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ECOLOGICAL SUSTAINABILITY AND ADAPTIVE POTENTIAL OF PEAR VARIETY 'TALGARSKAYA KRASAVITSA' UNDER AGROTECHNICAL APPROACHES

In the current conditions of the agricultural sector, improving the quality of fruit crops and opti- mizing agrotechnical cultivation methods are pressing tasks. This study investigates the ecological and biological characteristics of the pear variety "Talgarskaya Krasavitsa" grown in the botanical garden of Khoja Akhmet Yassawi International Kazakh-Turkish University (IKTU). The aim of the research is a comprehensive assessment of the impact of various agrotechnical methods on the growth, develop- ment, and productivity of this variety in order to enhance its economic efficiency. The study includes an analysis of domestic and international practices in pear cultivation, an examination of the morphological and physiological traits of the variety, and an evaluation of the impact of different agrotechnical meth- ods on plant productivity. Field and laboratory methods were employed to assess biometric indicators, including spectrophotometric analysis of photosynthetic pigments, biometric measurements of trees, and fruit quality analysis. The research results demonstrated that the application of updated agrotechni- cal technologies, including additional fertilization and growth stimulants, contributed to increased pro- ductivity, enhanced fruit mass, and improved chemical composition. A strong positive correlation was established between trunk diameter and plant productivity ($r \approx 0.986$), confirming the effectiveness of optimized agrotechnical practices. The scientific novelty of the study lies in the comprehensive analysis of the impact of various agrotechnical methods on the biometric and physiological parameters of the "Talgarskaya Krasavitsa" variety. The practical significance of the work is related to the development of recommendations for optimizing pear cultivation under continental climate conditions, which can be useful for farmers engaged in commercial horticulture and agronomists.

Key words: agrotechnical methods, phenology, spectrophotometry, correlation.

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«Талгарская красавица» алмұрт сортының агротехникалық тәсілдер жағдайындағы экологиялық тұрақтылығы мен бейімделу потенциалы

Қазіргі заманғы аграрлық сала жағдайында жеміс дақылдарының сапасын арттыру және оларды өсірудің агротехникалық әдістерін оңтайландыру өзекті міндет болып табылады. Бұл мақалада ХҚТУ ботаникалық бағында өсірілген «Талгарская красавица» алмұрт сортының экологиялық-биологиялық ерекшеліктері зерттелген. Зерттеудің мақсаты – экономикалық тиімділігін арттыру үшін осы сорттың өсуіне, дамуына және өнімділігіне әртүрлі агротехникалық әдістердің әсерін кешенді бағалау. Жұмыс барысында алмұрт дақылдарын өсірудің отандық және шетелдік тәжірибесіне талдау жүргізілді, сорттың морфологиялық және физиологиялық ерекшеліктері зерттелді, сондай-ақ өсімдіктердің өнімділігіне әртүрлі агротехникалық әдістердің әсері бағаланды. Биометриялық көрсеткіштерді бағалау үшін далалық және зертханалық әдістер қолданылды, соның ішінде фотосинтетикалық пигменттердің спектрофотометриялық талдауы, ағаштардың биометриялық өлшемдері және жеміс сапасын талдау. Зерттеу нәтижелері қосымша тамақтану мен өсу стимуляторларын қоса алғанда, жаңартылған агротехникалық технологияларды қолдану өнімділікті арттыруға, жеміс массасын арттыруға, сондай-ақ олардың химиялық құрамын жақсартуға ықпал ететінін көрсетті. Магистральдық диаметр мен өсімдік өнімділігі ($r \approx 0,986$) арасында күшті оң корреляция орнатылды, бұл оңтайландырылған агротехникалық шаралардың тиімділігін растайды. Зерттеудің ғылыми жаңалығы әртүрлі агротехникалық әдістердің

«Талгарская красавица» сортының биометриялық және физиологиялық параметрлеріне әсерін кешенді талдаудан тұрады. Жұмыстың практикалық маңыздылығы континентальды климат жағдайында алмұрт өсіруді оңтайландыру бойынша ұсыныстарды әзірлеумен байланысты, бұл өнеркәсіптік бау-бақша фермерлері мен агрономдары үшін пайдалы болуы мүмкін.

