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Justification of agrobiological parameters for winter garlic cultivation in organic production

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ABSTRACT

The results of improving the elements of winter garlic cultivation technology in the conditions of the Ivano-Frankivsk region through the application of fertilizers to enhance quality and yield are presented. The study focused on fertilizing winter garlic varieties Lyubasha and Kharkivskyi fioletovyi. The research showed that fertilization positively influenced the phenological phases, growth, and development of plants, increased biomass, and improved yield. It was proven that achieving high yields depends on proper fertilization. In terms of crop structure, the best results were achieved with the combined application of green manure and the preparation Sizarin Ultra, which ensured a bulb weight of 95.6 g, a clove weight of 18.4 g, while maintaining a clove count of 5.2 per bulb. A similar effect was observed with the use of the growth regulator Profi-K, which increased productivity almost to the level achieved with green manure (bulb weight – 89.8 g, clove weight – 17.6 g, clove count – 5.1 per bulb). The maximum indicators for the Lyubasha variety were obtained through the combination of green manure with Profi-K: bulb weight was 95.7 g, clove weight – 18.4 g, and clove count – 5.2 per bulb. For the Kharkivskyi fioletovyi variety, the indicators were lower compared to Lyubasha. In the control group, the bulb weight was only 26.1 g, clove weight – 5.8 g, and the clove count per bulb – 4.5. The use of green manure positively affected these indicators: bulb weight increased to 35.3 g, clove weight to 6.3 g, and clove count rose to 5.6 per bulb. It was established that the combination of green manure and Profi-K produced the highest results throughout the research period. The yield of the Lyubasha variety increased to 12.55 $t \cdot ha^{-1}$, providing a gain of 3.9 $t \cdot ha^{-1}$ (40.4%) compared to the control, while the yield of the Kharkivskyi fioletovyi variety reached 10.11 $t \cdot ha^{-1}$ (+2.46 $t \cdot ha^{-1}$, or 32.2%). This fertilization combination proved to be the most effective both for increasing yields and ensuring stable results over the years of research.

Keywords: winter garlic, variety, fertilization, growth regulator, crop structure, green manure, yield.

INTRODUCTION

Garlic (*Allium sativum*) is cultivated almost worldwide and has an ancient origin. This crop is one of the most promising agricultural crops in Ukraine, capable of being grown not only for personal consumption but also for commercial production. The high popularity of garlic in Ukrainian cuisine and its beneficial properties make it indispensable in the food and processing industries. Garlic, according to botanical classification, belongs to the family *Alliaceae*, genus

Allium, species *Allium sativum* L. As a result of prolonged cultivation, it has developed a wide variety of forms and is divided into subspecies based on morphological characteristics, the ability to produce scapes, and cultivation peculiarities [Barabash, 2011; Melnyk et al., 2020; Karbivska et al., 2022a]. The classification of garlic, both in Ukraine and globally, is still under development. However, garlic is generally divided into table varieties and technical varieties, which differ in their essential oil content and taste qualities.

Despite the high demand of this crop, garlic can still be considered a niche product. Industrial-scale production is not widely popular, with approximately 80% of the harvest in Ukraine being produced in household plots and small-scale farms. Analyzing global winter garlic production, it can be noted that China produces 81.16% of this product, making it the cheapest on the market. Such countries as Argentina and Spain account for 5.31% and 3.91% of garlic production, respectively. The remaining countries collectively produce approximately 10% of the world's garlic [Puzik et al., 2020a, 2020b; Tykhonova et al., 2021].

An analysis of garlic production in Europe shows that the leading positions are held by Spain (49.43%), Romania (24.42%), and Italy (10.78%). The remaining EU countries supply the garlic market within the range of 6% to 0.6% [Yakovenko, 2001; Kornienko et al., 2015]. Analyzing the dynamics of garlic cultivation in Ukraine, it is evident that in the 1970s and 1980s, the cultivation area reached up to 3.2 thousand hectares with an average yield of 2.7 t ha^{-1}. In the 1990s, a sharp decline in garlic cultivation was observed, with the area barely reaching 1 thousand hectares. Over the past decade, the area under winter garlic has fluctuated between 18 thousand and 20 thousand hectares, and its yield has significantly increased, averaging about 8 t ha^{-1} [Ignat, 2010; Voytovyk et al., 2024].

