Agronomy Research **7**(Special issue I), 436–443, 2009

The effects of climate factors on sugar beet early sowing timing

B. Petkeviciene

Rumokai Research Station of the Lithuanian Institute of Agriculture
post LT-4293 Zalioji, district Vilkaviskis, Lithuanian;
tel: +370-342-49422, +370-342-49435; e-mail: rumokai@post.omnitel.net

Abstract. Important environmental variables that affect determination of sugar beet growing processes are temperature, precipitation and soil moisture. The optimal time for sugar beet sowing was determined in the variety testing trial conducted at the Rumokai Research Station of the Lithuanian Institute of Agriculture during the period 2000–2006. This time was found to be when the mean daily temperature for three subsequent days reached the limit of base air temperatures (> 10ºC). The sowing time was found to strongly correlate (r = 0.9*) with the amount of precipitation and accumulated base temperatures (> 5ºC) in March and May. The potential of sugar beet root biomass and white sugar correlated moderately strongly with the duration of the growing season (r = 0.55 and 0.62) and sowing time (r = −0.64 and −0.70).

Data from the sowing timing trial averaged over the period 2000–2004 suggests that in the case of early sowing the soil moisture at sowing depth was 16.3%. With the delay of sowing soil moisture decreased. At early sowing the stand density was by 3.3 % lower compared with the average (99,900 plants ha^{-1}). One week's delay in sowing reduced roots by 4.7 t ha^{-1} and white sugar 0.9 t ha^{-1} and increased alpha amino nitrogen content in roots by 2.58 mg $100g^{-1}$.

Key words: sugar beets, biomass, sowing time, varieties

INTRODUCTION

While modelling sugar beet technological processes, a focus should be placed on agroclimatic parameters, soil physical maturity, crop growth stages, and physiological needs (Romaneckas et al., 2003). When spring is early, sugar beet is sown earlier, which provides a longer period of sunshine interception for crops (Petkeviciene, 2002), but does not always mean an early beginning of vegetation. The lowest base air temperature at the sugar beet field was recorded to be +3–5°C (Durr & Boiffin, 1995; Siddique et al., 2002; Mavi & Tupper, 2004). Sugar beet sowing time also depends on the cultivation technology chosen (Romaneckas et al., 2003) and is influenced by soil moisture. Some authors indicate that soil surface can be loosened when the soil moisture is 20.0–25.0% (Uhlir et al., 2006).

For most plants, phenological development is strongly related to the accumulation of heat or temperature units above a threshold or base temperature below which little growth occurs. This lower threshold temperature varies with plant species (Ash, 1995; Bellin et al., 2007). Growing degree days have proven useful for scientists, crop consultants, and producers who use them to predict plant development rate and growth stage (Lu & Saylan, 2001; Derscheid & Lytle, 2002).

Sugar beets emerge the fastest when the soil moisture in the seedbed is 20–23 %, and air and soil temperature ranges between 15–25°C (Khan, 1992; Copeland et al., 2001; Sroller I. & Svachula V. 1990; Spaar et al., 2004). In Europe, sugar beets are sown from March 20 to May 1 (Sugar beet, 2004). Depending on the geographical region of sugar beet cultivation, the yield potential can range from 11–40 % (Pidgeon et al., 2001). A delay in sowing by on average one day results in a root yield loss of 300 kg ha^{-1}, and 50 kg ha^{-1} of white sugar (Abracham et. al. 1987; Kolbe & Petzold, 2002). In Lithuania, during the period 1934–1975, the early-sown sugar beet crops produced 22.3–8.1% of bolters, which deteriorated technological crop properties (Lazauskas, 1998). Root biomass potential of sugar beet varieties ranged from 35 t ha^{-1} (until 1989) to 50 t ha^{-1} (during 1991–2000) (Kaunas, 1998; Petkeviciene, 2008). Early sown sugar beets always have enough time to mature, therefore their technological properties are better (Povilaitis & Grigiene, 1995). Sugar beet varietal disease resistance increases their biopotential (Petkeviciene, 2002; Petkeviciene & Kaunas, 2004; Gaurilcikiene et al., 2006). Sugar beet biomass potential is influenced by crop stand density or seed germination (Siuliauskiene et al., 2005).

