherkaska Oblast, UKR	75	76	76
Sh-14	Cherkaska Oblast, UKR	75	77	76
LSD 05				1.3

Of the shallot cultivars under investigation on average for 2019-2020, the earliest ripening of bulbs was observed in 'Sh-8', which was delivered from the Dnipropetrovska Oblast. Its growing period was the same as that of 'Lira' (74 days). Bulbs ripened one or two days later in 'Sh-4', 'Sh-5', 'Sh-7', 'Sh-11', 'Sh-12', 'Sh-1'3, and 'Sh-14'. 'Sh-2', 'Sh-6', 'Sh-9', 'Sh-10' had intermediate duration. Their growing periods lasted 81, 79, 80, and 81 days, respectively.

The bulb yields of the shallot cultivars and local forms differed between two years. The yield level directly depended on both environment and genotype. Thus, 'Sh-1' (Kyivska Oblast), 'Sh-2' (Kyivska Oblast), 'Sh-6' (Dnipropetrovska Oblast), and 'Sh-10' (Chernihivska Oblast) gave high yields in 2019 (Table 2): 28.4, 24.5, 18.5, and 18.2 t/ha, respectively, which was 13.2, 9.3, 3.3, and 3.0 t/ha more than in the control cultivar ('Lira'). A good yield was also harvested from 'Sh-9', which came from the Dnipropetrovska Oblast: it yielded 16.3 t/ha of bulbs or by 1.1 t/ha more than 'Lira'. 'Sh-3' (14.8 t/ha) and 'Sh-8' (14.6 t/ha) yielded almost as much as the control cultivar. 'Sh-4' and 'Sh-11' delivered from the Kyivska and Chernihivska Oblasts, respectively, produced the lowest yields of bulbs: 11.6 and 11.2 t/ha, respectively.

Table 2. Yield capacity of the shallot local forms

Accession	Origin	Bulb yield, t/ha			Lewis's phenotypic stability factor (SF)
		2019	2020	Mean for 2019-2020	
Lira (control cultivar)	Kharkivska Oblast, UKR	15.2	15.8	15.5	1.0
Sh-1	Kyivska Oblast, UKR	28.4	32.6	30.5	1.1
Sh-2	Kyivska Oblast, UKR	24.5	26.3	25.4	1.1
Sh-3	Kyivska Oblast, UKR	14.8	15.5	15.2	1.0
Sh-4	Kyivska Oblast, UKR	11.6	12.8	12.2	1.1
Sh-5	Kyivska Oblast, UKR	14.1	15.2	14.7	1.1
Sh-6	Dnipropetrovska Oblast, UKR	18.5	19.3	18.9	1.0
Sh-7	Dnipropetrovska Oblast, UKR	11.4	12.5	12.0	1.1
Sh-8	Dnipropetrovska Oblast, UKR	14.6	15.5	15.1	1.1
Sh-9	Dnipropetrovska Oblast, UKR	16.3	19.8	18.1	1.2
Sh-10	Chernihivska Oblast, UKR	18.2	20.6	19.4	1.1
Sh-11	Chernihivska Oblast, UKR	11.2	12.5	11.9	1.1
Sh-12	Chernihivska Oblast, UKR	13.2	14.3	13.8	1.1
Sh-13	Cherkaska Oblast, UKR	12.7	13.6	13.2	1.1
Sh-14	Cherkaska Oblast, UKR	12.6	13.4	13.0	1.1
LSD 05				1.6	

The weather in 2020 was favorable for shallot growth, development and yield. The best yields in 2020 were harvested from ‘Sh-1’ (KyivskaOblast), ‘Sh-2’ (Kyivska Oblast), ‘Sh-6’ (Dnipropetrovska Oblast), ‘Sh-9’ (Dnipropetrovska Oblast), and ‘Sh-10’ (Chernihivska Oblast): 32.6, 26.3, 19.3, 19.8, and 20.6 t/ha, respectively. It was more than the yield harvested from the control cultivar, ‘Lira’, by 16.8, 10.5, 3.5, 4.0, and 4.8 t/ha, respectively.

Lower yields were harvested in 2020 from ‘Sh-4’ (Kyivska Oblast), ‘Sh-7’ (Dnipropetrovska Oblast), and ‘Sh-11’ (Chernihivska Oblast): from 12.5 t/ha (‘Sh-11’ and ‘Sh-7’) to 12.8 t/ha (‘Sh-4’). ‘Sh-3’ (15.5 t/ha), ‘Sh-5’ (15.2 t/ha), and ‘Sh-8’ (15.5 t/ha) yielded almost the same as ‘Lira’.

On average for the two study years, the following accessions had significantly increased yields of bulbs: ‘Sh-1’ (30.5 t/ha), ‘Sh-2’ (25.4 t/ha), ‘Sh-6’ (18.9 t /ha), ‘Sh-9’ (18.1 t/ha), and ‘Sh-10’ (19.4 t/ha). ‘Sh-4’ (12.2 t/ha), ‘Sh-7’ (12.0 t/ha), ‘Sh-11’ (11.9 t/ha), ‘Sh-12’ (13.8 t/ha), ‘Sh-13’ (13.2 t/ha), and ‘Sh-14’ (13.0 t/ha) yielded significantly less. ‘Sh-3’ and ‘Sh-8’ from Kyivska and Dnipropetrovska Oblasts, respectively, yielded almost the same as the control cultivar, ‘Lira’ (15.5 t/ha).

Adaptability in vegetatively propagated crops is of great importance, as it characterizes the biological potential of a crop. Most of the shallot accessions under investigation were collected in different regions of Ukraine, and therefore were created in different conditions. Growing of such accessions under non-optimal conditions can reduce their yields, and sometimes lead to their death. In 2019, the spring was early: as early as in May, the air temperature was higher than the optimum for shallots. In the middle of the period of bulb formation and ripening, there was an excessive amount of precipitation, contributing to mass appearance of diseases and disrupting the ripening process. All these led to a decrease in the shallot yield in 2019 compared to 2020.

The shallot accessions’ adaptability differed between the two study years. ‘Sh-3’ (Kyivska Oblast) and ‘Sh-6’ (Dnipropetrovska Oblast) turned out to be best adapted to the Right-Bank Forest-Steppe. Their Lewis’s phenotypic stability factors were 1. Accessions from other Oblasts were slightly worse adapted to the4 environment: ‘Sh-7’ and ‘Sh-8’ from the Dnipropetrovska Oblast, ‘Sh-10’, ‘Sh-11’, and ‘Sh-12’ from the Chernihivska Oblast, ‘Sh-13’ and ‘Sh-14’ from the Cherkaska Oblast. This group should include four accessions from the Kyivska oblast (‘Sh-1’, ‘Sh-2’, ‘Sh-4’, and ‘Sh-6’), which can be explained by hereditary features. Their Lewis’s phenotypic stability factors were 1.1. A local form originating from the Dnipropetrovska Oblast, ‘Sh 9’, was worst adapted to the growing conditions in the Right-Bank Forest-Steppe. Its Lewis’s phenotypic stability factor was 1.2.

The bulb weight and number per clump directly affected the shallot yield (Table 3). The mean bulb weight per clump in 2019 ranged from 24.9 g (‘Sh-1’) to 9.8 g (‘Sh-11’). However, good results regarding this indicator were noted for ‘Sh-2’ (Kyivska Oblast), ‘Sh-9’ (Dnipropetrovska Oblast), ‘Sh-13’ (Cherkaska Oblast), and ‘Sh-14’ (Cherkaska Oblast). The meant bulb weight was 14.3 g in the first two accessions, and 14.8 g and 14.7 g in the third and fourth accessions, respectively. In ‘Lira’ (control cultivar), the mean bulb weight per clump was 13.3 g. In ‘Sh-3’ (13.0 g), ‘Sh-4’ (13.5 g), ‘Sh-6’ (13.0 g), ‘Sh-8’ (12.8 g), and ‘Sh-10’ (12.7 g), the mean bulb weight clump was similar to that in the control cultivar.

In 2020, the weather was more favorable for the growth and development of shallot plants. Therefore, we observed an increase in the mean bulb weight per clump in some accessions and an increase in the bulb number per clump in others. The heaviest bulbs were formed in local forms that came from the Kyivska Oblast and were well adapted to the environmental conditions: ‘Sh-1’ and ‘Sh-2’. Their mean bulb weight per clump in 2020 was 28.5 g and 15.3 g, respectively, exceeding than in the control cultivar by 14.7 and 1.5 g. The lighted bulbs were harvested from ‘Sh-12’ (10.0 g), ‘Sh-5’ (10.6 g), ‘Sh-3’, ‘Sh-7’, ‘Sh-8’, and ‘Sh-11’ (10.9 g). In ‘Sh-6’, the mean bulb weight per clump was 13.5 g, which was similar to that in ‘Lira’ (13.8 g).

On average for 2019-2020, the mean bulb weight per clump differed between the shallot cultivars and local forms. In ‘Sh-1’ (Kyivska Oblast), it was 26.7 g and significantly higher than that in ‘Lira’ (13.6 g). The lightest bulbs were noted for ‘Sh-7’ (10.5 g) and ‘Sh-11’ (10.4 g).

Plants of accessions originating from the Kyivska (‘Sh-2’) and Chernihivska (‘Sh-10’) Oblasts had the greatest number of bulbs – 6. ‘Sh-3’, ‘Sh-5’, ‘Sh-6’, ‘Sh-8’, ‘Sh-9’, had ‘Sh-12’ as many as 5 bulbs per clump. The other ac

cessions had on average 4 bulbs per clump in the conditions of the Right-Bank Forest-Steppe.

In 2019-2020, we established a pattern that the yields of most accessions increased in the favorable year due to additional bulbs per clump. This phenomenon was observed in ‘Sh-3’, ‘Sh-4’, ‘Sh-5’, ‘Sh-8’, ‘Sh-9’, ‘Sh-10’, ‘Sh-12’, ‘Sh-13’, and ‘Sh-14’. In this case, the mean bulb weight per clump decreased from 0.7 g (‘Sh-10’) to 3 g (‘Sh-14’).

Table 3. Bulb weight and number per clump in the shallot local forms

Accession	Origin	Mean bulb weight per clump, g			Bulb number per clump
		2019	2020	Mean for 2019-2020	
Lira (control cultivar)	Kharkivska Oblast, UKR	13.3	13.8	13.6	4
Sh-1	Kyivska Oblast, UKR	24.9	28.5	26.7	4
Sh-2	Kyivska Oblast, UKR	14.3	15.3	14.8	6
Sh-3	Kyivska Oblast, UKR	13.0	10.9	12.0	5
Sh-4	Kyivska Oblast, UKR	13.5	11.2	12.4	4
Sh-5	Kyivska Oblast, UKR	12.3	10.6	11.5	5
Sh-6	Dnipropetrovska Oblast, UKR	13.0	13.5	13.3	5
Sh-7	Dnipropetrovska Oblast, UKR	10.0	10.9	10.5	4
Sh-8	Dnipropetrovska Oblast, UKR	12.8	10.9	11.9	5
Sh-9	Dnipropetrovska Oblast, UKR	14.3	11.6	13.0	5
Sh-10	Chernihivska Oblast, UKR	12.7	12.0	12.4	6
Sh-11	Chernihivska Oblast, UKR	9.8	10.9	10.4	4
Sh-12	Chernihivska Oblast, UKR	11.6	10.0	10.8	5
Sh-13	Cherkaska Oblast, UKR	14.8	11.9	13.4	4
Sh-14	Cherkaska Oblast, UKR	14.7	11.7	13.2	4
LSD 05				2.9	0.9

For the complex use of shallots, for both bulbs and leek during plant starting, leaf characteristics are important. In particular, it is important to evaluate plants for the leaf number and length, bulb shape and arrangement of leaves above the soil surface (Table 4). In particular, leaves can be spreading or erect, correlating with the bulb shape. Rounded bulbs are associated with spreading leaves, while elongated bulbs – with erect ones, and the latter is most valued in growing this crop for leek, especially for plant starting.

Analysis of the morphological traits of the shallot cultivars and local forms demonstrated the variability of the maximum leaf length, leaf number and bulb shape. In 2019, the maximum leaf length ranged from 30.2 cm ('Sh-1') to 37.3 cm ('Sh-1'). In the control cultivar ('Lyra'), the maximum leaf length was 32.8 cm; it was also similar (did not differ significantly from that in 'Lira') in 'Sh-3' and 'Sh-6' – 33.0 and 32.6 cm, respectively. Tall plants were formed by accessions from the Kyivska ('Sh-2') and Chernihivska ('Sh-10') Oblasts – 35.3 and 35.4 cm, respectively. In 'Sh-4', 'Sh-7', 'Sh-11', 'Sh-12', 'Sh-13', and 'Sh-14', the longest leaves were shorter than in the control cultivar by 1.0 -2.6 cm.

Table 4. Morphological characteristics of the shallot local forms

Accession	Origin	Maximum leaf length, cm			Leaf number per plant	Bulb shape
		2019	2020	Mean for 2019-2020		
Lira (control cultivar)	Kharkivska Oblast, UKR	32.8	35.4	34.1	28	Elliptical
Sh-1	Kyivska Oblast, UKR	37.3	38.6	38.0	28	Round-flat with downward and upward narrowing
Sh-2	Kyivska Oblast, UKR	35.3	36.2	35.8	42	Round-flat with downward narrowing
Sh-3	Kyivska Oblast, UKR	33.0	34.1	33.6	32	Elongated and cigar-shaped
Sh-4	Kyivska Oblast, UKR	30.2	31.3	30.8	25	Elongated and cigar-shaped
Sh-5	Kyivska Oblast, UKR	33.8	35.4	34.6	32	Round-flat with downward and upward narrowing
Sh-6	Dnipropetrovska Oblast, UKR	32.6	34.1	33.4	35	Elongated and cigar-shaped
Sh-7	Dnipropetrovska Oblast, UKR	30.7	32.0	31.4	28	Elongated and cigar-shaped
Sh-8	Dnipropetrovska Oblast, UKR	33.8	34.4	34.1	32	Round-flat with downward and upward narrowing
Sh-9	Dnipropetrovska Oblast, UKR	33.5	34.3	33.9	35	Round-flat with downward and upward narrowing
Sh-10	Chernihivska Oblast, UKR	35.4	37.0	36.2	39	Round-flat with downward and upward narrowing
Sh-11	Chernihivska Oblast, UKR	30.5	31.8	31.2	28	Round-flat with downward and upward narrowing
Sh-12	Chernihivska Oblast, UKR	31.8	32.8	32.3	32	Elongated and cigar-shaped
Sh-13	Cherkaska Oblast, UKR	30.8	31.4	31.1	25	Elongated and cigar-shaped
Sh-14	Cherkaska Oblast, UKR	30.2	31.9	31.5	25	Round-flat with downward and upward narrowing
LSD 05				0.77	6.5	

Analysis of the morphological traits of the shallot cultivars and local forms demonstrated the variability of the maximum leaf length, leaf number and bulb shape. In 2019, the maximum leaf length ranged from 30.2 cm (‘Sh-1’) to 37.3 cm (‘Sh-1’). In the control cultivar (‘Lyra’), the maximum leaf length was 32.8 cm; it was also similar (did not differ significantly from that in ‘Lira’) in ‘Sh-3’ and ‘Sh-6’ – 33.0 and 32.6 cm, respectively. Tall plants were formed by accessions from the Kyivska (‘Sh-2’) and Chernihivska (‘Sh-10’) Oblasts – 35.3 and 35.4 cm, respectively. In ‘Sh-4’, ‘Sh-7’, ‘Sh-11’, ‘Sh-12’, ‘Sh-13’, and ‘Sh-14’, the longest leaves were shorter than in the control cultivar by 1.0 -2.6 cm.

The more favorable weather conditions in 2020 affected the length of shallot leaves. The best values of this parameter were recorded for accessions from the Kyivska (‘Sh-1’ and ‘Sh-2’) and Chernihivska (‘Sh-10’) Oblast: 38.6, 36.2, and 37.0 cm, respectively, which were by 3.2, 0.8, and 1.6 cm shorter than 'Lira' longest leaves. 'Sh-4' (31.3 cm), 'Sh-7' (32.0 cm), 'Sh-11' (31.8 cm), 'Sh-12' (32.8 cm), 'Sh-13' (31 .4 cm), and 'Sh-14' (31.9 cm) had the shortest leaves.

On average for the two study years, the longest leaves were formed by 'Sh-1' and 'Sh-2' (Kyivska Oblast) and 'Sh-10' (Chernihivska Oblast): 38.0, 35.8 and 36.2 cm, respectively. Significantly shorter leaves were formed by 'Sh-4' (Kyivska Oblast; 30.8 cm), 'Sh-7' (Dnipropetrovska Oblast; 31.4 cm), 'Sh-11' (Chernihivska Oblast; 31.2 cm), 'Sh-12' (Chernihivska Oblast; 32.3 cm), 'Sh-13' (Cherkaska Oblast; 31.1 cm), and 'Sh-14' (Cherkaska Oblast; 31.5 cm). There were no significant differences in this parameter between 'Sh-3', 'Sh-5', 'Sh-6', 'Sh-8', and 'Sh-9'. Their maximum leaf length ranged from 33.4 cm ('Sh-6'; Dnipropetrovska Oblast) to 34.6 cm ('Sh-5', Kyivska Oblast).

As to the leaf number per plant, all the accessions under investigation were similar to the control cultivar, 'Lira', which had 28 leaves per plant on average for the two years. Two accessions from the Kyivska and Chernihivska Oblasts ('Sh-2' and 'Sh-10') turned out to be exceptions in terms of this parameter: their leaf number per clump was 42 and 39, respectively.

Conclusions. Data demonstrated that, on average for 2019-2020, the control cultivar, 'Lira', and a local form from the Dnipropetrovska Oblast, 'Sh-8', had the shortest growing periods of 74 days. 'Sh-1' (Kyivska Oblast) had the longest growing period: as long as 86 days.

The highest yields of bulbs were harvested from the following local forms: 'Sh-1' (30.5 t/ha), 'Sh-2' (25.4 t/ha), 'Sh-6' (18.9 t/ha), 'Sh-9' (18.1 t /ha), and 'Sh-10' (19.4 t/ha). The worst yields were given by 'Sh-4' (12.2 t/ha), 'Sh-7' (12.0 t/ha), 'Sh-11' (11.9 t/ha), 'Sh-12' (13 .8 t/ha), 'Sh-13' (13.2 t/ha), and 'Sh-14' (13.0 t/ha).

On average for the two study years, the yield in 2020, which was a favorable year for growing shallots, was increased in most accessions due to increased number of bulbs per clump. This phenomenon was noticed for 'Sh-3', 'Sh-4', 'Sh-5', 'Sh-8', 'Sh-9', 'Sh-10', 'Sh-12', 'Sh-13', and 'Sh-14'. In this case, the mean bulb weight per clump decreased from 0.7 g ('Sh-10') to 3 g ('Sh-14').

The greatest bulb weight per clump of 26.7 g was recorded for an accession originating from the Kyivska Oblast, 'Sh-1'. The lightest bulbs were formed by 'Sh-7' (10.5 g) and 'Sh-11' (10.4 g).

As to the bulb number per clump, two accessions stood out: 'Sh-2' and 'Sh-10', which had 6 bulbs per clump. Good values of this parameter were also observed in 'Sh-3', 'Sh-5', 'Sh-6', 'Sh-8', 'Sh-9', and 'Sh-12': 5 bulbs per clump.

The maximum leaf length was recorded for 'Sh-1' (38.0 cm), 'Sh-2' (35.8 cm), and 'Sh-10' (36.2 cm). However, the largest number of leaves per plant was observed in 'Sh-2' (42), 'Sh-6' (35), 'Sh-9' (35), and 'Sh-10' (39).

References

Aklilu Shimeles. (2014). The performance of true seed shallot lines under different environments of Ethiopia. *Journal of Agricultural Sciences.* Vol. 59, No. 2. P. 129-139.

Arifin, B., Azam, N., Martianto, D., & Karlina, L. (2019). The future of indonesian food consumption. *J. Econ. Indones*., Vol. 8, No. 1, P. 71–102.

Askari-Khorasgani & Pessarakli M. (2019). Agricultural management and environmental requirements for production of true shallot seeds – a review. *Adv. Plants Agric. Res*., Vol. 9, No. 2, P. 318–322. https://doi.org/10.15406/apar.2019.09.00441.

Bilenka, O.M. (2015). A new shallot cultivar – Hranat. *Ovochivnytstvo i Bashtannytstvo*: interdepartmental scientific collection. Kharkiv. Issue 61. P. 34-38.

Bilenka, O.M. (2018). Evaluation of shallot collection accessions in breeding for yield capacity. *Henetychni Resursy Roslyn*. Kharkiv. Issue 23. P. 58-66.

Bondarenko, H.L., Yakovenko, K.I. (2001). State of-art technologies in vegetable growing. Kharkiv, IOB UAAN, 128 p.

FAOSTAT. (2018). *Modeling the Future of Indonesian Food Consumption.* Retrieved from: https://reliefweb.int/report/indonesia/modeling-future-indonesian-food-consumption-june-2018

Fasika Sendec, Haily Tefera, Kobede W/ Tsadic. (2009). Corelation and path analysis in shallot (Al- lium cepa L., var. ascalonicum Baker.) genotypes. *East African Journal of Sciences*. Vol. 3 (1), P.55-60.

Herlina, L., Reflinur, R., Sobir, S., Maharijaya, A., Wiyono, S., & Istiaji, B. (2019). Genetic diversity of Indonesian shallots based on bulb-tunic patterns and morphological characters. *Indones. J. Agric*. Sci., vol. 20, no. 1, p. 19. http://doi.org/10.21082/ijas.v20n1.2019. P. 19-28.

Hriunvald, N.V. (2021). State register of plant varieties suitable for dissemination in Ukraine in 2021. 531 p. Available at: https://sops.gov.ua/reestr-sortiv-roslin

Hriunvald, N.V. (2022). State register of plant varieties, suitable for dissemination in Ukraine in 2022. 532 p. Available at: https://sops.gov.ua/reestr-sortiv-roslin

Korniienko, S.I., Bilenka, O.M. Chernyshenko, T.V., Kovalenko, Ye.M. (2013). Methodical approaches to shallot breeding and seed production. Kharkiv: TOV «VP «Pleiada».IOB NAAN. 27 p.

Kotlinska, T. (1995). *Variability of some features in shallot landrances.* (A.cepa var. aggregatum). *Repport of a Working Group on Allium* (Rome, 5th meeting, 25-27 May. Rome. International Plant Genetic Resources Institute. P. 73.

Melnyk, S.I. (2019). State register of plant varieties suitable for dissemination in Ukraine in 2019. 497 p. Available at: https://sops.gov.ua/reestr-sortiv-roslin.

Melnyk, S.I. (2020). State register of plant varieties suitable for dissemination in Ukraine in 2020. 516 p. Available at: https://sops.gov.ua/reestr-sortiv-roslin.

Ministry of Agrarian Policy and Food of Ukraine. (2021). Tests for distinctness, uniformity and stability on vegetables, potatoes and mushrooms. Kyiv. Available at: https://sops.gov.ua/uploads/page/Meth_DUS/Method_veget.pdf

Rabinowitch, H.D., & Kamenetsky, R. (2002). Shallot *(Allium cepa, Aggregatum group). Allium crop science: recent advances*, 409-430.

Rahmawati, A., Fariyanti, A., & Rifin, A. (2018). Spatial market integration of shallot in Indonesia. *J. Manaj. dan Agribisnis.* Vol. 15, No. 3, Pp. 258–267. http://doi.org/10.17358/jma.15.3.258

Sych, Z.D. & *Kovalenko, Ye.* M. (2007). Classification of shallot starting material by multivariate statistics in the conditions of the Northern Steppe of Ukraine. *Ovochivnytstvo i Bashtannytstvo*: interdepartmental scientific collection. Kharkiv. Issue 53. P. 228-234.

Sych, Z.D. (1993). *Metodicheskie rekomendacii postatisticheskoj ocenke selekcionnogo materiala ovoshhnyh i bahchevyh kul'tur* [Guidelines for the statistical assessment of breeding material of vegetable and melons]. Kharkiv, IOB UAAN, 72 p.

Sych, Z.D., Kubrak, S.M. (2023). Biological potential of shallots. Basic, less common and non-traditional plant species - from study to implementation (agricultural and biological sciences): Abstracts of the 7th International Scientific and Practical conference (within the framework of the 8th Scientific Forum "Science Week in Kruty - 2023", March 2, 2023, Kruty village, Chernihivska Oblast, Ukraine) / RS «MAYAK» Institute of Vegetable and Melon Growing: 2 volumes. Obukhiv: Printing house FOP Huliaieva V.M., 2023. Vol. 1. P. 277-281.

Tabor, G. (2018). Development of seed propagated shallot (*Allium cepa* L var. aggregatum) varieties in Ethiopia. *Sci. Hortic*. (Amsterdam). Vol. 240, No. 20, P. 89–93. http://doi.org/10.1016/j.scienta.2018.05.046

Wulaisfan, R., Musdalipah, & Nurhadiah (2018). Aktivitas Ekstrak Kulit Bawang Merah (Allium ascalonicum L .) Terhadap Pertumbuhan Bakteri Streptococcus mutans Penyebab Karies Gigi. *J. Ilm. Farm. Farmasyifa*. Vol. 1, No. 2, P. 126–132.

Yakovenko, K.I. (Eds). (2001). Experimentation methods in vegetable and melon growing. Kharkiv: Osnova. 369 p.

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СЕЛЕКЦІЙНА ЦІННІСТЬ СОРТІВ І МІСЦЕВИХ ФОРМ ЦИБУЛІ ШАЛОТ ЗА КОМПЛЕКСОМ ГОСПОДАРСЬКИХ ОЗНАК ДЛЯ УМОВ ПРАВОБЕРЕЖНОГО ЛІСОСТЕПУ УКРАЇНИ

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Мета. Виділити кращі сорти та місцеві форми шалоту за тривалістю вегетаційного періоду, урожайністю цибулин, продуктивністю листків, масою та кількістю цибулин у «гнізді» в умовах Правобережного Лісостепу України. **Методи.** Статистичні, польової оцінки, розрахунково-аналітичні. **Результати.** Проведено оцінювання колекційних зразків цибулі шалот за тривалістю вегетаційного періоду, масою, кількістю та урожайністю цибулин. Виділено ранньостиглий зразок Ш-8 з тривалістю вегетаційного періоду 74 доби. Найкращою за середньою масою цибулин у гнізді (26,7 г) виявилася місцева форма Ш-1 з Київської області. Найвищою врожайністю цибулин характеризувалися зразки з Київської (Ш-1, Ш-2), Дніпропетровської (Ш-6, Ш-9) та Чернігівської областей (Ш-10) – відповідно 30,5; 25,4; 18,9; 18,1; 19,4 т/га. У сорту-контролю Ліра цей показник складав 15,5 т/га. Найнижча вона за вирощування зразків Ш-4 (12,2 т/га), Ш-7 (12,0 т/га), Ш-11 (11,9 т/га), Ш-12 (13,8 т/га), Ш-13 13,2 (т/га) та Ш-14 (13,0 т/га). Найкраще пристосованими до умов навколишнього середовища Правобережного Лісостепу України виявилися два зразки, з Київської (Ш-3) та Дніпропетровської областей (Ш-6). Коефіцієнт стабільності Левіса у них дорівнював 1, що свідчить про найвищий ступінь стабільності до зміни кліматичних умов. Найгірше адаптувалася місцева форма із Дніпропетровської області – Ш 9, в якого цей показник становив 1,2. Максимальна довжина листка найбільша у зразків із Київської (Ш-1, Ш-2 – відповідно 38,0 і 35,8 см) та Чернігівської областей (Ш-10 – 36,2 см). **Висновки.** У результаті проведених досліджень виділено зразки цибулі шалот з коротким вегетаційним періодом, великою масою і кількістю цибулини та врожайністю культури в умовах Правобережного Лісостепу України. Найкращі результати за масою цибулин (26,7 г) та врожайністю (30,5 т/га) отримали від вирощування зразка походженням із Київської області Ш-1. Однак за тривалістю вегетаційного періоду він виявився пізньостиглим (86 діб), а у «гнізді» формувалося в середньому лише 4 цибулини. Максимальна довжина листка складала 38 см. Найбільш ранньостиглим (74 доби) була місцева форма з Дніпропетровщини Ш-8.

Ключові слова: цибуля-шалот, урожай; період вегетації, сорти, місцеві форми, маса цибулини, ознаки листків.

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EFFECT OF MYCORRHIZAL FORMULATION MYCOFRIEND ON POTATO PRODUCTIVITY

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The **purpose** was to investigate the effect of mycorrhizal formulation Mycofriend on biometric parameters, productivity and biochemical composition of potatoes, as well as to determine the economic effect of its use**. Methods.** Field, laboratory, statistical. The study was conducted at the Institute of Vegetable and Melons Growing of NAAS. **Results**. The results on the effect of different doses of mycorrhizal formulation Mycofriend (complex of mycorrhizal fungi: *Glomus VS, Trichoderma harzianum;* microorganisms supporting the formation of mycorrhiza and rhizosphere of plants: *Streptomyces sp., Pseudomonas fluorescens*; phosphate-mobilizing bacteria: *Bacillius megaterium var. phosphaticum, Bacillus subtilis, Bacillus muciloginosus, Enterobacter* sp) on biometric parameters, yield and its constituents and biochemical composition of tubers are presented. Mycofriend clearly tend to increase the potato yield. On average, it was higher than the control (33.6 t/ha) by 4.6 t/ha and 4.4 t/ha at Mycofriend concentrations of 1.0 L/t and 2.0 L/t, respectively. Mycofriend also increased biometric parameters in comparison with the control (without treatment). In particular, the plant height after treatment of tubers with 1.0 L/t and 2.0 L/t increased by 0.19 m and 0.26 m, respectively; at the same time, the plant weight was also increased by 278 g and 590 g, respectively. There were upward trends in the contents of starch (by 1.29–3.03%) and ascorbic acid (by 4.08–5.94 mg/100 g) in tubers. Additional costs in the experiments ranged UAH 5935 to UAH 18,67 1/ha. However, a reduction in the prime costs by 0.17–0.33 UAH/kg was achieved, leading to a corresponding increase in the profitability of cultivation by 8.8–12.8 %. The most economically justified dose of the formulation was 1.0 L/t. **Conclusions.** It is possible to treat potato tubers with mycorrhizal formulation Mycofriend at a dose of 1.0 L/t and 2.0 L/t during pre-planting preparation, which significantly improves biometric parameters (plant height and vegetative weight). The highest gain in the yield was noted with 1.0 L/ha of Mycofriend – 4.6 t/ha. Here, the most significant decrease in the prime costs and increase in the profitability were observed.

Keywords*:* mycorrhiza, potato, yield, biometric parameters, biochemical parameters, economic efficiency.

Introduction. In view of the climatic changes observed in the territory of Ukraine, there is a need to switch to new, more adapted, economically justified and economical technologies in order to adapt plants to stressful weather conditions. This will allow increasing the productivity of agricultural crops, preserve and improve natural resources, ensure the preservation of soil fertility and effective use of nutrients (*Didenko & Konovalova*, 2019).

Since it is impossible to avoid extreme meteorological factors when growing potatoes in Ukraine, the search for ways to minimize their negative impact on plants is gaining relevance (*Holovatiuk et al.,* 2021). New high-yielding varieties and high-quality planting material can ensure the maximum performance of plants if they are fully supplied with nutrients, timely cared and effectively protected against weeds, diseases and pests, optimal level of soil moisture is maintained during the growing period, and technological regulations are followed *(Bilinska et* al., 2021). However, due to the shortage of organic and mineral fertilizers and plant protectors, an effective way to solve the problem of increasing the potato yield is to apply biologicals, which help actively use soil nutrients and fertilizers, boost protective capacities of plants, their resistance to diseases, stresses, adverse weather conditions and have growth-stimulating and antimicrobial effects. This makes it possible to reduce the amount of pesticide load by 20–30% without reducing their protective effect (*Polishchuk et al*., 2013). Application of biologicals to restore soil fertility and to obtain high-quality plant products is a strategic trend in the modern agriculture development.

Among agricultural biologicals, microbial agents play an important role. These are ecologically safe agents with complex action, because microorganisms in their formulations not only fix nitrogen from the atmosphere or dissolve phosphates in the soil, but also produce amino acids as well as other compounds and substances with antipathogenic activities, restraining the development of phytopathogens, do not pollute the environment and are safe for animals and humans. In addition, enhancement of resistance of plants to adverse environmental factors (high and low temperatures, water deficit, phytotoxic pesticides) is an important aspect of the action of microbial agents. The harsher the soil, climatic and weather conditions are, the more important the role of biologization in crop cultivation technologies becomes. This explains the feasibility of using biologicals to improve plant nutrition and increase product quality (*Kovalenko et al.,* 2019).