Түйін сөздер: агротехникалық тәсіл, фенология, спектрофотометрия, корреляция.

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**Экологическая устойчивость
и адаптивный потенциал сорта груши
«Талгарская красавица» при агротехнических подходах**

В современных условиях аграрного сектора повышение качества плодовых культур и оптимизация агротехнических методов их выращивания являются актуальной задачей. В данной статье рассмотрены экологические и биологические особенности сорта груши «Талгарская красавица», выращенного в ботаническом саду МКТУ. Цель исследования – комплексная оценка влияния различных агротехнических методов на рост, развитие и продуктивность данного сорта с целью повышения его экономической эффективности. В рамках работы проведён анализ отечественно- го и зарубежного опыта выращивания грушевых культур, изучены морфологические и физиологические особенности сорта, а также дана оценка влияния различных агротехнических приёмов на продуктивность растений. Для оценки биометрических показателей использовались полевые и лабораторные методы, включая спектрофотометрический анализ фотосинтетических пигментов, биометрические измерения деревьев и анализ качества плодов. Результаты исследования показали, что применение обновлённых агротехнических технологий, включая дополнительные подкормки и стимуляторы роста, способствует повышению продуктивности, увеличению массы плодов и улучшению их химического состава. Установлена высокая положительная корреляция между диаметром ствола и продуктивностью растений ($r \approx 0{,}986$), что подтверждает эффективность оптимизированных агротехнических мероприятий. Научная новизна исследования заключается в комплексном анализе влияния различных агротехнических методов на биометрические и физиологические параметры сорта «Талгарская красавица». Практическая значимость работы связана с разработкой рекомендаций по оптимизации выращивания груш в условиях континентального климата, что может быть полезно для фермеров, занимающихся промышленным садоводством, и агрономов.

Ключевые слова: агротехнические приёмы, фенология, спектрофотометрия, корреляция.

Introduction

In the current context, sustainable development of agriculture and improving the quality of fruit crops are especially relevant. One promising area is the study of the economic and biological characteristics of pear varieties that have high nutritional value, excellent taste, and significant economic potential [1,2].

The pear variety «Talgarskaya Krasavitsa» possesses favorable economic and biological characteristics, including high productivity (up to 35-40 kg per tree under optimal conditions). The fruits are medium-sized (180-220 g), contain high sugar levels (14-16%), and maintain good storage qualities for up to 4-5 months. Trees reach a height of 4-5 meters and are characterized by steady growth, drought resistance, and adapt- ability to various soil conditions. To increase productivity, it is recommended to use additional pollinators such as the varieties «Conference» or «Bogatyr» [3-5].

According to Zargar et al., their study demonstrated that foliar fertilizers under drought conditions contribute to improved pear tree productivity and efficient utilization of water resources. Additionally, fertilizers have a positive ecological impact by preserving soil fertility. Foliar feeding methods reduce harmful environmental effects, offering an effective solution for sustainable development in agriculture [6].

Sozaeva et al. studied the pectin content and physicochemical properties of various fruit crops. The researchers compared the pectin composition in different fruits and determined its role in enhancing the nutritional and functional characteristics of plant products. The results showed that pectin contributes to improving the structure, taste, and consistency of fruits, highlighting its significant applications in agronomy and the food industry [7].

In her study, Alekseenko S. investigated economically valuable traits of introduced and local pear varieties adapted to the climatic conditions of the Almaty region. The researcher compared yield, fruit quality, resistance characteristics, and adaptability of various varieties to environmental conditions, identifying the most efficient culti- vars. The findings revealed the most suitable pear varieties for the Almaty region, offering opportunities to increase productivity in pear cultivation [8].