The present study was aimed to estimate and determine optimal sugar beet sowing time under changing climate conditions. The data obtained in this study will be used for modelling the interactions between the environment and crop and soil management practices, prediction of sugar and biomass potential, and for the improvement of natural resources management methods and sugar beet cultivation technology. Spring operations could be planned based on weather forecasts.

MATERIALS AND METHODS

The trial was conducted during 2000–2006 at the Lithuanian Institute of Agriculture’s Rumokai Research Station. The soil of the experimental site is *Haplic – Epihypogleyic Luvisol*. The soil pH_{KCl} was 6.4–6.6). It contained 0.116–0.156% of total nitrogen, 1.18–1.38 % humus, P_2O_5 186–209 mg kg^{-1} and K_2O 151–177 mg kg^{-1}.

The trial was replicated 4 times. The total area per plot in the variety testing trial was 20.25 m^2, and the harvested plot area was 8.1 m^2. The following sugar beet varieties, included in the National Variety List were studied: Svea, Epos, Pancho, Marathon, Madison, Manhattan, Linna, Anna, Salut, Oxford, Gala, Ariana, Pilot, Kassandra, Medina, Helmi, Tangare, Byzance Clovis, Daniela, Juvena, Belmonte, Tristan, Milenium, Pirat, Helsinki, Silvana, Lorenza, Manila, Moldau, Figaro, Dorena.

Sugar beet growing degree day (GDD) values were calculated using the equation:

Sugar beet GDD = Daily $(T_{max} + T_{min}) / 2 - T_{base}$ (+5°C) (Holen & Dexter, 1996).

Phosphorus and potassium fertilizers were applied in the autumn and nitrogen in the spring. The fertilizer rates N_{160} P_{128} K_{192} were broadcast-applied. Soil tillage, sowing and crop management operations were done observing sugar beet cultivation technological requirements.

Sugar beet root analyses were done at the Kedainiai sugar factory. The data of analyses were processed using analysis of variance and correlation regression analysis methods using software ANOVA and STAT (Tarakanovas & Raudonius, 2003).

RESULTS AND DISCUSSION

Sugar beets are long-day crops, therefore they are generally sown as early in spring as possible. Important environmental variables that determine the beginning of sugar beet growing processes are temperature, precipitation and soil moisture. Trials designed to compare biological potential of the sugar beet varieties were conducted at the Lithuanian Institute of Agriculture Rumokai Research Station. During the period 1990-2000 sugar beets were sown from April 22–May 3. The sowing time was influenced by the cultivation technology: the pre-sowing application of soil herbicides tended to delay the sowing date. During 2000-2006, sugar beets were sown earlier, from April 11–30. This was influenced by no application of soil herbicides and soil moisture (better soil ploughing quality). The beginning of sowing also depends on the weather conditions (Table 1). During the period 2000–2006, the average sowing date of sugar beet varieties was April 20, while the average soil maturity date on the national level is April 27. Due to the agroclimatic conditions, sugar beet sowing can start earlier or can be delayed: precipitation which often occurs during pre-sowing soil tillage replenishes soil moisture reserves and can cause a delay. During the period 2000-2006, the amount of precipitation that fell from the beginning of the year to sowing varied considerably (variation coefficient 43.64%) from 83.3 mm (in 2006) to 409.2 mm (in 2001). In 2000 and 2001 the total precipitation before sugar beet sowing exceeded the long-term mean (134.0 mm) twice or three times. The data averaged over 2000–2006 indicate that the amount of precipitation in January, February, and March was 28.7% per each month (from the total) and exceeded the long-term monthly rate by 57.7%, 95.9%, 95.3%, respectively. In April, during the two ten-day periods before the sugar beet sowing the amount of precipitation exceeded the long-term rate by 32.8 %. In winter months (January-February) the amount of precipitation varied from 52.7 mm (in 2006) to 179 mm (in 2001 and 2004). In the first month of spring, the amount of precipitation close to the long-term mean fell in 2002 (39.8 mm) and in 2003 (36.9 mm), and in 2000 and 2001 the amount of precipitation exceeded the long-term mean by 3-4 times. Moderately strong (r=0.6*) correlation was determined between the sowing time and amount of precipitation in April (before sugar beet sowing): $Y=15.06221 \cdot 1{,}00688^{X}$, where

