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The influence of foliar buckwheat fertilization with copper, manganese and iron on selected parameters of its nectar production and seed yield

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Abstract. The aim of the study was to determine whether it is possible to increase the amount of nectar from buckwheat by foliar feeding with micronutrients (copper, manganese and iron), which simultaneously ensuring proper nutrition and thus increasing the seed yield. The field experiment was established using the randomized block design with the 'Kora' cultivar of buckwheat. In the experiment, there were three treatments of foliar fertilization with Cu (ADOB 2.0 Cu IDHA), Mn (ADOB Mn 2.0) and Fe (ADOB 2.0 Fe IDHA) in the form of new generation chelates, 100% water-soluble. No significant effect of the fertilization was observed on the nectar mass, the concentration of sugars in nectar, the sugar mass per 10 flowers of buckwheat, and the sugar mass per hectare (ha). Similarly, no significant differences were noted following the fertilization treatments in the mean values of yield components, such as, the number of seeds per plant and the mass of 1000 seeds.

Keywords: buckwheat, copper, foliar fertilization, iron, manganese, nectar production

INTRODUCTION

Buckwheat (*Fagopyrum esculentum*) is a plant cultivated for its grain and as a cover crop, especially after the harvest of other crops. It is also a valuable nectariferous plant, which in favorable growth conditions allows bee colonies to obtain significant amounts of honey. The average amount of raw material honey obtained from buckwheat ranges from 70 to 100 kg ha^{-1}, and for the best cultivars, it can even reach 150–300 kg ha^{-1} (Campbell, 1997; Cawoy et al., 2008). Particularly, the tetraploid cultivars of buckwheat are characterized by increased (even by 30–40%) production of nectar and pollen (Alekseyeva, Bureyko, 2000; Jabłoński, Szklanowska, 1990). During one season, a single buckwheat plant can yield 500–2000 flowers during 2–3 months (Quinet et al., 2004), each of which can potentially produce from 0.05 to 0.10 µl of nectar. The concentration of sugars in nectar is very variable (from 8 to 51%), and depends not only on weather conditions, but also on the time of day. The amount of nectar produced can be reduced up to 15 times due to high temperature and drought. As a consequence, the concentration of sugars in the flowers increases, but such nectar dries quickly in the nectaries, becoming difficult to access for bees. In such conditions, only pollen-collecting bees are observed in plantations (Alekseyeva, Bureyko, 2000; Cawoy et al., 2009; Jabłoński, Szklanowska, 1990; Racys, Montviliene, 2005).

Cawoy and others revealed a positive correlation between the amount of nectar produced by buckwheat flowers and the intensity of visiting by pollinators (Cawoy et. al., 2008, 2009). An increase in the level of nectar production by the plant attracts a greater number of bees and other insects, increasing the number of visits to the flowers, and thus enhancing the chances of their cross-pollination. Even though plants produce a huge number of flowers, only 5–10% of them form seeds (Liszewski, 2009; Ścigalska, 2004), mostly due to the allogamy of buckwheat (Cawoy et al., 2008, 2009). Buckwheat flowers develop early in the morning and bloom only for one day. To pollinate a single flower, at least 10 grains of foreign pollen is necessary. The time available for this process is less than one hour (Björkman, 1995 bc). In Poland, Germany, Korea, and the USA, the main pollinators of buckwheat are Apidae (honeybees and bumblebees). They constitute from 58 to more than 90% of all the insects observed on these crop plantations (Björkman, 1995 a; Goodman et al., 2001; Hedtke, Pritsch, 1993; Jabłoński, Szklanowska, 1990; Jacquemart et al., 2007). A worker bee (*Apis mellifera*) visits an average of 14–20 flowers per minute and works buckwheat for 4–5 hours a day, effectively transferring pollen between

