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INFLUENCE OF CULTIVATION METHODS AND FOLIAR NUTRITION WITH Cu AND Mn ON YIELDS AND BIOLOGICAL VALUE OF SCORZONERA ROOTS (*Scorzonera hispanica* L.)

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Abstract. Root crops are particularly sensitive towards growth conditions, while simplifications recommended at present in agricultural technology exert diverse effects on reactions of cultivated plants. The study aimed at evaluating the impact of varied tillage systems and plant cultivation as well as foliar cooper and manganese nutrition on root yields of scorzonera and some of their qualitative traits. The field experiments were carried out in 2005–2007 on lessive soil developed from loess formations covering the chalky marls. Scorzonera of Duplex cv. was the testing plant. The experimental pattern included the following factors: two plant cultivation methods (on flat soil and on ridges), two pre-sowing tillage systems (harrowing, rototiller), as well as foliar nutrition with copper and manganese. The highest total and marketable yields of scorzonera roots at the lowest share of non-commercial roots in total yield, was achieved due to cultivation in ridges, after pre-sowing tillage using rototiller, and manganese foliar nutrition. The positive influence of scorzonera cultivation on ridges on dry matter content in roots was recorded. Diverse tillage systems and plant foliar nutrition had no significant effects on inulin content in scorzonera roots; however the increasing tendency of the component concentration at plants cultivated on ridges after shallow spring tillage procedures, was observed. Studied experimental factors did not exert any considerable influence on protein contents in scorzonera roots.

Key words: scorzonera, inulin, ridges, copper, manganese, pre-sowing tillage

INTRODUCTION

Along with the increase of knowledge on nutritional issues, the interests in plant-origin products that contain substances with pro-health action to human's organisms, arise as well. Among many valuable plant species met in Poland, those containing fruc-

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tooligosaccharides (FOS) with the most important inulin, are worth of special attention [Cieślik et al. 2001, Roberfroid 2002]. Inulin is counted to components of soluble nutritional fiber that cannot be digested in small intestine and reaches in its intact form to large intestine where is metabolized by probiotic bacteria of *Bifidobacterium* and *Lactobacillus* genera, which makes them reproduced. Consuming the inulin has its advantages for digestive tract [Wszołek 1999, Kolida et al. 2002, Skowronek and Fiedurek 2003]. It binds cholesterol and biliary acids, which results in decreased levels of triglycerides and cholesterol in blood serum, thus preventing from development of atheromatous plaque in blood vessels. Inulin is also a valuable nutrient for obese people and those having contraindications for sugars consumption, namely diabetic ones; it is characterized by hypoglycemic action [Hébette et al. 1998, Causey et al. 2000, Kim 2000, Cabezas et al. 2002, Cherbut 2002, Delzenne et al. 2002, Gałązka 2002, Monti et al. 2005].

Scorzonera (*Scorzonera hispanica* L.) is an inulin-abundant plant species. It is a root crop vegetable that, despite of its nutritional, dietetic, and taste values, is poorly known and rarely met in commercial production in Poland. However, due to its high biological value as well as possibility to enhance the spectrum of raw vegetable assortment in winter and early spring, it is worth of recommendation and spreading both among producers and consumers [Dolota et al. 2005].

The inulin content in plant tissues can be affected by plant maturity, applied agricultural technology, as well as conditions the raw material is stored after the harvest [Konopiński 2003]. Treating plants with some micronutrients, e.g. copper or manganese, can lead to the increase in inulin concentration in roots [Łachowski 1961]. The tillage system before sowing is also important yield-forming factor in vegetables cultivation Traditional tillage, which is characterized by numerous cultivating measures, remarkably increases the time, labour, and energy inputs, and frequent driving of the devices contributes to worse physical properties of the soil. Therefore, some simplifications consisting in reducing the number of operations and tillage depth, are applied in modern cultivation technologies [Kęsik and Błażewicz-Woźniak 1994, Uppenkamp 2002, Konopiński 2003]. Higher yielding of root crops can be also achieved by means of their cultivation on ridges [Cebulak and Sady 2000].

The aim of work is to determine the effect of plant cultivation methods (on flat soil, on the ridges), presowing soil tillage and foliar nutrition with copper and manganese on growth, yield and biological value of scorzonera roots.