Currently, Ukraine produces approximately 200 thousand tons of garlic, placing the country only 12th in global garlic production. The production volumes in Ukraine do not meet the needs of the domestic market, and in 2023, 80% of the demand was met through imports from China. Leading experts note that imported garlic significantly falls short of Ukrainian garlic in terms of taste quality. However, its lower cost drives down procurement prices for domestic products [Lishchak et al., 2006; Hryhoriv et al., 2021; Karbivska et al., 2022b].

Ukraine has significant potential for garlic production in the global market, which has an annual turnover exceeding $100 million. By implementing competitive garlic production technologies, it will be possible to fully meet domestic market demand and produce garlic for export within the next 5–10 years [Yatsenko, 2017, 2019; Karbivska et al., 2023].

In modern garlic production, there are both positive and negative factors that influence the scale of its cultivation. The high market value of garlic generates interest among farmers. On average, with an investment of $15–17 thousand per hectare, the product's value can reach up to $65 thousand per hectare. This not only fully covers production costs but also ensures high profitability.

The factors that negatively affect the widespread adoption of industrial garlic cultivation are as follows:

- The crop, under intensive technology conditions, is highly demanding in terms of agronomic practices;
- Significant costs for mineral fertilizers and plant protection products;
- The largest share of expenses is allocated to seeds;
- The availability of modern vegetable storage facilities to ensure proper product preservation [Bobos, 2011; Palamarchuk, 2020; Kolisnyk et al., 2024].

One of the main challenges faced by agricultural enterprises aiming for industrial garlic production is the insufficient quantity and variety of planting material, along with its high cost. When planting garlic cloves, the seed material requirement can reach up to 1.3 tons per hectare, which, combined with low yields, can lead to unprofitable production.

One approach to reducing the cost of garlic cultivation is the use of planting material from aerial bulbs. Although this method extends the cultivation period to two years, it offers several advantages. Aerial bulbs are more viable, can be mechanically processed, and increase the crop multiplication rate by 10–15 times, significantly reducing the cost of planting material.

Additionally, the method of propagating garlic using aerial bulbs contributes to the health improvement and enhancement of varietal traits of the plants. It also lowers the risk of infection by nematodes, diseases, and mites [Baumann et al., 2012; Melnyk et al., 2020; Voitovyk et al., 2023].

An important factor in determining the productivity of winter garlic is the fertilization system, which significantly affects both the cost and quality of the product. It is known that to achieve a garlic yield of around 10 tons per hectare, the nutrient uptake includes 100 to 120 kg of nitrogen, 75 kg of phosphorus, and 90 kg of potassium per hectare [Alemu-Degwale et al., 2016; Yarovyi et al, 2017; 2019].

However, these values can vary significantly depending on the biological characteristics of the variety, cultivation technology, soil differences, and climatic conditions. Considering that garlic responds positively to good soil organic matter availability, one cost-reduction strategy is the cultivation of green manure crops after the predecessor crop to provide organic mass for garlic. This measure is particularly effective and justified in cases of insufficient organic fertilizers and on soils with a heavy granulometric composition [Castellanos et al, 2004; Block, 2009; Datsko et al, 2025].

The efficiency of fertilization can also be enhanced through foliar feeding with growth regulators and by treating planting material with preparations that promote and ensure the availability of macro- and microelements in the root zone [Golmohammadzadeh, et al., 2015; Radchenko et al., 2023]. The justification and study of the scientific aspects of garlic cultivation have been carried out by researchers such as Kurtyn, Kapustina, Bohatyrenko, Palamarchuk, Snytinskyi, Lishchak, Sych, Ulyanych, Yatsenko and others [Kurtin et al., 2003; Lishchak et al., 2006; Kapustina L.I., 2006; Snitynskyi et al., 2010; Sych et al., 2012; Likhatskyi et al., 2017; Ulyanych et al., 2018; Ulyanych et al., 2019a; Ulyanych et al., 2019b].