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the plants. Other bees as well as Syrphidae can also make a significant contribution to buckwheat pollination, especially in Asia (Aryal et al., 2014; Jacquemart et al., 2012). Buckwheat is a plant that places high demands on the soil due to its underdeveloped root system. To increase yield, both macro- and microelements are applied through fertilizing. Nitrogen fertilization causes an increase in the foliar mass of buckwheat, and increases the number of both inflorescences and flowers, resulting in an increased seed yield (Tahir, Farooq, 1988; Vazhov et. al., 2013). However, due to lodging, there is an inverse correlation between unduly high doses of nitrogen or unduly high densification of plants in the field and the yield obtained (Wang et al., 2015; Xiaomei et al., 2018). Fertilization with micronutrients, in the form of soil fertilization as well as a foliar application, is used to improve the growth conditions of buckwheat. The field tests confirmed a positive effect of boron or selenium fertilization on the quality of buckwheat yield (Chertko et al., 1974; Jiang et al., 2015; Liszewski, 2003). In agricultural practice, it often happens that nutrients may be present in the soil in insufficient amounts or in forms that are difficult for plants to absorb. Foliar fertilization of plants is an effective method to immediately deliver deficient micronutrients. It can be especially effective if it is carried out in the phases of intensive plant growth and the periods of dry soil (Czuba, 2000). Micronutrients regulate many biochemical processes in plants. These elements are components or activators of many enzymatic reactions (Michałojć, Szewczuk, 2003). Tobiasz-Salach et al. (2018) obtained the greatest increase in the number and mass of seeds per plant by foliar fertilization of buckwheat with Herbagreen®, a multicomponent fertilizer with a nutritional and bio-stimulating effect, containing i.a. iron (Fe_2O_3) and manganese (MnO_2). This is probably due to the fact that fertilization with microelements largely determines photosynthesis or plant respiration.

The research conducted by Chorbiński and Liszewski (2014), using foliar feeding of buckwheat with copper and manganese, did not show that such treatments increased the attractiveness of the plant for bees. It was a constant formula, in which Cu and Mn were chelated with EDTA. However, it has been proven that boron fertilization has a positive effect on increasing the nectar production from buckwheat flowers (Kurguzov, 1960; Lesik, 1953). Chorbiński and Liszewski (2021) in their studies on foliar fertilization of buckwheat with boron (a dose of 2 l ha^{-1}) also noted an increase in the nectar mass from 10 buckwheat flowers by almost 5%, but the result was not statistically significant.

Foliar feeding of buckwheat with copper, manganese and iron may contribute to the growth of chlorophyll in buckwheat leaves and increase the nectar production in flowers. Improving the attractiveness of flowers to bees can increase the yield of seeds (Liszewski, 2003). Moreover, microelements may also increase the efficiency of fertilization with macronutrients, thus contributing to the yield growth and improving the biological value of seeds. (Liszewski, Błażewicz, 2015)

The research aimed to determine the influence of foliar fertilization with microelements (Cu, Mn and Fe) contained in new generation preparations (100% solubility of microelements in the working fluid) on the apiculture value of buckwheat as well as on its yield and mass of 1000 seeds. The nectar production, the concentration of sugars and the sugar mass were assessed.

MATERIAL AND METHODS

The research was conducted between 2014 and 2016 in the fields of the Institute of Agroecology and Plant Production at the Wrocław University of Environmental and Life Sciences in Pawłowice (Poland) (51°17'36''N, 17°11'66''E). A field experiment was established using randomized blocks with the 'Kora' cultivar of buckwheat. The experiment was established on sandy soil , classified as V soil class belonging to brunic arenosols (FAO, 2014). Before establishing the experiment, soil samples were taken to determine the content of basic macronutrients, including nitrogen (N min.), and micronutrients as well as the acidity. For individual years of the study, the phosphorus content was assessed as high or very high, the potassium content as average or low, and the magnesium content as very low or low. The soil pH was mildly acidic or acidic, and the nitrogen content was evaluated as low or very low. Detailed results are presented in Tables 1 and 2.

