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ORIGINAL PAPER

Mineral components in green stems and inflorescences of *Allium tuberosum* rottler ex sprengel*

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Abstract

Garlic chives (*Allium tuberosum* Rottler ex Sprengel), a versatile plant, is easy to grow and resistant to the diseases and pests of bulb vegetables. In years 2020-2021, a preliminary study was carried out to assess the levels of macro- and micronutrients in green stems and inflorescences of garlic chives growing in moderate climate conditions and harvested in the first and second year of cultivation. The field experimental design involved randomized sub-blocks with three repetitions. A single plot area was 1.44 m^2. Inflorescence stems were assessed for mass (t ha^{-1}) and number (thousand pcs ha^{-1}). The levels of the macro- and micronutrients were assessed separately in the stems and inflorescences of garlic chives, in the first year and second year of cultivation. The number and mass of the one- and two-year-old inflorescence stems depended on the harvest time. More stems were obtained in the second harvest time from both one- and two-year-old plants. Green stems and inflorescences of garlic chives are a source of valuable macro- and micronutrients. Higher levels of N, Ca, and Mg were found in the one-year-old green stems and inflorescences than in the two-year-old ones, whereas the latter had higher concentrations of S. Higher levels of P were found in the inflorescences of the one-year-old plants, and the two-year-old ones contained more K. The inflorescences of the one-year-old plants as well as their stems were much more abundant in B, Zn, Mn, Fe, and Cu.

Keywords: macro- and micronutrients, harvest time, number of inflorescence stems, mass of inflorescence stems, plant age

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INTRODUCTION

Garlic chives (*Allium tuberosum* Rottler ex Spreng.) is a valuable perennial species (Kawagishi et al. 2009) belonging to the family of *Alliaceae* (Yang et al. 2021, Manjunathagowda et al. 2022), or according to Hanif et al. (2022), to *Amaryllidaceae*. The genus *Allium* is a good source of sulfur compounds *inter alia* (Shim 2012), and it comprises species of economic importance, such as onion and garlic (Manjunathagowda et al. 2022). The species described in this paper originates from China (Kawagishi et al. 2009). It is cultivated and consumed mainly in East Asia, Southeast Asia, and in the northeast regions of India (Rodkiewicz 1999, Kawagishi et al. 2009, Sharma, Gohil 2013, Khalid et al. 2014, Hanif et al. 2022).

Garlic chives is highly resistant to the diseases and pests of bulb vegetables (Żurawik and Żurawik, 2015). It is used in many ways as a vegetable. It does not need any crop protection chemicals; therefore, the species may perfectly well be grown in organic farming (Żurawik, Żurawik, 2015). In moderate climate conditions, it overwinters uncovered in the field. Garlic chives is also a highly decorative plant. It blooms from late August to early October, forming a great number of white honey umbels that attract insect pollinators such as the honey bee by their unusual smell of honey. According to Pantey et al. (2014), it is also a perfect choice for use in wasteland and for landscaping home gardens. It is an essential vegetable in Chinese and Korean cuisine, where mainly its leaves and young inflorescences are used (Kawagishi et al. 2009). It has antibacterial and antifungal properties (Zhang et al. 2013). Garlic chives may be grown and sold in pots, but after cutting it is also sold in bunches. In some regions of the world, it is grown as a substitute for *Allium cepa* (Pandey 2014). The leaves and young inflorescence stems as well as the inflorescences themselves taste perfectly well with many foods, including bread (Jung et al. 1999), or cream crackers (Cho 2010). According to Pandey et al. (2014), the leaves can be eaten raw, cooked, or marinated, or after drying as a seasoning. They have a huge export potential. The leaves, stems and undeveloped flower buds can also be used as a seasoning for frying, just like garlic, chives, or green onion. The plant may also be freeze-dried for use in the processing and food industries (Żurawik et al. 2013). However, despite its resistance to diseases and pests, its easy and inexpensive cultivation, high decorative value, and numerous applications, the vegetable is far from being popular in cultivation or on the markets in Europe (Żurawik, Żurawik 2015, Adamczewska-Sowińska, Turczuk 2016). There is not enough validated information on the nutritional value of the green stems and inflorescences of garlic chives. Edible flowers have tended for some time to be perceived as a "new vegetable" with a promising potential in human health care and in other applications (Benvenuti, Mazzoncini 2021, Hanif 2022), as well as a source of valuable mineral compounds (Śmiechowska 2018). The flowers of garlic chives have been used in cooking for many years and, although they are safe in most cases, it is indispensable to properly identify their nutritional components (Halder, Khaled 2022). Garlic chives, as a plant with a huge potential, may become an inexpensive and valuable supplementary component of human diet, supplying it with valuable nutrients.