Y – sugar beet sowing date in April; X – amount of precipitation before sowing.

To sow at optimal dates, the amount of precipitation in April should not exceed 67 mm, and in the warm spring period, 164 mm until sowing.

The warm period starts when the daily mean air temperature becomes positive. For vegetation plants need a higher temperature, however, the minimum spring temperature differs for different crops. For winter crops, it is + 1–3°C; for spring crops, +3–8°C higher (Durr et al., 2001). In other words, this temperature is called biological zero or base temperature. This usually occurs in Lithuania in the middle of April (15–18), and in southern Lithuania on April 10. Soil moisture reduction in spring is affected by air temperature. Under Lithuania's conditions, the soil matures when the daily mean temperature is above 5–7°C, therefore base temperatures are very important for soil moisture and the beginning of sowing. The date of the beginning of base temperatures (Table 2) varied between years (variation coefficient 40.97%) from January 29 (in 2002) to April 3 (in 2005). The cold period in 2004–2005 started in the third ten-day period of January in 2005 and lasted until April 3: then the temperatures rose suddenly.

Table 1. Precipitation before sugar beet sowing. Rumokai, 2000–2006.

Sowing date	*Amount of precipitation before sugar beet sowing, mm*				
	Total, mm	*January*	*February*	*March*	*April*
15 IV 2000	271.8	85.7	44.9	132.3	8.9
30 IV 2001	409.2	76.0	103.0	129.0	101.2
11 IV 2002	168.4	62.0	66.2	39.8	0.4
22 IV 2003	246.6	62.0	111.2	36.9	36.5
14 IV 2004	247.9	94.4	85.5	52.6	15.4
21 IV 2005	192.5	59.5	20.0	52.0	61.0
27 IV 2006	83.3	19.7	33.0	21.9	8.7
Variation coefficient %	29.27	36.87	53.15	68.00	90.07
Average (2000-2006) IV 20	231.4	65.6	66.6	66.4	33.2
Long-term average (1950–2000 m.)	134.0	41.0	34.0	34.0	25.0

Previous to sugar beet sowing (April 21) the sum of base temperatures exceeded the mean of the experimental period. In 2002 and 2003 the beginning of base temperatures was January 29. Until the sugar beet early sowing, the cold period was long and cooler compared with the experimental years' mean (161.9°C).

In 2002 and 2004 the warm period started on March 11 and 16, respectively, but until sugar beet early sowing it was by 147°C warmer in 2001 compared with that period in 2004. The warmest period in April until sugar beet early sowing was in late spring in 2001, 2005 and 2006; the latest was in 2002. We determined sugar beet early sowing time in relation to the following: the sum of base (> 5°C) temperatures (r = 0.7) during the warm period, the sum of base (> 5°C) temperatures from March to April (r = 0.8*) and the sum of base (> 5°C) temperatures from April to sugar beet early sowing (r = 0.9*). The most optimal early sugar beet sowing is when the sum of base (> 5°C) temperatures reaches 109.7°C during the warm spring period or during March and April 90.35°C, and in April 31.1–44.3°C.

