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EVALUATION OF THE BIOLOGICAL VALUE OF THE DANDELION LEAVES (*TARAXACUM OFFICINALE* WEBER EX WIGG.) GROWN ON SOIL CONTAMINATED WITH COPPER

OCENA WARTOŚCI BIOLOGICZNEJ LIŚCI MNISZKA LEKARSKIEGO (*TARAXACUM OFFICINALE* WEBER EX WIGG.) UPRAWIANEGO NA GLEBIE ZANIECZYSZCZONEJ MIEDZIĄ

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Streszczenie. Badania przeprowadzono w 2013 roku. Materiał badawczy stanowiły rośliny mniszka lekarskiego (*Taraxacum officinale* Weber ex Wigg.) – korzenie z częścią nadziemną, zebrane przed zawiązaniem koszyczków kwiatostanowych *(Taraxaci radix cum herba)*. Analizy laboratoryjne, stanowiące kontynuację doświadczenia wazonowego, wykonano w laboratorium Katedry Ogrodnictwa Zachodniopomorskiego Uniwersytetu Technologicznego w Szczecinie. W wysuszonym surowcu (w liściach mniszka lekarskiego) oznaczono zawartość: suchej masy i popiołu całkowitego, witaminy C jako kwasu L-askorbinowego, chlorofilu a, b i ogółem, karotenoidów ogółem oraz aktywności antyoksydacyjnej. Na podstawie uzyskanych wyników badań stwierdzono, że zarówno cechy biometryczne roślin mniszka lekarskiego, jak i ich wartość biologiczna podlegały istotnym zmianom w zależności od ilości miedzi zawartej w glebie oraz terminu zbioru roślin.

Key words: *Taraxacum officinale*, date of harvest, the concentration of Cu^{2+} in the soil, biological value.
Słowa kluczowe: *Taraxacum officinale*, termin zbioru, stężenie Cu^{2+} w glebie, wartość biologiczna.

INTRODUCTION

Dandelion (*Taraxacum officinale* Weber ex Wigg.), also called a common dandelion (*Taraxacum vulgare* Web.), belongs to the family Asteraceae *(Asteraceae)* (Potarzycki and Zawidzka 2005).

The most popular English name of this species is *dandelion* (in French *dent de lion*), and German *löwenzahn*, what in both languages means the lion's tooth (Pawłowicz and Bylka 2004). Dandelion has valuable medicinal properties (Hu and Kitts 2005). The most important active substances of the dandelion leaves are: sesquiterpene lactones, such as: taraxine acid (taraxacine), triterpenes (cycloartenol), phytosterols, flavonoids. They also contain substantial amounts of vitamin A and substances of enzymatic properties, such as, e.g.,

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insulin (Sugier 2004). The healing effect of dandelion is related mainly to the presence of sesquiterpene lactones – derivatives of eudesmane, germacrane and guaian (Williams et al. 1995). Dandelion, due to its valuable properties, has a wide application in medicine, veterinary, dietetics, as well as in cosmetics (Kisiel and Barszcz 2000). All parts of this plant are the pharmaceutical raw material (roots, herbs and flowers) (Sugier 2004). Dandelion is characterised by a high degree of accumulation of heavy metals, sulphur dioxide and PAH (Dzierżanowski and Gawroński 2011). Its usefulness in bio-monitoring is evidenced by the fact of the common prevalence in the country and the rapid increase in biomass (Kabata--Pendias 1989). Dandelion belongs to soil indicator plants (Musiał 2009).

Among the substances which have a negative impact on the environment, heavy metals arouse the increasing interest, the source of which are, among others, mineral fertilisers or plant protection products (Gruca-Królikowska and Wacławek 2006). Copper is one of them, which is a biogenic element, taken by plants in trace amounts (Szatanik-Kloc et al. 2010).

According to many researchers (Michaud et al. 2008; Swędrzyńska and Sawicka 2010) copper is an element essential in the life of organisms, and yet highly toxic, if it is present in the environment in excess. Copper taken from soil by plants in amounts exceeding their physiological needs has a phytotoxic effect (Kaszubkiewicz and Kawałko 2009).

Toxic effect of copper concerns both plants and soil microorganisms, causing the inhibition of their growth and development. Copper absorbed by the plant in excess influences, just like lead and cadmium, the reduction of chlorophyll biosynthesis (Buczkowski et al. 2000).

The aim of this study was to evaluate the biological value of dandelion leaves (*Taraxacum officinale* Weber ex Wigg.) grown on the soil contaminated with copper.

MATERIAL AND METHODS

The experiment was conducted in 2013. A pot experiment was performed in the greenhouse of the West Pomeranian University of Technology, Szczecin, in the system of random blocks, in four replications. The soil taken from the humus level of black soils of the Gumieniecka Plains was led to the air-dried state and sieved through a sieve with an aperture of 2 mm. The characteristics of the soil used in the experiment are presented in Table 1.