Considering the above background, our study aimed at assessing the yield of inflorescence stems of garlic chives and the content of micro- and macronutrients in its green stems and inflorescences in the first and second year of cultivation in temparate climatic conditions. We hypothesized that the harvest dates would affect the yield of inflorescences, and that the plant age would determine the level of micro- and macronutrients in its individual organs.

MATERIAL AND METHODS

Experimental design

A field experiment was conducted in years 2020-2021, at the experimental station of the West Pomeranian University of Technology in Szczecin (14°31′E and 53°26′N). The seeds of garlic chives for the experiment were obtained from a commercial seed company.

A single-factor field experiment was established in a sub-block design with three repetitions. The experimental factor was the date of harvesting the inflorescence stems. Their yield in terms of mass (t ha-1) and number (thousand of pcs. ha-1) was assessed separately for one-year and two-year-old plants. The area of a single plot was 1.44 m^2 (1.2 m x 1.2 m).

The plant age was the experimental factor in the laboratory tests: the levels of micro- and macronutrients were compared separately for the garlic chives stems and inflorescences in the first and second year of cultivation.

Garlic chives was cultivated using non-potted bare root seedlings, prepared in a heated greenhouse. On March 9, 2020, the seeds were sown into sowing trays filled with a substrate prepared from peat at pH of 5.4-6.0, containing 0.6 kg m^{-3} macronutrients NPK (14-16-18) + Mg (5), and 0.2 kg m^{-3} micronutrients. On April 24, 2020, the seedlings were planted in the field, in groups consisting of five pieces, and spaced every 30 x 30 cm.

The soil in which the plants were grown is classified as anthropogenic soil. It was formed recently from mineral materials as a result of leveling works. Before planting, a total of five samples of the soil from the experimental field, deep down to 30 cm, were collected. They were then combined to form a composite 0.5 kg sample. After a chemical analysis of the soil from the experimental field (Table 1), the soil was fertilized to obtain a recommended substrate for the cultivation of onion (Grześkowiak 2002). In both years of the study, the plants were fertilized with a multi-component fertili-

Table 1

Chemical properties of mineral soil

Year	pH in H_2O	Nutrient content (mg dm^{-3})						Salt concentration (NaCl g dm^{-3})
		N-NO_3	P	K	Ca	Mg	Cl	
2020	7.7	60	30	107	5821	100	16	0,3
2021	7,8	48	33	128	6150	116	23	0,3

zer Azofoska (N 13.6, P_2O_5 6.4, K_2O 19.1, MgO 4.5, B 0.045, Cu 0.18, Fe 0.17, Mn 0.27, Mo 0.04, Zn 0.045) at a dose of 70 g m^{-2} provided in two batches. In 2020, one half of the dose was applied before planting the plants (April 3), and the other during their vegetation (July 1). In 2021, the first half of the fertilizer dose was supplied at the beginning of the vegetation period (March 30), and the other also during this period (June 30). During the plant growth and development, the substrate was subjected to basic treatments such as weed control, soil tilling, and watering. During the two years of cultivation, the plants did not need any chemical protection from the diseases and pests of bulb vegetables. Before overwintering in the first year, in November, the leaves were cut 5 cm above the ground. The analysis of weather conditions in the years 2020-2021 was based on data obtained from the Institute of Meteorology and Water Management (IMGW), Hydrological-Meteorological Station in Szczecin-Dąbie (Tables 2 and 3).

