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Influence of sowing and harvest dates on production of two different cultivars of sugar beet

Klára PAVLŮ[1,*], Jaromír CHOCHOLA[1], Josef PULKRÁBEK[2], Jaroslav URBAN[2]

[1]Sugar Beet Institute, Semčice, Czech Republic
[2]Faculty of Agrobiology, Food and Natural Resources, Czech University of Life Sciences Prague, Prague, Czech Republic
*Corresponding author: pavlu@semcice.cz

ABSTRACT

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Small-plot trials conducted in 2013–2015 studied the impact of longer vegetation periods (by means of earlier drilling and/or later harvest) on production results of two sugar beet cultivars – one nematode-tolerant cultivar and one cultivar without such tolerance. The trials took place at two sites with different *Heterodera schachtii* infestation levels. In all trial seasons, root yield was significantly higher in the earlier drilled plots. On average, prolongation of the vegetation period in spring by 13 days increased root yield by 10.9%. Therefore, each day by which drilling is postponed represents a 0.7–0.8% loss of yield. As to sugar content, no statistically significant benefit of vegetation period prolongation by early drilling was found. The spring gain was slightly higher for the non-tolerant cultivar than for the tolerant one on average over all trial seasons. This result confirms the theory that nematodes impact the crop mainly in later stages of vegetation, and early drilling can thus help eliminating, to a certain degree, the risk of nematode damage. In the autumn, root yield increased by 14.3% on average over 39 days. The autumn daily gain was about half of the rate found in the spring. The increase in sugar content was between 0.6% and 1% (abs.) on average. Autumn growth achieved at the non-infested site was much higher than at the infested site.

Keywords: prolongation of vegetation; *Beta vulgaris*; parasite

Sugar beet is one of the most productive temperate-climate crops; despite this, it has been facing difficulties lately, and sustainability of its growing in Europe needs major efforts to be safeguarded. The expected restructuring of the beet-growing and sugar industry in the EU will deregulate the market and liberalize pricing. The advent of free market environment will lead to attempts by a number of successful growers – or sugar manufacturers – to secure larger market shares than what they were previously allowed to have. This will inevitably lead to efforts to maximize cost-effectiveness (Špička and Janotová 2015). The Czech Republic is the 7th biggest sugar producer in Europe; the country's average yearly production is higher than that of Spain, Austria, Hungary or Slovakia for example (Reinbergr 2016).

Sugar beet yields have been showing strong growing trends in comparison with other commodity crops, such as wheat or oil rape for example. This is greatly helped by new knowledge aiming at improving yields and/or beet quality (Artyszak et al. 2014, 2015, Ondrišík et al. 2016). In the future, per-hectare root yields will need to reach 80 t/ha in our farms, and polarizing sugar yields at least 13 t/ha. To maximize yields, one possibility is to prolong the vegetation period. In view of the current climatic change, the main growing season becomes longer and longer. Starting drilling on 20 March is now becoming standard practice, and the trend seems about to continue in the years to come. Postponing harvest, on the other hand, is not fully under growers' control. However, many

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Table 1. Information about localities of experiment

Locality	Soil type	Altitude (m a.s.l.)	Average temperature (°C)[1]			Sum of precipitation (mm)[1]		
			2013	2014	2014	2013	2014	2015
Bezno	Harpic Luvisol	280	13.0	14.5	14.3	507.0	426.0	342.9
Všestary	Harpic Luvisol	285	12.9	14.3	14.3	447.7	422.7	261.8

[1]Vegetation period III–X

sugar companies also wish to have longer processing campaigns, and later harvest thus becomes possible. In this respect, beet storage and the associated losses remain an important aspect (Chochola and Pavlů 2015, Kumbár et al. 2015).

According to expected climate change scenarios, the average annual temperature should go up by 1–2°C in the Central Europe in the next few decades. The climatic change will cause gradual shift of altitudinal zones towards higher elevation levels, and the acreage located in climatic conditions suitable for sugar beet growing will increase (Kopecká et al. 2013). The importance of year-specific factors and of long-term climatic changes for sugar beet production is also emphasized by Potopová et al. (2015).