Table 1. Characteristics of soil used in the experiment
Tabela 1. Charakterystyka gleby zastosowanej w doświadczeniu

Granulometric fractions Frakcje granulometryczne	
2,00 ≥ d > 0.05 mm	47%
0,05 ≥ d > 0.002 mm	48%
d ≤ 0.002 mm	55%
Granulometric group Grupa granulometryczna	light clay (gl) glina lekka (gl)
C_{org}	1.09%
N_t	0.25%
pH in – w:	
H_2O	7.09
1M KCl	6.81

Laboratory analyses, that were the continuation of the pot experiment, were performed in the laboratory of the Department of Horticulture of the West Pomeranian University of Technology, Szczecin.

Dandelion plants were the research material (*Taraxacum officinale* Weber ex Wigg.) – roots with the above-ground part, collected before tying of flower baskets (*Taraxaci radix cum herba*).

The first experimental factor was the plant harvest date (18 VII, 7 VIII, 28 VIII), and the second experimental factor was the amount of Cu $(NO_3)_2 \cdot 3H_2O$ introduced to the soil (control – without the addition of copper, 0.05 mmol Cu^{2+} – 1.208 mg salt/kg of soil, 0.50 mmol Cu^{2+}– 12.08 mg salt/kg of soil and 5.00 mmol Cu^{2+} – 120.8 mg salt/kg of soil).

The sieved soil material was divided into 3 parts, each of 3kg and it was treated with aqueous solutions of nitrate (V) copper (II). Salt doses were converted into the amount of the introduced copper: 0 (control), 0.05, 0.50, 5.00 mmol Cu^{2+}. Every vase was sown with 0.05 g seeds of dandelion ('Rocalba' Company). Soil moisture during the experiment was maintained at the level of approx. 60% of the capillary water capacity.

During the plant vegetation, care treatments were performed which consisted mainly of their watering.

Every time, after harvesting plants, the following biometric measurements were conducted: the weight of the plant [g], the height of the plant [mm], the length of leaves [mm] and the length of the tap root [mm].

The resulting material of the plant was dried at the temperature of 35ºC, in the laboratory ejector drier.

Chemical analyses in the dried raw material (in dandelion leaves), covered the determination of the content: of the dry mass and total ash, vitamin C as L-ascorbic acid, chlorophyll a, b and total, total carotenoids and antioxidant activity.

The dry matter content was determined by the drying method to the constant weight at the temperature of 105ºC (Kretowska-Kułas 1993). In order to determine the content of total ash, the sample of plant material (approximately 5g) was weighed in a porcelain crucible (pre-weighed and adjusted to constant weight), and then incinerated in a muffle furnace at 600ºC (until obtaining white-grey ash) (Krełowska-Kułas 1993). The vitamin C content as L-ascorbic acid was determined by the Tillmans method, involving the reduction of the coloured solution of 2.6-dichlorophenoloindophenol to colourless leuco-compound under the effect of the L-ascorbic acid (Krełowska-Kułas 1993). Determination of the content of chlorophyll a, b, total and total carotenoids was performed according to Lichtenthaler and Wellburn (1983). The plant material was extracted with 80% acetone. Samples were ground in a mortar, in the presence of a small amount of acetone, and then quantitatively moved to volumetric flasks for 50 cm^3. The extinction of the obtained extract was conducted on the Helios Gamma spectrophotometer (ThermoSpectronic), at wavelengths: 441, 646, 652 i 663 nm.

Determination of antioxidant activity with the reduction method of free radicals DPPH, was performed according to Yen and Chen (1995), and the calculation of DPPH inhibition according to the formula provided by Rossi et al. (2003). The determination principle is based on a colorimetric measurement of the reduction degree of the amount of DPPH radicals.

The obtained study results were statistically developed, conducting the analysis of variance corresponding to the adopted system of experiment – the system of random sub-blocks. The confidence intervals were determined using the Tukey test with the significance level of $\alpha = 0.05$.

RESULTS

Biometric assessment of plants

Assessing the impact of the soil contaminated with copper on the growth and development of the dandelion plants the following biometric measurements were performed: the weight of the plant, the height of the plant, the length of leaves and the length of the tap root. Measurements were performed in three dates, and their results were presented in Fig. 1–4.

The highest average weight characterised the plants collected in the last time – 1.19 g (Fig. 1). A slightly lower average weight was noted in the case of the second time of harvest – 1.18 g, and the least in the first harvest – 0.68 g. A clear effect of the contamination degree of the soil with copper was stated in the conducted experiment. Regardless of the time of harvest, the smallest weight characterised the plants, which were grown in the soil with the largest addition of the aqueous solution of copper nitrate and it was on average 0.82 g. Analysing the influence of both factors of the experiment it was stated that the largest weight characterised the plants collected in the second time from the control object (1.96 g), while the smallest – collected in the first time, where 0.05 mmol Cu^{2+} (0.55 g) was used and with the doses of 0.5 and 5 mmol Cu^{2+} (0.66 g).