Mialkovskyi and Bezvikonnyi (2022) reported that biologicals allowed increasing the assimilation surface of plants due to the stem number and height. In turn, this contributed to the formation of a larger vegetative mass and enlarged the assimilation surface. The plant performance rose due to application of biologicals, Kartoplex and Aminorost, because the number of marketable tubers increased. The yield increased by 4.2–5.1 t/ha, depending on varieties.

The drastic climate changes that we have observed in recent decades have a huge impact on agriculture. Currently, drought is one of the most influential factors limiting the productivity of agricultural crops. Water deficit in plants delays the growth of leaves and stems, and, in case of prolonged drought, the growth of roots, suppresses photosynthesis and respiration, accelerates leaf aging, results in retarded and underdeveloped generative organs, and finally leads to a significant drop in yield.

Experts think that it is possible to help plants cope with stresses by using mycorrhizal fungi-based biologicals. Mycorrhiza is a type of mutually beneficial symbiosis between plants and zygomycete fungi. During the formation of a mycorrhizal symbiosis, the fungus colonizes the root cortex tissues, establishing inner mycelium and modifying the cells contacting with the mycorrhiza. Having taken root on a plant, mycorrhizal fungi multiply on plant roots and spread into the surrounding soil as a large mass of absorbing threads, increasing the plant's absorption of water and nutrients. These threads are more than an order of magnitude thinner than root hairs and therefore are able to penetrate into the finest pores of soil minerals; there are such pores even in each sand grain. In 1 cm^3 of the soil surrounding the roots, the total length of mycorrhizal threads is from 20 to 40 meters. Mycorrhizal fungus increases the water absorption area by almost 100 times. It also increases the absorption of not only relatively immobile ions from the soil, i.e. phosphorus, potassium, calcium, magnesium, sulfur, zinc, copper, iron, but also enhances absorption and transport of much more mobile nitrogen ions, especially under arid conditions. Today, not only experimental, but also production indicators prove that agricultural crop cultivation using mycorrhizal formulations is several orders of magnitude more stable and effective in increasing yields while reducing production costs.

At the 7^{th} International Conference on Mycorrhiza (*New Delhi*, 2013), the following results on yields that were increased due to mycorrhiza in different soils and in different climates were reported: soybeans yielded 15–40 % more, corn – 20–70 % more, spiked cereals – 15–30 % more, vegetables – 30–200 % more.

Review of Resent Studies and Publications. *Trichoderma spp*.-containing formulations were proven to positively affect morphological parameters of plants, such as root length, biomass, height, numbers of leaves, branches, fruits, etc. (*Halifu, Deng, Song, Song, 2019; Sajeesh*, 2015). *T. harzianum* significantly enlarges the cucumber root biomass (*Yedidia, Srivastva, Kapulnik, Chet*, 2001) and increases the number of lateral roots (*Contreras-Cornejo, Macías-Rodriguez, Cortes-Penagos, Lopez-Bucio,* 2009). *T. longipile* and *T. tomentosum* significantly increase the total leaf area of cabbage seedlings when they are grown in a greenhouse (*Rabeendran, Moot, Jones, Stewart*, 2000). *Trichoderma spp*. beneficially regulates physiological processes in plants, such as photosynthesis, gas exchange, absorption and assimilation of nutrients, water exchange, etc. The fungus improves the absorption of magnesium, a key component of chlorophyll (*Doni et al*., 2014). Harman et al. revealed that different strains of *Trichoderma* secreted acids such as coumaric, glucuronic and citric acids, which promote the release of phosphate ions that are unavailable to plants in most soils (*Zhao et* al., 2014). *T. harzianum* strain in the soil increased the availability of phosphorus, iron and zinc to plants. Enhanced growth of roots and shoots in response to *Trichoderma* inoculation boosted uptake of Cu, Na, Zn and other trace elements (*Li et al.*, 2015). Treatment with various Trichoderma species guaranteed high yields of agricultural crops such as mustard, wheat, corn, tomato, etc. (*Tucci et al., 2011; Haque, Ilias, Molla, 2012; El-Katatny, Idres, 2014; Naznin et al., 2015; Idowu , Olawole, Idumu, Salami, 2016*) and was a cheap, effective and environmentally safe method of biocontrol of phytopathogenic microflora in agrocenoses (*Sood et al., 2020*). Although *Trichoderma* is currently the most extensively studied fungal biocontrol agent, with some species already commercialized as biopesticides or biofertilizers, their widespread use is hindered by unpredictable field performance (*Alfiky, Weisskopf*, 2021). The stimulating effect of *Trichoderma* spp. was noted in many studies. Thus, positive effects of these fungal species on the growth of roots and above-ground mass of eggplant, pepper, and tomato were reported (*Rozenfeld*, *Vashchenko*, 2005). At the same time, some researchers (*Pidoplichko*, 1953) observed a phytotoxic effect and inhibition of the germination of coniferous seeds by fungi of the genus *Trichoderma,* which are noticeable for high enzymatic activity. Other scientists pointed to the fact that stimulatory and inhibitory effects depended on the fungus species of the genus *Trichoderma* (*Alvarez-García et al*., 2022).

Since potatoes yield in soil, effects of pre-planting treatment with mycorrhizal fungi consist not only in root formation, but also in stolon and tuber formation. Here, concentrations of beneficial microorganisms in soil affect both nutrient amounts and influx rates of nutrients reaching plants. Therefore, studies of effects of different doses of biologicals in pre-planting treatment of tubers on the potato performance features are relevant.

The **purpose** was to investigate the effect of mycorrhizal formulation Mycofriend on biometric parameters, productivity and biochemical composition of potatoes and to determine the economic effect of its application.

Materials and Methods. The study was conducted at the Institute of Vegetable and Melon Growing of NAAS in accordance with methods accepted in potato, vegetable and gourd growing in 2020–2022 (*Dospekhov, 1985; Bondarenko & Yakovenko, 2001; Kutsenko, Osypchuk & Podhaietskyi, 2002*). Field and laboratory experiments were carried out. Analysis of variance was used to test significance of the results.

The study design involved treatment of tubers of the Sifra potato variety by spraying with different concentrations of mycorrhizal formulation Mycofriend1-2 days prior to planting:

1. Control (no treatment)
2. Treatment of tubers with 0.3 L/t of Mycofriend.
3. Treatment of tubers with 1.0 L/t of Mycofriend.
4. Treatment of tubers with 2.0 L/t of Mycofriend.

Mycofriend is a complex of mycorrhizal fungi: *Glomus* VS and *Trichoderma harzianum*; microorganisms that support the formation of mycorrhizae and rhizosphere of plants: *Streptomyces* sp., *Pseudomonas fluorescens*; phosphate-mobilizing bacteria *Bacillius megaterium var. phosphaticum, Bacillus subtilis*, *Bacillus muciloginosus*, *Enterobacter* sp; and biologically active substances (phytohormones, vitamins, amino acids).

Potatoes were planted within the third 10 days of May in accordance with the 70x35 cm arrangement (plant density = 40,800 plants/ha); harvesting was completed within the third 10 days of August. The planting rate was 3 t/ha. The record plot was 25 m^2 in four replications. During the growing period, the biometric parameters were measured; the yield and its constituents were determined; tubers were biochemically analyzed; and the main economic indicators of the Mycofriend-containing technology of potato growing were calculated. Fertilizers were applied before planting at the dose of $N_{90}P_{90}K_{90}$. Drip irrigation was carried out; the lowest moisture content in the soil was maintained at 75–80 %.

Results. The meteorological conditions in the study years significantly influenced the growth and development of potato plants and caused fluctuations in the yields level of the studied varieties (Figs. 1 and 2). A significant increase in the maximum air temperature during the 2020 and 2021 growing periods was associated with high average daily temperatures in critical phases of the potato growth and development, which did not meet biological needs of the crop. Under these conditions, stolons and tubers developed mainly at night. To a large extent, this situation was caused by very little precipitation from mid-June to mid-August. This trend regarding weather changes has been observed in the study location for the last 20-25 years, confirming meteorological forecasts about climatic changes in the country and the world. However, the weather variability over the years is characteristic of the Eastern Forest-Steppe of Ukraine. Thus, in 2022, the average daily air temperature had a uniform profile and was lower than the long-term average. The average daily air temperature in the critical developmental phases of 17–21°C enabled vegetative mass to intensively grow, preventing the soil from overheating and favoring the development of underground parts of plants. The uniform distribution of precipitation in June, July and August helped maintain an optimal microclimate in the potato plantations. Due to sufficient moisture supply and moderate air temperature without extreme fluctuations, lots of tubers were formed, which meant a corresponding increase in the yield.

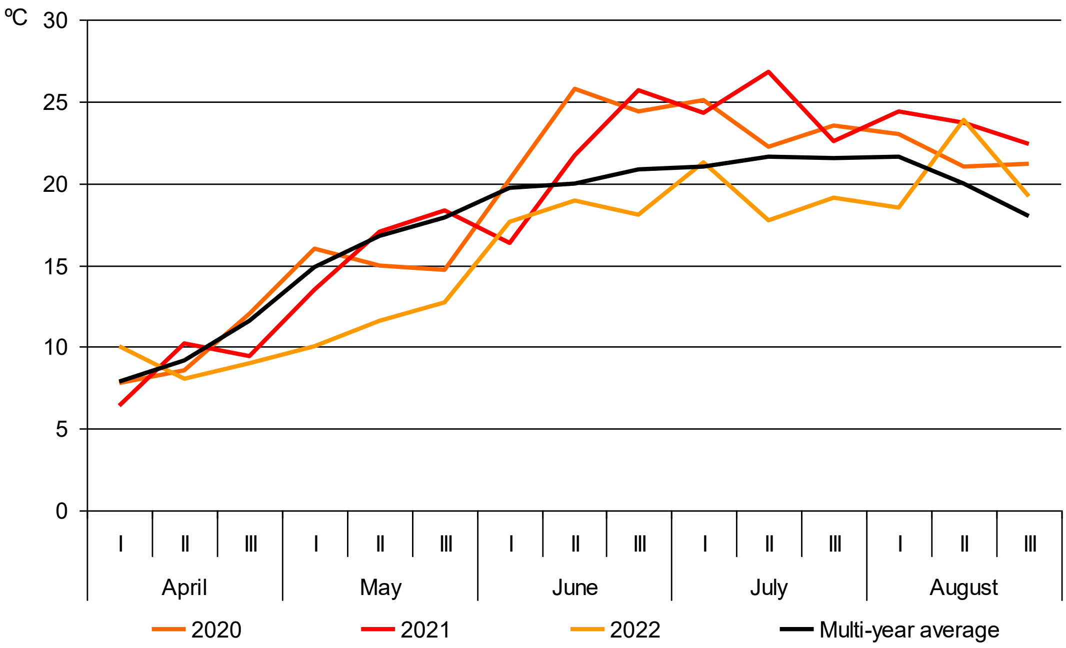

Figure 1. Average daily air temperatures during the 2020–2022 growing periods

During the 2020 growing period, 230.5 mm fell; in 2021–256.5 mm; and in 2022–344.4 mm (long-term average = 276.5 mm). Thus, in 2020–2022, we obtained data on the effectiveness of inoculation of tubers with Mycofriend under different growing conditions. Of particular interest are the results obtained in 2020 and 2021, when the weather was relatively unfavorable.

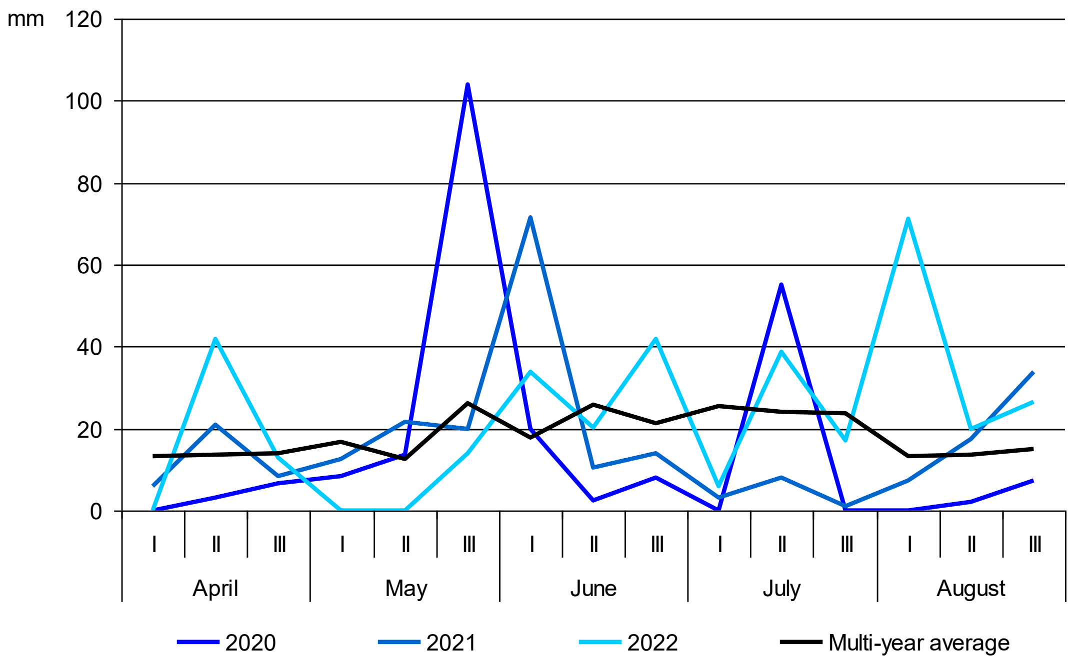

Figure 2. Rainfall dynamics during the 2020–2022 growing periods.

Rapidness of transition of potato plants to autotrophic nutrition and the bushing intensity are the main criteria for the effectiveness of preparation of tubers for planting. Depending on concentrations of beneficial microorganisms, temperature and water content in the root formation zone of the soil, plants change their intensity of absorption of nutrients and water. Increased doses of Mycofriend for pre-planting inoculation of tubers enhanced the growth of shoots and leaves. However, the mean height of plants was 0.72 m in 2020 and 0.70 m in 2021, while in 2022 it amounted to 0.82 m. The weather also affected the bush habitus and assimilation surface area. The mean weight of plants was 858 g in 2020 and 860 g in 2021, but in 2022 it increased to 1,300 g. At the same time, there was an upward trend in the biometric parameters of plants in the Mycofriend experiments (Table 1). With Mycofriend, plants were taller compared to the control by 0.16–0.26 m, depending on the formulation doses. The corresponding increase in the plant weight was 88-590 g. Analysis of the biometric parameters demonstrated that the largest vegetative mass of plants was achieved when Mycofriend was applied at a dose of 1.0 L/t or 2.0 L/t.

Table 1. Effect of Mycofriend on the biometric parameters of potatoes, 2020–2022

Dose, L/t	Plant height, m				Plant weight, g			
	2020	2021	2022	Mean	2020	2021	2022	Mean
No treatment (control)	0.59	0.55	0.64	0.59	688	692	920	767
0.3	0.70	0.68	0.87	0.75	640	646	1280	855
1.0	0.75	0.74	0.86	0.78	851	849	1436	1045
2.0	0.84	0.82	0.90	0.85	1251	1255	1564	1357
LSD_{05}	0,07	0.06	0.03		8.2	7.4	10.6	

Mycofriend-induced activation of growth processes not only promoted the development of the photosynthetic surface in plants, but also intensified the stolon and tuber formation. Regardless of the weather, the gain in the potato yields ranged 2.1 t/ha to 4.6 t/ha related to the control (33.6 t/ha) (Table 2). The most pronounced gain was achieved with 1.0 L/t and 2.0 L/t of Mycofriend.

Table 2. Effect of Mycofriend on the potato yield in 2020–2022

Dose, L/t	Yield, t/ha			
	2020	2021	2022	Mean
No treatment (control)	32.0	31.9	36.8	33,6
0.3	35.6	32.4	39.1	35,7
1.0	38.1	35.0	41.6	38,2
2.0	37.6	35.4	41.1	38,0
LSD_{05}	4,1	2.7	3.8	

The yield structure also changed under the influence of the formulation. Thus, the mean weight of tubers in the control was 60 g, and the number of tubers was 13.6/bush (Table 3). Treatment of tubers with Mycofriend at a dose of 2.0 L/t resulted in the maximum mean weight of tubers of 66 g, but not the greatest number of tubers (14.3/bush). The greatest number of tubers (14.6/bush) was obtained when Mycofriend was applied at a dose of 1.0 L/ha, which made it possible to obtain the greatest gain in the yield in this variant.

Table 3. Effect of Mycofriend on the potato yield structure in 2020–2022

Dose, L/t	Tuber number per bush				Mean weight of tubers, g			
	2020	2021	2022	Mean	2020	2021	2022	Mean
No treatment (control)	13.3	12.8	14.7	13.6	59	61	61	60
0.3	13.7	13.0	15.4	14.0	64	61	62	62
1.0	14.2	13.3	16.4	14.6	66	64	62	64
2.0	13.6	13.1	16.0	14.3	68	66	63	66
LSD_{05}	0.2	0.2	0.3		3.2	2.6	2.1	

Biochemical analyses showed that in the control the commercial product had the lowest amounts of starch (8.73%), ascorbic acid (10.9 mg/100 g) and nitrates (40.0 mg/kg) (Table 4). Treatment of tubers with Mycofriend at a dose of 1.0 L/ha produced yields with the highest amount of starch (11.76%) and the lowest amount of total sugars (0.86%). Increasing the dose of Mycofriend to 2.0 L/ha allowed increasing the dry matter content to 15.5% and the ascorbic acid content to 16.9 mg/100 g as well as accumulating the largest amount of nitrates (43.5 mg/kg), although this amount was not higher than the permissible level (250 mg/kg).

Table 4. Effect of Mycofriend on the biochemical composition of potato tubers, mean for 2020–2022

Dose, L/t	Dry matter, %	Starch, %	Total sugars, %	Ascorbic acid, mg/100 g	Nitrates, mg/kg
No treatment (control)	14.9	8.73	1.02	10.9	40.0
0.3	14.0	10.12	0.89	15.0	40.6
1.0	14.8	11.76	0.86	15.8	41.2
	15.5	10.43	0.89	16.9	43.5

Analysis of the main economic indicators of the Mycofriend-containing technology of potato growing indicated their improvement compared to the basic technology (Table 5). Additional costs in the experimental variants range UAH 5935 to UAH 18,671/ha. However, due to increased yields, the prime costs were reduced by 0.17–0.33 UAH/kg, meaning a corresponding increase in the profitability of cultivation by 8.8-12.8%.

Table 5. Economic indicators of the potato growing with Mycofriend application, mean for 2020-2022

Dose, L/t	Total costs, UAH/ha	Prime costs, UAH/kg	Profitability, %
No treatment (control)	194598	5.79	33.6
0.3	200533	5.62	42.4
1.0	208776	5.46	46.4
2.0	213269	5.61	42.5

1.0 L/t turned out to be the most economically justified dose of the formulation: its prime cost was UAH 5.46/kg (UAH 5.79/kg in the control) and the profitability was 46.4% (33.6% in the control).

Discussion. Mycorrhizal fungi are obligate symbionts that have a positive effect on the growth and development of host plants, increasing its provision with mineral nutrients resistance to adverse environmental conditions.

Mycorrhizae on potatoes enhances growth, boosts resistance to pathogens and increases yield. Colonization of roots with fungi increases the dry matter content both in vegetative mass and in roots, chlorophyll content and tuber yield. Such positive effects are attributed to increased rates of absorption of phosphorus, iron and magnesium by potato plants and to increased coefficients of utilization of phosphorus from the soil. In addition, fungus colonization reduces frequencies of some infections on potatoes or reduces the intensity of diseases. Some researchers noted that these fungi had a bioprotective function against the leaf pathogen *Phytophthora infestans*, as potato plants with mycorrhiza less suffered from disease as a result of the activation of systemic plant resistance to pathogens.

The obtained results confirm data on beneficial influence of useful microbiota on the the potato performance. This pattern was also observed in growing periods with adverse meteorological factors. The effectiveness of pre-planting treatment of potato tubers is confirmed by improved economic indicators of potato cultivation. The effectiveness of the investigated element of the technology has been confirmed by numerous studies, which demonstrated that this approach be an additional reserve for increasing the potato performance in the Ukrainian climate.

Conclusions. Mycorrhizal formulation Mycofriend can be used to treat potato tubers at a dose of 1.0 L/t and 2.0 L/t during pre-planting preparation, significantly improving the biometric parameters (plant height and vegetative mass). The highest gain (4.6 t/ha) in the yield was noted when tubers were treated with Mycofriend at a dose of 1.0 L/ha. Concurrently, the most significant decrease in the prime costs and increase in the profitability were recorded.

References

Alfiky, A., Weisskopf, L. (2021). Deciphering trichoderma–plant–pathogen interactions for better development of biocontrol applications. J. Fungi. 7(1). P. 61. https://doi.org/10.3390/jof7010061

Alvarez-García, S., Manga-Robles, A., Encina, A., Gutiérrez, S., Casquero, P. (2022). Novel culture chamber to evaluate in vitro plant-microbe volatile interactions: Effects of Trichoderma harzianum volatiles on wheat plantlets. Plant Science. Vol. 320. Article number 111286.
http://doi.org/10.1016/j.plantsci.2022.111286

Bilinska, O.M., Kulka, V.P., Samets, N.P., Holod, R.M. (2021). Effect of Albit on seed productivity of the pre-basic material of potatoes. Visnyk Ahrarnoi Nauky Prychornomoria. Vol. 2 (110). P. 71–79. http://doi.org/10.31521/2313-092X

Bondarenko, H.L., Yakovenko, K.I. (2001). Methods of experimentation in vegetable and melon growing. Kharkiv: Osnova. 369 p.

Dospekhov, V.A. (1985). Methods of field experimentation. M.: Agropromizdat. 351 p.

Contreras-Cornejo, H.A.; Macías-Rodríguez, L.; Cortés-Penagos, C.; López-Bucio, J. (2009). Trichoderma virens, a plant beneficial fungus, enhances biomass production and promotes lateral root growth through an auxin-dependent mechanism in Arabidopsis. Plant Physiol. 149. P. 1579–1592.

Didenko, N.O., Konovalova, V.M. (2019). Soybean performance depending on technological measures of cultivation in the south of Ukraine. World Plant Resources: State and Prospects of Development: Abstracts of The 5th International Scientific and Practical Conference (June 7, 2019, Kyiv). P.183-186.

Doni, F.; Isahak, A.; Zain, C.R.C.M.; Ariffin, S.M.; Mohamad, W.N.W.; Yusoff, W.M.W. (2014). Formulation of Trichoderma sp. SL2 inoculants using different carriers for soil treatment in rice seedling growth. Springerplus. 3. P. 532.

El-Katatny, M.H.; Idres, M.M. (2014). Effects of single and combined inoculations with Azospirillum brasilense and Trichoderma harzianum on seedling growth or yield parameters of wheat (Triticum vulgaris L., Giza 168) and corn (Zea mays L., hybrid 310). J. Plant Nutr. 37. P. 1913–1936.

Holovatiuk, R.Yu., Mialkovskyi, R.O., Bezvikonnyi, P.V. (2021). Effectiveness of complex microfertilizers and biostimulants during the cultivation of potatoes in the Western Forest-Steppe of Ukraine. Tavriiskyi Naukovyi Visnyk: Scientific journal. Vol. 119. P. 28–35.

Halifu, S.; Deng, X.; Song, X.; Song, R. (2019). Effects of two trichoderma strains on plant growth, rhizosphere soil nutrients, and fungal community of pinus sylvestris var. mongolica annual seedlings. forests. 10. P. 758. https://doi.org/10.3390/f10090758

Haque, M.M.; Ilias, G.N.M.; Molla, A.H. (2012). Impact of Trichoderma-enriched biofertilizer on the growth and yield of mustard (Brassica rapa L.) and tomato (Solanum lycopersicon Mill.). Agriculturists. 10. P. 109–119.

Idowu, O.O.; Olawole, O.I.; Idumu, O.O.; Salami, A.O. (2016). Bio-control effect of Trichoderma asperellum (Samuels) Lieckf. and Glomus intraradices Schenk on okra seedlings infected with Pythium aphanidermatum (Edson) Fitzp and Erwinia carotovora (Jones). J. Exp. Agric. Int. P. 1–12.
https://doi.org/10.9734/AJEA/2016/21348

Kovalenko, A.M., Tymoshenko, H.Z., Kovalenko, O.A., Novokhyzhnii, M.V. (2019). Microbiological and nutritional state of the soil in sunflower fields under different methods of basic tillage and application of biologicals. World Plant Resources: State and Prospects of Development: Abstracts of The 5th International Scientific and Practical Conference (June 7, 2019, Kyiv). P.186–190.

Kutsenko, V.S., Osypchuk, A.A. & Podhaietskyi, A.A. (2002). Methodological recommendations for conducting research with potatoes. *Institute for Potato Research*. Nemishaieve.

Li R.-X.; Cai F.; Pang G.; Shen Q.-R.; Li.R.; Chen W. (2015). Solubilisation of phosphate and micronutrients by Trichoderma harzianum and its relationship with the promotion of tomato plant growth. PLoS ONE. 10. e0130081.

Mialkovskyi, R.O., Bezvikonnyi, P.V. (2022). Effects of biologicals on potato. Abstracts of the 6th International Scientific and Practical Conference "State and Prospects of the Development and Implementation of Resource- and Energy-Saving Technologies for Agricultural Crop Cultivation"

(Dnipro, November 16–17, 2022). Dnipro: DDAEU, 2022. P. 49–51.

Naznin, A.; Hossain, M.M.; Ara, K. A.; Hoque, A.; Islam, M. (2015). Influence of organic amendments and bio-control agent on yield and quality of tuberose. J. Hort. 2. P. 1–8.

Polishchuk, I.S., Polishchuk, M.I., Palahniuk, O.V. (2013). Effects of Azotophyte and Phytocide biologicals on yield capacities of potato varieties. Science in the Information Space: Abstracts of the 9th International Scientific and Practical Internet Conference. Vinnytsia National Agrarian University., Retrieved from: http://www.confcontact.com/2013-nauka vinformatsionnompros-transtve/sh1_polischuk_ vpliv.htm (Cited on 11/09/2022)

Pidoplichko, N.M. (1953). Fungal flora on forages. Kyiv: Publishing House of the Academy of Sciences of the Ukrainian SSR. 488 p.

Rabeendran, N.; Moot, D.J.; Jones, E.E.; Stewart, A. (2000). Inconsistent growth promotion of cabbage and lettuce from Trichoderma isolates. New Zeal. Plant Prot. 53. P. 143–146.

Rozenfeld, V.V., Vashchenko, L.M. (2005). Phytopathogenic properties of strains isolated from pine seeds. Abstact book of the International Scientific Conference "Phytopathogenic Bacteria. Phytoncides. Allelopathy” (Kyiv, October 4–6, 2005). Zhytomyr: State Agroecological University, 2005. P. 122–125.

Sajeesh, P.K. (2015). Cu-Chi-Tri: A Triple Combination for the Management of Late Blight Disease of Potato (Solanum tuberosum L.). Ph.D. Thesis, GB Pant University of Agriculture and Technology, Pantnagar, India, 2015.

Sood, M., Kapoor, D., Kumar, V., Sheteiwy, M. S., Ramakrishnan, M., Landi, M., Araniti, F., Sharma, A. (2020). Trichoderma: The «Secrets» of a Multitalented Biocontrol Agent. Plants. 9. P. 762. http://doi.org/10.3390/plants9060762

Tucci, M.; Ruocco, M.; de Masi, L.; de Palma, M.; Lorito, M. (2011). The beneficial effect of Trichoderma spp. On tomato is modulated by the plant genotype. Mol. Plant Pathol. 12. P. 341–354.

Yedidia, I.; Srivastva, A.K.; Kapulnik, Y.; Chet, I. (2001). Effect of Trichoderma harzianum on microelement concentrations and increased growth of cucumber plants. Plant Soil. 235. P. 235–242.

Zhao, K.; Penttinen, P.; Zhang, X.; Ao, X.; Liu, M.; Yu, X.; Chen, Q. (2014). Maize rhizosphere in Sichuan, China, hosts plant growth promoting Burkholderia cepacia with phosphate solubilizing and antifungal abilities. Microbiol. Res. 169. P. 76–82.

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ДІЯ МІКОРИЗОФОРМУЮЧОГО ПРЕПАРАТУ МІКОФРЕНД НА ПРОДУКТИВНІСТЬ КАРТОПЛІ

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Мета – дослідити дію мікоризоформуючого препарату Мікофренд на біометричні показники, продуктивність і біохімічний склад картоплі, а також визначити економічний ефект від його використання. **Методи.** Польовий, лабораторний, статистичний. Дослідження проводили в Інституті овочівництва і баштанництва НААН. **Результати**. Наведено результати впливу різних доз мікоризоформуючого препарату Мікофренд (комплекс мікоризоформуючих грибів: *Glomus VS, Trichoderma harzianum*; мікроорганізмів, що підтримують утворення мікоризи та ризосфери рослин: *Streptomyces sp., Pseudomonas Fluorescens*; фосфатмобілізуючі бактерії: *Bacillius Megaterium var. phosphaticum, Bacillus Subtilis, Bacillus Muciloginosus, Enterobacter sp*) на біометричні показники, врожайність, структуру врожаю та біохімічний склад бульб. Використання мікоризоформуючого препарату Мікофренд забезпечує чітку тенденцію до збільшення показників урожайності картоплі. В середньому вона була вищою ніж на контролі (33,6 т/га) на 4,6 і 4,4 т/га за концентрації препарату 1,0 та 2,0 л/т відповідно. Застосування мікоризоформуючого препарату дозволило збільшити також і біометричні показники у порівнянні з контролем (без обробки). Так, зокрема, висота рослин у варіанті з концентрацією препарату 1,0 л/т збільшилась на 0,19 м, а з концентрацією 2,0 л/т на 0,26 м; при цьому маса рослини також збільшилася відповідно на 278 г та 590 г. Також спостерігається тенденція до зростання вмісту крохмалю (на 1,29–3,03 %) та аскорбінової кислоти (на 4,08-5,94 мг/100 г) у бульбах. Додаткові витрати у варіантах досліду складають від 5935 до 18671 грн /га. Проте досягнуто зменшення собівартості продукції на 0,17-0,33 грн/кг, що призвело до відповідного зростання рентабельності вирощування на 8,8-12,8 %. Найбільш економічно обґрунтованою є доза препарату 1,0 л/т. **Висновки**. Використання для обробки бульб картоплі мікоризоформуючого препарату Мікофренд можна проводити з дозуванням 1,0 л/т та 2,0 л/т за передсадивної підготовки, що значно покращує біометричні показники (висоту рослин і масу вегетативної маси). Найвищий приріст врожайності був відмічений на варіанті з обробкою Мікофрендом у дозі 1,0 л/га – 4,6 т/га. При цьому спостерігається найбільш суттєве зменшення собівартості продукції та зростання рентабельності.

Ключові слова: мікориза, картопля, врожайність, біометричні показники, біохімічні показники, економічна ефективність.

