Zeszyty Problemowe Postępów Nauk Rolniczych
nr 576, 2014, 151–160

EFFECT OF DIFFERENT SYSTEMS CONSERVATION TILLAGE ON TECHNOLOGICAL VALUE OF SUGAR BEET ROOTS

Bernadeta Strochalska, Lesław Zimny, Piotr Regiec
University of Environmental and Life Sciences in Wrocław

Summary. The aim of research was determination of the content of selected constituents (dry matter, ash, α-aminonitrogen, reducing sugars, Mg, Ca, K), of sugar beet roots grown under conservation tillage using mulch from straw, winter rye and winter vetch, as well as two levels of nitrogen fertilization. This experiment was conducted between 2007–2010 at the Experimental Station of University of Environmental and Life Sciences in Wroclaw. From among conservation tillage systems of sugar beet, the highest amount of ash was found in roots grown under rye mulch and the lowest one was found in roots collected from plots under fore-crop straw mixed with harrow. Sugar beet roots under mustard mulch had the best technological quality (the lowest amount of α-amino-nitrogen) while the worst quality was observed under winter vetch mulch.

Key words: sugar beet, conservation tillage, technological value of roots

INTRODUCTION

Changes introduced by the European Union in legislation concerning sugar industry consist of, inter alia, reducing prices of sugar beet roots. Moreover, the European Union becomes a much bigger importer of sugar [Pokorná et al. 2011]. As a result, the necessary reduction of cultivation costs seem possible through the usage of conservation tillages. Changes in the technology of cultivation should undoubtedly take place without impairing on technological quality of roots.

The production of sugar beet, in compliance with specifications of the sugar industry, is characterized by high yield roots, high-sugar content, low molassigenic (non-sugars)

Corresponding author – Adres do korespondencji: Lesław Zimny, Uniwersytet Przyrodniczy we Wrocławiu, Katedra Kształtowania Agroekosystemów i Terenów Zieleni, pl. Grunwaldzki 24A 50-363 Wrocław, e-mail: leslaw.zimny@up.wroc.pl

content which result in considerable amount of sugar being transferred into molasses. Among nonsugars are: sodium, potassium, invert and α-amino-nitrogen [Ostrowska and Artyszak 2005]. Fruits and qualitative features of sugar beet depend mostly on optimal cultivation. In order to reduce costs of production, increase crop yield and improve technological quality, new and simplified technologies of agriculture are being researched. One of the methods allowing for limitations of expenditures the usage of conservation tillage involving sowing in frozen mulch with a stubble catch crop [Lal et al. 1990, Zimny 1999, Nowakowski 2013]. This type of cultivation impacts profitably on soil environment, which enables earlier sowing and makes deeper rooting easier. There isn't any detailed research of conservation tillage with usage of mulch from winter catch crop. In this technology, mulch is achieved through the desiccation of winter crops with total herbicides prior to sugar beet being sown.

The aim of research was determination of the content of selected constituents (dry matter, ash, α-amino-nitrogen, reducing sugars, Mg, Ca, K) of sugar beet roots grown under conservation tillage using mulch from straw, winter rye and winter vetch, as well as two levels of nitrogen fertilization.

MATERIAL AND METHODS

This experiment was conducted between 2007 and 2010 at the Experimental Station of University of Environmental and Life Sciences in Wroclaw as a strict di-factor field experiment. It was established by split-plot method in three repetitions on good rye soil complex. The fore-crop for sugar beet was winter wheat. Before the experiment the field was limed and subsoiled.

During the experiment two factors were taken into consideration. The first factor was diverse systems of conservation tillage. Traditional conservation tillage (stubble catch crop – white mustard left until spring, which was, before sowing, mixed using cultivation unit composed of rotary harrow and string packer) was applied in the first (control) plot. The Split forecrop straw having been covered by stubble cultivator (object 2), or after being stirred with spike-tooth harrow was left until spring in mulch (object 3). Rye (object 4) and winter vetch (object 5) were cultivated as a winter catch crops on other plots, where after pre-seed devastation were used as mulch. In the early spring *Roundup Energy 450 SL* in a dose 2,5 $l \cdot ha^{-1}$ was applied on the objects 2, 3, 4, and 5 in order to neutralize catch crops and weeds. A cultivation unit, consisting of rotary harrow and string packer was also applied prior to sowing. The second factor were two levels of nitric fertilization: A – optimal – 1 N (120 $kg \cdot ha^{-1}$) and B – reduced – 2/3 N (80 $kg \cdot ha^{-1}$).

