

COMPARISON OF YIELD AND QUALITY OF RED BEET ROOTS CULTIVATED USING CONVENTIONAL, INTEGRATED AND ORGANIC METHOD

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ABSTRACT

The experiment on different means of cultivation of red beet cv. 'Regulski Cylinder' was conducted in the years 2006-2009, using conventional, integrated, and organic methods. The greatest impact on total and commercial yield, the average root weight, dry weight and chemical constituents' content in the roots had the season. In the years 2006 and 2008, the highest total and marketable yields of beet roots were obtained by organic method, but in 2009 these parameters were the lowest in organically produced plants. Total yield was correlated with mean root weight. In the years 2006 and 2008, betanine content was the lowest in organically produced roots while in the year 2009 it was the highest. The low yield of marketable roots and the low nitrates' content were the only two parameters, which distinguished organically produced red beet roots throughout the years of experiment.

Key words: red beet, yielding, roots quality, organic cultivation, integrated cultivation, conventional cultivation

INTRODUCTION

Red beet (*Beta vulgaris* L.) is an important vegetable, which is on the fourth position in Poland in terms of production and consumption, after cabbage, carrot, and onion. Its cultivation does not cause any problems, and good storability ensures availability of fresh product year around without the need of applying expensive storage equipment. Red beets are also widely used in food industry. This generates farmers' interest, including those specialising in sustainable technologies of production. For many years, organic products received unflagging interest of consumers because of their pro health properties, which are due to their high content of minerals, vitamins, and pigments, i.e. compounds having beneficial effect on human organism (Szura *et al.* 2008, Zujko and Witkowska 2009, Hunter *et al.* 2011).

For health promoting activity of the red beets, the content of pigments in the roots is of a special importance. These pigments belong to two groups: red-violet betacyanins and yellow betaxantins. The betacyanins include betanine and isobetanine. Among betaxantins, the main position is occupied by vulgaxanthines (I and II). Betacyanins have been recently included to the group of natural plant antioxidants (Cai *et al.* 2003). It was demonstrated that all plant products containing betacyanins are characterised by high antioxidative potential. Among them is the red beet, which was recently included into the group of ten vegetables with the highest antioxidative potential. Pigments of the red beets, especially betanine, effectively inhibit lipid peroxidation and exhibit some anticarcinogenic, antibacterial and antiviral activity (Kanner *et al.* 2001). Red beets are the main source of betacyanins, used in food industry as natural dyes for food products (Szalaty 2008). Different redness

shades of the root flesh are determined by the ratio of betacyanins to betaxantins, and their relative content depends on root size, variety, weather conditions during cultivation and fertilization (Felczyński and Elkner 2008).

The negative feature of red beets is a high tendency to accumulate nitrates, which after consumption may be converted in human intestines to carcinogenic nitrosamines. The presence of nitrates is a consequence of excessive nitrogen fertilization (Moćko and Waławek 2005), however their accumulation may also occur even if the proper agrotechnique has been applied (Nabrzyski, Gajewska 1994).

The study aimed to determine the differences in the content of basic components determining quality of red beet roots cultivated using organic, integrated and conventional methods. Inconsistent results of numerous studies concerning quality of organic products with relation to products coming from other production systems justify the rightness of the undertaken study.

MATERIAL AND METHODS

Three methods of red beet 'Regulski Cylinder' cultivation were investigated: organic, integrated and conventional, during the years 2006, 2008, and 2009. All the experiments were performed in Wiśniowa, Podkarpackie Voivodship, on brown acidic soils with humus content ranging from 2.38 to 2.41%. The treatment using organic method was conducted on a certified field. Integrated and conventional treatments were located on neighbouring fields in order to minimise variation resulting from different soil and climatic conditions.

