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Application of para-aminobenzoic acid in sustainable potato cultivation under climate change conditions

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ABSTRACT

This study focuses on the influence of para-aminobenzoic acid (PABA) and ash on potato growing processes, with a special emphasis on the genetic potential of potato varieties to increase tuber stress resistance and improve nutrient assimilation efficiency. PABA, known for its properties in the biosynthesis of folic acid, is critical for cell division and growth of potatoes. Based on the data obtained, the effect of different concentrations of the acid on the physiological parameters of tubers, including their ability to withstand abiotic stresses such as drought and high temperatures, was analyzed and investigated. In addition, the issue of safe use of PABA in agronomy was considered, assessing its potential impact on environmental safety and sustainability of agrosystems. Black ash was also used to reduce the rate of mineral fertilizers. The research examined the benefits of using PABA in modern potato growing technologies, given the growing demands on the efficiency and environmental friendliness of agricultural products, which has become increasingly important in recent years in view of Ukraine's European integration. An important aspect of the use of biostimulants is a significant increase in the stress resistance of potatoes to adverse conditions, which has been a frequent phenomenon in recent years due to climate change on the planet. In the present study, in addition to the biostimulant, ash was used as a source of nutrients and trace elements, including phosphorus, potassium, and magnesium. Ash provided potatoes with starter nutrition during tuber germination, which additionally had an impact on the protection of planting material from diseases and pathogens. The use of biostimulants and ash can further reduce the cost of potato production for the farmer compared to expensive mineral fertilizers. In the study, it can be stated that the use of growth stimulants and ash has a positive effect on plant vegetation, stress resistance and potato quality compared to control combinations without the use of PABA.

Keywords: para-aminobenzoic acid, potato cultivation, plant stress resistance, folic acid biosynthesis, sustainable development, yield, growth stimulants, varieties.

INTRODUCTION

In modern potato tuber production, farmers face a range of challenges, including decreased genetic productivity of potato varieties and reduced product quality due to non-optimized pre-planting treatment methods [Bondarchuk, 2010; Podhayets'kyi, 2011; Hryhoriv et al., 2024]. Traditional methods, such as soaking tubers in chemical solutions or spraying or dusting them with various substances, often prove insufficiently effective due to uneven coverage or poor penetration of active substances into plant tissues, which may indicate the use of low-quality treatment agents. This leads to unstable yields and increased costs due to the need for additional plant protection and nutrition inputs [Melnyk et al., 2001; Vdovenko, 2022; Kolisnyk et al., 2024].

The use of para-aminobenzoic acid (PABA) as a biostimulant, along with ash, not only enhances yield but also significantly improves the potato's resilience to abiotic stresses caused by

climate change, making this research area important for agronomy and vegetable growers, especially potato producers [Tokman, 2007; Karmazina et al., 2013].

The main challenge is to find effective, environmentally safe, and economically viable treatment methods that ensure high-quality seed potatoes and promote healthy plant growth and development [Alyokhin, 2016a; Murashev et al., 2020; Radchenko et al., 2024]. Scientists and practitioners are exploring alternatives that reduce dependence on synthetic chemicals while increasing the efficiency of agronomic practices without harming the environment [Tkachuk, 2014; Butenko et al., 2025a].

In agronomy, recent experiments emphasize the importance of innovative crop treatment methods, especially in potato production, aiming to increase yields and minimize negative environmental impacts. Farmers have begun experimenting with biologically-derived products [Ilchuk et al., 2013; Bilinska et al., 2018; Datsko et al., 2025]. Much attention is being paid to the use of natural biostimulants that improve plant growth and help them adapt to stressful conditions in Ukraine [Vyshnevska et al., 2013; Alyokhin, 2016; Ilchuk et al., 2020]. PABA, an effective plant growth stimulator, shows promising results in pre-planting treatment of tubers and seeds, helping to enhance the genetic potential of potato varieties and improve plant stress resistance during the growing season [Bondarchuk, 2010; Polishchuk et al., 2015; Lazarchuk, 2016]. Ash, as a source of micronutrients, in combination with PABA, plays a key role in the early nutrition of potato tubers during the initial sprouting phase [Tokman, 2007]. The use of ash allows for partial or complete substitution of mineral fertilizers, thereby reducing potato production costs and the application rate per hectare, while supplying essential nutrients like potassium and phosphorus for healthy plant development and increased productivity [Podhayets'kyi, 2004; Vdovenko, 2022; Kovalenko et al., 2024].