The beginning of base (> 10°C) temperatures occurs when the mean daily temperature is 10^{o}C or higher and active crop vegetation begins. The data from the 2000–2006 experimental period show that the beginning of base (> 10°C) temperatures was April 3–21 (variation coefficient 56.1%). In 2004 sugar beets were sown when the daily mean air temperature had not reached the range of base (> 10°C) temperatures. In 2002 and 2003 sugar beet sowing was started on the first day of base (> 10°C) temperatures occurrence, while in 2006, 12 days after the beginning of base (> 10°C) temperatures. Until sugar beet sowing, the sum of base (> 10°C) temperatures ranged from 0–88.0°C.

For early sowing of sugar beet it is necessary to accumulate 33.5^{o}C according to the GDD and for optimal sowing, 52.7–64,3°C.

The beginning of sugar beet early sowing is when the sum of base (> 0°C) temperatures has reached 30.7°C. During the experimental period (2000–2006), until sugar beet sowing, the mean daily air temperature had reached the average for 3 days and exceeded the range of base (> 10°C) temperatures. The data of the variety testing trials averaged over the period 2000–2006 show a strong correlation (r = 0,9*) between the sowing time and amount of precipitation and sum of base (>10°C) temperatures in April and spring months (March and April together).

Table 2. Sums of base temperatures before sugar beet drilling. Rumokai, 2000–2006.

Base (>5°C) temperatures						Base (>10°C) temperatures	Growing degree day (GDD) Tbase 5°C
start	sum,°C	January	February	March	April	sum,°C	
05 II 2000	120.0	-	20.5	12.0	87.5	42.0	60,0
11 II 2001	245.5	-	-	5.5	240.0	31.5	115,5
29 I 2002	145.9	5.0	42.4	67.4	31.1	10.5	35,9
29 I 2003	206.4	5.0	40.4	72.2	88.8	10.5	41,4
16 III 2004	98.5	-	-	54.2	44.3	-	33,5
03 IV 2005	162.7	41.0	-	-	162.1	88.0	52,7
28 III 2006	154.3	-	-	-	154.3	62.1	64,3
Average 01 III	161.9	7.3	14.8	30.2	109.7	30.7	57.6

Weaker correlation (*r* = 0.7) of sowing time occurred with the amount of precipitation (from the beginning of the year to sowing) and sum of base (> 5°C) temperatures (from the beginning of base (> 5°C) temperatures to sowing.

In the sugar beet variety comparison trial we tested 14 varieties (in 2000) and up to 33 varieties (in 2006). The length of their vegetation (Table 3), depending on the date of sowing, ranged from 148 days (sown on 30-04-2001) to 172 days (sown on 15-04-2000). The emergence of sugar beet seed sown at the earliest date (11-04-2002) was long, therefore the beginning of vegetation was later and the duration was shorter.

The data indicated that average duration of vegetation of the sugar beet varieties tested was 157 days. The sowing rate was 133 thousand seed balls per hectare, but due to the field germination of 67.7% the crop stand density was 90.6 thousand plants per hectare (averaged data). In 2002, with increased field germination to 78.5%, the sugar beet stand density increased by 14.4 thousand plants. This increased sugar beet biomass potential by 8.1 t ha^{-1}, compared with the experimental mean. The variation of sugar beet root biomass between years was 11.07%.

During the experimental period, we established positive correlation (*r* = 0.55) of sugar beet root biomass with the length of vegetation and negative correlation (*r* = –0.64) with sowing time. This shows that with delaying of sowing date the sugar beet biomass potential declined, and with longer vegetation, the biomass potential increased. In the variety trial conducted during 2000-2006, at a sugar beet stand density of 83.2–98.0 thousand, and plant vegetation length 149-165 days, optimal sugar beet root biopotential (63.69–78.22 t ha^{-1}) was produced. During 2000-2006, the average root biomass potential of the varieties tested was 71.7 t ha^{-1}.