The green mass of stubble catch crop amounted: mustard 28 $t \cdot ha^{-1}$, winter vetch 1,14 $t \cdot ha^{-1}$, rye 3,72 $t \cdot ha^{-1}$, and forecrop straw 4,86 $t \cdot ha^{-1}$. Sugar beet cultivar *Jagoda* was sown at 0,18 × 0,45 m span. The sowing was achieved using a mechanic single seeder, which can be used on average-size farms. Monogerm pelleted beet seed ball with calibre 3,50–4,75 mm and laboratory germination capacity of 98% were used. Weeds were fought with a chemical method of divided doses of: *Betanal Elite 274 EC* (1 $l \cdot ha^{-1}$), *Goltix 700 SC* (1 $l \cdot ha^{-1}$) and *Kemiron Koncentrat 500 EC* (0,2 $l \cdot ha^{-1}$).

The average crop of roots was 63,4 t·ha^{-1} and average sugar content was 15,2%.

The content of the following substances was determined in the roots' pulp: sucrose – polarimetric method, α-aminonitrogen – colorimetric method, soluble ash – short conductometric methods [Butwiłowicz 1997] and reducing sugars – with the Lane-Eynon's method [Krełowska-Kułas 1993].

Test results were subjected to variance analysis. The significance of differences was verified by the Duncan test with a level of significance of α = 0,05.

RESULTS AND DISCUSSION

Systems of sugar beet cultivation, nitrogen doses and interaction of both factors did not have any significant influence on dry matter content in sugar beet roots (Table 1). Roots cultivated on straw mixed by harrow contained the highest amount of dry matter (21,7%), whereas roots cultivated on winter rye mulch contained the lowest (20,3%). Lower nitrogen dose in comparison with the optimal one resulted in higher amount of dry matter in sugar beet roots. It was verified by Zimny's and others research [2010], where roots cultivated on straw were characterized by the highest amount of dry matter. On the other hand, Buraczyńska's research [2005] indicated that sugar beet roots fertilized with manure, straw, all catch crops biomass combined with straw and crop residues from catch crops contained significantly more dry matter than sugar beet roots from the object without organic fertilization.

The amount of ash in sugar beet roots wasn't differentiated by experimental factors or their interaction (Table 1). Sugar beet roots cultivated on mulch from winter catch crops contained more ash (average 0,83%) than the control object – mulch from mustard, while sugar beet roots cultivated on straw contained less ash (average 0,70%) than the control object. After applying nitrogen in a dose of 80 kg·ha^{-1} to sugar beet roots, higher amount of ash was found than after applying a dose of 120 kg·ha^{-1}. However, opposite results were achieved by Ostrowska and Kucińska [1998] and Wesołowski and others [2003], where fertilizing with straw with an addition of nitrogen was conducive for the accumulation of ash in roots. On the other hand, Zimny and others [2010] research indicated , that using only catch crop contributes to accumulation of ash in roots, while fertilizing with straw and stubble catch crop reduces the amount of ash in comparison with the control object (stubble catch crop ploughed down with fall ploughing).

The amount of α-aminonitrogen wasn't considerably differentiated by experimental factors or their interaction (Table 2). The highest amount of this molassigenic was characteristic for roots cultivated on winter vetch mulch (average 37,2 mg/100 g) and the lowest for roots cultivated on mustard mulch (31,0 mg/100 g). After using nitrogen at a dose of 120 kg·ha^{-1} in comparison with a dose of 80 kg·ha^{-1}, the difference between the amount of α-aminonitrogen was 2,1% in favor of the higher dose. Similar results were achieved by Gutmański and others [1998] when, by cultivating sugar beet on mixed white mustard mulch, they achieved roots with very high processing quality compared with traditional cultivation. On the other hand, Kostka-Gościniak and others [2000] found that fertilizing with catch crop caused an increase in the amount of α-aminonitrogen in roots in