MATERIAL AND METHODS

The field experiment was carried out in 2005–2007 at the Experimental Farm of University of Life Sciences in Lublin located in Felin, district of Lublin (22º 56'E, 51º 23'N, Central East of Poland, 200m a.s.l.), on lessive soil developed from loess formations covering the chalky marls, of granulometric composition corresponded to moderate dusty loam. Scorzonera of Duplex cv. was the test plant species. The experiment was set in split-plot pattern in four replicates included following factors: two cultivation methods (on flat soil and on ridges), two methods of pre-sowing spring tillage (harrow-

ing up to 5 cm depth, applying rototiller up to 15 cm depth), as well as foliar nutrition (with copper and manganese). Before sowing one part of the field was harrowed, while rototiller was applied on the other. Within these objects, ridges were formed on half of the field area, whereas remaining area was flat. The scorzonera seeds were sown into rows 50 cm apart to 3 cm depth at the amount of 12 kg·ha^{-1}. Plant fertilization was following: 100 kg N·ha^{-1}, 44 kg P·ha^{-1}, 166 kg K·ha^{-1}. Doses of nutrients were determined on the base of soil analysis. Nitrogen was applied at two doses: ½ before sowing and ½ as a top dressing. Phosphorus-potassium nutrition was applied in a single dose before sowing. In the middle of August, plants were sprayed with studied micronutrients twice in interval of 10 days. Copper was used in a form of copper chelate – Mikrovit Cu (3.5% Cu/1 l of fertilizer) at the concentration of 0.5%. Manganese was applied in a form of manganese chelate – Mikrovit Mn (3.5% Mn/1 l of fertilizer) at 0.5% concentration. Ethylenediaminetetraacetic acid (EDTA) was chelating agent in both preparations used. Plants were harvested at the end of October. The plot size for harvest was 2.5 m^2. Harvested roots were divided and weighed to evaluate the total root yield and its structure. Marketable yield distinguishing the 1st class roots (length of roots minimum 22 cm, diameter 1.5 cm) and 2nd class (length minimum 15 cm, diameter 1.2 cm) as well as non-marketable yield (containing fine, branched, and shapeless roots) were singled out from the yield structure [Polska Norma PN-R-75533:1996]. Provided with the root harvest, their nutritional value was assessed; dry matter (by means of dryer method), inulin content (HPLC technique), and proteins level (applying Kjeldahl method) were determined in roots. Achieved results were statistically processed by means of variance analysis and finding the difference significance by Tukey test for significance level $\alpha = 0.05$.

RESULTS

The average total roots yield amounted to 20.1 t·ha^{-1} (tab. 1). Studied experimental factors exerted some significant effects on scorzonera yielding. Root yield was remarkably higher under ridge cultivation conditions rather than on flat soil (by 2.2 t·ha^{-1}, on average), as well as when rototiller instead of harrowing was used in spring. Harrowing and cultivators had no significant effect on total roots yield in the cultivation of plants on the flat soil. In the plants cultivation on the ridges, pre-sowing soil tillage with cultivator contributed to a significant increase of scorzonera roots yield. It was also found that treating the vegetable with manganese had considerable impact on increasing the total root yield (by 2.8 t·ha^{-1}) as compared to harvest of plants that were not amended. A tendency to enhance the scorzonera yielding after applying foliar spraying with copper in comparison to that not fertilized was observed as well. Considering the interactions between cultivation methods and tillage systems, it was concluded that the highest yields of roots (23.3 t·ha^{-1}) could be produced when plants were grown on ridges and rototiller as pre-sowing cultivating measure was made at the same time.

Regardless of examined factors, the mean marketable root yield was 12.6 t·ha^{-1} (tab. 2). When scorzonera grew on ridges, the commercial root yield increased (by 2.1 t·ha^{-1}, on average) as compared to flat soil cultivation. Some significantly improved

yielding (by 3.0 t·ha^{-1}) was also recorded under conditions of pre-sowing tillage using rototiller. Regardless of diverse cultivation methods, considerably higher marketable root yields were achieved from treatments where plants were supplied with manganese. A tendency to better yielding was also observed due to copper spraying as compared to not treated object. Like for a total root yield, the highest marketable root yield was also harvested from objects that were applied with pre-sowing rototiller and those where vegetables grew on ridges (16.0 t·ha^{-1}), whereas the lowest yields were achieved from objects with flat soil cultivation along with shallow pre-sowing tillage (10.9 t·ha^{-1}).