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ALLELOPATIC COMPATIBILITY OF COMMON BEAN AND COMPANION CROPS

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Purpose. To investigate the allelopathic compatibility of common bean seeds and companion crops, to establish interaction patterns using water extracts from seeds and other plant parts of common bean and companion crops. **Methods.** Laboratory, statistical. **Results.** Biotest: interaction of germinating seeds of bean and companion crops in Petri dishes. Biologically active substances from winter and spring triticale seeds (the bean seeds/seeds of companion crops ratio was 1:10) negatively affected bean seedlings, which was seen from all parameters under investigation: hypocotyl length (with the root included), length of the longest adventitious root, the adventitious root number, and true leaf length (with epicotyl included). At a ratio of 1:5, winter triticale-induced inhibition of hypocotyl growth was enhanced up to 38 %, while, on the contrary, spring triticale had a neutral effect on this parameter. A stimulating effect (106 %) of spring triticale seeds on the true bean leaf length (with epicotyl) was noted. For winter and spring triticale in a ratio of 1:1 (compared to the control – without seeds of companion crops), inhibition of the growth of the hypocotyl with the root by 21 % and the true leaf with the epicotyl by 10–9 %, respectively, is observed. Biotest: germination of bean seeds in a water extract from whole seeds of bean and companion crops in Petri dishes. Water extract from spring triticale seeds in a ratio of 1:2 had the greatest stimulating effect on the tap root and the first leaf lengths; winter triticale extract in a ratio of 1:4 had the greatest effect on the adventitious root an epicotyl lengths; bean extract in a ratio of 1:2 had the greatest effect on the epicotyl length. Biotest: germination of bean seeds in a water extract from vegetative mass, roots and post-harvest residues of bean and companion crops in Petri dishes. Water extracts from roots of bean, winter and spring triticale weakly inhibited the main bean root elongation. A neutral allelopathic effect on the bean seed germination was exerted by extract from post-harvest residues of spring triticale. A water extract from top parts of bean had a negative allelopathic effect on germinating bean seeds, indicating self-incompatibility of this crop. **Conclusions.** The laboratory tests showed that biologically active substances from seeds of both winter triticale and spring triticale at a ratio of 1:10 were toxic for bean ssedlings. Combined germination of bean and spring triticale seeds at a ratio of 1:5 had a more positive effect compared to other ratios of seeds of companion crops, and combined germination of bean seeds with spring and winter triticale seeds at a ratio of 1:1 demonstrated very similar parameters of germinating bean seeds. It was found that water extracts from bean and spring triticale in a ratio of 1:2 and from bean and winter triticale (1:4) had a clear allelopathic effect on the bean parameters. Water extracts from winter triticale (1:1) and spring triticale (1:4) were more toxic to bean seedlings. Water extracts from roots of bean, winter and spring triticale weakly inhibited the main bean root elongation. A water extract from the aboveground parts of bean had a negative allelopathic effect on the germinating seeds of bean, indicating self-incompatibility of this crop. A neutral allelopathic effect on the germination of bean seeds was exerted by extract from post-harvest residues of spring triticale. Combined germination of seeds of bean and companion crops in the laboratory allows for assessments of peculiarities of seed germination and mutual influence of components as early as at the initial stage, for selection of crops for growing in heterogeneous fields aimed at forming a highly productive agrophytocenosis.

Key words: common bean, seeds, companion crops, biotests, allelopathy.

Introduction. Famous Ukrainian scientists A.O. Babych (*Babych A.O., Petrychenko V.F., Poberezhna A.A., 1994*), V.F. Kaminskyi (*Kaminskyi V.F., Holodna A.V., Shliakhturov D.S., 2008*), S.I. Ivaniuk (*Ivaniuk S.V., Lekhman A.A. , Ovcharuk O.V., 2015*) confirmed that bean, like soybeans, among other grain legumes, is a strategically necessary high-protein crop, and the economic and bioenergetic effects of its cultivation are promising and relevant. All this has prompted a recent growth of the bean-sown area in Ukraine (*Ovcharuk O.V., 2015*).

Under current farming conditions, the vast majority of vegetables are mainly grown using intensive technologies in highly specialized crop rotations. This is sure to accelerate the soil degradation, to worsen the phytosanitary condition of the agrocenosis and to pollute the environment greatly. As a result, energy costs increase, in particular, for soil cultivation, synthetic fertilizers, growth regulators, and plant protectors, the quality of products deteriorates, and sometimes yields also decrease. The main difference between an organic producer and a traditional producer is his/her attitude to the land. For organic farmers, land is not only a means of production, but also a living environment that develops (*Vitanov A.D., 2007*).

Agroecosystems (agrocenoses), unlike natural ecosystems, are poorly adapted. The philosophy of alternative (organic) agriculture in vegetable growing is based on the creation of conditions for self-regulation and self-maintenance of ecosystems, which, like natural ones, should comprise diversity (diversification). Introduction into practice of so-called intercropping (polycrop), which means growing two or more plant species on the same area, that is, in one plant community, seems to be a promising trend. Such a community is managed by special technological measures. Compatibility of vegetables and companion crops is preliminarily determined using special allelopathic tests (*Kaminskyi V.F. (Ed), 2016*).

Review of Resent Studies and Publications. Vegetable production faces problems of yield reduction due to soil fatigue and autotoxicity upon continuous cultivation for several years. In current crop production, allelopathic relationships between plants are gaining importance, becoming a scientific basis for the development of reasonable crop rotations and mixed (thickened) fields to increase the performance of agrocenoses, to prevent soil fatigue in monocrops, to control weeds, pests, phytopathogens, etc. (*Grodzinskшу A.M. 1965; Wato T., 2020*).

Allelopathy is a biological phenomenon by which plants produce physiologically active substances – allelochemicals. Allelochemicals is very diverse chemically; their composition can even vary in the same plant. Allelochemicals can improve or slow down all signs of plants' vital activity in a biocenosis. In this regard, a plant, falling into one or another biocenosis, changes its requirements for environmental conditions that ensure its optimal development (*Hrodzinskyi, O.M., 1973*). This is of direct importance to agriculture: an excess of physiologically active substances in the biocenosis is as harmful to the growth and development of plants as their deficit (*Golovko Ye.A., Bilyanovskaya T.M., Vorobey I. et al., 1999; Kosolap N.P., 2008; Yurchak L.D., 2005*).

Allelopathy is important for the performance of phytocenoses. Allelopathic interactions through plant secretions are an ecological factor. Most agricultural crops were shown to have a certain allelopathic activity (*Holovko Ye.A., Puzik V.K., 2003; Simagina N.O., 2006; Bukharov A.F., Baleyev D.N., Bukharova A.R., 2011*). Plants release various biochemical substances into the environment — simple and complex, organic and mineral, active and neutral. These substances undergo complex chemical transformations and play important roles in the formation of "allelopathically neutral" systems — chemically self-regulated biogeocenoses (*Grodzinskiy A.M., 1965; Hnatiuk N.O., 2003; Yurchak L.D., 2005; Bohovin A.V., 2009*).

Most allelopathy assessments involve biotests of plant or soil extracts, filtrates, fractions, and residues that affect seed germination and seedling growth in laboratory and field experiments. Biotests in Petri dishes with aqueous extracts from different parts of donor plants showed a considerable phytotoxic activity, depending on concentrations, with the greatest effect of aqueous leaf extracts (*Mushtaq W., Siddiqui M.B., 2018*).

Laboratory biotests are the first step used to investigate possible involvement of allelopathy in plant-plant, plant-microorganism and plant-insect relationships and interactions (*Kondratyev M.M., Budarin S.M., Larikova Yu.S., 2014; Inderjit, Foy C.L., Dakshini K.M (Eds.), 1999*). Biotests are useful and necessary tools for studying the allelopathic potential of plant or soil extracts and for evaluating the activity of extracts upon purification and identification of allelochemicals. Almost all reports about allelopathy describe biotests used to demonstrate allelopathic activity (*Haugland E. Brandsaeter L.O., 1996; Macias F.A., Molinillo J.M.G., Varela R.M, Galindo J.C.G., 2007*). Biotests are most widely used to test allelopathic activity in extracts of germinating seeds in Petri dishes on filter paper, sand, soil, or agar. Percentage of seed germination in recipient plants was commonly used to measure effects of allelochemicals. It is an express-method for a large number of biological replicates. Description of seed and fruit germination is a widely used analytical approach, but several studies demonstrated that it was not the most sensitive parameter (*Kadioglu I., Yanar Y., 2004; Leather G.R., Einhellig F.A., 1988*)., Root length more often turns out to be a more sensitive growth indicator than germination, possibly because roots only elongate by increasing the number and volume of cells (*Leather G.R., Einhellig F.A., 1986*). Measuring root length and volume is not so easy as counting the number of germinated seeds and describing their condition (color, branching, hairs) (*Wardle D.A., Njchotson K.S., Rahman A., 1993*).

Biotests using aqueous extracts of plants are useful to prove the presence of allelochemicals; such effects often disappear in the field due to adsorption of allelochemicals by soil particles, decomposition and leaching (*De Almeida F.S., 1985*). With due account for critical comments on biotests of aqueous extracts, screening biotests using intact plant seedlings were developed. Seedlings were also used in allelopathy studies (*Wu H.; Haig T., Pratley J., Lemerle D. and An., 2000*). From laboratory results, it was concluded that biologically active substances from common bean seeds did not inhibit the growth of seedlings of the studied vegetables. Vegetable seedlings became longer when germinated together with bean seeds than without them. Cucumber seedlings were 6.0 cm long or by 0.5 cm longer compared to the control; late-ripening white cabbage seedlings - 7.1 cm long or by 0.3 cm longer; early potato seedlings - 3.6 cm long or by 1.0 cm longer; red beet seedlings - 6.8 cm long or by 1.8 cm longer; tomato seedlings - 6.5 cm long or by 0.8 cm longer (*Harbovska T.M., Zelendin Yu.D., Chefonova N.V., Honcharenko V.Yu., 2020*).

Cultivation of sweet corn in fields thickened with garden pea and green bean allows harvesting high yields not only of the main crop (3.7 t/ha of sweet corn), but also of the compacting plant (0.7 t/ha of garden pea and 2.2 t/ha ha of green bean) (*Didukh N.O., 2013*).

Volatile emissions from winter crop and perennial legume (white clover, hairy tare, and crimson clover) residues prevent the germination and development of onion, carrot, and tomato seedlings. Tests in a germination chamber showed that alfalfa residues were toxic to the germination of cucumber seeds and their seedlings. Alfalfa roots were also toxic to pre-germinated cucumber seeds. However, cucumber seedlings grew normally if chemicals were leached in crushed root- containing medium and seeds were stored for 1 day prior to planting (*Bradow J.M., Connick W.J.Jr., 1990*).

Laboratory tests (in Petri dishes) did not reveal negative effects of seeds of companion crops (winter and spring components) on the seedling length and germination energy of onion seeds. In general, water extractions from aboveground phytomass and roots of companion crops significantly suppressed the germination of onion seeds on day 3 of germination. Later (on days 7 and 10), suppression got weaker. Aqueous extracts from roots of companion crops were less toxic to germinating onion seeds than extracts from aboveground phytomass. Extract from onion roots and aboveground phytomass collected during the leaf lodging phase was most toxic for onion seedlings: Control 2 – germination ability was 24–36% on day 3; Control 1 (distilled water) – it was 51–55%. (*Vitanov O.D., Zelendin YU.D., Chefonova N.V., Melnyk O.V., Ivanin D.V., 2020*).

Therefore, there is an urgent need for further research to widely apply allelopathy in agriculture. Given a limited number of recommendations in scientific literature, laboratory and field studies of allelopathic compatibility of common bean and companion crops are required to grow seed pllants in polycrop agrocenoses (Mix Cropp).

Purpose: To investigate the allelopathic compatibility of seeds of common bean and companion crops; to establish interaction patterns using water extracts from seeds and other plant parts of common bean and companion crops.

Methods. The study was carried out in the laboratory conditions of the Laboratory of Adaptive Vegetable Growing of IVMG NAAS in 2021. We studied the compatibility of common bean ‘Kniahynia’ with the following companion crops: winter triticale ‘Tymofii’ and spring triticale ‘Kripost Kharkivska’. Their allelopathic effects were assessed in the laboratory (Figs. 1, 2.) and the field (Fig. 3.). Allelopathic properties of plants were determined by biotests (*Hrodzinskyi, O.M., 1973*). The experiments and observations were carried out in accordance with "Experimentation Methods in Vegetable and Melon Growing" (*Bondarenko, N.L., Yakovenko, K.I. (Eds), 2001*). The record plot was 0.7 m x 2.0 m = 1.4 m^2, in six replications.

Biotest procedures

Interaction of seeds in Petri dishes (biotest: interaction of germinating seeds of bean and companion crops). Sorted, swollen seeds of common beans are placed on filter paper moistened with distilled water in a thermostat at 23...25^{o}C. Seeds: control (10 bean seeds); various experimental combinations with seeds of other species (10 bean seeds/10 seeds of a companion crop [ratio 1:1]; 5 beans seeds/25 seeds of a companion crop [ratio 1:5]; 5 bean seeds/50 seeds of a companion crop [ratio 1:10]). On day 3, germinated seeds are sampled and the tap root length, hypocotyl length, length of adventitious roots, epicotyl length, and length of the first true leaf are measured. Their growth is expressed as a percentage related to the growth of control seedlings, which is taken as 100%. Experiments are carried out in three replications. Results are compared with the control.

Extraction method (biotest: germination of bean seeds in water extracts from whole seeds of bean and companion crops). Bean seeds are placed on filter paper moistened with distilled water and exposed in a thermostat at 23...25°C for 48 hours. When roots are 3–5 mm long, bean seedlings are transferred to Petri dishes filled with distilled water (control) or extracts from whole seeds of bean or companion plants (*Grodzinskiy A M., 1991*).

To prepare water extracts from seeds by active extraction, 5 g of seeds of bean and companion crops are weighed, poured with 50 mL of hot tap water (85°C), incubated at room temperature for a day, with periodically stirring. Then the extracts are filtered through filter paper, diluted with water in ratios of 1:1, 1:2 and 1:4 (experimental solutions), cooled to 4...10°C and stored until use (*Mushtaq W., Siddiqui M.B., 2018*).

On day 5, the tap root length, hypocotyl length, length of adventitious roots, epicotyl length, and length of the first true leaf are measured. Experiments are carried out in three replications. Results are compared with the control (distilled water).

Extraction method (biotest: germination of bean seeds in water extracts from vegetative mass, roots and post-harvest residues of bean and companion crops). Plants are sampled in the specified phenological phase of development: plants are dug out, roots are washed from the soil, and dried at 40°C in a thermostat to a constant weight. A weight of crushed aboveground plant parts or of roots is placed in a glass container, and distilled water is added in a ratio of 1:20 (1 g of plant mass/20 mL of distilled water). The container is shaken so that the plant mass is completely submerged in water. Extraction lasts one day at 20°C. Water-soluble compounds are solved. After 1 day, extract is transferred into another container and filtered. Bean seeds are placed on filter paper in Petri dishes and 3 mL of extract is added (3 mL of distilled water in the control). Petri dishes are incubated in a thermostat at 23...25°C. On day 5, the tap root length, hypocotyl length, length of adventitious roots, epicotyl length, and length of the first true leaf are measured. Experiments are carried out in three replications. Results are compared with the control. Control bean seeds (10 seeds) were soaked in distilled water (C-1) or in water extract from aboveground parts of bean plants (C-2), or in water extract from bean roots (C-3).

Results and Discussion. Root length is a more sensitive growth indicator than germination (*Leather G.R., Einhellig F.A., 1986*), so we conducted the biotest for the compatibility of bean seeds with seeds of companion plants in Petri dishes in ratios of 1:1, 1:5, 1:10 and measured the tap root length, hypocotyl length, length of adventitious roots, epicotyl length, and length of the first true leaf (Fig. 1)

Figure 1. Germination of bean seeds with seeds of companion plants in Petri dishes in a ratio of 1:1, 1:5 and 1:10.

Biotest: interaction of germinating seeds of bean and companion crops in Petri dishes. We established that biologically active substances from winter and spring triticale seeds (ratio 1:1) inhibited the hypocotyl and root growth by 21% and the true leaf and epicotyl growth by 10-9%. At the same time the number of adventitious roots in the experiments with winter triticale was similar to the control (C); the length of the longest adventitious root in the experiments with spring and winter triticale decreased by 21–26% compared to the control experiment with common bean seeds (C) (Table 1).

Table 1. Compatibility of bean seeds with seeds of companion plants in Petri dishes, 2021

Experiment	Hypocotyl and root length, mm	%	Length of the longest adventitious root, mm	%	Number of adventitious roots	%	True leaf and epicotyl lengtgh, mm	%
Bean (C)	120	100	53	100	12	100	19	100
Winter triticale 1:1	94	79	39	74	12	100	17	90
Winter triticale 1:5	74	62	34	65	11	92	16	87
Winter triticale 1:10	68	57	23	44	9	75	15	79
Spring triticale 1:1	94	79	42	79	11	92	17	91
Spring triticale 1:5	107	89	45	85	12	100	20	106
Spring triticale 1:10	91	76	33	62	12	100	15.5	83
LSD_{05}	19	-	4	-	0.9		0.9	

At a ratio of 1:5, winter triticale-induced inhibition of the hypocotyl growth was enhanced to 38%, but spring triticale seeds, on the contrary, had a neutral effect on this parameter. A stimulating effect of spring triticale seeds on the true leaf length (with epicotyl included) was noted: 106% compared to the control experiment with bean seeds (C). The results showed that biologically active substances from seeds of both winter triticale and spring triticale at a ratio of 1:10 were to be toxic to bean seedlings. Combined germination of bean seeds with spring triticale seeds at a ratio of 1:5 had a more positive effect compared to other ratios of seeds of the companion crops, and combined germination of bean seeds with spring and winter triticale seeds at a ratio of 1:1 gave similar parameters of germinating bean seeds.

Biotest: germination of bean seeds in water extracts from whole seeds of bean and companion crops in Petri dishes. Extracts from whole seeds of many plants were found to inhibit germination. The influence of external conditions on the release of substances by seeds has been little studied. It is obvious that all factors that enhance the hydration of proteins, solubility of various substances and permeability of protoplasm will facilitate the release of substances from seeds. The release of substances by seeds largely depends on their biological features (*Grodzinskiy A.M., 1991*).

Our allelopathy studies included testing the compatibility of bean seeds with water extracts from whole seeds of bean and companion plants. We compared experimental solutions (diluted with water in ratios of 1:1, 1:2 and 1:4) between themselves and with the control and concluded where biologically active substances from seeds of the companion plants did not inhibit the growth of bean seedlings (Fig. 2).

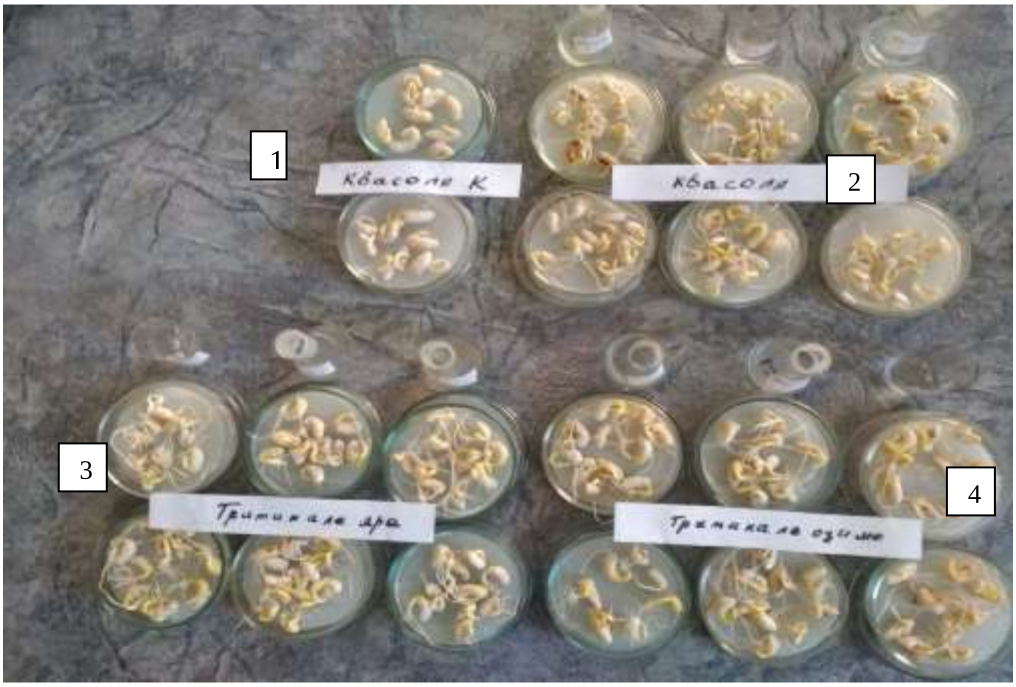
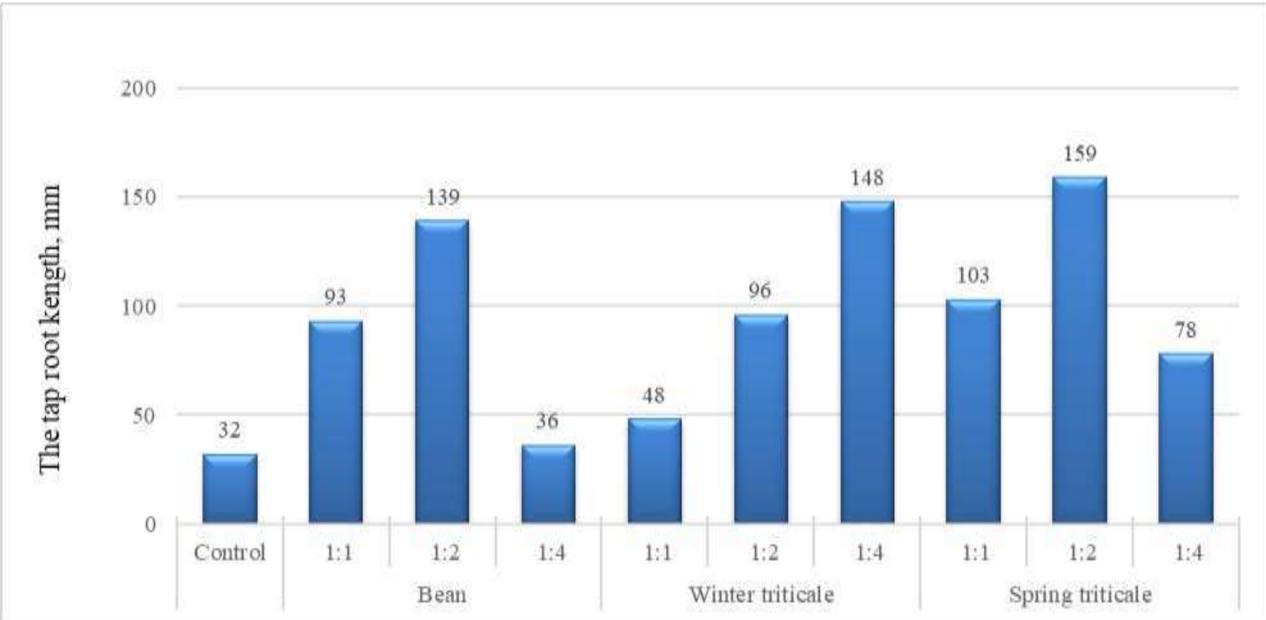


Figure 2. Germination of common bean seeds in water extracts from seeds of the companion crops in a ratio of 1:1, 1:2 and 1:4. *1 – bean (C); 2 – bean; 3 – spring triticale; 4 – winter triticale.*

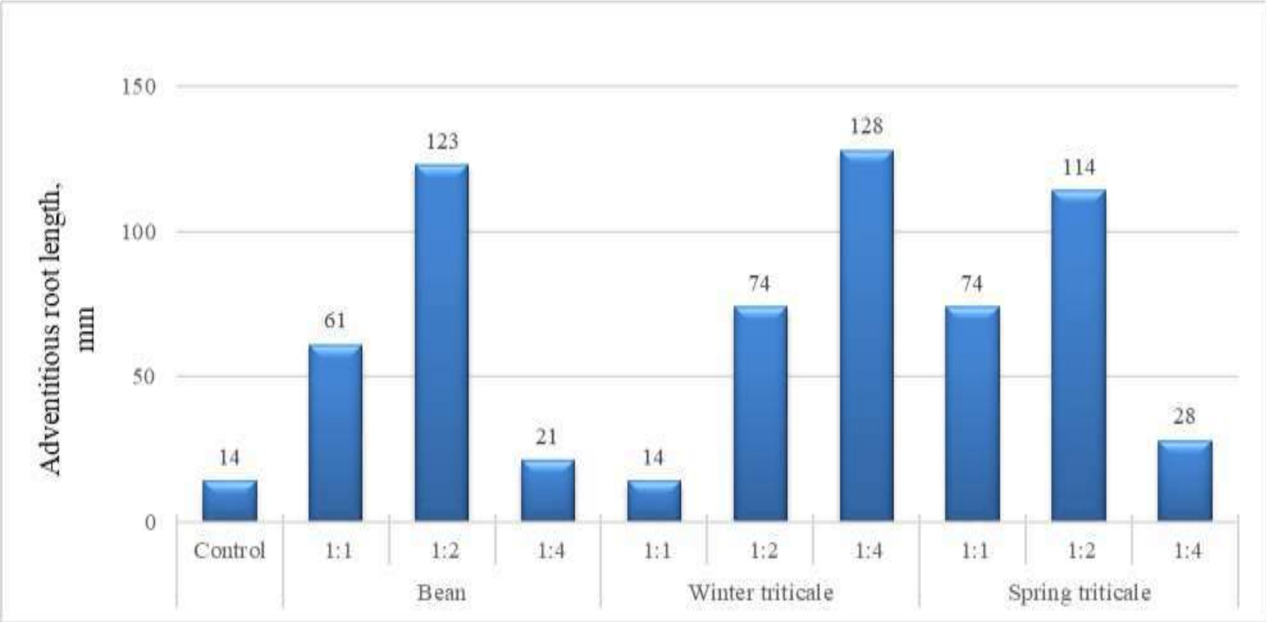
Different concentrations of water extracts from bean, winter and spring triticale affected the tap root length in germinating bean seeds: almost all variants positively affected or had no effect (no difference compared to the control experiment with distilled water) – 32 mm (Fig. 3). A strong allelopathic effect was noted with water extract from bean seeds (1:2) – 139 mm, winter triticale seeds (1:4) – 148 mm and spring triticale seeds (1:2) – 159 mm.



LSD =17.4

Figure 3. The tap root length in bean seedlings depending on water extracts from seeds of the companion plants (ratio 1:1, 1:2 and 1:4).

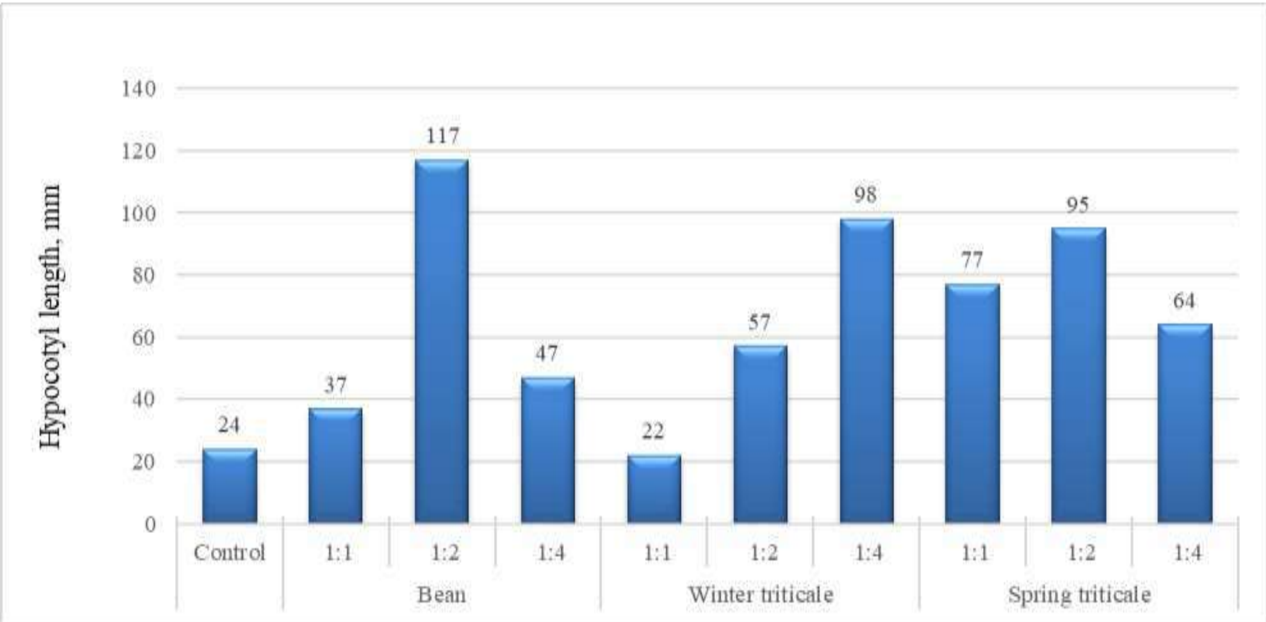
An increase in the adventitious root length was observed in almost all variants compared to the control (distilled water). We observed a clear allelopathic effect of water extracts from bean seeds (1:2) – 123 mm, winter triticale seeds (1:4) – 128 mm and spring triticale seeds (1:2) – 114 mm on the adventitious root length of been seedlings (Fig. 4).



LSD =9.83

Figure 4. The adventitious root length in bean seedlings depending on water extracts from seeds of the companion plants (ratio 1:1, 1:2 and 1:4).

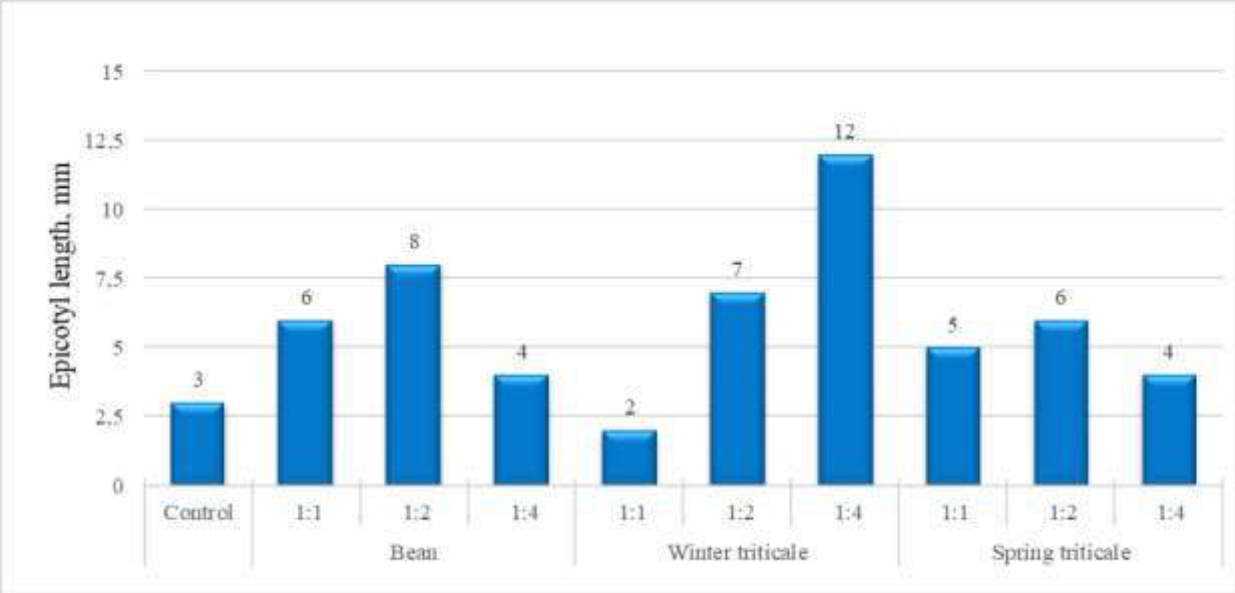
Water extract from winter triticale (1:1) did not have a significant effect on the hypocotyl growth. A strong stimulating allelopathic effect was seen in the following variants: water extract from bean sseds (1:2) – 117 mm, winter triticale seeds (1:4) – 98 mm and spring triticale seeds (1:2) – 95 mm (Fig. 5).



LSD = 9.50

Figure 5. The hypocotyl length in bean seedlings depending on water extracts from seeds of the companion plants (ratio 1:1, 1:2 and 1:4)

Water extract from winter triticale seeds (1:1) tended to shorten the epicotyl to 2 mm, while water extracts from bean seeds and spring triticale seeds in a ratio of 1:4 had no significant effect and this parameter was similar to the control (distilled water) value – 3 mm A strong stimulating allelostatic effect on the bean epicotyl growth was recorded for water extract from winter triticale seeds (1:4) – 12 mm (Fig. 6).



LSD = 1.10

Figure 6. The epicotyl length in bean seedlings depending on water extracts from seeds of the companion plants (ratio 1:1, 1:2 and 1:4)

As to the first true leaf length, a positive effect was noted in most variants; however, the following water extracts exerted a pronounced stimulating allelopathic effect on the first leaf growth in beans seedlings: from bean seeds (ratio 1:2) – 24 mm, winter triticale seeds (1:4) – 25 mm and spring triticale seeds (1:2) – 28 mm (Fig. 7).

LSD = 4.45

Figure 7. The first leaf length in bean seedlings depending on water extracts from seeds of the companion plants (ratio 1:1, 1:2 and 1:4)

We found that water extracts from bean and spring triticale seeds in a ratio of 1:2 as well as from winter triticale seeds (1:4) had a clear allelopathic effect on these parameters of bean seedlings. Water extracts from winter triticale (1:1) and spring triticale (1:4) seeds were more toxic to bean seedlings

Biotest: germination of bean seeds in water extracts from vegetative mass, roots and post-harvest residues of bean and companion crops in Petri dishes. Water extracts from both bean roots (C-3) and winter and spring triticale roots inhibited the tap root elongation less than extracts from aboveground parts (Fig. 8).