The plants were evaluated in the first and second year of cultivation (as one-year-old and two-year-old plants). The leaves were not harvested in the vegetation period. The inflorescence stems were harvested many times, once a week: three times in the first year of cultivation on September 22 and 29, and October 5, and seven times in the second year of cultivation on August 21 and 29, September 6, 13, 20, and 27, and October 4. Fully grown inflorescence stems were cut 5 cm above the ground if the inflorescence had more than 50% developed flowers. Just after each harvest, the number and mass of all the collected inflorescence stems were assessed. To find their mass, the stems were weighed using the WPT 5C scales (Radwag, Poland).

Mineral content of the plant material

In the first year of the study, to obtain average samples for laboratory analyses of the macro- and micronutrient content, the green stems and inflorescences from the three harvest times were dried using a laboratory drying oven SLN 115Eco (at 40°C). Dry random samples from individual harvest dates were mixed, separately for stems and inflorescences, and were then ground in a laboratory grinder WŻ-1. The procedure provided two average samples, 0.3 kg each, of the stems and inflorescences. The samples were placed in plastic bags and labeled. The same procedure was applied in the second year of cultivation, except that an average sample consisted of seven random samples from the respective harvests. The collective samples were

Table 2

Meteorological data from the period of *Allium tuberosum* growing in 2020 (Institute of Meteorology and Water Management Szczecin-Dąbie)

Year of study	Months												Mean/ total
	I	II	III	IV	V	VI	VII	VIII	IX	X	XI	XII	
Mean daily temperature (°C)													
2020	4.6	5.8	5.1	9.2	11.8	18.1	17.8	20.3	14.8	11.1	7.1	3.0	10.73
Multiyear 1991-2020	0.6	1.5	4.2	9.2	13.6	16.8	18.9	18.5	14.3	9.5	4.9	1.9	9.492
Variation	4.0	4.3	0.9	0.0	-1.8	1.3	-1.1	1.8	0.5	1.6	2.2	1.1	1.238
Total rainfall (mm)													
2020	35.0	46.0	29.0	23.0	31.0	26.2	21.0	43.0	70.0	12.0	10.0	31.0	377.2
Multiyear 1991-2020	50.0	32.8	38.4	31.2	55.8	60.3	76.2	60.3	47.7	43.5	39.0	43.0	578.2
Variation	-15.0	13.2	-9.4	-8.2	-24.8	-34.1	-55.2	-17.3	22.3	-31.5	-29.0	-12.0	-201.0
Insolation (h)													
2020	56.0	63.0	196.0	289.0	270.0	259.3	222.0	278.0	220.0	88.0	54.0	33.0	2028.3
Multiyear 1991-2020	42.7	66.7	121.2	199.3	244.5	242.3	246.3	230.3	160.0	105.7	47.4	32.2	1738.6
Variation	13.3	-3.7	74.8	89.7	25.5	17.0	-24.3	47.7	60.0	-17.7	6.6	0.8	289.7

Table 3

Meteorological data from the period of *Allium tuberosum* growing in 2021 (Institute of Meteorology and Water Management Szczecin-Dąbie)

