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Impact of Care and Nutrition Methods on the Content and Uptake of Selected Mineral Elements in *Solanum tuberosum*

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Abstract: The aim of the study was to evaluate the content and uptake of macronutrients (P, Ca, Mg, K) in *Solanum tuberosum* tubers and the effect of care with biostimulants from a three-year field experiment conducted at the Agricultural Experimental Station in Zawady, Poland. The experiment was set up in a split-plot arrangement with three replications. The first factor was two varieties of edible potato (Oberon and Malaga), and the second factor was five treatments with herbicide and biostimulants: (I) control facility, (II) herbicide (chlomazone + metribuzin), (III) herbicide and biostimulant PlonoStart, (IV) herbicide and biostimulant Aminoplant, (V) herbicide and biostimulant Agro-Sorb Folium. Biostimulants and herbicide increased the concentration of P, Mg, Ca, and K compared to tubers harvested from the control facility. The Oberon variety had the highest macronutrient uptake capacity. The application of herbicide with biostimulants increased the uptake of the mentioned mineral nutrients compared to the control variant. Climatic conditions affected the content and uptake of selected elements.

Keywords: field experimentation; mineral content; tuber nutritional composition; biotic and abiotic stress

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1. Introduction

The potato (*Solanum tuberosum* L.), owing to its high yields and unique nutritional values, is among the staple crops grown worldwide [1]. Macro- and micronutrients constitute about 1–1.2% of the total content of potato tubers [2,3]. In human nutrition, macroelements are elements whose demand in the diet exceeds 100 mg per day, e.g., phosphorus, calcium, magnesium, and potassium, which are components taken up by plants in relatively large quantities at various stages of development [1]. These elements play mainly building and physiological functions in the plant, and determine the dietary value. Phosphorus is the basic component of compounds that determine energy processes. It is a part of specific proteins and participates in the transformation of carbohydrates. Calcium is considered to be an element conditioning the proper growth and development. Magnesium in the plant determines the basic processes of metabolism and energy, takes part in about 300 enzymatic reactions, and is also the active center of the chlorophyll molecule. Potassium plays an important role in water and ionic management of the organism, therefore in some diseases a potato diet is recommended [2,4]. The chemical composition of potato tubers depends on the cultivar, weather conditions, technology of cultivation, fertilization, harvesting storage conditions, and cropping systems [4–7]. In modern plant cultivation, various plant growth regulators called biostimulants are increasingly used. They are one of the elements of agrotechnics, which, apart from fertilizing and protection plants, can positively affect the size and quality of crops [8–11]. These preparations improve the uptake of nutrients from the soil [12–14], positively affect the intensity of photosynthesis and the course of life processes [15,16], increase the resistance of plants to stress factors such as diseases, high temperature, drought [9,17], and have a positive effect on the chemical composition and yields of plants [6,7,18,19]. So far, six distinct categories of biostimulants have been recognized, including microbial inoculants, humic substances, such as humic and fulvic acids, protein hydrolysates and amino acids, biopolymers, inorganic compounds, and seaweed extracts, all of which are commercially available with wide applications in agriculture [20–23]. The biostimulants can also increase nutrient use efficiency, partly substitute the chemical fertilizer inputs, and ameliorate the yield and quality of crops [24–26]. Foliar fertilization allows one to improve otherwise poor plant nutrition or supplement deficiencies of some bioelements [27,28]. Therefore, the purpose of the study was to determine the effect of the herbicide and selected biostimulants on the content and uptake of phosphorus, calcium, magnesium and potassium with the yield of two edible potato varieties. The research hypothesis regarding the use of herbicide and foliar fertilization with biostimulants was verified in the paper to positively affect the increase in the content of macronutrients in relation to the null hypothesis, suggesting no differences between them in objects where the herbicide is used and foliar fertilization with biostimulants.

2. Materials and Methods

2.1. Plant Growth Conditions and Experimental Design

Field studies were conducted from 2018 to 2020 at the location shown in Figure 1.

Figure 1. The experiment was conducted in Zawady, a town located in Mazowieckie province, Siedlce county, Zbuczyn municipality, Poland.

The experiment was conducted in triplicate in a split-plot arrangement. Soil parameters are shown in Figure 2.

