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Assessment of the impact of growth biostimulants on the effects of stimulating branching in maiden apple tree

Ocena wpływu biostymulatorów wzrostu na efekty stymulacji rozgałęzienia u okulantów jabłoni

Abstract. Modern methods of cultivating trees in a nursery plants require nursery stock of very good quality, free from viruses, with an extensive root system, strong growth and, most importantly, with the correct structure of the tree crown, i.e. the number of lateral shoots. High-quality planting material, properly branched, determines the productive efficiency of the trees in a nursery in subsequent years of cultivation and its profitability. The research was conducted in 2017–2019 at a private nursery farm near Lublin. The purpose of the research was to analyze the effect of mixtures of biostimulants with growth regulators of natural origin on the effectiveness of chemical treatment to stimulate the emergence of lateral shoots in apple trees of the Gloster. The study showed that the height of maiden apple trees of the Gloster. significantly depended on the concentration of growth regulators. The best results were achieved using a mixture of AGRIMIX PRO (35 ml) and Maxifruit, producing trees 6% taller than the control. The number of side shoots, the average length of one shoot and the sum of the lengths of side shoots significantly depended on the number of growth regulator applications. Double application of AGRIMIX PRO resulted in an increase in the number of side shoots by 37.5% compared to single application, while in the case of a mixture of growth regulators with a biostimulant this effect was less pronounced and amounted to 17.0%.The biostimulation treatment with Maxifruit does not guarantee improved tree growth and quality, but its use in combination with the growth regulator AGRIMIX PRO improves the effectiveness of treatments that stimulate apple branching.

Keywords: biostimulants for growth, branching stimulation, nursery, apple tree

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INTRODUCTION

The efficiency and profitability of a nursery farm depends on the quality of the plants produced there. On the other hand, the use of high-quality nursery stock in horticultural cultivation determines the productive efficiency of the trees in subsequent years of cultivation [Gudarowska 2002, Rejman et al. 2002, Basak 2009, Czynczyk 2012, Kumawat et al. 2023, 2025], and thus its profitability [Skrzyński and Poniedziałek 2000, Bielicki and Pąśko 2013, Kapłan et al. 2017].

Modern methods of cultivating trees in a nursery plants require planting material of very good quality, free of viruses, with an extensive root system [Zhalnerchyk et al. 2015], with strong growth and the right structure of the tree crown, i.e. the number of lateral shoots [Skrzyński and Poniedziałek 2000, Bielicki and Pąśko 2013, Kapłan et al. 2017]. Producing plants with such characteristics is a complex process, often taking several years, e.g., trees on a 3-year cycle (the so-called knip-boom) or on a 2-year cycle [Gudarowska 2002, Basak 2009, Czynczyk 2012].

The quality of the nursery stock produced is influenced by a number of factors, starting with the growth strength of the rootstock used [Gudarowska 2002, Kviklys 2004, 2006, Kapłan and Baryła 2006, Nečas et al. 2018, 2020], the predisposition of the cultivar to form lateral shoots [Kapłan and Baryła 2006] and ending with external factors, i.e. the type and effectiveness of treatments to stimulate branching, soil and climatic conditions related to the location of the nursery and weather conditions during the initiation and growth of lateralshoots [Gudarowska and Szewczuk 2002, Jacyna 2002, Matysiak and Adamczewski 2009, Kapłan et al. 2017, Laňar et al. 2020].

Many popular apple tree cultivars at the nursery stage have a problem with the formation of a crown consisting of 5–8 lateral shoots. The reason for this is the apical dominance of the main shoot. In an attempt to prevent this phenomenon, nurserymen use mechanical treatments to stimulate branching of young trees, such as pinching the apical shoot, twisting the apex of growth by 180°, removing lateral shoots from the lower parts of the tree and rootstock [Rejman et al. 2002, Kapłan 2016] and chemical treatments [Kopytowski and Markuszewski 2009, Elfving 2010, Dorić et al. 2015, Lordan et al. 2017, Nečas et al. 2018].