Table 1. Total yield of scorzonera roots of Duplex cv., mean from years 2005–2007 (in t·ha^{-1})
Tabela 1. Plon korzeni ogółem skorzonery odm. Duplex, średnio z lat 2005–2007 (w t·ha^{-1})

Plants cultivation Uprawa roślin	Pre-sowing soil tillage Przedsiewna uprawa roli	Without foliar nutrition Bez dokarmiania	Foliar nutrition with Cu Dokarmianie Cu	Foliar nutrition with Mn Dokarmianie Mn	Mean Średnia
On flat soil Na płask	harrowing bronowanie	18.3	20.5	17.9	18.9
	rototilling uprawa glebogryzarką	17.0	16.7	23.5	19.1
	mean średnia	17.7	18.6	20.7	19.0
On ridges Na redlinach	harrowing bronowanie	16.4	19.4	21.4	19.0
	rototilling uprawa glebogryzarką	23.6	22.7	23.5	23.3
	mean średnia	20.0	21.0	22.4	21.2
Mean Średnia	harrowing bronowanie	17.4	19.9	19.6	19.0
	rototilling uprawa glebogryzarką	20.3	19.7	23.5	21.2
	mean średnia	18.8	19.8	21.6	20.1
LSD $_{(0.05)}$ for: – NIR $_{(0.05)}$ dla:					
plants cultivation – uprawy roślin					1.4
pre-sowing soil tillage – przedsiewnej uprawy roli					1.4
foliar nutrition – dokarmiania pozakorzeniowego					2.1
plants cultivation × pre-sowing soil tillage – uprawy roślin × przedsiewnej uprawy roli					2.7

The 1st and 2nd class roots made up the highest share in the total root yield structure, while non-marketable roots showed the lowest percentage. It was the most prominent when scorzonera was grown on ridges after rototiller and foliar nutrition with manganese. Cultivation on ridges resulted in the decrease of non-commercial yield share by 4.5% as compared to flat soil (fig. 1), whereas that of the 1st class roots increased by 3%. Deeper pre-sowing tillage (rototiller application) caused the increase of the 1st class

Table 2. Marketable yield of scorzonera roots of Duplex cv., mean from years 2005–2007 (in t·ha^{-1})
Tabela 2. Plon handlowy korzeni skorzonery odm. Duplex, średnio z lat 2005–2007 (w t·ha^{-1})

Plants cultivation Uprawa roślin	Pre-sowing soil tillage Przedsiewna uprawa roli	Without foliar nutrition Bez dokarmiania	Foliar nutrition with Cu Dokarmianie Cu	Foliar nutrition with Mn Dokarmianie Mn	Mean Średnia
On flat soil Na płask	harrowing bronowanie	10.8	11.6	10.3	10.9
	rototilling uprawa glebogryzarką	9.6	10.8	16.0	12.1
	mean średnia	10.2	11.2	13.2	11.5
On ridges Na redlinach	harrowing bronowanie	10.0	11.2	12.4	11.2
	rototilling uprawa glebogryzarką	15.4	15.5	17.0	16.0
	mean średnia	12.7	13.4	14.7	13.6
Mean Średnia	harrowing bronowanie	10.4	11.4	11.4	11.1
	rototilling uprawa glebogryzarką	12.5	13.2	16.5	14.1
	mean średnia	11.5	12.3	13.9	12.6
LSD $_{(0.05)}$ for: – NIR $_{(0.05)}$ dla:					
plants cultivation – uprawy roślin					1.5
pre-sowing soil tillage – przedsiewnej uprawy roli					1.5
foliar nutrition – dokarmiania pozakorzeniowego					2.2
plants cultivation × pre-sowing soil tillage – uprawy roślin × przedsiewnej uprawy roli					2.7

roots share by 5.0% and decrease of non-marketable roots percentage from 42.6% to 33.7% compared to shallow tillage. Regardless of other experimental factors, foliar nutrition had also considerable impact on yield structure. Treating the scorzonera with copper resulted in the increase of the 1st class roots share in total yield by 0.9%, while when plants were sprayed with manganese – by 1.8% as compared to the control. Percentage of non-marketable roots in those treatments decreased by 2.3% and 4.2%, respectively.