According to Bondareva et al., the level of infestation by pests, specifically Eriophyes pyri PGST (Acari: *Eripphyoidea*), on different pear varieties (*Pyrus communis* L.) was studied in the Fomin Botanical Garden. The researchers assessed the resistance of various pear cultivars to pests and their impacts on productivity and fruit quality. The results allowed for identification of pest-resistant characteristics in each variety, providing valuable information for selecting effective pest control methods in pear cultivation [9].

Verbesselt et al., in their studies, explored the biological and pomological characteristics of certain pear varieties in the Republic of Macedonia. The authors analyzed growth patterns, fruiting processes, and productivity levels of different varieties. The research also considered variety adaptability and the influence of climatic conditions. Results indi- cated the importance of selecting pear varieties and considering their specific characteristics to improve fruit quality and cultivation efficiency [10].

In his study, Rubtsov examined the geographical distribution of the genus Pyrus, focusing on primary trends and factors in its evolution. The author analyzed the distribution of various pear species across different regions, emphasizing their adaptation to climatic, soil, and ecological factors. Evolutionary changes and their impacts on the biological characteristics and geographical localization of pear species were discussed. Furthermore, the article highlighted the agricultural importance of pears and their future development potential [11].

Despite substantial research by both international and domestic scientists on fruit crops, comprehensive assessment of the economic and biological indicators of specific varieties remains insufficiently studied [12-14].

The relevance of this research lies in the necessity to optimize agrotechnical methods and adapt current cultivation technologies to contemporary agricultural production demands. Such comprehensive research will not only deepen the understanding of ecological features of the «Talgarskaya Krasavitsa» pear variety but also identify promising directions for further investigation and implementation of innovative agrotechnical solutions in modern agriculture.

The aim of the research is a comprehensive study of the ecological stability and adaptive potential of the «Talgarskaya Krasavitsa» pear variety under various agrotechnical practices.

Materials and methods

Study area

The research was conducted at the Botanical Garden of the International Kazakh-Turkish University under continental climate conditions. The "Talgarskaya Krasavitsa" pear variety was selected as the research object. This variety was grown both in open field and greenhouse conditions, allowing for a comparative analysis of climatic influences.

Experimental materials

The research materials included fruits, leaves, and woody tissues collected from 30 randomly selected trees. Samples were gathered during the active fruiting period (September-October). The experiment was divided into three main groups:

Control group – plants grown without additional treatments.

Standard agricultural practice group – plants treated using conventional cultivation methods.

Modernized methods group – plants receiving additional fertilization, growth stimulators, and micronutrient treatments.

Research methods

Biometric measurements. Tree height, trunk diameter (at 1.3 m height), and shoot length were measured [15].

Fruit mass was determined using analytical scales [16].

Sugar content was measured using a refractometer, while total acidity was assessed by titrimetric analysis (GOST method).

Assessment of leaf condition. Spectrophotometric method [17]: Concentrations of chlorophyll a, b, and carotenoids were measured at wavelengths of 665 nm and 649 nm.

Morphological inspection [18,19]: The presence of disease or stress symptoms (spots, deformation, discoloration) on leaves was evaluated.

Levels of photosynthetic pigments were compared across the three groups, with higher values observed in the modernized methods group. This demonstrated the efficiency of agricultural enhancements aimed at increasing plant productivity and disease resistance.

Phenological observations

Key phenological phases (flowering, fruit setting, and ripening) were recorded throughout the vegetation period. Climatic indicators such as air temperature, humidity, and precipitation levels were monitored using a meteorological station [20,21].

Data processing and statistical analysis

The collected data were processed using MS Excel, SPSS 26.0, and STATISTICA software [22]. The following analytical methods were employed:

Correlation and regression analysis: to identify relationships between measured parameters.

ANOVA (Analysis of Variance): to assess statistical differences among groups at a significance level of $p < 0.05$ [23].