Horticultural production is constantly looking for innovative solutions that have a beneficial effect on plant productivity, and the introduced EU restrictions require them to be environmentally friendly at the same time [Pacholczak et al. 2012, Kozak et al. 2016, Buraczyk et al. 2020, Laňar et al. 2020]. Therefore, in nursery cultivation one can notice an increase in interest in biopreparations, which can be such a group combining both features, i.e. stimulate the growth and development of plants (e.g. growth of the root system and aboveground parts), and, in addition, contain substances that have little impact on the environment [Hetman and Adamiak 2003, Kapłan et al. 2021]. Biostimulants meet these challenges.

According to the EU definition for Member States, a plant biostimulant means a material containing substance(s) or microorganisms, intended for application to the plant, seed or root zone to stimulate natural processes that increase nutrient use efficiency, abiotic stress tolerance and/or yield quality, the effect of which does not depend on nutrient content [Traon et al. 2014]. These are natural or synthetic compounds, which include free amino acids, humic substances, extracts from marine algae, the polysaccharide chitosan,

equivalents of natural phytohormones, phosphites, effective microorganisms and vitamins [Gawrońska and Przybysz 2011]. Biostimulants are safe and all-purpose preparations that support various physiological processes of plants and positively affect their overall condition, and the demonstration of their positive effect on plants depends largely on the preparation used and the plant species [Matyjaszczyk 2015].

The aim of the study was to analyze the influence of mixtures of growth biostimulants: AGRIMIX PRO and Maxifruit SL on the effectiveness of chemical growth stimulation on the growth and quality of maiden apple trees of the Gloster, budded on the M9 rootstock in the Lublin region in eastern Poland.

MATERIAL AND METHODS

Description of the experimental design

The study was conducted in 2017–2019 years at a private nursery farm located in the Lublin district, 5 km from Lublin (GPS: 51.285260, 22.616847). The experimental material was an apple Gloster budded on M.9 RN 29 rootstocks. The experiment evaluated the growth and quality of apple cv. apple trees after the application of treatments to stimulate branching. The experiment was set up in a randomized block design and included 11 combinations in 5 repetitions (one repetition was a plot with 10 plants). In each of the tested combinations, 50 plants were observed and measured.

The following combinations were used in the experiment:

Control – trees not sprayed, not treated to stimulate branching,
2. AGRIMIX PRO 25 ml per 1 liter of water – 1 application,
3. AGRIMIX PRO 35 ml per 1 liter of water – 1 application,
4. AGRIMIX PRO 25 ml + Maxifruit SL 0.2% per 1 liter of water – 1 application,
5. AGRIMIX PRO 35 ml + Maxifruit SL 0.2% per 1 liter of water – 1 application,
6. AGRIMIX PRO 25 ml per 1 liter of water – 2 applications,
7. AGRIMIX PRO 35 ml per 1 liter of water – 2 applications,
8. AGRIMIX PRO 25 ml + Maxifruit SL 0.2% per 1 liter of water – 2 applications,
9. AGRIMIX PRO 35 ml + Maxifruit SL 0.2% per 1 liter of water – 2 applications,
10. Maxifruit SL 0.2% per 1 liter of water – 1 application,
11. Maxifruit SL 0.2% per 1 liter of water – 2 applications.

Principles and application methods of growth regulators and biostimulation

Each year, the experiment was established in June, when the maiden apple trees reached a height of approximately 75 cm. The six youngest, well-developed lateral buds and leaves just below the cone were sprayed with a water solution. Applications were performed once or twice during the growing season – the first application after the maiden apple trees reached an average height of approximately 75 cm, while the second application, in the case of the double-application combination, was performed 10 days after the first spray. Chemical treatments for branching stimulation consisted of application in the form of an aqueous solution of AGRIMIX PRO (manufacturer Agrimix s.r.l.) at a dose of 25 and 35 ml per liter of water. AGRIMIX PRO [GA_{4+7} gibberellins – 19.1 g/l (1.8%) and

6-benzyladenine – 19.1 g/l (1.8%)] is the Italian equivalent of the Promalin 3.6 SL formulation. Depending on the combination, the AGRIMIX PRO preparation was applied as a single-component solution or a mixture, i.e. the growth biostimulant Maxifruit (manufacturer Timac Agro) was added to the prepared solution. Maxifruit (NMX® Complex, N 3%, P 7%, K 7%, Mn 0.05%, Zn 0.1%), contains extracts from plants living in extreme conditions (marine, desert and tropical), phytohormone precursors and transmitters for their expression and nutrients that support the action of substances that stimulate the production of natural phytohormones in the plant. The adjuvant Superam 10 AL was added to the prepared solution each time. During the experiment, regular protection against diseases, pests and weeds was carried out, and all treatments were carried out in accordance with the current nursery stock protection program. Adjuvant was used only in combinations where growth regulators were used.