The forecrop for buckwheat was the potato. In spring, phosphorus and potassium were applied in doses (kg ha^{-1}) as follows: 50 – P_2O_5 and 70 – K_2O. Phosphorus was supplied to the soil in the form of granular superphosphate, and potassium in the form of 60% potassium salt. Nitrogen fertilization was applied completely before sowing in the form of 34% ammonium nitrate in the amount of 40 kg ha^{-1}. Buckwheat was sown on May 20, 2014, April 27, 2015 and April 26, 2016, using a plot seeder (Wintersteiger), in the amount of 250 germinating seeds per 1 m^2 at intervals of 15 cm. The experiment included 16 experimental plots (4 × 4 replications) each year. Four plots were used for each treatment of fertilization and four for the control treatment (without foliar fertilization).

Three treatments of foliar fertilization were tested in the experiment: 1. Cu (ADOB 2.0 Cu IDHA), 2. Mn (ADOB Mn 2.0) and 3. Fe (ADOB 2.0 Fe IDHA); the doses recommended by the producer for cereals were used (https://adob.com.pl/). The formula of liquid fertilizers of this type has been additionally enriched with biodegradable tensides (IDHA). Foliar feeding with copper, manganese and iron was carried out twice each year – firstly in the phase of formation of flower buds (BBCH 51), and then at the beginning of flowering (BBCH 61), i.e., on June 10 and June 24, 2014, June 3 and June 11, 2015, and May 31 and June

Table 1. Macroelement content [mg (100 g)$^{-1}$], pH of the soil, and N-min.

Vegetation season	P_2O_5	K_2O	Mg	pH (in 1 M KCl)	N-min. (0–30 cm) [kg ha^{-1}]
2014	18.3 (high)	10.9 (average)	1.30 (very low)	5.6 (mildly acidic)	48.9 (low)
2015	26.9 (very high)	11.4 (average)	1.50 (very low)	6.2 (mildly acidic)	31.3 (very low)
2016	16.7 (high)	7.1 (low)	1.5 (low)	5.3 (acidic)	36.7 (very low

Table 2. Microelement content [mg kg^{-1}] in the soil.

Vegetation season	Cu	Mn	Fe
2014	2.90 (average)	68.1 (average)	737 (average)
2015	3.60 (average)	101.3 (average)	684 (average)
2016	3.00 (average)	68.4 (average)	608 (low)

Table 3. Doses and stages of application of microelement fertilizers.

Application stage	ADOB 2.0 Cu IDHA	ADOB Mn 2.0	ADOB 2.0 Fe IDHA
		dose [l ha^{-1}]	
Formation of flower buds BBCH 51	1.0	3.0	1.5
Beginning of flowering BBCH 61	0.2	3.0	1.5

13, 2016 (Table 3). The ADOB 2.0 type of fertilizers is a group of foliar feeding products, 100% water-soluble, designed to supplement the deficiencies of macro- and micronutrients in crops. The micronutrients (Cu and Fe) contained therein are chelated with the IDHA (iminodisuccinic acid) to increase the bioavailability of longer-acting micronutrients. The copper content in the fertilizer is 4.4% by weight, the manganese content – 10.1%, and the iron content – 9.0%. The seeds were harvested with a Wintersteiger plot harvester. The area of the plot for harvesting was 15 m^2. The yield of seeds is given, after conversion up to 15% humidity, in Mg ha^{-1}.