Year of study	Months												Mean/ total
	I	II	III	IV	V	VI	VII	VIII	IX	X	XI	XII	
Mean daily temperature (°C)													
2021	0.7	0.3	4.6	6.4	12.2	19.6	20.4	17.0	15.6	11.1	6.5	1.2	9.633
Multiyear 1991-2020	0.6	1.5	4.2	9.2	13.6	16.8	18.9	18.5	14.3	9.5	4.9	1.9	9.492
Variation	0.1	-1.2	0.4	-2.8	-1.4	2.8	1.5	-1.5	1.3	1.6	1.6	-0.7	0.141
Total rainfall (mm)													
2021	55.0	37.0	36.0	13.0	51.0	99.0	48.0	55.0	21.0	24.0	64.0	35.0	538.0
Multiyear 1991-2020	50.0	32.8	38.4	31.2	55.8	60.3	76.2	60.3	47.7	43.5	39.0	43.0	578.2
Variation	5.0	4.2	-2.4	-18.2	-4.8	38.7	-28.2	-5.3	-26.7	-19.5	25.0	-8.0	-40.2
Insolation (h)													
2021	24.0	112.0	159.0	183.0	222.0	296.0	254.0	196.0	159.0	142.0	21.0	28.0	1796.0
Multiyear 1991-2020	42.7	66.7	121.2	199.3	244.5	242.3	246.3	230.3	160.0	105.7	47.4	32.2	1738.6
Variation	-18.7	45.3	37.8	-16.3	-22.5	53.7	7.7	-34.3	-1.0	36.3	-26.4	-4.2	57.4

prepared as described in the manual on plant material sampling, to be found on the website of the Regional Chemical and Agricultural Station (SChR) in Szczecin. The chemical analyses were performed in the accredited SChR laboratory in Szczecin. The following macronutrients were determined in dry matter: total N – by the Kjeldahl method, P – by the spectrophotometric method, K – by the flame photometric method, Ca and Mg – by the ASA method, total S – by the nephelometric method. The following micronutrients were determined: Cu, Zn, Mn, Fe – by flame atomic absorption spectrometry (FAAS), PB. 07 ed. 1 of May 4, 2015 and B – by the colorimetric method (Kretowska-Kułas 1993).

Statistical analysis

The results of analyses of green stems and inflorescences, as well as their content of macro- and micronutrients were processed statistically using the Statistica Professional 13.3 package (TIBCO StatSoft, Palo Alto, CA, USA), and verified by means of the one-factor analysis of variance (ANOVA) for the various harvest times and years of study. Average results were compared with the Tukey test at the significance level of α=0.05.

RESULTS AND DISCUSSION

Martins et al. (2016) report that the quality of garlic chives, expressed for example by its chemical composition, is highly dependent on the cultivation conditions. According to Pandey et al. (2014), garlic chives can be cultivated in those regions of Europe where moderate climate conditions prevail. In our study, carried out in the moderate climate conditions of Poland, we collected a total, for all harvest dates, of 344.5 thousand pcs ha^{-1} and 2.397 t ha^{-1} of inflorescence stems from one-year-old plants (Figures 1 and 2), and 3655.5 thousand pcs ha^{-1} and 22.136 t ha^{-1} of inflorescence stems from two-year-old plants (Figures 3 and 4). Pandey et al. (2014) reported that garlic chives starts to bloom in July. In our study, the harvest of the blooming inflorescence stems began as late as September 22, in the first year of the experiment, and on August 21, in the second year. The different harvesting times were due to the plant age and to the weather conditions in the years of the study. In comparison with the multiannual average, September 2020 was warmer, with a higher amount of precipitation and more sunlight hours, whereas in August 2021, the temperature, precipitation, and sunlight hours were below the multiannual average. We found that both the number and mass of the inflorescence stems of garlic chives differed with the harvest time in the first and second year of cultivation. The number and mass of the stems formed by the one-year-old plants were higher on the second harvest date (29 September), as compared with the first and third harvest times, and the differences were significant – 48.20 and 53.89 %, and 22.26 and 125.5%, respectively (Figures 1 and 2). The plants resumed vegetation in March of the following year and, even though the temperature, precipitation, and sunlight hours in April and May were lower by 2.8°C, 18.2 mm, and 16.3 h, and by 1.4°C, 4.8 mm, and 22.5 h, respectively, in comparison with the mul-

