Effects of sowing dates on technological qualities of sugar beets grown in middle CIS-Urals

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Abstract: The purpose of the research was to identify patterns of productivity changes and technological qualities of sugar beet depending on the sowing time under the conditions of the Middle CIS-Urals. In 2017-2020, field experiments were conducted in the experimental fields of the Bashkir State Agrarian University. It was sowed the Hercules sugar beet hybrid. As a result of the research, the regularities of changes in the yield and technological qualities of sugar beet root crops at different sowing dates were determined. The first ten-day period of May is revealed to be the optimal time for sugar beet sowing under the conditions of the Middle CIS-Urals. The optimal dates for sowing sugar beets are recommended for beet-growing farms in the Middle CIS-Urals (the sum of precipitation is 450-500 mm per year, the sum of active temperatures above 10 degrees is 2200-2500, the hydrothermal coefficient is 1.1-1.2). Most beet-growing regions of Russia, as well as European countries (Germany, Austria), have similar soil and climatic conditions. The research results can be used in these regions and countries, as the patterns of productivity changes and technological qualities of sugar beet depending on the sowing time were revealed. The optimal parameters of their application in the technology of sugar beet cultivation were determined. They will allow getting a high yield of root crops with good technological qualities (the optimal content of alpha- aminonitrogen is 2.5 mmol/100 g of crude mass, potassium – up to 5 mmol/100 g of crude mass, sodium – up to 3.5 mmol/100 g of crude mass.)

Keywords: yield and sugar content of sugar beet; content of molasses-forming substances; standard sugar losses; gross yield of refined sugar; optimal sowing time

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1 Introduction

Sugar beet is one of the most important industrial crops. In the world, 40% of sugar is obtained from sugar beet roots. In some countries (for example, Germany, France, Belarus, etc.), it is a key sugar production source and is of great economic importance.

Today, the demand for sugar is growing rapidly. Sugar consumption increased from 35 to 38 kg per capita consumption (Mohammadi-Ahmadmahmoudi et al., 2020). In this regard, the issue of increasing sugar production is relevant and important. The sowing time is an important condition for obtaining strong, even sugar beet shoots and the highest yield. Silva et al. (2020) reported that during germination, sugar beet seeds absorb 150%-160% of moisture from their mass, and pelleted seeds - 200% or more (Silva et al., 2020). Also, the sowing time has a serious impact on crop protection from

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diseases, pests and weeds. High-quality and timely sugar beet sowing increases the yield and quality of root crops (Schnepel and Hoffmann, 2016; Hajkova et al., 2020; Rimaz et al., 2020).

Determining the optimal sugar beet sowing time is particularly relevant for the regions of the Middle CIS-Urals (Rother, 1998). This problem is caused by the fact that earlier, due to the boltering, the sugar beet sowing took place at a later date. The market appearance of new hybrids resistant to boltering allows us to review the sugar beet sowing time and determine its optimal term (Zagorulko and Zagorulko, 2020).

The source of further growth in sugar production is the expansion of raw material production and the improvement of its quality. Varga et al. (2017, 2020) claims that improving the quality of raw materials makes it possible to increase the sugar yield and reduce its cost. Lamichhane et al. (2019, 2021) suggest that one way to increase sugar production from its raw materials is the optimal sowing time (Lamichhane et al., 2019, 2021). Buchholz noted in his research that the chemical composition and technological qualities of sugar beet supplied for processing largely depend on the sowing time (Buchholz et al., 1995; Steinmetz et al., 1998). Research by Draycott (2006), Enikiev and Islamgulov et al. (2019) proved that timely and high-quality seed sowing ensures the emergence of full-fledged friendly seedlings, which significantly facilitates the mechanised formation of crop density. Lubova et al. (2018) also obtained similar results.