Table 1. Content of dry matter and ash (mean for 2008–2010)
Tabela 1. Zawartość suchej substancji i popiołu (średnie z lat 2008–2010)

Cultivation systems Systemy uprawy	Dry matter Sucha substancja [%]			Ash Popiół [%]		
	1 N	2/3 N	mean średnio	1 N	2/3 N	mean średnio
Mustard – Gorczyca	20.54	21.21	20.87	0.77	0.75	0.76
Straw covered by cultivator Słoma przykryta kultywatorem	21.31	20.47	20.90	0.67	0.81	0.74
Straw mixed using harrow Słoma wymieszana broną	21.40	21.98	21.70	0.75	0.56	0.65
Rye mulch – Żyto – mulcz	19.94	20.66	20.30	0.83	0.92	0.88
Winter vetch mulch Wyka oz. – mulcz	20.94	20.00	20.46	0.72	0.84	0.78
Mean – Średnio	20.82	20.86	–	0.75	0.78	–
$LSD_{0.05}$ cultivation systems $NIR_{0,05}$ systemy uprawy		n.s.			n.s.	
$LSD_{0.05}$ rates of nitrogen $NIR_{0,05}$ dawki azotu		n.s.			n.s.	
$LSD_{0.05}$ interaction $NIR_{0,05}$ interakcja		n.s.			n.s.	

n.s. – not significant/różnica nieistotna.

Table 2. Content of harmful nitrogen and reducing sugars (mean for 2008–2010)
Tabela 2. Zawartość azotu α-aminowego i cukrów redukujących (średnie z lat 2008–2010)

Cultivation systems Systemy uprawy	N-α-NH_2 mg/100 g			Reducing sugars Cukry redukujące [%]		
	1 N	2/3 N	mean średnio	1 N	2/3 N	mean średnio
Mustard – Gorczyca	32.4	29.6	31.0	0.37	0.19	0.28
Straw covered by cultivator Słoma przykryta kultywatorem	31.7	33.6	32.7	0.20	0.29	0.25
Straw mixed by harrow Słoma wymieszana broną	34.8	35.3	35.1	0.24	0.24	0.24
Rye mulch – Żyto – mulcz	33.9	33.9	33.9	0.14	0.20	0.17
Winter vetch mulch Wyka ozima – mulcz	35.2	39.2	37.2	0.31	0.27	0.29
Mean – Średnio	33.6	34.3	–	0.25	0.24	–
$LSD_{0.05}$ cultivation systems $NIR_{0,05}$ systemy uprawy		n.s.			n.s.	
$LSD_{0.05}$ rates of nitrogen $NIR_{0,05}$ dawki azotu		n.s.			0.05	
$LSD_{0.05}$ interaction $NIR_{0,05}$ interakcja		n.s.			n.s.	

n.s. – not significant/różnica nieistotna.

comparison with fertilizing with just straw. Zimny and others [2010] research proved that roots harvested from no-tillage (forecrop straw left until spring), intensively protected, were characterized by the best technological quality (the lowest amount of α-aminonitrogen). Moreover, Nowakowski and Szymczak-Nowak [2007] proved that forecrop straw in comparison with manure, led to a significant reduction of α-amino-nitrogen amount in sugar beet roots.

The amount of reducing sugars was significantly differentiated by doses of nitrogen (Table 2). Sugar beet roots contained much higher amount of reducing sugars (0,25%) after applying nitrogen in a dose of 120 kg·ha^{-1} in comparison with a dose of 80 kg·ha^{-1}. Cultivation systems and interaction of both experimental factors didn't have any considerable influence on the amount of reducing sugars, however. In sugar beet roots cultivated on winter vetch mulch the highest amount of reducing sugars (0,29%) was found, whereas the lowest amount (0,17%) was found in sugar beet roots cultivated on rye mulch. Sugar beet roots cultivated on straw contained, on average, 0,25% reducing sugars. Similar results were achieved by Zimny and others [2010], where the lowest amount of reducing sugars characterized sugar beet roots cultivated by no-tillage method (forecrop straw left until spring).

The relation between each of harmful non-sugars and the amount of sucrose affects the technological quality, since the efficiency of sugar can be significantly reduced with their high amount, despite the rather high amount of sucrose in roots. That is the reason why the results of the amount of ashes, α-aminonitrogen and reducing sugars were presented as per 100 g of sucrose (Fig. 1–3).