According to Pulkrábek et al. (2008), the crop potential would be currently used at 69% as to root yield, and at 98% for sugar content. This estimate is based on comparison of the Central Institute for Supervising and testing in Agriculture in Czech Republic small-plot cultivar trials with farm results in 1998–2007. No significant correlation was found between the total rainfall over the growing season and root yields. Distribution of that rainfall among different months was more important, though. The most significant correlation values were found in May (R = 0.41), July (R = –0.43) and August (R = 0.54). Temperatures, on the other hand, showed a positive correlation mainly in July (R = 0.40), and a negative one in August (R = –0.35). The situation was similar for sunshine hours. The above findings clearly show how crucial a specific year's climate is for sugar beet yield and sugar content. Despite such year-to-year fluctuations, the yield potential utilization rate continues to increase. As to root yield, that rate grew from 67.7% (1981–1990) to 71.6% (2001–2005). Improvement was also observed for sugar content (Prugar et al. 2008). The importance of proper crop rotation and structure, and associated long-term changes in soil properties, are pointed out by Stehlíková et al. (2015). Mühlbachová et al. (2015) stresses new, soil-protecting tilling methods and their use.

Over the last few years, nematodes have been more and more present in fields; the parasite manifests itself by typical wilted spots in the crop. The most frequent solution in our conditions is to grow tolerant or resistant sugar beet cultivars. The degree of yield loss depends on a large number of factors. Besides the extent of infestation as such, these include the overall course of the growing season, which is closely linked to the drilling and harvest dates. Therefore, an earlier drilling can moderate the impact of nematodes (Buhre et al. 2011).

This article aims at demonstrating the impact of early drilling and of the harvest date, and the importance of cultivar with respect to nematode infestation of soils. It attempts to show that a suitable cultivar/harvest date combination can contribute to stabilizing polarized sugar yields around 13 t/ha.

MATERIAL AND METHODS

In 2013–2015, small-plot trials were conducted at trial sites of the Semčice Sugar Beet Institute. This study discusses results from two sites: Bezno (medium strong to strong nematode infestation), and Všestary (none to weak infestation). Basic data about both trial sites are summarized in Table 1.

The impact of longer vegetation periods on production results of two types of sugar beet was studied: a nematode-tolerant cultivar, and a cultivar without such tolerance. The extent of *Heterodera*

Table 2. The number of cysts (*Heterodera schachtii*) in soil samples from the experimental localities

Year	Locality	Live cysts in 100 g soil	Dead cysts in 100 g soil	Level of infestation
2013	Bezno	40	40	strong
	Všestary	2	2	weak
2014	Bezno	8	16	medium
	Všestary	0	0	without
2015	Bezno	5	19	medium
	Všestary	2	7	weak

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Table 3. Terms of drilling, terms of harvest and length of vegetation in years 2013–2015

Year	Site	Drilling		Harvest		Days of vegetation		
		sooner	later	sooner	later	pre-	main	post-
2013	Bezno	7.4.	18.4.	23.9.	1.11.	11	158	38
	Všestary	17.4.	26.4.	24.9.	2.11.	9	151	38
2014	Bezno	31.3.	8.4.	17.9.	1.11.	8	162	44
	Všestary	23.3.	7.4.	23.9.	4.11.	16	169	41
2015	Bezno	10.4.	25.4.	28.9.	31.10.	15	156	32
	Všestary	23.3.	13.4.	25.9.	3.11.	21	165	38

presence was determined at both sites in the course of the trial. Specific information about the presence of nematodes per trial season is shown in Table 2.

Each plot contained 3 beet rows, 90 plants per plot. The area of each harvested plot was 10 m^2. Two drilling dates and two harvest dates were used. This resulted in three treatments with different vegetation periods (early drilling – early harvest; late drilling – early harvest; and early drilling – late harvest). The precise dates of drilling and harvesting are shown in Table 3. For each vegetation period, two sugar beet cultivars with different nematode tolerance were sown. Cultivar with tolerance is marked as RINEM-cultivar, cultivar without tolerance is marked as RI-cultivar. Each cultivar was tested in 6 repetitions.

During the trials, usual products were sprayed on the crops at usual times. In most cases, 3–4 herbicide treatments were practised, as well as 1–2 fungicide treatments. All sugar beet harvested from each trial plot was washed, weighed, and then sliced. A sample taken from the laboratory slicer was frozen. All samples were then analysed in a German KWS laboratory for sugar content, alpha-amino nitrogen content, sodium and potassium content. From the values thus obtained, white sugar content was calculated using the Braunschweig formula. The Statistica 12 software (Tulsa, USA) was used to evaluate the trial results.

