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The Effects of Reduced Mineral Fertilisation Combined with the Foliar Application of Biostimulants and Fertilisers on the Nutrition of Maiden Apple Trees and the Contents of Soil Nutrients

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Abstract: The experiment compared the use of a dose of mineral fertilisation reduced by half in a nursery, which was replaced by foliar treatment with biostimulants and fertilisers. The control combination was a full dose of mineral fertilisation without foliar treatments. The half dose of mineral fertiliser applied into the soil decreased its acidity and salinity. At the same time, it decreased the soil content of macro- and micronutrients, except for calcium and iron. In most cases the simultaneous foliar application of the four biostimulants tested in our experiment reduced the content of macronutrients in the leaves of maiden apple trees, except for calcium. On the other hand, it increased the iron (28.2% average) and manganese (24.8% average) levels in the leaves but reduced the levels of zinc (11.8% average) and copper (25% average). The foliar application of two fertilisers increased the leaf contents of phosphorus (12% average) and calcium (9.3% average). One of the fertilisers also increased the leaf contents of potassium, magnesium, and micronutrients.

Keywords: nursery; mineral fertiliser dosage; leaves; soil; content of macro- and micronutrients

1. Introduction

Poland is the largest producer of maiden apple trees in Europe and the third largest apple producer in the world. Large amounts of mineral fertilisers are used in nursery production to intensify the vegetative growth of fruit trees. On the other hand, plants do not use large amounts of nutrients supplied with mineral fertilisers, because these are leached into deeper soil layers, where they degrade the environment [1–4]. Plants can absorb more nutrients at a faster rate if foliar fertilisation is applied, especially at low temperatures [5,6]. According to some authors [1,7,8], the combination of these two methods of plant nutrition guarantees the best results in the cultivation of apple trees. Foliar fertilisation should be practised due to the insufficient uptake of soil nutrients during periods of low rainfall [9]. It should also be applied if plants' roots are damaged and during stagnation of water on the soil surface. This method of fertilisation is particularly important for magnesium and calcium supplementation deficiencies, because the root absorption of these nutrients is limited due to their antagonistic relationship with other elements [10,11].

Biostimulants change the solubility and transport activity of nutrients supplied to plants [12,13]. As results from the research conducted so far, the foliar application of marine algae extracts stimulated the uptake of nutrients in various plant species, e.g., lettuce and grape [14], soybean [15], tomato [16], and winter rapeseed [17]. The treatment increased the contents of both macro- (N, P, K, Ca, S) and micronutrients (Mg, Zn, Mn, Fe) in these plants. Some researchers [14,15,18] observed that these biostimulants increased the leaf potassium content. In contrast, Shehata et al. [19] found that the seaweed extract had no effect on the potassium content in celeriac leaves. Additionally, Filipczak et al. [20] did not observe any significant effect of various biostimulants on the contents of minerals in strawberry

leaves. Furuya et al. [21] observed that the application of amino-acid-based biostimulants increased the uptake of nutrients by peach plants. According to De Pascale et al. [22], natural bioactive substances and microbial inoculants may be valuable tools that enhance the availability of soil nutrients, their uptake, and their assimilation.

Multi-component fertilisers are usually used in foliar spray treatments. The influence of foliar fertilisation on the growth of maiden apple trees in a nursery was studied by Świerczyński and Stachowiak [23]. However, neither of the fertilisers (urea, calcium nitrate) used in their experiment improved the growth of the maiden apple trees significantly. In a later study [24], only one of the foliar fertilisers (Maxi Grow Excel) used in the experiment improved the growth of maiden cherry trees. Other foliar preparations and fertilisers, which also contained microelements (Black Jack and Biopuls Forte), increased the contents of nitrogen and phosphorus, and less frequently the contents of potassium, calcium, and micronutrients in the leaves of maiden sweet cherry trees. Other authors [25] used two fertilisers (Florovit Eko and Florovit Pro Natura) and observed increased potassium contents in the leaves of maiden apple and cherry trees.

The aim of experiment was to compare the results of the contents of soil nutrients fertilised with a full dose and half dose of mineral fertilisers used in the production of maiden apple trees in a nursery. Additionally, we compared the contents of macro- and micronutrients in the leaves of maiden apple trees after the application of a reduced dose of mineral fertilisers in combination with foliar treatment with selected biostimulants and fertilisers in relation to the full dose without these treatments. The presented results of the experiment complement the previously described effects of a reduced dose of mineral fertilisation with spraying treatment with biostimulants and fertilisers on the growth of maiden apple trees, to which the authors refer in the present publication.