Measurements and observations

In autumn, after October 10 and the end of apple tree growth, the height, number of side shoots and length of all lateral shoots were measured. The height of the trees from the ground to the apical bud of the main shoot was measured with a scaler with an accuracy of 1.0 cm. On each maiden apple trees, lateral shoots were counted and their length was measured. Based on the measurements, the following were calculated: the sum of the length of the lateral shoots and the average length of the lateral shoot.

Statistical analysis

The results obtained in the experiment were statistically analyzed using the one-way analysis of variance method. Additionally, the results were presented graphically using a dendrogram. Correlations between parameters determining the growth and quality of maiden apple trees and weather conditions were estimated by calculating Pearson correlation coefficients. Inference was based on significance $p < 0.05$. All statistical analyses were performed in SAS Enterprise Guide 5.1 software.

RESULTS

The average air temperature for the 2017–2019 growing season was higher than the multi-year average (in 2017 by 1.5°C, while in 2018 and 2019 by 2.5°C). The above dependence were also observed in the individual months of the growing season. The warmest month in all the analyzed years was August, while the coolest month was April (tab. 1).

Table 1 shows the total precipitation for the 2017–2019 period, which varied significantly by growing season. In the first year it was 292.00 mm higher than the multi-year average, in 2018 it was 61.00 mm, while in 2019 it was equal to the multi-year average. The highest precipitation was recorded in 2017 in June (282.00 mm), 2018 in July (124.00 mm), and in 2019 in August (102.00 mm).

Table 1. Average monthly air temperatures and total precipitation according to the Agrometeorological Station in Lublin during the months of April to October in 2017–2019

Air temperature (°C)								
Year	IV	V	VI	VII	VIII	IX	X	average
2017	8.0	14.1	19.6	18.9	20.2	13.5	8.5	14.7
2018	7.5	16.7	18.8	20.6	20.8	15.5	10.0	15.7
2019	9.5	13.4	21.5	19.4	20.3	14.5	11.0	15.7
Multi-year average	7.4	13.0	16.3	18.0	17.2	12.6	7.6	13.2
Total precipitation (mm)								
Year	IV	V	VI	VII	VIII	IX	X	sum
2017	55.0	29.1	282.0	107.9	48.0	80.0	90.0	692.0
2018	40.0	56.0	65.0	124.0	72.0	68.0	36.0	461.0
2019	49.0	93.0	37.0	38.0	102.0	52.0	29.0	400.0
Multi-year average	39.0	60.7	65.9	82.0	70.7	53.7	40.1	400.0

The height of maiden apple trees ranged from 153.92 to 166.07 cm (tab. 2). It was shown that the trait under study was significantly influenced by branching and biostimulation treatments. In the case of maiden apple trees treated with growth regulators, no significant effect of the number of applications on the studied trait was shown. A significant effect of the number of treatments was shown only in the case of biostimulant application. It was found that significantly the highest maiden apple trees were after the application of Maxifruit, while significantly the lowest were after AGRAMIX PRO. Within the maiden apple trees treated with growth regulators, a significantly favorable effect of biostimulation on the final height of the studied apple trees was shown (tab. 2).

The number of lateral shoots of maiden apple trees of the Gloster ranged from 0.84 to 4.36 units (tab. 2). A significant effect of branching and biostimulation treatments and the number of applications on the studied trait was shown. In the case of maiden apple trees treated with branching, it was found that two applications of growth regulators significantly increased the number of shoots compared to a single application. In maiden apple trees treated with a biostimulant preparation, the relationships were significantly opposite. A significantly beneficial effect of growth regulators on the studied trait was demonstrated. The trees in the above-mentioned combinations formed significantly more lateral shoots than the control and biostimulation-treated trees. Within the combinations where AGRAMIX PRO was applied, it was shown that the addition of the biostimulant to the solution significantly positively increased its effect. The maiden apple trees treated with the biostimulant preparation formed significantly fewer lateral shoots than the control (tab. 2).