However, for the conditions of the Ivano-Frankivsk region, the technologies of foliar feeding, the fertilization system, and the impact of green manure cultivation on the productivity and quality of winter garlic remain insufficiently studied.

MATERIAL AND METHODS

The research on improving the elements of garlic cultivation technology under the conditions of the Ivano-Frankivsk region was conducted during 2022–2024 at the NADIYA-AGROIF farm. The farm is in the village of Cherniatyn, Kolomyia Territorial Community, and belongs to the Dniester soil and climatic zone. The farm has been engaged in garlic cultivation since 2008 and is one of the leading producers in the Ivano-Frankivsk region.

The climatic conditions during the research years did not significantly differ from the long-term averages, with annual precipitation ranging from 658 to 702 mm. The sum of active temperatures above 5 °C averaged 2950 °C, and the hydrothermal coefficient during the study period was 1.1, indicating satisfactory moisture conditions.

The study on optimizing the nutrient system for winter garlic was determined by the soil conditions of the farm, for which soil surveys and laboratory analyses were conducted. It was established that the soil in the research area, based on morphological and laboratory indicators, is classified as light loamy podzolized chernozem on loess-like loams with a typical profile.

The humus content in the 0–30 cm layer is 3.4%, while phosphorus and potassium levels range from 5.8 to 6.9 mg per 100 g of soil. The soil acidity (pH) is 6.1. The soil's bulk density during the vegetation period fluctuates between 1.24 and 1.33 g/cm^3, and the structure is granular-nutty. The winter garlic varieties Lyubasha and Kharkivskyi fioletovyi used in the research are well-adapted to the conditions of the Ivano-Frankivsk region.

Lyubasha is a mid-ripening variety characterized by high productivity and quality. It was included in the State Register of Varieties of Ukraine in 2008. This is a scape-forming variety, reaching up to 1 meter in height, with a well-developed leaf mass. Bulbs weigh between 90 and 110 g and consist of 4 to 7 cloves weighing 15–20 g each. The dry matter content in this variety reaches 42%, making it a high-quality variety suitable for culinary use and with excellent storage longevity.

Under regional conditions, the Lyubasha variety produces yields ranging from 8 to 15 tons per hectare, with yields reaching up to 17 tons per hectare in certain years. The variety is resistant to fungal diseases and is characterized by good frost tolerance. The winter garlic variety Kharkivskyi fioletovyi, developed at the Institute of Vegetable and Melon Growing of the Ukrainian Academy of Agrarian Sciences, is a mid-ripening, scape-forming variety. It is suitable for both industrial and culinary use. The plant reaches a height of up to 80 cm and typically develops up to eight leaves. The bulbs are round and slightly flattened, with an average weight of 50 g and 4–6 cloves per bulb. This garlic has a very sharp taste, a dry matter content of 38–40%, and a sugar content of up to 28%. Under optimal growing conditions, the variety can provide yields of 12 to 16 tons per hectare. It is highly frost-resistant, even in the absence of snow cover, and exhibits strong immunity to fungal infections and rot.

Modern studies show that combining mineral fertilization with the use of growth regulators and the cultivation of green manure crops before sowing increases the productivity of winter garlic and improves product quality.

While studying the productivity indicators of winter garlic under the application of different rates of mineral fertilizers and green manuring, the following experimental design was developed:

- without fertilizer application (fertilization background $N_{90}P_{90}K_{90}$),
- fertilization background + green manure,
- fertilization background + Sizarin Ultra,
- fertilization background + green manure + Sizarin Ultra,
- fertilization background + Profi-K.
- fertilization background + green manure +Profi-K.

The experimental plot area is 2100 m², with an accounting area of 10 m². Sizarin Ultra is a complex fertilizer free from nitrates, promoting larger fruit size and enhancing ripening. It possesses fungicidal properties and contains a rich set of amino acids, microelements, and other beneficial substances that are easily absorbed by plants through roots or leaves. Sizarin helps plants cope with stressful conditions such as transplantation or unfavorable weather due to the presence of stress adaptogens. It also enhances overall soil fertility and its resistance to diseases.