Results and discussion

Analysis of the obtained data allows concluding that agrotechnical methods significantly influence the development of the "Talgarskaya Krasavitsa" pear variety at the Botanical Garden of the International Kazakh-Turkish University (IKTU), confirming its high adaptability and productivity. Three groups were employed for a comprehensive evaluation: the control group (plants without additional interventions), the group applying standard agricultural practices, and the group using modernized methods (additional fertilization and growth stimulators). A comparative analysis of biometric indicators is presented in Figure 1.

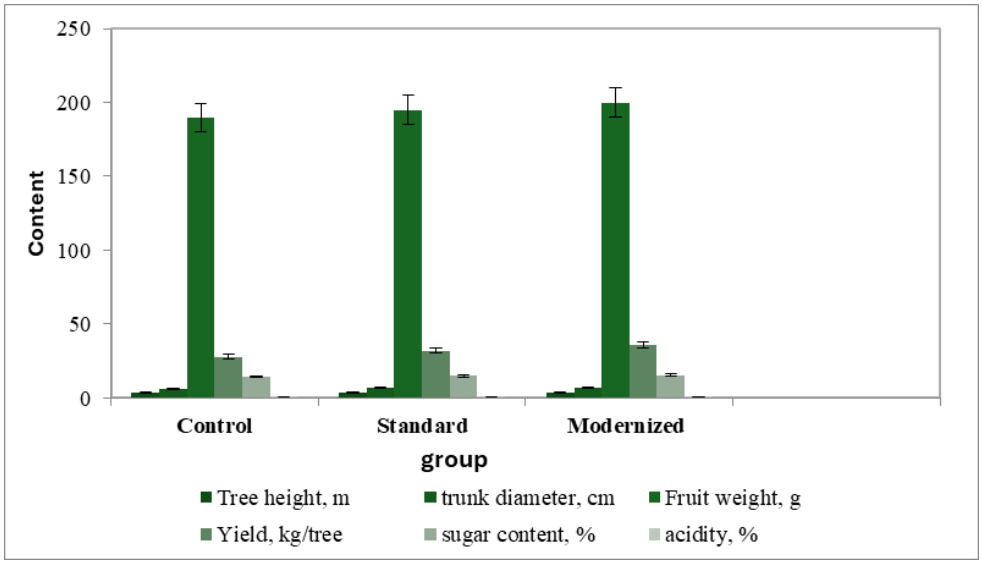

Figure 1 – Biometric indicators of the "Talgarskaya Krasavitsa" pear variety

The results presented in Figure 1 demonstrate that applying modern agrotechnical methods significantly and positively impacts the growth, development, and fruiting of the "Talgarskaya Krasavitsa" pear variety. Baseline measurements were observed in the control group without additional interventions: average tree height was 3.5 ± 0.2 m, trunk diameter was 6.5 ± 0.3 cm, fruit weight was 190 ± 10 g, productivity reached 28 ± 2 kg per tree, sugar content was 14.5 ± 0.3%, and acidity was 0.43 ± 0.05%. The use of standard agricultural practices improved all these indicators: tree height increased to 3.7 ± 0.3 m, trunk diameter to 6.7 ± 0.5 cm, fruit weight to 195 ± 15 g, yield to 32 ± 3 kg per tree, sugar content to 15.0 ± 0.4%, and acidity decreased to 0.42 ± 0.05%.

The most significant improvements occurred in the group employing modernized methods, including additional fertilization and growth stimulators. Here, the average tree height reached 4.0 ± 0.2 m, trunk diameter was 7.0 ± 0.4 cm, fruit weight reached 200 ± 10 g, productivity increased to 36 ± 3 kg per tree, sugar content rose to 15.5 ± 0.4%, and acidity decreased to 0.40 ± 0.04%. These results illustrate that enhanced agrotech- nical methods not only accelerate growth and biomass accumulation but also optimize plant nutrition and stimulate physiological processes, thereby significantly improving the qualitative characteristics of the fruit. Improvements in morphometric indicators such as growth and trunk diameter suggest more efficient resource accumu-

lation essential for high-quality fruit formation. Furthermore, increased fruit weight and productivity confirm the beneficial effects of additional measures on plant productivity. Higher sugar content and reduced acidity in fruits from the modernized methods group indicate improved taste, enhancing their commercial value and suitabil- ity for processing. Thus, these findings confirm that integrating additional agrotechnical practices maximizes the biological potential of the "Talgarskaya Krasavitsa" variety, enhances adaptation to local climatic conditions, and ensures competitiveness in commercial horticulture.