Analyzing the average length of one shoot showed that this trait depended significantly on the number of applications and branching and biostimulation treatments (tab. 2). Regardless of the combination, trees treated twice with growth regulators and biostimulant had significantly longer shoots than those treated once. AGRIMIX PRO had a significantly beneficial effect on lateral shoot length compared to trees treated with biostimulants and controls. Within the combinations where chemical branching treatment with AGRAMIX PRO was applied, a significantly unfavorable effect of biostimulation on the tested parameter was shown. Control trees formed significantly shorter shoots than after application of Maxifruit (tab. 2).

Table 2. Influence of the number of applications on the growth and quality of maiden apple trees Gloster

Parameter	Number of applications	Control	Maxifruit	AGRIMIX PRO	AGRIMIX PRO + Maxifruit	p-value
Height of maiden apple trees in autumn (cm)	1	156.36 ±14.22 ^{Ac}	165.18 ±15.02 ^{Ba}	153.92 ±14.00 ^{Ad}	161.12 ±14.65 ^{Ab}	0.0001
	2		166.07 ±15.10 ^{Aa}	156.00 ±14.18 ^{Ac}	162.66 ±14.79 ^{Ab}	0.0001
	p-value	0.9874	0.0001	0.1045	0.6252	–
Number of lateral shoots (pcs)	1	1.28 ±0.12 ^{Ac}	1.04 ±0.09 ^{Ad}	2.88 ±0.26 ^{Bb}	3.72 ±0.34 ^{Ba}	0.0001
	2		0.84 ±0.08 ^{Bd}	3.96 ±0.36 ^{Ab}	4.36 ±0.40 ^{Aa}	0.0001
	p-value	0.9621	0.0001	0.0001	0.0027	–
Average length of one shoot (cm)	1	2.56 ±0.23 ^{Ad}	15.62 ±1.42 ^{Bc}	25.10 ±2.28 ^{Ba}	22.07 ±2.01^{Bb}	0.0001
	2		17.24 ±1.57 ^{Ac}	28.49 ±2.59 ^{Aa}	27.24 ±2.48 ^{Ab}	0.0001
	p-value	0.9854	0.0001	0.0473	0.0001	–
Total length of lateral shoots (cm)	1	3.28 ±0.30 ^{Ad}	16.24 ±1.48 ^{Ac}	72.62 ±6.60 ^{Bb}	82.30 ±7.48 ^{Ba}	0.0001
	2		14.48 ±1.32 ^{Bc}	112.28 ±10.21 ^{Ab}	118.50 ±10.77 ^{Aa}	0.0001
	p-value	0.9631	0.0001	0.0001	0.0001	–

Different letters A, B, C in the same column and a, b, c in the same line indicate statistically significant differences ($p < 0.05$)

The sum of lateral shoot lengths ranged from 3.28 to 118.50 cm and significantly depended on the number of applications and branching and biostimulation treatments (tab. 2). Trees treated twice with AGRAMIX PRO were characterized by a significantly higher sum of lateral shoot lengths than after a single application. The opposite relationship was found for trees treated with Maxifruit. Trees treated with branching had a significantly higher sum of lateral shoots than the others. Within the maiden apple trees treated with growth regulators, it was found that the addition of the biostimulant treatment significantly positively affected the level of the evaluated parameter. Maxifruit-treated maiden apple trees had significantly higher sum of lateral shoot lengths than controls (tab. 2).

Table 3 shows the effect of the concentration of growth regulators in the form of the AGRAMIX PRO preparation and a mixture of AGRAMIX PRO and Maxifruit preparations on the height and quality parameters of maiden apple trees of the 'Gloster', regardless of the examined year and the number of applications. The height of apple tree maiden in autumn in combinations with AGRAMIX PRO preparations treated with a lower concentration, i.e. 25 ml, was significantly lower than the others. In the case of a mixture of AGRAMIX PRO and Maxifruit preparations, it was shown that the maiden apple trees treated with a higher concentration of growth regulators, i.e. 35 ml, were significantly the highest. Analyzing the structure of the crown, which consists of such parameters as the number and average length of lateral shoots and the sum of the length of syleptic shoots, showed an unambiguous significantly beneficial effect of growth regulators. There was no significant effect of the dose of AGRAMIX PRO preparation on the evaluated quality parameters of apple trees, this tendency persisted in the case of the combination with AGRAMIX PRO preparation and the mixture of AGRAMIX PRO and Maxifruit preparations (tab. 3).

