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Assessment of the Possibilities of Using Cross-Linked Polyacrylamide (Agro Hydrogel) and Preparations with Biostimulation in Building the Quality Potential of Newly Planted Apple Trees

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Abstract: The research was carried out in a commercial apple orchard in southeastern Poland. The aim of the research was to evaluate the effect of fertilizer with biostimulation and humic acids with algae extracts and agrogel on the reception and growth of newly planted maiden apple trees of the 'Gala Must' variety. One-year-old budwoods were planted annually on the site where fruit trees had grown for 20 years. For the purpose of the experiment, old trees were grubbed up every year in autumn. The experiment assessed the growth and quality of apple trees in the fall of the first year after planting them permanently using a biostimulator in the form of fertilizer and agrogel. On the basis of 3-year studies, it was shown that the application of the assessed preparations had a positive effect on the quality parameters of the trees. The experiment showed the positive effect of the preparation with biostimulation on the best growth and quality parameters every year, which was confirmed by the multidimensional cluster analysis. The fact that the use of agrogel significantly modified the height of the evaluated apple trees in the second year of the study, when lower amounts of rainfall were recorded, is particularly noteworthy.

Keywords: seaweeds extract; maiden trees; humic acids; superabsorbents

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1. Introduction

Currently, to set up new apple orchards, strong and branched maiden trees, or 2-year-old young trees produced in 2- or 3-year cycles from winter grafting with 1-year lace, are recommended [1]. This type of nursery material makes it possible to obtain the first crop and the reimbursement of plantation costs in a short time. However, it requires creating optimal growth conditions for growing plants. Young trees with an extensive and heavily formed crown need very well-prepared stands with adequate water capacity to be able to take root well and meet the expectations of growers. According to Treder et al. (2009), providing orchard cultivations with optimal soil moisture is particularly important in growing plants with a shallow and not very extensive root system on dwarf and semi-dwarf rootstock [2].

In our climate, even with the first-rate agrotechnics, plants' growth, together with the quantity and quality of crops, are determined by the availability of water for plants [3]. An effective and common way to provide newly planted young fruit trees with adequate water is irrigation, which is not always possible due to the lack of water availability. It is estimated that 45% of the world's agricultural area is subject to constant or frequent drought problems [4]. Water contained in the soil is effectively used by plants only in a small part. In soils, especially sandy soils, a significant part of water is lost through infiltration into deeper layers or through evaporation [5]. Occurring and forecast climate changes lead to long-term trends toward higher temperatures, evapotranspiration and a higher and increased frequency of drought [6]. This means that there is a greater risk of usable water shortage for plants and an increasing demand for plant irrigation [7]. The decreasing water resources not only increase the costs of irrigation but also force the search for other alternative methods to provide optimal soil moisture. To counteract humidity fluctuations or periodic water shortages in soil, solutions are sought to improve, among other properties, the soil's sorption. One of the solutions may be superabsorbents called agrogels and hydrogels, which are synthetic gel polymers or polymeric soil additives [8,9]. Currently, the use of such solutions is not applied on a large scale [10]. The cheap solution is to use basalt wool or lignocellulosic materials. Superabsorbents used in agriculture usually come from a group of cross-linked polyacrylamides or cross-linked acrylamide-acrylate copolymers [11–13]. They can absorb large amounts of water and additionally increase the soil's water capacity while preventing its loss by infiltration and evaporation [13]. The agrogel crystals in the soil allow the wide capillaries to retain water. This phenomenon is affected by an increase in the number of small capillaries and a reduction in pore size [14]. Hydrogels cause changes in soil structure, particularly loosening, through repeated swelling and contractions caused by the uptake of water by plants. An important feature exhibited by superabsorbents is the ability to improve soil aeration. Thanks to the free growth of plant roots through geocomposite geotextile, they can take up water accumulated in the hydrogel [15]. Paluszek (2009) indicated that high-molecular synthetic polymers contribute to the binding of soil particles and microaggregates into stable macroaggregates [16]. The beneficial effect of superabsorbents is associated not only with an increase of water retention in soil but also with a positive effect on soil structure and the reduction of biogens in water [12]. As soil additives, they can also counteract water and air erosion [8,16–19]. Geocomposites improve aggregate durability, thus contributing to soil compaction and its physicochemical, biological and air-water properties [8]. They lose their activity and effectiveness by 10–15% every year [10]. In horticultural production, fertilisation is the basic agrotechnical procedure that ensures optimal growth and cropping of plants. In order to increase the efficiency of fertilisation, preparations enriched with biostimulants are increasingly used [20]. The term 'biostimulator' is used to describe a substance that is not a plant's nutrient, but that, in some positive way, affects their health [21], growth and metabolism and increases the content of antioxidants and the availability of nutrients [22,23]. The first congress dealing with the plant biostimulators, which was held in Strasbourg in 2013, defined biostimulators as substances able to stimulate either phytomass formation or phytomass and that contained substances at the same time, or possibly only the substances contained in the phytomass. Biostimulators were also defined as substances which have the ability to stimulate the defence potential of a plant organism in a nonspecific way. Therefore, they help the plant adapt to the changing environment and stress better and more promptly [24]. The variety of these substances is very extensive and, according to Karnok (2000), marine algae extracts have many of such compound [25]. Seaweed extracts have been exhibited to contain macro and micronutrients, amino acids, vitamins, cytokinins, auxins and abscisic acid (ABA) [26–33]. In coastal countries, farmers have used seaweed or their extracts for centuries to fertilise their crops. According to Stephenson (1968) [34], Munda and Gubensek (1975) [35], Abetz (1980) [36], Finnie and Van Staden (1985) [26], Moore and Van Staden (1986) [27], Verkleij (1992) [22] and Khan et al. (2009) [37], seaweed extracts contain macronutrients, i.e., Ca, K, P; micronutrients, i.e., Fe, Cu, Zn, B, Mn, Co and Mo; amino acids; vitamins; cytokinins; gibberellins; auxins; and abscisic acid (ABA). Seaweed has a positive effect on soil structure and water capacity [38] and stimulates the development of beneficial soil microorganisms [37]. Plants treated with marine algae extracts absorb and absorb nutrients faster compared to untreated ones [39], have stronger and stronger growth [37,38] and have a well-developed root system with numerous fine lateral roots [40,41]. Seaweed extracts have a positive effect on the effectiveness of plant protection against diseases and pests [42,43] and increase tolerance to drought [44] and high temperature [45,46].