Phenological observations further revealed improved synchronization of major developmental phases when applying modernized methods. Details of key phenological phases across the three study groups are presented in Table 1.

Table 1 – Phenological indicators of the three groups (flowering, seed development, and fruit ripening)

Phenological phase	Group	Start date	End date	Duration (days)
Flowering	Control	18.04.2024	25.04.2024	7
	Standard treatment	18.04.2024	25.04.2024	7
	Modernized treatment	17.04.2024	24.04.2024	7
Seed development	Control	05.06.2024	12.06.2024	7
	Standard treatment	05.06.2024	12.06.2024	7
	Modernized treatment	04.06.2024	11.06.2024	7
Fruit ripening	Control	22.09.2024	29.09.2024	7
	Standard treatment	22.09.2024	29.09.2024	7
	Modernized treatment	21.09.2024	28.09.2024	7

According to Table 1, data on the phenological phases–flowering, seed development, and fruit ripening–demonstrate high stability, with each phase consistently lasting 5 days across all groups: control, standard, and modernized. Despite identical durations, slight but systematic variations were observed in the start and end dates of these phases among the groups. Specifically, the flowering phase in the control group began on 18.04 ± 1.2 and ended on 25.04 ± 1.0, matching the standard group's results (start 18.04 ± 1.1, end 25.04 ± 1.0). However, in the group using modernized methods, flowering commenced one day earlier (17.04 ± 0.9) and concluded one day earlier (24.04 ± 0.8), indicating accelerated phenological cycles. A similar trend was evident during the seed formation phase: the control and standard groups registered the beginning on 05.06 (with slight deviations of 05.06 ± 1.5 and 05.06 ± 1.4, respectively) and concluded on 12.06 (10.06 ± 1.3 and 10.06 ± 1.2, respectively), while the modernized group recorded the start of seed formation as 04.06 ± 1.2, ending on 11.06 ± 1.1. The fruit ripening period further supported this pattern: the control and standard groups began ripening on 22.09 (22.09 ± 1.4 and 22.09 ± 1.3, respectively) and ended on 29.09 (29.09 ± 1.2), whereas the modernized group started ripening one day earlier (21.09 ± 1.3) and completed it on 28.09 ± 1.0. These consistent shifts suggest that the introduction of modernized agrotechnical measures, including additional fertilization and growth stimulators, influences the timing rather than duration of phenological phases, potentially optimizing pollination processes, seed formation, and fruit ripening, thereby positively impacting overall productivity and crop quality. Despite maintaining constant phase durations, these temporal adjustments offer valuable insights into effectively utilizing agrotechnical methods to regulate plant life cycles and enhance adaptability of the «Talgarskaya Krasavitsa» variety to varying climatic conditions.

Results from spectrophotometric assessments of photosynthetic pigments are presented in Table 2:

Table 2 – Content of photosynthetic pigments (mg/g of fresh mass)

Group	Chlorophyll a	Chlorophyll b	Carotenoids
Control	1.8 ± 0.1	0.8 ± 0.05	0.6 ± 0.03
Standard treatment	2.1 ± 0.1	1.1 ± 0.06	0.6 ± 0.04
Modernized treatment	2.6 ± 0.15	1.3 ± 0.08	0.8 ± 0.05