Sugar beet root biomass and root quality theoretical possibilities are described by white sugar yield. In 2001, when the severity and incidence of sugar beet leaf disease *Cercospora beticola Sacc*., were high in the sugar beet crops in Lithuania, white sugar potential in the variety testing trial was by 30 % lower compared with the average (11.0 t ha^{-1}).

Table 3. Indices of sugar beet. Rumokai, 2000–2006.

Sowing date	Number of varieties	Duration of vegetation, days	Crop density 1000 plants ha^{-1}	Biomass of roots, t ha^{-1}	White sugar t ha^{-1}
15 IV 2000	14	172	87.0	76.2	12.9
30 IV 2001	18	148	97.0	59.5	7.6
11 IV 2002	22	162	105.0	79.5	13.7
22 IV 2003	20	154	87.0	60.7	9.5
14 IV 2004	26	160	80.3	71.0	9,8
21 IV 2005	29	152	88.0	79.0	12.8
27 IV 2006	33	151	90.0	73.8	10.4
Average		157	90.6	71.4	11.0
LSD_{05}			11.97	7.10	1.00

Table 4. Soil moisture and effects of early sowing on sugar beet indices. Rumokai, 2000–2004.

Sowing timing	Soil moisture at 3 cm depth, %	Crop density, 1000 plants ha^{-1}	Biomass of roots, t ha^{-1}	Alfa amino N, mg $100g^{-1}$ beet	White sugar, t ha^{-1}
Early sowing	16.3	96.6	69.3	24.0	9.6
1 week later	14.7	101.2	66.1	29.0	9,1
2 week later	13.6	101.6	59.4	30.3	8.0
3 week later	12.0	100.8	54.3	31.6	7.2
4 week later	12.2	99.1	50.6	34.3	5.9
Average	13.7	99.9	59.9	29.8	8.0
LSD_{05}	0.82	0.92	3.50	1.70	0.66

White sugar potential (13.7 and 12.8 t ha^{-1}) in 2002 was determined by the stand density and root biomass potential, and in 2005 by root biomass potential and quality. During 2000–006 it was found that white sugar potential depended on the length of vegetation period (r = 0.62) and sowing time (r = -0.70).

Soil surface loosening is started when soil moisture is 20–22% (Feiza et al., 2005). Optimal soil moisture for sugar beet sowing is 15–20% for (Paltik & Porubsky, 1999).

The first soil loosening was done at 1.5 cm in depth. In order to preserve soil moisture, the second soil loosening was performed at 3.0 cm pre-sowing. The data averaged over the period 2000–2004 indicated that during early sowing soil moisture in the seedbed was 16.3%. With delayed sowing the soil moisture declined. When sown early, the stand density was 3.3% lower compared with trial average (99,900 plants ha^{-1}). These findings suggest that in the case of early sowing the sowing quality was often poor. When the sugar beet sowing was delayed for 1, 2, 3 and 4 weeks and even more, root biomass declined by – 4,7 t ha^{-1}, 9.9 t ha^{-1}, 15.0 t ha^{-1} and 18.7 t ha^{-1} respectively. Sugar beet roots were harvested in the second ten-day period of October. With delayed sowing the content of alpha amino nitrogen in root increased, which indicates that later- sown crops fail to reach complete maturity. A delay in sowing by on average one week resulted in 0.9 t ha^{-1} lower white sugar yield.

CONCLUSIONS

Important environmental variables that determine the beginning of sugar beet growing processes are temperature, precipitation and soil moisture.

Meteorological indicators describing sugar beet early sowing conditions were established. The amount of precipitation in April should not exceed 67 mm, and during the warm period of spring, 164 mm. The sum of base temperatures should reach 109.7°C in the warm period of spring, or 90.35°C during March and April, and 31.1–44.3°C in April. In Lithuania the timing of sugar beet sowing can be associated with a 3-day period, when the mean daily temperature rises higher than the range of base (> 10°C) temperatures. We established strong correlation (r = 0.9*) of sowing time with the amount of precipitation and sum of base temperatures in March and April. Sugar beet root biomass and white sugar potential correlated with the length of the vegetation period (r = 0.55 and 0.62) and with sowing time (r = –064 and –0.70). The correlations were moderately strong.

