


Article

Effect of Biostimulants on the Yield and Quality of Selected Herbs

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Abstract: The aim of this study was to determine the effect of amino acid biopreparations on the yield of summer savory, marjoram, and lemon balm, and the concentrations of selected biochemical and mineral compounds in their herbage. The first experimental factor was plant species: summer savory (*Satureja hortensis* L.) var. *Saturn*, marjoram (*Origanum majorana* L.) var. *Miraż*, and lemon balm (*Melissa officinalis* L.). The second experimental factor was the effect exerted by two biopreparations, Calleaf Aminovital and Maximus Amino Protect, on herbage yield and quality. In the control treatment, plants were sprayed with water. The analyzed herb species differed considerably in yield and the concentrations of selected biochemical compounds and minerals. Lemon balm was characterized by the highest yield (1.73 kg m⁻²). Marjoram var. *Miraż* was characterized by the highest concentrations of reducing sugars (0.89 g 100 g⁻¹ FM) and L-ascorbic acid (39.7 mg 100 g⁻¹ FM). Summer savory was most abundant in total N, K, and Ca. The tested biostimulants contributed to a decrease in nitrate concentrations in the studied plants. The interaction between the experimental factors significantly affected the content of nitrates and mineral compounds and total N, P, K, and Ca in the herbage of the analyzed plant species.

Keywords: plant growth regulators; plant properties; biochemical compounds; mineral compounds; crop quality



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1. Introduction

The improvement of human health is a priority for many individuals dealing with food, including herb, vegetable, and fruit growers. Mineral elements play an important role in healthy growth and development, help maintain fitness, and prevent infections [1]. Among crops, herbs are valuable sources of readily absorbable mineral substances [2,3]. Herbs have gained popularity among consumers due to their medicinal properties and unique aroma [4]. As a source of biologically active substances, bioavailable micronutrients, and macronutrients, herbs can also be used in the prevention and treatment of many fungal diseases. The high bioavailability and optimal ratios of nutrients have contributed to the growing demand for plant raw materials [4–8]. The Polish market offers a wide range of herbs and spices. However, despite their medicinal properties, they are used mostly for culinary purposes, to enhance the taste, aroma, color, and appearance of dishes [9]. Summer savory (*Satureja hortensis* L.), marjoram (*Origanum majorana* L.), and lemon balm (*Melissa officinalis* L.) are well-known and highly valued species of the family *Lamiaceae*. Their herbage is used in both fresh and dried forms. In Poland, these herbs are used mostly to flavor foods and beverages [9]. The leaves of summer savory and marjoram have antiseptic, anti-inflammatory, analgesic, antioxidant, and antimicrobial properties. Lemon balm also exerts calming and antidepressant effects [4,8,10,11].

The chemical composition and nutrient content of the herbage of medicinal plants are determined by genetic and environmental factors [6]. According to Gugafa et al. [12], inte-

grated plant production technologies are insufficient to utilize the full biological potential of herb species due to the poor absorption of nutrients by leaves and difficult transport through plant tissues during periods of climatic or biotic stress. The increased consumption of organic herbs and spices in fresh form has contributed to the development of new cultivation methods. These new methods aim to optimize the growth and development of plants [11,13–16]. Amino acid biostimulants can counteract adverse environmental effects. Amino acids are the building blocks of proteins, and their supply decreases energy expenditure for nitrogen (N) synthesis [17]. According to Trawczyński [18], Maciejewski et al. [9], and Sawicka et al. [19], biostimulants support biochemical, morphological, and physiological processes in plants. Biostimulants promote the vegetative growth of herbaceous plants. Amino acid biostimulants available on the market enhance enzyme activity in plants and improve their stress tolerance.

Therefore, the research hypothesis postulates that the tested biostimulants may have a positive effect on the morphological traits and yield of herbs. Biostimulants are expected to increase the content of selected compounds as well as macronutrients and micronutrients in herbal raw material. In view of the above, the objective of this study was to determine the effect of amino acid biopreparations on the morphological traits and yield of summer savory var. *Saturn*, marjoram var. *Miraż*, and lemon balm, and the concentrations of selected nutrients and chemical elements in their herbage.

2. Materials and Methods

2.1. Study Site and Experimental Factors

The experiment was conducted in a heated greenhouse equipped with movable flood tables, at the University of Warmia and Mazury in Olsztyn (20°29' E, 53°45' N; 125 m a.s.l.), between 28–30 April and 30 June 2017–2018. The experiment had a randomized block design with three replications. The first experimental factor was plant species: summer savory (*Satureja hortensis* L.) var. *Saturn*, marjoram (*Origanum majorana* L.) var. *Miraż*, and lemon balm (*Melissa officinalis* L.) (Seed Company W. Legutko, Nad Stawem, Poland). The herbs selected for the study are most widely cultivated in Poland. The second experimental factor was the effect exerted by two biopreparations, Calleaf Aminovital (Calfert[®], Warsaw, Poland), and Maximus Amino Protect (Ekoplön, Grabki Duże, Poland). The products were used in diluted form.

Caleaf Aminovital (according to the product label) is an organic foliar fertilizer in liquid form, with an amino acid-balanced composition, which contains large amounts of polypeptides and free amino acids. The product is obtained in the process of the hydrolysis of natural proteins.

Maximus Amino Protect (according to the product label) is a combination of free amino acids, peptides, and potassium phosphate, which has strong biostimulatory and antistress effects. Potassium phosphite stimulates the immune system of plants and prevents fungal diseases. Peptides improve the biological effectiveness of the fertilizer—they support the active uptake and penetration of micronutrients and plant protection products. It is practically advisable to use this fertilizer as an addition to treatments against fungi attacking plants (fungicide treatments), as it significantly improves the effectiveness of these treatments. In the control treatment, plants were sprayed with water.