Dry matter content in scorzonera roots amounted to 26.6%, on average (tab. 3). Roots from treatments where vegetable grew on ridges accumulated more dry matter (by 0.8%) in comparison with roots from flat soil cultivation. The pre-sowing tillage system as well as foliar nutrition had no significant influence on dry matter content in roots.

Average inulin concentration in scorzonera roots, regardless of other studied experimental factors, was 74.19% d.m. Different tillage systems and cultivation methods as well as foliar nutrition had no considerable effects on inulin content. However, it was

Table 3. Dry matter, inulin and protein content in scorzonera root of Duplex cv., mean from years 2005–2007
Tabela 3. Zawartość suchej masy, inuliny i białka w korzeniu skorzonery odm. Duplex, średnio z lat 2005–2007

Plants cultivation Uprawa roślin	Pre-sowing soil tillage Przedsiewna uprawa roli	Dry matter – Sucha masa %				Inulin – Inulina % of dry matter – % s.m.				Protein – Białko % of dry matter – % s.m.			
		k	Cu	Mn	mean średnio	k	Cu	Mn	mean średnio	k	Cu	Mn	mean średnio
On flat soil Na płask	A	26.0	26.1	26.1	26.0	76.74	73.60	74.53	74.96	12.17	13.94	14.90	13.67
	B	26.4	26.2	26.5	26.4	74.09	73.53	69.57	72.43	14.29	15.10	15.25	14.88
	mean – średnia	26.2	26.2	26.3	26.2	75.42	75.62	72.05	73.69	13.23	14.52	15.07	14.27
On ridges Na redlinach	A	26.2	26.9	26.8	26.6	75.10	71.58	76.27	74.32	13.90	12.21	13.38	13.16
	B	27.2	27.6	27.2	27.3	72.81	76.49	75.89	75.06	13.98	11.67	13.63	13.09
	mean – średnia	26.7	27.2	27.0	27.0	73.96	74.04	76.08	74.69	13.94	11.94	13.50	13.13
Mean Średnio	A	26.1	26.5	26.4	26.3	75.92	72.59	75.40	74.64	13.03	13.07	14.14	13.41
	B	26.8	26.9	26.8	26.8	73.45	75.06	72.73	73.75	14.14	13.39	14.44	13.99
	mean – średnia	26.4	26.7	26.6	26.6	74.69	73.83	74.06	74.19	13.58	13.23	14.29	13.70
LSD $_{(0.05)}$ for: – NIR $_{(0.05)}$ dla:													
plants cultivation – uprawy roślin					0.7				n.s.				n.s.
pre-sowing soil tillage – przedsiewnej uprawy roli					n.s.				n.s.				n.s.
foliar nutrition – dokarmiania pozakorzeniowego					n.s.				n.s.				n.s.

*n.s. – no significant
A – harrowing – bronowanie,
B – rototilling – uprawa glebogryzarką,
k – without foliar nutrition – bez dokarmiania,
Cu – foliar nutrition of copper – dokarmianie miedzią,
Mn – foliar nutrition of manganese – dokarmianie manganem

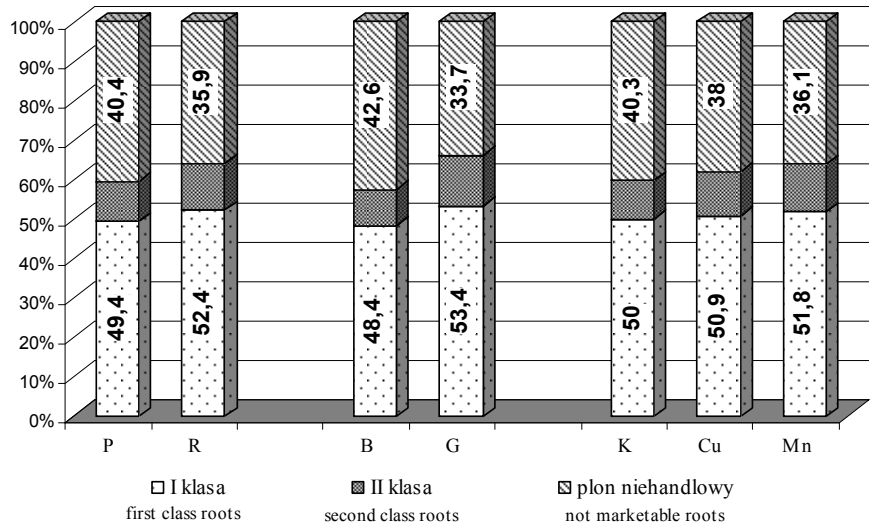

Fig. 1. Yield structure of scorzonera roots of Duplex cv., mean from years 2005–2007: P – cultivation on flat soil, R – cultivation on ridges, B – harrowing, G – rototilling, K – without foliar nutrition, Cu – foliar nutrition of copper, Mn – foliar nutrition of manganese