Draycott (2006), and Shpaar et al. (2006) studied the influence of sowing time on the productivity of sugar beet root crops. These scientists found that sugar beet sowing should be carried out during soil maturity at the earliest possible time (Hoffmann, 2010; Maerlaender et al., 2018). The sowing time was studied by Yuhin (2014), and Šarauskis et al. (2010). They found that the optimal time for sowing sugar beet is 2nd-3d ten-day period of May. The increase in yield ranged from 118 c ha^{-1} to 167 c ha^{-1} compared to early and late dates in different years of research (Yuhin, 2014; Enikiev and Islamgulov, 2019). However, there are no studies in terms of the effect of sowing time on the technological quality of root crops. In this regard, the study of the productivity and technological qualities (main parameter of qualities is a content of K, Na, Alpha-amino nitrogen) of sugar beet root crops, depending on different sowing dates, is an urgent task of the agro-industrial complex of the country and is aimed at improving the quality of raw materials increasing the sugar yield and sugar production (Komissarov et al., 2021).

The purpose of the research was to identify patterns of productivity changes and technological qualities of sugar beet depending on the sowing time under the conditions of the Middle CIS-Urals.

Research objectives are to identify:(1) the yield of sugar beet root crops at different sowing dates; (2) indicators of technological qualities of sugar beet root crops (the content of potassium, sodium, alpha-amino nitrogen, sugar, refined sugar) at different sowing dates; (3) sugar loss in molasses, gross sugar yield, the gross yield of refined sugar in root crops at different sowing dates; and to reveal: (1) features of productivity and technological qualities formation of sugar beet root crops at different sowing dates; (2) the optimal time for sowing sugar beet under the conditions of the Middle CIS-Urals.

2 Material and methods

We were using the hybrid from MariboHillshog called Hercules.

According to genetic characteristics, the Hercules hybrid is a one-germ diploid hybrid of the standard type. It has the potential for high sugar content and productivity. The shape of the roots is oval. The Hercules hybrid is resistant to cercosporosis, powdery mildew, rust, and yellows. The main feature of the hybrid is its resistance to bolstering (Trimpler et al., 2017; Artyszak et al., 2021).

In 2017-2020, field experiments were conducted in the experimental fields of the Bashkir State Agrarian University (Ufa district of the Republic of Bashkortostan).

The research field is represented by low-lying terraced, gently sloping and hillside plains. The soil cover is leached chernozem. The arable layer contains an average of 8%-9% of humus. (pH = 5.4). The soil has good agrophysical, agrochemical and microbiological properties (Figure 1).

Figure 1. Field experiment point (54.79 °N, 55.76 °E)

Source: MariboHillshog company

In the experiment, seven sowing dates were studied: April 30; May 7; May 14; May 21; May 28; June 4; June 11. Sowing took place every seven days. The sown area was 378 m^2. The plot length was 8 m, and the width 2.7 m. The length of the harvested plot was 5 m, the width – 0.9 m. The total plot area was 21.6 m^2, the total registration plot area – 4.5 m^2. The variants repetition was 4-fold. Weather conditions in 2017-2020 were close to the long-time annual average. The average annual precipitation was 495 mm. During the year, precipitation was distributed evenly, and the plants did not suffer from a lack of moisture. The snow cover settled in mid-November and melted in the second decade of April. The average annual air temperature was 2.5 ℃. The sum of favourable temperatures (above 10 ℃) was 2100 ℃-2300 ℃.

Humus was in the range of 8.8%, phosphorus was 112 mg kg^{-1}, nitrogen was 124 mg kg^{-1}, potassium was 177 mg kg^{-1}. The crop density was 95000 plants per 1 ha. Sugar beet was in the beet crop rotation. The forecrop was winter rye.

Sowing was carried out with an EarthWay (Earthway Products, Inc., USA) manual seeding-machine at the final plant stand. Harvesting and weed control were carried out manually. The crops were weeded once every two weeks until the leaves closed in rows. The registration plots were harvested manually on September 14.

Sugar content in sugar beet root crops was determined by the direct method. The essence of the direct method is to obtain the water extract from the pulp of sugar beets and determine the sugar content with a polarimeter (Polytec GmbH).