Potato producers are also aiming to optimize soil treatment and introduce new techniques before planting potatoes in the field. For instance, deep loosening of the selected area helps reduce the time required for pre-planting preparation. PABA increases the effectiveness of active substances penetrating deep into the potato cells, enhancing the uptake of macro- and micronutrients from the soil [Balashova, 2013; Podhayets'kyi & Hnitetskyi, 2017]. Advancements in techniques that ensure even coating of tubers with biostimulants and ash allow for uniform pre-planting treatment with minimal labor input [Lazarchuk, 2016; Polishchuk, 2021; Vdovenko et al., 2023]. This approach not only enables an assessment of PABA and ash impacts on yield and quality but also helps define optimal conditions for scaling this technology in potato production, ensuring more sustainable and profitable cultivation for farmers [Melnyk et al., 2001].

Biostimulants not only improve stress resistance and potato quality but also contribute to reducing the use of mineral fertilizers and chemicals in agriculture, confirming the necessity of further development and adoption of environmentally friendly technologies in this field [Polishchuk et al., 2015; Alyokhin, 2016b; Butenko et al., 2025b].

MATERIAL AND METHODS

The goal of this research was to assess the effectiveness of applying para-aminobenzoic acid (PABA) and ash in potato cultivation, particularly their impact on the stress resistance and yield of the Myroslava and Zhytnytsia varieties.

Between 2021 and 2023, the experiments were conducted on the educational and research fields of the Scientific-Production Complex of Sumy National Agrarian University to evaluate the effects of PABA and black ash.

The soil used for the trials was a typical medium-humus chernozem, with a humus content of 4.1–4.5% (high); salt pH of 5.8–6.2 (near neutral); nitrogen content – 135 mg kg^{-1} (low); mobile K_2O and P_2O_5 – 77 mg kg^{-1} (medium) and 207 mg kg^{-1} (very high), respectively. Soil classification followed DSTU 4362:2004 "Soil quality – indicators of soil fertility".

Annual meteorological data were obtained from the Institute of Agriculture of the North-East NAAS of Ukraine (village Sad – located 6 km from the research site).

Analysis of the collected meteorological data showed that from the beginning and throughout the entire growing season, abiotic environmental factors like humidity and temperature varied significantly (Fig. 1).

High ambient temperatures and excessive precipitation in April, May, and June 2021 led to increases in the hydrothermal coefficient (HTC) by 0.76, 1.34, and 1.59, respectively. In contrast, July experienced drought-like conditions with