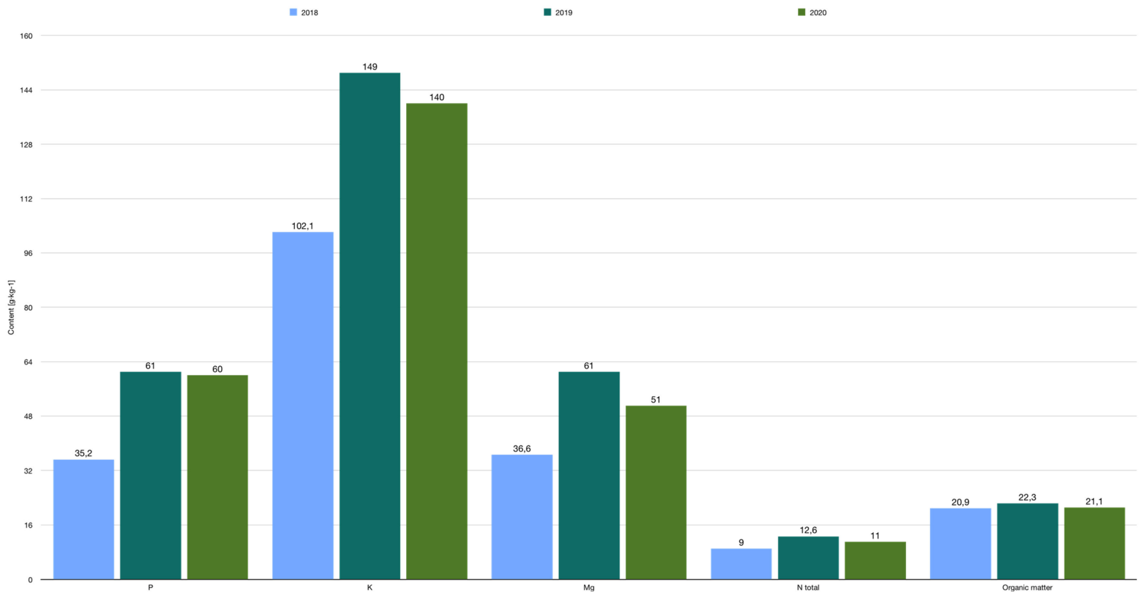

Figure 2. Soil parameters.

The effects of two factors were studied: the yields of Malaga and Oberon potato tubers and the five methods of care given in Table 1.

Table 1. Description of the second factor of the experiment.

No.	Active Substance/Composition	Dose Preparation	Usage
1	* C object mechanical weeding—no preparations were used		
2	** H	1.5 dm^3 ha^{-1}	7–10 days following tuber planting
3	*** H + P (N_{total}—16.4,%, K_2O—0.75%, CaO—0.07%, MgO—0.02%, S—941 mg kg^{-1}, lactic acid bacteria, actinomycetes)	1.5 dm^3 ha^{-1} and 2.0 dm^3 ha^{-1}	herbicide—7–10 days following tuber planting biostimulator twice—end of emergence and rows closure
4	**** H + AP (N_{total}—9.48%, $N_{organic}$—9.2%, N-NH_4—0.88%, $C_{organic}$—25%, free amino acids—11.57%, organic matter—87.7%)	1.5 dm^3 ha^{-1} and 1.5 dm^3 ha^{-1}	just before plants emergence
5	***** H + ASF (N_{total}—2.2%, B—0.02%, Mn—0.05%, Zn—0.09%, total amino acids—13.11%, free amino acids—10.66%)	1.5 dm^3 ha^{-1} and 4.0 dm^3 ha^{-1}	herbicide—just before plants emergence biostimulator twice—end of emergence and rows closure

* C—control, ** H—clomazone + metribuzin *** P—PlonoStart, **** AP—Aminoplant ***** ASF—Agro-Sorb Folium.

Herbicides and biostimulants were dissolved in 300 dm^3 of water per hectare. Other agrotechnical measures that were applied in the experiment are shown in Table 2. At the time of harvest, the yield from a plot of 12.96 dm^3 per hectare was recalculated and tubers were sampled for determination according to the methodology of [28].

Table 2. Treatments used in the experiment.

Agrotechnical Treatments	Specification	Dates
Fertilization	25 t ha^{-1} farmyard manure and mineral fertilizers: 44.0 kg ha^{-1} P (46% TSP triple superphosphate), 124.5 kg ha^{-1} K (60% potash salt), and 100 kg ha^{-1} N (34% ammonium salt)	autumn, spring—before planting
Planting of potato tubers	spacing 0.675 × 0.37 m	the third week of April
Weed control	mechanical weeding and herbicides with biostimulants	after planting to rows closure
Colorado potato beetle control	insecticides: thiamethoxam * at a dose of 0.08 kg ha^{-1}, deltamethrin at a dose of 0.15 dm^3 ha^{-1}, lambdacyhalothrin at a dose of 0.25 dm^3 ha^{-1}, thiacloprid * and deltamethrin at a dose of 0.4 dm^3 ha^{-1}	during vegetation
Late blight control	fungicides: metalaxyl-M + mancozeb * at a dose of 2.0 kg ha^{-1} and mancozeb * at a dose of 2.5 kg ha^{-1}	during vegetation
Harvesting of potato tubers	physiological maturity	first week of September

* substances have been withdrawn by the European Union.

2.2. Chemical Analysis Methods

Chemical analyses were performed in three replications. The dry samples of approximately 0.2–0.3 g were digested with 6 mL HNO_3 and 2 mL HCl. The samples and acid mixture were placed in the rotor and heated in the microwave digestion system. Mineralized samples were diluted to 50 mL with ultra-pure water. The resultant solution was tested by ICP-OES Spectrometer (SpectroBlue).

2.3. Statistical Analysis

Data were statistically tested using variance analysis. Samples were analyzed and variance was performed using the Fisher–Snedecor test. A significant of difference was detected at $p < 0.05$ between the compared averages using multiple Tukey ranges [29].