RESULTS AND DISCUSSION

Early drilling. Improvement of root yield and sugar content was studied in early- vs. late-drilling trials conducted in Bezno (Table 4). In all trial seasons, root yield was significantly higher in earlier drilled plots (Figure 1). A longer growing season increased root yield by 6.3 t/ha on average (in relative value, 8.4% as compared to the later drilling date). Therefore, each day by which drilling is postponed represents a loss of yield amounting to about 0.55 t/ha (or 0.73%). In trials quoted by Stehlík (1982), postponing drilling from 29/03 to 24/04 reduced root yield by 20.8%. Fiedler (1975) mentions root yield loss of about 16.1% over 15 days. This rather coincides with Winner's data (1982), according to which yields losses amount to 5–15% in the first half of April.

Similar results were obtained in the Všestary site (Table 5, Figure 2). Prolongation of the growing season increased root yield by 9.8 t/ha (rel. 9.4%) on average. When dividing this figure by the number of days, it appears that the loss per day of postponed drilling is around 0.64 t/ha (or 0.87%).

White sugar yield was also significantly higher in case of earlier drilling. In the Bezno site, the per-day gain was calculated at 0.10 t/ha (rel. 0.82%).

Table 4. Comparison of production indicators of two sugar beet cultivars at two drilling dates in Bezno

2013–2015	RI – cultivar			RINEM – cultivar			Average of cultivars		
	1st term	2nd term	difference	1st term	2nd term	difference	1st term	2nd term	difference
Root yield (t/ha)	80.62	73.63	6.990**	81.85	76.4	5.450	81.23	75.02	6.210**
Sugar content (%)	18.59	18.36	0.230	18.36	18.29	0.070	18.47	18.33	0.140
α-amino nitrogen (mmol/100 g)	0.83	0.85	0.020	1.10	1.10	0.000	0.96	0.98	0.020
Potassium (mmol/100 g)	3.34	3.34	0.000	3.67	3.66	0.010	3.51	3.50	0.010
Sodium (mmol/100 g)	0.34	0.34	0.000	0.37	0.38	0.010	0.36	0.36	0.000
White sugar yield (t/ha)	13.59	12.22	1.370**	13.47	12.53	0.940**	13.53	12.38	1.150**

**significant difference at $\alpha = 0.01$

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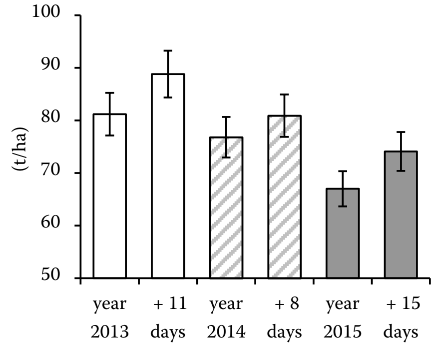

Figure 1. The effect of spring prolongation of vegetation period on root yields in individual years, Bezno

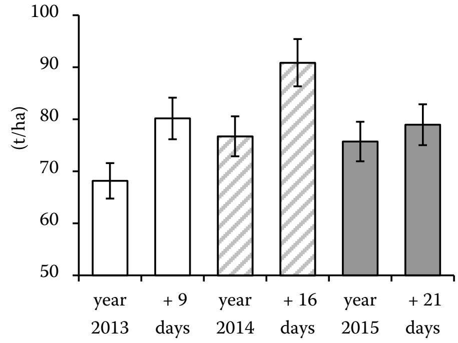

Figure 2. The effect of spring prolongation of vegetation period on root yields in individual years, Všestary

Drilling postponed by 11 days therefore represents white sugar yield loss of about 1.15 t/ha (rel. 9.4%). The spring gain was slightly higher in the Všestary site. A growing season longer by 15 days thanks to early drilling made white sugar yield grow by 1.68 t/ha (rel. 14.1%). This represents a daily gain or loss of around 0.11 t/ha (rel. 0.91%). According to Fiedler (1975), postponing drilling by 15 days led to white sugar yield lower by 17.9%.

As to sugar content, no significant benefit of the vegetation period prolongation by early drilling was found. In the Bezno site, the average sugar content increase amounted to 0.013% per day, while in Všestary only to 0.005% per day. Nevertheless, sugar content went up with a longer growing season in all three seasons and at both sites. In his study, Stehlík (1982) indicates that drilling 25 days later reduces sugar content by 0.6% (abs.). Winner (1982) presents trial results where postponing drilling by 26 days reduced sugar content from 18.1% to 16.5%. It is evident that sugar content increase can be very variable. In the Bezno site, the daily increase amounted to 0.03% (abs.) in 2014, but only to 0.004 (abs.) in 2015. These differences are certainly linked to each specific season's conditions, but also to soil structure and to numerous other factors.