The data averaged over the period 2000–2004 showed that at early sowing soil moisture content in the seedbed was 16.3%. With a delay in sowing soil moisture declined to 12.0%. When sown early, stand density was by 3.3% lower compared with the trial average (99,900 plants ha-1). One week delay in sowing reduced root yield by 4.7 t ha^{-1} and sugar 0.9 t ha^{-1}, and increased alpha amino nitrogen content in roots by 2.58 mg $100g^{-1}$.

REFERENCES

Abracham, I., Abracham, U., Aridt, R. et. al. 1987. *Intensive technology of sugar beet growing.* Agropromizdat, Maskva, pp. 146–147 (in Russian).

Ash, G.H.B., D.A. Blatta, B.A. Mitchell, B. Davies, C.F. Shaykewich, J.L. Wilson, & Raddatz, R.L. 1999. Agricultural Climate of Manitoba. http://www.gov.mb.ca/agriculture/climate/waa50s00.html [accessed December 2002]

Bellin, D.,Schutz, B. Soerensen, T.R., Salamini, F. & Schneider, K. 2007. Transcript profiles at different growth stages and tap-root zones identity correlated developmental and metabolic pathways of sugar beet. *Journal of experimental botany* **58**(3), 699–715.

Copeland, L.O. & McDonald, M.B. 2001. *Seed Science and technology*. Norwell, Massachusetts: Kluwer Academic Publishers, Boston, pp.72–124 (in English).

Derscheid, L.A. & Lytle, W.F. 2002. Growing degree days (GDD). http://agbiopubs.sdstate.edu/articles/FS522.pdf [accessed December 2002] (in English)

Duur, C., Aubertot, J.N., Richard, G., Dubrulle, O., Duval, Y. & Boiffin, J. 2001. A model for simulation of plant emergence predictive of the effects of soil tillage and sowing operation. *Soil Science Society of America Journal* **65**, 414–423(in English).

Duur, C.& Boiffin, J. 1995 Sugarbeet seedling growth from germination to first leaf stage. *Journal of Agricultural Science* **124**(3), 427–435 (in English).

Feiza, V., Simanskaite, D., Deveikyte, I. & Slepetiene, A. 2005. The possibility of reduction of primary tillage on sandy loam soil. *Zemdirbyste-Agriculture* **92**(4), 66–79 (in Lithuanian, English abstr.).

Fortune, R.A., Burke, J.J., Kennedy, T. & Sullivan, E. 1999. *Effect of early sowing on the growth, yield and quality of sugar beet*. Teagase, 19 Sandymount Avenue, Dublin, 4 p.

Gaurilcikiene, I., Deveikyte, I. & Petraitiene, E. 2006. Epidemic progress of Cersospora beticola Sace. In Beta vulgaris L. under different conditions and cultivar resistance. *Biologija* **4**, 54–59 (in English).

Holen, C.D. & Dexter A.G. A. 1996. Growing degree day equation for early sugarbeet leaf stages. *Research and extension Reports* **27**, 152–157 (in English.)

Jalilian, A., Mazahen, D., Rahimian, H., Afshari, R.T., Abdolahian, M. & Gohari, J. 2005. Estimation of base temperature and the investigation of germination and field emergence trend of monogerm beet under various temperatures. *Journal of Sugar Beet* **20**(2).

Kaunas, J. 1998. *Sugar beet varieties: Achievements and problems of sugar beet growing in Lithuania: presentations of the scientific conference.* UAB Arx-Baltica, Rumokai, pp. 58–61 (in Lithuanian, English abstr.).

Khan A.A. 1992. Preplant physiological seed conditioning. *Horticultural Reviews* **13**, 131–166.