2.4. Meteorological Conditions

Meteorological conditions from April to September were determined using the Sielianinov coefficient (K), expressed by the formula:

$$K = \frac{\sum total\ precipitation}{0.1 \sum sum\ of\ temperatures}$$

According to the K-factor up to 0.4—extremely dry, 0.41–0.7—very dry, 0.71–1.0—dry, 1.01–1.3—relatively dry, 1.31–1.6 optimal, 1.61–2.0—relatively humid, 2.01–2.5—humid, 2.51–3.0—very humid, above 3.0—extremely humid [30].

According to the analysis presented by Skower et al. [30], 2018 was dry, 2019 was very dry, and 2020 was relatively dry. The comparison of the Sielaninov factor over the experiment is presented in Figure 3.

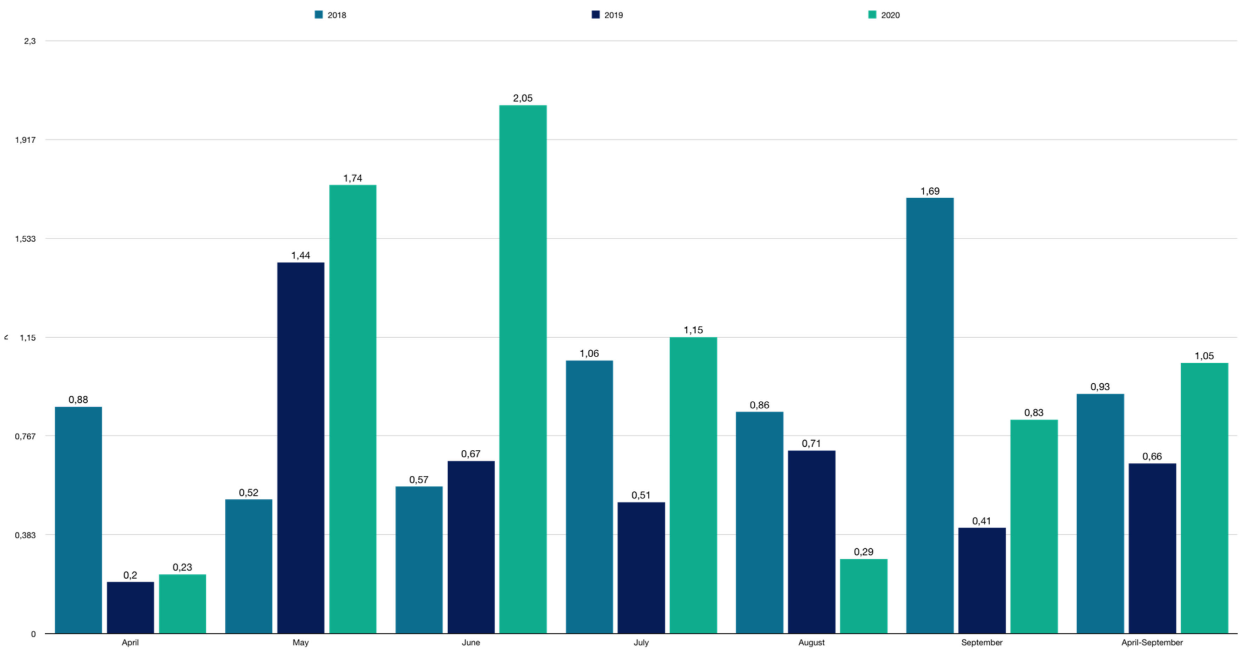

Figure 3. Sielianinov's coefficient.