In 2017–2018, in the last days of April, 10 seeds of each herb species were sown in 0.7 dm³ pots. Each treatment consisted of 64 pots and had an area of 1 m². The experiment was performed in triplicate. The horticultural substrate used in the experiment was characterized by salt concentration of 1.5 g dm⁻³, pH 5.9, and the following chemical composition: N-NO₃—112 mg dm⁻³, P—80 mg dm⁻³, K—143 mg dm⁻³, Ca—1240 mg dm⁻³, and Mg—383 mg dm⁻³. Crop protection chemicals were not applied. Yellow sticky traps were placed over the pots to control the number of pests (*Trialeurodes vaporariorum* and *Sciara militaris*). *Encarsia formosa* (three individuals per m²) were used for the biological control of *Trialeurodes vaporariorum*. Leaves were harvested at maturity.

2.2. Greenhouse Microclimate Conditions

Greenhouse microclimate conditions were modified to meet the needs of plants in different growth stages [20]. The microclimate was controlled by a climate computer, and temperature parameters were manually adjusted. The temperature was maintained at 24 °C during seed germination. To increase air humidity, the pots were covered with non-woven fabric. The non-woven fabric was removed after the seeds had germinated. At the same time, the temperature was lowered to 20 °C during the day and 18 °C at night. During the growing season, cultivation measures were limited to plant watering and pruning at 5 weeks after sowing to promote growth.

The biostimulants were applied three times, at 14-day intervals, beginning at 2 weeks after seedling emergence, at a dose of 0.3%. The doses given in amounts per ha were diluted in water at 500 L ha⁻¹. In order to prepare a smaller amount of working solution, the recommended dose was adjusted proportionally. Plants were supplied with water from the water mains.

2.3. Harvest and Yield of Herbs

A once-over harvest of herbage was carried out. The plants were cut manually, 1.5 cm above the ground, in the vegetative growth stage. Plant height and plant weight per pot were determined, and average samples of herbage were collected from marketable yield in each treatment. Plant height was measured using a 1 m ruler. Fresh weight was determined using the Radwag PST 750 R2 digital balance (Radwag, Radom, Poland). The weight and height of fresh herbs were determined separately for each pot. The results were then summed up and averaged. Marketable yield was identical to total yield.

2.4. Chemical Analysis of Herbs

Immediately after cutting and weighing the herbs, all plant material was dried. The herbs were dried for 12 h at 45 °C in a Binder Avantgarde Line laboratory dryer with air circulation. Herbage samples were analyzed to determine the content of selected biochemical compounds. The chemical composition of herbage was analyzed by determining the content of air-dry matter and dry matter (DM) by drying the samples at 105 °C to a constant weight [21] in a Pol-Eko Aparatura SLW 535 SD laboratory dryer. To calculate the percentage of DM in air-dried samples, the weight of the sample after drying was divided by the weight of the sample before drying and multiplied by 100. All herb samples were weighed in containers (in duplicate). The containers were placed in an oven at 60 °C for 72 h. The containers were re-weighed and the weight of the samples was determined. Weight loss is an indicator of the amount of water and DM.

Total sugars and reducing sugars were determined as described by Luff-Schoorl [22], L-ascorbic acid was determined by the method proposed by Tillmans and modified by Pijanowski [23], and total acidity [24] and nitrates (V) were determined colorimetrically with the TECHCOMP UV2310II spectrometer, using salicylic acid [25].

The concentrations of macronutrients were determined in dry and wet mineralized plant materials in three replications. Plants were dried for 24 h at 65 °C in a Binder ED400 dryer (Binder GmbH, Tuttlingen, Germany), and were ground in a Grindomix GM300 knife mill (Retsch GmbH, Haan, Germany). To determine macronutrient content, herbage samples were wet mineralized in H₂SO₄ with the addition of H₂O₂ as the oxidizing agent, using the SpeedDigester K-439 unit (Büchi Labortechnik AG, Flawil, Switzerland). To determine micronutrient content, herbage samples were wet mineralized in a mixture of HNO₃ + HClO₄ + HCl using a CEM Mars 5 Digestion Oven (CEM Corporation, Matthews, NC, USA).

Herbage samples were analyzed to determine the content of total nitrogen (N_{total}) by the Kjeldahl method, phosphorus (P) by the colorimetric method (UV-1201V spectrophotometer, Shimadzu Corporation Kyoto, Tokyo, Japan), potassium (K) and calcium (Ca) by atomic emission spectrometry (AES) (Flame Photometers, BWB Technologies Ltd.,

Newbury, UK), and magnesium (Mg) by atomic absorption spectrometry (AAS) (AASIN, Carl Zeiss Jena, Jena, Germany).

2.5. Statistical Analysis

The results were presented as means for the years of study since only minor differences were noted. A two-way analysis of variance (ANOVA) was performed to determine significant differences between each treatment and the control treatment for both experiments. The differences between treatment means were pooled by Tukey's test at a 0.05 probability level. The analysis was performed using SAS (Statistical Analysis System) software, ver. 12 (TIBCO Software Inc. Statistica, Paolo Alto, CA, USA).

3. Results and Discussion

Differences in the growth rate and yields of the analyzed herb species are presented in Table 1 and Figure 1. Lemon balm was characterized by the significantly highest fresh herbage weight per pot (27.8 g). At the time of harvest, summer savory plants were the tallest, and marjoram plants were the shortest. The use of the Maximus Amino Protect biostimulant in the cultivation of the tested plant species has a positive effect on the height and weight of plants, increasing them by 3.4% and 1.4%, respectively, on average. When applied in small concentrations, these substances enhance nutrition efficiency, abiotic stress tolerance, and/or crop quality traits, regardless of their nutrient content. Exogenously applied biostimulants have a similar mode of action to that of plant hormones such as auxins, gibberellins, and cytokinins [26]. Similar results can be obtained by cultivating garden savory [10] and bell peppers [27] at different rates of nitrogen–potassium fertilizers. According to El-Gohary et al. [28], NPK and amino acids have a pronounced effect on all tested parameters (fresh and dry herbage of *Satureja hortensis* L., essential oil content and its constituents).