Rys. 1. Struktura plonu korzeni skorzonery odm. Duplex, średnio z lat 2005–2007: P – uprawa na płask, R – uprawa na redlinach, B – bronowanie, G – uprawa glebogryzarką, K – bez dokarmiania, Cu – dokarmianie miedzią, Mn – dokarmianie manganem

recorded that plants grown on ridges accumulated slightly more inulin (by 1%) than under flat soil cultivation conditions. Applying shallow pre-sowing tillage (harrowing) caused negligible increase of this compound in scorzonera roots (by 0.89%). Plants cultivated on control plots contained 74.69%, those treated with copper – 73.83 %, and manganese – 74.06% of inulin, on average.

Protein content in scorzonera roots was 13.7% d.m. Studied experimental factors had no significant influence on that trait. Nevertheless, a tendency to higher (by 1.14%) protein accumulation when plants were grown on flat soil and on plots with pre-sowing rototiller tillage (by 0.58%), was recorded. Copper nutrition led to a slight decrease of protein content in roots, while manganese spraying made it slight increased.

DISCUSSION

The three-year studies upon scorzonera yielding under conditions of different tillage systems and foliar nutrition revealed remarkable influence of examined factors on the size and quality of root yields. Cultivation of scorzonera on the ridges contributed to improved yielding. Babik [2000] also found positive effect of ridges on common chicory yielding; and similarly Babik and Dudek [2000] achieved higher yields of carrot and chicory roots as well as their better qualities when grown on ridges as compared to

cultivation on flat soil. Konopiński [2009] recorded significantly higher yields of common salsify roots when grown on ridges versus flat soil cultivation. Similar effects were observed referring to carrot [Cebulak and Sady 2000] as well as carrot and parsley [Polák et al. 1999]. The plant cultivation method also exerted considerable influence on celery yielding in experiments performed by Michalik [2003]. The author recorded that the highest total yield was achieved when plants were cultivated on ridges. Studies by Tisdall and Hodgson [1990] indicated that higher yields of plants grown on ridges was associated mainly with better aeration-moisture conditions in the soil. Results achieved by Wierzbicka et al. [2004] in experiments upon the influence of carrot cultivation methods on yield and compactness of its roots revealed that higher marketable yield was achieved for Flacoro cv. grown on ridges, while Dolanka cv. in flat soil system, although the total yields of both were higher on ridges. In opinion of Konopiński [2003] cultivation of scorzonera on the ridges has a positive influence on weight, length and thickness of roots; however, it has no significant effects on total and marketable yields of roots. Dolota and Dąbrowska [2007] recorded significantly lower total and marketable yields of scorzonera when grown on ridges, which probably resulted both from unfavourable weather conditions during the vegetable vegetation, the way the ridges were made, and number of rows per area unit (the spacing was 40 cm in flat soil, while 67.5 cm in ridges). Diverse techniques of soil preparation greatly affect the root proliferation. Pre-sowing tillage using rototiller considerably contributed to the increase of total and marketable root yields. Studies made by Kęsik et al. [1992] as well as by Błażewicz-Woźniak [1998] also revealed that pre-sowing tillage with rototiller caused the improvement in roots yield (parsley, carrot, and beet root) as compared to soil cultivation by ploughing. Plants can react in extremely different ways to pre-sowing tillage. In studies of Kęsik et al. [1999], the highest carrot yield was achieved after pre-sowing rototiller tillage, meanwhile the yields were the lowest after the spring ploughing. During the parsley and beet root cultivation, making the medium ploughing had more positive effects on root yields than other techniques of spring pre-sowing tillage. The highest total and marketable scorzonera root yields – significantly higher as compared to the control – were recorded when manganese was applied. Copper also improved the vegetable yielding, but it was statistically insignificant. In a view of experiments carried out by Wróbel [1996], fertilizing the beet root with boron and manganese resulted in remarkably increase of root yields as compared to the control object, that was no treated with microelements at all. Studies performed by Rożek et al. [2000] revealed that foliar nutrition had positive influence on carrot yielding. Similar results were achieved by Kołota and Biesiada [2000], who found that complementary foliar nutrients supply affected the higher total and marketable carrot root yields. Jaskulski [2007] confirmed a positive influence of foliar nutrition on yielding of vegetables (carrot, parsley, leek).