The nectar production from buckwheat was determined by the pipette method according to Jabłoński (2002) on seven dates from June 27 to July 18, 2014, eight dates from June 10 to July 3, 2015, and eight dates from June 6 to June 30, 2016. Samples of flowers (from at least 10 plants) were collected from the center of the canopy of each field. Samples of plants (of uniform growth) were taken at 6.00 am, before the buckwheat flowers were visited by the bees, and were placed in large string bags. It has been established earlier that it is at this time that the highest amounts of nectar are collected in such trials, being responsible for the nectar output from the buckwheat field. Drawing nectar in the lab was always carried out between the second and the third hours from the collection of plant samples. At the beginning of buckwheat flowering, nectar was collected from all nectar-containing flowers, and in full flowering – from 100 flowers for each sample. The total number of flowers with nectar per 10 plants was also counted. The collected nectar was weighed and the concentration of sugars in nectar was measured in an Abbe refractometer. The sugar mass was calculated according to the formula: sugar mass = (nectar mass × % concentration of sugars)/100. The result was then converted to 10 flowers of buckwheat and the actual planting rate per square meter in flowering moment. It was used to calculate the number of flowers with nectar per plant, per square meter, per hectare, and the availability of raw sugar (sugar mass) per hectare, as an average for the days of observation.

The meteorological conditions for the years 2014–2016 were obtained from the Agro- and Hydrometeorology Station in Wrocław-Pawłowice. To describe the impact of weather conditions on the development of buckwheat, Selyaninov's Hydrothermal Coefficient (HTC) (Radomski, 1987) was used; it was calculated using the formula: HTC = 10P/T, where: HTC – Selyaninov's Hydrothermal Coefficient; P – total rainfalls for individual months; T – the sum of average daily temperatures for individual months. The HTC calculated based on the average values of temperature and the sums of rainfalls showed high variability in the vegetative seasons and individual months of buckwheat growth (Table 4). The analysis of these data indicates that growth conditions in the studied three-year pe-

Table 4. Air temperature, rainfall and Selyaninov coefficient between 2014 and 2016.

Month	Temperature [°C]				Rainfalls [mm]				Selyaninov coefficient		
	2014	2015	2016	mean 1981–2015	2014	2015	2016	mean 1981–2015	2014	2015	2016
IV	10.6	8.9	8.7	8.9	55.2	15.8	46.4	33.6	2.05	0.59	1.79
V	13.3	13.5	15.3	14.4	101.4	21.0	5.3	54.1	2.46	0.50	0.11
VI	16.5	16.6	18.6	17.3	40.2	73.3	44.6	67.4	0.81	1.46	0.80
VII	21.2	20.3	19.5	19.6	52.9	55.6	114.3	78.0	0.80	0.89	1.89
VIII	17.3	22.7	17.9	18.6	75.0	5.6	27.1	65.3	1.40	0.08	0.49
IX	15.5	15.1	16.4	13.7	72.2	23.2	44.7	44.9	1.55	0.51	0.91
Mean/sum (IV–IX)	15.7	16.2	16.1	15.4	437.0	194.5	282.4	358.9	-	-	-

riod were variable, mainly in terms of precipitation, to the extent that it generated disturbances in the absorption of micronutrients by buckwheat plants from the soil.

When fully mature, the buckwheat seeds were collected from each plot from 10 plants for the estimation in the lab: the number of seeds per plant, the mass of seeds per plant and the mass of 1000 seeds. After harvest by a plot harvester, seed yield was also determined for each fertilizing variant (in 10^3 kg ha^{-1}).

To evaluate differences between the groups defined by the applied fertilization treatment (control, Cu, Mn, and Fe), the one-way analysis of variance (ANOVA) was used, preceded by the test of normality of variable distribution with the Shapiro-Wilk method. All analyses were conducted at the 5% significance level, using the STATISTICA package (data analysis software system), version 12 from the TIBCO Statistica (2014). The significance of differences between the means was assessed using the HSD Tukey test.

RESULTS

The study showed (Table 5) a statistical tendency for the plants to produce more nectar in the control treatment. In the assessed period, the highest masses of nectar per 10 flowers of buckwheat were obtained in 2015, and the lowest in 2016. The analyzed results showed no statistically significant differences between the applied fertilization treatments in terms of their effect on the nectar mass in individual years and these differences did not occur for the averages for the three years of the study. When comparing the mean nectar masses individually for each fertilization and control treatment, significant differences between the research years were noted. Also, the average sugar concentration in nectar did not differ between treatments. The highest values were recorded in the group fertilized with iron, and the lowest in the control group. The year 2016 was the most favorable for this parameter. However, no statistically significant difference was found between the averages for the test periods. When assessing the average sugar mass per 10 buckwheat flowers, a similar tendency was observed as in the case of the average nectar mass; the best result was obtained in the control group, and the lowest in the group fertilized with iron. Also, in this case, differences in the average sugar mass between the fertilization treatments were not statistically significant for each year and the years 2014–2016. However, there were significant differences between the years of research, analyzing each fertilization treatment individually or average sugar mass.