The Stanek-Pavlas method, modified by Wieninger and Kubadinov (1971), was used to determine alpha-amino nitrogen in sugar beet root crops. The method was used to measure the optical density of the formed complex compound of an α-amino acid with a copper solution. The measurement was performed using a spectrophotometer or photoelectric colourimeter in the wavelength range λ = 530-630 nm. The content of sodium and potassium was estimated by Silin's method (Kukhar et al., 2019). For this, a flame photometer was used (DeBruyn et al., 2017; Khasanov et al., 2019).

Tests for the content of molasses-forming substances were carried out in the laboratory of the scientific and educational centre of the Bashkir State Agrarian University.

The Braunschweig formula is used to calculate the standard sugar loss during molasses formation. The coefficient of 0.12 is multiplied by the sum of the potassium and sodium content. The resulting value is added to the product of alpha-amino nitrogen content with a coefficient of 0.24 and a coefficient of 0.48. The value of standard sugar loss is obtained as a percentage (Kadar and Kiss, 2000; Racca et al., 2015).

The refined sugar content (RSC) is calculated as the difference between sugar content and standard sugar loss in molasses.

The gross sugar yield is calculated as the sugar yield per unit of the area sown. For this, the values of the products of yield and sugar content are divided by 100.

$$GSY = Y \times S / 100, \quad (1)$$

where, *GSY* is the gross sugar yield, t ha^{-1};*Y* is the yield of root crops, t ha^{-1}; and *S* is the sugar content of root crops, %.

The gross yield of refined sugar is expressed in terms of the yield and refined sugar content.

$$GYRS = Y \times RS / 100, \quad (2)$$

where, *GSY* is gross yield of refined sugar, t ha^{-1}; *Y* is the yield of root crops, t ha^{-1}; and *RS* is the refined sugar content of root crops, %.

What statistical procedures or tests were used to determine statistical significance in the results? This needs to be mentioned in the methods.

3 Results and discussion

The study results in Table 1 showed that the yield of sugar beet root crops on average for 2017-2020 naturally decreased from May 7 to June 11. When sowing the Hercules hybrid on May 7, the highest yield was 46.98 ton ha^{-1}, and the lowest yield was shown when sowing on June 11 – 95.4 c ha^{-1}. On average, a one-day delay in sowing resulted in a loss of 10.7 c ha^{-1}.

The yield of the earliest sowing period (April 30) was lower than the yield of sugar beet root crops sown on May 7. This is due to the fact that when sown on April 30, the soil does not have time to warm up enough, so the development of the initial phases of sugar beet growth is slower. At the same time, starting from May 7, there is a pattern: the later the sowing period, the lower the yield. The yield decrease occurred due to a reduction in the sugar beet growing season and, consequently, the intense activity of its assimilation apparatus at late sowing dates (Enikiev and Islamgulov, 2019).

Four-year studies have shown (Table 1) that the sugar content of sugar beet root crops naturally decreased from May 7 to June 11, the later the sowing period, the lower the sugar content of root crops. The highest sugar content of the Hercules hybrid was 18.15% when sown on May 7, and the lowest sugar content was 15.27% when sown on June 11.

Table 1 Technological qualities and yield of sugar beet root crops during the harvesting period on average for 2017-2020

Sowing Dates	Yield, C Ha^{-1}	Content			
		Sugar,%	K, mmol per 100 g	Na, mmol per 100 g	α-amino nitrogen, mmol per 100 g
APRIL 30	438.0	18.01	3.20	0.48	1.05
MAY 7	469.8	18.15	3.16	0.45	1.06
MAY 14	402.4	18.06	3.22	0.51	1.17
MAY 21	339.9	17.69	3.33	0.60	1.34
MAY 28	256.9	16.97	3.47	0.77	1.53
JUNE 4	189.0	16.21	3.63	0.95	1.77
JUNE 11	95.4	15.27	3.92	1.11	2.06
LSD0,05	5.82	0.19	0.032	0.037	0.042

The sugar content of the earliest sowing period (April 30) was lower than the sugar content of sugar beet root crops sown on May 7. This is due to the fact that when sown on April 30, the soil does not have time to warm up enough, so the development of the initial phases of sugar beet growth is slower. At later sowing dates, the sugar content of root crops decreased. This is explained by the fact that as the days become shorter, the "working day" of the photosynthetic apparatus of plants also decreases (Abyaneh et al., 2017). Late sowing leads to significant underutilisation of the PhAR energy (Shpaar, 2006).