2. Materials and Methods

2.1. Plant Material and Growth Conditions

The experiment was conducted on one-year-old maiden apple trees of four varieties, ‘Gala Schniga’, ‘Ligol’, ‘Red Boskoop’, and ‘Topaz’, grown in a nursery on an M.9 rootstock. Between 2017 and 2018, two separate series of the experiment were conducted. The experiment was carried out on two parallel plots in the nursery. On one of them, full mineral fertilisation ($120 \text{ N} \cdot \text{h}^{-1}$, $40 \text{ P}_2\text{O}_5 \cdot \text{h}^{-1}$, $140 \text{ K}_2\text{O} \cdot \text{h}^{-1}$), was applied and four varieties of maiden apple trees were grown, which were not treated with foliar treatment during their growth. In the second plot, the dose of mineral fertilisation was reduced by half ($60 \text{ N} \cdot \text{h}^{-1}$, $20 \text{ P}_2\text{O}_5 \cdot \text{h}^{-1}$, $70 \text{ K}_2\text{O} \cdot \text{h}^{-1}$), and foliar treatments with four biostimulators and two fertilisers were applied during the growth of maiden trees of four apple varieties. During the cultivation of the maiden trees of individual cultivars, six foliar feeding combinations were randomly distributed in the second plot. Before the nursery was established, the soil was analysed chemically, containing the following amounts of soluble forms of macronutrients: $87 \text{ mg} \cdot \text{dm}^{-3}$ phosphorus, $113 \text{ mg} \cdot \text{dm}^{-3}$ potassium, $485 \text{ mg} \cdot \text{dm}^{-3}$ calcium, and $83 \text{ mg} \cdot \text{dm}^{-3}$ magnesium (mean value for 2017–2018). The total rainfall volumes in individual years of the study were 338 mm (2017) and 228 mm (2018).

2.2. Biostimulants and Fertiliser Experiment

Four biostimulants were applied at the concentrations recommended by the manufacturer (Aminoplant 0.4%, Biamino Plant 0.2%, Bispeed 0.2%, Fylloton 0.4%). Two foliar fertilisers (Basfoliar 6-12-6 and Basfoliar 4-6-12 + S) were applied at a concentration of 0.5% ($5 \text{ mL} \cdot \text{L}^{-1}$).

Aminoplant contained 18 L-amino acids and bioactive peptides (N 8.5%; organic substances 54%; bioactive peptides 82.7%, amino acids 17.3%). The composition of Biamino Plant was dominated by L-amino acids of plant origin (organic nitrogen 7.6%, organic carbon 21.0%, amino acids 42.6%, Fe 1.2%, Mn 0.6%, Zn 0.7%). Bispeed was composed of potassium 4-nitrophenolate 0.25–0.30% m/m, potassium 2-nitrophenolate 0.14–0.20% m/m, and potassium 5-nitroguaiacolate 0.07–0.10% m/m. Fylloton contained brown algae

extract (*Ascophyllum nodosum*) and plant-derived amino acids (organic nitrogen 6%, organic carbon 20.8%, organic substance 35%). Basfoliar 6-12-6 is a multi-component liquid foliar fertiliser composed of N 6%, P₂O₅ 12%, K₂O 6%, B 0.01%, Cu 0.01%, Fe 0.02%, Mn 0.01%, Mo 0.005%, Zn 0.05%. Basfoliar 12-4-6+S was composed of: N 12%, P₂O₅ 4%, K₂O 6%, sulphur, and all microelements. Each of the twenty-eight experimental combinations (four biostimulants, two fertilisers, one control combination, and 4 varieties of apple) was represented in one plot by ten maiden trees in triplicate. Between early May and late July, the plants were sprayed with the biostimulants and fertilisers four times at three-week intervals. The control plants were treated with distilled water only. A 0.2% Slippa adjuvant was added to the solution with which the maiden trees were treated.

2.3. Chemical Analyses

In each year, the experiment soil samples were collected for chemical analyses in late July. Collected samples of the substrate were chemically analysed using the universal method. Extraction of macronutrients (N-NH₄, N-NO₃, P, K, Ca, Mg, S-SO₄), Cl, and Na was carried out in 0.03 M CH₃COOH with a quantitative 1:10 ratio of substrate to extraction solution. After extraction, the following determinations were made: N-NH₄, N-NO₃—by microdistillation according to Bremer in Starck's modification; P—colorimetrically with ammonium vanadomolybdate; K, Ca, Na—photometrically; Mg—by atomic absorption spectrometry (ASA); S-SO₄—nephelometrically with BaCl₂; Cl—nephelometrically with AgNO₃. Micronutrients (Fe, Mn, Zn, Cu) were extracted from the soil with Lindsay's solution, which in 1 dm³ contained: 5 g EDTA (ethylenediaminetetraacetic acid); 9 cm³ of 25% NH₄ solution, 4 g citric acid; 2 g Ca (CH₃COO)₂·2H₂O. Micronutrients were determined using the ASA method. Salinity was identified conductometrically as electrolytic conductivity (EC in mS·cm⁻¹) (substrate/water = 1:2) and pH was determined by potentiometric method (substrate/water = 1:2). In early August in both years of the research, samples of leaves were collected from the middle part of the long shoots of randomly selected maiden trees for analyses of the contents of macro- and micronutrients. The total nitrogen content was measured with the Kjeldahl method on a Parnas–Wagner apparatus. The phosphorus content was measured with the colorimetric method with ammonium molybdate. The potassium and calcium contents were measured using flame photometry, whereas the magnesium content was measured with atomic absorption. The content of macronutrients was expressed as a percentage. The content of the total forms of micronutrients, such as iron, zinc, manganese, and copper (ppm), was measured by means of atomic absorption spectrometry (ASA) after wet mineralisation of 2.5 g samples in a mixture of nitric acid and perchloric acid at a volume ratio of 3:1.