Different systems of scorzonera cultivation affected the chemical composition of plants. More dry matter was accumulated by roots when plants were grown on ridges, which was probably associated with lower soil moisture. The result is consistent with that achieved by Evers et al. [1997], who recorded higher dry matter content in carrot roots when grown on ridges. However, Cebulak and Sady [2000] as well as Wierzbicka et al. [2004] achieved opposite findings, because the authors recorded the tendency to higher accumulation of dry matter in roots of carrots when grown on flat soil. The inulin

concentration in scorzonera roots did not significantly depend on varied tillage systems, although some tendency to its increase due to ridges as well as shallow pre-sowing tillage (harrowing) could be observed. Considerable increase of inulin content in scorzonera roots grown on ridges was also recorded by Konopiński [2003, 2009], while results from studied made by Dolota and Dąbrowska [2003] indicated that majority of examined scorzonera cultivars showed higher inulin contents when grown on flat soil. Here, in present study, the tendency to increase the protein content in roots of plants cultivated on flat soil was observed, which was confirmed by other experiments performed by Konopiński [2003, 2009].

CONCLUSIONS

1. Scorzonera yielded the best when grown on ridges, after pre-sowing rototiller tillage, and foliar nutrition with manganese.
2. Applied tillage systems and foliar nutrition had no significant impact on inulin content in scorzonera roots; only the increasing tendency of the component concentration in plants cultivated on flat soil after shallow spring tillage was observed.
3. Cultivating the scorzonera on ridges resulted in the increase of dry matter in roots.
4. Growing the scorzonera on ridges and on flat soil, as well as foliar nutrition with copper and manganese did not exert any influence on protein content in roots.

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WPŁYW METODY UPRAWY I DOKARMIANIA POZAKORZENIOWEGO Cu I Mn NA PLON I WARTOŚĆ BIOLOGICZNĄ KORZENI SKORZONERY (*Scorzonera hispanica* L.)

Streszczenie. Rośliny korzeniowe są szczególnie wrażliwe na warunki wzrostu, natomiast zalecane uproszczenia w agrotechnice wywołują zróżnicowaną reakcję uprawianych roślin. Celem badań było określenie wpływu zróżnicowanych metod uprawy roli i roślin oraz dolistnego dokarmiania roślin miedzią i manganem na plon korzeni skorzonery i niektóre ich cechy jakościowe. Doświadczenie polowe przeprowadzono w latach 2005–2007 na glebie płowej wytworzonej z utworów lessowych zalegających na marglach kredowych. Rośliną doświadczalną była skorzonera odmiany Duplex. W schemacie doświadczenia uwzględniono następujące czynniki: dwie metody uprawy roślin (uprawa na płask i na redlinach), dwa sposoby przedsiewnej uprawy roli (bronowanie, uprawa glebogryzarką) oraz dokarmianie pozakorzeniowe roślin (miedzią i manganem). Największy plon ogólny i handlowy korzeni, przy najniższym udziale korzeni niehandlowych w plonie ogólnym uzyskano w wyniku uprawy skorzonery na redlinach, po przedsiewnej uprawie roli glebogryzarką i dokarmianiu roślin manganem. Stwierdzono korzystny wpływ uprawy skorzonery na redlinach na zawartość suchej masy w korzeniach. Zróżnicowane systemy uprawy roli oraz dokarmianie dolistne roślin nie miały istotnego wpływu na zawartość inuliny w korzeniach badanych roślin, wykazano jedynie tendencję wzrostową zawartości tego składnika w roślinach uprawianych na redlinach po spłyconej wiosennej uprawie roli. Badane czynniki doświadczenia nie wywierały istotnego wpływu na zawartość białka w korzeniach.

Słowa kluczowe: skorzonera, inulina, redliny, miedź, mangan, przedsiewna uprawa roli

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