Table 3. Effect of the concentration of AGRIMIX PRO preparation on the growth and quality of maiden apple trees of the Gloster

Preparation	Dose	Height of maiden apple trees (cm)	Number of lateral shoots (pcs)	Average length of one shoot (cm)	Total length of lateral shoots (cm)
AGRIMIX PRO	control	156.36 ±14.22 ^{A}	1.28 ±0.12 ^{B}	2.56 ±0.23 ^{B}	3.28 ±0.30 ^{B}
	25 ml	153.74 ±2.65 ^{B}	3.60 ±0.61 ^{A}	26.49 ±0.72 ^{A}	94.98 ±13.65 ^{A}
	35 ml	156.18 ± 0.37 ^{A}	3.24 ±0.57 ^{A}	27.11 ±4.43 ^{A}	89.92 ±29.80 ^{A}
	p-value	0.0173	0.0001	0.0001	0.0001
AGRIMIX PRO + Maxifruit	control	156.36 ±14.22 ^{B}	1.28 ±0.12 ^{B}	2.56 ±0.23 ^{B}	3.28 ±0.30 ^{B}
	25 ml	158.16 ±4.21 ^{B}	3.84 ±0.53 ^{A}	24.71 ±3.49 ^{A}	96.16 ±26.12 ^{A}
	35 ml	165.62 ±2.52 ^{A}	4.24 ±0.18 ^{A}	24.61 ±2.17 ^{A}	104.64 ±13.54 ^{A}
	p-value	0.0001	0.0001	0.0001	0.0001

* Different letters A, B, C in the same column and a, b, c in the same line indicate statistically significant differences ($p < 0.05$)

Table 4 shows the impact of biostimulation in the form of Maxifruit on the effectiveness of AGRIMIX PRO regardless of the number of applications and year of study. In the case of a lower dose of AGRIMIX PRO, no significant effect of biostimulation on the growth and quality of apple tree maiden was shown. A similar tendency occurred in the

combination where a higher dose of AGRIMIX PRO was applied, when the average length of one shoot and the sum of the length of lateral shoots were evaluated. A significantly beneficial effect of the higher dose of AGRIMIX PRO + Maxifruit was found for the height of maiden apple trees in autumn and the number of lateral shoots (tab. 4).

Table 4. Effect of biostimulation on the effectiveness of growth regulators regardless of the number of applications and year of study

Dose	Preparation	Height of maiden apple trees (cm)	Number of lateral shoots (pcs)	Average length of one shoot (cm)	Total length of lateral shoots (cm)
25 ml	AGRIMIX PRO	153.74 ±2.65 A	3.60 ±0.61 A	26.49 ±0.72 A	94.98 ±13.65 A
	AGRIMIX PRO + Maxifruit	158.16 ±4.21 A	3.84 ±0.53 A	24.71 ±3.49 A	96.16 ±26.12 A
	p-value	0.0545	0.4835	0.2509	0.9238
35 ml	AGRIMIX PRO	156.18 ±0.37 B	3.24 ±0.57 B	27.11 ±4.43 A	89.92 ±29.80 A
	AGRIMIX PRO + Maxifruit	165.62 ±2.52 A	4.24 ±0.18 A	24.61 ±2.17 A	104.64 ±13.54 A
	p-value	0.0001	0.0021	0.2431	0.2964

* Different letters A, B, C in the same column and a, b, c in the same line indicate statistically significant differences ($p < 0.05$)