2.4. Data Analysis

The results of the study were analysed with STATISTICA 13.1 (Statsoft Polska, Kraków, Poland). Homogeneous groups for individual traits and treatments were calculated with Tukey's HSD test. The statistical significance level was $p = 0.05$. The results of measurements of the mineral elements were analysed separately by means of two-way analyses of variance, where the apple tree cultivars and foliar treatments were the factors.

3. Results

3.1. Chemical Analysis of Soil Samples from Nursery with Maiden Apple Trees

The experiment compared the effects of two doses of mineral fertilisers, full and half, on the contents of nutrients in the soil, where all applied foliar treatments constituted one group with a half dose. The soil treated with half the dose of the mineral fertiliser had lower pH and exceeded the optimal pH level for apple tree growing (6.3–6.7) (Table 1). The soil treated with lower doses of the fertiliser had higher Na and Cl contents but lower salinity and S-SO₄ contents.

Table 1. The salinity and pH of the soil and the contents of soluble forms of Na, Cl, and S-SO₄ in nursery soil (mean value for 2017–2018).

Dose of Mineral Fertilisation	pH	EC (mS·cm ⁻¹)	Na	Cl	S-SO ₄
			(mg·dm ⁻³)		
Full	6.40	0.27	14	4.4	6
Half	7.19	0.065	17	8	5

The content of ammoniacal nitrogen in the soil treated with half the dose of the mineral fertiliser was lower than the full dose. There were only traces of the nitrate form in both experimental variants (Table 2). The contents of phosphorus, potassium, and magnesium in the soil treated with the full dose of the fertiliser were respectively 75%, 50%, and about 30% greater than in the soil treated with half the dose of mineral fertiliser. The contents of individual components in the soil were compared with the ranges recommended by Breš et al. [26] for mineral soils used for the cultivation of horticultural crops.

The phosphorus content exceeded the average value recommend by Breš et al. [26] with both doses of the mineral fertiliser. The reduced dose of fertiliser resulted in a low potassium content, although the full dose resulted in a high content of this element. Lipiński [27] observed that the magnesium content did not reach the average level when a reduced dose of fertiliser was applied, although Breš et al. [26] noted increased levels of this element in both cases. The soil treated with a reduced dose of the mineral fertiliser had a higher calcium content. The K/Mg ratio was correct and amounted to 1.5 at the full dose of the mineral fertiliser and 1.1 at the reduced dose.

Table 2. The contents of soluble forms of N-NH₄, N-NO₃, P-PO₄, K, Ca, and Mg in nursery soil (mean values for 2017–2018).

Dose of Mineral Fertilisation	N-NH ₄	N-NO ₃	P	K	Ca	Mg
			(mg·dm ⁻³)			
Full	28	trace amounts	107	145	520	96
Half	trace amounts	trace amounts	82	69	675	65

The iron level was higher in the soil treated with the lower dose of mineral fertiliser (Table 3). However, this soil had lower contents of manganese, zinc, and copper. The contents of micronutrients for both doses of the fertiliser were as follows: Fe—below optimal; Mn—above optimal (optimal range: 20–40 mg·dm⁻³); Zn—within optimal and high (optimal range: 5–20 mg·dm⁻³); Cu—optimal (optimal range: 2.0–5.0 mg·dm⁻³).

Table 3. The contents of soluble forms of Fe, Mn, Zn, and Cu in nursery soil (mean values for 2017–2018).

Dose of Mineral Fertilisation	Fe	Mn	Zn	Cu
	(mg·dm ⁻³)			
Full	115.9	73.7	21.2	3.9
Half	121.9	70.4	18.3	2.6

3.2. Contents of Macro- and Micronutrients in Leaves of Maiden Apple Trees

In order to facilitate the inference process, the contents of macro- and micronutrients in the leaves of the maiden apple trees were assessed on the basis of the average values in the four cultivars used in the experiment. The contents differed significantly, depending on the dose of mineral fertiliser, the foliar treatments applied, and the cultivar. The highest nitrogen level was found in the control plants (Table 4 and Figure 1). Lower level were found in the combinations with the two fertilisers, while the lowest levels were found in the combinations with foliar biostimulants. The leaves of the maiden trees of the 'Topaz' cultivar had the highest nitrogen content, whereas the leaves of the 'Gala Schniga' cultivar had the lowest content of this element (Table 4 and Figure 2).