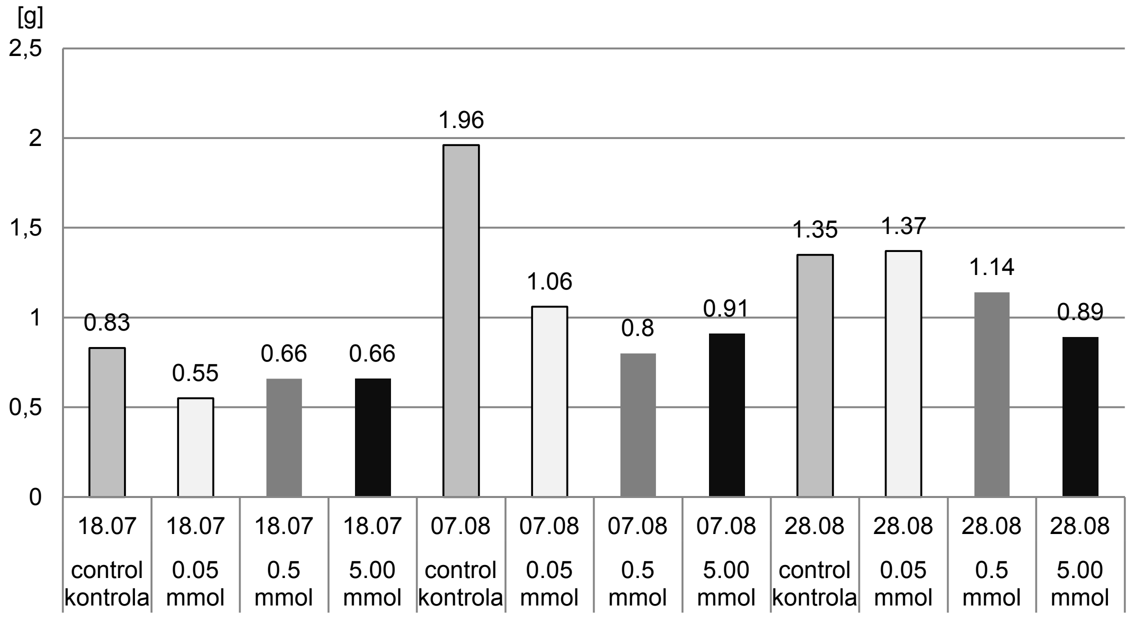

Fig. 1. The effect of the plant harvest time and the amount of $Cu(NO_3) \cdot 3H_2O$ introduced to the soil on the plant weight
Ryc. 1. Wpływ terminu zbioru roślin oraz ilości $Cu(NO_3) \cdot 3H_2O$ wprowadzonej do gleby na masę roślin

Analysing the impact of the harvest time used in the experiment of the addition of aqueous solution of copper nitrite on the height of plants the similar dependency was stated as in the case of the plant weight (Fig. 2). The highest plant height was noted in the third plant harvest – 338.25 mm. It was also stated that with the increasing dose of mmol Cu^{2+}, the height of plants was increasingly smaller: with the dose of 0.05 mmol Cu^{2+} – 288.22 mm; 0.5 mmol Cu^{2+} – 282.78 mm; 5.0 mmol Cu^{2+} – 255.33 mm. The greatest height was found in the plants collected from the control object – 292.89 mm. Taking into account the impact of both factors of the experiment, the largest height of plants was noted in the third harvest time: with the dose of 0.05 mmol Cu^{2+} (368 mm), 0.5 mmol Cu^{2+} (349 mm) and from the control object (346 mm), and the smallest with the first harvest in the case of using 5.0 mmol Cu^{2+} (208 mm).