The trials also aimed at establishing whether and how the longer vegetation influenced alpha-amino nitrogens and amount of soluble ash. In this respect, either, no correlation was established between the longer growing season thanks to early drilling, and the content of such substances. Any measured differences were negligible, and it can be therefore stated that qualitative parameters of sugar beet remain practically unchanged whatever the drilling date.

When comparing yields between cultivars (Figure 3), the spring growth was practically the same at both sites. Statistical processing did not establish any difference as to the spring gain between the nematode-tolerant and the non-tolerant cultivar. However, the spring gain of the non-tolerant cultivar was slightly higher than that of the tolerant cultivar on average of different trial seasons. This result confirms the hypothesis that nematodes impact the crop mainly in later stages of vegetation, and early drilling can thus help eliminating, to a certain degree, the risk of nematode damage.

Later harvest. On 3-year average (Table 6), postponing the harvest date by 38 days made the root yield grow by 6.4 t/ha (rel. 8.3%). This represents a daily gain of around 0.17 t/ha (or rel. 0.21%). This value seems rather low compared to some data

Table 5. Comparison of production indicators of two sugar beet cultivars at two drilling dates in Všestary

2013–2015	RI – cultivar			RINEM – cultivar			Average of cultivars		
	1st term	2nd term	difference	1st term	2nd term	difference	1st term	2nd term	difference
Root yield (t/ha)	83.32	72.06	11.260**	83.32	75.00	8.320**	83.32	73.53	9.790**
Sugar content (%)	18.73	18.68	0.050	18.50	18.41	0.090	18.62	18.54	0.080
α-amino nitrogen (mmol/100 g)	1.37	1.36	0.010	1.74	1.74	0.000	1.56	1.55	0.010
Potassium (mmol/100 g)	3.88	4.03	0.150	4.26	4.32	0.060	4.07	4.17	0.100
Sodium (mmol/100 g)	0.68	0.60	0.080	0.71	0.65	0.060	0.70	0.62	0.080
White sugar yield (t/ha)	13.91	12.01	1.900**	13.63	12.17	1.460**	13.77	12.09	1.680**

**significant difference at α = 0.01

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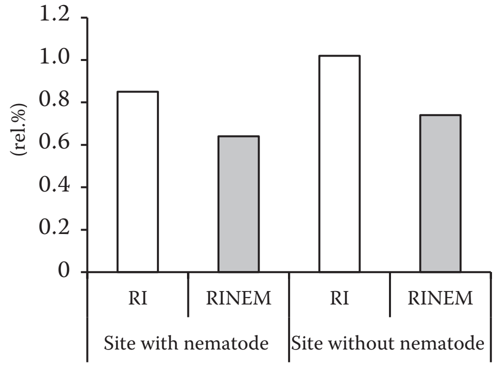

Figure 3. Comparison of spring daily additions of each type of sugar beet (2013–2015)

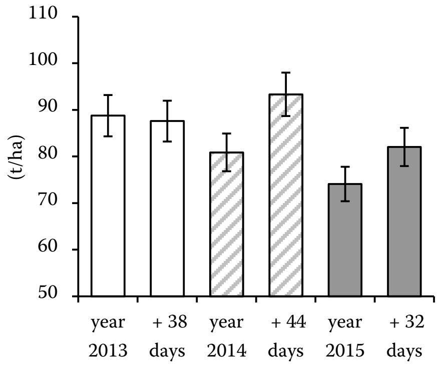

Figure 4. The effect of autumn prolongation of vegetation period on root yields in individual years, Bezno

found in the literature. This is largely due to the atypical 2013 season. In 2013, when the vegetation period was prolonged by 38 days, a 1.2 t/ha decrease in yield was observed at the Bezno site (Figure 4). This decrease was compensated, to a degree, by a significant sugar content increase – by 1.6% (abs.). It must be stressed that the yield deterioration mainly concerned the non-tolerant cultivar, in a site with strong nematode infestation. Extra vegetation days in the autumn brought about a significant increase in sugar content, i.e., around 1.0% (abs.) on average. A benefit for sugar content was also established. The average gain was calculated as 2.0 t/ha, i.e., 15.2%.