The aim of the study was to assess the impact of fertilizer with biostimulation with humic acids and agrogel preparations on the reception and growth of newly planted apple maiden variety of the 'Gala Must' cultivated on the 'M.9' RN29 rootstock.

2. Materials and Methods

The research was carried out in 2012–2014 in a commercial apple orchard in the Sandomierz Upland in southeastern Poland (50°39′ N; 21°34′ E). One-year-old maiden trees were planted annually in a place where fruit trees had been growing for 20 years. The trees were planted on lessive soil developed from loess, which contained 2.1% of organic matter, spaced 3 × 1 m, i.e., 3330 trees × ha^{-1}. Metal poles with wires, together with bamboo stakes, were used as supports. In every year, preceding the setting up of the experiment in the autumn after the fruit harvest, the old apple trees were grubbed and removed. Every year, soil analysis was performed, and on its basis, nutrients were supplemented to the optimum level. Maiden trees were stored in a trench. During the experiment, regular protection against diseases, pests and weed was carried out in accordance with the current protection program. The trees were not irrigated, and the soil pH fluctuated between 6.0 and 6.5 depending on the year of the study. The experiment evaluated the growth and quality of apple trees in the autumn of the first year after planting using a biostimulator in the form of fertilizer with biostimulation (Fertiactyl Starter Timac Agro) and agrogel (Agro Hydrogel Ever Chem). The following combinations were used in the experiment using the abovementioned preparations:

1. Control—the trees not treated with preparations.
2. Fertilizer with biostimulation and humic acids 1% (1 L·99 L^{-1} water)—spraying the herbicide belt twice a season (the first treatment was done 7 days after planting, the second 21 days after planting).
3. Fertilizer with biostimulat ion and humic acids 1% (1 L·99 L^{-1} water)—soaking the root system for 1 h before planting the trees by dipping the entire root system of maiden trees. The solution was prepared in the morning before planting the trees.
4. Fertilizer with biostimulation and humic acids 1% (1 L·99 L^{-1} water)—soaking the root system for 12 h before planting the trees by dipping the entire root system of maiden trees.Tthe solution was prepared in the evening the day before planting.
5. Agrogel 0.5 kg·100 L^{-1} water—the solution was made 12 h before planting the trees, in the evening of the day before planting. Then, the root systems of the planted trees were dipped just before planting.
6. Fertilizer with biostimulation and humic acids 1% (1 L·99 L^{-1} water) + agrogel 0.5 kg·100 L^{-1} water—the solution was made 12 h before planting the trees, in the evening of the day before planting. Then, the root systems of the planted trees were dipped just before planting.

The experiment was based on a random block system and included 6 combinations in 5 replications. Repetitions were plots with 15 plants.

Fertiactyl Starter (Timac Agro) is a liquid fertilizer containing biostimulating substances with foliar and subsurface action. It contains a special complex formed by selected humic and fulvic acids, a cytokinin complex formed by the main natural citokinins and an antistress complex formed by an amino acid (glicine-betaine) with osmoregulatory properties and a natural phenol (SM1) with the capacity to stimulate the natural mechanisms that the plant activates under stress conditions. The ensemble of these 3 regulatory complexes is called the Fertiactyl® complex. The main concepts involved in Fertiactyl are covered and protected by patents. Fertiactyl Starter contains also NPK: N 13%, P 5%, K 8%. Agro Hydrogel (Ever Chem) is a cross-linked polyacrylamide with a granulation of 0.35–1.10 mm and density of 1.1 g·cm^{-3}. It absorbs water by binding it in the form of a transparent gel.

Test results were analysed statistically using the 1-way analysis of variance method. In addition, the results are presented graphically using a box and whisker chart. The inference was based on the significance level < 0.05. Correlations between qualitative parameters of trees and meteorological conditions were evaluated by calculating Pearson correlation coefficients. Multidimensional techniques of data analysis were performed by conducting cluster analysis, the purpose of which was to group objects (agrotechnical operations) into homogeneous groups in such a way that in one cluster the objects were more similar to each other than to objects from other clusters. The results of the analysis were presented using a dendrogram. All statistical analyses were performed in the SAS Enterprise Guide 5.1 program.

Figure 1. Monthly rainfall sums during the growing season in the years of research 2012–2014 (based on the data from the weather station of the Soska Konsulting com-pany).