Red beets were sowed in the third year after manure application. Potatoes cultivated on manure were used as the forecrop in the first year and cereals with a cover crop of legumes for autumn tillage in the second year. Additional supplementing fertilisation was applied in the spring, basing on results of soil analysis. In conventional and integrated methods it was done in a form of mineral fertilisers (nitrate, granular superphosphate and potassium salt) while in organic method in a form of liquid manure and certified fertilisers (phosphate rock powder). The nutrients in the soil were main-

tained at the following levels: N - 70 mg·dm⁻³, P - 60 mg·dm⁻³, K - 150 mg·dm⁻³, Mg - 60 mg·dm⁻³, Ca - 1500 mg·dm⁻³. The cultivation of red beets, irrespective of the applied method, was conducted on low ridges with one-row sowing. At a stage of 2-4 true leaves, the thinning every 4-6 cm was applied.

In organic cultivation, mechanical weed control was applied. Before sowing, the seeds were dressed with soft soap. No pesticides controlling diseases were applied during the cultivation. Beet seeds for sowing in integrated and conventional technologies were primed with Thiram 75%. The weed control was based on products approved for use in red beet cultivations. The first treatment with Lenacil 80% was carried out on broadleaf weeds 3 days after the sowing. The second treatment was performed on monocot weeds using Fluazifop-P-butyl 150 g·dm⁻³. The other weeding treatments in integrated method were conducted mechanically while in the conventional method, an additional application of herbicide Quizalofop-P-ethyl 5% was used. In both integrated and conventional methods of cultivation, treatment against *Cercospora beticola* with Mankozeb 75% was applied at the first true leaf stage. No other plant protection treatment was used in both methods.

Directly after harvesting, the roots' weight, length, and diameter were measured along with the analysis of the dry matter content using oven-drying method at temperature 65 °C as well as soluble sugars content with anthrone method (Yemm and Wills 1954), nitrates content using spectrophotometric method (PN-92/A-75112) and the content of ascorbic acid using iodate method (Samotus *et al.* 1982). The pigments of red beets - betanine and vulgaxanthine - were determined according to Nilsson (1970).

In the presented study, each experimental object (cultivation method), was replicated four times, where the replication was 200 m² plot. Obtained results were worked out with Statistica 8 software, using analysis of variance and NIR at a significance level of p=0.05.

RESULTS AND DISCUSSION

Temperature and precipitation during the 3 years of the experiment varied significantly (Ta-

ble 1). The year 2006 was the coldest, but with the highest temperature in July and September, as compared to other years. The mean temperature was the highest in 2008 and relatively uniform during the whole season, without low or high extremes. The year 2006 had the lowest total precipitation, with especially dry July but wet August. In May, July and September of 2008 precipitation was abundant. The season 2009 was most rainy, especially in May, June and July.

The total and marketable yields varied significantly between years (Table 2). In the years 2006 and 2008, the total and marketable yields of organically produced red beets were higher than those produced by conventional method. In the year 2009 in turn, the total and marketable yields of organically produced roots were the lowest when compared to the yields of conventionally produced red beets. Obtained results show a strong impact of conditions during vegetative season on the yield. When analysing mean yields from the three years of cultivation, no significant influence of cultivation method on the yield was noted. Marketable yield of the red beet roots cultivated in organic system constituted 88, 74 and 71% of the total yield in the subsequent years in comparison to 83, 100 and 93% in conventionally grown roots. Higher yield of organically produced red beets in the years 2006 and 2008 was reported also by Felczyński and Elkner (2008). On the contrary, Mäder *et al.* (1993) reported that yields of organically produced vegetables were by about 25% lower than of those produced conventionally. Yields of organically grown cabbage, carrot, onion, tomatoes, spinach and peas lower by 47-88% compared to integrated production, were reported by Fjelkner-Modig *et al.* (2000). It is generally believed that yields in organic agriculture are 10-40% lower for a particular species when compared to the conventional one. The more intense the conventional agriculture and the higher its efficiency is, the greater is the difference (Kuś 2003). In Poland, considerably small differences in yielding of plants from organic and conventional cultivation are due to relatively extensive technology used in traditional farms, with low amounts of fertilisers and pesticides applied (Krasowicz 1996).

Marketable red beet roots from organic cultivation had lower mean weight in 2009 compared to the roots coming from conventional cultivation but higher than those produced according to integrated technology in the year 2006 (Table 3). Significantly lower mean weight of red beet roots cultivated using organic method is consistent with the results obtained by Mäder *et al.* (1993).