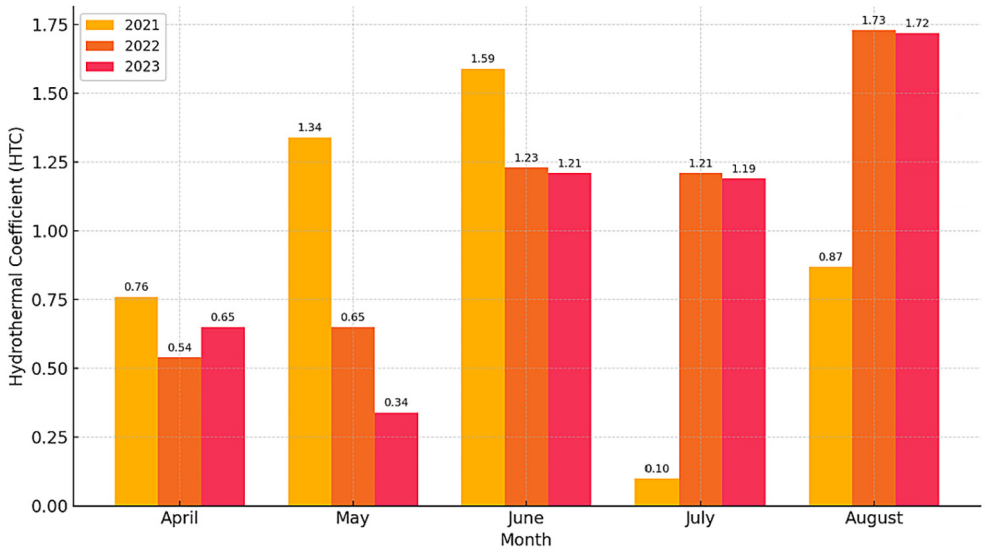

Figure 1. Values of the hydrothermal coefficient (HTC) for 2021–2023

HTC = 0.1. The extremely high temperatures and low precipitation in April 2021 classified that period as dry. July 2021 was the most unfavorable for plant growth and was characterized as very dry (HTC = 0.10).

According to the recorded data, the values of the hydrothermal coefficient in 2022 indicated that conditions for potato vegetation in June and August were excessively humid for normal plant development, with HTC values of 1.23 and 1.73, respectively. The weather conditions in April and May, based on HTC values, were characterized as severely dry, with an average index of 0.66.

Throughout the entire research period, the most unfavorable conditions for potato cultivation were recorded in all ten-day periods of July 2021, which can be classified as arid, with an HTC value of 0.10. In June, July, and August 2023, slightly dry conditions were observed, with HTC values of 1.22, 1.19, and 1.72, respectively.

A significant rise in temperature and excessive precipitation in August 2023 led to an increase in the hydrothermal coefficient to 1.72. In summary, the hydrothermal conditions during the experiment years were close to optimal for the growth, development, and formation of a sufficient number of tubers under each plant and for ensuring the high quality of potato plant structures.

The pre-planting treatment study of potato tubers using para-aminobenzoic acid (4-Aminobenzoic acid, or para-aminobenzoic acid (PABA, NH_2-C_6H_5-COOH), is a component of folic acid (vitamin B9) and takes an active part in the creation of coenzymes necessary for the synthesis of nucleic acids in the plant and other important substances for optimal plant development) and ash included several critical stages.

First, the tubers were sorted, and only healthy ones without signs of disease or damage were selected. Then, they were cut in half, ensuring an equal number of eyes on each half to increase the absorption area for the solution. For preparing the PABA solution, water with a temperature of 60–80°C was used, in which the specified amount of PABA powder was dissolved to achieve the required concentration. The cut tubers were then soaked in the solution for 11–13 hours to ensure deep penetration of PABA into the tuber tissues.

After soaking, the tubers were air-dried for 1.5–2.0 hours, then dusted with ash at a rate of 130–180 mg kg^{-1}, providing additional nutrient supply. The treated tubers were planted in soil according to standard agronomic practices, after which careful monitoring was carried out for tuber condition, vegetative mass, plant growth, development, and yield. The data collected from the experimental plots were compared with control groups (untreated with either PABA or ash) and analyzed using statistical methods to evaluate the effectiveness of PABA and ash application.

The field experiment was planned and conducted according to the methodological recommendations of Bondarchuk et al. [2019]. The biometric indicators and yield of potato varieties were recorded according to the Methodological Recommendations for Experiments with Potatoes of the Institute of Potato Growing of the NAAS [Kutsenko et al., 2002]. Starch was determined

by the Parov method, which measures the difference in density between tubers and water [Kononuchenko, 2002]. The dry matter content was investigated by the gravimetric method [Bondarchuk et al., 2021]. Microsoft Excel and Statistica 6.0 programs were used to process the obtained statistical data [Ermantraut et al., 2007].