3. Results and Discussion

3.1. Content and Uptake of Phosphorus in Potato Tubers

Cultivated cultivars Oberon and Malaga had an impact on the content of phosphorus in potato tubers. The majority of this component was accumulated by cultivar Malaga. The applied methods of weed control and feeding with biostimulators increased the content of phosphorus in comparison to the control object. The herbicide Avatar 293 ZC increased the content of phosphorus in potato tubers, and then the biostimulators PlonoStart, Aminoplant, and Agro-Sorb Folium, in combination with the herbicide Avatar 293 ZC, increased the content of phosphorus. Weather conditions influenced the concentration of phosphorus. The most phosphorus was recorded in tubers harvested in 2020, a humid and warm year, in which July and August were characterized by above-average rainfall throughout the season. The analysis of variance did not prove the interaction of years with cultivars, years with care methods, varieties with care methods and years with experience factors (Table 3). Some authors [31,32] proved in their studies that the analyzed herbicides increased the content of phosphorus in comparison to the control object. Others have observed a decrease in phosphorus content under the influence of herbicides [33,34]. The applied fertilization with biostimulators in Bienia et al.'s research [35] caused the phosphorus content in the tubers to significantly increase by the Asahi SL biostimulant, while in the research [35] the application of Fortis Duotop Zn Mn + Fortis Aminotop fertilizers affected the phosphorus content. In the presented study, it was found that the P content of tubers depends on the type of herbicide, as well as on the applied biostimulants and weather conditions affecting the weed infestation of plantations. An evaluation of the weed infestation was performed using the quantitative-weight method about 2 weeks after the application of the treatment methods and before harvesting the potato tubers. The application of herbicide and herbicide with biostimulants showed a positive effect on reducing the number and fresh weight of weeds compared to the control variant [36]. In years characterized by increased moisture, the weed infestation of the plantation increases, and the competitiveness of the plants increases, which may result in lower nutrient content. In our study, after the application of an effective herbicide (Avatar 293 ZC), weed infestation was reduced, which significantly increased the supply of phosphorus to tubers, additionally supported by the biostimulant Agro-Sorb Folium 4. In domestic research, the content of phosphorus in potato tubers was at the level of 1.8–3.9 g kg^{-1} [32,34], and in foreign ones it was usually larger and amounted to 2.2–4.9 g kg^{-1} [37,38]. Potato and other plants take phosphorus, calcium, and magnesium from the soil solution in the cation forms. The number of elements taken up by plants depends on the variety, soil richness in available forms of cations, and on the content of other ions in the soil, in particular. The research has shown that the Malaga variety was characterized by the smallest average phosphorus uptake (17.16 kg ha^{-1}), and the Oberon variety was the highest average uptake of the element (22.69 kg ha^{-1}) with the tuber yield (Table 4). The uptake is the percentage of the element in the tuber multiplied by the tuber dry matter yield. The object with the highest phosphorus uptake capacity was characterized by a mixture of Avatar 293 ZC herbicide and Agro-Sorb Folium4 biostimulant. After application of the Avatar 293 ZC herbicide with the Agro-Sorb Folium 4 biostimulator, the uptake of P with tuber yield was 23.65 kg ha^{-1}. In the analyzed growing seasons, a significant differentiation of phosphorus uptake and tuber yield was found. The highest phosphorus uptake was obtained in 2018, 21.24 kg ha^{-1} (Table 5). This was due to better hydrothermal conditions (Table 3). High humidity (as indicated by the K-factor) in 2018, the months decided for the harvest, July–September, were relatively dry, dry, and relatively humid. Varieties influenced the formation of phosphorus uptake by the yield of tubers in a varied way, as evidenced by the demonstrated interaction of variety 3 years. In 2018, the highest amounts of phosphorus were taken up by potatoes of the Oberon variety 26.78 kg ha^{-1}, a slightly lower intake of this component, but were shown in 2019 by the Malaga variety 18.05 kg ha^{-1} (Figure 4). The Agro-Sorb Folium 4 biostimulator significantly increased the uptake of phosphorus by the tuber yield of the tested cultivars. The phosphorus content is significantly influenced by the cultivar factor, and the applied NPK fertilization did not significantly differentiate this feature [39].

Table 3. Phosphorus in *Solanum tuberosum* (g kg^{-1} D.M.).

Variant	Years			Mean
	2018	2019	2020	
		Oberon		
1. C	2.644	2.641	2.650	2.645
2. H	2.618	2.640	2.642	2.633
3. H + P	2.685	2.653	2.718	2.685
4. H + AP	2.836	2.648	2.819	2.768
5. H + AS	2.899	2.698	2.902	2.833
Mean	2.736	2.656	2.746	2.713
		Malaga		
1. C	2.783	2.653	2.787	2.741
2. H	2.750	2.642	2.753	2.715
3. H + P	2.871	2.682	2.888	2.814
4. H + AP	2.900	2.727	2.903	2.843
5. H + AS	2.911	2.879	2.920	2.903
Mean	2.843	2.717	2.850	2.803
		Mean for varieties		
1. C	2.714	2.647	2.719	2.693 a
2. H	2.684	2.641	2.698	2.674 a
3. H + P	2.778	2.668	2.803	2.750 a
4. H + AP	2.868	2.789	2.861	2.806 a
5. H + AS	2.905	2.789	2.911	2.868 a
Mean	2.790	2.687	2.798	2.758

Means followed by the same letters do not differ significantly at $p \leq 0.05$. Means in columns marked with letters refer to interactions between the factors.

Table 4. Uptake of phosphorus with the of *Solanum tuberosum* (kg ha^{-1} D.M.).

Variant	Years			Mean
	2018	2019	2020	
		Oberon		
1. C	23.86 A	18.24 A	15.80 A	19.30 c
2. H	25.26 A	19.85 A	16.43 A	20.51 c
3. H + P	26.87 A	23.25 A	20.57 A	23.56 b
4. H + AP	27.95 A	22.48 A	19.14 A	23.19 b
5. H + AS	29.98 A	24.78 A	25.84 A	26.87 a
Mean	26.78	21.72	19.56	22.69
		Malaga		
1. C	14.22 A	12.58 A	14.61 A	13.80 c
2. H	15.37 A	18.09 A	15.19 A	16.22 b
3. H + P	16.50 A	19.29 A	17.96 A	17.92 b
4. H + AP	16.37 A	18.56 A	17.44 A	17.46 b
5. H + AS	17.81 A	21.72 A	21.76 A	20.43 a
Mean	16.05	18.05	17.39	17.16
		Mean for varieties		
1. C	19.04	15.41	15.21	16.55 c
2. H	20.32	18.97	15.81	18.37 c
3. H + P	21.69	21.27	19.27	20.74 b
4. H + AP	22.16	20.52	18.29	20.32 b
5. H + AS	23.90	23.25	23.80	23.65 a
Mean	21.24	19.89	18.48	19.87

Means followed by the same letters do not differ significantly at $p \leq 0.05$. Means in columns marked with capital letters refer to interactions between the factors.