The results of the average sugar mass in kilograms per hectare (the availability of raw sugar for bees) correspond with the results of the sugar mass per 10 flowers. As they also depend on the number of flowers per hectare, no statistically significant differences were obtained for this parameter in any arrangement: years/fertilization. By analyzing the number of flowers on one plant (an average for the days of observation) and the number of flowers per hectare, it was discovered that the control group had the best results for the years 2014–2016. In the analyzed period, the most flowered buckwheat was in 2014, and the least in 2015, regardless of the foliar fertilization treatments used in the experiment. However, the three-year results showed no difference in the mean number of flowers per plant or the mean number of flowers per hectare.

Similar to the nectar production parameters, no statistically significant differences were found between the average values of the crop structure elements, i.e., the number of seeds per plant and the weight of 1000 seeds, with regard to the fertilization treatment used. The most buckwheat flowers per unit of surface area was in the control group, but the greatest number and mass of seeds per plant, and the highest seed yield were found in the manganese-fertilized group, and the lowest in the group fertilized with iron (Table 6). The year 2014 was characterized by the lowest number of seeds per plant, in 2015 it increased by 50,3%, and in 2016 by 65.7%. A similar increase in comparison with 2014 was observed in 2015 (50%) and in 2016 (60.4%) for the mass of seeds per plant. The lowest buckwheat yield was obtained in 2014, but the low number of

Table 5. The mean values of nectar production and flowering of the buckwheat according to the variant of fertilization (± SD).

Years	Fertilization			
	Cu	Mn	Fe	Control
	Nectar mass per 10 flowers of buckwheat [mg]			
2014	8.27 ±3.23	7.83 ±2.36	6.75 ±1.56	8.11 ±2.26
2015	9.95 ±3.05	10.50 ±4.14	9.51 ±3.07	10.33 ±2.99
2016	5.98 ±2.06	6.11 ±2.03	6.07 ±2.18	6.17 ±2.32
Mean	8.06 ±3.17	8.16 ±3.45	7.44 ±2.75	8.20 ±3.02
SE	±0.661	±0.718	±0.573	±0.629
	The concentration of sugars in nectar of buckwheat [%]			
2014	7.55 ±1.63	7.47 ±1.65	7.56 ±1.99	7.41 ±1.57
2015	6.65 ±2.18	6.71 ±2.21	7.19 ±2.39	6.79 ±2.35
2016	9.58 ±5.63	9.21 ±5.00	9.53 ±4.88	9.12 ±4.47
Mean	7.94 ±3.73	7.81 ±3.38	8.11 ±3.41	7.79 ±3.14
SE	±0.778	±0.704	±0.710	±0.654
	Sugar mass per 10 flowers of buckwheat [mg]			
2014	0.60 ±0.168	0.55 ±0.12	0.53 ±0.11	0.58 ±0.11
2015	0.66 ±0.11	0.69 ±0.11	0.66 ±0.09	0.67 ±0.12
2016	0.47 ±0.11	0.47 ±0.10	0.45± 0.09	0.48 ±0.13
Mean	0.576 ±0.15	0.572 ±0.14	0.550 ±0.13	0.577 ±0.14
SE	±0.031	±0.029	±0.026	±0.029
	Sugar mass [kg ha^{-1}]			
2014	3.06 ±0.79	2.72 ±0.81	2.66 ±0.87	2.91 ±0.79
2015	2.56 ±1.20	2.49 ±1.18	2.21 ±0.69	2.78 ±1.04
2016	2.28 ±1.10	2.23 ±0.66	2.20 ±0.92	2.48 ±0.98
Mean	2.69 ±1.00	2.49 ±0.90	2.44 ±0.97	2.51 ±0.86
SE	±0.208	±0.188	±0.203	±0.179
	Number of flowers per 1 plant of buckwheat			
2014	25.48 ±9.44	24.96 ±11.58	24.30 ±9.09	24.80 ±9.72
2015	15.33 ±5.41	14.81 ±6.48	13.93 ±5.08	16.58 ±5.02
2016	20.17 ±7.92	19.47 ±5.12	20.06 ±7.21	21.08 ±5.42
Mean	20.10 ±8.43	19.52 ±8.70	19.22±8.12	20.65±7.40
SE	±1.757	±1.814	±1.692	±1.542
	Number of flowers in million ha^{-1}			
2014	54.26 ±20.10	53.15 ±24.66	51.75 ±19.36	52.81 ±20.70
2015	37.39 ±13.19	36.14 ±15.81	33.99 ±12.39	40.44 ±12.24
2016	49.21 ±19.33	47.50 ±12.49	48.95 ±17.58	51.44 ±13.23
Mean	46.64±18.34	45.27±18.62	44.60±17.71	48.03±15.90
SE	±3.824	±3.883	±3.692	±3.314