The roots of red beets cultivated using different methods did not differ in terms of dry matter content, while significant differences between years of cultivation were noted (Table 4). The lowest content of dry matter in all the treatments was noted in the year 2008, which was probably due to abundant precipitation in September. Lack of differences in dry matter content in roots of red beet produced in various technologies was reported by Sikora *et al.* (2010) and Mäder *et al.* (1993) and by Zarzyńska and Goliszewski (2006) for potatoes. Also Fjelkner-Modig *et al.* (2000) did not find any differences in dry matter content in onions produced by organic and integrated method, but they obtained higher dry matter content in organically cultivated peas, potatoes, carrots and tomatoes, while for cabbage the highest content of dry matter was noted in integrated production. Rossi *et al.* (2008) demonstrated that dry matter content in tomatoes coming from organic production was higher compared to these produced conventionally.

The content of nitrates in the roots varied depending on a cultivation method used and a year of cultivation. The lowest content was found in the roots coming from organic cultivation, while the highest in the roots from conventional one. The roots from integrated cultivation did not differ from the roots produced conventionally in terms of the trait discussed. Kosson *et al.* (2011) reported similar findings. Worthington (2001) concluded that nitrate's content in organic products is on average 15.1% lower as compared with traditionally produced ones. Zarzyńska and Goliszewski (2006) confirmed such a relationship for potatoes produced by organic and integrated methods. Comparing the nitrate's content in white and red cabbages, potatoes, lettuce, beets, parsley, carrots, celery, and Chinese cabbage from conventional and organic cultivation Rembiałkowska *et al.* (2012) concluded

Table 1. Average monthly air temperature and precipitation at the experimental site

Year of cultivation	April	May	June	July	August	September	Annual mean
Temperature (°C)							
2006	9.4	13.5	17.0	21.3	18.3	15.5	8.7
2008	9.3	13.6	18.0	18.7	18.9	13.0	9.6
2009	11.1	13.3	16.6	20.0	18.8	15.2	9.0
Precipitation (mm)							
2006	38	106	91	16	104	25	612
2008	46	105	87	118	55	103	736
2009	4	103	146	98	45	32	773

Table 2. Red beet yield depending on cultivation method

Method of production	Total yield (kg·10 ⁻² ha ⁻¹)				Marketable yield (kg·10 ⁻² ha ⁻¹) (% of total yield)			
	2006	2008	2009	Mean for the method	2006	2008	2009	Mean for the method
Conventional	16.14 a*	10.32 a	33.13 b	19.86 ns**	13.39 a (83)	10.32 a (100)	30.97 b (93)	18.23 ns (92)
Integrated	29.42 b	10.62 a	29.08 ab	23.04 ns	23.91 b (81)	10.50 a (99)	26.94 b (93)	20.45 ns (89)
Organic	28.80 b	24.85 b	23.45 a	25.70 /s	25.35 b (88)	18.45 b (74)	16.68 a (71)	20.16 ns (78)
Annual mean	24.78 b	15.26 a	28.55 b		20.88 b (84)	13.09 a (86)	24.86 b (87)	

* Means marked with the same letter within methods of cultivation and seasons do not differ significantly

** n/s - insignificant difference

Table 3. Parameters of red beet roots depending on cultivation method

Method of production	Mean weight of marketable root (g)				Root length (cm)				Root diameter (cm)			
	2006	2008	2009	Mean for the method	2006	2008	2009	Mean for the method	2006	2008	2009	Mean for the method
Conventional	177.60 a*	159.93 n/s**	269.62 c	202.38 b	16.27 n/s	11.77 n/s	18.47 b	15.50 b	5.81 ab	5.99 b	5.88 b	5.89 b
Integrated	278.92 b	134.98 n/s	181.65 b	198.52 ab	16.07 n/s	12.59 n/s	16.75 b	15.14 b	6.00 b	5.14 a	5.72 b	5.62 b
Organic	212.09 a	145.65 n/s	90.44 a	149.39 a	16.75 n/s	12.70 n/s	9.66 a	13.03 a	5.43 a	5.43 a	5.00 a	5.29 a
Annual mean	222.87 c	146.85 a	180.57 b		16.36 b	12.35 a	14.96 b		5.75 n/s	5.52 n/s	5.53 n/s	

*, ** for explanations see Table 2.