RESULTS AND DISCUSSION

One of the pre-planting treatment methods involves the use of para-aminobenzoic acid (PABA) and ash, which are applied to improve the physiological condition of potatoes and their vegetative capacity. It is known that PABA activates cellular enzymes that play a key role in plant growth and development. Application of a 0.1% PABA solution before field planting increases the rate of biochemical reactions in tubers and improves plant stress resistance. The effect of growth biostimulants plays a crucial role in increasing the vegetative mass of plants.

On the 14th day after sprout emergence, the leaf area of potato plants showed no significant difference among all combinations, averaging 11.0–11.3 thousand m² ha^{-1} over the years of research. However, as the active growth phase began and environmental temperatures stabilized, differences emerged among the combinations where growth stimulants were used. On the 21st day of vegetation after sprout emergence, the Zhytnytsia variety showed a better leaf area than Myroslava. In the fourth combination, the highest increase in leaf area was recorded: 31.2 thousand m² ha^{-1} for both Myroslava and Zhytnytsia. The lowest leaf development was observed in the control group.

The next measurement, on the 28th day of vegetation, showed little difference in leaf area for the Myroslava variety compared to the control. For Zhytnytsia, the largest increase in leaf area – 49800 m² ha^{-1} – was again recorded in the fourth combination, using 0.1% PABA on halved tubers with ash dusting (130–180 kg ha^{-1}), which was 4.9 thousand m² ha^{-1} greater than the control. During the peak flowering period, leaf area formation slowed for both varieties, as the plants focused their energy on flower development. Analysis of the leaf photosynthetic apparatus during vegetation confirmed that biostimulants promote expansion of the leaf area.

Ash, on the other hand, serves as a natural source of essential microelements such as potassium, magnesium, and phosphorus, contributing to improved plant development. This method includes cutting the tubers in half to improve reagent absorption, drying, soaking in PABA solution, and dusting with ash. This integrated treatment not only improves the stress resistance and viability of tubers but also significantly increases the final yield.

On the 42nd day of observation, all experimental combinations, except the control, demonstrated increased leaf area. After flowering, the potato bushes began allocating more nutrients to berry maturation, which caused loss of turgor in

Table 1. Effect of applied growth regulators on biometric indicators of Myroslava and Zhytnytsia potato varieties (average for 2021–2023)

Variant		Leaf area, thousand m² ha^{-1}, days after emergence				
		14	21	28	35	42
Myroslava						
1	Treatment of whole tubers with 0.05% PABA (Background)	11.1	29.7	45.3	52.7	51.6
2	Treatment of halved tubers with 0.1% PABA	11.2	29.8	47.7	54.6	54.6
3	Halved tubers with 0.05% PABA + ash dusting (130–180 kg ha^{-1})	11.2	29.3	44.3	54.2	52.1
4	Halved tubers with 0.1% PABA + ash dusting (130–180 kg ha^{-1})	11.3	31.2	47.8	54.8	54.4
$LSD_{0.5}$		0.4	1.4	2.4	2.5	1.5
Zhytnytsia						
1	Treatment of whole tubers with 0.05% PABA (Background)	11.0	28.6	44.9	53.4	49.6
2	Treatment of halved tubers with 0.1% PABA	11.2	30.4	48.5	57.4	52.9
3	Halved tubers with 0.05% PABA + ash dusting (130–180 kg ha^{-1})	11.0	30.0	44.7	54.3	51.2
4	Halved tubers with 0.1% PABA + ash dusting (130–180 kg ha^{-1})	11.3	31.2	49.8	57.3	53.9
$LSD_{0.5}$		0.5	1.5	2.6	2.3	1.6

plants. The application of growth regulators and ash positively affected leaf area in the combinations using cut seed tubers (Table 1).

The results of the conducted studies on the use of growth stimulants through various application methods on potato tubers demonstrate an increase in yield compared to traditional planting methods without growth stimulants. For instance, in the experiment where tubers were treated with PABA and ash, a yield increase of 15–20% per hectare was recorded compared to the control, confirming the high effectiveness of the proposed combinations.