Table 5. Calcium in *Solanum tuberosum* (g kg^{-1} D.M.).

Variant	Years			Mean
	2018	2019	2020	
		Oberon		
1. C	0.385	0.325	0.223	0.311
2. H	0.388	0.327	0.234	0.316
3. H + P	0.391	0.331	0.243	0.322
4. H + AP	0.437	0.335	0.264	0.345
5. H + AS	0.447	0.379	0.281	0.369
Mean	0.410	0.343	0.249	0.334
		Malaga		
1. C	0.389	0.331	0.243	0.321
2. H	0.390	0.346	0.256	0.331
3. H + P	0.393	0.352	0.260	0.335
4. H + AP	0.454	0.371	0.260	0.362
5. H + AS	0.460	0.386	0.283	0.376
Mean	0.417	0.357	0.260	0.345
		Mean for varieties		
1. C	0.387	0.328	0.233	0.316
2. H	0.389	0.337	0.245	0.324
3. H + P	0.392	0.342	0.252	0.329
4. H + AP	0.446	0.363	0.262	0.357
5. H + AS	0.454	0.383	0.282	0.373
Mean	0.414 a	0.350 b	0.255 c	0.340

Means followed by the same letters do not differ significantly at $p \leq 0.05$. Means in columns marked with letters refer to interactions between the factors. Means in the last row (followed by lowercase) are for treatments and cultivars and years.

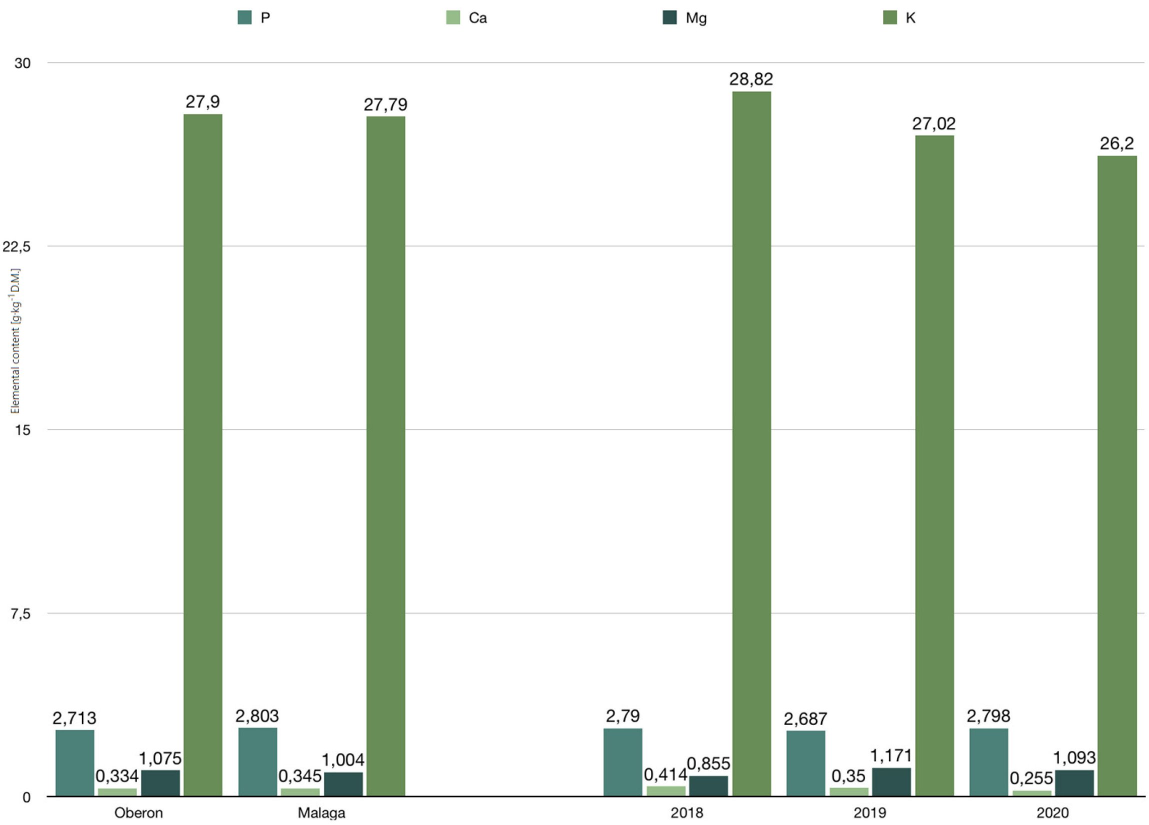

Figure 4. Content of selected macronutrients in varieties (Malaga and Oberon) and years 2018–2020.