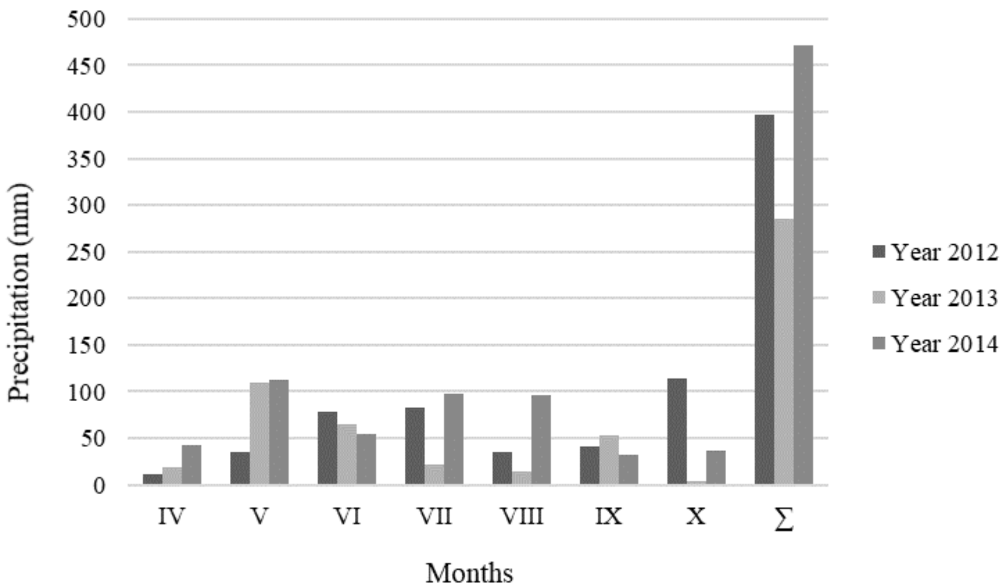

Figure 1. IV—April, V—May, VI—June, VII—July, VIII—August, IX—September, X—October, ∑—Sum of precipitation for the season.

Figure 1 presents the sum of precipitation in subsequent growing seasons 2012–2014. The sum of precipitation in particular growing seasons ranged from 286.0 mm to 471.80 mm. The lowest amount of precipitation was recorded in 2013, whereas the highest was recorded in 2014. It was observed that the sum of precipitation in the first month of vegetation in 2014 was more than twice that in 2012 and 2013. In 2012, a rainfall deficit was also observed in May. In the summer months of 2013, i.e., July and August, very little rainfall was recorded, at 21.6 mm and 14.4 mm, respectively. Meanwhile, in October 2013, 4.4 mm was recorded. Moreover, the distribution of precipitation had an impact on the sum of precipitation during the growing season (Figure 1).

The average air temperature in subsequent growing seasons ranged from 14.98 °C to 15.32 °C. During the entire study period, there were no clear differences in the values of average monthly air temperatures between the studied years (Figure 2).

Figure 2. Monthly average daily air temperature during the growing season in the years 2012–2014 (based on data from the meteorological station of the Soska Konsulting).

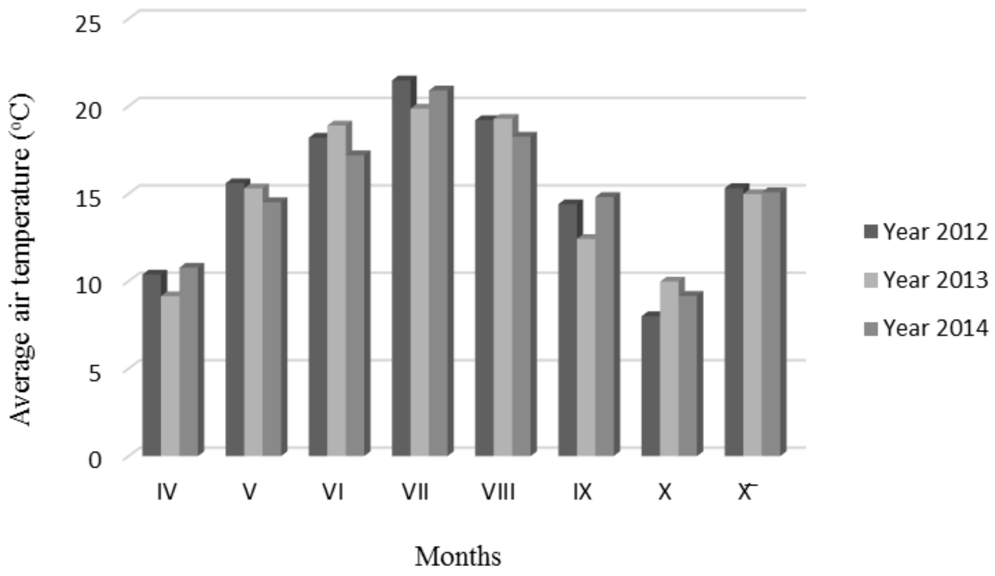

Figure 2. IV—April, V—May, VI—June, VII—July, VIII—August, IX—September, X—October, $\overline{X}$—Average for the season.