Analysis of Table 2 on potato yield shows a significant increase in tuber productivity for the Myroslava and Zhytnytsia varieties as a result of applying biostimulants and ash to seed potatoes, compared to conventional approaches without tuber treatment.

Treatment of whole tubers with PABA (background) resulted in relatively low average yields compared to other combinations. The highest yield for the Myroslava variety was recorded in the third combination – 31.3 t ha^{-1}, which is 7.1 t ha^{-1} higher than the control.

The Zhytnytsia variety showed better yield performance compared to Myroslava in the experiment, likely due to its genetic characteristics. In the combination where 0.1% PABA and ash dusting were applied, the highest yield for Zhytnytsia was achieved – 39.3 t ha^{-1}, which is 2.8 t ha^{-1} higher than the background combination. This indicates the effectiveness of deep penetration of PABA and ash into the internal tissues of potato tubers, which ensures better absorption of active substances at the start of development. The use of ash as a nutrient source effectively improves plant vitality and productivity, as well as resistance to biotic stressors.

The combined method of treating halved tubers with PABA and dusting them with ash at a rate of 130–180 kg ha^{-1} showed the best results among all combinations, achieving increased yield. This confirms the synergistic effect of combining chemical and natural stimulation of plant growth.

These findings highlight the importance of modern approaches in agronomic practices for vegetable cultivation. In potatoes treated with growth stimulants, the plant's potential improves, which significantly increases the productivity of the crop, ensures more efficient resource use, and enhances growing conditions.

This evidence points to the promising application of PABA and ash in agriculture, which could become a key factor in reducing costs and increasing productivity in potato cultivation. In the conducted experiment, no significant effect of the growth stimulants EPS and PABA was observed on the vegetative development of potatoes or on the tuber quality of the studied varieties (Table 3).

Over the course of the experiment, no significant accumulation of dry matter was observed compared to the control combination. However, the starch content of the studied potato varieties increased compared to the control. The highest starch content in the tubers was recorded in the second experimental variant, where a 0.1% PABA solution was applied to halved tubers in both potato varieties.

It is worth noting that the best results for the accumulation of dry matter and starch were achieved in the combination with 0.05% PABA applied to halved tubers that were also treated with ash at a rate of 130–180 kg ha^{-1}. It was observed that increasing the concentration of para-aminobenzoic acid to 0.1% led to a decrease in the accumulation of both dry matter and starch.

Based on the obtained research results, it can be concluded that the use of the PABA growth regulator and similar preparations is appropriate during the cultivation of Myroslava and Zhytnytsia potato varieties. Similar results were obtained in their studies by Ivanov et al., [1997], Bekusarova et al., [2013], Rosen et al., [2014], Murashev et al., [2020].

Table 2. Potato yield for different treatment variants with growth stimulants and potato varieties (average for 2021–2023)

Variant	Yield, t ha^{-1}	
	Myroslava	Zhytnytsia
Treatment of whole tubers with 0.05% PABA (Background)	24.2	36.5
Treatment of halved tubers with 0.1% PABA	28.8	36.6
Treatment of halved tubers with 0.05% PABA and ash dusting (130–180 kg ha^{-1})	30.7	38.7
Treatment of halved tubers with 0.1% PABA and ash dusting (130–180 kg ha^{-1})	31.3	39.3
$LSD_{0.5}$	2.31	2.24

Table 3. Effect of growth regulators on tuber quality of potatoes (average for 2021–2023)

No.	Combination	Starch content, %	Starch, t ha^{-1}	Dry matter content, %	Dry matter, t ha^{-1}
Myroslava					
1.	Treatment of whole tubers with 0.05% PABA (Background)	15.7	3.97	26.2	5.03
2.	Treatment of halved tubers with 0.1% PABA	17.1	3.29	23.9	4.38
3.	Treatment of halved tubers with 0.05% PABA and ash dusting (130–180 kg ha^{-1})	16.4	3.58	23.3	4.98
4.	Treatment of halved tubers with 0.1% PABA and ash dusting (130–180 kg ha^{-1})	15.1	3.02	22.2	4.31
Zhytnytsia					
1.	Treatment of whole tubers with 0.05% PABA (Background)	15.9	3.87	22.3	5.53
2.	Treatment of halved tubers with 0.1% PABA	16.7	3.19	23.1	4.33
3.	Treatment of halved tubers with 0.05% PABA and ash dusting (130–180 kg ha^{-1})	16.1	3.59	22.6	4.81
4.	Treatment of halved tubers with 0.1% PABA and ash dusting (130–180 kg ha^{-1})	15.5	2.97	22.3	4.19