The treatment of the plants with three of the biostimulants used in the experiment (except the Aminoplant) resulted in significantly lower leaf phosphorus contents than in the control combination. The foliar application of two fertilisers resulted in a higher phosphorus content than in the control combination (Table 4 and Figure 1). Only these two fertilisers ensured the optimal phosphorus content in the leaves (0.16–0.26%) according to Breš et al. [26]. The highest content of this element was noted in the 'Ligol' cultivar, while the lowest contents were noted in the 'Gala Schniga' and 'Red Boskoop' cultivars (Table 4 and Figure 2).

The leaves of the maiden trees had the highest potassium content after the foliar treatment with the Basfoliar 6-12-6 fertiliser (Table 4 and Figure 1). The treatment of the trees with the Basfoliar 12-4-6+S fertiliser resulted in a significantly lower potassium content than in the control combination, whereas the treatment with the Biamino Plant and Fylloton biostimulants resulted in the same potassium contents. All results exceeded the optimal leaf potassium content (1.00–1.50%). The 'Topaz' cultivar had the highest leaf potassium content. The 'Red Boskoop' cultivar had the lowest content of this element (Table 4 and Figure 2).

On average, the highest leaf calcium contents were observed after the foliar spray treatment of the maiden trees with the Aminoplant, Bispeed, and Basfoliar 12-4-6+S products (Table 4 and Figure 1). The lowest leaf calcium contents were noted after the treatment with the Biamino Plant biostimulant and in the control plants. The leaves of the 'Ligol' cultivar had the lowest calcium content. The highest content of this element was found in the leaves of the 'Red Boskoop' cultivar (Table 4 and Figure 2).

The foliar treatment of the maiden apple trees with the Basfoliar 6-12-6 fertiliser resulted in the optimal content of magnesium in their leaves (0.22–0.32%), which was the best result (Table 4 and Figure 1). The other combinations had low contents of this component (0.18–0.21%). The lowest leaf magnesium contents, which was lower than in the control combination, were observed after the treatment of the plants with the Biamino Plant, Bispeed, and Fylloton biostimulants. On average, for all of the considered fertiliser combinations, the maiden trees of the 'Topaz' cultivar had the lowest (deficient) magnesium content in their leaves. The highest (optimal) leaf magnesium content was noted in the trees of the 'Red Boskoop' cultivar (Table 4 and Figure 2).

The treatment of the maiden trees with the Biamino Plant biostimulant resulted in the lowest leaf sodium content. On average for all combinations, 'Topaz' was the cultivar with the lowest content of this element. The treatment of the plants with the Fylloton product resulted in the highest leaf sodium levels, while the highest content was found in the 'Red Boskoop' cultivar (Table 4).

Table 4. The contents of macronutrients in the leaves of maiden apple trees.