Cultivation systems, doses of nitrogen and their interaction had no impact on the amount of water-soluble ash per 100 g in pulp (Fig. 1). Roots collected from plots cultivated on rye mulch had the highest amount of water-soluble ash – 5,5 g/100 g of sucrose while roots from plots cultivated on straw mixed by harrow had the lowest (3,8 g/100 g sucrose). A dose of 120 kg·ha^{-1} nitrogen led to a reduction of water-soluble

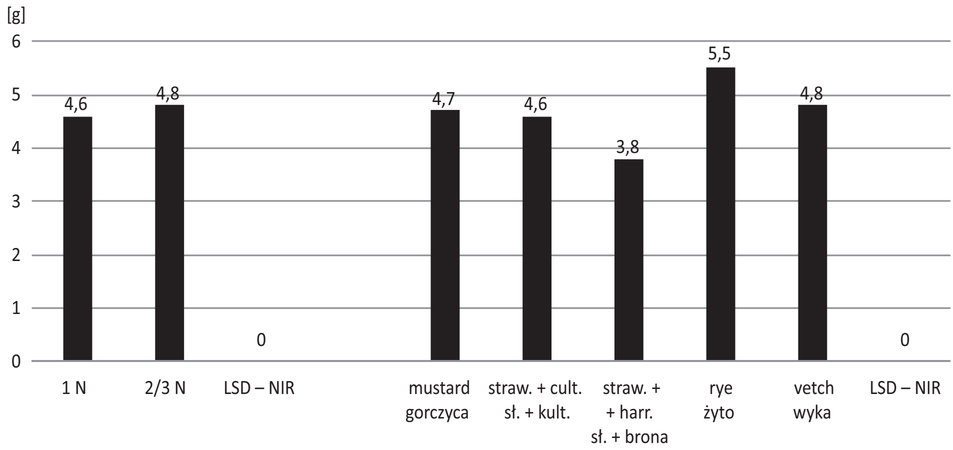

Fig. 1. Content of ash per 100 g sucrose

Rys. 1. Zawartość popiołu w g/100 g sacharozy ash per 100 g sucrose in pulp in comparison with a dose of 80 kg·ha^{-1}. The difference between them is 0,2 g/100 g of sucrose.

The amount of α-aminonitrogen per 100 g of sucrose was not considerably differentiated by experimental factors or their interaction (Fig. 2). Roots cultivated on mustard mulch (0,19 g) contained the lowest amount of α-aminonitrogen, whereas roots cultivated on winter vetch mulch – the highest amount (0,23 g). The amount of α-amino-nitrogen in roots cultivated on the object with straw covered using a cultivator and the object with straw mixed using harrows was the same – 0,20 g/100 g of sucrose. After applying doses of nitrogen (120 and 80 kg·ha^{-1}), the difference between the amount of α-aminonitrogen per 100 g of sucrose in sugar beet roots was insignificant and amounted to 0,01 g/100 g of sucrose.