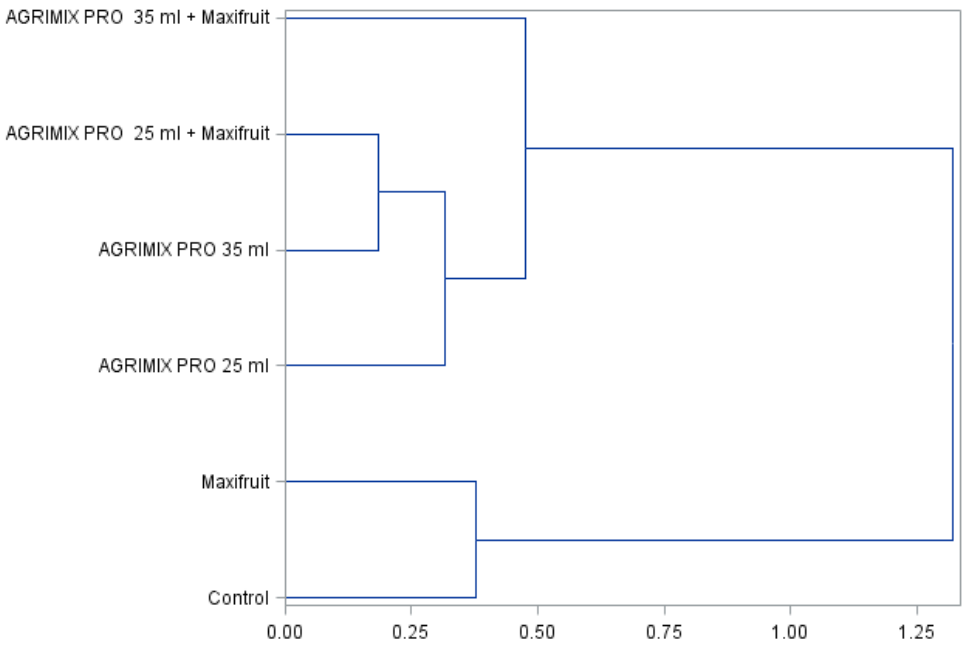

Fig. 1. Cluster analysis of parameters determining the branching quality of maiden apple trees of the Gloster

Figure 1 shows a cluster analysis of the crown structure of the Gloster of apple trees regardless of the year of study and number of applications. The dendogram below shows two distinct clusters. The first cluster refers to combinations in which growth regulators and mixtures of growth regulators and biostimulation were applied. Within the large cluster, we can distinguish a subgroup that includes combinations showing very high similarity, i.e. AGROMIX PRO 25 ml + Maxifruit and AGROMIX PRO 35 ml. The next similarity was observed with AGRO-MIX PRO 25 ml and AGROMIX PRO 35 ml + Maxifruit. Controla and the Maxifruit combination formed a separate cluster.

It was observed that the number and total length of lateral shoots correlated with average air temperature, while the height of maiden apple trees and average length of one shoot did not show this relationship. The analyzed traits showed no correlation with the sum of precipitation and the year of the study (tab. 5).

Table 5. Correlation of growth and quality of maiden apple trees with weather conditions during the plant growth period (April–October) and the year of study

Specification	Average air temperature (°C)	Rainfall totals (mm)	Year of study
Height of maiden apple trees in autumn (cm)	–0.1248	–0.3551	–0.2987
Number of lateral shoots (pcs)	0.5189*	0.1157	0.2684
Average length of one shoot (cm)	0.3703	0.1381	0.3111
Total length of lateral shoots (cm)	0.4875*	0.1447	0.2631

DISCUSSION

Biostimulants contain biologically active substances that positively affect plant growth and development. They improve the tolerance of plants to unfavorable environmental conditions, and some can affect the development of the root system [Hetman i Adamiak 2002, Jankowski and Dubis 2008, Kapłan et al. 2021, Kapłan et al. 2023]. Extracts from marine algae are used in horticultural practice as agents that increase the size and quality of crops [Matysiak and Adamczewski 2009, Pacholczak et al. 2012]. In the work of Klimek et al. [2018] demonstrated the is-total effect of a growth regulator and its dosage as well as biostimulation on the height of Szampion Reno maiden apple trees. These studies demonstrated that the use of AGRIMIX PRO at the highest dose, 35 ml, resulted in a significant reduction in the height of the trees under evaluation. This could be attributed to the extensive branching of the plants and their well-developed side shoots. Biostimulant applications in the form of Asahi SL in the study by Klimek et al. [2018] had a significantly beneficial effect on the evaluated parameter, which was also confirmed in the present study. Kaplan and Baryła [2006] showed no significant effect of the preparation dose on the height of the maiden apple trees of two-year-old apple trees. The growth of maiden apple trees was significantly independent of average air temperature and precipitation sum, these relationships did not confirm the previous results of Klimek et al. 2018 and Kaplan and Baryła [2006]. Gąstoł et al. [1999, 2012] using preparations based on bezyladein (BA) and gibberellins (GA_3 and GA_{4+7}) showed no significant effect on the height of maiden apple trees of Boskoop and Mutsu cultivars. In a study by Hetman and