Element	Cultivar	Treatment							Mean for Cultivar
		Control	Amino Plant	Biamino Plant	Bispeed	Fylloton	Basfoliar 6-12-6	Basfoliar 12-4-6+S	
N (%)	Gala Schniga	1.96 e–g	1.72 bc	1.79 cd	1.77 b–d	1.96 e–g	1.72 bc	1.56 a	1.78 a
	Ligol	2.07 g–i	1.79 cd	1.82 cd	1.82 cd	1.89 d–f	2.17 jk	2.17 jk	1.96 c
	R. Boskoop	2.15 ij	1.86 de	1.70 bc	1.87 de	1.66 ab	1.98 e–h	2.10 hi	1.90 b
	Topaz	2.28 kl	2.00 f–h	2.31 l	2.00 f–h	2.00 f–h	2.24 j–l	2.35 l	2.16 d
	Average for treatment	2.11 d	1.84 a	1.90 b	1.86 ab	1.87 ab	2.02 c	2.04 c	
P (%)	Gala Schniga	0.13 a–c	0.12 a–c	0.11 ab	0.13 a–c	0.13 a–c	0.14 bc	0.13 a–c	0.13 a
	Ligol	0.15 c	0.13 a–c	0.13 a–c	0.12 a–c	0.13 a–c	0.24 d	0.22 d	0.16 c
	R. Boskoop	0.13 a–c	0.14 bc	0.13 a–c	0.13 a–c	0.10 a	0.13 a–c	0.12 a–c	0.13 a
	Topaz	0.15 c	0.13 a–c	0.12 a–c	0.12 a–c	0.14 bc	0.14 bc	0.15 c	0.14 b
	Average for treatment	0.14 b	0.13 ab	0.12 a	0.13 a	0.13 a	0.16 c	0.16 c	
K (%)	Gala Schniga	2.13 i–k	2.00 e–h	1.88 c–e	2.13 i–k	2.22 k–m	2.29 mn	1.92 c–f	2.08 b
	Ligol	2.04 f–i	2.14 i–l	2.11 h–k	2.14 i–l	2.11 h–k	2.21 j–m	2.14 i–l	2.12 c
	R. Boskoop	2.09 h–j	1.85 cd	1.80 bc	1.68 ab	1.60 a	2.26 l–n	1.96 d–g	1.86 a
	Topaz	2.12 h–k	2.27 mn	2.13 i–k	2.36 n	2.05 g–i	2.23 k–m	2.14 i–l	2. d
	Average for treatment	2.09 d	2.06 cd	1.98 a	2.07 cd	1.99 ab	2.24 e	2.04 bc	
Ca (%)	Gala Schniga	0.67 d–g	0.74 h–j	0.68 e–h	0.97 lm	0.94 kl	1.10 op	0.90 k	0.86 c
	Ligol	0.71 g–i	0.64 d–f	0.62 de	0.62 de	0.64 d–f	0.23 a	0.38 c	0.55 a
	R. Boskoop	1.04 no	1.02 mn	0.76 ij	0.98 l–n	0.79 j	1.18 r	1.14 pr	0.99 d
	Topaz	0.31 b	0.72 g–i	0.71 g–i	0.61 d	0.63 d–f	0.37 bc	0.69 f–h	0.58 b
	Average for treatment	0.68 a	0.78 d	0.69 a	0.80 d	0.75 c	0.72 b	0.78 d	
Mg (%)	Gala Schniga	0.19 c–f	0.22 f–h	0.21 e–g	0.16 bc	0.19 c–f	0.20 d–f	0.17 b–d	0.19 b
	Ligol	0.22 f–h	0.15 ab	0.15 ab	0.16 bc	0.18 b–e	0.28 jk	0.26 ij	0.20 c
	R. Boskoop	0.21 e–g	0.30 k	0.20 d–f	0.25 h–j	0.24 g–i	0.21 e–g	0.20 d–f	0.23 d
	Topaz	0.16 bc	0.15 ab	0.16 bc	0.15 ab	0.12 a	0.19 c–f	0.15 ab	0.15 a
	Average for treatment	0.20 b	0.21 b	0.18 a	0.18 a	0.18 a	0.22 c	0.20 b	
Na (%)	Gala Schniga	0.003 a–c	0.003 a–c	0.002 ab	0.005 b–e	0.007d–f	0.004 a–d	0.004 a–d	0.004 b
	Ligol	0.004 a–d	0.005 b–e	0.001 a	0.007d–f	0.004 a–d	0.004 a–d	0.004 a–d	0.004 b
	R. Boskoop	0.004 a–d	0.005 b–e	0.006 c–f	0.004 a–d	0.00 f	0.006 c–f	0.006 c–f	0.006 c
	Topaz	0.004 a–d	0.003 a–c	0.001 a	0.001 a	0.008 ef	0.002 ab	0.002 ab	0.003 a
	Average for treatment	0.004 b	0.004 b	0.003 a	0.004 b	0.007 c	0.004 b	0.004 b	

Data followed by the same letters do not differ significantly at $p = 0.05$ for each macronutrient according to Tukey's test. The influence of the years was not statistically significant.

Figure 1. A comparison of the contents of macronutrients in the leaves of maiden apple trees depending on the applied foliar treatment. Data followed by the same letters do not differ significantly at $p = 0.05$ for each macronutrient according to Tukey's test.

Figure 2. A comparison of the contents of macronutrients in the leaves of maiden apple trees depending on the variety used. Data followed by the same letters do not differ significantly at $p = 0.05$ for each macronutrient according to Tukey's test.

The treatment of the plants with the Basfoliar 12-4-6+S fertiliser resulted in a lower leaf iron level than in the control plants (Table 5 and Figure 3). The other foliar treatments resulted in higher contents of this micronutrient than in the control plants. The highest leaf

iron content was noted in the trees of the ‘Red Boskoop’ cultivar. The lowest content of this element was found in the leaves of the ‘Topaz’ cultivar (Table 5 and Figure 4).

The use of the biostimulants resulted in the optimal manganese content in the leaves of the maiden trees (41–100 ppm), but it was low (21–40 ppm) in the other combinations. The treatment of the plants with the Basfoliar 12-4-6+S fertiliser resulted in a lower leaf manganese level than in the control plants (Table 5 and Figure 3). The other foliar treatments resulted in a higher level of this element. The highest manganese level was noted in the leaves of the ‘Gala Schniga’ and ‘Red Boskoop’ cultivars. The ‘Topaz’ cultivar had the lowest leaf manganese content (Table 5 and Figure 4).

The leaf zinc content was higher than in the control plants only after the foliar treatment of the maiden trees with the Basfoliar 6-12-6 product (Table 5 and Figure 3). All the other treatments resulted in lower leaf zinc levels. The ‘Red Boskoop’ cultivar had the highest zinc content, whereas the ‘Gala Schniga’ had the lowest level of this element (Table 5 and Figure 4).

The treatment of the plants with the biostimulants resulted in a lower leaf copper content than in the control plants (Table 5 and Figure 3). The two fertilisers applied to the plants resulted in higher contents of this element than in the control combination. The lowest copper level was found in the leaves of the ‘Gala Schniga’ cultivar, while the highest was found in the ‘Topaz’ cultivar (Table 5 and Figure 4).