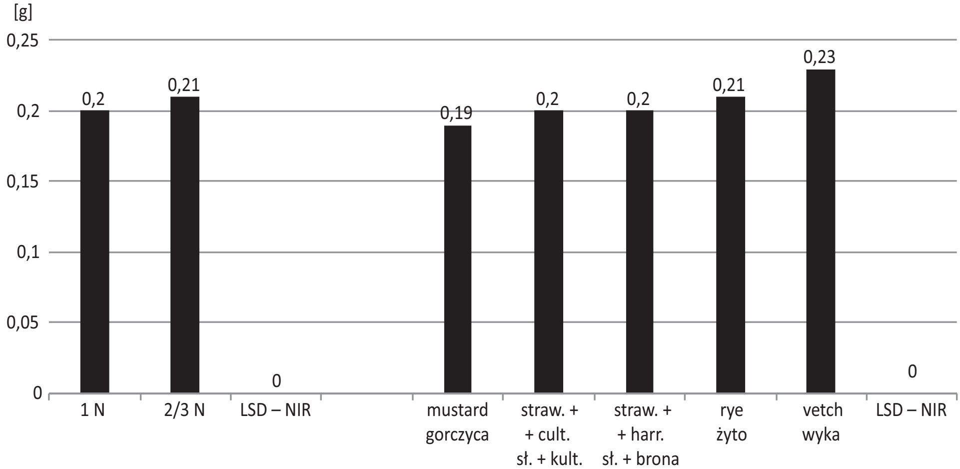

Fig. 2. Content of harmful nitrogen per 100 g sucrose

Rys. 2. Zawartość azotu szkodliwego w g/100 g sacharozy

Although the amount of reducing sugars per 100 g of sucrose wasn't significantly differentiated by cultivation systems and doses of nitrogen, a crucial difference was observed with the interaction of both experimental factors (Fig. 3). The lowest amount of reducing sugars (1,06 g) was found in roots cultivated on rye mulch and the highest amount (1,86 g) in roots cultivated on winter vetch mulch. The amount of reducing sugars in roots cultivated on forecrop straw accounted for, on average, 1,49 g/100 g of sucrose. After applying doses of nitrogen, the difference between amounts of reducing sugars per 100 g of sucrose in sugar beet roots reached 5,7%. The lowest amount of reducing sugars (0,91 g) was found in roots cultivated on rye mulch after applying nitrogen at a dose of 120 kg·ha^{-1}, whereas the highest amount (2,32 g) in roots cultivated on mustard mulch, also after applying nitrogen at a dose of 120 kg·ha^{-1}.

Analysis of the amount of magnesium in sugar beet roots confirmed the importance of applied cultivation systems' impact on magnesium's quantity (Table 3). The highest amount of magnesium (35,84 mg/100 g) was characteristic for roots cultivated on straw mixed by harrow, the lowest amount (26,18 mg/100 g) – for roots cultivated on mustard mulch; the

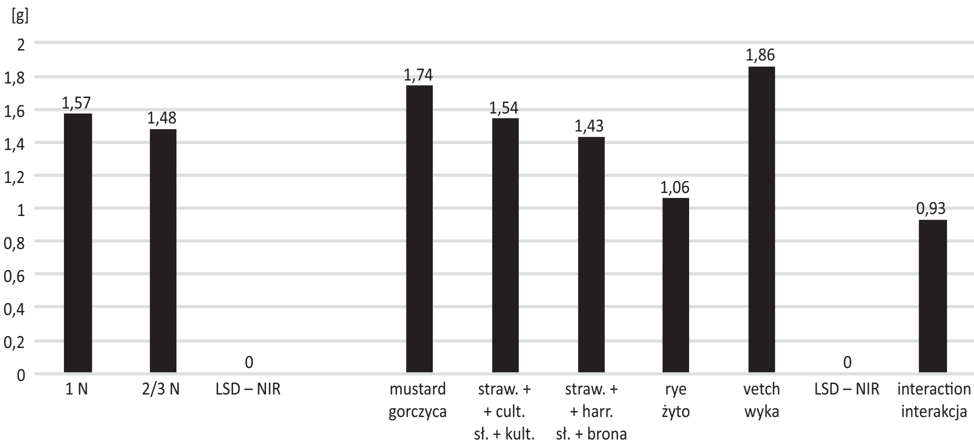

Fig. 3. Content of reducing sugars per 100 g sucrose

Rys. 3. Zawartość cukrów redukujących w g/100 g sacharozy

Table 3. Content of Mg, K and Ca [mg/100 g] (mean for 2008–2010)

Tabela 3. Zawartość Mg, K i Ca [mg/100 g] (średnie z lat 2008–2010)

Cultivation systems Systemy uprawy	Mg			K			Ca		
	1 N	2/3 N	mean średnio	1 N	2/3 N	mean średnio	1 N	2/3 N	mean średnio
Mustard – Gorczyca	26,84	25,52	26,18	226,1	206,3	216,2	31,17	31,33	31,25
Straw covered by cultivator Słoma przykryta kultywatorem	31,38	28,14	29,76	165,5	160,6	163,1	32,94	32,60	32,77
Straw mixed by harrow Słoma wymieszana broną	35,80	35,88	35,84	194,1	175,7	184,9	28,07	36,24	32,16
Rye mulch – Żyto – mulcz	26,72	33,75	30,23	196,9	192,8	194,9	27,41	30,54	28,97
Winter vetch mulch Wyka ozima – mulcz	32,21	29,64	30,93	187,4	182,5	184,9	31,43	28,91	30,17
Mean – Średnio	30,59	30,58	–	194,0	183,6	–	30,20	31,92	–
$LSD_{0.05}$ cultivation systems $NIR_{0,05}$ systemy uprawy	5,42			n.s.			n.s.		
$LSD_{0.05}$ rates of nitrogen $NIR_{0,05}$ dawki azotu	n.s.			n.s.			n.s.		
$LSD_{0.05}$ interaction $NIR_{0,05}$ interakcja	n.s.			n.s.			n.s.		