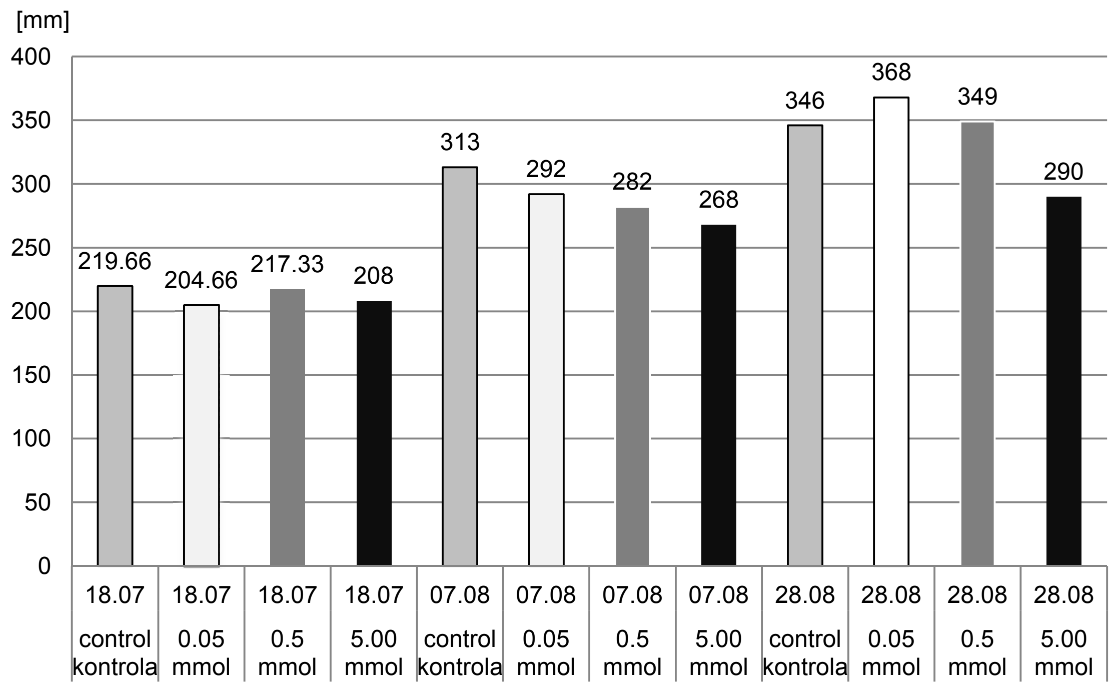

Fig. 2. The effect of the plant harvest time and the amount of $Cu(NO_3) \cdot 3H_2O$ introduced to the soil on the height of plants
Rys. 2. Wpływ terminu zbioru roślin oraz ilości $Cu(NO_3) \cdot 3H_2O$ wprowadzonej do gleby na wysokość roślin

Dandelion leaves differed significantly in terms of the length depending on the harvest time and the dose of copper used in the experiment (Fig. 3). In the case of the harvest time the similar dependencies were stated as in the assessment of the previously discussed biometric features. The greatest length of the leaves characterised the plants collected in the third time – 185.69 mm. While analysing the impact of the applied addition of copper it was stated that the length of the leaves increased with the increase of the amount of $Cu(NO_3) \cdot 3H_2O$ introduced to the soil to the level of 0.5 mmol Cu^{2+}. The impact of both factors of the experiment on the length of the dandelion plant leaves was similar to the one, which was noted in the case of the plant's height. The longest length of the leaves characterised the plants collected in the third time: with the dose of 0.5 mmol Cu^{2+} – 224.00 mm, 0.05 mmol Cu^{2+} – 203.75 mm and from the control object – 172.00 mm.

Analysing the impact of the plant harvest time on the length of the tap root it was stated that the plants collected in the first time were characterised by the shortest root – 26.95 mm, while the longest was in the plants collected in the second time – 47.25 mm (Fig. 4). The impact of the applied addition of the aqueous solution of copper nitrite was the same as for the weight and height of the plant. With the increase of the amount of copper in the soil, the dandelion roots were characterised by a smaller length. Assessing the impact of both experimental factors it was stated that the longest tap root was found in the plants collected in the second time from the control object (57.00 mm), while the shortest – plants collected in the first time while grown in the soil with the addition of 5.00 mmol Cu^{2+} – 22.67 mm.

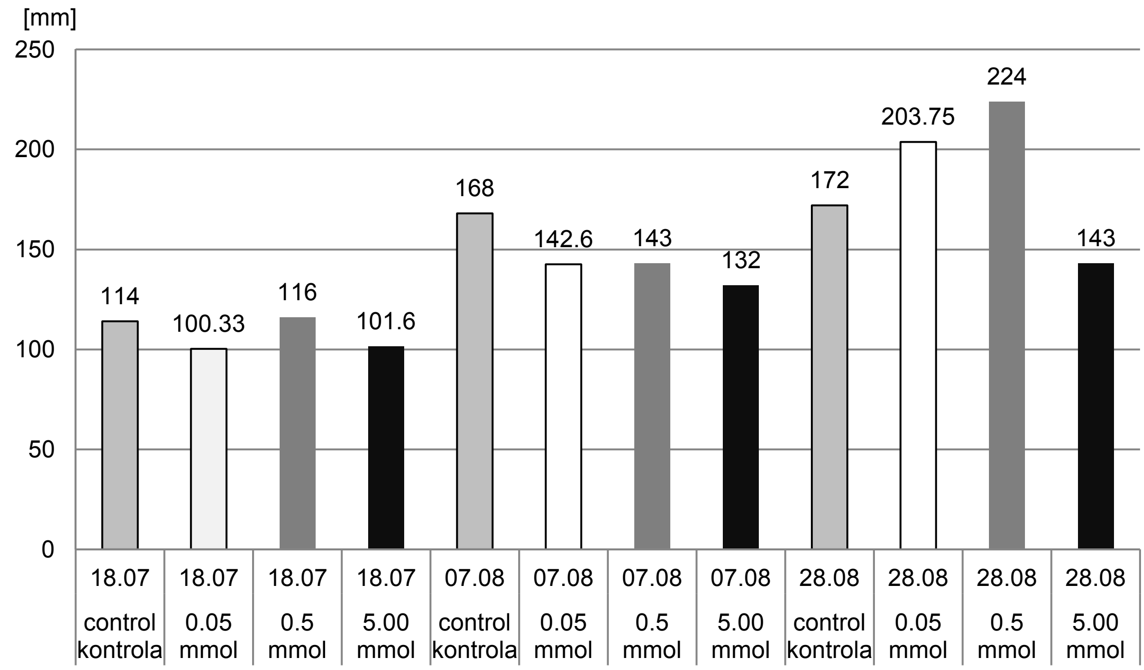

Fig. 3. The effect of the plant harvest time and the amount of $Cu(NO_3) \cdot 3H_2O$ introduced to the soil on the length of the leaves
Rys. 3. Wpływ terminu zbioru roślin oraz ilości $Cu(NO_3) \cdot 3H_2O$ wprowadzonej do gleby na długość liści