3.2. Content and Uptake of Calcium in Potato Tubers

The Malaga variety had a higher average calcium content compared to the Oberon variety. The Avatar 293 ZC herbicide used in the experiment and the same herbicide with biostimulators: PlonoStart, Aminoplant, and Agro-Sorb Folium 4 increased the calcium content in tubers in all the objects (Table 6). The highest average calcium contents were in tubers collected from objects treated with Agro-Sorb Folium 4 biostimulator and Avatar 293 ZC herbicide. (Table 6). In studies [34], significantly higher calcium content was the result of the Asahi SL biostimulator. Studies [35] also confirm the increase in calcium concentration using foliar fertilizers. During the years of the study, weather conditions significantly affected Ca concentration. The highest content and uptake of this element was found in tubers harvested in 2018, which was characterized by a favorable distribution of temperatures and precipitation during the potato vegetation. The lowest concentration and intake of calcium were obtained in 2020 (Figure 4). Meteorological conditions in the years of research had a significant impact on the uptake of calcium by the yield of potato tubers. The average calcium uptake by potato tubers was significantly dependent on the cultivar factor (Table 7). The Oberon cultivar was characterized by the highest calcium uptake capacity with tuber yield. The herbicide biostimulators used in the experiment increased the uptake of calcium on all tested objects (Figure 5).

Table 6. Uptake of calcium in potato tubers (g kg^{-1} dry matter).

Variant	Years			Mean
	2018	2019	2020	
		Oberon		
1. C	3.44 A	2.24 B	1.33 B	2.34 c
2. H	3.75 A	2.47 B	1.45 C	2.56 c
3. H + P	3.91 A	2.91 B	1.87 C	2.90 b
4. H + AP	4.30 A	3.01 B	1.78 C	3.03 b
5. H + AS	4.60 A	3.50 B	2.48 C	3.53 a
Mean	4.00 a	2.83 b	1.78 c	2.87
		Malaga		
1. C	2.00 A	1.56 A	1.28 A	1.61 c
2. H	2.19 A	2.37 A	1.40 B	1.99 b
3. H + P	2.24 A	2.54 A	1.62 B	2.13 b
4. H + AP	2.57 A	2.52 A	1.58 B	2.22 b
5. H + AS	2.80 A	2.92 A	2.11 B	2.61 a
Mean	2.36 a	2.38 a	1.60 b	2.11
		Mean for varieties		
1. C	2.72	1.90	1.31	1.98 b
2. H	2.97	2.42	1.43	2.27 b
3. H + P	3.07	2.72	1.75	2.52 b
4. H + AP	3.44	2.77	1.68	2.63 b
5. H + AS	3.70	3.21	2.30	3.07 a
Mean	3.18 a	2.60 b	1.69 c	2.49

Means followed by the same letters do not differ significantly at $p \leq 0.05$. Means in columns marked with capital letters refer to interactions between the factors. Means in the last row (followed by lowercase) are for treatments and cultivars and years.

Table 7. Magnesium in *Solanum tuberosum* (g kg^{-1} D.M.).

Variant	Years			Mean
	2018	2019	2020	
		Oberon		
1. C	0.846 A	1.155 B	1.129 A	1.043 a
2. H	0.857 A	1.186 B	1.147 A	1.063 a
3. H + P	0.879 A	1.195 B	1.151 A	1.075 a
4. H + AP	0.880 A	1.212 B	1.161 A	1.084 a
5. H + AS	0.893 A	1.258 A	1.174 A	1.108 a
Mean	0.871	1.201	1.152	1.075
		Malaga		
1. C	0.822 A	0.983 B	0.931 C	0.912 b
2. H	0.827 A	1.154 A	1.005 B	0.995 b
3. H + P	0.832 A	1.163 A	1.013 B	1.003 b
4. H + AP	0.850 A	1.193 A	1.098 A	1.047 a
5. H + AS	0.859 A	1.214 A	1.125 A	1.066 a
Mean	0.838	1.141	1.034	1.004
		Mean for varieties		
1. C	0.834	1.069	1.030	0.978 b
2. H	0.842	1.170	1.076	1.029 a
3. H + P	0.856	1.179	1.082	1.039 a
4. H + AP	0.865	1.203	1.130	1.066 a
5. H + AS	0.876	1.236	1.150	1.087 a
Mean	0.855 c	1.171 a	1.093 b	1.040

Means followed by the same letters do not differ significantly at $p \leq 0.05$. Means in columns marked with capital letters refer to interactions between the factors. Means in the last row (followed by lowercase) are for treatments and cultivars and years.