The use of an appropriate biostimulant can improve the vitality of roots and shoots, thus increasing crop yields. The total fresh herbage yield was 1.07 kg m⁻² (*Satureja hortensis* L.), 1.35 kg m⁻² (*Origanum majorana* L.), and 1.73 kg m⁻² (*Melissa officinalis* L.) on average. Crop yield is significantly affected by the cultivated species. The obtained results corroborate the findings of other authors, indicating that plants characterized by different growth rates of aboveground and underground organs may differ in the yield of edible parts [10,15].

There are differences in the chemical composition of the analyzed herb species (Table 2, Figure 2). According to other authors, DM content is highest in marjoram (20.4%), savory, lemon balm, hyssop, and chervil (16.4% on average), and lowest in basil and tarragon (12.9% on average) [29]. Fresh herb species tested in this experiment had a relatively low DM content ranging from 12.2% in *Satureja hortensis* L. to 16.3% in *Origanum majorana* L. Biostimulants had no significant effect on the DM content of the analyzed herbs. Similar DM content was reported by Nurzyńska-Wierdak and Zawislak [30] with 9.4% on average in sweet basil and lemon balm, Kazimierczak et al. [13,31] with 22.1 to 26.0% in lemon balm, and Nurzyńska-Wierdak et al. [15] with 13.5 to 17.4% in lemon balm and 11.9 to 17.1% in marjoram, depending on the sowing date and pot size. In a study by Telesiński et al. [32], summer savory and marjoram had higher DM contents (21.4% and 30.3%, respectively).

Table 1. *p*-Value of ANOVA for plant height, fresh herbage weight, and yield in the analyzed herb species.

Factor	Plant Height	Fresh Herbage Weight per Pot	Yield
Treatment (A)	0.922	0.991	0.991
Species (B)	<0.001	<0.001	<0.001
Interaction (A × B)	0.834	0.351	0.351

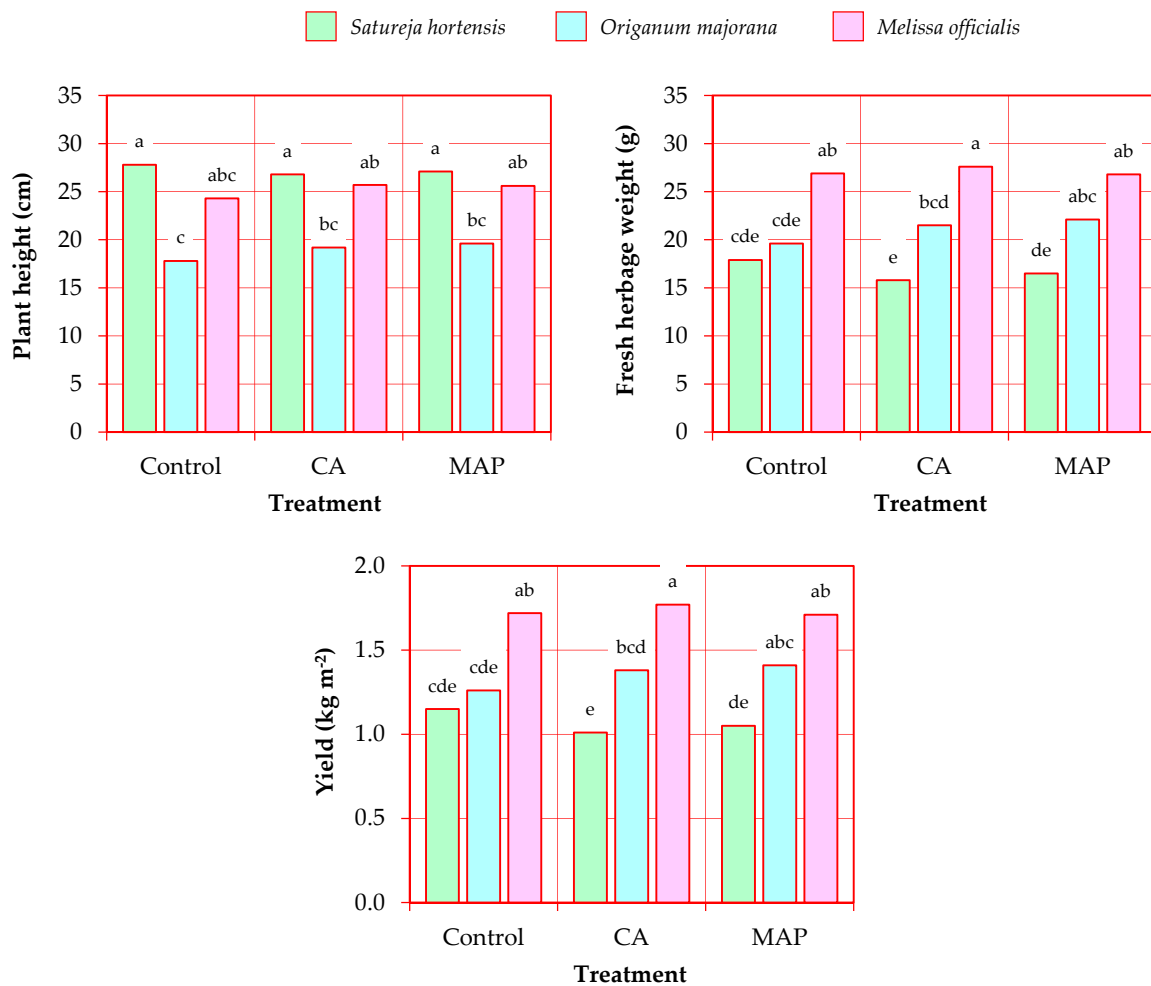


Figure 1. Effect of biostimulants on plant height, fresh herbage weight, and yield in the analyzed herb species: a–e—various letters denote significant differences at $p < 0.05$ (Tukey’s test); CA—application of Calleaf Aminovital; MAP—application of Maximus Amino Protect.