The situation at the Všestary site, however, was completely different (Table 7, Figure 5). The average increase in root yield amounted to 16.3 t/ha (rel. 20.3%) with 39 extra days on average. The average daily gain amounted to 0.42 t/ha (i.e. rel. 0.52%). This result is more than double as compared to the Bezno site. The autumn yield increase is summarized in Figure 5. On average over the three trial seasons, sugar content increased by 0.6% (abs.); the increase, however, was not significant.

Table 6. Comparison of production indicators of two sugar beet cultivars at two terms of harvest in Bezno

2013–2015	RI – cultivar			RINEM – cultivar			Average of cultivars		
	1st term	2nd term	difference	1st term	2nd term	difference	1st term	2nd term	difference
Root yield (t/ha)	80.62	84.68	4.054	81.85	90.63	8.784**	81.23	87.65	6.419**
Sugar content (%)	18.59	19.53	0.941**	18.36	19.41	1.057**	18.47	19.47	1.002**
α-amino nitrogen (mmol/100 g)	0.83	0.75	0.076	1.10	1.00	0.097	0.96	0.88	0.086
Potassium (mmol/100 g)	3.34	3.06	0.283	3.67	3.40	0.278	3.51	3.23	0.281
Sodium (mmol/100 g)	0.34	0.34	0.001	0.37	0.32	0.058	0.36	0.22	0.029
White sugar yield (t/ha)	13.59	15.15	1.564**	13.47	16.00	2.519**	13.53	15.57	2.042**

**significant difference at α = 0.01

Table 7. Comparison of production indicators of two sugar beet cultivars at two terms of harvest in Všestary

2013–2015	RI – cultivar			RINEM – cultivar			Average of cultivars		
	1st term	2nd term	difference	1st term	2nd term	difference	1st term	2nd term	difference
Root yield (t/ha)	83.07	100.97	17.901**	78.86	93.54	14.680**	80.96	97.25	16.290**
Sugar content (%)	19.42	19.99	0.587	19.23	19.85	0.625	19.32	19.92	0.601
α-amino nitrogen (mmol/100 g)	1.42	1.41	0.011	1.62	1.35	0.272	1.52	1.38	0.141
Potassium (mmol/100 g)	3.91	3.92	0.010	4.13	3.93	0.202	4.02	3.93	0.096
Sodium (mmol/100 g)	0.46	0.39	0.067	0.54	0.40	0.138	0.50	0.40	0.102
White sugar yield (t/ha)	14.37	18.12	3.752**	13.44	16.69	3.257**	13.90	17.41	3.504**

**significant difference at α = 0.01

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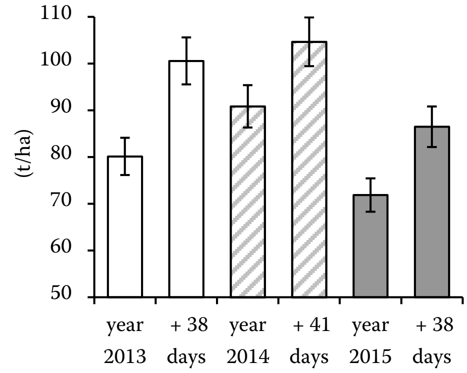

Figure 5. The effect of autumn prolongation of vegetation period on root yields in individual years, Všestary

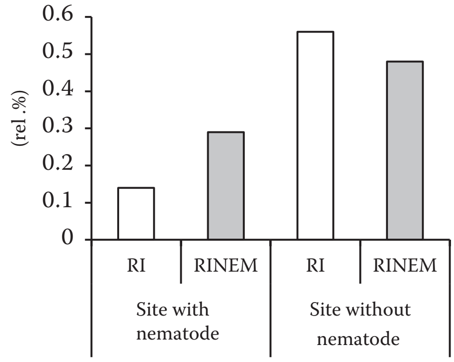

Figure 6. The effect of autumn daily additions of each type of sugar beet (2013–2015)

A longer vegetation period in the autumn clearly pushed white sugar yields up – by 3.5 t/ha (rel. 25.3%) on average. Josefyová (2004) quotes average root-yield gains between 0.3 and 0.6 t/ha per day in the end of September and beginning of October. Their magnitude is closely linked to the weather and health condition of the foliage, and decreases as the autumn advances.

When comparing relative yield increase at both sites (Figure 6), the three-year average daily gain was almost double for the tolerant cultivar as compared to the non-tolerant cultivar at the nematode-infested site. At the nematode-free site, the gain was higher for the non-tolerant cultivar, but the difference was much lower. Gains achieved in the non-infested site were much higher than in the infested site.

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