The potassium content in sugar beet root crops naturally increased from May 7 to June 11: the later the sowing period, the higher the potassium content in sugar beet root crops (Table 1). The highest potassium was contained when sowing on June 11 at 3.92 mmol per 100 g of wet weight. When sowing on May 7, there was the lowest potassium content – 3.16 mmol per 100 g of wet weight. At the earliest sowing time (April 30), the potassium content was higher than sown on May 7. One of the main indicators of technological qualities is the potassium content. The higher its content, the more sugar passes and is lost in molasses. It is believed that one part of this cation holds about five parts of sugar in molasses. Potassium controls the concentration of ions in plant cells and the transfer of sucrose in the root crop

The sodium content in sugar beet root crops naturally increased from May 7 to June 11: the later the sowing period, the higher the sodium content in sugar beet root crops. When sown on June 11, the sodium content was the highest – 1.11 mmol per 100 g of wet weight. Sowing on May 7 showed the lowest value – 0.45 mmol per 100 g of wet weight. At the earliest sowing time (April 30), the sodium content was higher than sown on May 7. Potassium and sodium have similar effects on the growth, development and productivity of sugar beet. These elements can replace each other. Sodium plays a significant role in regulating water exchange in the plant (Jacobs et al., 2018). Restraining the loss of moisture through the stomata on the surface of the leaves (Petkeviciene, 2009). The content of alpha-amino nitrogen varies depending on the sowing time: the later the sowing period, the higher the content of alpha-amino nitrogen in sugar beet root crops. Alpha-amino nitrogen in the largest amount was detected when sawn on June 11 – 2.06 mmol per 100 g of wet weight. When sowing on April 30, the lowest content of alpha-amino nitrogen was observed – 1.05 mmol per 100 g of wet weight.

In the years of the study, we had obvious trend to increasing of standard sugar losses, it showed values from 1.17% to 1.57% (Figure 2). On June 11, sugar losses amounted to 1.57%. This is the highest value. It is associated with a high content of molasses-forming substances in root crops. On May 7, the loss of sugar in the formation of molasses was 1.17%. This is the smallest value. The later the sowing period, the higher the content of harmful molasses-forming agents in root crops and the higher the sugar loss during the molasses formation.