Table 4. Content of dry matter and nitrates in roots of red beet depending on cultivation method

Method of production	Dry matter content (% FM)				Nitrate content in juice (mg·dm ⁻³)			
	2006	2008	2009	Mean for the method	2006	2008	2009	Mean for the method
Conventional	14.45 ab*	13.15 ns**	14.06 a	13.88 ns	3397 b	2220 ns	2827 ns	2815 b
Integrated	14.64 b	12.84 ns	14.53 ab	14.00 ns	3200 b	1817 ns	2770 ns	2595 b
Organic	13.78 a	12.95 ns	14.85 b	13.86 ns	1585 a	995 ns	2275 ns	1618 a
Annual mean	14.29 b	12.98 a	14.48 b		2727 b	1677 a	2624 b	

*, ** for explanations see Table 2.

Table 5. Content of sugars and ascorbic acid in roots of red beet depending on cultivation method

Method	Soluble sugars (% FM)				Ascorbic acid (mg%)			
	2006	2008	2009	Mean for the method	2006	2008	2009	Mean for the method
Conventional	8.28 ns**	6.98 ns	7.43 ab*	7.57 ns	6.24 b	7.81 b	9.46 c	7.83 b
Integrated	8.51 ns	6.76 ns	6.54 a	7.27 ns	5.06 a	7.01 a	8.25 b	6.77 ab
Organic	8.16 ns	7.61 ns	8.13 b	7.97 ns	5.44 a	7.59 ab	6.71 a	6.58 a
Annual mean	8.32 b	7.12 a	7.37 a		5.58 a	7.47 b	8.14 b	

*, ** for explanations see Table 2.

Table 6. Content of pigments on roots of red beet depending on cultivation method

Method	Betanine (% FM)				Vulgaxanthine (% FM)				Ratio of betanine to vulgaxanthine			
				Mean for the method				Mean for the method				Mean for the method
	2006	2008	2009		2006	2008	2009		2006	2008	2009	
Conventional	0.529 b	0.499 c	0.306 a	0.445 n/s	0.321 n/s	0.168 n/s	0.129 b	0.271 b	1.65 n/s	2.97 a	2.37 n/s	2.33 a
Integrated	0.564 b	0.433 b	0.292 a	0.430 n/s	0.282 n/s	0.124 n/s	0.081 a	0.162 ab	2.00 n/s	3.49 a	3.60 n/s	3.03 a
Organic	0.394 a	0.376 a	0.439 b	0.403 n/s	0.141 n/s	0.059 n/s	0.132 ab	0.111 a	2.79 n/s	6.37 b	3.32 n/s	4.16b
Annual mean	0.496 b	0.436 b	0.346 a		0.248 n/s	0.117 n/s	0.171 n/s		2.15 a	4.28 b	3.10 a	

*,** for explanations see Table 2.

that it was higher by 148.39% on average in conventionally produced vegetables than in those coming from organic cultivation. In our experiment, the highest differences in nitrate's content were between years of cultivation. They were high in 2006 and 2009, which coincides with high temperature and low precipitation in September. Drought increases the nitrate's content by inhibiting their reduction in plant tissues. An impact of

cultivation method, climatic conditions, and genotype on nitrates content in roots of red beets was discussed by Mäder *et al.* (1993). Several authors reported influence of the form and amount of fertilizer used, weather conditions, soil type, cultivation and genetic factors (Michalik and Grzebelus 1995, Rożek 2000, Felczyński and Elkner 2008). Felczyński and Elkner (2008) reported that at lower levels of manure fertilization an additional

fertilization with mineral nitrogen increased the level of nitrates in beet roots. Szura *et al.* (2008) noted lower level of nitrates in red beets in cooler summers, when fertilizers with reduced forms of nitrogen (NH_4^+) and fertilizers containing nitrification inhibitors (CULTAN method) were used. Soil pH is of a big importance for the accumulation of nitrates in plants. Maintenance of pH level at 6.5-7.5 is one of the factors necessary to reduce NO_3^- content in vegetables (Sady 2000). Usually, high accumulation of nitrates in red beet roots coming from integrated and conventional cultivation can be explained both by excessive nitrogen uptake from the applied mineral fertilizers and by lower range of soil pH.