Figure 8. Germination of common bean seeds in water extracts from vegetative mass, roots and post-harvest residues of the companion crops, which were sampled during mass anthesis and after bean harvest, 2021

It was found that water extracts from spring triticale roots did not exert a significant effect on the tap root length (121 mm) and the adventitious root length (88 mm); similarly extracts from bean roots (C-3) did not influence the hypocotyl length (103 mm) and extracts from bean roots (C-3) and triticale spring roots had no effect on the true leaf length (13 mm), as these parameters were at the control level: distilled water (C-1) - 134 mm, 90 mm, 106 mm and 14 mm, respectively (Table 2).

Usually, water extract from bean aboveground parts (C-2) had a significant negative effect on all parameters of bean seedlings compared to the control.

The hypocotyl was 103 mm and 104 mm long with water extracts from bean roots and from aboveground mass of winter triticale, respectively, which did not fifer from the distilled water control (C-1).

Water extract from aboveground parts of bean had a negative allelopathic effect on the germinating seeds of bean, indicating self-incompatibility of this crop.

Control water extract (C-2) from post-harvest residues of bean plants suppressed all parameters of the bean seed germination compared to the distilled water control (C-1) and other extracts, confirming self-incompatibility of this crop (Table 3). The tap and adventitious root lengths (141 cm and 95 cm, respectively) as well as the hypocotyl length (107 mm) were not affected by extracts from post-harvest residues of spring and winter triticale, being at the distilled water control (C–1) levels.

Table 2. Compatibility of bean seeds testing depending on water extracts from vegetative mass and roots of bean and the companion plants (phase – mass anthesis of bean), 2021

Experiment	Length, mm					pH
	Tap root	Adventitious root	Hypocotyl	Epicotyl	True leaf	
Distilled water (C–1)	134	90	106	10	14	7.3
Bean aboveground mass (C–2)	95	71	82	5	12	6.5
Bean roots (C–3)	107	72	103	7	13	6.6
Winter triticale aboveground mass	96	91	104	8	13	6.5
Winter triticale roots	112	87	93	7	13	6.4
Spring triticale aboveground mass	98	81	98	5	12	6.3
Spring triticale roots	121	88	97	7	13	6.5
LSD_{05}	17.54	6.3	5.53	1.1	1.04	

Table 3. Compatibility of bean seeds depending on water extracts from post-harvest residues of common bean plants and the companion crops, 2021

Experiment	Length, mm					pH
	Tap root	Adventitious root	Hypo-cotyl	Epicot-yl	True leaf	
Distilled water (C–1)	133	90	107	10	14	7.3
Bean (C–2)	87	67	91	6	13	6.5
Winter triticale	115	87	107	7	13	6.9
Spring triticale	141	95	96	6	13	7.2
LSD_{05}	14.8	5.4	10.9	1.7	0.9	–

Conclusions. Germination of common bean seeds with seeds of the companion crops as well as with aqueous extracts from seeds of common bean and the companion crops and with aqueous extracts from aboveground parts, roots and post-harvest residues under the laboratory conditions makes it possible to assess their mutual influence as early as at the initial stage and to select crops for cultivation in heterogeneous fields to form a high-performance agrophytocenosis.

The results showed that biologically active substances from seeds of both winter triticale and spring triticale at a ratio of 1:10 were toxic for bean seedlings. Combined germination of bean seeds with spring triticale seeds at a ratio of 1:5 had a more positive effect compared to other ratios of seeds of the companion crops. Upon combined germination of bean seeds with spring triticale seeds and winter triticale seeds at a ratio of 1:1, the parameters of bean seedlings were very similar to the control ones.

Water extracts from bean and spring triticale seeds at a ratio of 1:2 and from winter triticale seeds (1:4) had a pronounced allelopathic effect on the parameters of bean seedlings. Water extracts from winter triticale seeds (1:1) and spring triticale seeds (1:4) were more toxic to bean seedlings.

Water extracts from bean, winter triticale and spring triticale roots slightly suppressed the tap root elongation in bean seedlings. Water extract from aboveground parts of bean was revealed to have a negative allelopathic effect on germinating seeds of bean, indicating self-incompatibility of this crop. A neutral allelopathic effect on the germination of bean seeds was exerted by extract from the post-harvest residues of spring triticale.

Biotests with seeds of companion crops and water extracts from seeds and various parts of common bean plants and plants of companion crops proved to be useful in screening for allelochemicals. Winter triticale and spring triticale can be used as a forecrop and as a companion crop for common bean. Allelopathy should be taken into account when one designs a crop rotation.

References

Babych, A.O., Petrychenko, V.F., Poberezhna, A.A. (1994). Global production of annual grain legumes to solve the problem of protein and biological nitrogen. *Kormy i Kormovyy Bilok*: Abstracts of the 1st All-Ukrainian (International) Conference. Vinnytsia. P. 164–165.

Bohovin, A.V. (2009). Biogeocenotic role of relationships between living organisms in the formation and functioning of ecological systems. *Ekolohiia ta Noosferolohiia*. Vol. 20. No 1–2. P. 102–104.

Bondarenko, H.L., Yakovenko, K.I. (Eds). (2001). Methods experimentation in vegetable and melon growing. Kharkiv: Osnova. 369 p.

Bradow, J.M., Connick, W.J.Jr., (1990). Volatile seed germination inhibitors from plant residues. Journal of Chemical Ecology. 16. P. 645–666.

Bukharov, A.F., Baleyev, D.N., Bukharova, A.R. (2011). Assessment of adaptability and stability of allelopathic activity of extracts from seeds of celeries. *Vestnik Altayskogo Gosudarstvennogo Agrarnogo Universiteta.* No 3. (77). P. 36–39.

De Almeida, F.S. (1985). Effect of some winter crop mulches on the soil weed infestation. In: Proceedings British Crop Protection Conference Weeds. P. 651–659.

Inderjit, Foy C.L., Dakshini K.M.M. (eds.). (1999). How to make bioassays for allelopathy more relevant to field conditions with particular reference to cropland weeds. In: Principals and Practices in Plant Ecology: Allelopathic Interactions. P. 25–33.

Ivaniuk, S.V., Lekhman, A.A., Ovcharuk, O.V. (2015). Grain density variability in common bean varieties in the Right-Bank Forest-Steppe of Ukraine. *Kormy i Kormovyrobnytstvo*. Vinnytsia. Issue 80. P. 17–24.

Golovko, Ye.A. Bilyanovskaya, T.M., Vorobey, I.I. et al. (1999). Allelopathy in domestic plants. Fiziologiya i Biokhimiya Kulturnykh Rasteniy Vol. 31. No. 2. P. 103–110.

Holovko, Ye.A. Puzik, V.K. (2003). Allelopathy and design of landscape compositions. *Introduktsiia Roslyn*: collection of scientific papers. No 1–2. P. 149–157.

Hoagland R.E., Williams R.D. (2004). Bioassays: useful tools for the study of allelopathy. In: Macias, F.A., Galindo, J.C.G., Molinillo, J.M.G. and Cutler, H.G. editors. Allelopathy: *Chemistry and Mode of Action of Allelochemicals.* Boca Raton, FL: CRC Press. P. 315–351.

Hnatiuk, N.O. (2003). Evaluation of allelopathic properties of seeds of some aromatic plant species. Introduktsiia roslyn. No. 4. P. 109–113.

Hrodzinskyi, O.M. (1973). Fundamentals of chemical interactions of plants. Kyiv: Naukova Dumka. 205 p.

Harbovska, T.M., Zelendin, Yu.D., Chefonova, N.V., Honcharenko, V.Yu. (2020). Allelopathic interactions of common bean (*Phaseolus vulgaris* L.) with other vegetables. *Ovochivnytstvo i Bashtannytstvo.* Issue 67. P. 51–56.

Grodzinskiy, A.M. (1965). Allelopathy in the life of plants and their communities. Kyiv: Naukova Dumka. 187 p.

Grodzinskiy, A.M. (1991). Plant allelopathy and soil fatigue: Selectas. Kyiv: Naukova Dumka. 432 p.

Kaminskyi, V. F., Holodna, A.V., Shliakhturov, D.S. (2008). Intensification of the grain legumes production in the northern forest-steppe. *Zemlerobstvo.* Kyiv: Ekmo. Issue 80. P. 109–115.

Didukh N.O. (2013). Cultivation of sweet corn in thickened fields in the Left-Bank Forest-Steppe of Ukraine. *Visnyk Kharkivskoho Derzhavnoho Ahrarnoho Unstytutu imeni V.V. Dokuchaieva.* No 9. P. 235–239.

Kaminskyi, V.F. (Ed) (2016). Scientific basics of organic production in Ukraine: monograph. Kyiv: Ahrarna Nauka. P. 221–230.

Kondratyev, M.N., Budarin, S.N., Larikova, Yu.S. (2014). Effects of water extracts from leaves of *Heracleum sosnowskyi* Manden on seed dispersal and seedling growth in some agricultural and medicinal plants. Abstracts of the All-Russian Scientific Conference (with international participation) "Biological Aspects of Plant Dissemination, Adaptation and Resistance" (Saransk, May 15–18, 2016). P. 46–50.

Kosolap, N.P. (2008). Allelopathy - the cause of many consequences. *Zerno*: collection of scientific papers. No. 9. P. 46–51.

Kadioglu, I., Yanar, Y., (2004). Allelopathic effects of plant extracts against seed germination of some weeds. Asian. *Journal of Plant Sciences*. 3. P. 472–475.

Leather, G.R., Einhellig, F.A. (1988). Bioassay of naturally occurring allelochemicals for phytotoxicity. *Journal of Chemical Ecology*. 14: 1988. P. 1821–1828.

Leather, G.R., Einhellig, F.A. (1986). Bioassays in the study of allelopathy. In: A.R. Putnan, C.-S. Tang (Eds.), *The Science of Allelopathy*, Wiley-Interscience, New Jersey. P. 133–145.

Macias, F.A, Molinillo, J.M.G., Varela, R.M., Galindo, J.C.G. (2007). Allelopathy – a natural alternative for weed control. *Pest Manag Sci*. 63. P. 327–348.

Mushtaq, W., Siddiqui, M.B. (2018). Allelopathy in Solanaceae plants. *Journal of Plant Protection Research* 58(1). P. 1–7.

Ovcharuk, O.V. (2015). Prospects for bean growing in Ukraine. *State-or-Art Farming Techniques: Trends and Innovations*: Abstracts of All-Ukrainian Scientific and Practical Conference. October 17-18, 2015. Vinnytsia, P. 282–284.

*Simagina, N.O. (*2006). Allelopathic properties of glycohalophyte *Artemisia santonica* L. Uchyonyye Zapiski Tavricheskogo Natsionalnogo Universitetata imeni V.I. Vernadskogo. Series "Biologiya i Khimiya". Vol. 19. No. 4. P. 177–185.

Vitanov, A.D. (2007). Organic farming methods in vegetable growing - innovative product. *Ovochívnytstvo í Bashtannytstvo* No 53. P. 386–391.

Wato, T. (2020) The role of allelopathy in pest management and crop production. *Food Science and Quality Management*. Vol. 93. P. 13–21. DOI: 10.7176/FSQM/93-02

Wardle, D.A., Njchotson K.S., Rahman A. (1993). Influence of plant age on allelopathic potential of Nodding Thistle (*Curduus nutans* L.) against pasture grasses and legumes. *Weed Research*. 33. P. 69–78.

Wu H., Haig T., Pratley J., Lemerle D. and An. (2000). Distribution and exudation of allelochemicals in wheat *Triticum aestivum*. *Journal of Chemical Ecology*. 26. P. 2141-2154.

Yurchak, L.D. (2005). Allelopathy in agrobiocenoses of aromatic plants. Kyiv: [sine nomine]. 250 p.

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АЛЕЛОПАТИЧНА СУМІСНІСТЬ КВАСОЛІ ОВОЧЕВОЇ ТА СУПУТНІХ КУЛЬТУР

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Мета. Дослідити алелопатичну сумісність насіння квасолі овочевої та супутніх культур. Встановити закономірності взаємодії через рослинні виділення з водних витяжок насіння квасолі овочевої та супутніх культур і водних витяжок з різних частин рослин квасолі овочевої та супутніх культур. **Методи.** Лабораторний, статистичний. **Результати.** Біотест: взаємовплив проростаючого насіння квасолі і супутніх культур в чашках Петрі. Біологічно активні речовини з насіння тритикале озимого і тритикале ярого (за співвідношення: 1 частина насіння квасолі до 10 частин супутніх культур) проявили негативний ефект на проростки насіння квасолі за всіма показниками: довжиною гіпокотиля з коренем, довжиною найдовшого придаткового кореня, кількістю придаткових коренів і довжиною справжнього листка з епікотилем. За співвідношення 1:5 посилювалося пригнічення росту гіпокотилю дією тритикале озимого до 38 %, і, навпаки, відмічено нейтральний вплив тритикале ярого на цей показник. Виявлено стимулюючу дію насіння тритикале ярого на довжину справжнього листка квасолі (з епікотилем) – 106 %. За тритикале озимого і ярого у співвідношенні 1:1 (у порівнянні до контролю – без насіння супутніх культур) спостерігається пригнічення росту гіпокотилю з коренем на 21 %, справжнього листка з епікотилем – на 10–9 % відповідно. Біотест: пророщування насіння квасолі на водній витяжці з цілого насіння квасолі і супутніх культур в чашках Петрі. Водна витяжка з насіння тритикале ярого у співвідношенні 1:2 мала найбільшу стимулюючу дію на довжину головного кореня та першого листка, тритикале озимого у співвідношенні 1:4 – на довжину придаткового кореня та епікотиля, квасолі у співвідношенні 1:2 – на довжину епікотиля. Біотест: пророщування насіння квасолі на водній витяжці з вегетативної маси, коренів і пожнивних решток квасолі і супутніх культур в чашках Петрі. Водні витяжки з коренів квасолі, тритикале озимого та ярого слабо пригнічували проростання головного кореня квасолі. Толерантний алелопатичний ефект на проростання насіння квасолі проявила витяжка з пожнивних решток тритикале ярого. Водна витяжка з надземної частини квасолі виявила негативну алелопатичну дію на проростаюче насіння самої квасолі, що свідчить про самонесумісність цієї культури. **Висновки.** Результати лабораторних досліджень свідчать, що біологічно активні речовини з насіння як тритикале озимого, так і тритикале ярого за співвідношення 1:10 виявилися токсичним для проростків насіння квасолі. Спільне пророщування насіння квасолі з насінням тритикале ярого за співвідношення 1:5 має більш позитивний ефект в порівнянні з іншими співвідношеннями насіння супутніх культур, а спільне пророщування насіння квасолі з насінням тритикале ярого та озимого за співвідношення 1:1 – майже однакові параметри проростючого насіння квасолі. За результатами досліджень встановлено, що чітко виражений алелопатичний вплив на дані показники квасолі проявили водні витяжки з квасолі і тритикале ярого у співвідношенні 1:2, тритикале озимого (1:4). Водні витяжки з тритикале озимого (1:1) і тритикале ярого (1:4) були більш токсичними для проростків квасолі. Водні витяжки з коренів квасолі, тритикале озимого та ярого слабо пригнічували проростання головного кореня квасолі. Водна витяжка з надземної частини квасолі виявила негативну алелопатичну дію на проростаюче насіння самої квасолі , що свідчить про самонесумісність цієї культури. Толерантний алелопатичний ефект на проростання насіння квасолі проявила витяжка з післяжнивних решток тритикале ярого. Спільне пророщування насіння квасолі овочевої й супутніх культур в лабораторних умовах дає змогу уже на початковій стадії оцінити особливості його проростання і взаємовплив компонентів, підібрати культури для вирощування у гетерогенному посіві з метою формування високопродуктивного агрофітоценозу.

Ключові слова: квасоля овочева, насіння, супутні культури, біотести, алелопатія.

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GOURD GROWING EFFICIENCY USING SILICON-CONTAINING FERTILIZERS IN THE SOUTH OF UKRAINE

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Purpose. To evaluate the effect of pre-sowing soaking of seeds on the plant performance and economic efficiency of watermelon and melon growing on drip irrigation in the South of Ukraine. **Methods.** Field, measuring, computational, comparative, and mathematical/statistical methods, analysis of economic efficiency. **Results.** Pre-sowing soaking of seeds in solutions of silicon-containing fertilizers was shown to help obtain early and full-bodied watermelon and melon seedlings, increase the length and number of lateral shoots, and improve fruit setting. Balanced plant nutrition contributed to high performance of watermelon and melon plants in the South of Ukraine. The highest yields of watermelon (23.4 t /ha) and melon (17.5 t/ha) fruits were harvested with 10% Quantum AquaSil solution, which increased the yield by 35.3 and 35.7%, respectively, compared to the untreated control. Silicon-containing fertilizers, 15% Bai-Si and Kelik Potassium-Silicon solutions, increased the fruit yield in watermelon fields by 22.5% and 19.7%, respectively, compared to the untreated control. The greatest economic effect of watermelon and melon growing was achieved by soaking seeds in 10% Quantum AquaSil solution prior to sowing; the profitability amounted to 122 and 101%, respectively. **Conclusions.** Pre-sowing soaking of seeds in silicon-containing fertilizer solutions contributed to high performance of plants and allowed increasing the economic efficiency of cultivation. The maximum percentage of fruit setting was recorded after seed treatment with 10% Quantum AquaSil solution. For example, this parameter was 67% in watermelon 'Charivnyk' and 87% in 'Didona' melon. In the south of Ukraine, the economic effect of outdoor watermelon and melon cultivation increased by 16,030–19,220 UAH/ha and 21,230–26,340 UAH/ha, respectively.

***Key words*:** watermelon, melon, seed treatment, silicon-containing fertilizers, performance, economic efficiency.

Introduction. Currently, under progressive global climatic changes on the planet, effects of adverse environmental factors are becoming more and more noticeable, determining the country's position at the world's agricultural market. In Ukraine, like in many regions of intensive agriculture, high-quality agricultural production depends on sharp weather fluctuations during growing periods of plants. This issue is especially acute for the South of Ukraine, where long droughts have often been occurring in growing periods recently. Increased aridity of the climate, which is evident at the moment and is probable under climatic change scenarios, without adaptation measures in the southern regions is most likely to result in a 10 - 20% decrease in yields of almost all agricultural crops by 2050 and, in the case of a more severe scenario, such decrease may reach 25% or even 50% (*Romashchenko, M., Husiev, Y., Shatkovskyi, A., Saidak, R., Yatsiuk, M., Shevchenko, A., & Matiash, T.*, 2020). Application of silicon-containing fertilizers is a way to increase gourd yields.

Review of Recent Studies and Publications. According to data of the International Food and Agriculture Organization of the United Nations (UN FAO), in 2000, 76,382,000 tons of watermelons were harvested in the world, in 2010 – 93,530,000 tons, in 2021 – 101,635,000 tons. The mean fruit yield increased from 24.3 to 33.5 t/ha during this period (*Agricultural statistics FAOSTAT*, 2022). In Ukraine, over the past five years, gourd yields occupied 61,800–63,600 hectares, of which watermelons were grown on 42,700-43,200 hectares. The Khersonska Oblast has been the largest producer of gourds. In 2021, 168,500 tons of fruits were harvested, accounting for 67.2% of the gross production in the southern region and 33.5% of the total production in Ukraine (*Roslynnytstvo Ukrainy. Statistical collection*, 2021).

Current intensive technologies involve integrated mineral nutrition of vegetables and gourds due to increased efficiency of mineral fertilization on reclamation lands (*Lymar V. A.,* 2015). During long periods of intensive cultivation of agricultural crops, the content of available silicon in the soil drops and this can possibly become a limiting factor (among others), which reduces yields of agricultural crops (*Meena, V. D., Dotaniya, M. L., Coumar, V., Rajendiran, S., Ajay, S., Kundu, S., and Rao, A.S.,* 2014). Silicon is a biologically important element, necessary for plants. The silicon content in plant biomass ranges 0.02% to 0.15%. Silicon forms a cuticular-silicon wall in the epidermal cells of leaves, stems and roots, which protects plants from excessive water loss and regulates water absorption (*Szulc, W., Rutkowska, B., Hoch, M., Spychaj-Fabisiak, E., and Murawska, B.,* 2015). Gross collections depend on the granulometric composition and acidity of soil solutions. Liming of acidic soils increases the content of available forms of silicon (*Kadalli, G. G., Rudresha, B. A., Prakash, N. B.,* 2017). Diatomites and zeolites are the most famous examples of silicon fertilizers, which are mined as mineral raw materials. These compounds have relatively high solubility and are used in agriculture. When diatomite was applied at a dose of 150 kg/ha in combination with 50% of the fertilizer (NPK+manure) amount, potatoes yielded by 38.7% of tubers compared to the control (without fertilizers) and by 12.9% compared to the full dose of mineral fertilizers (*Marodin J. C., Resende J. T. V., Morales R. G. F., Silva M. L. S., Galvão A. G., Zanin D. S.,* 2014). In Brazil, studies of three silicate fertilizers, calcium silicate, potassium silicate and sodium silicate, were conducted; it was shown that the fertilizers significantly increased the yield to 60.8 t/ha. Application of these fertilizers at a dose of 400 kg/ha increased the yield of marketable products by reducing tomato dehiscence (*Kleiber, T., Krzesiński, W., Przygocka-Cyna, K., and Spiżewski, T.,* 2015). In Poland, studies were conducted on lettuce plants that were stressed by manganese excess. Application of a complex silicon-containing fertilizer for fertigation had a positive effect on plants: the relative water content increased (ratio of the current water content in the tissue to its content in the moistened tissue) (*Liang, Y., Nikolic, M., Bélanger, R., Gong, H., and Song, A.,* 2015). Chinese studies with soil application of silicon demonstrated that the tomato yield increased by 8.7-15.9% compared to the control (without application) (*Ma, J. F. and Yamaji N.,* 2008). Other scientists confirmed positive effects of silicon on resistance to abiotic and biotic stressors, including drought, lodging, frost, and soil salinity, plant growth and development in general, and on yield in sweet pepper (*French-Monar, R. D., Rodrigues, F. A., Korndorfer, G. H., and Datnoff, L. E.,* 2010), cauliflower (*Wenneck G. S., Saath R., Rezende R., e-Vila V. V., Terassi D. D. S. & Andrean A. F. B.,* 2023), and China squash (*Mitani, N., Yamaji, N., Ago, Y., Iwasaki, K., and Ma, J. F.,* 2011). Application of silicon boosts resistance of gourds to major diseases - bacterial spot of melons (*Ferreira, H. A., Nascimento, C. W. A., Datnoff, L. E., Nunes, G. H. S., Preston, W., Souza, E. B., & Mariano, R. L. R.,* 2015). Chemical analysis of disease- affected leaves revealed some patterns, namely a significant reduction in the contents of phosphorus, potassium, calcium, magnesium, and iron. Adding calcium silicate and lignin modified with silicic acid to the soil increased the contents of nitrogen, potassium, phosphorus, and calcium in plant leaves. An increase in the calcium level in plants due to silicon application indicates activation of transport of macronutrients and provision with nutritional compounds. Under such conditions, the supply of potassium (which is responsible for the water status of plants and ensures their resistance to drought) to plants is enhanced. It is known that plants with weak turgor are more susceptible to pathogenic fungi (*Makarenko N. V., Zaimenko N. V.,* 2020). However, silicon is currently recognized as a minor element for plants, and there are no economic studies to demonstrate benefits of silicon-containing fertilizers to growers (*Zellner, W., Tubaña, B., Rodrigues, F. A., and Datnoff L. E.,* 2021). Increasing the economic efficiency of production of any economic entity plays a significant role in its activities; therefore, there is a need for constant control and search for ways of its growth (*Yaroslavskyi A.O., 2018*).

The efficiency of different fertilization regimens in gourd cultivation depends on technological approaches of cultivation and soil/climatic conditions. No studies of the efficiency of silicon-containing fertilizers for watermelon and melon cultivation in the Steppe of Ukraine were conducted.

Purpose. To evaluate the effect of pre-sowing soaking of seeds on the plant performance and economic efficiency of complex fertilizers in watermelon and melon growing in the South of Ukraine.

Materials and Methods. The study was conducted in an experimental field of the Institute of Climate Smart Agriculture of NAAS in 2021–2022. The soil in the experimental field is solodized, sabulous chernozem, with a humus content in the arable (0–30 cm) layer of 1.52 %. The soil density in the 0–30 cm layer is 1.35 g/cm^3; the total porosity is 34 %. The soil solution was almost neutral (pH of the water extract was 6.8–7.2).

The studied formulations are modern silicon-containing fertilizers, which in small doses beneficially affect the germination energy and ability of seeds and further development of plants. Kelik Potassium-Silicon is a concentrated potassium-silicon chelate fertilizer (liquid), which contains 20.0 % of K_2O, 13.0 % of Si_2O and 2.0 % of EDTA. Manufacturer: Atlantica Agricola (Spain). Quantum AquaSil is a domestic highly concentrated complex chelate fertilizer (liquid). Composition: K_2O – 10 %, SiO_2 – 20 %, humic substances – 1 %. Bai-Si is a domestic silicon-based immunoprotector. Composition: SiO_2 – 5-7 %, K_2O – 2.2-3.3%, SiO_2 – 99.7 %, CuO – 0.54 %, FeO – 0.24 %, ZnO – 0.1 %.

The experiments was carried out with an 8-, 10- or 12-hour exposure depending on fertilizer concentration: 1) sowing of dry seeds (control I); 2) sowing of water-soaked seeds (control II); 3) pre-sowing treatment of seeds with 5% solution of Kelik Potassium-Silicon; 4) 10 % Kelik Potassium-Silicon; 5) 15 % Kelik Potassium-Silicon; 6) 5 % Quantum AquaSil; 7) 10 % Quantum AquaSil; 8) 15 % Quantum AquaSil; 9) 5 % Bai-Si; 10) 10 % Bai-Si; 11) 15 % Bai-Si. The sown plot was 125 m^2, with the record area of 100 m^2. Upon seed treatments, the manufacturers' recommendations were taken into account: according to them, the standard concentrations are as follows: Kelik Potassium-Silicon – 0.6 % solution; Quantum AquaSil – 1.0 % solution; Bai-Si – 150 mL/t, working solution 1:50. The experiments were carried out in four replications. Watermelon 'Charivnyk' and melon 'Didona' were used in the experiments. The study was conducted on drip irrigation.

Results. A lot of scientists reported that complex silicon-ontaining fertilizers had positive effectson the growth and development of gourds (root weight and number of shoots) (*Preston, H. A. F., Nascimento, C. W. A., Preston, W., Nunes, G. H. S., Loureiro, F. L. C., and Mariano, R. De L. R., 2020; Lozano, C. S., Rezende, R., Hachmann, T. L., Santos, F. A. S., Lorenzoni, M. Z., de Souza, Á. H. C.,* 2018).

In the South of Ukraine, it was shown that pre-sowing soaking of seeds in solutions of silicon-containing fertilizers contributed to emergence of early and full-bodied seedlings of watermelon and melon; the length and number of lateral shoots increased; fruit setting improved. Silicon-containing fertilizers increased the shoot number in watermelon plants by 1–2 shoots; the shoots became by 31.9–41.8 % longer; and the fruit setting was enhanced by 14–21 %. Pre-sowing soaking of seeds in solutions of silicon-containing fertilizers increased the shoot number by 1–2 shoots; the shoots were by 11.5–50.6 % longer; and the fruit setting was enhanced by 15–19 %.

Percentage of fruit setting is an important indicator when one evaluates experimental variants to boost resistance of gourds to unfavorable growing conditions. Fruit set in gourds was shown to be directly correlated with yield: the coefficient of correlation was 0.70 for watermelon and 0.72 for melon (Fig. 1).

The fruit set percentage, depending on experimental variants, ranged 46 % to 69 % for watermelon 'Charivnyk' and 60% to 82 % for melon 'Didona'. Seed treatments influenced to a greater extent and the influence of concentrations were slightly weaker. The maximum percentage of fruit set were noted after Quantum AquaSil treatment of seeds. In watermelon 'Charivnyk', this parameter was 67 %; in melon 'Didona', it was 87 %.

The lowest percentage of fruit set was observed in the control and, depending on the crop, it ranged from 46 % (watermelon) to 60 % (melon) (Fig. 2).

The weather in 2020 was favorable for shallot growth, development and yield. The best yields in 2020 were harvested from 'Sh-1' (KyivskaOblast), 'Sh-2' (Kyivska Oblast), 'Sh-6' (Dnipropetrovska Oblast), 'Sh-9' (Dnipropetrovska Oblast), and 'Sh-10' (Chernihivska Oblast): 32.6, 26.3, 19.3, 19.8, and 20.6 t/ha, respectively. It was more than the yield harvested from the control cultivar, 'Lira', by 16.8, 10.5, 3.5, 4.0, and 4.8 t/ha, respectively.

Lower yields were harvested in 2020 from 'Sh-4' (Kyivska Oblast), 'Sh-7' (Dnipropetrovska Oblast), and 'Sh-11' (Chernihivska Oblast): from 12.5 t/ha ('Sh-11' and 'Sh-7') to 12.8 t/ha ('Sh-4'). 'Sh-3' (15.5 t/ha), 'Sh-5' (15.2 t/ha), and 'Sh-8' (15.5 t/ha) yielded almost the same as 'Lira'.

On average for the two study years, the following accessions had significantly increased yields of bulbs: 'Sh-1' (30.5 t/ha), 'Sh-2' (25.4 t/ha), 'Sh-6' (18.9 t /ha), 'Sh-9' (18.1 t/ha), and 'Sh-10' (19.4 t/ha). 'Sh-4' (12.2 t/ha), 'Sh-7' (12.0 t/ha), 'Sh-11' (11.9 t/ha), 'Sh-12' (13.8 t/ha), 'Sh-13' (13.2 t/ha), and 'Sh-14' (13.0 t/ha) yielded significantly less. 'Sh-3' and 'Sh-8' from Kyivska and Dnipropetrovska Oblasts, respectively, yielded almost the same as the control cultivar, 'Lira' (15.5 t/ha).

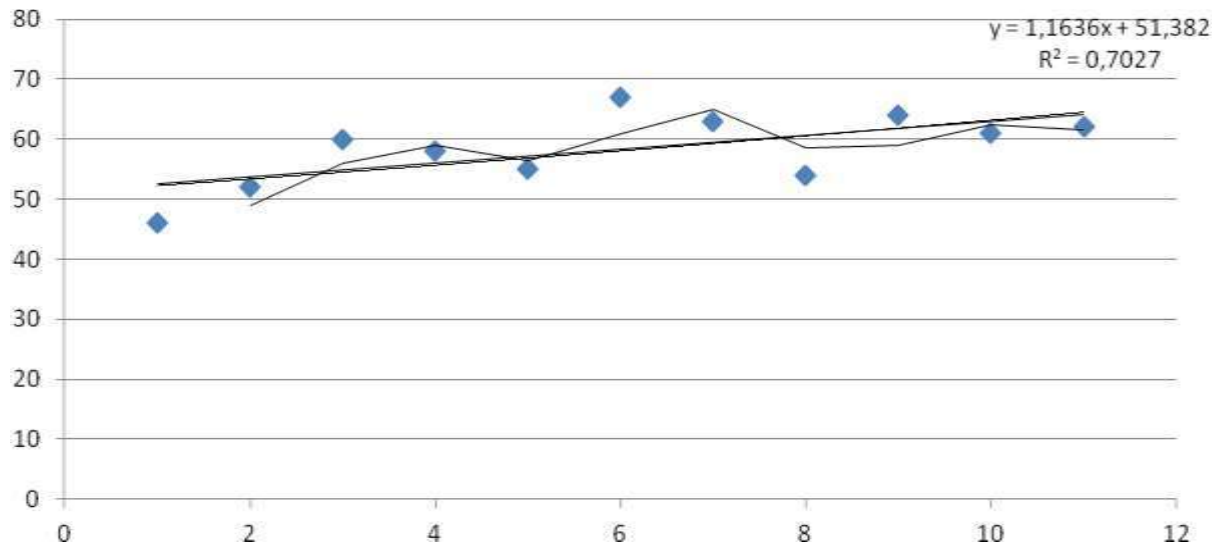

Figure 1. Correlation between fruit set on yield in watermelon

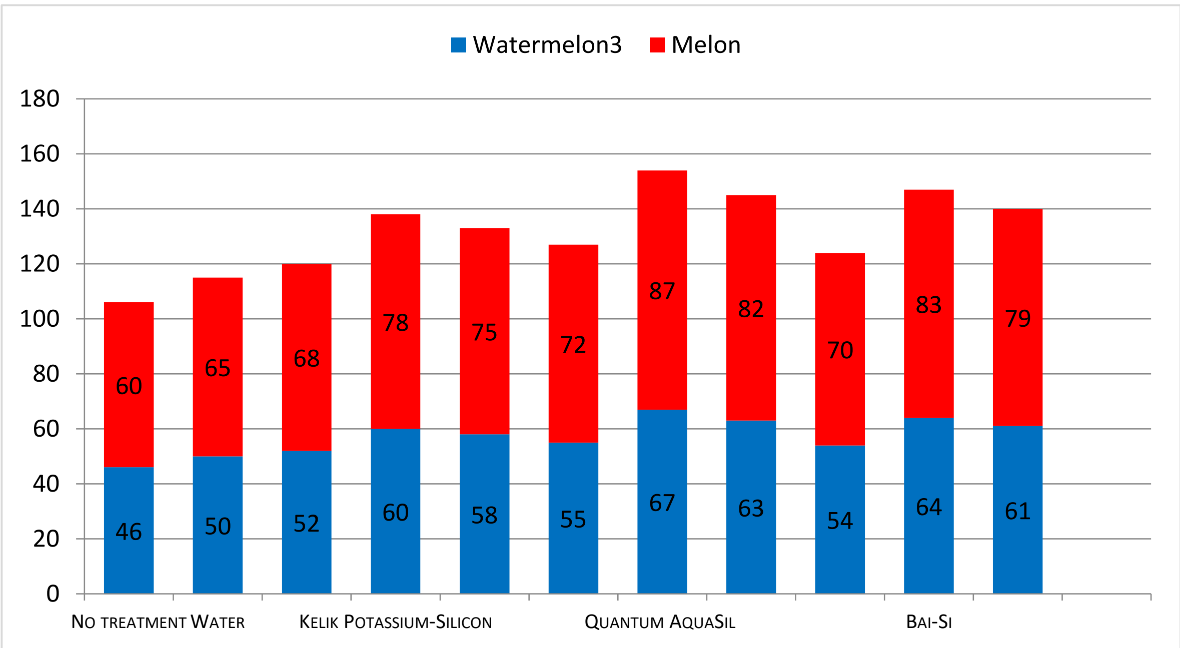

Figure 2. Fruit set percentage in gourds

The silicon-containing complex fertilizers significantly increased the gourd yields. Increased performance of watermelon plants and improved quality of its fruits after application of silicon-containing fertilizers into the soil is confirmed by studies of Spanish and Chinese scientists (*Kim, Y. S., Kang, H. J., Kim, T. I., Jeong, T. G., Han, J. W., Kim, I. J., and Kim, K. I.,* 2015), (*Toresano, F., Díaz, M., Pérez, L., Camacho, F.,* 2021).