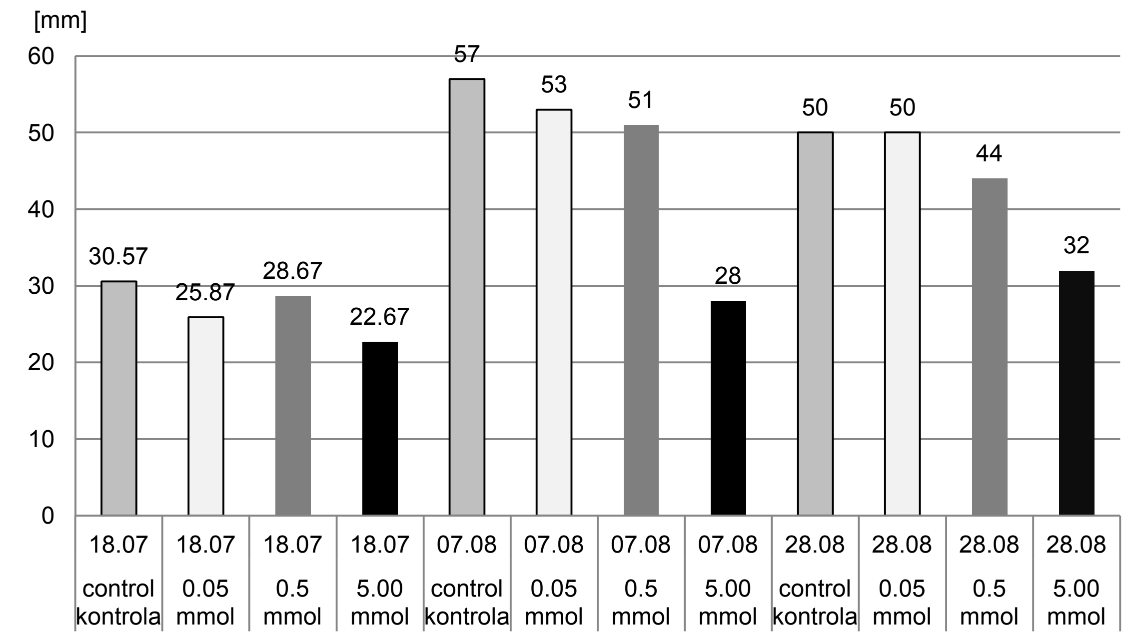

Fig. 4. The effect of the plant harvest time and the amount of $Cu(NO_3) \cdot 3H_2O$ introduced to the soil on the length of the tap root
Rys. 4. Wpływ terminu zbioru roślin oraz ilości $Cu(NO_3) \cdot 3H_2O$ wprowadzonej do gleby na długość korzenia palowego

Assessment of the biological values of dandelion leaves

The dry matter, total ash and L-ascorbic acid content

No significant differences in the dry mass content in dandelion leaves were stated depending on the harvest time and it was, on average, 92.70% (Table 2). In all applied copper concentrations, the dry matter values are similar and do not differ significantly.

Table 2. The dry matter, total ash and L-ascorbic acid content depending on the plant harvest time and the amount of $Cu(NO_3)_2 \cdot 3H_2O$ introduced to the soil
Tabela 2. Zawartość suchej masy, popiołu całkowitego i kwasu L-askorbinowego w zależności od terminu zbioru roślin oraz ilości $Cu(NO_3)_2 \cdot 3H_2O$ wprowadzonej do gleby

Harvest time (factor I) Termin zbioru (czynnik I)	Cu^{2+} dose size introduced to the soil (factor II) Wielkość dawki Cu^{2+} wprowadzonej do gleby (czynnik II)	Dry matter Sucha masa [%]	Total ash [% d.m.] Popiół całkowity [% s.m.]	L-ascorbic acid [mg · 100 g^{-1} d.m.] Kwas L- askorbinowy [mg · 100 g^{-1} s.m.]
July 18 18 lipca	control kontrola	92.94	14.91	7.69
	0.05 mmol	92.85	15.26	12.05
	0.50 mmol	93.13	15.58	12.98
	5.00 mmol	92.70	14.30	11.54
Mean Średnia		92.91	15.01	11.07
August 7 7 sierpnia	control kontrola	92.31	18.94	9.13
	0.05 mmol	92.70	19.52	7.69
	0.50 mmol	91.78	16.53	10.09
	5.00 mmol	93.21	20.10	10.1
Mean Średnia		92.50	18.77	9.25
August 28 28 sierpnia	control kontrola	92.53	18.14	11.05
	0.05 mmol	92.58	17.74	12.03
	0.50 mmol	92.99	17.04	8.65
	5.00 mmol	92.70	16.42	9.63
Mean Średnia		92.70	17.34	10.34
Mean for factor II Średnia dla czynnika II	control kontrola	92.59	17.33	9.29
	0.05 mmol	92.71	17.51	10.59
	0.50 mmol	92.63	16.38	10.57
	5.00 mmol	92.87	16.94	10.42
$LSD_{0.05}$ for I NIR I		n.i.	n.i.	0.025
$LSD_{0.05}$ for II NIR II		n.i.	n.i.	0.032
$LSD_{0.05}$ for I × II NIR I × II		0.81	n.i.	0.055

n.i. – statistically insignificant – nieistotne statystycznie.