Table 2. p -Value of ANOVA for the nutrient composition of herbage in the analyzed herb species.

Factor	c_{dm}	c_{ts}	c_{rs}	c_O	c_L	c_N
Treatment (A)	0.061	0.381	0.791	0.379	0.803	<0.001
Species (B)	0.096	0.887	<0.001	0.324	<0.001	0.016
Interaction (A × B)	0.520	0.340	0.145	0.325	0.318	<0.001

c_{dm} —Dry matter content, c_{ts} —total sugar content, c_{rs} —reducing sugar content, c_O —organic acid content, c_L —L-ascorbic acid content, c_N —nitrate (V) content.

There were no statistically significant differences in the content of total sugars and reducing sugars between the tested herb species; the content of total sugars ranged from 0.52 to 1.61 g 100 g⁻¹ FM, and the content of reducing sugars ranged from 0.31 to 1.01 g 100 g⁻¹ FM. The concentrations of total sugars and reducing sugars were the highest in marjoram herbage and the lowest in summer savory herbage. Nurzyńska-Wierdak et al. [15] reported similar concentrations of total sugars and reducing sugars, i.e., 0.56–1.49 and 0.25–0.32 g 100 g⁻¹ FM, respectively, in lemon balm, and 0.93–1.00 and 0.17–0.42 g 100 g⁻¹ FM, respectively, in marjoram.

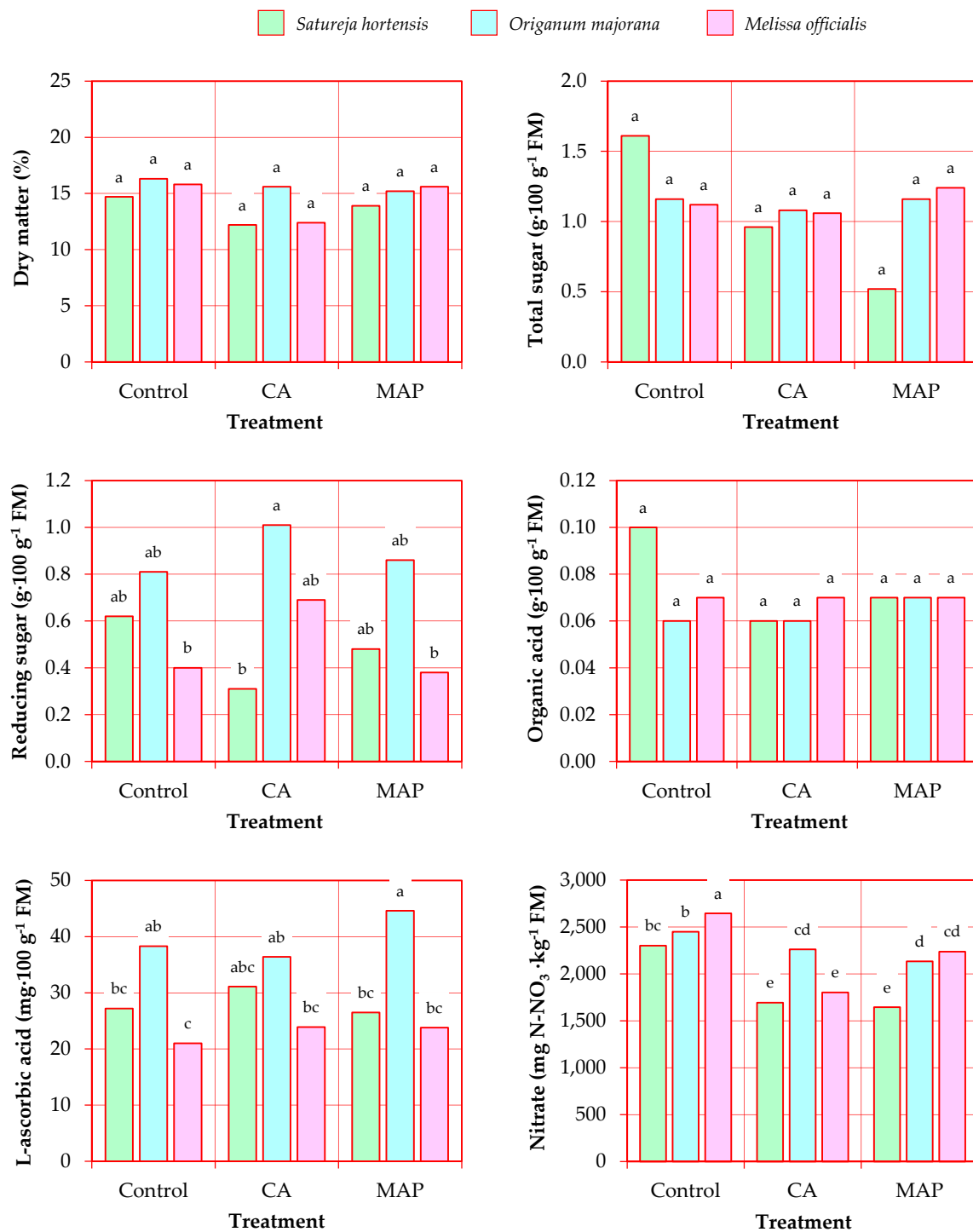


Figure 2. Effect of biostimulants on the nutrient composition of herbage in the analyzed herb species: a–e—various letters denote significant differences at $p < 0.05$ (Tukey's test); CA—application of Calleaf Aminovital; MAP—application of Maximus Amino Protect.