Watermelon 'Charivnyk' yielded 17.3–23.4 t/ha of fruits in the experiments of the Institute of Climate Smart Agriculture of NAAS, depending on fertilization regimen; melon 'Didona' yielded 12.9–23.4 t/ha.

The highest yield of watermelon fruits (23.4 t/ha) was harvested after treatment with 10% Quantum AquaSil solution; the gain compared to the untreated control was 35.3 %, with the highest concentration of 30.6 %. With 5 % Kelik Potassium-Silicon solution, 20.7 t/ha of fruits were harvested, which is plus 19.7 % to the control (untreated seeds). 10 % solution of this formulation increased the yield by 18.5 % compared to the. The $LSD_{0.95}$ between the variants was 1.2. Pre-sowing soaking of seeds in 15 % Bai-Si solution resulted in a fruit yield of 21.2

t/ha, which was plus 22.5 % to the untreated control. 10 % solution of this formulation increased the yield by 13.9 % compared to the control, with the corresponding $LSD_{0.95}$ of 0.7.

In the melon fields, the highest yield of melon fruits (17.5 t/ha) was harvested with pre-sowing soaking of seeds in 10 % Quantum AquaSil solution; the gain compared to control I was 35.7 %. 15% solution of this formulation increased the yield by 31.0% compared to control I (Fig. 3). The $LSD_{0.95}$ between the variants was 1.3.

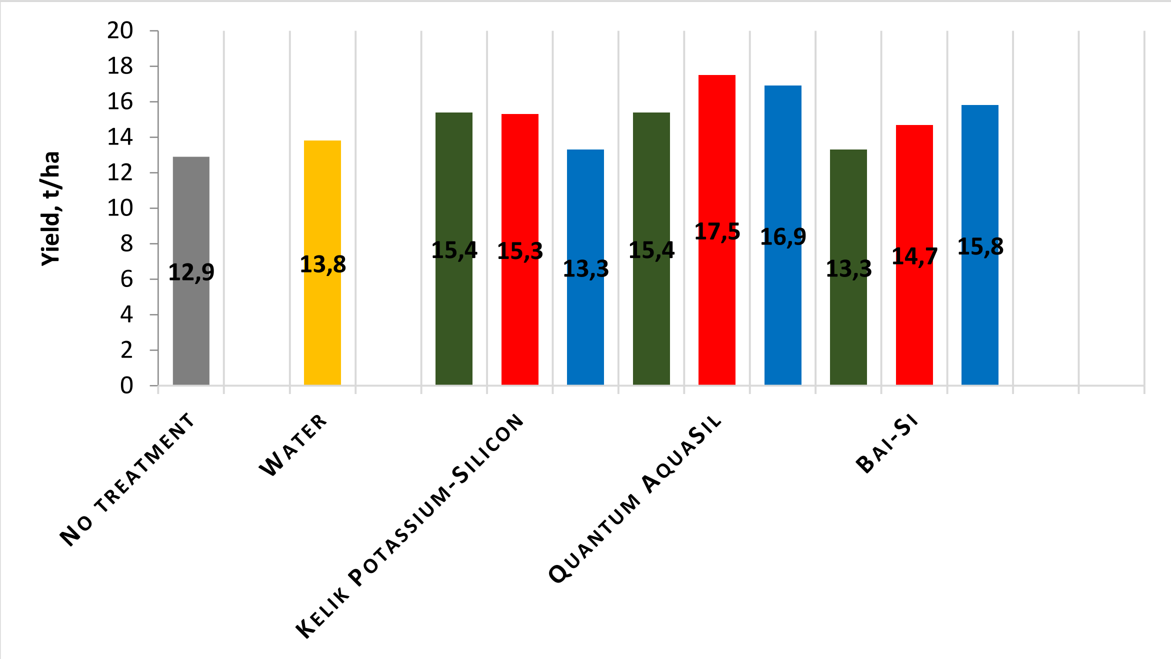

Figure 3. Performance of melon plants depending on pre-sowing treatment with silicon-containing fertilizer solutions, mean for 2020–2022

5 % and 10 % Kelik Potassium-Silicon solutions increased the plant performance by 19.4 % and 18.6 %, respectively. Pre-sowing soaking of seed in 10 % and 15 % Bai-Si solutions increased the yield by 14.0 % and 22.5 %, respectively. Thus, the highest yields of watermelon and melon were achieved with 10 % Quantum AquaSil fertilizer solution (the $LSD_{0.95}$ was 0.4).

The experience of economically developed countries shows that high and stable yields of agricultural crops are only possible provided intensification of their growing technologies. The essence of intensive technologies is to create optimal conditions for growing field crops, with due account for natural environmental factors. The southern regions of Ukraine are most suitable for growing watermelons of high commercial quality. This is attributed to light- and medium-textured soils, which are warm up well and have the average daily temperature and relative air humidity close to the optimal values in addition to adequate lighting. At the same time, there is a threat of crop failure because of droughts and high air temperatures during intensive anthesis and growth, so it is necessary to constantly search for ways to compensate these risks with assessments of the crop not only from the point of view of its performance, but also from an economic point of view, because economic evaluation of a technological process of production or individual branches of the economy allows for detection of specific opportunities for improving the efficiency of their functioning through certain measures and methods.

Therefore, one of our objectives was to evaluate the economic efficiency of the studied techniques in watermelon cultivation. The main efficiency criteria were: production costs per hectare, cost of 1 ton of fruits, net profit per hectare, and profitability. The production costs per hectare and the cost of 1 ton of fruits were calculated on the basis of compiled technological charts and current methodical recommendations in compliance with standards and prices that are currently valid at enterprises. The production costs per hectare were determined by purchase wholesale prices. The net profit was defined as difference between the yield cost and its production costs.

The experimental data (Tables 1, 2) indicate that the gourd cultivation in the Southern Steppe of Ukraine is profitable.

The results of analysis of the economic efficiency of watermelon cultivation are summarized in Table 1. The total production costs for watermelon cultivation were 15,210–15,810 UAH/ha; the operating profit was 10,670–19,220 UAH/ha; the profitability amounted to 70–122 %.

Table 1. Efficiency of watermelon growing depending on pre-sowing treatment of seeds with solutions of the silicon-containing fertilizers, mean for 2020–2022

Pre-sowing soaking of seeds		**Yield, t/ha**	**Cultivation cots, UAH/ha**	**Cost of sold products, UAH/ha**	**Operating profit, UAH/ha**	**Profitability, %**	**Economic effect (additional profit), UAH/ha**
Formulation	**Concentration, %**						
No treatment (control I)	-	17.3	15,210	25,880	10,670	70	x
Water (control II)	-	17.9	15,550	26,850	11,300	73	0,660
Kelik Potassium-Silicon	5	20.7	15,710	30,980	15,270	97	4,600
	10	20.5	15,720	30,680	14,960	95	4,290
	15	17.8	15,680	26,70	11,020	70	0,350
Quantum AquaSil	5	20.6	15,720	30,900	15,180	97	4,510
	10	23.4	15,810	35,030	19,220	122	8,550
	15	22.6	15,800	33,900	18,100	115	7,430
Bai-Si	5	17.8	15,650	26,700	11,050	71	0,380
	10	19.7	15,720	29,550	13,830	88	3,160
	15	21.2	15,770	31,800	16,030	102	5,360

The greatest economic effect from watermelon cultivation (19,220 UAH/ha) was achieved via pre-sowing soaking of seeds in 10% Quantum AquaSil solution: plus 8,550 UAH/ha to control I. The profitability was 122 %, or by 52 % higher than in control I. 15 % Bai-Si solution allowed gaining the operating profit of additional 5,360 UAH/ha. The profitability was 102 %, or by 32% more than in the control. When watermelon was grown with Kelik Potassium-Silicon, the best result was obtained with 5 % solution for seed soaking. Under these conditions, the operating profit of 15,270 UAH/ha was secured, meaning plus 4,600 UAH/ha to control I. The profitability increased by 27%. With 10 % solution, the there was a 25 % rise in the profitability.

In Table 2, the economic efficiency indicators of melon cultivation with pre-sowing treatment of seeds with solutions of the silicon-containing fertilizers are summarized. The total production costs for melon cultivation were 25,930–26,250 UAH/ha; the operating net profit was 12,770–26,340 UAH/ha; the profitability was 49–101 %.

The greatest economic effect from melon cultivation (26,340 UAH/ha) was obtained from pre-sowing soaking of seeds in 10 % Quantum AquaSil solution: plus 13,570 UAH/ha to control I. The profitability was 101 %, or higher than control I by 52 %. 15 % Bai-Si solution allows one to gain the operating profit of additional 8,460 UAH/ha compared to control I. The profitability was 81 %, or by 32 % higher than in the untreated control. When melon was grown with Kelik Potassium-Silicon, the best result (operating profit of 19,950 UAH/ha) was achieved with 5 % solution; the increase was 7,180 UAH/ha compared to control I; the profitability increased by 27 %.

Table 2. Efficiency of melon growing depending on pre-sowing treatment of seeds with solutions of the silicon-containing fertilizers, mean for 2020–2022

Pre-sowing soaking of seeds		Yield, t/ha	Cultivation cots, UAH/ha	Cost of sold products, UAH/ha	Operating profit, UAH/ha	Profitability, %	Economic effect (additional profit), UAH/ha
Formulation	**Concentration, %**						
No treatment (control I)	-	12.9	25,930	38,700	12,770	49	x
Water (control II)	-	13.8	26,020	41,400	15,390	59	2,620
Kelik Potassium-Silicon	5	15.4	26,250	46,200	19,950	76	7,180
	10	15.3	26,140	45,900	19,760	76	6,990
	15	13.3	26,050	39,900	13,850	53	1,080
Quantum AquaSil	5	15.4	26,130	46,200	20,070	77	7,300
	10	17.5	26,160	52,500	26,340	101	13,570
	15	16.9	26,220	50,700	24,480	93	11,710
Bai-Si	5	13.3	26,170	39,900	13,730	52	0,960
	10	14.7	26,160	44,100	17,940	69	5,170
	15	15.8	26,170	47,400	21,230	81	8,460

Conclusions. The maximum percentage of fruit set was recorded for seed treatment with 10 % Quantum AquaSil solution. Thus, this parameter was 67 % in watermelon 'Charivnyk' and 87 % in melon 'Didona'.

Watermelon 'Charivnyk' produced the maximum yield (23.85 t/ha) when its seeds were treated with Quantum AquaSil, while the lowest yield (17.66 t/ha) in the experiment was harvested upon sowing untreated watermelon seeds. Melon 'Didona' gave the maximum yield (17.88 t/ha) after treatment of its seeds with Quantum AquaSil.

Pre-sowing treatment of seeds with silicon-containing fertilizer solutions, Kelik Potassium-Silicon, Quantum AquaSil, and Bai-Si, significantly increased the watermelon and melon yields and economic efficiency of watermelon and melon growing in the South of Ukraine. Due to using the complex silicon-containing fertilizers in the gourd cultivation technologies, the profitability of production increased by 32–52 %.

References

Agricultural statistics FAOSTAT. Database of the Food and Agricultural Organization of the United Nations. https://www.fao.org/faostat/ru/#data/QCL/visualize

Ferreira, H. A., Nascimento, C. W. A., Datnoff, L. E., Nunes, G. H. S., Preston, W., Souza, E. B., & Mariano, R. L. R. (2015). Effects of silicon on resistance to bacterial fruit blotch and growth of melon. *Crop Protection*. Vol. 78. P. 277–283. https://doi.org/10.1016/j.cropro.2015.09.025

French-Monar,R. D., Rodrigues, F. A., Korndorfer, G. H., and Datnoff, L. E. (2010). Silicon suppresses Phytophthora blight development on bell pepper. *Jorunal Phytopathology*. Vol. 158. P.

554–560. https://doi.org/10.1111/j.1439-0434.2009.01665.x

Kadalli, G. G., Rudresha, B. A., Prakash, N. B. (2017). Effect of diatomite as a silicon source on growth, yield and quality of potato. *In Proceedings of the 7th International Conference on Silicon in Agriculture, Bengaluru, India, October.24–28.* P. 136.

Kim, Y. S., Kang, H. J., Kim, T. I., Jeong, T. G., Han, J. W., Kim, I. J., and Kim, K. I. (2015). Effects of granular Silicate on watermelon (Citrullus lanatus var. lanatus) growth, yield, and characteristics of soil under greenhouse. *Korean Journal of Soil Science and Fertilizer*. Vol. 48(5). P. 456–463. https://doi.org/10.7745/KJSSF.2015.48.5.456

Kleiber, T., Krzesiński, W., Przygocka-Cyna, K., and Spiżewski, T. (2015). The response of hydroponically grown lettuce under Mn stress to differentiated application of silica sol. *Jorunal Elementology*. Vol. 20. P. 609–619.

Liang, Y., Nikolic, M., Bélanger, R., Gong, H., and Song, A. (2015). Effect of silicon on crop growth, yield and quality. /In Silicon in Agriculture. Springer Science + Business Media: Dordrecht. The Netherlands, P. 209–224.

Lozano, C. S., Rezende, R., Hachmann, T. L., Santos, F. A. S., Lorenzoni, M. Z., de Souza, Á. H. C. (2018). Yield and quality of melon under silicon doses and irrigation management in a greenhouse. *Pesquisa Agropecuária Tropical Goiânia.* Vol. 48. P. 140–146. https://doi.org/10.1007/s12633-020-00673-1

Lymar, V. A. (2015). Justification of agromelioration measures to increase the performance of vegetables and gourds in the South of Ukraine. *Tavriiskyi Naukovyi Visnyk: Scientific Journal.* Vol. 93. P. 53–60.

Ma, J. F. and Yamaji, N. (2008) Functions and transport of silicon in plants. *Cellular and Molecular Life Sciences.* Vol. 65. P. 3049–3057. https://doi.org/10.1007/s00018-008-7580-x

Makarenko, N. V., Zaimenko, N. V. (2020). Biochemical changes and growth dynamics and development of different plant species affected by representatives of the order *Erysiphales* in the presence of silicon-containing fertilizer mixtures. *Fiziolohiia Roslyn i Henetyka*. Vol. 52(4). P. 100–110. https://doi.org/10.15407/frg2020.04.000

Marodin, J. C., Resende, J. T. V., Morales, R. G. F., Silva, M. L. S., Galvão, A. G., and Zanin, D. S. (2014). Yield of tomato fruits in relation to silicon sources and rates. *Horticulture Brasileira*. Vol. 32. P. 220–224.

Meena, V. D., Dotaniya, M. L., Coumar, V., Rajendiran, S., Ajay, S., Kundu, S., and Rao, A. S. (2014). A case for Silicon fertilization to improve crop yields in tropical soils. Proceedings of the National Academy of Sciences. *India Section Biological Sciences.* Vol. 84. P. 505–518. https://link.springer.com/article/10.1007/s40011-013-0270-y

Mitani, N., Yamaji, N., Ago, Y., Iwasaki, K., and Ma, J. F. (2011). Isolationand functional characterization of an influx silicon transporter in two pumpkin cultivars contrasting in silicon accumulation. *Plant Jorunal.* Vol. 66. P. 231–240. https://doi.org/10.1111/j.1365-313X.2011.04483.x

Preston, H. A. F., Nascimento, C. W. A., Preston, W., Nunes, G. H. S., Loureiro, F. L. C., and Mariano, R. De L. R. (2020). Silicon slag increases melon growth and resistance to bacterial fruit blotch. *Acta Scientiarum Agronomy*. Vol. 43(1). 45075. https://doi.org/10.4025/actasciagron.v43i1.45075

Romashchenko, M., Husiev, Y., Shatkovskyi, A., Saidak, R., Yatsiuk, M., Shevchenko, A., & Matiash, T. (2020). Impact of current climate changes on water resources and agricultural production. *Melioratsiia i Vodne Hospodarstvo*. Vol.1. P. 5–22. https://doi.org/10.31073/mivg202001-235

Plant production in Ukraine. Statistical collection. (2021). Kyiv: Derzhkomstat. 183 p.

Szulc, W., Rutkowska, B., Hoch, M., Spychaj-Fabisiak, E., and Murawska, B. (2015). Exchangeable silicon content of soil in a long-term fertilization experiment. *Plant Soil Environment.* Vol. 61(10). P. 458–461. https://doi.org/10.17221/438/2015-PSE

Toresano, F., Díaz, M., Pérez, L., Camacho, F. (2021). Effect of the application of monosilicic acid fertilizer on yield and quality of greenhouse triploid watermelon. *Acta Horticulturae*. Vol. 927. P. 373–378. https://doi.org/10.17660/ActaHortic.2012.927.45

*Wenneck G. S., Saath R., Rezende R., e-Vila V. V., Terassi D. D. S. & Andrean A. F. B. (*2023). Silicon application increases water productivity in cauliflower under sub-tropical condition. *Agricultural Research*. Vol. 12. P. 2–19. DOI: 10.1007/s40003-022-00628-5

Yaroslavskyi A. O. (2018). Economic efficiency of the business of an enterprise: theoretical aspects. *Naukovyi Visnyk Uzhhorodskoho Natsionalnoho Universytetu*. Vol. 20(3). P. 174–177.

Zellner, W., Tubaña, B., Rodrigues, F. A., and Datnoff L. E. (2021). Silicon's role in plant stress reduction and why this element is not used routinely for managing plant health. *Plant Disease*. Vol. 105(8). P. 2033–2049. https://doi.org/10.1094/PDIS-08-20-1797-FE

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ЕФЕКТИВНІСТЬ ВИРОЩУВАННЯ БАШТАННИХ КУЛЬТУР ЗА ВИКОРИСТАННЯ КРЕМНІЄВМІСНИХ ДОБРИВ В УМОВАХ ПІВДНЯ УКРАЇНИ

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Мета досліджень. Визначити вплив передпосівного замочування насіння на продуктивність рослин та ефективність вирощування кавуна і дині за краплинного зрошення на півдні України. **Методи.** Польовий, вимірювально-розрахунковий, порівняльний, математично-статистичний методи, аналіз економічної ефективності. **Отримані результати.** Встановлено, що передпосівне замочування насіння у розчинах кремнієвмісних добрив сприяє отриманню ранніх і повноцінних сходів кавуна та дині, збільшенню довжини і кількості бокових пагонів, зав'язування плодів. Дослідженнями доведено, що збалансоване живлення рослин сприяє формуванню високої продуктивності рослин кавуна і дині в умовах півдня України. Визначено, що найбільшу врожайність плодів кавуна (23, т/га) і дині (17,5 т/га) отримано за використання препарату Квантум АкваСил (концентрація розчину 10 %), збільшення над необробленим контролем становить 35,3 і 35,7 % відповідно. Застосування кремнієвмісних добрив Bai-Si (концентрація 15 %) на посівах кавуна забезпечує збільшення врожайності плодів на 22,5 %, за обробки Келік Калій-Кремній – на 19,7 % порівняно з контролем. Найбільший економічний ефект при вирощуванні плодів кавуна і дині отримано за передпосівного замочування насіння у 10% розчині Квантум АкваСил, рівень рентабельності становив 122 і 101 % відповідно. **Висновки.** Передпосівне замочування насіння у розчинах кремнієвмісних добрив сприяє формуванню високої продуктивності рослин і дозволяє підвищити економічну ефективність вирощування. Встановлено максимальні значення відсотку зав'язування плодів за обробки насіння препаратом Квантум АкваСил з концентрацією 10 %. Так сорт кавуна Чарівник за даної взаємодії забезпечив даний показник на рівні 67 %, диня Дідона – 87 %. В умовах відкритого ґрунту півдня України економічний ефект вирощування кавуна збільшився на 16,03–19,22 тис. грн/га, дині – на 21,23–26,34 тис. грн/га.

Ключові слова: кавун, диня, оброблення насіння, кремнієвмісне добриво, врожайність, економічна ефективність, рентабельність

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CONTROL OF WHITE CABBAGE DISEASES USING BIOLOGICALS

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Purpose. To investigate effects of biologicals on disease-induced damage to white cabbage plants during the growing period and on yield. **Methods**. Informational/analytical (collection and review of publications), field research (planning and conducting experiments, records of plant damage, harvesting and accounting of yields), phytopathological (isolation and identification of pathogens), mathematical/statistical (processing of data). The following biologicals were used in he experiments: Azotobacterin liq. (*Azotobacter chroococcum* IMV B-7171), Ecophosphorin liq. (*Bacillus megaterium* IMV B-7168, *Azotobacter chroococcum* IMV B-7171, *Agrobacterium radiobacter* IMV B-7246), Planrhiz liq. (*Pseudomonas fluorescens*), Haupsin liq. (*Pseudomonas auerofaciens*), Serenade ASO SC, Serenade MAX WP (*Bacillus subtilis* QST 713), and Trichodermin liq. (*Trichoderma lignorum* TD 93). Biologicals were sprayed on plants 3-4 times during the cabbage growing period. Antifungal potentials of mixtures of biologicals with fungicides were also investigated on white cabbage. **Results**. During the study years, Alternaria leaf spot, Fusarium wilt, black and soft rots were dominating diseases on plantations with different varieties of white cabbage. Biologicals effectively restrained the development of both fungal and bacterial diseases of white cabbage. The protective effect of the biologicals against fungal diseases averaged 45-62%, against bacterial diseases – 65-79%. The effectiveness of mixtures of biologicals and chemicals, in which fungicides were applied at minimally permissible doses, was similar to that of fungicides applied at full doses. Biologicals, due to their protective and growth-stimulating properties, significantly increased the crop yield. **Conclusions.** The potentials of biologicals to control fungal and bacterial diseases of white cabbage during the growing period were evaluated. The biologicals effectively limited infection-inflicted damage to cabbage. The protective effect of the biologicas against various diseases of white cabbage during the growing period of different varieties averaged 45-79%. The biologicals increased the yields of late-ripening white cabbage varieties on average by 14.5–92%.

Key words: biological control, disease affection, protective effect, performance

Introduction. Cabbage (*Brassica oleracea var. sapitata* L.) is one of the most common vegetables. In Ukraine, white cabbage is grown on about 68,000 hectares, which is almost 16% of the vegetable-sown area. Households (85-91%) are the main producers of vegetables in Ukraine. The average yield of white cabbage ranges from 30 t/ha to 40 t/ha. Due to its cold tolerance, yield, excellent palatability and dietary qualities, cabbage is grown everywhere. In the vegetable consumer set, cabbage accounts for 25% (*Halat, L. M.,* 2019).

Diseases caused by phytopathogenic microorganisms result in significant losses of cabbage yields. It was proven that the degree, time of manifestation, type and intensity of disease development largely depend on growing conditions, meteorological factors, varieties' resistance, fertilization, harvest timeframe, and storage mode.

Chemical plant protectors are usually used to reduce yield losses from damage by phytopathogenic microorganisms. However, the global use of pesticides leads to environmental pollution and undesirable sanitary and hygienic consequences (*Apazhev A K, et al., 2022; He Dun-Chun, et al, 2021; He M.-H., et al., 2021*). The structure of biocenoses is impaired and their capacity for self-regulation is reduced. Pesticides are accumulated in soil, water, and food. Pathogens become more resistant to them and, as a result, the effectiveness of pesticides drops.

In this regard, it is extremely important to develop and implement environmentally safe methods of plant protection, using natural substances and biologicals.

Review of Recent Studies and Publications. Application of biologicals for plant protection is ecologically, socially and economically expedient. Unlike chemicals, biologicals have no or negligible negative effects on the environment but a number of advantages. First, microorganism-based formulations are not phytotoxic. This can be explained by the fact that bioagents are a component of the natural microflora of soil and plants. Compared to some chemical plant protectors, biologicals do not disrupt natural connections in the biocenosis, act selectively, and do not facilitate the emergence of resistance in harmful organisms. The latter means that no increase in doses of biologicals is required, ulike the situation with chemical pesticides (*Azizbekyan A.A.,* 2019, *Mozhovskyi, O. F., et al.,* 2020). The degree of disease suppression achieved with bioagents can be comparable to the effect of chemical substances (*O'Brien Ph.*, 2017).

Biological control is most suitable for organic farming. It is environmentally safe, economically beneficial and highly specific (*Pandit M.A.,* 2022). Application of biological control agents and biostimulants is growing in the world by more than 10% annually (*Shocham J.,* 2020).

Ecologically safe methods of plant protection are especially relevant for vegetables, as they are consumed fresh. Wide application of biologicals allows farmers to completely refuse or significantly reduce application chemical plant protectors on vegetables and thereby improve the quality and safety of products. The ecologically safe production helps preserve the environment and natural biodiversity and restore the natural fertility of soils. In addition, due to application of biologicals, the pesticide load on agrocenoses during growing periods of crops is reduced; the ecological purity of grown products and absence of harmful substances in plants and soil are ensured. Bacteria that are useful for plants positively affect the quality of products; contents of vitamins, flavonoids, and antioxidants increase and they act as plant probiotics in vegetables (*Jimynez-Gumez A.,* 2017).

Currently, biologicals are used to treat planting materials, to enrich soils with useful microflora and to spray plants. They can be used separately or in combinations with pesticides, which are added mainly at reduced (minimum permissible) doses. In our experiments, combinations of biologicals with fungicides had a protective effect against diseases of vegetables, which in most cases was similar to or slightly stronger than that of fungicides applied at full doses (*Tytova L.V., Serhiienko V.H,.* 2018*; Borzykh O.I., et al.,* 2021).

Biologicals are biological agents - living microorganisms or products of their vital activity. These microorganisms are isolated from the environment (soil, plant residues, etc.), that is, they are part of the circulation of substances in nature. The effectiveness of biologicals is attributed to the antipathogen activities of microorganisms. Understanding mechanisms of action of microorganisms is important in order to optimize biological control of plant diseases (*Köhl J.,* 2019). Microorganisms, which are used for biological control, produce metabolites that trigger growth mechanisms, prevent plant infections, eliminate biotic and abiotic stresses, and increase yields (*Pham J. V.*, 2019).

Researchers noted that bacteria of the genera *Azotobacter, Bacillus, Pseudomonas, Strepthomyces* and micromycetes of the genera *Alternaria, Aspergillus, Penicillum, Rhizoctonia, Fusarium, Trichoderma*, *Rhizopus*, which produce a wide range of biologically active substances with restorative, immunostimulating and protective effects, were rather promising and most widespread groups of microorganisms (*Shepstoboieva O.V., et al., 2009; Boughalleb-M'Hamdi N., et al.,* 2018).

The level of development of biological methods of plant protection determines the degree of the food security of a country, the quality of nutrition of the population and the nation’s health (*Zalizniak, V.O.,* 2021). In the world, ecologically clean, i.e. organic, products are more expensive than those produced by current technologies. However, vegetables grown via environmentally safe technologies seem to be promising and in a great demand in the market (*Terokhina L.A., Yurlakova O.M.,* 2017).

During the growing period, white cabbage is affected by many fungal and bacterial diseases. Pathogenic microorganisms affect it during the entire vegetation period - from seed germination to harvest. Among the diseases of white cabbage, Alternaria leaf spot, basal stem rot, Fusarium wilt, black and soft rots have become most widespread in recent years; clubroot disease and downy mildew have been less common (*Markov I., 2018; Butsenko, L.*, 2020). Indoors, root rot, Fusarium wilt, and soft rot are the most common diseases (*Zhou L., et al., 2014; Cui W., et al., 2019; Orynbayev, A.T.; et al., 2020; Allayarov A., et al.,* 2021). As a rule, there are no varieties with resistance to these diseases. Therefore, protection of cabbage plants during the growing period is an important pre-requisite for harvesting high yields.

Our **purpose** was to investigate effects of biologicals on disease-induced damage to white cabbage plants during the growing period and on yield.

Materials and Methods. The experiments were carried out on farms in the Kyivska Oblast (Borova township, Fastivskyi District; Skvyra Experimental station; Zlahoda family farm, Bilotserkivskyi District, Kreminne family farm, Brovarsky District), which are located in the Right-Bank Forest-Steppe of Ukraine, in 2013 - 2019. The soil is typical low-humus chernozem, with a humus content of 2.8–3.6% and pH of 5.9–6.3. The farming techniques were conventional for this zone. Seedlings of early-ripening varieties were planted according to the 50 cm x 30 cm design; of late-ripening varieties – according to the 70 cm x 40 cm design. The experiments were carried out in small plots (the plot area was 25 m^2) and replicated 4 times.

The following biologicals were used in he experiments: Azotobacterin liq. (*Azotobacter chroococcum* IMV B-7171), Ecophosphorin liq. (*Bacillus megaterium* IMV B-7168, *Azotobacter chroococcum* IMV B-7171, *Agrobacterium radiobacter* IMV B-7246), Planrhiz liq. (*Pseudomonas fluorescens*), Haupsin liq. (*Pseudomonas auerofaciens*), Kazumin 2L LC (*Streptomyces kasugaensis*, 20 g/L), Serenade ASO SC, Serenade MAX WP (*Bacillus subtilis* QST 713), and Trichodermin liq. (*Trichoderma lignorum* TD 93). The titer of microbial organisms was at least 10^9 cells/ml. Azotobacterin and Ecophosphorin were provided by the D.K. Zabolotny Institute of Microbiology and Virology of NASU; Haupsin, Planrhiz and Trichodermin were developed at the Institute of Plant Protection of NAAS; Kazumin 2L LC, Serenada ASO SC and Serenada MAX WP manufactured by Sumi Agro and Bayer and commercially available.

Protective effects of the biologicals were compared with those of fungicides approved for application on cabbage, namely: Quadris 250 SC (azoxystrobin, 250 g/L), 0.6 L/ha and Infinito 61SC (fluopicolide, 62.5 g/L + propamocarb hydrochloride, 625 g/L), 1.6 L/ha. These fungicides were also used in mixtures with the biologicals. In mixtures, the minimum permissible doses of the fungicides were used: by 17% and 25% lower, respectively, than the maximum permissible doses.

The biological were sprayed on plants 3–4 times during the vegetation period with 7- to10-day intervals, depending on time of the first signs and degree of disease development. The mixtures of bacterial and chemical (fungicide) agents were sprayed 2–3 times during the vegetation period. The first treatment with the studied formulations was conducted when the first signs of diseases appeared.

Disease-induced damage to white cabbage plants was assessed on natural infections. Diseases were recorded in accordance with published methods and our modification of a plant injury assessment scale (*Retman S.V.*, 2014).