CONCLUSIONS

The results of the study on pre-planting treatment of potatoes with para-aminobenzoic acid (PABA) and ash allow us to draw several important conclusions. The use of PABA improves tuber productivity and resistance to stressful conditions during the growing season. The combined application of PABA and ash demonstrated a strong synergistic effect, unlocking the genetic potential of Myroslava and Zhytnytsia varieties and improving potato yields compared to untreated controls.

Specifically, the treatment of halved potato tubers with PABA and subsequent dusting with ash resulted in the best yield indicators among all studied variants. The use of different PABA concentrations affects the sprouting time and final yield of potatoes. With each passing year, new biostimulants are being developed and improved, providing plants with everything necessary during the early vegetation phase across various climatic zones of Ukraine and Eastern European countries. This, in turn, enables farmers to maximize the genetic potential of potatoes and reduce production costs.

Ash, with its diverse chemical composition of macro- and micronutrients, has a positive effect on the initial development of potatoes and their subsequent growth. The use of PABA and black ash reduces production costs and the need for mineral fertilizers. Moreover, PABA application in professional potato cultivation positively influences the quantitative parameters of starch and dry matter content, improving the organoleptic qualities of the varieties.

REFERENCES

1. Alyokhin V.V. (2016a). The influence of levels and methods of mineral nutrition on the yield, growth and development of mid-ripening potato plants of the Legenda variety. *Young scientist*, *3*, 243–248.
2. Alyokhin V.V. (2016b). Potato yield and nutrient removal by vegetative mass and potato tubers depending on the levels and methods of mineral fertilizer application. *Potato growing, 43*, 72–81.
3. Balashova G.S., Chernychenko I.I., Chernychenko O.O. (2013). Potato varieties suitable for growing in spring planting in the south of Ukraine. *Irrigated agriculture. Kherson*, *59*, 170–171.
4. Bekusarova S.A., Bome N.A., Weisfeld L.I., Tzomatova F.T., Luschenko G.V. (2013). On the effect of PABA on germination. *Progress in organic and physical chemistry structurs and mechanisms*, 203–206.
5. Bilinska O., Golod R., Shubala G. (2018). The influence of a growth regulator on the formation of plant productivity in vitro in closed soil conditions. *Ternopil: Krok*, 9–11.
6. Bondarchuk A.A. (2010). Scientific foundations of potato seed production in Ukraine. *Bila Tserkva*, 264–286.
7. Bondarchuk A.A., Koltunov V.A., Oliynyk T.M. (2019). Potato growing: research methodology. *Vinnytsia: LLC "Tvory"*, 652.
8. Bondarchuk A.A., Koltunov V.A., Oliynyk T.M., Borodai V.V., Zakharchuk N.A., Vishnevska O.V., Furdyga M.M. (2021). Potato growing: Quality assessment methods. *Vinnytsia: Nilan LTD*, 455.
9. Butenko A., Datsko O., Shumkova O., Bahorka M., Musiienko V., Yurchenko N., Nechyporenko V., Zavhorodnia S., Mikulana M. (2025a). Sustainable buckwheat growing: Agrotechnical and

economic assessment of the mineral fertilizers' role. *Agriculture and Forestry*, *71*(1), 49–59. https://doi:10.17707/AgricultForest.71.1.04