Profi-K is a fertilizer designed for plant growth and development, featuring a high potassium content and a complex of chelated microelements. Its composition includes nitrogen (10%), phosphorus (25%), potassium (45%), and microelements: magnesium (9 $g \cdot l^{-1}$), sulfur (7 $g \cdot l^{-1}$), zinc (5 $g \cdot l^{-1}$), manganese (5 $g \cdot l^{-1}$), boron (5 $g \cdot l^{-1}$), iron (5 $g \cdot l^{-1}$), and copper (3 $g \cdot l^{-1}$). The fertilizer addresses potassium and microelement deficiencies, strengthens weak shoots to the level of strong ones, improves product taste, increases yield and quality, and enhances plant immunity to diseases. The research was conducted in accordance with generally accepted methodologies and standards, such as “Methodology of experimental work in vegetable and melon growing”, “Field experiment methodology”, “Methods of biological and agrochemical research of plants and soils”, and “Fundamentals of scientific research in agronomy”. [Bondarenko et al., 2001; Hrytsayenko et al., 2003; Yeshchenko et al., 2005].

Soil preparation followed a classic approach and included disking the field after winter wheat and plowing to a depth of 30–32 cm, followed by cultivation with harrowing. Garlic was sown using precision seed drills (VPS-3) to a depth of 6–8 cm at a sowing rate of 400 thousand seeds per hectare, with a row spacing of 35 cm and 10 cm between seeds. Simultaneously, 60% of the mineral fertilizer dose was applied. In variants where green manure was grown, disking was performed twice immediately after harvesting winter wheat, followed by sowing white mustard. The mustard was incorporated into the soil at the onset of flowering.

RESULTS AND DISCUSSION

Our phenological observations in the experimental variants did not reveal significant differences or changes in the duration of interphase periods among the variants. Among the factors determining the efficiency of light energy utilization, a special role is played by the leaf surface area, which depends on the biometric parameters of the winter garlic plant. The formation of the number of leaves varied depending on foliar feeding and the cultivation of green manure crops.

Analyzing the plant height of the winter garlic varieties Lyubasha and Kharkivskyi fioletovyi, it can be noted that in the control group, Lyubasha plants were 6 cm taller. Overall, across all fertilization variants, this variety demonstrated better biometric indicators compared to Kharkivskyi fioletovyi (Fig. 1).

The addition of green manure resulted in a noticeable increase in plant height. In the variant where green manure was used, plant height increased by 8.1% and 5.6% compared to the control. For the Kharkivskyi fioletovyi variety, plant height increased to 68.7 cm (+5.2 cm), while for the Lyubasha variety, it reached 73.4 cm (+3.9 cm). This confirms the positive effect of green manure on the development of vegetative organs.

Foliar feeding with Sizarin Ultra contributed to an increase in plant height to 67.1 cm for Kharkivskyi fioletovyi (+3.6 cm) and 71.8 cm for Lyubasha (+2.3 cm). Although the height increase

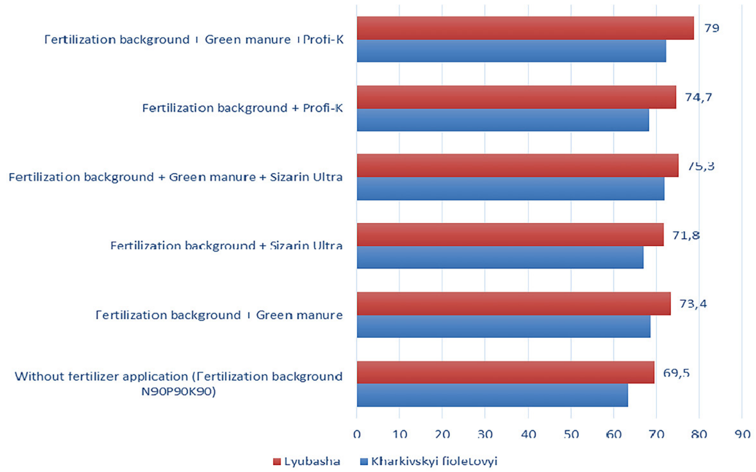

Figure 1. Plant height of winter garlic depending on green manuring and the use of growth regulators, cm (average for 2022–2024)

is less significant than with the use of green manure, the results indicate the impact of the preparation on the physiological growth processes.