3. Results

In the autumn of the year of planting the trees permanently, the diameter of rootstock trunks after growth to a height of 10 cm above the soil surface ranged from 31.03 mm to 36.60 mm and differed significantly between the combinations assessed (Table 1). Statistical analysis showed that, on average, after 3 years of research, the thickest stems were obtained using fertilizer with biostimulation and humic acids and agrogel, while the thinnest were obtained in the control group and after using fertilizer with biostimulation in the form of herbicide belt spraying. A significant impact of the year of the research on the parameters of the assessed feature was demonstrated. Regardless of the combinations used in 2014, the rootstocks of the assessed trees had significantly thicker trunks than in the first 2 years of experiment. The interaction of agrotechnical operations and the year of research were important for the analysed parameter. The diameter of the tree trunks at a height of 30 cm above the soil surface ranged from 16.3 mm to 21.93 mm and differed significantly between the assessed combinations (Table 1). Indeed, the thickest trees were obtained after using fertilizer with biostimulation and agrogel. The control trees had thinnest trunks, and their thickness did not differ significantly from those treated with fertilizer with biostimulation in the form of herbicide belt by spraying and soaking for 1 h in a 1% solution of the above-mentioned biostimulator. The examined growth parameter significantly depended on the year of research. Regardless of the procedures used, the trees in 2013 were the thinnest, and in 2014, the trees were the thickest. The interaction of agrotechnical operations and the year of research were important for the analysed parameter.

The diameter of tree trunks of rootstocks trunks and saplings was measured annually in October after the end of plant growth. The height of the trees in the autumn in the year of planting into the orchard to a permanent place depended on the type of agrotechnical treatment applied (Table 1). It was found that the applied treatments significantly improved the examined growth parameter. Control trees were the shortest among the examined showed significant differences compared to trees treated with fertilizer with biostimulation in the form of soaking for 12 h in a 1% solution of agrogel and a mixture of fertilizer with biostimulation and agrogel. The height of the studied trees depended on the year of research. In 2014, they were significantly taller than in the first 2 years. The interaction of agrotechnical operations and the year of research were important for the analysed parameter.

Table 1. Impact of agrotechnical operations on the diameter of rootstock and tree trunks and height in autumn after growth.

	Combination	Diameter of Rootstock Trunks, 10 cm above the Soil Surface, mm	Diameter of Tree Trunks, 30 cm above the Soil Surface, mm	Height in Autumn, cm
agrotechnical operations (A)	Control	31.03 c *	16.73 d	179.40 d
	Fertilizer with biostimulation 1%—spraying the herbicide belt	31.47 c	17.41 cd	186.13 cd
	Fertilizer with biostimulation 1%—soaking 1 h before planting	33.27 b	17.53 bcd	189.67 cd
	Fertilizer with biostimulation 1%—soaking 12 h before planting	34.07 b	18.41 bc	200.73 b
	Agrogel 0.5 kg/100 L water	33.43 b	18.46 b	195.93 bc
	Fertilizer with biostimulation 1% + Agrogel 0.5 kg/100 L water	36.60 a	21.93 a	211.67 a
YEAR (B)	2012	32.48 b	303.31 b	18916 b
	2013	32.51 b	302.22 c	188.50 b
	2014	34.93 a	304.51 a	204.10 a
	(A × B) *p*-value	<0.0001	<0.0001	0.0140

* Explanation: Means followed by the same letter are not significantly different at α = 0.05.

Based on the box chart (Figure 3), it can be unequivocally stated that the height of the trees presented in subsequent years of the study in the control combination differed from the others, mainly from those treated with fertilizer with biostimulation and agrogel. It was shown that the trees treated with the mixture of fertilizer with biostimulation and agrogel were significantly taller than the others in the first year of the research. In 2013, it was found that the trees treated with a mixture of fertilizer with biostimulation and agrogel and agrogel were of similar heigh, and were significantly taller xompared to other combinations. It should be noted that, in 2013, a small amount of precipitation was recorded during the growing season. In the last year, no significant influence of the applied treatments on the assessed parameter was demonstrated (Figure 3). When assessing the differences between the years of the research, it was found that the trees treated with Agrogel did not differ significantly in subsequent years of the research. In the remaining combinations, significant differences between the first and second year and the last year of the study were found, which were characterized by the highest amount of precipitation in the growing season.

The applied agrotechnical procedures had a significantly beneficial effect on the number of side shoots of young trees of the 'Gala Must' variety (Table 2). The most shoots were produced by the trees treated with a mixture of fertilizer with biostimulation and agrogel preparations, and no significant differences were shown only in the combination in which the root system was soaked for 12 h in the Fertiactyl Starter. There was no significant impact of the year of research on the examined feature. The interaction of agrotechnical operations and the year of research were not significant for the analysed parameter.

