The yield and technological quality of sugar beet roots cultivated in mulches

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ABSTRACT

In 2005–2008, in several locations of southern Poland, the yield and technological root quality of two sugar beet cultivars (Esperanza and Henrike) cultivated in mustard mulch, straw mulch and in conventional tillage (with pre-winter plough) were investigated. Mustard mulch let to achieve the highest plant density during harvest. Replacing conventional ploughing with mustard mulch caused 9.4% root yield increase and with straw mulch 11.2%. Cultivation system had no effect on the content of sucrose and melassigenic components in the roots, except for potassium. Technological sugar yields obtained from mustard mulch were by 8.0% and in straw mulch by 11.3% higher than in the conventional tillage. Cv. Esperanza allowed getting the higher root yield, average fresh mass of single root and technological sugar yield, than cv. Henrike. In addition, lower content of alpha-amino-nitrogen was obtained from roots of the cv. Esperenza. In contrast, higher sucrose content and lower sodium content were found in the roots of cv. Henrike. The lowest variability in the sugar beet root yield features and technological quality was achieved from straw mulch.

Keywords: conventional tillage; mustard mulch; *Beta vulgaris* L.; straw mulch; cultivar

Poland is the third producer of sugar beet in the EU. In 2017 the limits of sugar production will be abolished in the EU countries. Such conditions force the sugar beet producers to improve competitiveness through higher yields and reducing costs production. The pre-winter plough is the most expensive tillage in the sugar beet cultivation technology, and replacing it by preservative tillage becomes more and more popular and necessary (Kordas 2000, Petersen and Röver 2005, Koch et al. 2009, van den Putte et al. 2010). However, the results of experiments in this area are inconclusive. In many research works, plough resignation had no significant effect on beet root yield (Kuc and Zimny 2005). Other researchers (Kordas and Zimny 1997) found a slight decrease of sugar beet roots yield in minimized pre-sowing tillage conditions, but Kessel and Dahms (1991), obtained higher yields under conservation tillage. The main research hypothesis is the assumption that ploughing in the sugar beet cultivation can be replaced by mulch with no decrease in the yield of roots and sugar. The aim was to evaluate the effect of three tillage systems (mustard mulch, straw mulch, traditional cultivation) on the yield and technological quality of sugar beet roots of two sugar beet cultivars (Esperanza, Henrike).

MATERIAL AND METHODS

The experiment was conducted in several locations of southern part of Poland, in time period 2005–2008. In 2005 and 2007 – Janowiczki (50°19'N, 20°14'E), Stary Lubliniec (50°17'N, 23°04'E) and Zosin (50°51'N, 24°07'E), in 2006 – Kondratowice (50°46'N, 16°56'E) and Lewin Brzeski (50°45'N, 17°37'E) and in 2008 – Dobieszów (50°13'N, 18°00'E) and Lewin Brzeski (50°45'N, 17°37'E) (Figure 1). It was a two-factor experiment, carried out in split-

Figure 1. Location of the field experiments

plot design with 3 replications. The first factor (A) was tillage system (A1 – mustard mulch; A2 – straw mulch; A3 – traditional cultivation), and the second factor (B) was a sugar beet cultivar (B1 – Esperanza; B2 – Henrike). The area of a single plot was 10.8 m^2. In all years and at all locations the forecrop for sugar beet were cereals. Cereal straw from the forecrop was crushed and spread in the field after cereal harvest (in the first decade of August) in all cultivation systems of the experiment. The sequence of all other autumn and spring tillage practices according to tillage systems are placed in Table 1. Beets were sown with disc coulter beet drill in the decade from March 3rd to April 2nd depending on the year and location. Row spacing was 45 cm, distance in the row was 18 cm, and sowing depth 2–2.5 cm. Length of vegetation period was 174–185 days. Esperanza is a cultivar of moderate sugar level, Henrike belongs to the sugar type.