n.s. – not significant/różnica nieistotna.

difference between these objects amounted to 27%. The amount of magnesium in sugar beet roots cultivated on rye mulch and winter vetch mulch was quite similar – 30,58 mg/100 g on average. Doses of nitrogen and interaction of both experimental factors had no considerable impact on the content of magnesium in sugar beet roots. The amount of magnesium in sugar beet roots was the same – 30,59 mg/100 g after applying doses of nitrogen.

Potassium is a component, which has a negative impact on processing quality of sugar beet roots [Nowakowski 2004]. The highest amount of potassium cumulated was in sugar beet roots cultivated on mustard mulch (216,2 mg/100 g), while the lowest amount (163,1 mg/100 g) was in roots cultivated on straw covered using a cultivator with the difference between them being insignificant, though. Doses of nitrogen had no considerable impact on the amount of potassium. Gutmański and Nowakowski [1994] didn't observe any considerable impact of increasing doses of nitrogen on potassium content in roots, either. In our own research no significant interaction of the mentioned factors was observed. However, it was noticed that roots cultivated on straw covered using cultivators with the application of nitrogen at a dose of 80 kg·ha^{-1} contained the lowest amount of potassium.

The impact of both experimental factors on the amount of calcium in sugar beet roots was slight, ambiguous and statistically not proved. The lowest amount of this element (average 28,97 mg/100 g) was found in roots cultivated on rye mulch and the highest amount (average 32,46 mg/100 g) was in roots cultivated on forecrop straw. The difference between the amount of calcium in sugar beet roots after applying doses of nitrogen (120 and 80 kg·ha^{-1}) was 1,72 mg/100 g.

CONCLUSIONS

1. A comparison of the conservation tillage systems of sugar beet roots showed that the highest amount of ash was found in roots cultivated on rye mulch (0,88%) while the lowest (0,65%) was found in roots collected from a plot cultivated with forecrop straw mixed using harrows.
2. After applying nitrogen at a dose of 120 kg·ha^{-1}, the amount of reducing sugars was significantly higher than after applying a dose of 80 kg·ha^{-1}.
3. Sugar beet roots cultivated on mustard mulch had the best technological quality (the lowest amount of α-aminonitrogen – 31,0 mg/100 g), while those cultivated on winter vetch mulch had the worst (the highest amount of α-aminonitrogen 37,2 mg/100 g).
4. Applying different conservation tillage systems caused a change in the amount of magnesium. Sugar beet roots cultivated on straw mixed using harrows had the highest amount of magnesium (35,84 mg/100 g), while roots cultivated on mustard mulch had the lowest (26,18 mg/100 g) – the difference between these objects counted 27%.
5. Applying doses of nitrogen at 120 kg/ha and 80 kg/ha did not result in any considerable changes in the content of magnesium, potassium and calcium in sugar beet roots.

LITERATURE

Buraczyńska D., 2005. Kształtowanie się zawartości suchej masy i makroskładników w korzeniach i liściach buraka cukrowego pod wpływem nawożenia organicznego i mineralnego. Annales UMCS, sec. E. 60, 19–31.