Kolbe, H. & Petzold, W. 2002. *Sugar beet growing ecological agriculture system*. CRC Press, Dresden, pp. 14–19 (in German).

Lazauskas, J. 1998. *Crop production in Lithuania over the period 1895-1995*. Kaunas AB „Aušra“, Dotnuva-Akademija, pp. 227–238 (in Lithuanian, English abstr.).

Lu, M.K. & Saylan, L. 2001. Trends of growing degree-days in Turkey. *Water, air & soil pollution* **126**(1–2), 83–96.

Mavi, H.S. & Tupper, G.J. 2004. *Agrometeorology – principles and applications of climate studies in agriculture.* Haworth Press, Binghamton, pp. 43–70 (in English).

Paltik, J. & Porubsky J. 1999. Soil compaction due to sugar beet sowing units. *Zemdelska Technika* **45**(3), 95–98 (in Slovenian, English abstr.).

Petkeviciene, B. & Kaunas, J. 2004. Influence of natural conditions on the prevalence of Cercospora leaf spot (*Cercospora beticola Sacc.)* and Ramularia leaf spot (*Ramularia beticola Fant & Lamb*.) in different varieties of sugar beet. *Zemes ukio mokslai-Agricultural Sciences* **9**(4), 28–35 (in Lithuanian, English abstr.).

Petkeviciene, B. 2002. Effect of weather conditions on sugar content in sugar beet roots. *Zemdirbyste-Agriculture* **8**(4), 67–74 (in Lithuanian, English abstr.).

Petkeviciene, B. 2008. The effects of sowing time and variety on sugar beet productivity. *Zemdirbyste-Agriculture* **95**(4), 59–70 (in Lithuanian, English abstr.).

Pidgeon, J. D., Werker, A. R., Jaggard, K. W., et. al. 2001. Climatic impact on the productivity of sugar beet in Europe 1961–1995 *Agricultural and Forest Meteorology* **109**(1), 27–37.

Povilaitis, J. & Grigiene, I. 1995. The influence of drilling time and crop density on sugar beet growing, productivity and quality. *Zemdirbyste-Agriculture* **49**, 180–188 (in Lithuanian).

Romaneckas, K., Narkevicius, G. Liakas, V. & Siliauskas, A. 2003. *Technologies of contemporary crop productions* **4,** 67–103 (in Lithuanian).

Romaneckas, K. & Sarauskis, E. 2003. The investigations of sugar beet seedbed by Kriz method (Sweden) under different soil tillage and sowing pattern. *Zemdirbyste-Agriculture* **81**(1), 67–74 (in Lithuanian, English abstr.).

Siddique, A.B., Wright, D., Mahbub, & Ali S.M. 2002. Effects of Time of Sowing on the Quality of Flax Seed. *On Line Journal of Biological Sciences* **8**(2), 538–541 (in English).

Siuliauskiene, D., Liakas, V., Paltanavicius, V. & Siuliauskas, A. 2005. Impact of sowing depth and time on sugar beet germination on soils low in humus *Agronomijas vestis* **8**, 226–231.

Spaar, D., Dreger, D., Zacharenko, A. et al. 2004. *Sugar beet*. CUP „Orech“, Minsk, pp. 133–135 (in Russian).

Sroller, I. & Svachula, V. 1990. Influence of weather on the production and quality of sugar beets. In Baier, J., Bures, R., Coufal, V. I. et.al.: *Weather and production*. Agropromizdat, Maskva, pp. 247–269 (in Russian).

Sugar beet. (Kucera, L. & Genovese G.(eds)). 2004. *Crop monographies in central European countries* **1–4**, 24–156.

Tarakanovas, P. & Raudonius, S. 2003. *Statistical analyses of agronomic research data based on ANOVA, STAT, SPULIT-PLOT software from package SELEKCIJA ir IRRISTAT.* UAB“Arx-Baltica“, Akademija, pp. 57 (in Lithuanian).