Plant density was counted at harvest on the whole area of every plot. During harvest the parts of beet plants with leaves were cutout by hand, roots were dug up, cleaned, counted and weighed. The average single root fresh mass was calculated as the ratio of root yield and plant density at harvest. The representative samples of roots for the technological root quality determination was collected during the harvest day from each plot. Sucrose, alpha-amino-nitrogen, sodium and potassium content were determined with the Venema line by Kutno Sugar Beet Breeding Ltd. in Straszków. Based on the obtained results we were able to calculate:

Loss of sugar productivity (%) = standard molasses loss (%) + 0.6 (%);

Standard molasses loss (%) = 0.012 × (K + Na) + 0.024 (alpha-amino-nitrogen) + 0.48; where K, Na and alpha-amino-nitrogen are given in $mmol_+/kg$;

Technological sugar yield (t/ha) = root yield (t/ha) × [sucrose content in roots (%) – loss of sugar productivity (%)] (Buchholz et al. 1995).

Two-factor analysis of variance was performed for the split-plot design, where the effect of tillage system (factor A) and cultivar (factor B) were evaluated. Multiple comparisons of averages according to the Tukey's procedure were performed at level of significance 0.05. The assessment of the correlations among the investigative features based on Pearson simple correlation coefficients was also performed. The significance of these correlations was assessed at $P \leq 0.05$ and $P \leq 0.01$.

Table 1. Tillage practices sequence in the tillage systems of the experiment, through all locations in 2005–2008

Tillage practice	Tillage term (decade)	Mulch		Conventional tillage
		mustard	straw	
PK fertilization		+	+	+
N fertilization	August 3rd–September 1st	+	–	–
Stubble cultivator		+	+	+
Mustard sowing (17 kg/ha)	September 1st	+	–	–
Stubble cultivator	October 2nd–3rd	–	+	–
Winter plough	October 3rd	–	–	+
N fertilization		+	+	+
Active rotor harrow	March 3rd–April 2nd	+	+	+
Sugar beet sowing		+	+	+

Descriptive statistics of the tested variables as: standard deviations, variation coefficients, minimum and maximum values were calculated as well. Statistical analysis was performed in the SAS 9.1 software (Cary, USA).

The experiment was conducted on Chernozem (Zosin) and Luvisol soils (other locations) (FAO 2006), pH 6.7–7.1. The content of available macrocomponents averaged (mg/kg): 68.0 P, 118.4 K and 58.4 Mg. Weather conditions i.e. rainfall and temperature, are presented in Table 2.

RESULTS AND DISCUSSION

Regardless of the plant density and according to the established research hypothesis the higher sugar beet root yields from mulch cultivation system, as well straw (60.9 t/ha) as mustard mulch (59.6 t/ha) were obtained (Table 3). Omission of ploughing application had no significant effect on the root yields in other investigations (Kuc and Zimny 2005). But in contrast, in Kordas (2000) research beet cultivation in direct sowing caused significant (13%) root yield reduction compared to the conventional tillage. The highest average fresh mass of single beet root was obtained from straw mulch (615 g) and the smallest in the conventional tillage (558 g). Kordas (2000) found no differences in fresh root mass from conservation tillage and conventional one. Obtained results showed no significant effect of tillage system on sucrose content in beet roots which is consistent with the results obtained by the other authors (Roisin and Frankinet 1994). Becker (1997) and Becker and Märländer (1998) found a slightly higher sucrose content in beet roots cultivated in conventional tillage. But Kordas (2000) observed an opposite tendency. Results for technological sugar yield in presented research were obtained respectively 9.19 t/ha from straw mulch and 8.92 t/ha from mustard mulch. Koch et al. (2009) obtained a higher technological sugar yield from conventional tillage than from conservation tillage. From the melassigenic components only potassium content was significantly modified by tillage system. The content of this element was the lowest from conventional tillage (37.3 $mmol_+$/kg), and the highest from mustard mulch application (39.2 $mmol_+$/kg). However, Kuc and Zimny (2005) in their research obtained alpha-amino-nitrogen by 7.6%, potassium content by 0.4% higher and sodium content 18.3% lower under straw mulch conditions compared with conventional tillage. Sugar beet cultivars significantly modified the most of the researched sugar beet yield features and technological quality with the exception of potassium content. Greater root yield, average fresh mass of single root and technological sugar yield was obtained from cv. Esperanza than cv. Henrike. Similarly, a lower alpha-amino-nitrogen content was found from cv. Esperanza than cv. Henrike. In contrast, higher sucrose content and lower sodium content in the roots were obtained from cv. Henrike. Significant differences in the average fresh mass of single root, root yield, sucrose content and melassigenic components were obtained by Artyszak (2012) during his earlier study with both these cultivars. However, technological sugar yields for both cultivars were similar. The correlation coefficients analysis for particular pairs of researched features like root yield and technological quality of sugar beet yield clearly showed that they differ in different tillage systems. It seems that the reason was the diversity of plant density and average single root fresh mass at harvest, which had a direct effect on root yield and technological quality. The correlation between plant density and average single root fresh mass was significant and negative in both treatments with mulches, but stronger in combination with mustard mulch. The