A similar trend was observed with the use of Profi-K for both garlic varieties. Variants combining green manure cultivation provided the greatest plant height. The combination of green manure and Sizarin Ultra resulted in a significant increase in height: up to 71.9 cm for Kharkivskyi fioletovyi (+8.4 cm) and up to 75.3 cm for Lyubasha (+5.8 cm). This indicates a synergistic effect of organic and biological stimulation.

Thus, plant height significantly increases with the application of additional nutrition, particularly the combination of green manure with growth regulators. The "Lyubasha" variety consistently exceeds Kharkivskyi fioletovyi in height indicators, demonstrating its potential for vegetative development. The most effective method for increasing plant height is the combination of green manure and the Profi-K preparation, which provides the maximum growth boost.

We determined that the average number of leaves per winter garlic plant in the control group is 6.9 leaves for the Kharkivskyi fioletovyi variety, while for the Lyubasha variety, it is 5.4 leaves. An analysis of the influence of growth regulators and green manuring on leaf formation (Fig. 2) showed that the use of green manure before primary fertilization slightly increased the number of leaves: to 7.1 (+0.2) for Kharkivskyi fioletovyi and to 5.9 (+0.5) for Lyubasha. Organic soil improvement

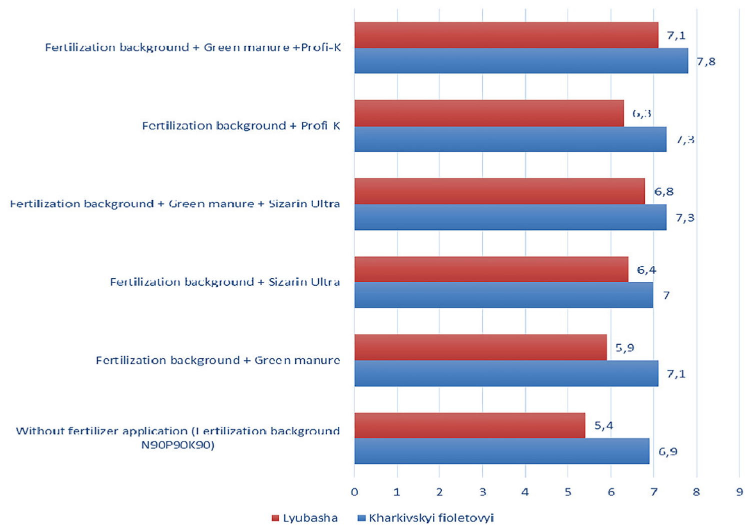

Figure 2. Number of leaves per winter garlic plant depending on green manuring and the use of growth regulators, pcs. (average for 2022–2024)

positively affects the leaf formation process. When Sizarin Ultra was used, the number of leaves for the Kharkivskyi fioletovyi variety remained nearly unchanged (7.0 leaves), while for Lyubasha, it significantly increased to 6.4 leaves (+1.0). This indicates the higher sensitivity of the "Lyubasha" variety to biological stimulation.

Significant improvement in leaf count was observed in variants with green manuring and the growth regulator Sizarin Ultra. For the Kharkivskyi fioletovyi variety, the average number of leaves increased to 7.3 (+0.4), while for Lyubasha, it rose to 6.8 (+1.4). The application of the growth regulator Profi-K increased the leaf count for Kharkivskyi fioletovyi to 7.3 (+0.4), whereas for Lyubasha, it was recorded at 6.3 (+0.9). These results indicate the effectiveness of Profi-K in creating favorable conditions for the development of the leaf apparatus.