Table 5. The contents of micronutrients in the leaves of maiden apple trees.

Micro-Nutrient	Cultivar	Treatment							Average for Cultivar
		Control	Amino Plant	Biamino Plant	Bispeed	Fylloton	Basfoliar 6-12-6	Basoliar 12-4-6+S	
Fe ppm	Gala Schniga	144.4 h	165.6 kl	173.7 m	190.7 o	176.1 mn	125.8 f	119.4 e	156.5 c
	Ligol	101.1 d	168.5 l	195.9 p	164.0 k	178.4 n	131.0 g	85.8 c	146.4 b
	R. Boskoop	199.2 r	241.2 u	225.9 t	268.6 x	219.4 s	263.4 w	152.7 i	224.3 d
	Topaz	82.0 b	129.1 g	160.0 j	131.8 g	147.1 h	71.8 a	79.4 b	114.5 a
	Average for treatment	131.7 b	176.1 d	188.9 f	188.8 f	180.3 e	148.0 c	109.3 a	
Mn ppm	Gala Schniga	26.5 bc	48.6 m–o	43.6 i–l	59.8 s	52.5 p	42.2 h–j	29.0 cd	43.2 c
	Ligol	46.5 l–n	42.4 h–k	41.5 g–i	31.7 d	35.0 e	36.1 ef	44.8 j–l	39.7 b
	R. Boskoop	39.3 gh	45.5 k–m	43.9 i–l	50.8 op	41.2 g–i	51.2 op	25.9 bc	42.5 c
	Topaz	25.0 ab	48.8 no	55.7 r	49.2 no	38.5 fg	25.8 ab	22.7 a	38.0 a
	Average for treatment	34.3 b	46.3 e	46.2 e	47.9 f	41.8 d	38.8 c	30.6 a	
Zn ppm	Gala Schniga	21.1 k	13.3 a	14.9 b	16.1 e	19.7 j	24.4 p	18.8 h	18.3 a
	Ligol	15.3 c	14.8 b	17.5 g	16.5 f	15.9 d	26.5 t	22.4 l	18.4 b
	R. Boskoop	30.7 u	24.4 p	26.6 t	26.1 s	19.1 i	39.3 w	25.4 r	27.4 d
	Topaz	22.6 m	24.2 o	24.1 o	19.6 j	22.9 n	19.1 i	21.0 k	21.9 c
	Average for treatment	22.4 f	19.2 a	20.8 d	19.6 c	19.4 b	27.3 g	21.9 e	
Cu ppm	Gala Schiga	6.6 j	5.0 b	5.0 b	6.1 gh	6.3 i	6.8 k	5.5 e	5.9 a
	Ligol	8.1 m	5.3 cd	5.0 b	4.3 a	5.2 c	9.5 r	8.8 n	6.6 c
	R. Boskoop	6.1 gh	5.7 f	5.4 de	6.0 g	4.4 a	8.7 n	7.1 l	6.2 b
	Topaz	10.0 s	6.9 k	6.2 hi	6.5 j	9.3 p	9.1 o	10.0 s	8.3 d
	Average for treatment	7.7 d	5.7 b	5.4 a	5.7 b	6.3 c	8.5 f	7.9 e	

Data followed by the same letters do not differ significantly at $p = 0.05$ for each micronutrient according to Tukey’s test. The influence of the years was not statistically significant.

Figure 3. A comparison of the contents of micronutrients in the leaves of maiden apple trees depending on the applied foliar treatment. Data followed by the same letters do not differ significantly at $p = 0.05$ for each micronutrient according to Tukey's test.

Figure 4. A comparison of the content of micronutrients in leaves of maiden apple trees depending on the variety used. Data followed by the same letters do not differ significantly at $p = 0.05$ for each micronutrient according to Tukey's test.

4. Discussion

4.1. The Contents of Soluble Forms of Chemicals in Soil

The soil pH decreased when the dose of mineral fertiliser was reduced by half. The results of our experiment were consistent with the observations made by the authors of other studies [28–31], according to which the use of chemical fertilisers can acidify the soil, affecting its microbiological properties, the availability of nutrients, the growth of plant roots, and consequently leading to decreased yields. Grzyb et al. [25] also found that a full dose of mineral fertiliser increased the soil pH in an apple tree nursery as compared with the effect of biopreparations applied into the soil. In our experiment, the lower dose of the mineral fertiliser decreased the salinity of the soil and its contents of S-SO₄, P-PO₄, K, Mg, Na, Zn, and Cu. Filipczak et al. [20] made similar observations to the results of our experiment. They found that the foliar or soil application of biostimulants in a strawberry plantation caused the soil phosphorus content to range from medium to high,

the potassium content from low to high, and the magnesium content from low to medium. The K/Mg ratio was correct in most of the experimental combinations. Grzyb et al. [25] noted similar nitrogen and phosphorus contents in the soil in all experimental combinations. The researchers observed that the full dose of mineral fertiliser and the application of the Florovit Eko and Florovit Pro Natura fertilisers into the soil significantly increased the level of potassium as compared with the effects of fertilisation with biopreparations. This result was consistent with our observations. The experiment conducted by these authors [25] also showed that the high accumulation of potassium in the soil after full mineral fertilisation resulted in a lower content of available forms of magnesium. This dependence was not observed in our experiment.