The significance of both experiment factors was shown for the second harvest time. A significantly greater dry matter characterised the plant leaves from the control object and from objects, where the addition of copper was 0.05 and 5.0 mmol Cu^{2+}. A significantly lower dry matter of leaves was noted in this time with the dose of 0.5 mmol Cu^{2+}.

In the conducted experiment no significant differences were stated in the content of total ash in dandelion leaves depending on the harvest time and the addition of copper in the soil (Table 2). Also no significant interaction of both factors of the experiment was stated.

The content of L-ascorbic acid in dandelion leaves differed significantly depending on the harvest time (Table 2). The highest content of L-ascorbic acid characterised the leaves of plants collected in the first time (11.07 mg · 100 g^{-1} d.m.), a smaller one in the third time (10.34 mg · 100 g^{-1} d.m.), and the smallest in the second time (9.25 mg · 100 g^{-1} d.m.). While analysing the influence of copper introduced to the soil it was stated that the highest content of L-ascorbic acid characterised the leaves of plants collected from objects, where the addition of 0.05 and 0.5 mmol Cu^{2+} was used (on average 10.58 mg · 100 g^{-1} d.m.), a smaller one in the case of the addition of 5.0 mmol Cu^{2+} (on average 10.42 mg · 100 g^{-1} d.m.), and the smallest in the case of the control object (9.29 mg · 100 g^{-1} d.m.). In the conducted experiment also a significant cooperation of both experimental factors was stated. In the first plant harvest time, the highest amount of L-ascorbic acid was noted in the concentration of 0.5 mmol Cu^{2+}, then – less in the concentration of 0.05 mmol Cu^{2+} and successively with the concentration of 5.0 mmol Cu^{2+}, and the least in the control sample. In the second harvest time, the largest amount of L-ascorbic acid was noted in the concentration of 5.0 and 0.5 mmol Cu^{2+}, less with the control sample, while the least – in the concentration of 0.05 mmol Cu^{2+}. In the third harvest time, the largest amount of L-ascorbic acid was stated for the concentration of 0.05 mmol Cu^{2+}, and then in the case of the control and in the concentration of 5.0 mmol Cu^{2+}, and the least in the concentration of 0.5 mmol Cu^{2+}.

The content of chlorophyll a, b and total

In the conducted experiment significant differences in the content of chlorophyll a, b and total was stated in dandelion leaves depending on the harvest time (Table 3). The highest content of chlorophyll a, b and total characterised the leaves of plants collected in the third time and it was, respectively, (293.67 mg · kg^{-1} d.m.), (130.06 mg · kg^{-1} d.m.) and (475.04 mg · kg^{-1} d.m.), smaller in the first time – chlorophyll a (250.58 mg · kg^{-1} d.m.), chlorophyll b (108.71 mg · kg^{-1} d.m.), total chlorophyll (398.39 mg · kg^{-1} d.m.).

A significant effect on the content of chlorophyll a, b and total in dandelion leaves was also shown in the case of copper doses applied in the experiment. The largest content of chlorophyll pigments was stated in the concentration of 5 mmol Cu^{2+}, then in the control samples and later on in the concentration of 0.5 mmol Cu^{2+}. The smallest amount of chlorophyll a, b and total was noted in the concentration of 0.05 mmol Cu^{2+}.

The statistical analysis of the obtained study results has also showed the significant cooperation of both experimental factors. In the first harvest time the most chlorophyll a, b and total was stated in the concentration of 5.0 mmol Cu^{2+}, then less in the control sample, and the least – in concentrations of 0.5 and 0.05 mmol Cu^{2+}. In the second harvest time the largest amount of chlorophyll a, b and total was noted in the concentration of 5.0 mmol Cu^{2+}. In the third harvest time in the case of concentration of 0.5 mmol Cu^{2+}.

Table 3. The content of chlorophyll a, b and total [mg · kg^{-1} d.m.] depending on the plant harvest time and the amount of $Cu(NO_3)_2 \cdot 3H_2O$ introduced to the soil
Tabela 3. Zawartość chlorofilu a, b i ogółem [mg · kg^{-1} s.m.] w zależności od terminu zbioru roślin oraz ilości $Cu(NO_3)_2 \cdot 3H_2O$ wprowadzonej do gleby