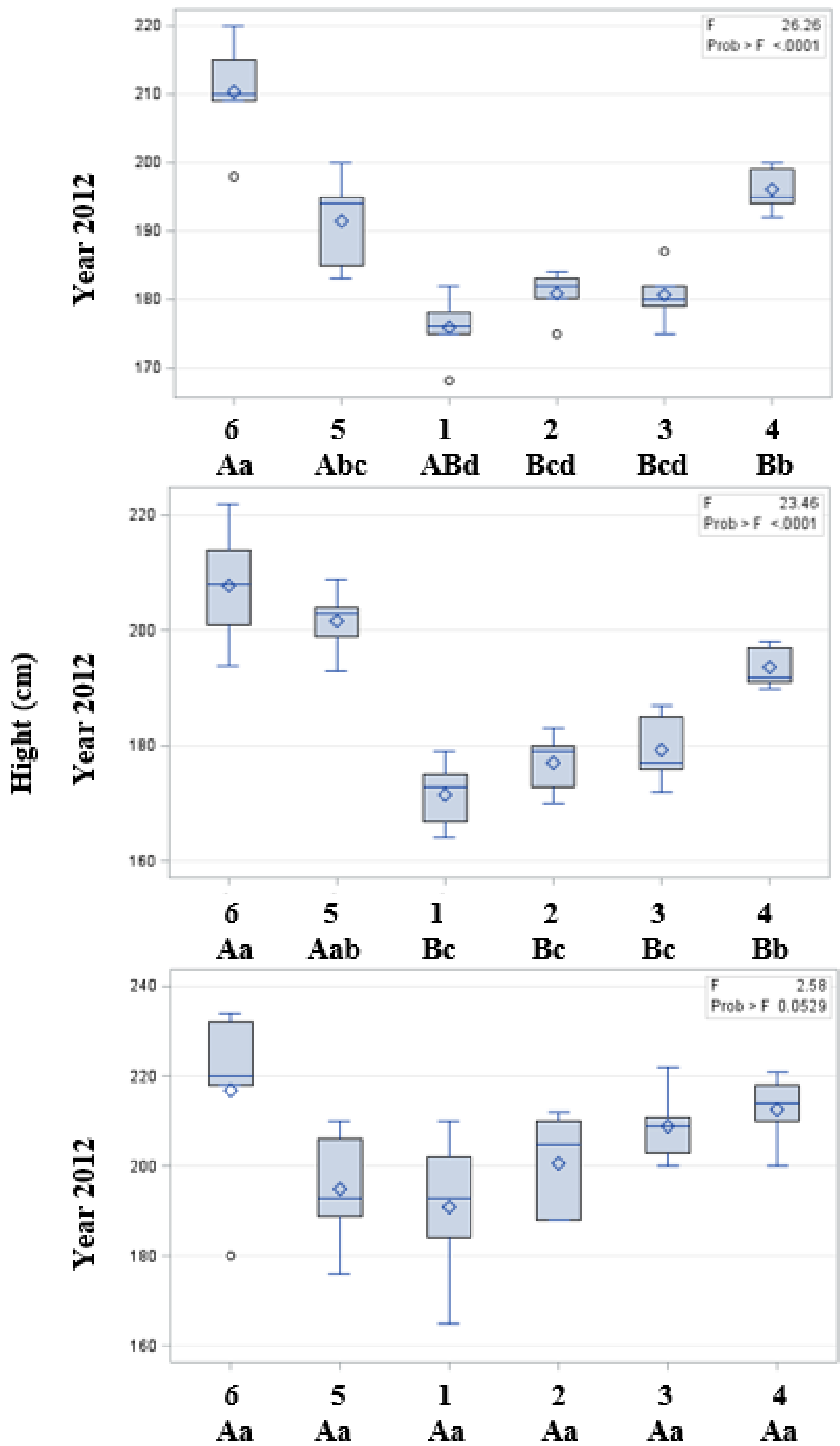

Figure 3. Distribution of tree height in subsequent years of research. Explanation: Means followed by the same letter are not significantly different at $\alpha = 0.05$. The means marked with capital letters show significant differences between the years of research in particular combinations. Means marked with lowercase letters show significant differences between the combinations in particular years of research. 1—Control; 2—Fertilizer with biostimulation 1%—the herbicide belt; 3—Fertilizer with biostimulation 1%—soaking 1 h; 4—Fertilizer with biostimulation 1%—soaking 12 h; 5—Agrogel; 6—Fertilizer with biostimulation 1% + agrogel.

Table 2. Impact of agrotechnical treatments on the number and average length of shoots and the sum of the length of the side shoots of young apple trees of the 'Gala Must' variety.

	Combination	**Number of Side Shoots, pcs**	**Average Shoot Length, cm**	**Total Length of Side Shoots, cm**
agrotechnical operations (A)	Control	16.81 d	21.13 b	351.63 c
	Fertilizer with biostimulation 1%—spraying the herbicide belt	22.03 c	22.83 ab	500.96 b
	Fertilizer with biostimulation 1%—soaking 1 h before planting	22.83 bc	22.03 ab	504.21 b
	Fertilizer with biostimulation 1%—soaking 12 h before planting	24.93 ab	22.66 ab	563.96 b
	Agrogel 0.5 kg/100 L water	22.83 bc	24.11 ab	548.43 b
	Fertilizer with biostimulation 1% + Agrogel 0.5 kg/100 L water	25.61 a	26.56 a	676.43 a
YEAR (B)	2012	306.95 a	307.07 a	738.74 a
	2013	306.17 a	307.24 a	716.05 a
	2014	307.45 a	308.11 a	756.04 a
	(AxB) *p*-value	0.6221	0.9999	0.9845

Explanation: Means followed by the same letter are not significantly different at $\alpha = 0.05$.