In our experiment, a lower dose of the mineral fertiliser resulted in lower soil micronutrient contents, except for iron. According to Kleiber et al. [32], low soil nutrient contents (especially micronutrients such as Fe, Cu, Zn, Mn, and B) may be caused by low soil pH and low salinity. These factors may have been the causes of the low contents of most micronutrients in our experiment.

4.2. The Contents of Macro- and Micronutrients in the Leaves of Maiden Apple Trees

Our experiment showed that the biostimulants and foliar fertilisers had diverse effects on the contents of macro- and micronutrients in the leaves of the four cultivars of maiden apple trees in the nursery. According to Świerczyński et al. [24], it is difficult to compare the results of studies on the contents of nutrients in leaves because they depend on various factors, including the compositions of the preparations used, the weather conditions, the soil abundance, as well as the plant species and cultivar. Our experiment showed that the foliar treatment of the maiden apple trees with the fertilisers guaranteed higher contents of nutrients in their leaves than with the use of biostimulants, which resulted in lower levels of most of the nutrients than in the control plants. However, this did not prevent us from obtaining better growth results for the same maiden apple trees than those described in the previous research by the same authors [33]. All of the maiden growth parameters described in this publication obtained from the same experiment after treatment with biostimulants and foliar fertilisers showed higher values than those obtained from the control combination with the full dose of mineral fertilisation. This proves the potential possibility of reducing the mineral fertilisation of the soil while maintaining the expected growth parameters for maiden apple trees in nursery settings. In the conducted experiment, no positive effect of the biostimulants used, even those containing nitrogen such as Aminoplant and Bioamino Plant, was found to increase the content of this element in the leaves. The lack of influence of the tested nitrogen biostimulators on the content of this nutrient in the leaves may be due to the fact that these biostimulators most effectively improved the growth of maiden apple trees, as presented in the previous publication [33]. Nitrogen contained in biostimulants, which is easier for plants to absorb, intensifies their growth. Rathore et al. [15] observed another dependence at a full dose of mineral fertiliser. The researchers found that the soybeans treated with biostimulants had higher contents of N, P, K, and Mg. Likewise, other authors [18,34,35] also observed that the foliar treatment of various plant species with various biostimulants increased the leaf nitrogen content. Garcia et al. [36] observed that the foliar application of a biostimulant containing amino acids, peptides, and nutrients increased the levels of potassium, calcium, magnesium, iron, copper, and zinc in tomato leaves, which improved the growth and development of the plants. Similarly, the foliar application of biostimulants alone or in combination with potassium and zinc increased the levels of N, P, K, Ca, Mg, and Zn in mandarin leaves [37]. Rouphael et al. [38] observed that protein hydrolysates increased the K and Mg contents in spinach leaves, being more effective than the seaweed extract. Abdala [39] observed that the *Moringa oleifera* extract increased the contents of N, P, K, Ca, Mg, and Fe in rocket leaves (*Eruca vesicaria* subsp. *sativa*). On the other hand, Soppelsa et al. [40] applied several biostimulants to strawberry leaves but they did not increase the concentration of macronutrients. According to Filipczak et al. [20], neither the soil nor foliar biostimulants

used in their study had significant influence on the contents of minerals in strawberry leaves. Likewise, Chitu et al. [41] could not confirm the effects of biostimulants on the contents of macronutrients in apple leaves. The differences between the results of our experiment and the findings of other authors' studies on the influence of biostimulants on the contents of minerals in leaves were caused by the fact that only half the dose of the mineral fertiliser was used in our experiment, whereas the other authors used a full dose.

Studies have proven that preparations based on marine algae increase the contents of K, Ca, and Mg in lettuce leaves [42], as well as the contents of N, P, K, Ca, Zn, and Fe in tomato leaves [43]. Similarly, Turan and Köse [18] noted that the foliar treatment of young grapevines with a marine algae extract increased the plants' uptake of N, P, K, Ca, Mg, Fe, Zn, Mn, and Cu. In our experiment, the preparation based on marine algae (Fylotton) did not increase the contents of nutrients in the leaves of the maiden apple trees. However, the concentration of this biostimulator used for the treatment of vegetable crops as recommended by the producer may not be sufficient for fast-growing perennial plants such as maiden apple trees. The increased contents of nutrients after the use of the seaweed extract was attributed to the increased permeability of the cell membrane [44]. According to some authors [45,46], the marine algae extract upregulates the expression of the nitrogen-transporting gene and improves nitrogen detection and auxin transport. Battacharyya et al. [47] observed that the marine algae extract improved nitrogen accumulation. Neither in our experiment nor in a similar experiment [25] did the preparation based on marine algae increase the leaf nitrogen content. None of the foliar treatments resulted in a higher leaf nitrogen content than in the control plants.