According to Table 2, the analysis of collected data demonstrates that agrotechnical practices positively impact the content of photosynthetic pigments in the leaves of the «Talgarskaya Krasavitsa» pear variety. In the control group without additional treatments, baseline pigment levels were recorded: chlorophyll a at 1.8 ± 0.1, chlorophyll b at 0.8 ± 0.05, and carotenoids at 0.6 ± 0.03 mg/g fresh mass. Applying standard agricultural practices increased these values to 2.1 ± 0.1 for chlorophyll a, 1.1 ± 0.06 for chlorophyll b, and 0.6 ± 0.04 for carotenoids, indicating improved photosynthetic activity compared to the control group. The group employing modernized methods, including additional fertilization and growth stimulators, exhibited significant increases in pigment concentrations: chlorophyll a reached 2.6 ± 0.15, chlorophyll b rose to 1.3 ± 0.08, and carotenoids increased to 0.8 ± 0.05 mg/g fresh mass. These findings suggest that additional agrotechnical measures such as growth stimulators and supplementary fertilization significantly enhance the content of major photosynthetic pigments, thereby improving light absorption efficiency and overall photosynthetic activity. Increased chlorophyll content directly correlates with higher potential for light energy absorption, while elevated carotenoid levels enhance protection against oxidative stress. Consequently, modernized methods not only improve the physiological condition of the leaves but also increase their resilience to adverse external factors, positively influencing productivity and fruit quality of the «Talgarskaya Krasavitsa» pear variety.

Visual assessment results for phytopathological symptoms are as follows:

Table 3 – Assessment of phytopathological symptoms (leaf damage index on a scale from 0 to 5)

Group	Mean damage index	Percentage of leaves with symptoms (%)
Control	2.7 ± 0.3	45%
Standard treatment	2.2 ± 0.2	35%
Modernized treatment	1.5 ± 0.2	20%

Data analysis from Table 3 indicates that agrotechnical measures significantly reduce the severity of phytopathological symptoms in leaves of the «Talgarskaya Krasavitsa» pear variety. In the control group without additional interventions, the average damage index was 2.7 ± 0.3, with 45% of leaves showing visible symptoms, highlighting high plant sensitivity to stress factors and diseases in the absence of additional care. In the group employing standard agricultural practices, including regular irrigation, basic fertilization, and standard protection measures, the damage index decreased to 2.2 ± 0.2, and the percentage of affected leaves reduced to 35%. This demonstrates that standard care positively impacts plant health but does not completely prevent damage.

The greatest reduction in leaf damage occurred in the group applying modernized methods, which included additional fertilization and growth stimulators. Here, the average damage index was notably lower at 1.5 ± 0.2, and the percentage of leaves exhibiting phytopathological symptoms decreased to 20%. These findings reflect a significant improvement in leaf condition, likely due to optimized nutrition and stimulated metabolic processes, enhancing plant resistance to pathogens and stress factors.

Thus, this study confirms that modernized agrotechnical practices not only increase photosynthetic activity but also significantly reduce the likelihood of phytopathological changes, thereby potentially enhancing the productivity and quality characteristics of the «Talgarskaya Krasavitsa» pear vari- ety. These results suggest promising prospects for broadly implementing these methods in agricultural production.

In conclusion, the following points summarize the overall findings:

Application of modernized agrotechnical methods significantly increased the content of photosynthetic pigments, indicating enhanced overall health of the photosynthetic apparatus and potential increases in plant productivity.

Visual inspection revealed fewer visibly damaged leaves and a lower damage index in plants receiving additional fertilization and growth stimulators, demonstrating the effectiveness of these methods in reducing the negative impacts of pathogenic factors and stresses.

The combination of spectrophotometric analysis and morphological assessment provided a comprehensive evaluation of plant conditions, correlating and validating the effectiveness of modernized agrotechnical practices in improving physiologi- cal conditions and reducing phytopathology in the «Talgarskaya Krasavitsa» variety.