The presented graph clearly shows that the control trees were characterised by a smaller number of side shoots than those treated with agrotechnical operations. The degree of branching in the trees treated with a mixture of fertilizer with biostimulation and agrogel preparations and soaked for 12 h in fertilizer with biostimulation solution was better than in the other combinations (Figure 4). The average length of one shoot ranged from 21.13 cm to 26.56 cm, and most combinations did not differ significantly from each other (Table 2). A significant effect of agrotechnical treatment on the examined feature was demonstrated when using a mixture of fertilizer with biostimulation and agrogel preparations. The trees in the abovementioned combinations had significantly longer shoots than the control shoots. The year of the study did not have a significant impact on the examined feature. The interaction of agrotechnical operations and the year of research were not significant for the analysed parameter. The sum of the lateral shoots of the 'Gala Must' apple trees varied from 351.96 cm to 676.43 cm and differed significantly between the combinations assessed (Table 2). The applied treatments significantly improved the examined feature. Among the trees treated with agrotechnical treatments, the largest sum of side shoots lengths was treated with the mixture of fertilizer with biostimulation and agrogel preparations. There was no significant impact of the year of the research on the examined feature. The interaction of agrotechnical operations and the year of the research were not significant for the analysed parameter. In the presented experiment, Pearson's correlation coefficient was calculated for all tree growth and quality parameters as well as meteorological conditions in the growing seasons. When assessing meteorological conditions, the average daily air temperature and total rainfall were taken into account. We show that:

- The diameter of the tree trunks at a height of 30 cm highly correlated with the diameter of the rootstock trunks,
- the height of the trees correlated with the thickness of the tree trunks,
- the number of side shoots correlated with the thickness of the rootstock trunks and the trees and the height of plants,
- the sum of the length of the side shoots correlated with all the assessed parameters except for the year of the test, and
- meteorological conditions showed a positive correlation with the number of side shoots and the sum of the length of side shoots (Table 3).

Table 3. Pearson's correlation coefficients > ∣ r ∣ at H0: Rho = 0.

Growth and Quality Parameters of 'Gala Must' Apple Trees	Year	Diameter of Rootstock Trunks—10 cm	Diameter of Tree Trunks—30 cm	Height of Tree Trunks in Autumn	Number of Side Shoots	Average Length of Shoots	Total Length of Side Shoots
Year	1						
Diameter of root trunks—10 cm	0.372	1					
Diameter of tree trunks—30 cm	0.192	0.681	1				
Height in autumn	0.376	0.676	0.639	1			
Number of side shoots	0.027	0.423	0.481	0.571	1		
Average length of shoots	0.080	0.246	0.284	0.206	0.097	1	
Total length of side shoots	0.060	0.453	0.513	0.510	0.690	0.778	1
Meteorological conditions	0.072	−0.252	0.132	0.324	0.516	0.326	0.653

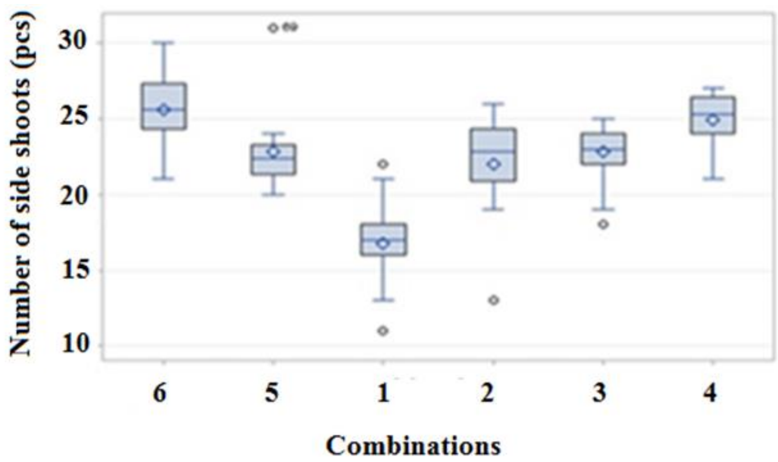

Figure 4. Distribution of shoots per tree average for all years of the research. 1—Control; 2—Fertilizer with biostimulation 1%—the herbicide belt; 3—Fertilizer with biostimulation 1%—soaking 1 h; 4—Fertilizer with biostimulation 1%—soaking 12 h; 5—Agrogel; 6—Fertilizer with biostimulation 1% + agrogel.

For the significance level $p = 0.05$, the calculated r was used. Assumed for the combination $n = 5$, and for the years $n = 2$. The sum of the principal components (PC; PC1 and PC2) of the total variable for growth and quality parameters of young apple trees and weather conditions was 56.8%, including PC1 (31.08%) and PC2 (25.72%) (Figure 5). PC1 was responsible for the average length of side shoots, and PC2 for the sum of the length of side shoots, diameter of rootstock trunks, number of side shoots and the height and diameter of trees. Principal component analysis (PCA) shows that the sum of precipitation was related to the average length of shoot, while the air temperature had a large impact on the sum of the length of side shoots and the diameter of the rootstock trunks.