In our experiment, the phosphorus level was the same as in the control plants only after the use of one biostimulant, i.e., Aminoplant. Likewise, in another experiment [25] the leaf phosphorus content was similar to the content of this element in the control plants only after one amino-acid-based preparation. On the other hand, Von Bennewitz et al. [48] observed that biostimulants increased the phosphorus content in apple leaves. Many authors [14,15,18] have observed that biostimulants based on seaweed extracts improve the phosphorus uptake by plants. No such dependence was observed in our experiment after the treatment of the plants with the Fylotton product.

None of the biostimulants tested in our experiment increased the leaf potassium content, whereas the marine algae extract decreased the content of this element. Our observation was partly confirmed by the results of the study by Shehata et al. [19], who found that the foliar treatment of celeriac plants with amino acid preparations did not have a significant influence on the leaf potassium content and that the marine algae extract increased the content of this element. Grzyb et al. [25] found that the treatment of maiden apple trees with the Florovit Eko and Pro Natura fertilisers significantly increased the leaf potassium content, whereas biostimulants decreased the level of this element. Likewise, in our experiment the Basfoliar 6-12-6 fertiliser increased the leaf potassium content, which was higher than in the control plants, whereas most of the other biostimulants decreased this content. This may indicate that foliar application of potassium-based fertilisers such as the applied Basfoliar 6-12-6 increases the content of this element in the leaves of plants. Grzyb et al. [25] observed that the high content of potassium in the leaves of maiden cherry trees caused significantly decreased contents of magnesium and calcium. This effect was not observed in our study, because the high potassium content in the leaves of the maiden apple trees mostly did not result in low calcium levels. The leaf magnesium content decreased only in some combinations.

Most of the biostimulants used in our experiment increased the calcium content and decreased the magnesium content in the leaves of the maiden apple trees. The results of our study were different from the findings of another experiment conducted in a nursery [25]. Maini [49] concluded that apple trees could take up calcium better if applied together with a biostimulant. This effect may also have taken place in our experiment.

In our experiment, the following biostimulants had the best effect on the contents of minerals in the maiden apple trees grown in the nursery: Aminoplant (K, Ca, Mg, Mn),

Fylloton (Na, Fe, Zn, Cu), Bispeed (Ca, Fe, Mn), and Biamino Plant (N, Fe, Zn). The Bioamino Plant biostimulant, which contained three micronutrients (Fe, Mn, Zn), increased the contents of two of them (Fe, Mn). Similarly, the two foliar fertilisers applied in our experiment increased the zinc and copper contents in the leaves because they contained these elements. According to Westwood [50], amino acids have a chelating effect. They increase the permeability of the cell membrane and facilitate the absorption and transport of microelements inside plants. In our experiment, this dependence was observed for iron and manganese but not for zinc or copper. Maini [49] observed that the foliar application of the Aminoplant biostimulant increased the uptake of micronutrients and concluded that it could be used with FeSO_4 to combat iron deficiency symptoms. This effect was also observed in our experiment. Soppelsa et al. [40] used several biostimulants and found that they increased the concentrations of some micronutrients (Fe, Zn, and Si). In our experiment, this effect was observed for iron. However, not all of the biostimulants increased the copper content. According to Allen et al. [51], plants react in a specific way to the type of fertiliser applied. Treatment with biostimulants increases the contents of soil minerals and improves the growth and development of plants. This thesis is consistent with the results of other studies [52–56]. In the considered experiment, the foliar treatment of maiden apple trees with biostimulants and fertilisers did not improve their nutritional status in terms of the contents of macronutrients and some micronutrients. However, based on previously published results [33], this did not have a negative impact on their growth.

The maiden apple tree cultivars used in our experiment differed in their leaf contents of macro- and micronutrients. Other authors [24,25,56] also observed species- or cultivar-dependent differences in the effects of the same biostimulants and fertilisers on the nutrition of plants.

5. Conclusions

The half dose of mineral fertiliser resulted in lower soil pH and salinity in the nursery, which undoubtedly improved the soil properties. However, it also reduced the soil abundance of macronutrients and some micronutrients as compared with the full dose of mineral fertiliser. The foliar application of the biostimulants combined with the reduced dose of mineral fertiliser resulted in worse nutrition of the maiden apple trees, which were less abundant in macroelements (except for calcium) and microelements (except for iron and manganese). On the other hand, the use of two fertilisers improved the nutrition of maiden apple trees for some macronutrients (phosphorus, calcium) and micronutrients (zinc, copper) in relation to control plants. Cultivar-dependent differences were observed in the contents of nutrients in the leaves of the maiden apple trees after the foliar treatments. It seems advisable to combine foliar fertilisers with biostimulants, although this requires further research. This will enable a full answer to the question of whether the use of foliar treatments is justified in the production of maiden apple trees, which are an important fruit tree species in Europe.

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