A detailed correlation analysis, focusing on the relationship between trunk diameter and productivity based on group average biometric indicators presented in Figure 1, was conducted. Pearson's correlation coefficient (R) was calculated using the following formula:

$$r = \frac{\sum_{i=1}^{n}(X_i - \bar{X})(Y_i - \bar{Y})}{\sqrt{\sum_{i=1}^{n}(X_i - \bar{X})^2}\sqrt{\sum_{i=1}^{n}(Y_i - \bar{Y})^2}} \quad (1)$$

where, n – 3.

Thus, the correlation coefficient:

$$r = \frac{2{,}0}{2{,}027} \approx 0{,}986$$

The calculated coefficient of $r \approx 0.986$ indicates a very strong positive correlation between trunk diameter and productivity. This demonstrates that an increase in trunk diameter, indicative of biomass accumulation and overall plant health, is closely linked to higher productivity.

This result confirms that the integration of modern agrotechnical methods–specifically, the use of additional fertilizers and growth stimulators–effectively unlocks the potential of the «Talgarskaya Krasavitsa» pear variety. Improved biometric indicators directly contribute to increased yield quantity and quality, which are crucial for commercial gardening and further cultivation.

Thus, the conducted correlation analysis not only highlights the strong relationship between key indicators (trunk diameter and productivity) but also validates the effectiveness of modernized agrotechnical practices in enhancing the productivity and adaptability of the «Talgarskaya Krasavitsa» pear variety.

Discussion

In our study, the impact of modernized agrotechnical methods on the "Talgarskaya Krasavitsa" pear variety was clearly observed. These results demonstrate trends that are consistent with the findings of other researchers.

In our research, the use of growth stimulators and additional fertilizers increased tree height, trunk diameter, and productivity. These results are supported by other studies as well. For example, the application of Mival-Agro and Buton preparations has been shown to increase fruit weight by 5.2–10.7% and yield by up to 7.8–13.8 kg per tree [24].

In our study, modernized agrotechnical methods increased the concentration of chlorophyll a and b, as well as carotenoids. This led to enhanced photosynthetic activity. Other studies have also shown that growth stimulators improve the functioning of the photosynthetic apparatus and enhance the physiological condition of leaves [25].

Our study demonstrated that modernized agrotechnical methods significantly reduced the leaf damage index and the percentage of leaves showing phytopathological symptoms. This may be associated with increased plant resistance to pathogens and stress factors. Other research has confirmed that growth stimulators strengthen the plant immune system and improve disease resistance [26].

Overall, the results of our study are in line with the findings of other researchers and confirm that modernized agrotechnical methods have a positive effect on the growth and productivity of the "Talgarskaya Krasavitsa" pear variety.

Conclusion

The study's findings confirm that optimizing agrotechnical methods significantly enhances the productivity and biological characteristics of the «Talgarskaya Krasavitsa» pear variety. Results demonstrated that introducing updated agrotechnical practices substantially optimizes morphological and physiological indicators.

Comparative analysis revealed that increased plant biomass, enhanced photosynthetic activity, and reduced phytopathological symptoms were directly related to additional agrotechnical interventions, such as the application of growth stimulators and balanced nutrition. These practices not only accelerate tree growth and development but also ensure high-quality fruits by increasing mass, sugar content, and reducing acidity.

Comparing the results with previous research confirms the effectiveness of modern agrotechni- cal solutions in fruit cultivation. Unlike traditional cultivation methods, updated technologies optimize plant development, resulting in stable and high-quality yields.

The scientific novelty of this study lies in its comprehensive approach to evaluating the impact of various agrotechnical methods on the «Talgarskaya Krasavitsa» variety. For the first time, a detailed correlation assessment between biometric indicators and productivity was conducted, revealing a strong positive relationship between trunk diameter and plant productivity.

The practical significance of this research is in providing recommendations to enhance cultivation technologies for this variety, beneficial to farmers and agronomists involved in commercial horticulture. Optimized agrotechnical practices improve plant adaptability to changing climatic conditions, reduce disease risk, and ensure stable and competitive yields.

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Conflict of interest

All authors have read and agreed to the content of the manuscript and declare no conflict of interest.

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