0 – No signs of damage;

1 – Slight damage, yellowing (browning), spots on single leaves;

2 – 3-4 leaves have turned yellow, or individual rotten spots;

3 – Half of the plant is affected;

4 – The entire plant is affected.

We assessed development of fungal diseases, damage by bacterial diseases, effectiveness of the formulations, and yield (*Methods of variety trials*, 2001). Pathogens were isolated and identified, as it is customary in phytopathology (*Popkova K.V.*, 1987).

Data were mathematically and statistically processed in Statgraphics Plus.

Results and Discussion. Of fungal diseases during the study years, Fusarium wilt (causing agent *Fusarium oxysporum f. sp. conglutinans* (Wr.)) dominated on early-ripening cabbage 'Nissa' and Alternaria leaf spot (causing agent *Alternaria brassicae* (Berk) Sacc.) – on late-ripening cabbage 'Yana'. The Fusarium wilt development in the control plots during the vegetation period was 10.5–23.2%; the Alternaria leaf spot development – 12.4-40.0% (Table 1).

Bacterial diseases, black rot (causative agent *Xanthomonas campestris pv. sampestris* (Dowson)) and soft rot (causative agent *Erwinia caratovora pv. caratovora* Bergey et al., *Erwinia aroidae* Holland, *Pseudomonas fluorescens* Mig.) were detected on late-ripening cabbage 'Ahresor' and 'Kamiana Holova'. The incidence of black and soft rots on white cabbage plants was 10.5–35.1% and 8.6–35.5%, respectively (Table 2).

The biologicals significantly limited the development and spread of diseases. On 'Nissa', the biologicals restrained the development of Fusarium wilt by 2.2-2.3 times at the beginning of disease development in the phase of 4-5 leaves (14-15 BBCH-scale) and by 1.7-1.8 times at the end of the growing period. On 'Yana', the development of Alternaria leaf spot decreased by 1.9-2.1 times and by 1.5-1.8 times at the initial stage of development and at the end of the growing period, respectively, due to application of the biologicals.

The protective effects of the formulations were most pronounced at the initial stage of disease development. On 'Nissa', the protective effects against Fusarium wilt amounted to 54.3–71.5%; on

'Yana', the protective effects against Alternaria leaf spot amounted to 53.2–65.4%. As diseases progresse, the effectiveness of the formulations declined. On average during the growing period, the effectiveness of the formulations was 45.1–61.6% on 'Nissa' and 44.5–62.5% on 'Yana'. Azotobacterin liq. exerted the strongest protective effect against fungal diseases of white cabbage. As Allayarov A. reported, a complex biological formulation, Orhanika F, showed high biological activity against Fusarium wilt of cabbage when applied under roots prior to planting seedlings and 15 days after planting seedlings (*Allayarov, A. et al.*, 2021).

Table 1. Effectiveness of the biologicals against fungal diseases of white cabbage

Variant	**Disease development, %**		**Effectiveness, %**		**Yield**	
	At the initial stage of disease development (phase of 4-5 leaves)	**Phase of the formed head**	**At the initial stage of disease development**	**Mean for the growing period**	**t/ha**	**% related to the control**
Cabbage 'Nissa'; Fusarium wilt (Skvyra Experimental Station)						
Control	10.5	23.2	-	-	11.1	-
Azotobacterin liq. 0.5 L/ha	4.5	13.7	57.1	45.1	12.4	111.5
Azotobacterin liq. 0.5 L/ha + Infinito 61 SC, 1.2 L/ha	4.0	10.9	61.9	52.8	11.8	106.3
Trichodermin liq. 1.0 L/ha	4.8	12.5	54.3	50.3	11.7	105.4
Trichodermin liq. 1.0 L/ha + Infinito 61 SC, 1.2 L/ha	3.5	7.9	66.7	60.4	12.3	110.9
Infinito 61 SC, 1.6 L/ha (reference)	3.0	10.5	71.5	61.6	12.3	110.9
LSD_{05}	2.1	3.2			1.2	
Cabbage 'Yana'; Alternaria leaf spot (Borova township, Kyivska Oblast)						
Control (no treatment)	12.4	40.0	-	-	40.0	-
Azotobacterin liq. 0.5 L/ha	6.5	26.4	59.7	46.5	45.5	113.7
Azotobacterin liq. 0.5 L/ha + Quadris 250 SC, 0.5 L/ha	4.5	19.6	63.7	62.5	45.8	114.5
Ecophosphorin liq. 2.0 L/ha	5.8	22.2	53.2	44.5	44.8	112.0
Ecophosphorin liq. 2.0 L/ha + Quadris 250 SC, 0.5 L/ha	4.3	20.0	65.4	52.4	45.2	113.0
Quadris 250 SC, 0.6 L/ha	4.6	20.2	62.9	49.5	45.6	114.0
LSD_{05}	1.7	2.5	-	-	2.2	-

Previous studies demonstrated that protective effects of biologicals were short-term, not longer than 3-5 days. Therefore, to extend protective action and achieve higher protection efficiency, it is advisable to use biologicals in mixtures with fungicides (*Tytova, L.V., Serhiienko, V.H., 2018; Borzykh O.I., et al.,* 2021). In our experiments, the mixtures of biologicals with fungicides, in which fungicide doses were reduced by 25% and 17%, had significantly higher protective effects compared to the biologicals alone. The highest efficiency on cabbage 'Nissa' was noted with Trichodermin liq1. 1.0 L/ha + Infinito 61 SC, 1.2 L/ha (on average 60.4%); on cabbage 'Yana variety', the best effect was recorded for Azotobacterin liq. 0.5 L/ha + Quadris 250 SC, 0.5 L/ha (62.5%). These protective effects were similar to or even stronger than those of the corresponding fungicides at full doses.

A strong protective effect was exerted by biologicals against bacterial diseases of white cabbage. On cabbage 'Ahresor', the biologicals reduced black rot-inflected damage to plants by 3.3 (Planrhiz liq.) – 15 times (Serenada MAX WP) in the rosette phase (41-43 VVSN) and by 3.3-4.1 times in the phase of the formed head (78-79 BBCH) (look Table 2). The effectiveness of biologicals averaged 70.0–75.8%.

Table 2. Effectiveness of the biologicals against bacterial diseases of white cabbage

Variant	Percentage of affected by developmental phases		Effectiveness, % (mean for the season)	Mean head weight, kg	Yield	
	Rosette	Formed head			t/ha	% related to the control
Cabbage 'Ahresor'; black rot (Zlahoda family farm, Bilotserkivskyi District**)**						
Control	10.5	35.1	-	2.2	37.8	-
Planrhiz liq. 2.0 L/ha	2.3	10.5	75.8	5.7	60.5	160.1
Trichodermin liq. 2.0 L/ha	4.7	8.9	70.0	5.45	69.2.	183.1
Kazumin 2L LC, 2.0 L/ha	4.1	9.5	74.6	5.65	71.2	192.0
Haupsin, tier 4.0 L/ha	2.9	10.3	71.5	4.7	60.8	160.9
Serenade MAX WP, 4 kg/ha	0.7	8.5	73.0	5.73	71.5	189.2
LSD_{05}	1.1	3.5	-	1.1	2.3	-
Cabbage 'Kamiana Holova', soft rot (Kreminne family farm, Brovarsky District)						
Control	8.6	35.5	-	3.2	34.4	-
Planrhiz liq. 2.0 L/ha	1.1	10.8	69.5	4.8	48.3	140.4
Trichodermin liq. 2.0 L/ha	2.3	12.1	65.9	4.6	47.5	138.1
Kazumin 2L LC, 2.0 L/ha	1.7	10.0	71.8	5.0	50.4	146.6
Serenada ASO SC, 6 L/ha	1.5	9.5	78.6	5.2	52.1	151.5
Serenade MAX WP, 4 kg/ha	1.2	9.0	79.2	5.3	53.1	154.4
LSD_{05}	0.8	3.1	-	0.42	3.7	-

Application of the biologicals against soft rot on cabbage 'Kamiana Holova' reduced lesions by 3.7–7.8 times at the disease manifestation onset and by 3.3–4.1 times in the phase of the formed head. The protective effect of the biologicals averaged 65.9–79.2%. The highest effectiveness against black rot was recorded for Kazumin 2L SC and Trichodermin liq. (74.6% and 75.8%, respectively); Serenada ASO SC and Serenade MAX WP were most feective against soft rot (78.6% and 79.2 %, respectively).

As Apazhev A. (2022) noted, Rhizoplan (*Pseudomonas fluorescens*) and Trichodermin (*Trichoderma viride*) with fungicidal and stimulating effects suppressed the development of many diseases, and could be recommended as alternative means of plant protection. Cui W. (2019) and Butsenko L. (2020) isolated bacteria of the genus *Bacillus* characterized by high antibacterial activities.

The biologicals contributed to increased performance of the crop. Obviously, this is associated with protective and growth-stimulating properties of bioagents. In early-ripening low-yielding (11.1 t/ha in the control) cabbage 'Nissa', the biologicals increased the yield by 5.4% and 11.5%, and their mixtures with fungicide - by 10.9% (Table 1). Late-ripening cabbage 'Yana' yielded 40.0 t/ha in the control; it most conspicuously increased its yield (by 13.7% and 14.5%) due to Azotobacterin liq. and Azotobacterin liq. 0.5 L/ha + Quadris 250 SC, 0.5 L/ha.

A significant gain in the yield due to application of the biologicals was noted in cabbage 'Ahresor' and 'Kamiana Holova'. They yielded 37.8 t/ha and 34.4 t/ha in the control, respectively. The biological treatments increased 'Ahresor's' yield by 22.7–33.4 t/ha and 'Kamiana Holova's' yield by 13.1–18.7 t/ha, i.e., their yields increased by 60.1–92.0% and 38.1–54.4%, respectively (Table 2). This is attributed to a significant increase in the head weight: it was 4.6–5.7 kg in the experimental variants versus 2.2 - 3.2 kg in the control.

Conclusions. Of the fungal diseases during the study years in the Right-Bank Forest-Steppe of Ukraine, Fusarium wilt and Alternaria leaf spot were most common; of the bacterial diseases, black and soft rots were most frequently detected.

The biologicals, which are based on *Azotobacter chroococcum, Bacillus megaterium, Agrobacterium radiobacter, Pseudomonas fluorescens, Pseudomonas auerofaciens, Bacillus subtilise*, and *Trichoderma lignorum*, showed strong protective effects against diseases of white cabbage diseases during the growing period: the effects averaged 50–75%, depending on cabbage varieties, diseases and formulations. Biological control of cabbage diseases helped increase the yield and product quality. Late-ripening cabbage varieties increased their yields by 14.5–92%.

In order to prolong the protective effects of the biologicals and increase the effectiveness of protective measures against fungal diseases, it is advisable to use mixtures of biologicals with fungicides, in which the minimum permissible doses of fungicides are used. This allows for reduction in the pesticide load on agrocenoses and improve the safety of products.

References

Allayarov, A., Zuparov, M., Khakimov, A., Omonlikov, A. (2021). Application of the biopreparation 'Orgamika F' against fusarium disease of cabbage and other cole vegetables. Topical Problems of Green Architecture, Civil and Environmental Engineering (TPACEE-2021). *E3S Web Conf. Vol. 284, Section Crop Production.*
https://doi.org/10.1051/e3sconf/202128403011. Published online12 July 2021

*Apazhev A K, Shekikhachev Y A, Hazhmetov L M, Didanova E N, Kurzhiev Kh G. (*2022). Ensuring the environmental safety of food when using biological products in the protection of cabbage agrocenosis*IOP Conf. Ser.: Earth Environ. Sci.* 981 022054.
http://doi.org/10.1088/1755-1315/981/2/022054

Azizbekyan, R.R. (2019). Biological Preparations for the Protection of Agricultural Plants (Review). Applied *Biochemistry & Microbiology*.Vol. 55, Issue 7, P. 816-823.
http://doi.org/10.1134/S0003683819080027

Borzykh, O.I., Tkalenko, H.M., Serhiienko, V.H. (2021). Effect of complex application of biological and chemical agents on the development of diseases and yield of potatoes. *Visnyk Ahrarnoi Nauky*. No 8. P. 15-25.
http://doi.org/10,31073/agrovisnyk.202108-2

Boughalleb-M'Hamdi, N., Salem, I. B., M'Hamdi M. (2018).Evaluation of the efficiency of *Trichoderma*, *Penicillium* and *Aspergillus* species as biological control agents against four soil-borne fungi of melon and watermelon. *Egyptian Journal of Biological Pest Control*. Vol.28, Issue 1, P. 1-12. http://doi.org/10.1186/S41938-017-0010-3

Butsenko, L. (2020). Black and soft rots of cabbage. *Propozytsiia,* No 6,. URL: https://propozitsiya.com/ua/sudinniy-bakterioz-i-myaka-gnil-kapusti

Cui, W., He, P., Munir, Sh., He, P., He Y., Li·,Y.X.L., Wang, B., Wu Y., He, P. (2019). Biocontrol of soft rot of chinese cabbage using an endophytic bacterial strain. *Front. Microbiol.*, Sec. Plant Pathogen Interactions. Vol. 10.
https://doi.org/10.3389/fmicb.2019.01471

Halat, L.M. (2019). Peculiarities of the market of fresh vegetables in Ukraine. *Ahrosvit.* No 11. P. 35-41.
http://doi.org/10.32702/2306"6792.2019.11.35

He, Dun-Chun, He, M.-H., Amalin, D. M., Liu W., Alvindia, D. G., Zhan, J. (2021). Biological control of plant diseases: An evolutionary and eco-economic consideration. *Pathogens*, 10(10): 1311.
http://doi.org/10.3390/pathogens10101311

Jimйnez-Gymez, A., Celador,-L. L., Fradejas-Bayyn, M., Rivas, R. (2017). Plant probiotic bacteria enhance the quality of fruit and horticultural crops**.** Review Special Issues. *AIMS Microbiology*. Vol. 3(3): 483-501.
http://doi.org/10.3934/microbiol.2017.3.483

Köhl, J., Kolnaar, R., Ravensberg, W. J. (2019). Mode of action of microbial biological control agents against plant diseases: relevance beyond efficacy. Review article. *Front. Plant Sci.*, 19.
https://doi.org/10.3389/fpls.2019.00845.

Markov, I. (2018). Cabbage diseases under control. *Ahronomiia Sohodni*. URL: http://agro-business.com.ua/ahrarni-kultury/item/12411-khvoroby-kapusty-pid-kontrolem.html

Methods of testing ald application of pesticides. (2001). Ed. by Prof. S.O. Trybel. Kyiv: Svit. 448 p.

Mozhovskyi, O.F., Mozhovska, H.V., Kuts, O.V. (2020). Biologicals as a basis of integrated plant protection. *Frukty i Ovoshchi*. No 1. URL: https://www.pro-of.com.ua/biopreparati-yak-osnova-sistemi-integrovanogo-zaxistu-roslin

O'Brien, Ph. A. (2017). Biological control of plant diseases. Published:23 March 2017*Australasian Plant Pathology*. Vol. 46, P.293–304.

Orynbayev, A.T., Dzhalilov, F.S., Maslennikova, S.N. (2020). The biological effectiveness of various preparations against seed infection of cabbage black rot. *Ovoshchi Rossii*. No 2, P. 88-91.

Pandit, M.A, Kumar J., Gulati,, S., Bhandari, N., Mehta, P., Katyal, R., Rawat, C.D., Mishra. V., Kaur, J. (2022). Major biological control strategies for plant pathogens. *Pathogens.* 11 (2): 273.
http://doi.org/10.3390/pathogens11020273

*Pham, J.V., Yilma, M.A. Feliz A.A. (*2019). Review of the microbial production of bioactive natural products and biologics. Review article. *Front. Microbiol*. Vol. 10
https://doi.org/10.3389/fmicb.2019.01404

Popkova K.V. Methods for determination of diseases and pests of agricultural plants. M.: Agropromizdat. 1987. P. 125-128.

Retman, S.V. (2014). Registration trials of fungicides in agriculture. Guidelines. Under the editorship of Doctor of Agricultural Sciences, Prof.. S.V. Retman. K.:Kolobih. 352 p.

Shepstoboieva, O.V., Chaykovska, V.V., Chabaniuk, Ya.V. (2009). Properties of new strains of bacteria - antagonists of phytopathogenic myxomycetes. *Silskohospodarska Mikrobiolohiia*: Interdepartmental thematic collection. Chernihiv: TSNTEI. Issue 9. P. 90- 94.

Shoham, J. (2020). Rise of Biological Products in Crop Protection and Plant Nutrition Markets. *Outlooks on Pest Management*, Vol. 31 (3), P. 129-131(3). https://doi .org/10.1564/v31_jun_09

Terokhina, L.A., Yurlakova, O.M. (2017). Innovative way of development in vegetable production. Abstracts of the International Scientific and Practical Conference "Scientific Fundamentals of Creation of Innovative Products in Plant Production. March 28, 2017. Institute of Vegetable and Melon Growing of NAAS. *Pleiada*,. P. 102 – 104.

Tytova, L.V., Serhiienko, V.H. (2018). Effectiveness of complex application of microbial agents with fungicides to control diseases and increase the performance of vegetables. *Mikrobiolohiia i Biotekhnolohiia.* No 4 (44). P. 30-41.
http://doi.org/10.18524/2307-4663.2018.4(44)149359

Zalizniak, V.O. (2021). Biological method of plant protection is effective and safe.
https://senchanska-gromada.gov.ua/news/1626088639

*Zhou, L., Zhang, L., He Y., , Liu, F., Li M., Wang, Z., Ji, G. (*2014). Isolation and characterization of bacterial isolates for biological control of clubroot on Chinese cabbage. *European Journal of Plant Pathology.* Vol. 140. P.159–168.

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КОНТРОЛЬ ХВОРОБ КАПУСТИ БІЛОГОЛОВОЇ ЗА ВИКОРИСТАННЯ БІОЛОГІЧНИХ ПРЕПАРАТІВ

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Мета. Дослідити вплив біологічних препаратів на обмеження ураження рослин капусти білоголової хворобами в період вегетації та її урожайність. **Методи.** Інформаційно-аналітичний (збір матеріалів і аналіз літературних джерел), польових досліджень (закладка і проведення дослідів, обліки ураження рослин, збір і облік урожаю), фітопатологічні (виділення та ідентифікація збудників хвороб), математико-статистичні (обробка результатів досліджень). В дослідах використовували біологічні препарати Азотобактерин, р. (*Azotobacter chroococcum* ІМВ В-7171), Екофосфорин, р. (*Bacillus megaterium* ІМВ В-7168, *Azotobacter chroococcum* ІМВ В-7171, *Agrobacterium radiobacter* ІМВ В-7246), Планриз, с. (*Pseudomonas fluorescens*), Гаупсин, р. (*Pseudomonas auerofaciens*), Серенада АСО, КС, Серенада МАКС WP, ЗП (*Bacillus subtilis* QST 713*)*, Триходермін, р. (*Trichoderma lignorum* ТД 93). Біопрепарати застосовували методом обприскування рослин 3-4 рази в період вегетації капусти. Проти грибних хвороб капусти білоголової також досліджували суміші біологічних препаратів з фунгіцидами. **Результати.** У роки досліджень на посадках капусти білоголової домінували на різних сортах альтернаріоз, фузаріозне в'янення, судинний та слизовий бактеріози. Застосування біологічних препаратів ефективно стримувало розвиток як грибних, так і бактеріальних хвороб капусти білоголової. Захисний ефект біопрепаратів проти грибних хвороб складав в середньому 45-62%, проти бактеріальних хвороб – 65-79%. Ефективність сумішей біологічних та хімічних препаратів, в яких фунгіциди застосовували з мінімально допустимими нормами витрати, знаходилась на рівні фунгіцидів з повними нормами витрати. Біологічні препарати за рахунок активації захисних і рістстимулювальних властивостей сприяли суттєвому підвищенню урожайності культури. **Висновки.** Розкрито потенціал біологічних препаратів у контролюванні грибних і бактеріальних хвороб капусти білоголової в період вегетації. Застосування біопрепаратів ефективно обмежувало ураження капусти інфекційними хворобами. *Захисний ефект біопрепаратів проти хвороб капусти білоголової впродовж періоду вегетації на різних сортах проти різних хвороб знаходився в середньому на рівні 45-79%.* За використання біопрепаратів урожайність пізньостиглих сортів капусти білоголової підвищилась в середньому на 14,5–92%.

Ключові слова: біоконтроль, ураження хворобами, ефективність, продуктивність

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WINTER GARLIC BULB WEIGHT LOSS DURING STORAGE DEPENDS ON PROTECTIVE COATINGS

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Purpose. To justify elements of the post-harvest winter garlic processing technology that will increase storability and shelf life of garlic. The working hypothesis was based on the assumption that it is possible to use a modified paraffin-containing coating, which will increase the stability of garlic bulbs during storage. **Methods.** General scientific: 1. hypothesis method - drawing up experimental designs; 2. experimental method – designs of laboratory experiments; 3. methods of analysis and synthesis - drawing conclusions and summarizing, computational and analytical. **Results.** Covering bulbs with a mixture of 90% shellac (food additive, E904) + 10% aloe vera gel ensured a storage length of 145 days with the daily weight loss of 0.036%. 20% sunflower wax increased the storage length up to 142 days with the daily weight loss of 0.036%, while with paraffin coating the storage period was 100 days and the daily weight loss was 0.10%.

It was established that the control specimens of garlic stored at reduced relative air humidity (RAH) (60–70%) significantly lost their weight. The increase in RAH during storage reduced the weight loss of garlic bulbs to 8.2%, i.e. 2.5-fold. Covering garlic bulbs with a protective film reduced the weight loss by 4.6–5 times at RAH of 60–70%. Increasing RAH to 75–85% and 90–95% reduced it by 4.7–5.3 and 2.9–3.1 times, respectively. With similar daily weight loss in the experiments with 75% paraffin + 5% glycerin + 20% sunflower wax, with 90% shellac + 10% aloe vera gel, with 85% paraffin + 5% glycerin + 10% sunflower wax, with 65% paraffin + 5% glycerin + 30% sunflower wax (the daily weight loss was 0.036%, 0.036%, 0.044%, and 0.044%, respectively), the storage lengths were not equal. Bulb coatings extended the storage period by 25-45 days depending on coating composition. The longest storage (142–145 days) was achieved with 75% paraffin + 5% glycerin + 20% sunflower wax and with 90% shellac + 10% aloe vera gel (the daily weight loss was 0.036%). **Conclusions.** The effects of the protective coatings on the bulb weight amounted to 76.0%, while the RAH contribution was 12.0%, and the interaction of the studied factors accounted for 12.0%.

Key words: winter garlic, weight loss, relative air humidity, protective coatings

Introduction. Garlic, a plant of life, has been known for thousands of years as the best natural medicine. There are more than 200 unique components in this amazing plant. Garlic is used in fresh and processed forms as a seasoning for various dishes, in sausage and meat production, as well as in salting and preserving vegetables. Garlic oil is used as a flavoring agent (*Internet resource; Jancic R.*, 2002).

Experts emphasize that an adult should eat no more than 15 g per day, which corresponds on average to 4 cloves (that is, 5.5 kg per year) (*Internet resource*).

Despite the unique properties of garlic, its consumption rates (per capita) in Ukraine do not reach physiological ranges, being of 0.6 kg per year, while, as a result of national traditions and culinary processing, the annual consumption of garlic amounts to 14 - 17 kg per capita worldwide (*Vanjkevic S.K*., 2002).

This situation depends on many factors and garlic storage technologies are one of them. Long-term storage of garlic from harvest to harvest is a prerequisite for continuous supply of garlic to the population.

The primary objective of storing vegetables is to preserve their quality and deliver good-quality products to the consumer with minimal weight loss. Vegetables lose their weights because of natural processes inherent in a living organism: water evaporation and respiration. The main portion of natural losses (70-90%) is attributed to evaporation of water; therefore, a decrease in water content and a relative increase in dry matter are observed during the storage of fruit and vegetable products (*Pusik L.M., Hordiyenko I.M.,* 2011).

The greatest influence on the intensity of water and gas exchange with the environment is exerted by external protective tissues, which serve as a natural barrier to prevent pulp cells from enhanced water loss and to inhibit oxygen influx from the air. The condition and structure of external protective tissues affect volumes of evaporated water. Reduction in water evaporation during storage of vegetables is possible via using paraffin coatings. However, prospects of widespread use of protective coatings for storage of vegetables largely depend on their quality and reliability.

Previously, the use of paraffin in food industry was limited to paraffined milk packages and paraffining surfaces of other containers for food products. Today, paraffin is used much more widely: edible paraffin is produced under the P-2 brand and used to cover fruits in order to prevent them from rotting and contamination. Citrus fruits, pineapples, peaches, pears, apples, coffee beans, as well as candies, dragees, chocolate and glazed flour confectionery products are covered with such paraffin. In cheese making, paraffin is used to cover cheese rinds (*Internet resource*).

Pure paraffin coatings, which are recommended in Ukrainian and foreign scientific literature, have not been widely used, as they lack the necessary adhesion and plasticity, so they peel off and crack. Hence, in order to improve the operational properties of coatings, the need for targeted modification of the dispersed structure of paraffin has arisen. This can be accomplished by adding emulsifiers and plasticizers to paraffin, with a scientifically justified selection of optimal compositions of protective paraffin-containing coatings.

Review of Studies and Publications. Emulsion wax, an emulsifier that has undeniable advantages, is one of the components of paraffin-containing formulations. Firstly, emulsion wax allows even beginners to create emulsions, as it is extremely easy to use. Wax emulsions enable one to create materials with excellent protective properties in a simple, economical way. Such emulsions are easy to apply, without thermal or melting, and this easiness leads to expansion of the range of their application in industries and everyday life. Preparation of ready-made mixtures of emulsifiers and additives can also be of great practical importance, allowing for improvement of both the main parameters of an emulsion and for addition of special properties with due account for specifics of the intended application sphere. Further development of technologies for generating and improving wax emulsions, which are demanded by the market at the day being and in the future, determines the relevance and necessity of studies on this topic (*Internet resource*).

Shellac (food additive, E904) is a component of paraffin-containing formulations. The main area of application of shellac is the confectionery industry. E904 is used as a glazing agent for fresh fruits (melons, peaches, pineapples, apples, pears, citrus fruits) to extend their shelf lives. Shellac can be an ingredient of chocolate glazes of candies, dragees, and glazed flour products. Shellac is used to cover chewing gum, coffee beans, and nuts; sometimes it is added to wax mass to make a protective shell for elite cheeses. Such wax coatings have the desirable gas permeability and preserve products well, without affecting the palatability and quality of the cheese (*Internet resource*).

A coating based on shellac and aloe gel has been developed to preserve the quality of apple slices. To do this, apple slices that had been previously ozonated in water and soaked for 10 minutes in a solution containing ascorbic and citric acids (200 mg/kg each) and Na benzoate, edible coatings consisting of shellac and aloe gel were applied alone and in combination (*Chauhan O.P., Raju P.S., Asha Singh, Bawa A.S.,* 2011). Liquids, in which products are immersed, and coatings with or without antimicrobial action are applied directly to products. Such protection mostly does not elicit concerns about toxicity. However, accidental transfer of packaging or/and coating components into food products is not excluded. Therefore, during the development of packages and coatings, it is worth focusing on the legal provisions on permissible substances that are used for this purpose (*Internet resource*).

Edible coatings may represent an alternative to extend the post-harvest life of perishable fruits such as strawberries. In a study, effects of edible coatings from cassava starch, supplemented with potassium sorbate, on mechanical properties, surface color, sensory perception and respiration rate of strawberries were evaluated (*Costa Garcia Lorena, Pereira Leila Mendes, Luca Sarantopoulos Claire I.G., Hubinger Miriam Dupas*, 2010).

Good integrity of edible cassava coatings on the strawberry surface was noted at starch concentrations of 2% and 3%, and the coatings with these concentrations reduced the strawberry respiration rate, presenting an opportunity to extend the fruit shelf life. All coatings beneficially affected, increasing resistance of specimens to water vapor, but a significant increase was achieved only with the 3% starch coating. Based on these results, coatings containing 3% cassava starch and 3% cassava starch + 0.05% potassium sorbate were selected for further investigating the shelf life of minimally processed strawberries (Costa *Garcia Lorena, Pereira Leila Mendes, Luca Sarantopoulos Claire I.G., Hubinger Miriam Dupas*, 2010).

Scientists explored consumer-oriented characteristics of a hydroxypropylmethylcellulose-based coating supplemented with hydrophobic components (beeswax and shellac) and food preservatives (sorbitol, Na benzoate, Na propionate and their mixtures) as antifungal agents. Intact tangerines and artificially inoculated with *Penicillium digitatum* or *P. italicum* were stored at 5°C for 30 days and at 20°C for 7 days more. It was established that, during the storage of refrigerated tangerines, coatings with antifungal additives protected the fruits from spoilage well (*Valencia-Chamorro Silvia A., Palou Liuis, Rio Miguel Angel, Perez-Gago Maria*, 2011).

In a study, a tilapia skin gelatin composite coating, which is transparent and has good barrier properties against O_2, CO_2 and lipids, was used (*W. Heristika, A. Ningrum*). To improve its physicochemical and functional qualities, it has to be modified by adding ingredients such as pectin as well as hydrophobic components such as garlic essential oil. Effects of gelatin-pectin composite coating (75:25, 50:50, 25:75) supplemented with garlic essential oil (2% and 3%) on physical and chemical properties of red chili peppers stored at room temperature (29°C, RAH 69%) for 14 days were evaluated. It was found that 50–50% pectin-gelatin composite supplemented with 2% or 3% garlic essential oil was the best variant. This treatment reduced the weight loss by 36.36% and 37.03% and pulp softening by 0.547 kg/84 mm^2 and 0.539 kg/84 mm^2, respectively.

The invention of an Israeli startup, Sufresca, will not only help reduce amounts of plastic waste, but also extend the shelf lives of vegetables and fruits (*Internet resource*). This is an invisible film that is applied onto fruits. Sufresca films slow down the ripening and spoilage of vegetables and fruits and can extend their shelf lives by several weeks. They slow down the weight loss of fruits during their storage, simultaneously ensuring optimal gas exchange of vegetables and fruits with the environment. In addition, this packaging is completely safe and even edible. The coating is made from plant additives and natural organic compounds. Edible coatings are ideal for replacing all conventional disposable plastic packaging because they are easier to implement in packaging plants, require less investments, and even outperform the state-of-the-art packaging, i.e. modified atmosphere packaging. The startup offers biofilm coatings for onions and garlic, coating for fresh fruits and vegetables such as avocado, tomato, cucumber, mango, pepper, and selective biocoatings for berries. Sufresca is not the only one successfully developing bio-packaging.

Effects of protective coatings on the garlic losses during warm and cold storage at various relative humidity were studied. A new hydrophobic coating of garlic bulbs with a paraffin formulation (PF) was proposed and its composition was scientifically rationalized (the main ingredient was paraffin; ceresin C-65 was a plasticizer; and a fraction of synthetic fatty acids served as a surfactant). The PF protective film applied to stored garlic bulbs was proven to reduce their moisture and weight losses by 3-13 times and 12 times, respectively, and to extend the storage time by 2 times (depending on varieties) compared to the control (*Naumova G.M.*, 2015).

The composition of a protective paraffin-containing coating of garlic bulbs is known; comprises, in addition to 0.5 wt% of a surfactant fraction of synthetic C17-C20 fatty acids (FA), ceresin C-67 in the amount of 20 wt%, and paraffin. There was an almost 2-fold decrease in the water vapor permeability (WVP) of this formulation (WVP=6.5 g/m^2 • d) compared to paraffin alone due to high dispersibility of the crystalline structure of the alloy, which is guaranteed by a fine-crystalline phase of ceresin. The storage of garlic was prolonged from 96 days to 132 days. The weight loss decreased from 24% to 7.7%. The water vapor permeability was only 6.9 g/m^2 • d. However, the disadvantage of this formulation consisted in the fact that the main modifier of the paraffin structure, ceresin C-67, was added in the amount of 15–20 wt%, and ceresin C-67 is a rather expensive scarce petroleum derivative. At the same time, the need for a special surfactant additive, an industrial fraction of synthetic C17-C20 fatty acids to ensure adhesion of the paraffin-ceresin alloy to garlic bulbs remains (*Naumova H.M., Aleksandrova E.A., Khadisova ZH.T., Musaieva B.V.*, 2009).

Wax emulsions are used to impregnate paper and cardboard, make them waterproof, and create protective coatings for fruits and vegetables. The main advantages of wax emulsions compared to the traditionally used wax heated to high temperatures include effective hydrophobization due to high dispersibility (the size of solid wax particles is about 1 micron); a simpler and more effective method of application; no storage costs (paraffin emulsions are stored at 5...30°C, and wax melts at about 80°C).