10. Butenko A., Datsko O., Sobko M., Onychko V., Turchina S., Dashutina L., Tymchuk N., Volokhova O., Vechirka V., Shpetnyi V. (2025b). Evaluation of the Effectiveness of Leanum Biofertilizer in the Management of Organic Crop Rotation and Buckwheat Productivity. *Rocznik Ochrona Środowiska, 27*, 305–311. https://doi.org/10.54740/ros.2025.024
11. Datsko O., Butenko A., Hotvianska A., Pylypenko V., Nozdrina N., Masyk I., Bondarenko O., Lemishko S., Litvnov D., Toryanik V. (2025). Influence of agroecological methods on biometric indicators of corn. *Ecological Engineering & Environmental Technology*, *26*(2), 264–271. https://doi.org/10.12912/27197050/199324
12. Ermantraut E.R., Prysyazhnyuk O.I., Shevchenko L.I. (2007). Statistical analysis of agronomic research data in the STATISTICA 6.0 package. *Kyiv: PolygraphConsulting*, 55.
13. Hryhoriv Y., Butenko A., Solovei H., Filon V., Skydan M., Kravchenko N., Masyk I., Zakharchenko E., Tykhonova O., Polyvanyi A. (2024). Study of the Impact of Changes in the Acid-Base Buffering Capacity of Surface Sod-Podzolic Soils. *Journal of Ecological Engineering, 25*(6), 73–79. https://doi.org/10.12911/22998993/186928
14. Ilchuk R.V., Ilchuk Yu.R. (2013). The effect of foliar feeding with mono- and microfertilizers and a growth stimulant on potato yield. *Foothill and Mountain Agriculture and Livestock*, *55*(1), 51–59.
15. Ilchuk Yu.R., Ilchuk R.V., Rudnyk-Ivashchenko O.I. (2020). The reaction of early-ripening potato varieties to agrotechnical cultivation measures in the conditions of the Western Forest-Steppe. *Potato Growing*, *45*, 138−147.
16. Ivanov G.E., Pavlyuk G.V., Dorokhov V.I., Fedyshyn B.M. (1997). The influence of benzoic acid derivatives on the productivity and quality of potatoes. Potato growing, *27*, 102-106.
17. Karmazina L.E., Kupriyanova T.M., Vyshnevska O.A. (2013). The influence of a combined fertilizer system on the productivity and yield of tubers of the seed fraction of new potato varieties. *Potato Growing of Ukraine, 3–4*, 40–44.
18. Kolisnyk O., Yakovets L., Amons S., Butenko A., Onychko V., Tykhonova O., Hotvianska A., Kravchenko N., Vereshchahin I., Yatsenko V. (2024). Simulation of High–Product Soy Crops Based on the Application of Foliar Fertilization in the Conditions of the Right Bank of the Forest Steppe of Ukraine. *Ecological Engineering & Environmental Technology, 25*(7), 234–243. https://doi.org/10.12912/27197050/188638
19. Kononuchenko V.V. (2002). Methodological recommendations for conducting research with potatoes. *Nemishaevo: Institute of Potato Growing*, 183.
20. Kovalenko V., Kovalenko N., Gamayunova V., Butenko A., Kabanets V., Salatenko I., Kandyba N., Vandyk M. (2024). Ecological and Technological Evaluation of the Nutrition of Perennial Legumes and their Effectiveness for Animals. *Journal of Ecological Engineering, 25*(4), 294–304. https://doi.org/10.12911/22998993/185219
21. Kutsenko V.S., Osypchuk A.A., Podhayetsky A.A. (2002). Methodological recommendations for conducting research with potatoes. *Nemishaevo: Intas*, 182.
22. Lazarchuk L.A. (2016). The effectiveness of using growth regulators and micronutrients in combination with fungicides in potato plantations. *Potato growing, 43*, 198–207.
23. Lazarchuk L.A. (2016). The effectiveness of using growth regulators and microfertilizers in combination with fungicides in potato plantings. *Potato farming, 43*, 198–207.
24. Melnyk I.P., Broschak I.S., Koval V.M. (2001). Biostimulant for potatoes. *Plant Protection, 1,* 10.
25. Murashev S.V., Kiru S.D., Verzhuk V.G., Pavlov A.V. (2020). Potato plant growth acceleration and yield increase after treatment with an amino acid growth stimulant. *Agronomy Research 18*(2), 494–506. https://doi.org/10.15159/AR.20.036
26. Murashev S.V., Kiru S.D., Verzhuk V.G., Pavlov A.V. (2020). Potato plant growth acceleration and yield increase after treatment with an amino acid growth stimulant. *Agronomy Research, 18*(2), 494–506. https://doi.org/10.15159/AR.20.036
27. Podhayets'kyi A.A. (2004). Characteristics of potato genetic resources and their practical use. *Plant genetic resources. 1,* 103–110.
28. Podhayets'kyi A.A. (2011). Evaluation of nematode-resistant potato starting material created using relatives of cultivated varieties. *Bulletin of Sumy State Agricultural University. Series "Agronomy and Biology*", 14, 204–211.
29. Podhayets'kyi A.A., Hnitetskyi M.O. (2017). The influence of backcrossing components of interspecific potato hybrids on the germination of botanical seeds. *Honchariv Readings*, 111–112.
30. Polishchuk I.S., Polishchuk M.I., Mazur V.A., Palahniuk O.V. (2015). The effectiveness of using biologically effective preparations and fertilizers when growing potatoes in the conditions of the Right-bank Forest-Steppe of Ukraine. *Agriculture and Forestry, 2,* 18–26.
31. Polishchuk M.I. (2021). The influence of tuber planting rates and fertilization systems on the productivity of the early-ripening potato variety Serpanok in the conditions of the Right-Bank Forestry. *Agriculture and Forestry, 4*(23), 203–215.