Harvest time (factor I) Termin zbioru (czynnik I)	$Cu(NO_3)_2$ dose size introduced to the soil (factor II) Wielkość dawki $Cu(NO_3)_2$ wprowadzonej do gleby (czynnik II)	Chlorophyll a [mg · kg^{-1} d.m.] Chlorofil a [mg · kg^{-1} s.m.]	Chlorophyll b [mg·kg^{-1} d.m.] Chlorofil b [mg · kg^{-1} s.m.]	Total chlorophyll [mg · kg^{-1} d.m.] Chlorofil ogółem [mg · kg^{-1} s.m.]
July 18 18 lipca	control kontrola	266.72	115.87	424.99
	0.05 mmol	207.06	88.47	326.54
	0.50 mmol	209.41	91.28	332.35
	5.00 mmol	319.13	139.21	509.69
Mean Średnia		250.58	108.71	398.39
August 7 7 sierpnia	control kontrola	138.29	61.96	224.77
	0.05 mmol	92.38	43.05	151.53
	0.50 mmol	131.15	60.73	215.70
	5.00 mmol	155.79	69.33	252.23
Mean Średnia		129.40	58.77	211.06
August 28 28 sierpnia	control kontrola	291.79	129.02	472.63
	0.05 mmol	270.16	119.58	436.85
	0.50 mmol	331.04	143.29	530.88
	5.00 mmol	281.69	128.36	459.80
Mean Średnia		293.67	130.06	475.04
Mean for factor II Średnia dla czynnika II	control kontrola	232.27	102.28	374.13
	0.05 mmol	189.87	83.70	304.97
	0.50 mmol	223.87	98.43	359.64
	5.00 mmol	252.20	112.30	407.24
$LSD_{0.05}$for I NIR I		5.081	6.861	13.14
$LSD_{0.05}$for II NIR II		2.522	1.94	4.46
$LSD_{0.05}$for I × II NIR I × II		4.368	3.37	7.73

The content of total carotenoids and antioxidant activity

In the conducted experiment significant differences in the content of total carotenoids were stated in dandelion leaves depending on the harvest time (Table 4). The highest content of these compounds characterised the leaves of plants collected in the third time (87.32 mg · kg^{-1}d.m.), a smaller one in the first time (70.56 mg · kg^{-1} d.m.), and the smallest in the second time (47.34 mg · kg^{-1} d.m.).

Assessing the effect of the copper dose applied in the experiment added to the soil, in which dandelion was grown, it was stated that the highest concentration of total carotenoids characterised the leaves of plants from the object, where the copper addition was 5.0 mmol Cu^{2+}, and then less: from the control object, where the addition of copper was 0.5 mmol Cu^{2+} and the least in the dose of 0.05 mmol Cu^{2+}.

Table 4. The content of total carotenoids and the antioxidant activity depending on the plant harvest time and the amount of Cu $(NO_3)_2 \cdot 3H_2O$ introduced to the soil
Tabela 4. Zawartość karotenoidów ogółem i aktywność antyoksydacyjna w zależności od terminu zbioru roślin oraz ilości Cu $(NO_3)_2 \cdot 3H_2O$ wprowadzonej do gleby

Harvest time (factor I) Termin zbioru (czynnik I)	Cu^{2+} dose size introduced to the soil (factor II) Wielkość dawki Cu^{2+} wprowadzonej do gleby (czynnik II)	Total carotenoids [mg · kg^{-1} d.m.] Karotenoidy ogółem [mg · kg^{-1} s.m.]	Antioxidant activity Aktywność antyoksydacyjna [% DPPH]
July 18 18 lipca	control kontrola	68.56	88.32
	0.05 mmol	64.48	88.32
	0.50 mmol	61.46	75.59
	5.00 mmol	87.74	87.88
Mean Średnia		70.56	85.03
August 7 7 sierpnia	control kontrola	56.27	86.64
	0.05 mmol	36.53	86.70
	0.50 mmol	47.33	83.00
	5.00 mmol	49.21	85.90
Mean Średnia		47.34	85.56
August 28 28 sierpnia	controla kontrola	85.13	50.62
	0.05 mmol	79.83	69.08
	0.50 mmol	96.87	49.19
	5.00 mmol	87.46	75.69
Mean Średnia		87.32	61.15
Mean for factor II Średnia dla czynnika II	control kontrola	69.99	75.19
	0.05 mmol	60.28	81.37
	0.50 mmol	68.55	69.26
	5.00 mmol	74.80	83.16
$LSD_{0.05}$for I NIR I		0.840	2.845
$LSD_{0.05}$for II NIR II		0.886	1.817
$LSD_{0.05}$for I × II NIR I × II		1.534	3.147

Based on the statistical analysis of the obtained study results the significant interaction of both factors of the experiment was stated. In the first harvest time, the largest amount of total carotenoids was noted in the concentration of 5.0 mmol Cu^{2+}. In the second harvest time in the control sample, while in the third harvest time – in the case of the concentration of 0.5 mmol Cu^{2+}.

In the conducted experiment also a significant effect of the plant harvest time on the antioxidant activity of their leaves was shown. A significantly higher antioxidant activity characterised the leaves of plants collected in two first times (an average of 85.03% DPPH), and a smaller one – in the third time (61.15% DPPH).

Assessing the effect of the copper addition to the soil it was stated that the highest antioxidant activity characterised the leaves of plants grown in the soil with the addition of 5.0 mmol Cu^{2+} and next a smaller one: with the addition of 0.05 mmol Cu^{2+}, from the control object and with the addition of 0.5 mmol Cu^{2+}.

The significance of the interaction of both factors of the experiment was shown for the first and third harvest time. In the first harvest time a significantly higher antioxidant activity characterised the leaves of plants from the control object, an object where the addition of copper was 0.05 and 5.0 mmol Cu^{2+}. In the case of the third harvest time the highest antioxidant activity was stated in the dose of 5.0 mmol Cu^{2+} and then successively smaller: with the dose of 0.05 mmol Cu^{2+}, from the control object and with the dose of 0.5 mmol Cu^{2+}.