Table 2. Weather conditions in 2005–2008 (April–October)

	Location	Total rainfall (mm)	Average temperature (°C)
2005	Janowiczki	492.0	15.7
	Stary Lubliniec	511.0	15.8
	Zosin	325.9	14.2
2006	Kondratowice	440.0	16.7
	Lewin Brzeski	347.1	15.9
2007	Janowiczki	499.0	15.8
	Stary Lubliniec	427.0	14.0
	Zosin	510.8	14.5
2008	Dobieszów	532.5	15.7
	Lewin Brzeski	403.0	15.2

Source: own study based on data from sugar factories: Cerekiew, Kazimierza Wielka, Przeworsk, Strzelin, Strzyżów and Wróblin

Table 3. The effect of the tillage system and cultivar on the plant density during harvest, yield and technological quality of sugar beet roots (average 2005–2008)

Tillage system (A)	Cultivar (B)		Average	*LSD*
	Esperanza	Henrike		
Plant density during harvest (thousands of plants/ha)				
Mustard mulch	103.4	103.1	103.3	
Straw mulch	100.9	99.4	100.2	LSD_A = 3.6*, LSD_B = ns, $LSD_{A/B}$ = 5.1*, $LSD_{B/A}$ = ns
Conventional tillage	99.2	97.0	98.1	
Average	101.2	99.9	–	
Average fresh mass of root (g)				
Mustard mulch	602	580	591	
Straw mulch	626	603	615	LSD_A = 32*, LSD_B = 21*, $LSD_{A/B}$ = 44*, $LSD_{B/A}$ = 37*
Conventional tillage	590	525	558	
Average	606	569	–	
Root yield (t/ha)				
Mustard mulch	60.8	58.4	59.6	
Straw mulch	63.0	58.8	60.9	LSD_A = 3.0*, LSD_B = 2.1*, $LSD_{A/B}$ = 4.3*, $LSD_{B/A}$ = 3.5*
Conventional tillage	58.0	51.0	54.5	
Average	60.6	56.0	–	
Technological yield of sugar (t/ha)				
Mustard mulch	8.81	9.02	8.92	
Straw mulch	9.48	8.90	9.19	LSD_A = 0.5*, LSD_B = 0.3*, $LSD_{A/B}$ = 0.7*, $LSD_{B/A}$ = 0.5*
Conventional tillage	8.68	7.84	8.26	
Average	8.99	8.59	–	
Sucrose content (%)				
Mustard mulch	16.4	17.3	16.9	
Straw mulch	17.0	17.1	17.1	LSD_A = ns, LSD_B = 0.2*, $LSD_{A/B}$ = 0.4*, $LSD_{B/A}$ = 0.3*
Conventional tillage	16.8	17.1	17.0	
Average	16.7	17.2	–	
Content of alpha-amino-nitrogen ($mmol_+$/kg)				
Mustard mulch	17.9	17.1	17.5	
Straw mulch	14.3	17.6	16.0	LSD_A = ns, LSD_B = 1.1*, $LSD_{A/B}$ = 2.3*, $LSD_{B/A}$ = 1.9*
Conventional tillage	15.4	16.8	16.1	
Average	15.9	17.1	–	
Content of sodium ($mmol_+$/kg)				
Mustard mulch	4.31	3.74	4.02	
Straw mulch	4.52	4.08	4.30	LSD_A = ns, LSD_B = 0.21*, $LSD_{A/B}$ = 0.44*, $LSD_{B/A}$ = 0.36*
Conventional tillage	4.46	3.86	4.16	
Average	4.43	3.59	–	
Content of potassium ($mmol_+$/kg)				
Mustard mulch	40.5	37.9	39.2	
Straw mulch	37.8	38.9	38.4	LSD_A = 1.4*, LSD_B = ns, $LSD_{A/B}$ = 2.0*, $LSD_{B/A}$ = 1.6*
Conventional tillage	37.2	37.4	37.3	
Average	38.5	38.1	–	