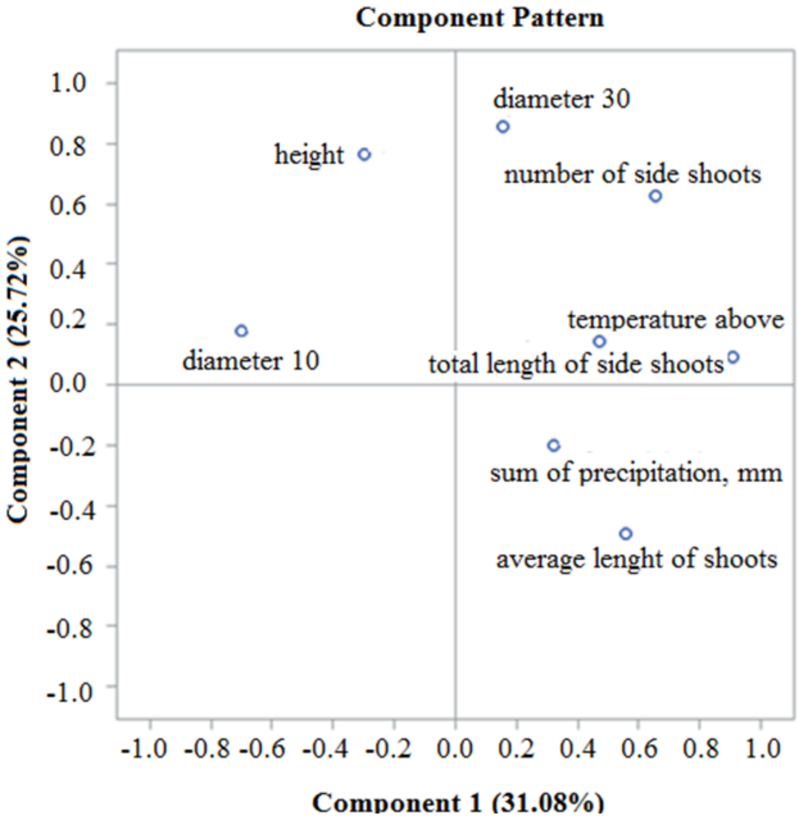

Figure 5. The PCA map shows the relationship between the value of the assessed growth parameters and quality of 'Gala Must' apple trees depending on weather conditions.

The list of all the growth and quality parameters for 'Gala Must' maiden trees on M.9 rootstock allowed us to determine the similarity of the effects of individual treatments (Figure 6). Obtaining homogeneous groups of examined objects, including agrotechnical operations, allowed us to compare and determine their similar impact on the growth and quality and behaviour of the trees in the first year of the growth. On the basis of the presented dendrogram, four clear clusters allowed a clear interpretation of the results:

1. The concentrations used in the procedure of mixing fertilizer with biostimulation and agrogel preparations.
2. The combination of using agrogel and soaking the root system for 12 h.
3. The application of fertilizer with biostimulation for 1 h, which was used as a spray on the herbicide belt.
4. The control roup, which did not merge into subsequent so-called branches, i.e., the trees, differed significantly in quality from the others.

Clusters 2 and 3 connected to each other at the next level and thus showed some similarities in the parameters of the trees. Based on the analysis, it is clear that the procedure using fertilizer with biostimulation and agrogel had the best effect on the growth and quality throughout the entire study period, and the other treatments differed significantly.

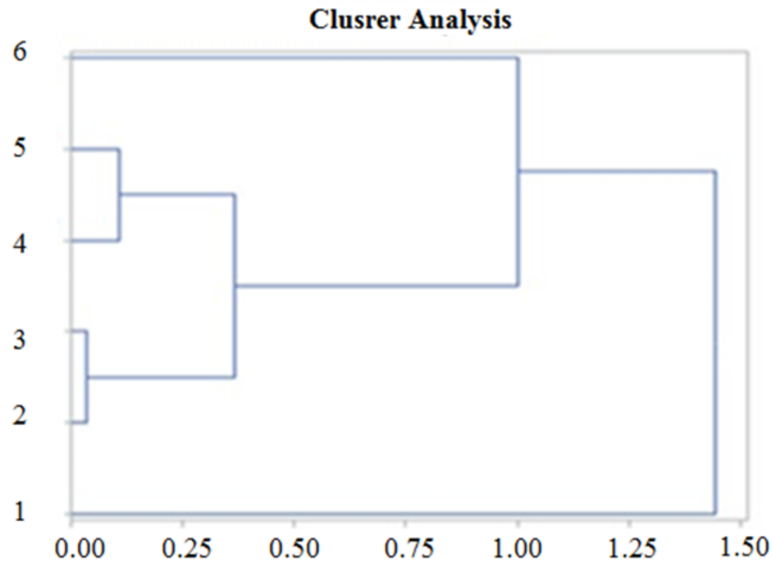

Figure 6. Dendrogram for different agrotechnical treatments. 1—Control; 2—Fertilizer with biostimulation 1%—the herbicide belt; 3—Fertilizer with biostimulation 1%—soaking 1 h; 4—Fertilizer with biostimulation 1%—soaking 12 h; 5—Agrogel; 6—Fertilizer with biostimulation 1% + agrogel.

4. Discussion

To counteract fluctuations in humidity or periodic water shortages in soil, solutions are sought to improve, among other properties, the sorption of the soil and its water capacity. The most important feature of superabsorbents is their ability to absorb water. When saturated with water, they increase their volume, absorbing 400–1500 g of water per 1 g of dry matter. Thus, they can accumulate at least 90–95% of the water available for plants and prevent it from seeping into deeper layers [47,48]. Thanks to this, superabsorbents in soil act as a moisture buffer, limiting water stress in plants [15]. By improving the soil's water capacity, superabsorbents affect the intensive development of the root system and aboveground part, which is not without effects on plant growth and cropping [49,50]. In the research by Paluszek (2003) [8], the plants produced using agrogel were characterized by a strongly developed root system thanks to the optimal air-water conditions in the root zone. Scientific research has indicated that agrogel shows great usefulness in rooting seedlings of decorative plants [51–53]. In the study by Bartnik (2008) [9], it was found that, in drought conditions, the survival period of pine seedlings growing in a substrate with the addition of hydrogel increased by about 50%.