According to Frąszczak et al. [33], the concentration of L-ascorbic acid in herbs is significantly affected by the species and cultivation method. In the present study, marjoram was characterized by the highest concentration of L-ascorbic acid ($39.7 \text{ mg } 100 \text{ g}^{-1} \text{ FM}$ on average). The L-ascorbic acid content of the herbage was not significantly modified by the biostimulants. The concentration of L-ascorbic acid increased in marjoram treated with Maximus Amino Protect ($44.6 \text{ mg } 100 \text{ g}^{-1} \text{ FM}$), whereas it was significantly lower in lemon balm in all treatments and in summer savory in the control treatment and in the treatment

with Maximus Amino Protect. Similar L-ascorbic acid concentrations were determined by Kazimierczak et al. [31] in lemon balm (32.1–76.3 mg 100 g⁻¹ FM depending on the cultivation method), and Nurzyńska-Wierdak et al. [15] (9.8–79.4 mg 100 g⁻¹ FM in lemon balm and 23.6–74.5 mg 100 g⁻¹ FM in marjoram). In a study by Frąszczak et al. [33], the L-ascorbic acid content of lemon balm herbage ranged from 4.2 to 5.3 mg 100 g⁻¹ FM.

The concentrations of organic acids in the analyzed herb species were not significantly affected by the experimental factors or their interaction. Summer savory herbage harvested in the control treatment had the highest organic acid content (0.10 g 100 g⁻¹ FM). The concentration of organic acids was the lowest (0.06 g 100 g⁻¹ FM) in summer savory and marjoram treated with Calleaf Aminovital.

According to Commission Regulation (EU) No. 1881/2006 of 19 December 2006 [34], which set the maximum levels for certain contaminants in foodstuffs, the maximum nitrate levels in lettuce plants grown in a greenhouse and in the field are 3500–4500 N-NO₃ kg⁻¹ FM and 2500–4000 N-NO₃ kg⁻¹ FM, respectively. Such standards have not been established for herbs and spices. In the current study, the nitrate content of herbage in the analyzed herb species was relatively low. Proper plant nutrition promotes good plant development and growth, as well as an adequate circulation of matter and the reduction of harmful residues. Nitrate levels were significantly affected by herb species, ranging from 1880 N-NO₃ kg⁻¹ FM in summer savory herbage to 2282 N-NO₃ kg⁻¹ FM in marjoram herbage on average. The use of Calleaf Aminovital and Maximus Amino Protect in the cultivation of spice plants reduced the accumulation of nitrates. The average differences were 22.8% and 18.7%, respectively, relative to control treatment plants. An analysis of the interaction between the experimental factors revealed that the significantly highest amounts of nitrates were accumulated in lemon balm in the control treatment (2646 N-NO₃ kg⁻¹ FM) and the lowest amounts were in summer savory treated with Maximus Amino Protect (1646 N-NO₃ kg⁻¹ FM). Telesiński et al. [32] reported similar nitrate levels in summer savory (1700 N-NO₃ kg⁻¹ FM).

Macronutrients play important functions in the body, including the regulation and maintenance of the acid–base balance. The daily requirement for these ingredients is over 100 mg. The mineral status of plants is important not only for the nutritional value of food, but also for the growth, development, and yielding of crops [1]. Plants are exposed to the influence of adverse environmental factors, which are known as abiotic stresses, excessive soil salinity, and the absence of mineral salts [3]. The concentrations of selected macronutrients in the analyzed herb species are presented in Figure 3. Herb species had a significant effect (Table 3, Figure 3) on total N content (14.4 g kg⁻¹ DM on average). Summer savory herbage was characterized by the significantly highest total N content (18.5 g kg⁻¹ DM on average). Maximus Amino Protect had a positive influence on total N levels in the examined herb species, which reached 16.1 g kg⁻¹ DM on average. However, the observed differences are not statistically significant. The total N content of summer savory treated with Maximus Amino Protect was significantly higher (24.8 g kg⁻¹ DM) than in the remaining treatments. Lower total N concentrations were noted in lemon balm herbage in all treatments, and in summer savory treated with Calleaf Aminovital. Different total N levels were reported by Seidler-Łożykowska et al. [35]—2.5–3.8% in summer savory and 2.0–2.6% in marjoram, depending on the cultivation method. Dzida and Jarosz [36] found that the total N content of summer savory herbage ranged from 2.9 to 4.5% DM, depending on fertilization. In the experiment conducted by Skubij et al. [3], nitrogen rate and plant growth stage had a significant effect of the total nitrogen content of summer savory var. *Saturn*.