Butwiłowicz A., 1997. Metody analityczne kontroli produkcji w cukrowniach. Instytut Przemysłu Cukrowniczego, Warszawa.
Gutmański I., Nowakowski M., 1994. Wpływ dawki i formy azotu na wschody, plony i jakość przetwórczą buraka cukrowego w dwóch terminach zbioru. Biul. Inst. Hod. Aklim. Rośl. 189, 41–49.
Gutmański I., Szymczak-Nowak J., Kostka-Gościniak D., Nowakowski M., Banaszak H., 1998. Wpływ obornika, słomy i międzyplonów ścierniskowych na plonowanie buraka cukrowego przy zróżnicowanej koncentracji jego uprawy w płodozmianie. Rocz. AR w Poznaniu 307, Rol. 52, 1, 263–271.
Kostka-Gościniak D., Szymczak-Nowak J., Nowakowski M., Sitarski A., Wąsacz E., Banaszak H., 2000. Wpływ nawożenia słomą i obornikiem na jakość przetwórczą wybranych odmian buraka cukrowego. Folia Univ. Agric. Stetin. 211, Agricultura 84, 175–178.
Krełowska-Kułas M., 1993. Badanie jakości produktów spożywczych. Państwowe Wydawnictwo Ekonomiczne, Warszawa.
Lal R., Eckert D.J., Fausey N.R., Edwards W.M., 1990. Conservation tillage in sustainable agriculture. W: Sustainable Agricultural Systems. Soil Water Cons. Soc. Ankeny, Iowa: 203–225.
Nowakowski M., 2004. Wpływ wybranych czynników agrotechnicznych na jakość przetwórczą buraka cukrowego i technologiczny plon cukru. Mat. Konf. „Jakość towarowych surowców roślinnych wyzwaniem dla nauki i praktyki rolniczej", Puławy, 85–90.
Nowakowski M., 2013. Przydatność gorczycy białej i rzodkwi oleistej jako mulczu, nawozu, i czynnika ochrony fitosanitarnej w uprawie buraka cukrowego. Monografie i Rozprawy Naukowe 43/2013, IHAR PIB Radzików.
Nowakowski M., Szymczak-Nowak J., 2007. Wpływ nawożenia obornikiem i słomą na jakość technologiczną czterech odmian buraka cukrowego. Pam. Puł. 146, 67–72.
Ostrowska D., Artyszak A. (red.), 2005. Technologia produkcji buraka cukrowego. Wyd. Wieś Jutra, Warszawa.
Ostrowska D., Kucińska K., 1998. Wpływ wzrastającego nawożenia azotem oraz różnych form nawozów organicznych na plon i jakość buraka cukrowego. Cz. 1. Rocz. AR w Poznaniu 52, 273–278.
Pokorná I., Smutka L., Pulkrábek J., 2011. Světová produkce cukru. Listy Cukrov. Řepař. 127, 4, 118–121.
Wesołowski M., Bętkowski M., Kokoszka M., 2003. Wpływ gospodarki bezobornikowej na jakość korzeni buraka cukrowego. Annales UMCS, sec. E, 58, 1–12.
Zimny L., 1999. Uprawa konserwująca. Post. Nauk Rol. 5, 41–51.
Zimny L., Rajewski J., Regiec P., 2010. Wpływ uprawy konserwującej na wartość technologiczną korzeni buraka cukrowego. Annales UMCS, Sec. E, 65, 2, 110–118.

WPŁYW RÓŻNYCH SYSTEMÓW UPRAWY KONSERWUJĄCEJ NA WARTOŚĆ TECHNOLOGICZNĄ KORZENI BURAKA CUKROWEGO

Streszczenie. Celem niniejszej pracy było określenie zawartości wybranych substancji (sucha substancja, popiół, azot α-aminowy, cukry redukujące) w korzeniach buraka cukrowego uprawianego metodą konserwującą z wykorzystaniem mulczu ze słomy, żyta i wyki ozimej oraz z zastosowaniem dwóch poziomów nawożenia azotowego. Ścisłe doświadczenie polowe realizowano w latach 2007–2010 w Rolniczym Zakładzie Doświadczalnym Uniwersytetu Przyrodniczego we Wrocławiu. Spośród porównywanych systemów uprawy konserwującej buraka cukrowego najwięcej popiołu stwierdzono w korzeniach uprawianych na mulczu z żyta, najmniej w korzeniach uprawianych na słomie przedplonowej wymieszanej broną. Najlepszą jakością technologiczną (najmniejsza zawartość azotu α-aminowego) charakteryzowały się buraki uprawiane na mulczu z gorczycy, a najgorszą – uprawiane na mulczu z wyki ozimej.

Słowa kluczowe: burak cukrowy, uprawa konserwująca, wartość technologiczna korzeni