The soluble sugars content in organically produced roots was significantly higher than in roots coming from the other systems only in 2009 (Table 5). The lack of differences in sugars content in roots of red beets originating from different cultivation technologies was also noted by Mäder *et al.* (1993), Sikora *et al.* (2010) and Kazimierczak *et al.* (2011). Hallmann (2012) showed an increase in the total content of sugars and in a higher sugar to organic acids ratio in organic tomatoes when compared to these produced conventionally. Rembiałkowska *et al.* (2012) confirmed a higher content of total sugars in organic fruits and vegetables, including carrots, beets, potatoes, spinach, kale, cherries, black currants and apples, which contributes to an increase in the technological and sensory quality (taste) of organic products. It is due to the sustainable management based on organic fertilizers, which are decomposed slowly by soil microorganisms and are gradually being made available for uptake by plants. Higher levels of easily available nitrogen in the conventional crops lead to the increased synthesis of amino acids and proteins, which inhibits the synthesis of carbon-rich compounds, including carbohydrates (Worthington 2001).

Ascorbic acid content depended significantly on the method and year of cultivation (Table 5). In each year, the lowest amounts were noted in roots coming from organic production, while in roots from conventional cultivation its level was the highest in each year of the study. Higher content of

ascorbic acid was noted in years 2008 and 2009, as compared to year 2006.

Reports on effect of the cultivation method on vitamin content are inconclusive. The lower content of vitamin C in the roots originating from organic cultivation as compared to roots from conventional cultivation was noted by Sikora *et al.* (2010), whereas Worthington (2001) reported that vitamin C content was on average 27% higher in organically grown vegetables when compared to conventional ones, with the exception of carrots. On the other hand, Kazimierczak *et al.* (2011) and Mäder *et al.* (1993) found no difference in vitamin C content in the red beet roots from different cropping systems and the same was observed by Fjelkner-Modig *et al.* (2000) in cabbage, onion, peas and tomatoes cultivated using organic and integrated methods. Hunter (2011) showed an increase in vitamin C content in organically grown carrots and potatoes. Higher level of ascorbic acid in organic potatoes and tomatoes was observed by Solarska *et al.* (2010); however there were no differences in case of carrots, red beets and leek. Brandt *et al.* (2011) compared the results of several studies and concluded that there is a tendency to higher levels of vitamin C in organic products.

The lowest content of betanine was determined in organically produced beet roots in the years 2006 and 2008, but in 2009 the organic roots had the highest content of this compound (Table 6). The content of the vulgaxanthine did not depend on the cultivation method or the year of cultivation. The only difference concerning higher content of this compound in conventionally grown beet root was recorded in 2009.

The ratio of betanine to vulgaxanthine ranged from 2.40 to 4.32, and was significantly higher in organic beets only in 2008. Higher betanine to vulgaxanthine ratio in flesh of organic red beets as compared to red beets coming from other cultivations was observed by Felczyński and Elkner (2008). They obtained the highest content of betanine and the highest ratio of betanine to vulgaxanthine using low doses of fertiliser (N-60 , $\text{P}_2\text{O}_5\text{-30}$, $\text{K}_2\text{O-70}$ $\text{kg}\cdot\text{ha}^{-1}$), achieving concurrently high marketable yields of well-coloured roots. Kosson *et al.* (2011) confirmed the higher content of betanine in

organic beet roots when compared to conventional ones and showed that its level depends on weather conditions at the time of planting, fertilization and plant genotype.

The results obtained in our experiment show that yield, dry matter and soluble sugars' content of red beet roots produced in organic, integrated and traditional technology do not differ significantly. However, organically grown red beets had smaller root diameter and length, which resulted in a smaller share of marketable roots when compared to red beets produced using conventional method. They were also characterised by a lower level of nitrates and ascorbic acid and by a higher betanine to vulgaxanthine ratio (in one year only) when compared to red beets coming from integrated and conventional production.

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