Pre-storage treatment of green tomatoes with an emulsion of natural candelina wax or with an emulsion of artificial wax substances delayed ripening, but in most cases reduced weight losses. In Germany, an emulsion consisting of 25% sublimated paraffin, 5% waxes and 0.2% disinfectant (sorbic acid) is widely used for processing fruit and vegetable products. In Great Britain, formulation Prolong is used for processing fruits. It is a mixture of sucrose esters, fatty acids, and sodium carboxymethyl cellulose glycerides. In Russia, a study of pre-storage surface treatment of fruit and vegetable products with mixtures or formulations containing polyvinyl alcohol, calcium chloride, and sorbic acid was conducted. The scientists recommended treating apples with 0.3% solution of topsin-M in combination with calcium chloride. This processing ensures preservation of apples in a refrigerator for more than 4 months with minimal losses (*Puzik L.M., Hordiienko I.M., 2011*).

Wax-based coatings have a lower vapor permeability and moisture resistance than other edible coatings. Nevertheless, wax-, fat- and oil-based coatings have several serious disadvantages: a non-uniform application layer, cracking during storage, deterioration of organoleptic indicators of products.

Ready-made mixtures of emulsifiers and additives can be of great practical importance, allowing both for improvement of the main parameters of emulsions and for addition of special properties that take into account the specifics of an application sphere. Further development of technologies for generating and improving properties of wax emulsions, which are demanded by the market at the day being and in the future, determines the relevance and necessity of studies on this topic (*Solomakha I., Zhabynska A.,* 2016).

The **purpose** of this study was to rationalize elements of the post-harvest processing technology for winter garlic, which will allow increasing the storability and shelf life of garlic products. The working hypothesis was based on the assumption that it is possible to use a modified paraffin-containing coating, which will increase the stability of garlic bulbs during storage. To accomplish the study purpose, we set the following objectives:

- To determine an optimal ratio of ingredients of the paraffin-containing coatings of garlic bulbs;
- To evaluate the weight loss of garlic bulbs during storage;
- To determine the storage length of garlic bulbs depending on ratios of the ingredients of the paraffin-containing coatings.

The effect of post-harvest treatment of bulbs with paraffin-containing coatings on the storability of winter garlic was the study object.

The Liubasha garlic variety, which is in the State Register of Plant Varieties Suitable for Dissemination in Ukraine, was the study subject.

Materials and Methods. At stage 1 of our study, standard garlic bulbs of at least 2.5 cm in diameter were picked out. The string bags were numbered, weighed, placed in the product mass and stored in a Polair refrigerating chamber at -1...-3±0.5°C and relative humidity of 75- 80%. In the experiment on the influence of relative air humidity on the weight loss of bulbs, garlic was stored at relative air humidity of 60–70%, 75–85%, 90–95%. Garlic was monitored over time. Samples for analysis were taken and prepared in accordance with DSTU ISO 874–2002. The natural loss of weight during storage was determined by the fixed sample method and presented as a percentage related to the initial weight. A sample was removed from storage if the natural loss of its weight reached ≥10% and the product showed signs of disease and physiological disorders. At the end of storage, the yield of standard products was determined.

The variants of bulb processing were evaluated. Bulbs were treated with following mixtures: 95% paraffin + 5% glycerol (control), 85% paraffin + 5% glycerol + 10% sunflower wax (variant 1), 75% paraffin + 5% glycerol + 20% sunflower wax (variant 2), 65% paraffin + 5% glycerol + 30% sunflower wax (variant 3), and 90% E904 (shellac) + 10% aloe vera gel (variant 4).

Paraffin is a wax-like mixture of saturated hydrocarbons (alkanes) of mostly normal structure from $C_{18}H_{38}$ (octadecane) to $C_{35}H_{72}$ (pentatriocontane). Its melting point is within the range of 45 - 65°C; the density is 0.880–0.915 g/cm^3 (15 °C). The chemical formula is C_nH_{2n+2}.

The main feature of sunflower wax, which was proposed as a dispersant and plasticizer, is its effective moisture-protective ability. Percentage of components of an alloy is one of the factors that determine manufacturing of an alloy with specified moisture-protective properties. The added amount of sunflower wax (10–30 wt%) is regulated by melting temperature of its alloy with paraffin, which should not exceed 70°C. This is due to the need to overheat the melt by 10...15° (not hotter than 85°C) before dipping garlic into it. Overheating above 85°C can negatively affect consumer-oriented characteristics of garlic.

Paraffin formulation (PF) is prepared by melting paraffin and sunflower wax in specified proportions to a homogeneous liquid mixture at 80...85°C and thorough mixing.

The water-proof formulation for storing garlic bulbs is an odourless, light-brown composite paraffin-wax alloy that is solid at room temperature, has a melting point of 60...65 °C and an unlimited shelf life under normal conditions.

Results. Relative air humidity plays an important role in reducing losses of fruit and vegetable products during storage. This parameter characterizes deficit of water that is required to saturate a unit volume of air at a certain temperature. Therefore, relative air humidity exerts a great effect on the water evaporation-attributed loss of weight.

A decrease in the relative air humidity enhances transpiration of water from tissues and evaporation-caused loss of weight and deteriorates the appearance of fruits and vegetables because of wilting. An increase in the relative air humidity poses a threat of droplet-liquid moisture on the product surface, increasing reported losses. The relative humidity of 90–95% is optimal for most fruit and vegetable products, except for vegetables and fruits, whose external protective tissues reliably protect them against evaporation. These are nuts and onions, for which the relative air humidity should be 70–80%. An increase in the relative air humidity moistens hygroscopic skins of onions and garlic, favoring microbiological spoilage. M.A. Nikolayeva revealed that, when onions were moistened, the weight loss from rotting increased. Onions stored at 80% air humidity for six months did not rot, but at 90-95% the percentage of rotten bulbs was 9.2%.

It was experimentally proven that bulb coatings extended the storage length by 25–45 days, depending on coatings. The longest storage was achieved in variants 2 and 4 – 142-145 days (Table 1).

Table 1. Weight loss of Liubasha garlic bulbs depending on water-proof coatings, % (2021-2023)

Variant	Storage length, days	Weight loss, %	Daily weight loss, %
Control (95 % paraffin+ 5 % glycerol)	98	10.0	0.11
Variant 1 (85 % paraffin + 5 % glycerol + 10% sunflower wax)	125	5.5	0.044
Variant 2 (75 % paraffin + 5 % glycerol + 20 % sunflower wax)	142	5.2	0.036
Variant 3 (65 % paraffin+ 5 % glycerol + 30 % sunflower wax)	130	5.8	0.044
Variant 4 (90 % E904 (shellac) + 10% aloe vera gel)	145	5.2	0.036
LSD_{05}		0.97	0.27

The daily weight loss in the control was 0.1%. Addition of sunflower wax to the paraffin mixture reduced the daily weight loss to 0.036-0.044%. On the other hand, with similar daily weight loss in variants 2 and 4 (0.036 %) and in variants 1 and 3 (0.044 %), the duration of storage was different. With a mixture of 90% shellac + 10% aloe vera gel (4), the storage duration was 145 days (daily weight loss = 0.036%). 20% sunflower wax extended the duration of storage up to 142 days (daily weight loss = 0.036%), while the control treatment was associated with the storage duration of 100 days and the daily weight loss of 0.10%.

Analysis of variance showed that 98% of the garlic weight loss during storage depended on the type of bulb coating.

The second significant factor affecting the quality of stored products is the relative humidity (RH) during storage. Therefore, to check the protective properties of the developed coating (variant 2 – 75% paraffin + 5% glycerol + 20% sunflower wax; variant 4 – 90% E904 (shellac) + 10% aloe vera gel), Liubasha garlic was stored at different relative humidity: 60–70%, 75–85%, and 90–95%. (Fig. 1).

It was found that the control garlic specimens stored at reduced air humidity (60–70%) significantly lost weight. An increase in RAH during storage reduced the weight loss of garlic bulbs to 8.2%, i.e. 2.5-fold. Covering garlic bulbs with a protective film reduced the weight loss by 4.6–5 times at a relative humidity of 60–70%. Increasing the relative air humidity to 75–85% and 90–95%

reduced it by 4.7–5.3 and 2.9–3.1 times, respectively. Similar studies were conducted by Solomakha I.V. She reported that treatment of bulbs with paraffin ensured the weight loss of 5.3–6.8% after 8-month storage. The profit from storing paraffined garlic at +3°C was only +0.61 UAH/t (*Irina Solomakha, Alena Zhabinskiy*, 2016).

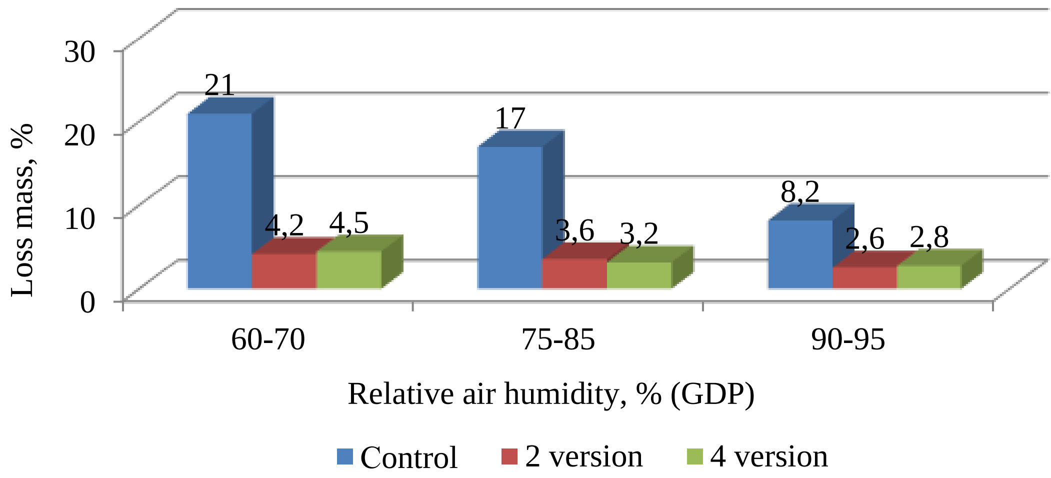

Figure 1. Weight loss of Liubasha garlic bulbs depending on the protective coatings, % (2021-2023)

During storage of garlic at RAH of 60–70%, bulbs were less affected by diseases, but cloves dried out more intensively.

Dried out garlic bulbs have smaller cloves; skins loosely wrap the cloves contributing to penetration of mold fungi; cloves falling from basal plates; and bulbs break into individual cloves. All these decrease the output of standard products and increase non-standard products after storage. The coatings, on the one hand, prevented intensive evaporation of water, and on the other hand, reduced the development of garlic diseases, extending the storage length (Fig. 2).

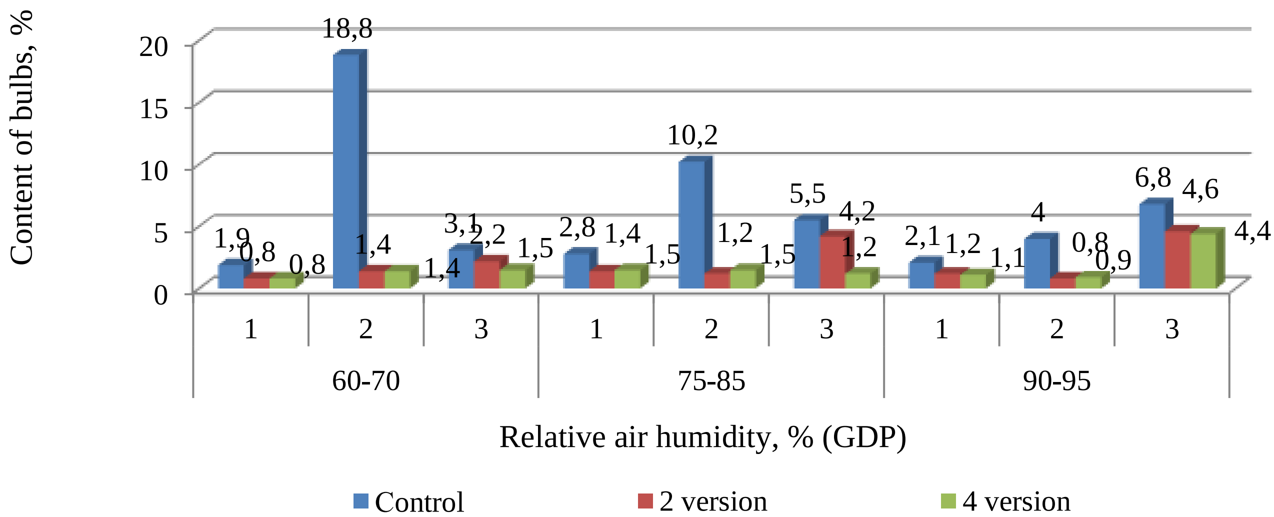

Figure 2. Perventages of diseased and dried out garlic bulbs after storage depending on the relative air humidity, %

With an increase in RAH during garlic storage, the portion of dried out bulbs in the control decreased from 18.8% to 4.0%. The percentage of diseased bulbs, on the contrary, increased from 3.1 to 6.8%. The protective coating suppressed disease development the most in variant 4. At different relative humidity, the percentage of bulbs was 1.5–4.4%.

To assess significance of the effect of relative air humidity and the type of protective coating on the weight loss during storage, we used analysis of variance and found that the contribution of protective coatings in the bulb weight loss variability was 76.0%, while the relative humidity accounted for 12.0%, and the interaction of the studied factors – for 12.0%. The least significant difference (LSD_{05}) between the variants of factor A (protective coating) was 0.68; of factor B (relative air humidity) – 0.58, of factors A-B – 1.18.

Conclusions. Covering bulbs with 90% shellac + 10% aloe vera gel (4) ensured the storage length of 145 days with the daily weight loss of 0.036%. 20% sunflower wax extended the duration of storage up to 142 days with the daily weight loss of 0.036%, while the control treatment was associated with the storage duration of 100 days and the daily weight loss of 0.10%.

An increase in RAH during storage reduced the weight loss of garlic bulbs to 8.2%, i.e. 2.5-fold. Covering garlic bulbs with a protective film reduced the weight loss by 4.6–5 times at a relative humidity of 60–70%. Increasing the relative air humidity to 75–85% and 90–95% reduced it by 4.7–5.3 and 2.9–3.1 times, respectively. The contribution of protective coatings in the bulb weight loss variability was 76.0%, while the relative humidity accounted for 12.0% and the interaction of the studied factors – for 12.0%.

With similar daily weight loss in variants 2 and 4 (0.036 %) and in variants 1 and 3 (0.044 %), the duration of storage was different.

Bulb coatings extended the storage period by 25-45 days depending on the coating type. The longest storage of 142–145 days was achieved in variants 2 and 4.

References

Allium sativum L. Plants of the World OnLine http://powo.science.kew.org/taxon/urn:lsid:ipni.org:names:528796-1

Benefits of garlic: TOP-10 useful properties and main contraindications https://news.glavred.info/polza-chesnoka-top-10-poleznyh-svoystv-i-glavnye-protivopokazaniya-10384359

Chauhan, O.P., Raju, P.S., Asha, Singh, Bawa, A.S. Shellac and aloe gel- based surface coatings for maintaining keeping quality of apple slices. Food Chem. 2011. 126, No 3. P. 961–966.

Costa, G.L., Pereira, L.M., Luca Sarantopoulos, C.I.G., Hubinger, M.D. Selection of an edible starch coating for minimally processed strawberry. Food and Bioprocess Technol. 2010. 3, No 6. P. 834–842.

Fields of paraffin application. https://analitic.ub.ua/35645-sferi-zastosuvannya-parafinu.html

Heristika, W., Ningrum, A., Munawaroh, H.S.H., Show, P.L. Development of composite edible coating from gelatin-pectin incorporated garlic essential oil on physicochemical characteristics of red chili (*Capsicum annnum* L.) https://doi.org/10.3390/gels9010049

Invisible edible film https://service-pack.com.ua/2400-nevidima-stvna-plvka.html

Jancic R. Beograd: Sluzbeni list SRJ; (2002). Botanika farmaceutika, P. 247. [in Serbian].

Naumova, H.M., Aleksandrova, E.A., Khadisova, Zh.T., Musaieva, B.V. Scientific rationalization and development of a protective paraffin-containing coating for garlic bulbs. Pratsi Kubanskoho Derzhavnoho Ahrarnoho Universytetu No 19, 2009. P. 101-104. http://elibrary.ru/item.asp?id=l2861286

Naumova, G.M. Influence of protective coatings under different storage conditions of garlic bulbs. KubGAU, No 13(09), 2015 http://ej.kubagro.ru/2015/09/pdf/58.pdf

Post-harvest treatment and storage of fruits and vegetables. Practical guide https://pdf.usaid.gov/pdf_docs/PA00KT4Z.pdf

Preparation of emulsions. http://4ua.co.ua/chemistry/qb3bc79b4d53b88521306d37_0.html

Puzik, L.M., Hordiienko, I.M. (2011). Technology of storage of fruits, vegetables and grapes. L.M. Puzik, Kharkiv, Publishing House «Maidan», 330 p.

http://4ua.co.ua/chemistry/qb3bc79b4d53b88521306d37_0.html

Solomakha, I., Zhabynska, A. Effects of storage methods on the quality of onions. Tekhnichni Nauki ta Tekhnolohii. No 2 (4). 2016.

The leading information site in the packaging industry. www.upakjour.com.ua_2'2016

Ukrainian Association of Halal Industry https://ukrhalal.org/ua/harchova-dobavka-e-904-shelak/

Valencia-Chamorro, S.A., Palou Liuis, Rio Miguel Angel, Perez-Gago Maria B. Performance of hydroxypropyl methylcellulose (HPMC)-lipid edible coatings with antifungal food additives during cold storage of «Clemenules» mandarin. LWT. Food Sci. And Technol. 2011.44. No 10. P. 2342–2348.

Vanjkevic, S.K. (2002). Beograd. Lecenje belim lukom; P. 10–17.

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ВТРАТА МАСИ ЦИБУЛИН ЧАСНИКУ ОЗИМОГО ПІД ЧАС ЗБЕРІГАННЯ ЗАЛЕЖНО ВІД ОБРОБКИ ЗАХИСНИМ ПОКРИТТЯМ

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Мета. Обґрунтування елементів технології післязбиральної доробки часнику озимого, що дозволить підвищити збереженість та тривалість споживання часнику. В основу робочої гіпотези покладено припущення можливості застосування модифікованого парафіновмістного покриття, що дозволить підвищити стійкості цибулин часнику під час зберігання. **Методи.** Загальнонаукові: 1. метод гіпотез – складання схем дослідів; 2. метод експерименту – схеми лабораторних дослідів; 3. метод аналізу та синтезу – формування висновків і узагальнень, розрахунково-аналітичні. **Результати.** Покриття цибулин сумішшю шелак 90 % + гель алое віра 10% забезпечує тривалість зберігання 145 діб з добовими втратами маси 0,036 %. Використання 20 % соняшникового воску збільшує тривалість зберігання до 142 діб з добовими втратами маси 0,036 %, тоді як обробка парафіном відповідно 100 діб та добовою втратою маси 0,10 %.

Встановлено, що контрольні зразки часнику, що зберігаються в умовах зниженої вологості повітря (60–70 %), значно втрачали у вазі. Збільшення ВВП під час зберігання зменшує втрати маси цибулин часнику до 8,2%, тобто у 2,5 рази. Покриття цибулин часнику захисною плівкою зменшує втрати маси у 4,6–5 разів за відносної вологості повітря 60–70 %. Підвищення відносної вологості повітря до 75–85 %, та 90 – 95 % зменшує у 4,7 – 5,3 і 2,9 – 3,1 разів відповідно. При однакових добових втратах маси у варіантах парафін 75 %+ гліцерин 5 % + соняшниковий віск 20 %, харчова добавка 904 (шелак) 90 % + гель алое віра 10% становила 0,036 % та у варіанті парафін 85 %+ гліцерин 5 %,+ соняшниковий віск 10%, парафін 65 %+ гліцерин 5 % + соняшниковий віск 30 % – 0,044 % тривалість зберігання була неоднаковою. Покриття цибулин подовжує тривалість зберігання на 25 – 45 діб залежно від варіанту покриття. Найвища тривалість зберігання була у варіантах парафін 75 %+ гліцерин 5 % + соняшниковий віск 20 %, харчова добавка 904 (шелак) 90 % + гель алое віра 10% (0,036 %) і становила 142–145 діб. **Висновки.** Сила впливу захисних покриттів на втрату маси цибулин становить 76,0 %, при цьому відносна вологість повітря впливає на 12,0%, взаємодія факторів, що вивчалися – 12,0%.

Ключові слова: *часник озимий, втрата маси, відносна вологість повітря, захисні покриття.*

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GLOBAL OVERVIEW OF THE ONION MARKET AND PRODUCTION PROSPECTS IN UKRAINE

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Purpose. To overview the onion production in Ukraine and the world, to highlight major challenges and ways of further efficient development of this segment in the vegetable market under integration processes. **Methods.** Dialectical method of cognition to review scientific publications, mathematical-statistical, grouping, analysis of statistical series, abstract/logical reasoning. **Results.** The current onion production in Ukraine was considered. The portion of this crop in the total agricultural areas and gross production of vegetables was determined; data on the distribution of onion production by natural and climatic zones of Ukraine and farm categories are summarized. Factors that inhibit the efficient development of this segment of the vegetable market were identified; they include: outdated technologies; few or no innovations; few processing, packing, and storing facilities; lack of professional branding and effective infrastructure; underdeveloped agro-logistics; non-compliance of domestic vegetable products with European standards. The general strategy and priority directions of scientific support for further onion production in the context of integration processes were outlined. **Conclusions.** As the population's material well-being improves, the food basket composition changes in favor of vegetables, including onions, and their consumption rises. Along with the expediency of the maximum use of the existing natural and economic potentials for onion production, one should be guided by this waymark when justifying further development of the vegetable industry in Ukraine. Further development of the onion production in Ukraine must be directed towards high-intensity production based on new high-yielding varieties and hybrids, with high palatability, and towards scientific support for the production. At the same time, in the future, technical re-equipment of the vegetable industry, development of information support systems, creation of marketing services, and development of market infrastructure are necessary.

Keywords: onion, market, demand, supply, efficiency, zonal distribution, development prospects, scientific support.

Introduction. Today, the global food market is developing under the influence of population growth, agriculture globalization, weakening of trade barriers, strengthening of the role of competition, worsening of food security, increasing requirements for and access to food products. This, in turn, affects the dynamic development of the vegetable market due to the growing demand for vitamin-rich vegetable products, especially onions. As a result, today onions are among the five most economically important vegetables in the world.

Review of Recent Studies and Publications. The global and domestic production of agrarian products was studied by *Shubravska O., Moldovan L., Paskhaver B., Datsii O., Makarenko P., 2012*. Problems of innovative development of agricultural production and implementation of advanced technologies were studied by economists such as *Prokopyshyn M., 2017, Grebennikova A., 2016, Dorosh-Kizym M., Dadak O., Hachek T., 2017.* Certain technological aspects of vegetable production were covered by *Lohosha's R., 2018* publication. As a general conclusion from these publications, we should note the following: the current vegetable production in Ukraine requires solving problems at all levels: state, region and farm. At the state level, protection of domestic producers, creation of wholesale food markets, including electronic auctions, and formation of competition in procurement, storage and processing are the most important issues. At the regional level, the formation of integration structures and processing enterprises are the priorities. At the farm level, it is necessary to develop marketing concepts and strategic plans with due account for farms' capabilities, to increase production volumes and yields, and introduce effective innovative solutions into production. It was established that radical shifts in the development of the agro-industrial sphere are only possible provided innovative production, more complete use of all economic levers and incentives, including, first of all, the huge potential of domestic science with the appropriate state policy in the vegetable market development.

The global and domestic production of vegetable products was studied in (*Zakharchuk O.,* 2018, *Supikhanov V.*, 2009, *Blyzkyi R.*, 2012, *Supskyi R*., 2015). At the same time, there are few publications on the global and domestic market of individual segments of the vegetable market by product. Thus, there are no analytical reviews of the onion market, which would consider zonal distribution of onion production, problems of onion producers, etc. Therefore, studies analyzing the onion market in the context of the global and domestic production are relevant and urgent.

Our **purpose** was to overview the onion production in Ukraine and the world, to highlight major challenges and ways of further efficient development of this segment in the vegetable market under integration processes.

Materials and Methods. In order to achieve the purpose, we used the following methods: dialectical method of cognition to review scientific publications, mathematical-statistical, grouping, analysis of statistical series, abstract/logical reasoning.

Results. Onion is one of the most important and popular vegetables. It has been known as a domestic crop for over 6 thousand years. It was grown in India, Persia, East Asia, China, Iran, and the Mediterranean countries, where it was known 4 thousand years B.C. The homeland of onions is Central Asia and Afghanistan. Onions were grown as a food plant in Ancient Rome, Greece and Egypt. For example, the Romans added onions to the mandatory diet of soldiers. Hippocrates prescribed onions to patients with rheumatism and gout. Onions were a study aid for astronomers. By showing a section of an onion bulb, ancient scientists clearly explained the universe structure. The onion, after it was imported to Europe from the Middle East, was treated as a miracle plant. In the Middle Ages, knights, like ancient warriors, wore bulbs on their chests as an amulet, because they believed that they would protected against sword and arrow blows. The use of onions as medicine was described in ancient books. It was believed that those who ate a bulb on an empty stomach would not get sick or age. Among the Slavic peoples, the onions' authority was and still is quite high today. Onions appeared in our country in the 12^{th}-13^{th} centuries.

Today, onion is one of the most important vegetables. Its high value and great strategic importance is determined by its chemical composition, palatability, medicinal properties, and good storability. It is an excellent vitamin remedy, as onion juice kills microbes and viruses and contains a lot of mineral salts. Bulbs contain nitrogenous substances (up to 2.5%), sugars (10-11%; glucose, fructose, sucrose, maltose), polysaccharide inulin, phytin, flavonoids, quercetin and its glucosides, fats, various enzymes, calcium and phosphorus salts, phytoncides, citric and malic acids, vitamins A (3.75 mg%), B1 (60 mg%), B2 (50 mg %), PP (0.20 mg%), and C (10.5-33 mg%). Onions are a rich source of vitamins B, C and E; they also contain minerals - iron, zinc, sulfur, phosphorus, magnesium, potassium, calcium, sodium, copper, and iodine. Due to allicin, onions have antibiotic and antifungal effects. 70-100 g of onions is enough to satisfy the human body's daily need for vitamin C. There are more than 300 onion species in nature.

Today, onion is a strategic export-oriented crop. It is noticeable for good storability, transportability and suitability for mechanized harvesting. In order to ensure year-round consumption of domestic vegetables and to increase export volumes, it is necessary to set an innovation-based stable production of onions. The recommended medical norm of onion consumption per capita is 9 kg/year, including 7.4 kg of fresh onions 1.6 kg of processed ones.

Onions are grown everywhere. The onion area in the world exceeds 8 million hectares, and the percentage of onion-sown area related to the total vegetable-sown area is about 10%. According to the British publishing, business intelligence, and exhibitions group "Informa", the global volume of onion production is 993.2 million tons worth about 24.5 billion dollars. According to industry experts, the global onion market grows by 2-3% annually and will reach 105 million tons by 2025. China is the largest producer of onions worldwide, annually producing 23.9 million tons. India ranks second with 19.4 million tons/year. Ukraine produces 1.017 million tons of onions per year and ranks 30-31 in the world (Tables 1, 2).

The gross harvest in Germany and United Kingdom decreased by 27%: these countries harvested 522 677 thousand million tons and 371 889 thousand tons of onions, respectively. At the same time, the onion production in France only amounted to 458 143 thousand tons, that is, it decreased by 14%. As a result of a decrease in the onion supply in 2021 compared to the previous period, prices have been raised in Belarus, Poland, Ukraine (Eastern European countries) and Uzbekistan Central Asia) - the main players in the onion market

Table 1. Onion production in European countries in 2021

Country	Production, thousand tons	Per capita, kg	Area, thousand hectares	Yield, t/ha
Germany	522 677	6.317	11.294	46.3
France	458 143	6.808	12.812	35.9
Italy	450 645	7.457	12.710	35.5
United Kingdom	371 889	5.631	8.889	41.8
Romania	325 074	16.650	30.273	10.7
Greece	225 746	20.964	6.397	35.3
Austria	163 292	18.476	3.512	46.5
Belgium	130 775	11.455	2.955	44.3
Portugal	124 396	12.088	5.078	24.5
Albania	100 236	34.921	4.802	20.9
Denmark	61 950	10.700	1.470	42.1
Macedonia	60 958	29.373	3.581	17.0
Sweden	59 360	5.836	1.330	44.6
Serbia	57 880	8.267	4.772	12.1
Hungary	48 483	4.962	1.721	28.2
Bosnia and Herzegovina	44 996	11.89	4.928	9.2
Czech Republic	42 018	3.959	1.545	27.2
Switzerland	39 506	4.652	0.900	43.9
Slovakia	29 302	5.383	0.799	36.7
Croatia	26 858	6.407	0.906	29.6
Lithuania	26 521	9.469	1.699	15.6
Finland	26 242	4.756	1.130	23.2
Latvia	15 154	7.869	0.825	18.4
Bulgaria	14 921	2.116	1.365	10.9
Slovenia	11 274	5.455	0.480	23.5
Malta	8 234	17.309	0.438	18.8
Cyprus	8 144	9.527	0.200	40.7
Ireland	6 000	1.235	0.214	28.0
Netherlands	1 449.4	84.017	32.723	44.3
Spain	1 319.2	26.891	24.205	54.1
Ukraine	1 017.1	24.066	55.100	18.5
Montenegro	867.0	1.393	0.480	18.3
Poland	651.4	16.947	26.548	24.5
Estonia	494.0	0.374	0.202	2.4
Luxembourg	120.0	0.199	0.004	29.3

Source: Formed by the authors on the basis of data (Informa information and analytical portal, 2022).

Table 2. Onion production in the former CIS countries in 2021

Country	Production, thousand tons	Per capita, kg	Area, thousand hectares	Yield, t/ha
Azerbaijan	178.249	18.0	11.950	14.9
Belarus	208.873	22.0	10.299	20.3
Armenia	53.922	18.2	2.044	26.4
Georgia	18.500	4.9	2.100	8.8
Moldova	57.936	16.3	5.390	10.8
Russian Federation	2.023	13.8	88.563	22.9

Source: Compiled by the authors from 2022 data of State Statistics Committee of Ukraine [1].

In the global fruit and vegetable trade, the sale of vegetables makes up about 30% compared to the fruit segment accounting for 70% of the global fruit and vegetable trade. This means that fruits are global, and vegetables are local. The production of vegetables is bigger and their assortment is quite large, but vegetables are grown more for domestic consumption and their portion in exports is always smaller than that of fruits.

According to the UN FAO and the international information and analytical platform East-Fruit.com, the absolute leaders in the global vegetable trade are tomatoes, peppers, frozen vegetables, and potatoes. The portion of onions, tomatoes and peppers is 6%, 15%, and 11%, respectively.

The onion production dynamics in Ukraine is summarized in Table 3.

Table 3. Onion area, gross harvest and yield in Ukraine (farms of all categories)

Period/year	Area, thousand hectares	Gross harvest, thousand tons	Yield, t/ha
1990	32.7	447.3	13.7
1991-1992	51.0	499.4	9.8
1993-1994	59.7	557.7	9.3
1995-1996	65.8	558.7	8.9
1997-1998	57.3	449.6	7.8
1999-2000	62.7	489.3	7.8
2001-2002	54.0	521.5	9.7
2003-2004	52.1	521.6	10.0
2005-2006	57.2	809.9	14.2
2007-2008	59.7	885.5	14.8
2009-2010	62.6	1025.3	16.4
2011-2012	64.1	1141.3	17.8
2013-2014	58.7	1064.3	18.1
2015-2016	55.4	987.1	17.8
2017-2018	54.8	1014.6	18.5
2019-2020	54.8	976.7	17.8
2021	53.8	1024.4	18.9
2021 related to 1990, %	164.5	229.0	137.9

Source: Compiled by the authors from 2021 data of State Statistics Committee of Ukraine

In Ukraine, the onion-sown area on farms of all categories was 32.7 thousand ha in 1990; 67.7 thousand ha in 1995; 64.5 thousand ha in 2000; 57.3 thousand ha in 2005; 66.7 thousand ha in 2010; 54.8 thousand ha in 2015, and 53.8 thousand ha in 2021.

It is obvious that the gross onion harvest increased over the period of 1990-2021 (Fig. 1).