The highest leaf count was achieved with the combined application of green manuring and Profi-K. For Kharkivskyi fioletovyi, this indicator reached 7.8 (+0.9), and for Lyubasha, it was 7.1 (+1.7). This demonstrates the highest efficiency of the combined impact of the growth regulator and organic fertilization.

The leaf area index (LAI) is one of the key physiological and biological parameters characterizing the plant's assimilation apparatus (Fig. 3). In our research, it was noted that in the absence of additional nutritional elements, the LAI for the Kharkivskyi fioletovyi variety was 1.27, while for Lyubasha, it was slightly higher at 1.33. The use of green manure increased the LAI to 1.36 for Kharkivskyi fioletovyi (+0.09) and to 1.40 for Lyubasha (+0.07). This increase indicates stimulation of the leaf-stem apparatus due to organic soil enrichment.

When only Sizarin Ultra was applied, the LAI increased slightly: to 1.34 (+0.07) for Kharkivskyi fioletovyi and to 1.38 (+0.05) for Lyubasha. The results demonstrate that the standalone effect of the regulator is less effective compared to the application of green manure.

In variants combining green manuring and Sizarin Ultra, a significant increase in the LAI is observed. The index rises to 1.49 for Kharkivskyi fioletovyi (+0.22) and to 1.54 for Lyubasha (+0.21). This highlights the effect of the combined application of organic soil improvement and biostimulants.

However, the highest LAI values were achieved with the combination of green manuring and the Profi-K preparation: 1.52 for Kharkivskyi fioletovyi (+0.25) and 1.59 for Lyubasha (+0.26). This combination demonstrates the highest efficiency for improving leaf area development (Table 1). In variants combining green manuring and

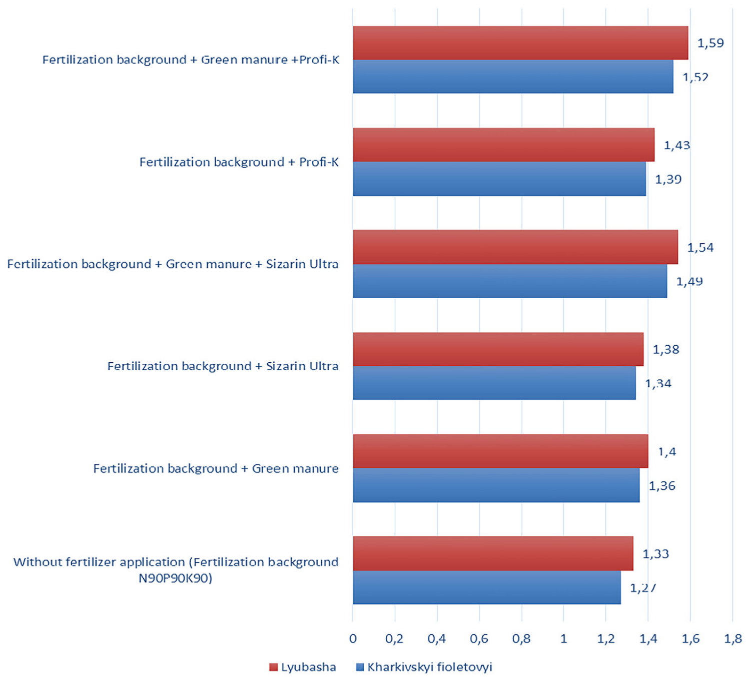

Figure 3. Leaf area index of winter garlic plants depending on green manuring and the use of growth regulators, average for 2022–2024

Table 1. Winter garlic yield structure depending on green manuring and the use of growth regulators, average for 2022–2024