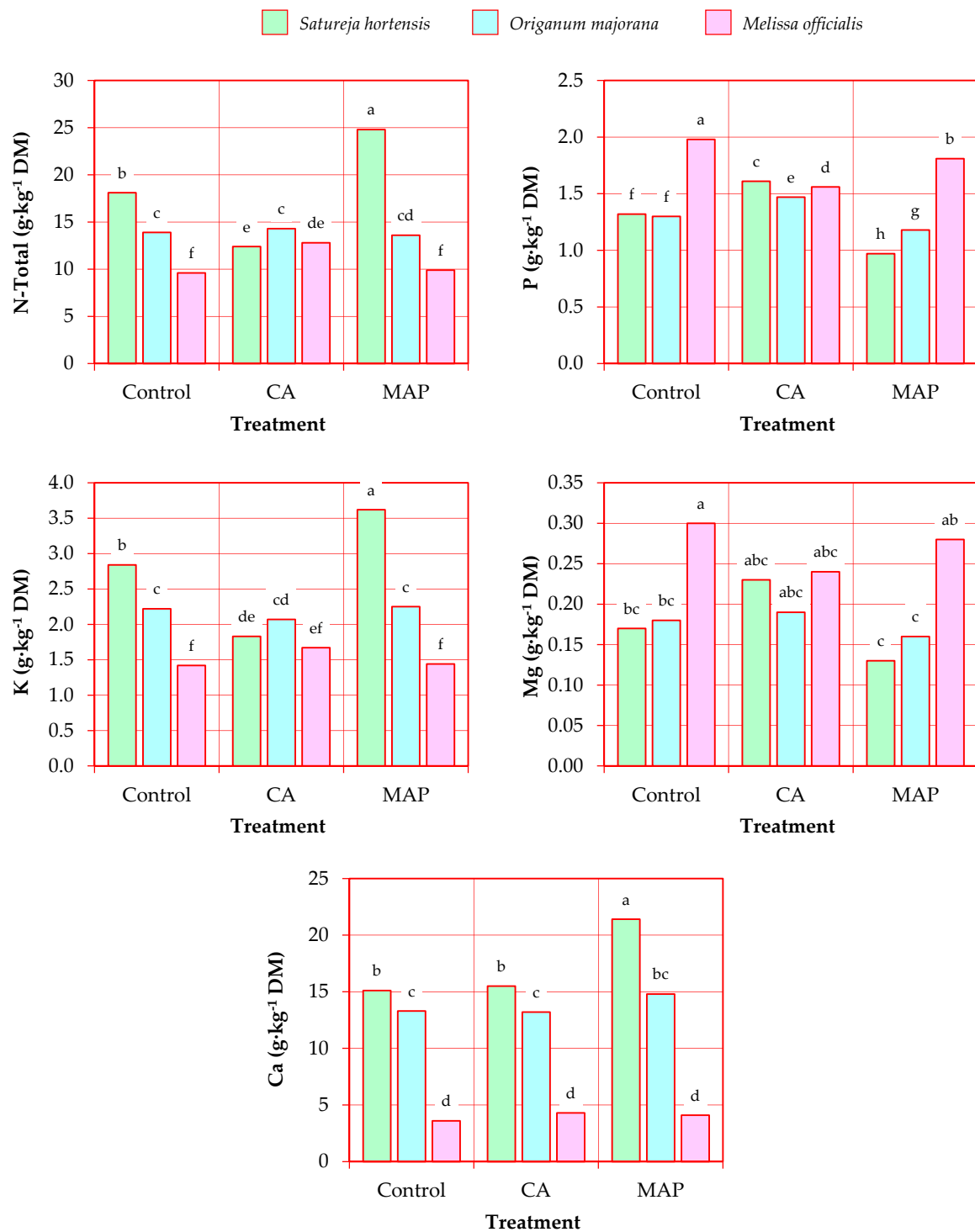


Figure 3. Effect of biostimulants on the mineral composition of herbage in the analyzed herb species: a–h—various letters denote significant differences at $p < 0.05$ (Tukey’s test); CA—application of Calleaf Aminovital; MAP—application of Maximus Amino Protect.

Table 3. p -Value for ANOVA on the mineral composition of herbage in the analyzed herb species.

Factor	N-Total	P	K	Mg	Ca
Treatment (A)	0.359	0.211	0.209	0.586	0.610
Species (B)	<0.001	<0.001	<0.001	<0.001	<0.001
Interaction (A × B)	<0.001	<0.001	<0.001	0.057	<0.001

In a study by Seidler-Łożykowska et al. [35], the P content of herbage ranged from 0.97 to 1.61 g kg⁻¹ DM in *Satureja hortensis* L. and from 1.30 to 1.47 g kg⁻¹ DM in *Origanum majorana* L. In the present study, the P content of herbage was the lowest in summer savory treated with Maximus Amino Protect (0.97 g kg⁻¹ DM) and the highest in lemon balm in the control treatment (1.98 g kg⁻¹ DM).

The average K content of herbage ranged from 1.51 g kg⁻¹ DM in lemon balm to 2.76 g kg⁻¹ DM in summer savory. An analysis of the interaction between the experimental factors revealed that summer savory treated with Maximus Amino Protect was characterized by the significantly highest K content, whereas K concentrations were lower in lemon balm herbage in all treatments. Seidler-Łożykowska et al. [35] demonstrated that the levels of this macronutrient varied across species and reached 2.4–4.1% in summer savory and 1.6–2.7% in marjoram.

According to Kudelka and Kosowska [37], the content of Mg and Ca in lemon balm, thyme, and cayenne pepper is lower than that in basil. In the present study, differences were found in Mg content between the analyzed herb species, and it was higher in lemon balm than in summer savory and marjoram. Similar results were reported by Dzida and Jarosz [10,36] for marjoram (0.15–0.31% DM) and summer savory herbage (0.32% DM to 0.46% DM). In the cited study, Mg concentrations were higher (1.72 g kg⁻¹ DM on average) in all analyzed herb species, and the Mg content of lemon balm ranged from 0.60 to 3.22 g kg⁻¹ DM in [37]. In a study by Seidler-Łożykowska et al. [35], Mg concentrations reached 0.41–0.71% in summer savory and 0.27–0.39% in marjoram, and were comparable with those noted in the present experiment.