Adamiak [2003], the application of Asahi SL in the form of plant sprays produced beneficial effects in the cultivation of multiflora rose rootstock. The application of Asahi SL concentrations from 0.1% to 0.6% had a stymulative effect on the diameter and length of the root neck, as well as the weight of the aboveground part and the root system. The result was a good quality of multifloral rose rootstocks, which grew to periculations already in the first half of August despite the not favorable weather conditions immediately after the establishment of the experiment. Similar observations were demonstrated in a newly established apple orchard, where the application of biostimulants had a beneficial effect on the growth and development of apple trees of the Gala Must cultivar [Kapłan et al. 2021]. This study demonstrated that the number of lateral shoots is influenced by the dose and number of AGRIMIX PRO applications and the biostimulation treatment. Maiden apple trees treated with growth regulators and biostimulation produced significantly more lateral shoots than control trees. These relationships have been confirmed in numerous papers [Gąstoł et al. 1999, Klimek et al. 2018, Kapłan 2006]. An inconclusive effect on the degree of branching of two-year-old apple trees was shown by Kaplan and Baryła [2006]. In the above study, more lateral shoots were obtained in combinations treated with growth regulators than in the control, but the effect was not always significant. The number of lateral shoots was observed to significantly increase after the application of the Maxifruit biostimulant. This phenomenon likely stems from the fact that the effectiveness of exogenous growth regulators depends on numerous environmental factors, and the use of the biostimulant supported and enhanced the branching effect. Hetman and Adamiak [2003], evaluating the effect of Asahi SL on the quality of large-flowered roses, showed that the least effective effect of the biostimulant was observed at the number of first-order shoots compared to plants growing in control plots. The average length per shoot depended significantly on the number of applications and branching and biostimulation treatments. Klimek et al. [2018] showed that the maiden apple trees of the cultivar Szampion Reno treated with the lowest dose of AGRIMIX PRO produced istotally longer shoots than after application at a dose of 35 ml and in the control trial. The aforementioned study showed a significantly beneficial effect of the Asahi SL preparation on the studied parameter. The sum of lateral shoot lengths significantly depended on the number of applications and branching and biostimulation treatments.

Klimek et al. [2018] showed that maiden apple trees treated with growth regulators formed a higher sum of all shoot lengths compared to the control. They found that as the concentration of AGRIMIX PRO increased, the sum of syleptic shoot lengths increased significantly.Similar results were obtained by Gąstoł et al. [1999]. In the study of Poniedziałek and Porębski [1992], a significant effect on the sum of lateral shoot lengths was exerted by spraying with a mixture of BA + GA_3 (Arbolin 036 SL), while the preparation Paturyl 100 SL (BA) had only a slight effect on increasing the sum of increments, since the resulting shoots are too short. In an earlier study by these authors Poniedzialek and Porębski [1992], the formulations Promalin 3.6 SL and Arbolin 036 SL affected the average sum of shoot length, but no significant differences were found between the formulations used.

CONCLUSIONS

1. The height of maiden apple trees of the Gloster significantly depended on the concentration of applied growth regulators. Trees treated with a higher concentration (35 ml) were significantly higher than those treated with a lower dose (25 ml). A significantly beneficial effect of the Maxifruit biostimulator on the height of the examined maiden apple trees was demonstrated with the use of a higher dose of AGRIMIX PRO.

2. The number of side shoots, average length of a single shoot, and the sum of side shoot lengths were significantly dependent on the number of growth regulator applications. A double application of AGRIMIX PRO had a beneficial effect on crown structure parameters of maiden trees of the Gloster cultivar compared to a single application.

3. The crown structure of maiden apple trees of the Gloster cultivar, determined by the number and length of lateral shoots and their sum, is significantly correlated with the average air temperature during the growing season, which indicates a significant influence of thermal conditions on the effectiveness of tree branching and should be taken into account when planning treatments stimulating the development of trees in the nursery.

4. Using the Maxifruit biostimulator alone does not significantly improve the growth or quality of young apple trees of the Gloster. However, its use in combination with growth regulators such as AGRIMIX PRO significantly increases the number of lateral shoots, promotes branching development, and improves crown structure parameters, indicating the significant value of this combination in nursery practice.

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