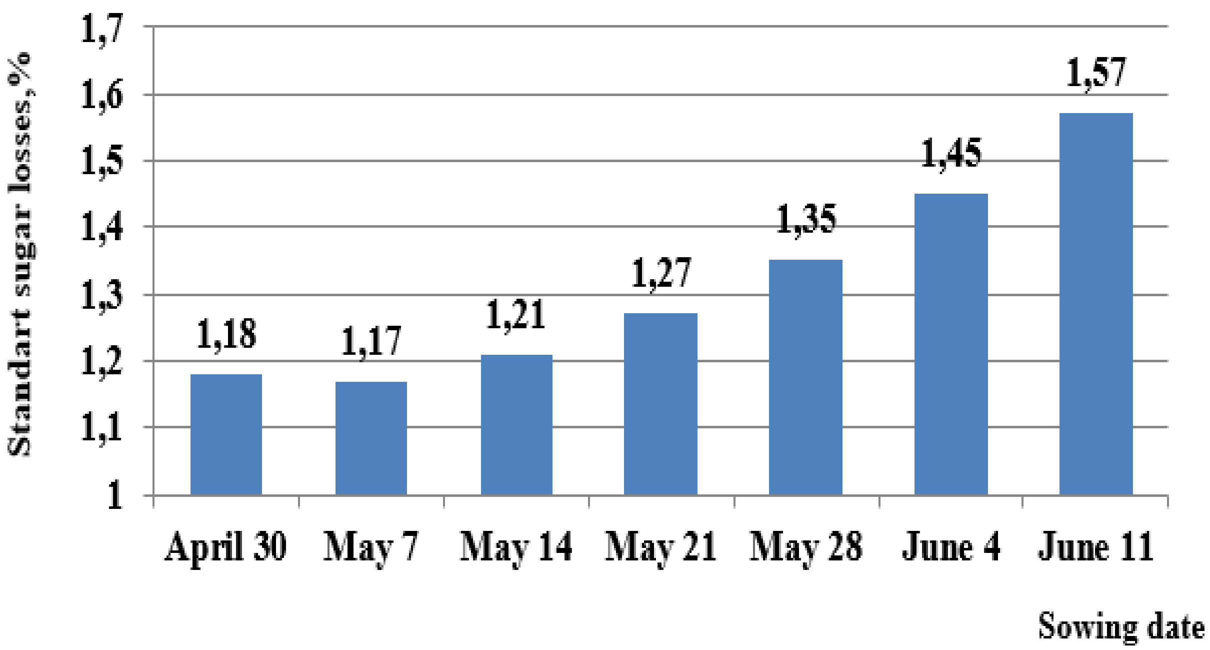

Figure 2 Value of standard sugar losses (SSL) of sugar beet in the formation of molasses on average for 2017-2020, %

The highest refined sugar (Figure 3) was detected when sown on May 7 – 16.91%, and the lowest was on June 11 (13.69%). The content of refined sugar varied depending on the sowing time: the later the sowing date, the higher the content of molasses-forming agents in root crops and the lower the content of refined sugar.

The experiment results revealed that the Hercules hybrid showed the highest sugar yield when sown on May 7 (8.52 t ha^{-1}). The lowest sugar yield was observed when sown on June 11 – 1.47 t ha^{-1} (Figure 3). The gross sugar yield was relatively higher in the early sowing date than in the late sowing time. This is primarily since the gross sugar yield directly depends on the yield and sugar content, which depends on the sowing time. Also, on June

11, there is a sharp decline in the gross sugar yield compared to other dates. This is primarily due to the fact that when sown on June 11, sugar beet root crops lacked moisture, so their yield and sugar content sharply decreased, which directly affected the gross sugar yield (Yuhin, 2014; Lubova et al., 2018).