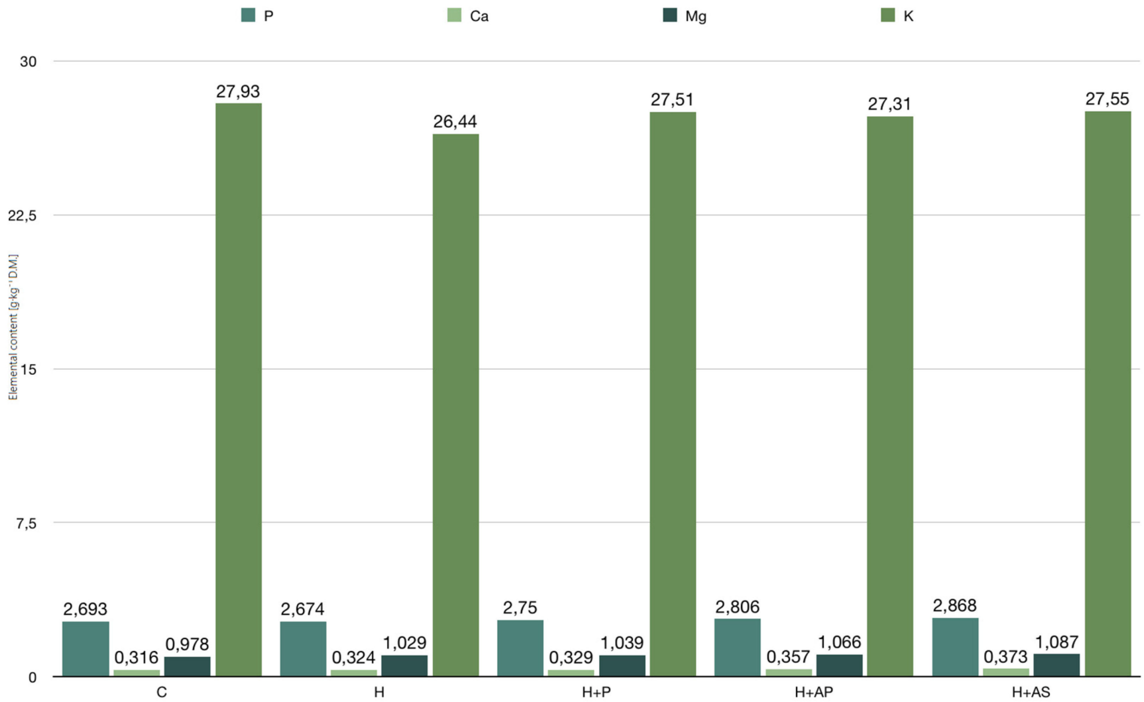

Figure 5. Content of selected macronutrients in the variants of the experiment.

3.3. Content and Uptake of Magnesium in Potato Tubers

The content of magnesium in tubers significantly depended on the cultivars, methods of herbicide and biostimulator application, and weather conditions in the years of the study (Table 8). The highest average content of magnesium was obtained in the Oberon variety. Other researchers found a significant influence of genetic factors on magnesium levels in potato tubers (Figure 4). The range of 0.8–1.1 g kg^{-1} [35,39] is most often given in the domestic literature, and even 5–10 g kg^{-1} [40] in the foreign literature. The tubers from the treatments treated with herbicide and biostimulators (objects 2–5) were characterized by a higher content of magnesium in relation to the control treatment. Studies that have been conducted indicate that the application of fertilizers can increase yields [41]. The highest amount of this element was recorded in tubers harvested from plots sprayed with Avatar 293 ZC herbicide and Agro-Sorb Folium 4 biostimulator (Figure 5). Tubers of the Oberon and Malaga cultivars accumulated the most magnesium in 2019 (Figure 4). The cultivars accumulated the least of this element in 2018, which was the most diverse in terms of moisture content. The interaction of years and methods of care, years, and experience factors was not demonstrated. The proven interaction of cultivars with herbicide and biostimulant application methods stems from the different response of cultivars in terms of magnesium content to herbicide and biostimulants applied (Table 9).

Table 8. Uptake of magnesium in potato tubers (g kg^{-1} dry matter).

Variant	Years			Mean
	2018	2019	2020	
		Oberon		
1. C	7.65 A	7.99 A	6.73 A	7.46 e
2. H	8.28 A	9.00 A	7.13 A	8.14 d
3. H + P	8.74 B	11.69 A	8.82 B	9.75 b
4. H + AP	8.68 B	10.27 A	7.89 B	8.95 c
5. H + AS	9.21 B	11.51 A	10.43 A	10.38 a
Mean	8.51	10.09	8.20	8.93
		Malaga		
1. C	4.19 A	4.68 A	4.87 A	4.58 d
2. H	4.63 B	7.89 A	5.50 B	6.01 c
3. H + P	4.76 C	8.33 A	6.31 B	6.47 b
4. H + AP	4.80 C	8.12 A	6.60 B	6.51 b
5. H + AS	5.21 B	9.16 A	8.39 A	7.59 a
Mean	4.72	7.64	6.33	6.23
		Mean for varieties		
1. C	5.92	6.34	5.80	6.02 b
2. H	6.46	8.45	6.32	7.07 a
3. H + P	6.75	10.01	7.57	8.11 a
4. H + AP	6.74	9.20	7.25	7.73 a
5. H + AS	7.21	10.33	9.41	8.99 a
Mean	6.62 b	8.86 a	7.27 b	7.58

Means followed by the same letters do not differ significantly at $p \leq 0.05$. Means in columns marked with capital letters refer to interactions between the factors. Means in the last row (followed by lowercase) are for treatments and cultivars and years.

Table 9. Potassium in *Solanum tuberosum* (g kg^{-1} D.M.).