№	Fertilization background	Varieties					
		Lyubasha			Kharkivskyi fioletovyi		
		Bulb weight, g	Clove weight, g	Number of cloves per bulb, pcs	Bulb weight, g	Clove weight, g	Number of cloves per bulb, pcs
1	Without fertilizer application (Fertilization background $N_{90}P_{90}K_{90}$)	80.9	16.5	4.9	26.1	5.8	4.5
2	Fertilization background + Green manure	90.0	17.3	5.2	35.3	6.3	5.6
3	Fertilization background + Sizarin Ultra	86.0	17.1	5.0	30.1	5.9	5.1
4	Fertilization background + Green manure + Sizarin ultra	95.6	18.4	5.2	40.0	6.9	5.8
5	Fertilization background + Profi-K	89.8	17.6	5.1	30.0	6.0	5.0
6	Fertilization background + Green manure +Profi-K	95.7	18.4	5.2	40.3	7.2	5.6

Sizarin Ultra, a significant increase in the LAI is observed. The index rises to 1.49 for Kharkivskyi fioletovyi (+0.22) and to 1.54 for Lyubasha (+0.21). This highlights the effect of the combined application of organic soil improvement and biostimulants.

However, the highest LAI values were achieved with the combination of green manuring and the Profi-K preparation: 1.52 for Kharkivskyi fioletovyi (+0.25) and 1.59 for Lyubasha(+0.26). This combination demonstrates the highest efficiency for improving leaf area development [Ulyanych et al., 2019a].

For the Lyubasha variety in the control variant, which included only background fertilization ($N_{90}P_{90}K_{90}$), the bulb weight was 80.9 g, clove weight was 16.5 g, and the number of cloves per bulb reached 4.9. The addition of green manure improved these indicators: bulb weight increased to 90.0 g, clove weight to 17.3 g, and the number of cloves to 5.2. The application of the growth regulator Sizarin Ultra without additional green manure increased bulb weight to 86.0 g, clove weight to 17.1 g, and the number of cloves to 5.0, although these results were inferior to those with green manure.

The best results were observed with the integrated use of green manure and Sizarin Ultra, where bulb weight reached 95.6 g, clove weight 18.4 g, and the number of cloves remained at 5.2. Similarly, the growth regulator Profi-K improved productivity to levels close to that of green manure (bulb weight – 89.8 g, clove weight – 17.6 g, and the number of cloves – 5.1). The combination of green manure with Profi-K achieved the maximum indicators for the "Lyubasha" variety: bulb weight – 95.7 g, clove weight – 18.4 g, and the number of cloves – 5.2.

For the Kharkivskyi fioletovyi variety, a tendency toward lower indicators compared to Lyubasha was observed. In the control variant, bulb weight was only 26.1 g, clove weight was 5.8 g, and the number of cloves per bulb reached 4.5. The addition of green manure improved these indicators: bulb weight increased to 35.3 g, clove weight to 6.3 g, and the number of cloves per bulb reached 5.6.

The application of Sizarin Ultra without green manure produced more modest results, with a bulb weight of 30.1 g, clove weight of 5.9 g, and 5.1 cloves per bulb. The combination of green manure with Sizarin Ultra improved these indicators to a bulb weight of 40.0 g, clove weight of 6.9 g, and 5.8 cloves per bulb.

The use of Profi-K increased the indicators to levels close to those achieved with green manure: bulb weight was 30.0 g, clove weight 6.0 g, and the number of cloves 5.0 per bulb. The maximum indicators for the Kharkivskyi fioletovyi variety were achieved through the integrated application of green manure and Profi-K: bulb weight increased to 40.3 g, clove weight to 7.2 g, and the number of cloves per bulb was 5.6.

Overall, the research showed that the varieties respond differently to the combination of agronomic techniques. The Lyubasha variety demonstrates greater potential in terms of bulb and clove weight, while Kharkivskyi fioletovyi shows a stable increase in quantitative characteristics. The combination of green manure and growth

Table 2. Yield of winter garlic depending on green manuring and the use of growth regulators, average for 2022–2024