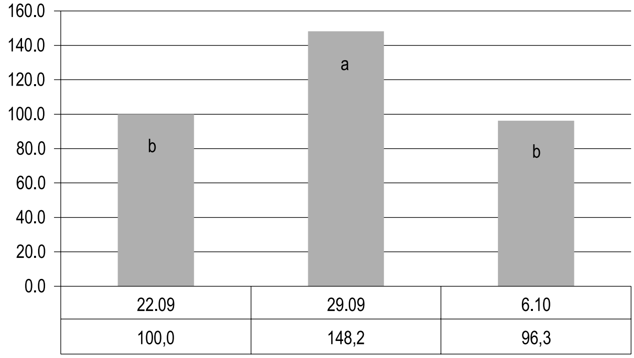


Fig. 1. Number of inflorescence stems of one-year-old garlic chives (thousand pcs ha^{-1})

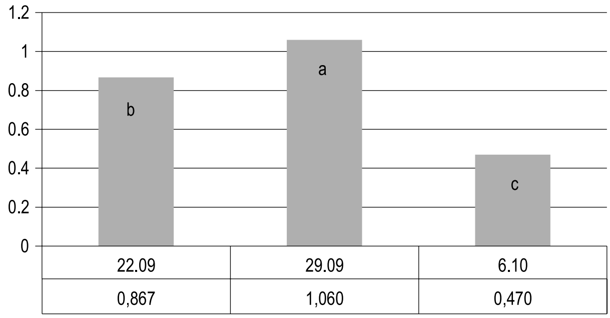
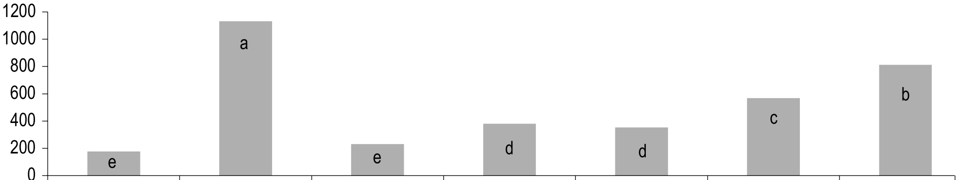


Fig 2. Mass of inflorescence stems of one-year-old garlic chives (t ha^{-1})

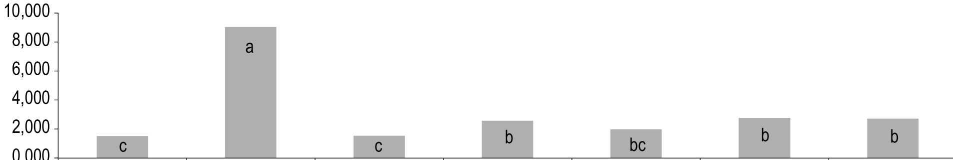
tiannual period (Table 2), the course of vegetation was correct. In the second year of the study, the inflorescence stems were harvested seven times. The plants started to bloom in the last ten days of August but there were not many flowers. The highest number and the highest mass of the inflorescence stems were harvested on August 28. In contrast, the lowest number and the lowest mass of the stems were obtained on August 21 and September 6. The differences were significant and reached 860.5 and 494.3 %, and 388.8 and 485.4 %, respectively. In the second year of cultivation, the last harvest of the inflorescence stems took place on October 4 (Figures 3 and 4).

Nishiwaki et al. (2021) confirmed the presence of K, Ca, Mn, Fe, Cu, and Zn in the leaves of garlic chives. In the opinion of Rop et al. (2012) and Grzeszczuk et al. (2018), mineral compounds are the essential part of enzymatic systems, they prevent many diseases, and strengthen the immune system, and edible flowers are a valuable source of mineral compounds.