Thanks to their strong water absorption and accumulation properties, including aqueous solutions of many substances such as fertilizers, biostimulators and plant protection products, superabsorbents (hydrogels, agrogels) have a very wide range of applications [54]. The possibility of incorporating various metals and nonmetal cations into hydrogels makes them a potential source of nutrients for plants [55,56].

According to Schmidt et al. (2003) [20], biostimulants with an admixture of mineral fertilizers in the form of foliar applications are not able to provide all of the necessary nutrients in an amount sufficient for proper growth and functioning, because their main function is to strengthen the tolerance of plants to environmental stress. In addition to proper mineral fertilisation, biostimulators can increase the effectiveness of conventional fertilizers [57] and absorb and accumulate larger amounts of macroelements at the leaf level [39]. In the studies by Mancuso et al. (2006) [39], the isopentyl adenine (IPA) extract successfully affected the accumulation of nitrogen, phosphorus and potassium in vine plants in almost all organs. The role of biostimulators in the accumulation of nutrients at the tissue level is still unknown. According to Salat (2004) [58], biostimulators may contain chelating compounds (e.g., mannitol in seaweed), which may increase the availability of nutrients and better absorption of chelate compounds from leaves.

In this study, the procedures used had a positive effect on the plants' height, with the control trees having the lowest heights among those tested. The height of the trees in subsequent years of research in the control combination differed from the others, mainly from those treated with fertilizer with biostimulation and agrogel. It was shown that the trees treated with the mixture of fertilizer with biostimulation and agrogel were significantly taller than the others in the first year of the research. In 2013, when a small amount of rainfall was recorded during the growing season, the trees treated with the mixture of fertilizer with biostimulation and agrogel and arogel preparations were characterized by a similar insignificant height, and compared to other combinations, they were significantly taller. The trees treated with agrogel did not differ significantly in subsequent years of research. According to Paluszek (2003) [8], stronger plant growth at the agrogel stand is the result of not only the improvement of soil moisture conditions and regulation of soil water relations, but also the beneficial effect of polymers on the uptake of macro- and microelements by plants. In the research by Gudarowska and Szewczuk (2009) [54], assessing the height of peach trees at the nursery stage, it was shown that 'Redhaven' maiden trees growing on the agrogel stand were significantly taller than the control ones, whereas in 'Inka' trees, no such relationship was demonstrated. According to Berlyn and Sivaramakrishnan (1996) [21], in the case of the species Coffea, Alnus and Pinus, the rate of development of plants treated with biostimulators was higher than untreated plants, but no significant differences were found. Similarly, beneficial effects of biostimulators (the IPA extract) on the growth rate of Vitis vinifera were demonstrated by Mancusso et al. (2006) [39].

Gudarowska and Szewczuk (2009) [54] reported that peach trees growing on the agrogel stand were thicker compared to the control and irrigated ones. In the case of the 'Redhaven,' on average, for 2 years of research, these differences were significant. In this study, it was shown that, on average, for 3 years of research, the thickest rootstock and tree trunks were obtained after the application of fertilizer with biostimulation and agrogel. Kelting et al. (1998) [59], assessing the effect of various biostimulators on the growth and quality of Acer rubrum and Cratageus phaenopyrum seedlings, showed that the preparations used had a positive effect on the height, diameter of the trunk and root length only in the case of Cratogeus.

In the study by Gudarowska and Szewczuk (2009) [54], the number of side shoots of 1-year-old peach trees in the nursery growing on the agrogel stand was significantly higher than that of control and irrigated ones. A similar correlation was found in the assessment of the length of the side shoots of the 'Redhaven' variety. Slightly different results regarding the number of side shoots were found in the apple trees of the 'Ligol' variety: The trees in the first 4 years of growth in a permanent place in the medium with the addition of geocomposite produced more shoots than the control ones, but these differences were not significant, regardless of the type of rootstock used (Gudarowska and Szewczuk 2011) [50]. In this study, the applied agrotechnical procedures had a significantly positive effect on the number of side shoots of the 'Gala Must' trees. Significantly, the most shoots were created by trees treated with a mixture of fertilizer with biostimulation and agrogel preparations, and no significant differences were shown only in the combination in which the root system was soaked for 12 h in fertilizer with biostimulation. Similar but insignificant correlations were observed in the studies of Berlyn and Sivaramakrishnan (1996) [21] and Mancuso, S.; Azzarello, E.; Mugnai, S.; and Briand, X. (2006) [39].

5. Conclusions

Based on the 3-year studies, it was shown that the use of fertilizer with biostimulation and agrogel preparations for the better acceptance and growth of 'Gala Must' apple trees had a positive effect on the quality parameters of the trees.

The agrotechnical treatment, in which fertilizer with biostimulation biostimulant fertilizer in the concentration of 1% was used to hydrate agrogel, is particularly noteworthy. The trees of the abovementioned combinations were characterized by the best growth and quality parameters every year, which was confirmed by a multidimensional cluster analysis.

A similar beneficial effect was shown by the hydration of the root system of the studied trees with fertilizer with biostimulation at a concentration of 1% for 12 h before planting the trees to a permanent place.

It is also particularly noteworthy that the use of agrogel significantly modified the height of the assessed apple trees in the second year of the research when smaller precipitation was recorded.

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