Cu = fertilizer: ADOB 2.0 Cu IDHA
Mn = fertilizer ADOB Mn 2.0
Fe = fertilizer ADOB 2.0 Fe IDHA
Control treatments without added microelements
SE standard error of mean from the years

seeds per plant in that year meant that they were best filled and the mass of 1000 seeds was the highest of all groups used in the experiment.

Since there were no significant differences between the control and fertilization treatment groups at a 5% level, no further statistical analysis was carried out.

Table 6. Buckwheat yield and yield components (means for fertilization and years).

Specification	Number of seeds per plant	Mass of seeds per plant [g]	Mass of 1000 seeds [g]	Yield [10^3 kg ha^{-1}]
		Fertilization		
Cu	24.8	0.65	26.4	0.95
Mn	27.3	0.70	26.2	1.01
Fe	25.0	0.62	25.5	0.93
Control	26.7	0.68	26.2	0.97
$LSD_{0.05}$	**n.s.**	**n.s.**	**n.s.**	**n.s.**
		Years		
2014	18.7	0.48	27.4	0.62
2015	28.1	0.72	25.7	1.20
2016	31.0	0.77	25.1	1.08
$LSD_{0.05}$	**4.80**	**0.13**	**0.80**	**0.12**

Cu = fertilizer: ADOB 2.0 Cu IDHA
Mn = fertilizer ADOB Mn 2.0
Fe = fertilizer ADOB 2.0 Fe IDHA
Control treatments without added microelements
n.s. not significant ($\alpha \geq 0.05$)

DISCUSSION

Buckwheat is a plant very dependent on climatic conditions. In periods of drought and high temperatures, nectar in buckwheat flowers dries so quickly that this plant becomes unattractive to bees (Cawoy et al., 2009). Analyzing the results, it can be noticed that the highest nectar production in all groups was obtained in 2015 (Table 5). It is associated with meteorological conditions, mainly rainfalls in the period, as indicated by the values of Selyaninov's Hydrothermal Coefficient (HTC) in June for the three years of the study (Table 4). Similarly, a much higher (by almost 2°C) average monthly temperature in June 2016 resulted in a higher concentration of sugars in flowers with a simultaneous decrease in the amount of nectar (Tables 4 and 5). The average sugar mass from 10 buckwheat flowers in all groups (0.565 mg) does not differ from the values of Potapov et al. (2017). In this study, the obtained sugar mass was 0.28 mg/10 flowers for buckwheat in the second decade of May, and 0.89 mg/10 flowers in the last eleven days of May.