№	Fertilization background	Varieties					
		Lyubasha			Kharkivskyi fioletovyi		
		yield, t·ha^{-1}	increase compared to control		yield, t·ha^{-1}	increase compared to control	
			t·ha^{-1}	%		t·ha^{-1}	%
1	Without fertilizer application (Fertilization background $N_{90}P_{90}K_{90}$)	9.65	–	–	7.65	–	–
2	Fertilization background + Green manure	11.91	2.26	23.4	8.91	1.26	16.5
3	Fertilization background + Sizarin Ultra	10.05	0.40	4.2	8.33	0.68	8.1
4	Fertilization background + Green manure + Sizarin Ultra	12.38	2.73	28.2	9.60	1.95	25.5
5	Fertilization background + Profi-K	10.66	1.01	10.4	8.57	0.92	12.0
6	Fertilization background + Green manure + Profi-K	12.55	3.9	40.4	10.11	2.46	32.2

regulators provides the highest yield indicators for both varieties, highlighting their effectiveness in improving garlic productivity. The results of winter garlic yield research, presented in Table 2, indicate a significant impact of the nutritional background, green manuring, and growth regulators on crop productivity. In the control variant ($N_{90}P_{90}K_{90}$ background), the yield of the Lyubasha variety was 9.65 t ha^{-1}, while for the Kharkivskyi fioletovyi variety, it was lower at 7.65 t ha^{-1}. The use of green manure significantly increased the yield. For the Lyubasha variety, the yield increased to 11.91 t ha^{-1}, representing a gain of 2.26 t ha^{-1} or 23.4% compared to the control. In the Kharkivskyi fioletovyi variety, the increase with green manure application was less pronounced but still significant – 1.26 t ha^{-1} or 16.5% compared to the control.

The application of the growth regulator Sizarin Ultra showed a smaller effect compared to green manuring. In this case, the yield of the Lyubasha variety increased by 0.40 t ha^{-1} (to 10.05 t ha^{-1}), representing a 4.2% increase. For the Kharkivskyi fioletovyi variety, the yield was 8.33 t ha^{-1}, providing an increase of 0.68 t ha^{-1} (8.1%). However, the combination of green manuring and Sizarin Ultra demonstrated a notable effect: the yield of the Lyubasha variety increased to 12.38 t ha^{-1} (+2.73 t ha^{-1} or 28.2%), while the Kharkivskyi fioletovyi variety reached 9.60 t ha^{-1} (+1.95 t ha^{-1} or 25.5%).

The application of the growth regulator Profi-K also demonstrated an increase in productivity; however, the gain was less pronounced compared to green manuring. The yield of the Lyubasha variety reached 10.66 t ha^{-1}, which is 1.01 t ha^{-1} higher than the control, representing a 10.4% increase. For the Kharkivskyi fioletovyi variety, the yield increased by 0.92 t ha^{-1} (to 8.57 t ha^{-1}), which amounted to a 12% increase.

The combination of green manuring and Profi-K delivered the highest results throughout the study period. The yield of the Lyubasha variety increased to 12.55 t ha^{-1}, providing a gain of 3.9 t ha^{-1} (40.4%), while the Kharkivskyi fioletovyi variety reached a yield of 10.11 t ha^{-1} (+2.46 t ha^{-1} or 32.2%). This combination proved to be the most effective for both increasing yield and ensuring stable results across all research years.

CONCLUSIONS

The use of green manure in combination with growth regulators, particularly Profi-K, demonstrates high efficiency in increasing the yield of winter garlic of the Lyubasha variety under the research conditions. The application of green manure significantly increased the yield of Lyubasha to 11.91 t ha^{-1}, exceeding the control by 2.26 t·ha^{-1} or 23.4%. For the Kharkivskyi fioletovyi variety, the yield increase was smaller but still substantial – 1.26 t·ha^{-1}, or 16.5% compared to the control.

The use of the growth regulator Profi-K resulted in a smaller increase compared to green manure application; however, the yield of Lyubasha reached 10.66 t ha^{-1}, surpassing the control by 1.01 t·ha^{-1} or 10.4%. For Kharkivskyi fioletovyi, the increase was 0.92 t·ha^{-1}, achieving 8.57 t·ha^{-1}, which corresponds to a 12% gain. The application of such technologies is promising in the Western Forest-Steppe zone of Ukraine, ensuring yields at the level of 12.55 t·ha^{-1}.

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