Variant	Years			Mean
	2018	2019	2020	
		Oberon		
1. C	30.55	27.89	26.53	28.32 a
2. H	28.18	27.21	25.48	26.96 b
3. H + P	30.27	27.29	26.32	27.96 a
4. H + AP	30.28	27.41	26.33	28.01 a
5. H + AS	30.44	27.83	26.48	28.25 a
Mean	29.94	27.53	26.23	27.90
		Malaga		
1. C	29.49	26.71	26.41	27.54 a
2. H	26.19	25.94	25.61	25.91 a
3. H + P	28.06	26.88	26.40	27.11 a
4. H + AP	27.20	26.61	26.05	26.62 a
5. H + AS	27.57	26.60	26.33	26.83 a
Mean	27.70	26.51	26.16	26.79
		Mean for varieties		
1. C	30.02	27.30	26.47	27.93 a
2. H	27.19	26.58	25.55	26.44 a
3. H + P	29.17	26.99	26.36	27.51 a
4. H + AP	28.74	27.01	26.19	27.31 a
5. H + AS	29.01	27.22	26.41	27.55 a
Mean	28.82 a	27.02 b	26.20 b	27.35

Means followed by the same letters do not differ significantly at $p \leq 0.05$. Means in columns marked with letters refer to interactions between the factors. Means in the last row (followed by lowercase) are for treatments and cultivars and years.

3.4. Content and Uptake of Potassium in Potato Tubers

The potassium content in tubers significantly depended on cultivars, herbicide and biostimulator application methods, and weather conditions in the years of the study (Table 9). The highest average content of potassium was obtained in the Oberon variety (Figure 4). The application of the herbicide Avatar 293 ZC and the herbicide with biostimulators: PlonoStart, Aminoplant, and Agro-Sorb Folium 4 caused a decrease in potassium in potato tubers of the Oberon and Malaga cultivars compared to the control (Figure 5). Studies [35] also report a decrease in potassium after applying foliar fertilizers. Meteorological conditions significantly differentiated the content of potassium in the dry matter of tubers. The tubers accumulated most of this component in the warm and humid year of 2018, and the least in 2020. There was no interaction of years and methods of care, years and factors of the experiment, and varieties with methods of herbicide and biostimulant application. Between potato varieties, there are large differences between calcium and potassium contents [42,43]. The potassium content in the experiments compared to literature data [34,35] was at a similar level and amounted to 27.35 g kg^{-1}. The Oberon variety had the highest potassium uptake capacity with tuber yield. The herbicide Avatar applied in the experiment with the biostimulant Agro-Sorb Folium 4 significantly increased the uptake of potassium in all the tested objects. The highest concentration of potassium was obtained in 2018 (Figure 4). It was a wet year with the highest air temperature. The lowest calcium concentration and uptake was obtained in 2020, which was characterized by excessive precipitation compared to the perennial average and was the coolest compared to the other growing seasons (Table 10).

Table 10. Uptake of potassium in potato tubers (g kg^{-1} dry matter).

Variant	Years			Mean
	2018	**2019**	**2020**	
		Oberon		
1. C	276.2	193.0	157.9	209.03 c
2. H	272.5	205.5	158.5	212.17 c
3. H + P	301.2	238.0	200.8	246.67 b
4. H + AP	298.3	232.6	178.7	236.53 b
5. H + AS	314.9	257.0	236.0	269.30 a
Mean	292.6	225.2	186.4	234.73
		Malaga		
1. C	150.2	126.9	138.3	138.47 c
2. H	146.6	177.2	141.3	155.03 b
3. H + P	161.3	192.0	164.2	172.50 b
4. H + AP	153.6	181.2	156.2	163.67 b
5. H + AS	166.6	200.2	196.5	187.77 a
Mean	155.7	175.5	159.3	163.50
		Mean for varieties		
1. C	213.2 A	160.0 B	148.1 B	173.77 b
2. H	209.6 A	191.4 A	149.9 B	183.63 b
3. H + P	231.3 A	215.0 A	182.5 A	209.60 a
4. H + AP	226.0 A	206.9 A	167.5 B	200.13 a
5. H + AS	240.1 A	228.6 A	216.3 A	228.33 a
Mean	224.1 a	200.4 b	172.9 c	199.13

Means followed by the same letters do not differ significantly at $p \leq 0.05$. Means in columns marked with capital letters refer to interactions between the factors. Means in the last row (followed by lowercase) are for treatments and cultivars and years.

4. Conclusions

The content of mineral components (P, Ca, Mg, and K) in the tubers depended on the variety, care, and nutrition and meteorological conditions. The Malaga variety accumulated the most P and Ca, while the Oberon variety accumulated Mg and K. Herbicide and applied biostimulants with the same herbicide increased the concentration of the tested macronutrients (P, Mg, and Ca) and decreased K compared to tubers harvested from the control object. The highest amount of minerals was found in potatoes after application of the biostimulant Agro-Sorb Folium 4 together with the herbicide Avatar 293 ZC, which suggests that Agro-Sorb Folium 4 is a stimulator of the accumulation of phosphorus, calcium, and magnesium. In the conducted studies, the uptake of macroelements was affected by the cultivars, the method of application of the herbicide with biostimulants, and the climatic conditions in the years of the study. The Oberon variety was characterized by the highest macronutrient uptake capacity with tuber yield in relation to the Malaga variety, which also resulted from the highest yielding of this variety. The application of herbicide with biostimulants increased the uptake of all tested elements (P, Ca, Mg, K) compared to the control, and the highest values were recorded after the application of Avatar 293 ZC with Agro-Sorb Folium 4. Their content and uptake were affected by weather conditions. The highest P, Mg, and K content and uptake with tuber yield were found in the warm and humid year of 2018, while the highest amount of Ca in tubers was determined in 2019, which was the most variable in terms of humidity.

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