*significant differences with the level of α = 0.05; ns – not significant; *LSD* – least significant difference

Table 4. Statistical characteristics of the variability of yield and quality of roots in 2005–2008

	Plant density during harvest (thousands of plants/ha)	Average fresh mass of single root (g)	Yield (t/ha)		Sucrose (%)	K	Na	Alpha-amino--nitrogen
			roots	technological sugar		($mmol_+$/kg)		
Mustard mulch								
Average	103.25	557.63	54.49	8.26	16.95	37.29	4.16	16.12
Minimum	75.00	199.00	20.80	2.25	12.14	23.90	1.60	3.80
Maximum	124.10	1131.00	96.50	13.89	21.28	53.70	10.30	37.20
SD	11.59	195.51	19.03	3.09	2.00	9.17	2.42	8.62
CV (%)	11.23	35.06	34.93	37.44	11.82	24.59	58.29	53.48
Straw mulch								
Average	100.18	614.53	60.88	9.19	17.07	38.36	4.30	15.95
Minimum	62.00	360.00	37.04	5.19	14.57	24.20	1.20	5.90
Maximum	125.90	1018.00	86.40	13.42	20.32	60.90	9.90	37.70
SD	12.42	145.95	13.35	2.21	1.54	9.06	2.25	7.28
CV (%)	12.39	23.75	21.93	24.06	9.02	23.63	52.31	45.62
Conventional tillage								
Average	98.09	590.67	59.57	8.92	16.85	39.19	4.02	17.45
Minimum	67.60	185.00	21.80	2.73	13.63	24.90	1.40	5.50
Maximum	116.70	1023.00	94.10	13.29	20.55	73.60	10.20	53.50
SD	12.29	194.29	16.69	2.80	1.80	9.86	2.30	10.00
CV (%)	12.53	32.89	28.02	31.39	10.66	25.16	57.28	57.27

SD – standard deviation; *CV* – coefficient of variation

correlation of technological sugar yield and root yield was similar (r = 0.91–0.95**). In contrast, the correlation of technological sugar yield and sucrose content in the roots was the strongest in combination of mustard mulch (r = 0.63**), and the weakest in combination of straw mulch (r = 0.45**). The smallest variability during harvest was obtained from mustard mulch combination (Table 4). The greatest variability was found for the alpha-amino-nitrogen content (45.6–57.3%) and the sodium content (52.3–58.3%) in beet roots. The lowest variability of sugar beet roots yield and technological quality was obtained from straw mulch. The obtained results showed that sugar beet cultivation with straw and mustard mulch under the conditions of southern Poland is possible and might be beneficial. Both methods of tillage system allow reducing costs of crop production because of plough omitting. Simultaneously these two tillage methods cause on increase of root yield and maintain technological quality of roots; as a result they increase technological yield of sugar. All these factors allow achieving better economic results. Therefore the economic effects, such as direct surplus will be the subject of another publication.

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