21.08	28.08	6.09	13.09	20.09	27.09	4.10
177,8	1131,5	231,5	379,6	353,7	568,5	812,9

Fig. 3. Number of inflorescence stems of two-year-old garlic chives (thousand pcs ha^{-1})



21.08	28.08	6.09	13.09	20.09	27.09	4.10
1,520	9,033	1,543	2,570	1,980	2,770	2,720

Fig. 4. Mass of inflorescence stems of two-year-old garlic chives (t ha^{-1})

The chemical analyses of the green stems and inflorescences of garlic chives, both in the first and second year of cultivation, were in accordance with the report by Śmiechowska (2018), who claimed that edible flowers can be a valuable source of mineral compounds. In comparison with the 2-year-old green stems, the 1-year-old ones were found to contain higher levels of N, Ca, and Mg, with differences of 138.0, 625.4, and 117.8%, respectively (Table 4). According to Żurawik et al. (2013), also more N was found in the leaves of the one-year-old plants, whereas higher levels of Ca and Mg were found in the leaves of the two-year-old plants. Hanif et al. (2022) reported that garlic chives is a source of valuable sulfur. Żurawik et al. (2013) found a higher level of S in the leaves of the one-year-old plants. In the green stems of garlic chives, the level of S was also higher, although it was more abundant in the stems of the 2-year-old plants (Table 4). According to Rop et al. (2012), edible flowers are an excellent source of P and K, whose amounts varied from 20.21 to 51.46 g kg^{-1} dry matter (dm) and from 184.26 to 396.48 g kg^{-1} dm, respectively. Also, the flowers of garlic chives proved to be a source of these valuable elements, although their levels were lower and varied, on average, between 4.11 g kg^{-1}dm for P and 13.92 g kg^{-1}dm for K (Table 5). Mlcek et al. (2021) reported the following order of macronutrient content in the flowers of *Begonia* × *tuberhybrida*, *Tropaeolum majus*, *Calendula officinalis*, *Rosa*, *Hemerocallis* and *Tagetes patula*: K>Ca>P>Mg. The same tendency was demonstrated for the levels of these elements in the stems and inflorescences of garlic chives. However, these results are not in accord with those obtained by Grzeszczuk et al. (2018), who reported that in the flowers of *Mimulus hybridus* 'Magic Yellow' and 'Magic Red'; *Antirrihinum majus* 'Cavalier', *Dianthus chinensis* 'Chianti', *Hemerocallis* × *hybrida*, *Paeonia officinalis* 'Sarah' the levels of macronutrients descended in the following order K>N>P>Ca. Skwierawska et al. (2006) claimed that the level of mineral compounds depends on species, among other things. According to Devi et al. (2018), *Allium ampeloprasum* is a good source of P, Mg, K, and S for example (118.39, 18.58, 457.64, and 225.23 mg 100 g^{-1}, respectively). The results we obtained for *Allium tuberosum* indicated differences between these species. We determined that, independent of the year of cultivation, green stems of garlic chives contain more P, Mg, and K (by 76.3%, 319.9%, and 322.6%, respectively) and less S (64%). The inflorescences were also more abundant in P, Mg, and K (by 248.3%, 203.9%, 927.9%, respectively) and less rich in S (by 52.1%). We found in this study that the levels of mineral compounds also differ between plant organs. A higher average content of N was found in the inflorescences than in the stems (Tables 4 and 5). Most probably, in the opinion of Wysokiński et al. (2013), this results from the transfer of N from the vegetative into generative organs of plants during the vegetative growth. Inflorescences of the one-year-old plants, as well as their stems, were a better source of N, Ca, Mg, and P.

Table 4

Content of macrocomponents in the green stems of garlic chives depending on the plant age (g kg^{-1} d.m.)

Macrocomponent	Plant age		Mean
	one-year-old	two-year-old	
N	22.50*a*	9.455*b*	15.98
P	2.205*a*	1.950*a*	2.078
K	19.56*a*	18.90*a*	19.23
Ca	17.41*a*	2.400*b*	9.905
Mg	1.100*a*	0.505*b*	0.803
S	0.210*b*	1.407*a*	0.809

Explanations: values marked with the same letter do not differ significantly at α=0.05

Table 5

Content of macrocomponents in the inflorescence stems of garlic chives depending on the plant age (g kg^{-1} d.m.)