Raczuk et al. [38] found that the average Ca content of herbage in the analyzed herb species was 19.6 g kg⁻¹ DM, ranging from 10.2 to 13.0 g kg⁻¹ DM in lemon balm. In the current study, Ca concentrations varied widely across species, from 4.0 g kg⁻¹ DM in lemon balm to 17.3 g kg⁻¹ DM in summer savory. Maximus Amino Protect contributed to an increase in the Ca content of herbage. Summer savory treated with Maximus Amino Protect was characterized by the highest Ca content (21.4 g kg⁻¹ DM). The concentrations of Ca were significantly lower in lemon balm in all treatments (3.6–4.3 g kg⁻¹ DM). In the work of Dzida and Jarosz [10,36], Ca content ranged from 0.7 to 1.9 g kg⁻¹ DM in summer savory herbage, and from 0.7 to 1.3 g kg⁻¹ DM in marjoram herbage, whereas Seidler-Łożykowska et al. [35] determined Ca concentrations at 1.0–2.4 g kg⁻¹ DM in summer savory and 1.5–2.9 g kg⁻¹ DM in marjoram. New products stimulating plant growth, based on amino acid preparations, applied at different doses, also contributed to an increase in the nutrient content of winter wheat grain, in particular copper (31–50%), as well as sodium, calcium, and molybdenum [39]. Biostimulants based on amino acids, tested in the present study, can be recommended for improving efficiency in agricultural production.

4. Conclusions

An analysis of the influence of the studied biostimulants on selected plant species revealed their beneficial interaction. The biostimulants had a positive effect on selected biometric and quality characteristics of the studied plants. They were particularly effective in reducing nitrate levels in herbal raw material. Therefore, they can be recommended for the commercial cultivation of herbs.

Marjoram var. *Miraż* was characterized by higher concentrations of DM, reducing sugars, and L-ascorbic acid than the other herb species.

The greatest amounts of minerals were accumulated by summer savory herbage (total N, K, and Ca) and lemon balm herbage (P and Mg).

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References

1. Grusak, M.A. Enhancing mineral content in plant food products. *J. Am. Coll. Nutr.* **2002**, *21*, 178S–183S. [[CrossRef](#)] [[PubMed](#)]
2. Özcan, M.M. Mineral contents of some plants used as condiments in Turkey. *Food Chem.* **2004**, *84*, 437–440. [[CrossRef](#)]
3. Skubij, N.; Dzida, K.; Jarosz, Z.; Pitura, K.; Jaroszuk-Sierocińska, M. Nutritional value of savory herb (*Satureja hortensis* L.) and plant response to variable mineral nutrition conditions in various phases of development. *Plants* **2020**, *9*, 706. [[CrossRef](#)] [[PubMed](#)]
4. Komaitis, M.E.; Ifanti-Papatragianni, N.; Melissari-Panagiotou, E. Composition of the essential oil of marjoram (*Origanum majorana* L.). *Food Chem.* **1992**, *45*, 117–118. [[CrossRef](#)]
5. Newerli-Guz, J. Factors shaping the quality of herbs and spices from organic and conventional crops. *Work. Mater. Fac. Manag. Univ. Gdańsk* **2010**, *2*, 451–459.
6. Rowayshed, G.H.; Abd-Elhameed, A.A.; Abd-Elghany, M.E.A.; Shahat, A.A.; Younes, O.A.A. Effective chemical compounds and antibacterial activities of marjoram leaves, teucrium leaves and fennel fruits essential oils. *Middle East J. Appl. Sci.* **2014**, *4*, 637–647.
7. Bina, F.; Rahimi, R. Sweet marjoram: A review of ethnopharmacology, phytochemistry and biological activities. *J. Evid. Based Complementary Altern. Med.* **2017**, *22*, 175–185. [[CrossRef](#)] [[PubMed](#)]
8. Połumackanycz, M.; Wesołowski, M.; Viapiana, A. Health benefits of lemon balm (*Melissa officinalis* L.). *Farmakognozja* **2019**, *75*, 659–663.
9. Maciejewski, T.; Szukała, J.; Jarosz, A. Influence of biostimulator Asahi SL i Atonik SL on qualitative tubers of potatoes. *J. Res. Appl. Agric. Eng.* **2007**, *52*, 109–112.
10. Dzida, K.; Jarosz, Z. Yielding and chemical composition of *Origanum majorana* L. depending of different nitrogen-potassium fertilization. *Acta Agroph.* **2006**, *7*, 561–566.
11. Majkowska-Gadomska, J.; Wierzbicka, B. Effect of the biostimulator Asahi SL on the mineral content of eggplant (*Solanum melongenum* L.) grown in an unheated plastic tunnel. *J. Elem.* **2013**, *18*, 269–276. [[CrossRef](#)]
12. Gugąła, M.; Zarzecka, K.; Sikorska, A.; Mystkowska, I.; Dołęga, H. Effect of herbicides and growth biostimulants on weed reduction and yield of edible potato. *Fragm. Agron.* **2017**, *34*, 59–66.
13. Kazimierczak, R.; Hallmann, E.; Ardasieńska, B.; Łoś, B.; Rembiałkowska, E. The impact of organic and conventional crop production systems on phenolic compounds content in medicinal plants. *J. Res. Appl. Agric. Eng.* **2011**, *57*, 198–203.
14. Paradiković, N.; Vinković, T.; Vrček, I.V.; Žuntar, I.; Bojić, M.; Medić-Šarić, M. Effect of natural biostimulants on yield and nutritional quality: An example of sweet yellow pepper (*Capsicum annuum* L.) plants. *J. Sci. Food Agric.* **2011**, *91*, 2146–2152. [[CrossRef](#)]
15. Nurzyńska-Wierdak, R.; Rożek, E.; Bolanowska, K. Growth and yield of chervil, rocket and parsley plants depending on the cultivation method. *Ann. UMCS Sec. EEE Hort.* **2012**, *22*, 1–12.
16. Nurzyńska-Wierdak, R. Lemon balm (*Melissa officinalis* L.)—Chemical composition and biological activity. *Ann. UMCS Sec. EEE Hort.* **2013**, *23*, 25–35.
17. Mystkowska, I.T. Biostimulators as a factor affecting the yield of edible potato. *Acta Agroph.* **2018**, *25*, 307–315. [[CrossRef](#)]
18. Trawczyński, C. Effect of amino biostimulators on Tecamin-on potato yield and quality. *Zienn. Pol.* **2014**, *3*, 29–34.
19. Sawicka, B.; Barbaś, P.; Dąbek-Gad, M. The problem of weed infestation in conditions of applying the growth bioregulators and foliar fertilization in potato cultivation. *Nauka Przyn. Tech.* **2011**, *5*, 1–12. [[CrossRef](#)]
20. Osińska, E.; Rosłon, W. *Ziela Uprawa i Zastosowanie [Herbs, Cultivation and Application]*; Hortpress: Warsaw, Poland, 2016; pp. 1–164. (In Polish)
21. EN 12145:1996. *Fruit and Vegetable Juices—Determination of Total Dry Matter—Gravimetric Method with Loss of Mass on Dryin*; Comite Europeen de Normalisation: Brussels, Belgium, 1996.
22. PN-A-75101-07:1990. *Fruit and Vegetable Products—Sample Preparation and Methods of Physicochemical Analyses—Determination of Sugar Content and Non-Sugar Extract Content*; Polish Committee for Standardization: Warsaw, Poland, 1990.