DISCUSSION

Based on own study results a significant impact of the contamination degree of soil with copper was stated on the biometric features of dandelion plants and their biological value. According to Preeti and Tripathi (2011), there is a direct relationship between chemical properties of the soil, the concentration of heavy metals, and the morphological and biochemical response of the plants. Plants growing on soils contaminated with heavy metals can accumulate them in their tissues, what can contribute to the adverse effects on health and morphology of plants (Keane et al. 2001).

In own studied it was stated that both the growth of plants and the level of L-ascorbic acid, chlorophyll a and b, carotenoids and antioxidant activity in dandelion leaves were subject to changes depending on the amount of copper contained in the soil and the harvest time.

The addition of copper used in the experiment in the dose of 0.5 mmol causes a significant reduction in weight and height of the plant, length of leaves and length of tap root, compared with the lower copper doses.

In the case of studies conducted on dandelion leaves it was stated that the higher the copper concentration in the soil, the higher the amount of chlorophyll a, b and total.

In studies conducted by Dopierała (2009), which concerned the effect of copper on the growth and content of chlorophyll in white quinoa (*Chenopodium album* L.) inhabiting the fields around the copper smelter “Głogów” it was stated that both the growth of the plants and the level of chlorophyll in white quinoa leaves from around Głogów and Skórzew were subject to changes depending on the amount of copper in the medium. Copper in doses of 400, 600 and 800 mg $\cdot$ kg^{-1} of dry matter of the soil caused a significant statistical reduction of the shoots growth compared to the lower doses of copper. Significant differences also occurred between successive higher concentrations of copper present in the medium (Dopierała 2009). In the leaves of white quinoa the content of chlorophyll remained at a similar level with the range from 0 to 200 mg of copper added to the medium. In conditions of higher doses of copper in the medium (400–800 mg $\cdot$ kg^{-1}) the level of chlorophyll underwent a slow decline (Dopierała 2009).

A significant effect on the content of heavy metals in the leaves of dandelion comes from: harvest time and the place of its occurrence. In studies conducted by Keane et al. (2001) on the dandelion leaves in 29 locations throughout the United States the highest concentrations of heavy metals were stated in autumn, which ranged 4.28–58.41 mg $\cdot$ kg^{-1}. In spring a much smaller concentrations of heavy metals were observed, ranged 1.62–12.01 mg $\cdot$ kg^{-1}.

From studies conducted in Italy by Bini et al. (2012), where the effect of heavy metals on the morphological features of dandelion growing in the soils near the mine was tested, it results that plants with the high concentration of heavy metals usually show abnormal growth. High concentrations of heavy metals in the soil affected the biochemical and morphological changes of plants – damages of plant roots and inhibition of absorption of nutrients. Morphology of the leaves of dandelion grown in locations contaminated with heavy metals in relation to plants grown on the not contaminated soil characterised by toxic changes, among others, reduction of the thickness of leaves. Concentrations of copper both in the leaves and in the roots in soils contaminated with heavy metals remained at a similar level – in the range of 40–64 mg · kg^{-1}. In the uncontaminated soil, the copper concentrations in the roots were 7 mg · kg^{-1}, and in the leaves 9 mg · kg^{-1}.

CONCLUSIONS

1. The addition of copper used in the experiment in the dose of 5.0 mmol caused a significant decrease of the weight and height of the plant, the length of leaves and the length of the tap root, compared with the lower doses of copper and the control object.
2. Analysing the obtained study results it was stated that the harvest time had a significant effect on the biometric features of dandelion. The largest sizes of individual parts of dandelion were noted in the case of the last harvest time, and the smallest in the case of the first harvest time.
3. Based on the obtained results of chemical analyses a significant effect of the amount of $Cu (NO_3)_2$ used in the experiment on the biological values of dandelion leaves was found. The highest dry matter characterised the leaves from the control object, while the biggest content of L-ascorbic acid was noted in concentrations of 0.05 and 5.0 mmol Cu^{2+}. In the addition to soil of 5.0 mmol Cu^{2+}, the plants were characterised by a significantly higher content of chlorophyll pigments, total carotenoids and the highest antioxidant activity.
4. The harvest time had a significant impact on the content of L-ascorbic acid (the highest – in the first harvest time, the least – in the second harvest time), chlorophyll a, b, total and total carotenoids (the highest – in the third time, and the least – in the second). The harvest time also had a significant effect on the antioxidant activity (the highest in the first and second harvest time, the least – in the third harvest time).

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Abstract. The experiment was conducted in 2013. Research material included the leaves of a dandelion (*Taraxacum officinale* Weber ex Wigg.) – roots with the above-ground part, gathered before tying of flower baskets *(Taraxaci radix cum herba)*. Laboratory analyses, which were the continuation of the pot experiment, were conducted in the laboratory of the Department of Horticulture of the West Pomeranian University of Technology in Szczecin. In the dried plant material (dandelion leaves) the content was determined: of dry mass and total ash, vitamin C as L-ascorbic acid, chlorophyll a, b and total, total carotenoid and antioxidant activity. Based on the obtained results it was found that both the biometric features of the dandelion plants and their biological value subjected to significant changes depending on the amount of copper contained in the soil and the crop harvest date.