32. Polishchuk M.I., Ermakova L.M., Palamarchuk V.D., Kalenska S.M., Polishchuk I.S. (2015). Systems of modern intensive technologies in crop production. *Textbook*, 400.
33. Radchenko M., Trotsenko V., Butenko A., Hotvianska A., Gulenko O., Nozdrina N., Karpenko O., Rozhko V. (2024). Influence of seeding rate on the productivity and quality of soft spring wheat grain. *Agriculture and Forestry, 70*(1), 91–103 https://doi.org/10.17707/AgricultForest. 70.1.06
34. Rosen C.J., Kelling K.A., Stark J.C., Porter G.A. (2014). Optimizing phosphorus fertilizer management in potato production. *American Journal of Potato Research, 91*, 145–160.
35. Tkachuk O.O. (2014) Environmental safety and prospects for the use of plant growth regulators. *Bulletin of Vinnytsia Polytechnic Institute, 3*, 41–44.
36. Tokman V.S. (2007). Growth regulators in potatoes. *Quarantine and plant protection, 7*, 16–18.
37. Vdovenko S.A. (2022). Study of growth and development processes of seed potato plants depending on fertilizer, growth regulator and foliar top dressing. *Agriculture and forestry, 4*(27), 64–73. https://doi.org/10.37128/2707-5826
38. Vdovenko S.A., Poltoretsky S.P., Polishchuk M.I., Vergeles P.M. (2023). Optimization of the seed potato nutrition system when grown in the Right Bank Forest-Steppe. *Agriculture and Forestry*, *1*(28), 62–73. https://doi.org/10.37128/2707-5826-2023-1-5
39. Vdovenko S.A., Poltoretsky S.P., Polishchuk M.I., Vergeles P.M. (2022). Study of the growth and development processes of seed potato plants depending on fertilizer, growth regulator and foliar feeding. *Agriculture and forestry, 4*(27), 64–73. https://doi.org/10.37128/2707-5826-2022-4-6
40. Vyshnevska O.V., Stolyarchuk L.V., Kostyanets M I., Lyashchenko S.A. (2013). Adaptive ability of domestic selection varieties in the conditions of the southern part of the Polissya zone of Ukraine. *Potato Growing of Ukraine, 1–2*, 32–37.