23. PN-A-04019:1998. *Food Products—Determination of Vitamin C Content*; Polish Committee for Standardization: Warsaw, Poland, 1998.
24. PN-A-75101.04:1990. *Fruit and Vegetable Products—Preparation of Samples and Physical and Chemical Test Methods—Determination of Total Acidity*; Polish Committee for Standardization: Warsaw, Poland, 1990.
25. Krauze, A.; Domska, D. *Ćwiczenia Specjalistyczne z Chemii Rolnej [Specialist Exercises in Agricultural Chemistry]*; ART: Olsztyn, Poland, 1991; pp. 64–65. (In Polish)
26. Yaronskaya, E.; Vershilovskaya, I.; Poers, Y.; Alavady, A.E.; Averina, N.; Grimm, B. Cytokinin effects on tetrapyrrole biosynthesis and photosynthetic activity in barley seedlings. *Planta* **2006**, *224*, 700–709. [[CrossRef](#)]
27. Bello, A.S.; Saadaoui, I.; Ahmed, T.; Hamdi, H.; Cherif, M.; Dalgamouni, T.; Al Ghazal, G.; Ben-Hamadou, R. Enhancement in bell pepper (*Capsicum annuum* L.) plants with application of *Roholtiella* sp. (Nostocales) under soilless cultivation. *Agronomy* **2021**, *11*, 1624. [[CrossRef](#)]
28. El-Gohary, A.E.; El Gendy, A.G.; Hendawy, S.F.; El-Sherbeny, S.E.; Hussein, M.S.; Geneva, M. Herbage yield, essential oil content and composition of summer savory (*Satureja hortensis* L.) as affected by sowing date and foliar nutrition. *Genet. Plant Physiol.* **2015**, *5*, 170–178.
29. Jadczyk, D.; Grzeszczuk, M. Spice herbs—biological value of selected species. *Panacea* **2008**, *2*, 15–17. (In Polish)
30. Nurzyńska-Wierdak, R.; Zawisław, G. Bioactive compounds and antioxidant activity of sweet basil (*Ocimum basilicum* L.) and lemon balm (*Melissa officinalis* L.). *Ann. UMCS Sec. EEE Hort.* **2016**, *26*, 43–51.
31. Kazimierczak, R.; Hallmann, E.; Kazimierczyk, M.; Rembiałkowska, E. Antioxidants content in chosen spice plants from organic and conventional cultivation. *J. Res. Appl. Agric. Eng.* **2010**, *53*, 164–170.
32. Telesiński, A.; Grzeszczuk, M.; Jadczyk, D.; Wysocka, G.; Onyszko, M. Assessment of changes in content of nitrates (V) in selected spice herbs depending on their preservation method and storage time. *Zywn. Nauk. Technol. Jakość* **2013**, *5*, 168–176. [[CrossRef](#)]
33. Frąszczak, B.; Gąsecka, M.; Golcz, A.; Zawirska-Wojtasiak, R. The chemical composition of lemon balm and basil plants grown under different lights condition. *Acta Sci. Pol. Hortorum Cultus* **2015**, *14*, 93–104.
34. Official Journal of the European Union. Commission Regulation (EC) No 1881/2006 of 19 December 2006 Setting Maximum Levels for Certain 424 Contaminants in Foodstuffs. 2006. Available online: <https://eur-lex.europa.eu/legal-content/EN/ALL/?uri=CELEX%3A32006R1881> (accessed on 28 December 2021).
35. Seidler-Łożykowska, K.; Kozik, E.; Golcz, A.; Mieloszyk, E. Macroelements and essential oil content in the raw material of the selected medicinal plant species from organic cultivation. *J. Res. Appl. Agric. Eng.* **2016**, *51*, 161–163.
36. Dzida, K.; Jarosz, Z. Influence of nitrogen-potassium fertilization on the yield and on the nutrient content in *Satureja hortensis* L. *Acta Agroph.* **2006**, *7*, 879–884.
37. Kudelka, W.; Kosowska, A. Components of spices and herbs determining their functional properties and their role in human nutrition and prevention of diseases. *Zesz. Nauk. Uniw. Ekonom. Krak.* **2008**, *781*, 83–111.
38. Raczuk, J.; Biardzka, E.; Daruk, J. The content of Ca, Mg, Fe and Cu in selected species of herbs and herbs' infusions. *Rocz. Panstw. Zakl. Hig.* **2008**, *59*, 33–40. [[PubMed](#)]
39. Popko, M.; Michalak, I.; Wilk, R.; Gramza, M.; Chojnacka, K.; Górecki, H. Effect of the new plant growth biostimulants based on amino acids on yield and grain quality of winter wheat. *Molecules* **2018**, *23*, 470. [[CrossRef](#)] [[PubMed](#)]