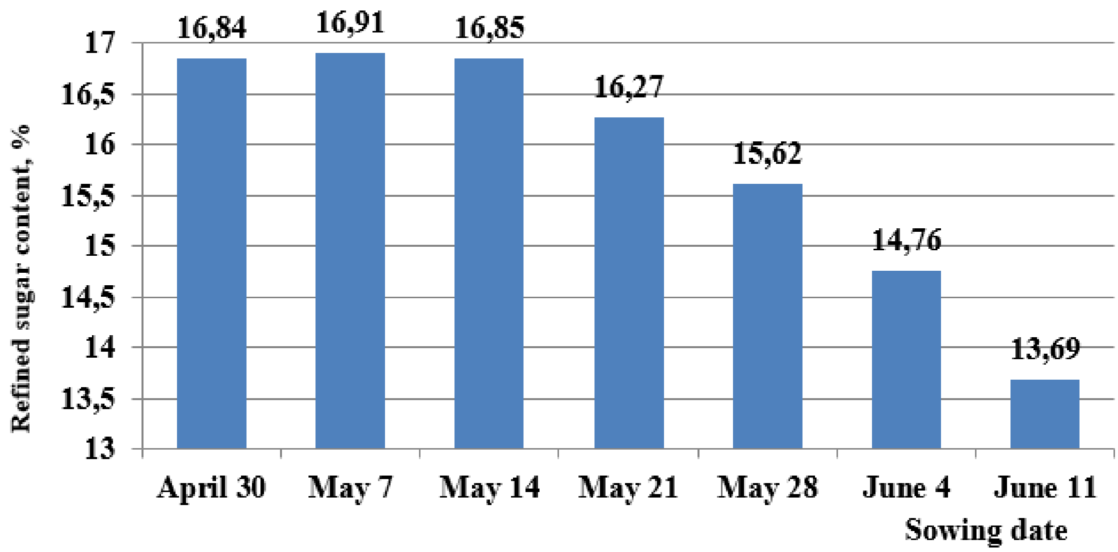

Figure 3 Refined sugar content in root crops (2017-2020)

The results of four-year studies show (Figure 4) that when sown on May 7, the gross yield of refined sugar was 7.97 t ha^{-1}. This is the highest value. It was obtained due to the high content of refined sugar and the high yield. When sown on June 11, the lowest gross yield of refined sugar was formed– 1.32 t ha^{-1}.

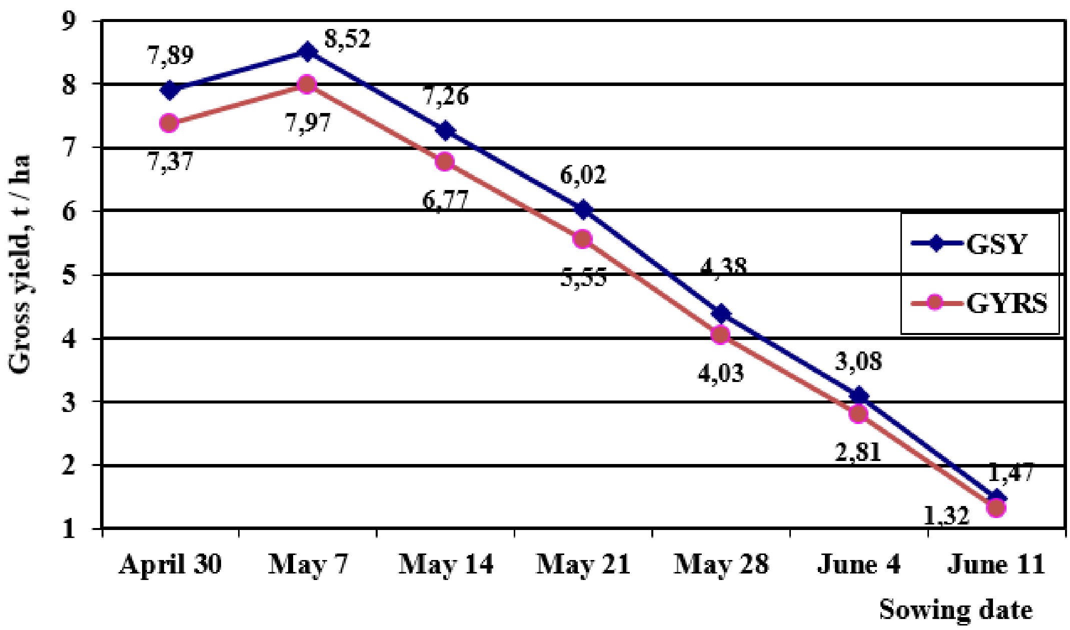

Figure 4 Results for gross sugar yield (GSY) and gross yield of refined sugar (GYRS) (2017-2020)

The later the sowing date, the lower the gross yield of refined sugar. When sown on April 30, the gross yield of refined sugar was lower than when sown on May 7. This is due to the fact that on April 30, the soil did not have time to warm up enough, and therefore the sugar beet plant lagged in development. Therefore, sowing at an earlier time contributes to the highest yield of refined sugar from 1 ha.