The availability of raw sugar for bees depends mainly on the overall sugar mass per flower and the number of flowers per hectare. The most favorable results for raw-material sugar for all fertilization treatments were obtained in 2014. It was due to good weather conditions in May, which was conducive to the growth of buckwheat plants and to a high number of flowers (Table 5). In May 2014, record rainfalls were recorded and the values of Selyaninov's Hydrotermal Coefficient (HTC) were the highest for the three years of the research (Table 4). The lowest number of buckwheat flowers in all groups was recorded in 2015. These flowers had the highest sugar mass in nectar and were probably more pollinated by insects. Therefore, seed yield in 2015 turned out to be the highest for the entire period of study. A similar relationship occurred in 2016. But it concerned the highest concentration (%) of sugar in nectar, which translated into a high grain yield. However, it was significantly lower from the 2015 yield (Tables 5 and 6). The weather is always an important factor in field experiments. To minimize its impact, the research was carried out for a period of three seasons. After analyzing the collected data, it should be stated that the parameters important for the apiculture value of buckwheat did not improve after the application of three foliar fertilizers. In the case of iron, a deterioration occurred nectar and suger mass per 10 flowers of buckwheat. Similar to the research by Chorbiński and Liszewski (2014), the use in this experiment of a completely new copper formulation for a foliar application to buckwheat did not significantly improve the nectar parameters of this plant. The studies of Chorbiński and Liszewski (2021) showed an increase in the mass of nectar and sugar from 10 buckwheat flowers after foliar fertilization of buckwheat with boron. The best result was obtained with a dose of 2 l per hectare (ADOB Bor) and for the BBCH 61 phase. The present results are also difficult to compare with the results of other authors. No information was found on the effect of foliar fertilization on the nectar production of buckwheat, but also other plants.

The foliar application of copper, manganese and iron in the form of new generation chelates also did not result in any significant increase in crop yield or improvement of the quality of buckwheat seeds. The course of weather during buckwheat vegetation proved to be decisive for the number of seeds and the mass of seeds obtained from the one plant. The influence of the weather factor is often so overwhelming that it is difficult to demonstrate the effect of fertilization on the yield and the yield components by using statistical methods.

The most stable features are the weight of 1000 seeds, the number of nodes on the main shoot and the height of the plant (Wolińska et al. 2006). In this study, the largest buckwheat seed yield characterized by plants grown buckwheat growing season in 2015 (Tab. 6). Tobiasz-Salach et al. (2018) in their research conducted in the years 2014–2016 achieved the best results in 2015. They focused on the yield and weight of 1000 seeds. In our research, the best results for the latter parameter were observed in 2014, but the yield during this period was the lowest.

Domska et al. (2009) showed that a foliar application of copper to winter wheat resulted in an increased grain yield, while the manganese foliar application increased the yield of winter triticale. Tobiasz-Salach, Augustyńska-Prejsnar (2020) found that in the case of barley, the manganese foliar fertilization resulted in a greater increase in grain yield and the mass of 1000 grains than the application of copper. The weather and the cultivar of plants were also of great importance in these experiments.

It is possible that the fertilization of buckwheat with microelements should have been conducted as early as in the BBCH 33 phase (the main shoot elongation phase). Continuing the research, it is necessary to determine the optimal development phase for the foliar fertilization of buckwheat. The use of single micronutrient fertilizers at different stages of development may have a different effect on the individual components of the crop as well as on the production of nectar by buckwheat flowers.

CONCLUSIONS

1. The foliar fertilizers with Cu, Mn and Fe, used in the experiment, did not improve the apiculture value of buckwheat in the form of increasing the nectar production, the number of flowers on the plants and the mass of sugar available for bees.

2. No significant influence of the applied options of fertilizing on the elements of the crop yield structure of buckwheat was demonstrated.

3. During the experiment, weather conditions had a decisive impact on the number and mass of seeds from the one plant, the mass of 1000 seeds, and buckwheat seed yield.

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