Using linear regression, we obtained the following equation of: $y = 367.16 + 23.502 x$, where y - annual gross harvest in tones, x - serial number of the year under investigation, and 367.16 - intersection point of the trend line with abscissa axis This equation shows that every year the gross onion harvest in Ukraine increased by 23.502 tons within the statistical range.

The step, where 492.7 thousand tons or 48.6% of the country's total harvest is produced, is the main producer of onions. It should be noted that the 2021 production only in this zone was similar to the country's total production in 1990. In the forest-steppe, 472.7 thousand tons of onions or 36.7% of the total gross harvest were produced; in the woodlands – 12.9 thousand tons or 12.1%; and in the Carpathians – 26.4 thousand tons or 2.6%. The highest yield was harvested in the forest-steppe (19.6 t/ha) and steppe (18.6 t/ha), while in the woodlands and the Carpathians, onions yielded 16.8 t/ha and 13.2 t/ha, respectively.

In Ukraine, onions are sown on about 60.0 thousand hectares. Most of this area (48.4%) is in the steppe regions of Ukraine; 34.7% - in the forest-steppe; 13.3% - in the woodlands, and 3.6% - in the Carpathians (Table 4).

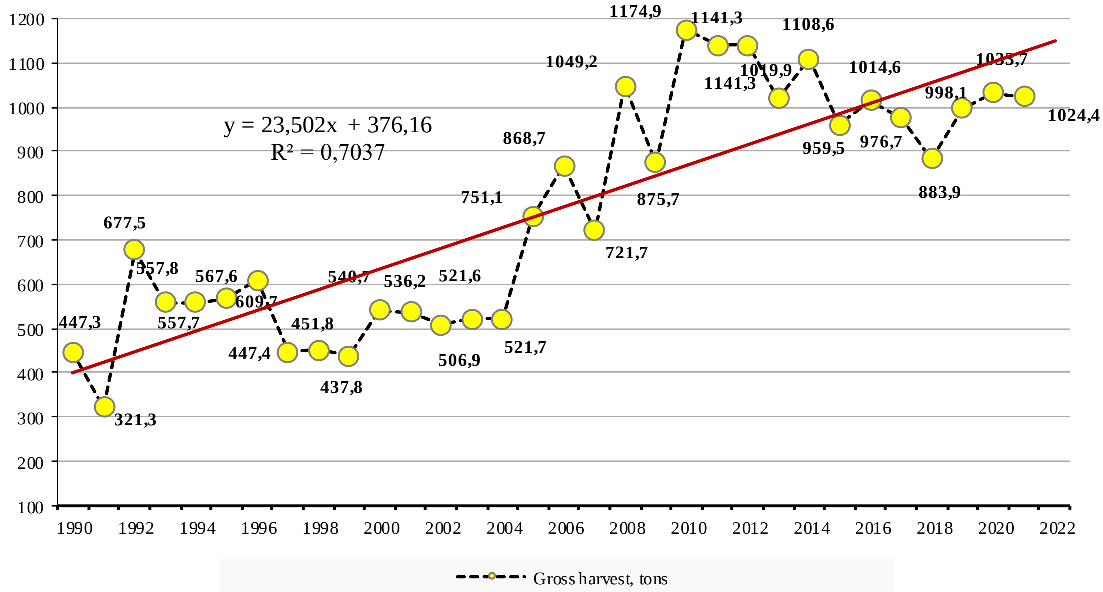

Figure 1. Gross onion harvest in Ukraine in 1990-2021 (farms of all categories), thousand tons Source: Constructed by the authors from 2021 data State Statistics Committee of Ukraine

Analysis revealed another pattern: the onion production underwent zonal transformations over the period of 1990–2021. Thus, despite the fact that this crop is grown mainly in two climatic zones - steppe and forest-steppe, where almost 65% of the total arable area was located in 2009-2021, over the last 30 years, the production area in these zones has grown at a slower rate, than in the woodlands or in the Carpathians. To model changes in the arable area in a specific zone, we used linear regression. The equations were as follows: for the step – y = 32,054 – 0,3031 x; forest steppe – y = 28,367 – 0,1804 x; woodlands – y = 10,752 + 0,3364 x; Carpathians – y = 4,1347 + 0,125 x.

Table 4. Onion distribution by natural/climatic zones of Ukraine (farms of all categories), thousand hectares

Period/year	Zone				Total
	Forest-steppe	**Steppe**	**Woodlands**	**Carpathians**	
1990	9.3	21.6	1.2	0.6	32.7
1991-1992	15.5	31.0	3.3	1.2	51.0
1993-1994	18.6	35.3	4.5	1.3	59.7
1995-1996	19.6	38.6	6.0	1.6	65.8
1997-1998	18.1	31.5	6.0	1.7	57.3
1999-2000	19.0	35.4	6.7	1.6	62.7
2001-2002	16.7	29.1	6.4	1.8	54.0
2003-2004	16.6	27.1	6.6	1.8	52.1
2005-2006	17.0	31.8	6.8	1.6	57.2
2007-2008	16.9	34.1	7.2	1.5	59.7
2009-2010	18.1	35.1	7.2	2.2	62.6
2011-2012	19.0	35.6	7.3	2.2	64.1
2013-2014	18.0	31.4	7.2	2.1	58.7
2015-2016	18.7	27.5	7.2	2.0	55.4
2017-2018	18.9	27.2	7.1	2.0	53.8
2019-2020	19.0	26.5	7.3	2.0	54.8
2021	19.2	27..2	7.4	2.0	55.8
2021 related to 1990, %	206.5	125.9	616.7	333.4	170.6

Source: Compiled by the authors from 2021 data State Statistics Committee of Ukraine

The top onion-producing regions in Ukraine in 2019-2021 were Khersonska (133 thousand tons), Odeska (105 thousand tons), Kyivska (72.5 thousand tons), Mykolaivska (72.2 thousand tons), Dnipropetrovska (68.2 thousand tons), Kharkivska (65.1 thousand tons), Vinnytska (63.1 thousand tons), Zaporizhska (42.0 thousand tons), Poltavska (40.5 thousand tons), and Cherkaska (37.1 thousand tons) Oblasts (Fig. 2).

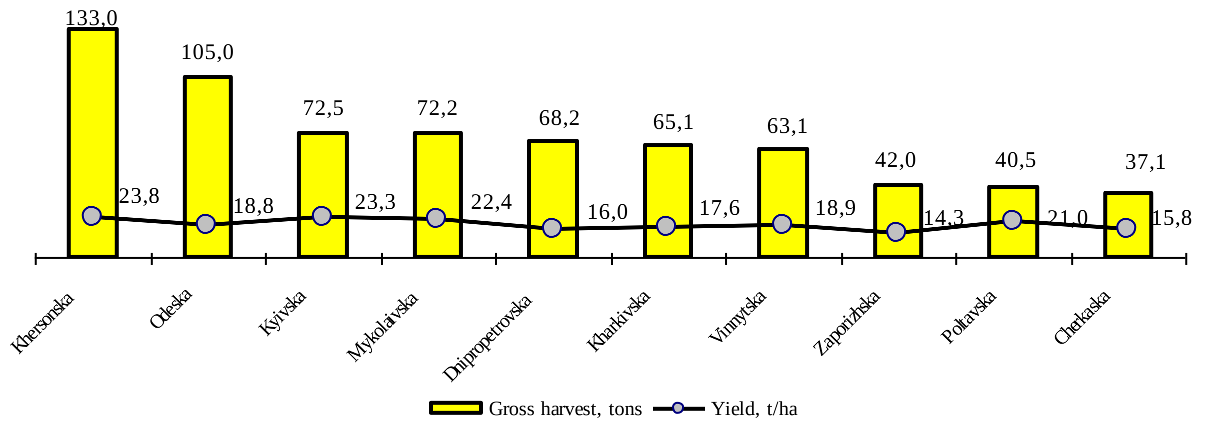

Figure 2. Onion production volume and yield in the 10 top onion-producing Oblasts (farms of all categories), mean for 2019-2021

Source: Constructed by the authors from 2021 data of State Statistics Committee of Ukraine

Agrarian enterprises producing most of onions are located in Khersonska (73.5 thousand tons), Mykolaivska (29.9), Odeska (21.4), Dnipropetrovska (12.5), Cherkaska (9.9), Donetska (6.9), Kyivska (3.5), Kharkivska (3.2), Zaporizhska (3.0), and Poltavska (2.3 thousand) Oblasts (Fig. 3).

The most productive, tolerant to diseases and pests, early-ripening and well-storable onion varieties and hybrids are a major pre-requisite for obtaining high yields. The importance of varieties cannot currently be underestimated, as they, being the main element in growing technologies, are an important way to increase yields and product quality.

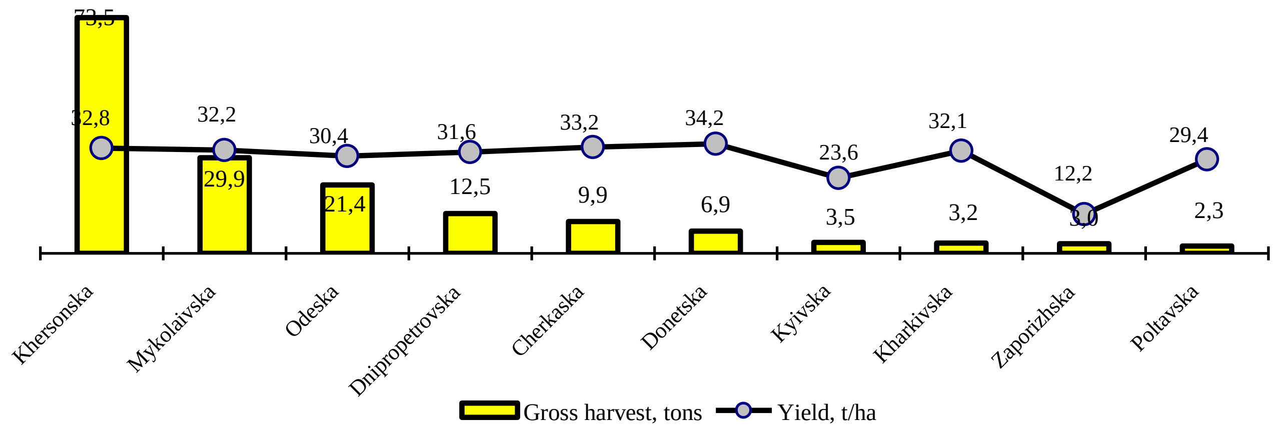

Figure 3. Late-ripening onion production volume and yield in the 10 top onion-producing Oblasts (agrarian enterprises), mean for 2019-2021

Source: Constructed by the authors from 2021 data of State Statistics Committee of Ukraine

The Institute of Vegetable and Melon Growing of NAAS develops intensive, resource-saving technologies for production of marketable vegetables and seeds, which allow one to significantly reduce costs while significantly increasing the plant performance.

Due to 50-year breeding, the Institute and its network have solved the problem of expanding the onion assortment, which is superior to onion 'Zolotystyy' by many indicators today. 'Tkachenkivska' and 'Hlobus' have become varieties - national brands of Ukraine. Later, 'Mavka', 'Variah', 'Veselka', 'Bilianka', 'Amfora', and 'Bella' were bred. 'Liubchyk''s bulbs are unusually cigar-shaped; this variety is widely used in production. In 2021-2022, spicy onion accessions were selected: by total yield – 'Zahrava', 'Maiak' and 'Buran', as they outperform the reference variety, 'Harmoniia', by 11-32% (2.1-2.5 kg/m^2); by marketable yield – 'Zahrava', 'Maiak', 'Hospodynia', and 'Buran' (+24-53% to the reference variety; 2.1-2.5 kg/m^2); by marketability – 'Zahrava' and 'Zolotysta' (100% and 99%, respectively); by early ripening – 'Red Baron' (96 days); by storability – 'Zahrava', 'Maiak', 'Buran', and 'Chernihivska 4' (96-95% or + 8% to the reference variety). We also singled out a semi-hot variety, 'Amfora', which is superior to the reference variety, 'Mavka', in terms of the total yield (+26%; 2.4 kg/m^2), marketable yield (+12%; 2.4 kg/m^2), marketability (+12%; 98%), and bulb weight (+8 g; 130 g). 'Zahrava', 'Maiak', 'Buran', and 'Amfora' were selected by a set of characteristics and will be involved in breeding programs. In the hybrid nursery, 4 accessions were selected be several characteristics; these accessions were superior to the reference in terms of yield (+12-36%; 2.2-2.5 kg/m^2) and marketability (97-99%). In the breeding nursery, 1 accession was selected: it yielded 2.2 kg/m^2, its marketability was 99%, and its bulb weighed 142 g.

In the collection nursery of blue chives, accession 32 (28 days) was distinguished because of the "growth onset - technical ripeness" phase length. In the breeding nursery, accession 12 (29 days) stood out due to the "growth onset - technical ripeness" phase length and accessions 18 (102 days), 24 (101 days) and 35 (103 days) – due to the "growth onset - anthesis" phase length. As to the early yield (19.2, 18.3 t/ha) and total yield (27.5-25.4 t/ha), respectively, accessions 12 and 40 turned out to be the best ones and work with them will be continued.

In the shallot breeding nursery, we distinguished 5 accessions by bulb yield (18.2-25.8 t/ha), 6 accessions by mean bulb weight (22.4-40.5 g), 1 accession by early ripeness and 1 accessions by bulb storability (82.8%). In the collection nursery, the following accessions were distinguished: 8 accessions by bulb yield (18.2-21.6 t/ha), 4 by bulb weight (23.2-31.6 g), 1 by early ripening (66 days), 7 by storability (71.7-77.3 %), and 3 by chemical composition. Two accessions, D-137 and D-93 ('Druzhok'), were selected by storability parameters, as they were characterized by a low number of diseased bulbs and low natural weight loss. D-93 ('Druzhok') and D-196, which are promising accessions for further breeding, were noted for their high bulb yield and good storability. D-93 ('Druzhok') and D-137 were selected as sources of bulb storability for shallot breeding. A short-season (67 days) accession, D-198, which was superior to the reference variety in terms of bulb yield by 23.6% (18.8 t/ha), leaf yield by 34.3% (49.7 t/ha) and 8-month bulb storability by 14.9% (74.0%), was selected for variety trials. Promising onion varieties were created: shallot 'Druzhok' and 'Lira', Welsh onion 'Piero', and leek 'Danko'.

Depending on agro-climatic changes in a particular year, these varieties allow planning stable yields of commercial products of more than 60 t/ha, with a potential of about 90 t/ha. Innovations and their scientific support will ensure additional output of products per unit of area and reduction in time for its processing, with further achieving additional profit at both large and small agricultural enterprises. Introduction of new onion varieties and hybrids, including varieties with unusually shaped bulb, into production requires the development of new technological methods. The Institute has developed a cassette technology for growing onions, including on drip irrigation. The Institute is striving to improve crop rotations and optimize mineral fertilization. A strategy of protection against diseases and pests has been developed. In the future, work will continued in these directions, which will allow harvesting high and stable yields.

Conclusions. Further development of the onion production in Ukraine must be oriented on high-intensity production based on new high-yielding varieties and hybrids with excellent palatability and on scientific support for their cultivation. At the same time, in the future, technical re-equipment of the vegetable industry, development of information support systems, creation of marketing services and development of market infrastructure are necessary.

References

Blyzkyi, R.S. Analysis of export-import volumes of vegetables in Ukraine. *Ekonomika, Menedzhment, Pidpryiemstvo: collection of scientific papars.* Volodymyr Dahl East Ukrainian National University. 2012. No. 24 (1). P. 46-52.

Dubovitskiy, A.A., Klimentova, E.A. Problems and prospects of vegetable growing development. Technologies of the food and processing industries of the agro-industrial complex - healthy food products. 2014. No. 3. P. 89–95.

Dorosh-Kizym, M.M., Dadak, O.O., Hachek, T.S. Innovations in the agrarian sector of Ukraine in the context of the European integration development. *Naukovyi Visnyk LNUVMB* Imeni S.Z. Gzhytskoho. 2017. Vol. 19. No. 81. P. 123–128.

Hrebennikova, A.A. Development of innovation-based agriculture. *Efektyvna Ekonomika*. 2016. No. 12. P. 112. URL: http://www.economy.nayka.com.ua/?op=1&z=5338

Kucherenko, T.E. Present and future of domestic vegetable growing [On-line resource] Propozythiia. No. 2. 2010. Access at: http://www.propozitsiya.com/?page=146& itemid=3144

Lohosha, R.V. Peculiarities of the vegetable industry development. *Naukovyi Visnyk Mizhnarodnoho Humanitarnoho Universytetu.* P. 2018. 86–90. [On-line resource]. Access at: http://repository.vsau.org/getfile.php/16687.pdf

On the approval of the Concept of the State target program for the development of vegetable growing for the period until 2025. [On-line resource]. Access at: https://zakon.rada.gov.ua/laws/show/1333-2020-%D1%80#Text

Onions for all tastes. [On-line resource]. – Access at: https://soncesad.com/statti/ovochi/czibulya/czibulya-na-vsi-smaki.html

Onions. [On-line resource]. – Access at: https://www.harbuz.info/cibulya-ripchasta/

Onions - calorie content. [On-line resource]. Access at: https://www.tablycjakalorijnosti.com.ua/stravy/tsybulya-ripchasta

Supikhanov, B.K. Development of agrarian *Prokopyshyn, M.M., Sus, T.Yo.* Mainstreams of agribusiness development in Ukraine under globalization. *Modern Economics*. 2017. No. 4. P. 114–121. URL: https://modecon.mnau.edu.ua/issue-4-2017/markets: monograph. K.: NNTs IAE, 2009. 530 p.

Supskyi, R.M. Current aspects of the formation and functioning of the vegetable market. *Prodovolchi Resursy. Series: Ekonomichni Nauky*. 2015. No. 4. P. 62-70.

Shubravska, O. V., Moldovan, L. V., Paskhaver, B. Yo. et al. Innovative transformations of the agrarian sector of the economy: [monograph] // edited by Doctor of Economic Sciences O. V. Shubravska/ NAS of Ukraine: Institute for Economics and Forecasting. K. 2012. P. 496.

State Statistics Service of Ukraine. [On-line resource]. Access at: http://www.ukrstat.gov.ua/

Terokhina, L.A., Ruchkin, O.V., Rudnytska, T.O. Innovations for vegetable growing. *Ovochivnytstvo i Bashtannytstvo*. 2011. No. 57. P.225-230.

Zakharchuk, O.V. Global vegetable market and Ukraine’s position. *Ahrosvit*. No. 3, 2018. P. 3-7.

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СВІТОВИЙ ОГЛЯД РИНКУ ЦИБУЛІ ТА ПЕРСПЕКТИВИ ВИРОБНИЦТВА В УКРАЇНІ

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Мета статі - визначити стан виробництва цибулі ріпчастої в Україні та Світі, обґрунтуванні сучасних проблем та шляхів ефективного розвитку цього сегменту ринку овочів на перспективу в умовах інтеграційних процесів. **Методи.** Для досягнення поставленої мети у процесі роботи використовували методи: діалектичний метод пізнання для аналізу наукових праць учених щодо проблематики статті, математико-статистичні, групувань, аналіз рядів динаміки, абстрактно-логічний. **Результати.** Розглянуто сучасний стан виробництва цибулі ріпчастої в Україні. Встановлено частку цієї культури у загальних посівних площах і валовому виробництві овочів, наведено дані щодо розміщення виробництва цибулі за природно-кліматичними зонами України та окремими категоріями господарств. Визначено причини, що стримують ефективний розвиток цього сегменту овочевого ринку, до яких належать: застосування застарілих технологій та практична відсутність інновацій; недостатня кількість необхідних потужностей для доробки, фасування, зберігання; переробки, відсутність професійного брендингу та ефективної інфраструктури, низький розвиток агрологістики, невідповідність вітчизняної овочевої продукції європейським стандартам. Викладено загальну стратегію і пріоритетні напрямки наукового забезпечення виробництва цибулі на перспективу в умовах інтеграційних процесів. **Висновки.** З підвищенням матеріального добробуту населення змінюється структура продовольчого кошика на користь збільшення споживання овочевої групи, у т. ч. цибулі ріпчастої. Цим орієнтиром, поряд з доцільністю максимального використання наявного природно-економічного потенціалу для виробництва цибулі й потрібно керуватися, обґрунтовуючи розвиток галузі овочівництва в Україні на перспективу. Подальший розвиток виробництва цибулі ріпчастої в Україні необхідно спрямовувати по шляху високо інтенсивного її виробництва на основі впровадження нових високопродуктивних сортів і гібридів, з високими смаковими показниками та наукового супроводу її виробництва. При цьому у перспективі необхідне технічне переоснащення галузі овочівництва, розвиток систем інформаційного забезпечення, створення служб маркетингу та розвиток інфраструктури ринку.

Ключові слова: цибуля ріпчаста, ринок, попит, пропозиція, ефективність, зональне розміщення, перспективи розвитку, наукове забезпечення.

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Language	English
Manuscript file format	MS Word (*.doc, *docx)
Page orientation	Portrait
Page size	A4
Manuscript size	From 4,000 to 7,000 words (30,000–50,000 characters with spaces), including tables, figures and references

Font	Times New Roman
Margins	All 2 cm
Interline spacing	1.0
Font size	12 pt
Paragraph indention	1.0
Alignment	Justified
References	Non-English titles of articles, books and conferences are translated into English, transliteration is not acceptable. Titles of journals and names of publishing houses are transliterated. Language of a non-English reference is indicated in square brackets.

Tables, figures, graphs, formulas

• Tables, figures, graphs and formulas should be numbered and presented after the first reference to them in the text (notes are placed directly under the table/figure/graph). All abbreviations should be deciphered the first time they are mentioned in the text.
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The section is submitted in Ukrainian and English with identical content (at least 1,800 characters with spaces). The abstract should be informative and structured as follows: **Purpose. Methods. Results. Discussion. Conclusions. Key words.**
It is not allowed to copy sentences from the sections of the article - paraphrase them.

Key words

5-7 words or phrases related to the study topic. Do not duplicate the title of the article. Do not use general words.

Introduction

The section highlights the current state of the problem at the global level and reviews recent studies and publications with references (7-10 publications) over the past 3-5 years. The relevance, purpose, objectives and scientific novelty of the study are rationalized. References to publications should be in round brackets. Do not cite more than three sources in one reference.

Literature review

This section is optional and should covers results of researchers who investigated general or specific aspects of the study topic. Each researcher's name must be followed by the corresponding reference from the list of sources.

Materials and methods

The section describes major stages of work and justifies the choice of used methods, techniques, approaches or actions aimed at obtaining new scientific results and their analysis. Strategies and criteria of sample formation are explained (if the article contains an empirical part). The experimental base of the study is indicated. The outlined methods should provide complete information on the study process so that it can be replicated by other scientists using the same materials and methods.

Results

The section presents major content of the study, with full justification of obtained data. Tables and graphs should be provided with results of statistical processing. Results should be sufficiently substantiated, methodologically correctly presented, be novel and of practical value.

Discussion

The discussion is supposed to interpret the results in at least 500 words. This section should compare the authors' results with results of other researchers on this topic: what they have in common, what are the differences, who considered other aspects of the problem, etc. It is necessary to compare your own results with five similar works of other domestic or foreign authors. Reviweing publications on the chosen topic, you should mention the authors' names and indicate the essence of their work.

Conclusions

Conclusions should fully and concretely reflect the study results, correspond to the purpose and title of the article. Verbatim duplication from the abstract is unacceptable. It is important to outline the prospects for further research on the chosen topic.

Acknowledgments

This section is mandatory. It acknowledges individuals or organizations for providing technical assistance, ideas, and financial support, owing to which the study has been conducted. If you have nobody to thank, write "None".

Conflict of interest

The authors must disclose all potential sources of conflict of interest. A conflict of interest is any interest or relationship that may be perceived as affecting the author's objectivity. They must be disclosed if they are directly relevant or directly related to the work that the authors describe in their article. The presence of a conflict of interest does not prevent publication. If the authors do not have a conflict of interest, they should declare this when submitting their manuscript and include a corresponding statement in the "Conflict of interest" section. If there is no conflict of interest, "None" is indicated.

References

References to sources in the text should be in round brackets "()", for example: (*Shevchenko, 2023*) or "Serhienko (2023) reported that…".
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ПРАВИЛА ДЛЯ АВТОРІВ

Редакцією збірника «Овочівництво і баштанництво» приймаються до друку оригінальні статті з фундаментальних проблем таких основних напрямів:

- Генетичні, біотехнологічні та імунологічні методи оптимізації селекційного процесу в овочівництві
- Генетичні ресурси рослин
- Селекція овочевих і баштанних культур
- Технологія вирощування овочевих і баштанних культур у відкритому і захищеному ґрунті
- Теоретичні та прикладні основи ведення насінництва овочевих і баштанних культур
- Системи захисту овочевих культур від хвороб і шкідників
- Оптимізація живлення рослин та механізм відтворення родючості ґрунту
- Зберігання і переробка овочевої і баштанної продукції
- Інноваційно-інвестиційний розвиток овочевого ринку

Рукопис подається до редакції мовою оригіналу (українською), для публікацій закордонних авторів – англійською. Послуги перекладу англійською ***безкоштовно***. Кількість авторів однієї статті не має перевищувати ***5 осіб.*** Після надання рукопису до редакції не допускається внесення змін до авторського складу статті.

Статті в електронному форматі направляються до редколегії за електронною адресою: patentiob@gmail.com.

Окремим файлом до статті додаються відомості про авторів двома мовами (українською та англійською): прізвища, імена, по батькові, назви і поштові адреси установ, де виконано роботу, а також контактні телефони, електронні адреси, науковий ступінь та посада. Обов'язково додаються ідентифікаційні номера ORCID кожного з авторів статті. Створити ORCID можна на офіційному сайті https://orcid.org/.

Назви файлів повинні відповідати прізвищу автора. Наприклад: Кондратенко_стаття, Кондратенко _відомості.

Датою отримання рукопису вважається дата надходження його до редакції. У разі надходження рукопису, що не відповідає цим правилам, редакція залишає за собою право не розглядати такий матеріал, про що повідомить авторам.

ЗАГАЛЬНІ ВИМОГИ ДО ОФОРМЛЕННЯ РУКОПИСІВ

Технічні вимоги

Мова публікації	English
Формат файлу з рукописом	MS Word (*.doc, *docx)
Орієнтація сторінок	Книжкова
Формат сторінок	A4

Обсяг статті	Від 4000 до 7000 слів (30000–50000 знаків з пробілами), включно з таблицями, ілюстративним матеріалом і бібліографічним списком
Шрифт	Times New Roman
Поля	2 см з усіх боків
Міжстроковий інтервал	1,0
Розмір шрифту	12 pt
Абзац	1,0
Вирівнювання	За шириною сторінки
Літературні джерела	Представлені англійською мовою; використання транслітерації неприпустиме

Таблиці, рисунки, графіки, формули

- Таблиці, рисунки, графіки та формули повинні бути пронумеровані та подані після першого посилання на них у тексті (примітки розміщуються безпосередньо під таблицею/рисунком/графіком). Усі абревіатури мають бути розшифровані при першому згадуванні в тексті.
- Формули мають бути створені в редакторі Equation Editor, змінні математичні величини у тексті відповідно до формул набираються курсивом.
- Рисунки та графіки повинні бути розташовані по центру, обтікання зображення текстом не дозволяється.
- Усі розмірності фізичних величин потрібно подавати відповідно до Міжнародної системи одиниць (СІ). Між одиницями виміру, символами та цифрами, до яких вони належать, ставиться пробіл.

Структура статті

Індекс УДК	За лівим краєм
Назва статті	Не більше 12 слів, за лівим краєм; подається українською та англійською мовами; прописними літерами, напівжирним шрифтом
Авторські дані	Подаються українською і англійською мовами. Ім’я, по батькові та прізвище авторів прописується повністю, повні офіційні назви та юридичні адреси установ авторів, контактні електронні адреси, науковий ступінь та посада кожного автора, ORCID

Анотація

Розділ подається українською та англійською мовами з ідентичним змістом (не менше 1800 знаків з пробілами). Анотація має бути інформативною, структурованою за схемою: **Мета. Методи. Результати. Обговорення. Висновки. Ключові слова**.
Не допускається копіювати речення з розділів статті – перефразуйте їх.
Ключові слова

5–7 слів або словосполучень, які стосуються теми дослідження, не дублюють назву статті та не складаються із загальних слів.

Вступ

У розділі висвітлюється сучасний стан розглянутої проблеми на світовому рівні, аналізуються останні дослідження та публікації з посиланнями на релевантні наукові видання (7-10 публікацій) за останні 3–5 років. Обґрунтовується актуальність, мета, завдання дослідження та наукова новизна роботи. Посилання на літературу необхідно подавати у круглих дужках. В одному посиланні не варто цитувати більше трьох джерел.

Огляд літератури

Цей розділ є факультативним і має містити результати досліджень науковців, що займались аналізом окремих аспектів досліджуваної теми так і дослідження в цілому. Кожне прізвище дослідника має обов'язково супроводжуватись відповідним посиланням зі списку використаних джерел.

Матеріали та методи

У розділі описуються основні етапи наукової роботи та обґрунтовується вибір використаних методів, прийомів, підходів чи дій, спрямованих на отримання нових наукових результатів дослідження та їх аналізу. Пояснюються стратегії та критерії формування вибірки (якщо стаття містить емпіричну частину), зазначається експериментальна база дослідження. Викладена методологія має надавати повну картину про хід дослідження у такий спосіб, щоб його могли повторити інші вчені, використовуючи ті ж матеріали та методи.

Результати

У розділі представляється основний матеріал дослідження з повним обґрунтуванням отриманих наукових результатів. Табличний або графічний матеріали обов'язково наводяться з результатами статистичної обробки даних. Результати досліджень мають бути достатньо обґрунтованими, методологічно правильно представленими, мати новизну та практичну цінність.

Обговорення

Обговорення має базуватися на інтерпретації результатів дослідження та становити за розміром не менше 500 слів. У цьому розділі необхідно порівняти свої результати з результатами робіт на обрану тему інших авторів: що спільного в отриманих результатах, які відмінності, хто розглядав інші аспекти проблематики тощо. Необхідно зіставити результати свого дослідження з п'ятьма аналогічними роботами інших вітчизняних та закордонних авторів. Під час аналізу публікацій з обраної теми необхідно згадувати прізвища авторів та зазначати суть їх роботи.

Висновки

Висновки мають повно і конкретно відображати результати досліджень, відповідати меті та назві статті, дослівне дублювання з анотації неприпустиме. Важливо вказати перспективи подальших досліджень обраної теми.

Подяки

Розділ є обов'язковим, у якому висловлюється подяка окремим особам чи організаціям за посильну технічну допомогу; ідеї; фінансову (матеріальну) підтримку, завдяки якому дослідження стало можливим. Якщо маєте жодних подяк, то вказується «Немає».

Конфлікт інтересів

Авторам необхідно розкривати всі потенційні джерела конфлікту інтересів. Конфліктом інтересів вважається будь-який інтерес або відносини, які можуть бути сприйняті як такі, що впливають на об'єктивність автора. Вони повинні бути розкриті, якщо мають пряме відношення або безпосередньо пов'язані з роботою, яку автори описують у своєму рукописі. Наявність конфлікту інтересів не перешкоджає публікації. Якщо автори не мають конфлікту інтересів, вони повинні заявити про це під час подання статті та включити відповідну заяву до розділу "Конфлікт інтересів". Якщо конфлікту інтересів немає, то зазначається «Немає».

Список використаних джерел

Посилання в тексті на джерела необхідно вказувати у круглих дужках "()", наприклад: (*Shevchenko*, 2023). Якщо потрібно зазначити посилання всередині рядка, варто вказувати рік у "()", наприклад: "Сергієнко (2023) в своїй роботі зазначала....".

У такому випадку прізвища та роки джерел у тексті мають чітко збігатися з даними у списку використаних джерел. В одному цитуванні не дозволяється згадувати більше трьох джерел.

Список використаних джерел повинен становити не менш 25 найменувань, у тому числі закордонні, транслітерація не допускається, джерела розташовуються в алфавітному порядку та оформлюються за APA 6th Referencing Style (2010).

Всі джерела повинні бути присутніми в інтернеті. **DOI** (за наявності) – обов'язковий елемент використаних джерел.

Бібліографія повинна бути опублікована за останні 5 років, допускається 5 % посилань на власні публікації та декілька джерел раннього видання (до п'яти) без індексів DOI.

Неприпустимо посилатися на гіперпосилання, автореферати дисертацій, матеріали конференцій, службові матеріалу (ДСТУ). Посилатися на інтернет-ресурси можна тільки за наявності DOI.