Macrocomponent	Plant age		Mean
	one-year-old	two-year-old	
N	34.40*a*	25.25*b*	29.83
P	4.705*a*	3.515*b*	4.110
K	12.31*b*	15.52*a*	13.92
Ca	18.11*a*	2.660*b*	10.39
Mg	2.405*a*	1.500*b*	1.953
S	0.415*b*	1.741*a*	1.078

Explanations as in the Table 4

In inflorescences of the two-year-old plants, the level of K was by 20.08% higher and that of S was as much as 319.5% higher in comparison with inflorescences of the one-year-old plants. In another study, Żurawik et al. (2013) found higher levels of Ca, Mg, and P in leaves of two-year-old plants, and more S and K in leaves of one-year-old ones.

Green stems and inflorescences of garlic chives in the first year of cultivation are a better source of micronutrients than harvested from the two-year-old plants (Tables 6 and 7). Inflorescences of the one-year-old plants

Table 6

Content of microcomponents in the green stems of garlic chives depending on the plant age (mg kg^{-1} d.m.)

Microcomponent	Plant age		Mean
	one-year-old	two-year-old	
B	5.600*a*	5.030*b*	5.315
Cu	5.600*a*	6.205*a*	5.903
Zn	20.41*a*	18.55*b*	19.48
Mn	26.81*a*	15.00*b*	20.91
Fe	66.01*a*	52.00*b*	59.01

Explanations as in the Table 4

Table 7

Content of microcomponents in the inflorescence stems of garlic chives depending on the plant age (mg kg^{-1} d.m.)

Microcomponent	Plant age		Mean
	one-year-old	two-year-old	
B	8.640*a*	7.200*b*	7.920
Cu	14.91*a*	10.75*b*	12.83
Zn	49.10*a*	20.01*b*	34.56
Mn	28.61*a*	17.80*b*	23.21
Fe	89.00*a*	50.36*b*	69.68

Explanations as in the Table 4

(Table 6), as well their stems were found to contain significantly higher levels of B, Zn, Mn, Fe, and Cu. Inflorescences of the two-year-old plants, as compared with the one-year-old ones (Table 7), contained by 78.73% less Zn and by 26.94% less Fe; the stems contained by 60.73% less Mn. Similar results were obtained by Żurawik et al. (2013), where higher levels of Mn, Cu, and Zn were found in leaves of one-year-old plants. Mlcek et al. (2021) detected higher levels of Zn and Mn than of Fe in flowers. In our study, garlic chives inflorescences were characterized by a higher level of Fe. We also identified the inflorescences and stems of *Allium tuberosum* to be a more abundant source of this micronutrient than those of *Allium sativum* (Yusuf et al. 2018). Irrespective of the year of cultivation, the investigated plant material contained more Fe (by 31.5% and 11.6%, respectively for the first and second year).

CONCLUSIONS

Garlic chives, a source of valuable mineral components, owing to its trouble-free cultivation and good yield, may be grown for inflorescence stems in the climate conditions prevailing in the West Pomerania.

The number and mass of one- and two-year-old inflorescence stems depend on the harvest time. More stems were obtained in the second harvest time from both the one-year-old and two-year-old plants.

One-year-old green stems and inflorescences contained higher levels of N, Ca, and Mg in comparison with the two-year-old plants, whereas the latter had a higher level of S. Inflorescences of the one-year-old plants were a better source of P, whereas the two-year-old plants had a higher level of K.

Green stems and inflorescences of garlic chives are a better source of microcomponents in the first than in the second year of cultivation. Inflorescences and stems of the one-year-old plants contained higher levels of B, Zn, Mn, and Fe, and were more abundant in Cu.

Conflict of interest

The authors declare that they have no conflict of interest. These authors contributed equally to this work.

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