The following dependencies follow from the given data. On average, over four years, the productivity indicators of sugar beet root crops (yield, sugar content and gross sugar yield) naturally decreased from May 7 to June 11: the later the sowing time, the lower the sugar content of root crops. When sown on April 30, productivity indicators were lower than when sown on May 7. This is due to the fact that when sown on April 30, the soil does not have time to warm up enough, so the development of the initial phases of sugar beet growth is slower.

Four-year studies have shown that the technological qualities of sugar beet root crops (the content of potassium, sodium, alpha-amino nitrogen) naturally increased from May 7 to June 11: the later the sowing date, the higher the content of harmful molasses-forming agents in sugar beet root crops and the higher the sugar loss during the molasses formation. The content of refined sugar also changed depending on the sowing time: the later the sowing date, the higher the content of harmful molasses-forming agents in root crops and the lower the content of refined sugar.

When sown on April 30, the indicators of technological qualities of sugar beet root crops were lower than when sown on May 7. This is due to the fact that on April 30, the soil did not have time to warm up enough, and therefore the sugar beet plant lagged in development. The later the sowing date, the lower the gross yield of refined sugar. Therefore, sowing at an earlier time contributes to the highest yield of refined sugar from 1 ha.

4 Conclusions

Judging by the results of yield analysis, the first ten days of May are the best days for sowing sugar beet in the Middle CIS-Urals. The sowing date of May 7 gave the highest yield with good sugar beet quality and is found to be the most ideal sowing date for sugar beet in the region. Farmers may want to sow sugar beet between days 4 and 10 while taking into account the readiness of soil for sowing and temperature conditions. The upward trend in yields was seen with sugar beets sown between April 30 and May 7. If the crops are sown between May 7 and June 11, sugar beet yields tend to decrease, most likely because the growing season gets shorter. At late sowing dates, the activity of the assimilation apparatus is more intense. As days became shorter, the efficiency of the photosynthetic apparatus of plants becomes lower. The delay in sowing led to significant underutilisation of PhAR energy. Consequently, there was a decrease in the sugar content.

The scientific significance of this study lies in the fact that it contributes the sowing principles and information on the optimal days for sugar beet cultivation in the Middle CIS-Urals. This information will allow farmers to reduce technological risks and improve the quality of domestic agricultural products. The productivity and technological qualities of sugar beet were found to change depending on the sowing date. This finding allows beet growers to apply the present results in other regions to maximize yields with good technological qualities.

References

Abyaneh, H. Z., M. Jovzi, and M. Albaji. 2017. Effect of regulated deficit irrigation, partial root drying and N-fertilizer levels on sugar beet crop (*Beta vulgaris* L.). *Agricultural Water Management*, 194: 13-23.

Artyszak, A., D. Gozdowski, and A. Siuda. 2021. Effect of the application date of fertilizer containing silicon and potassium on the yield and technological quality of sugar beet roots. *Plants*, 10(2): 370.

Buchholz, K., B. Märländer, H. Puke, H. Glattkowski, and K. Thielecke. 1995. Revaluation of the technical value of sugar beets. *Zuckerindustrie*, 120(2): 113-121.

DeBruyn, A. H., I. P. O'Halloran, J. D. Lauzon, and L. L. Van Eerd. 2017. Effect of sugarbeet density and harvest date on most profitable nitrogen rate. *Agronomy Journal*, 109(5): 2343-2357.

Draycott, P. A. 2006. *Sugar Beet*. Hoboken: Blackwell Publishing Ltd.

Enikiev, R. I., and D. R. Islamgulov. 2019. Influence of sowing dates on productivity and technological qualities of sugar beet root crops in the middle Urals. *Sugar Beet*, 10: 25-28.

Hajkova, L., V. Koznarova, M. Mozny, and Z. Zalud. 2020. Influence of climate change on terms of sugar beet sowing, emergence and harvest. *Listy Cukrovarnicke a Reparske*, 136(7-8): 256-261.

Hoffmann, C. M. 2010. Root quality of sugarbeet. *Sugar Tech*, 12(3): 276-287.

Jacobs, A., H. J. Koch, and B. Märländer. 2018. Preceding crops influence agronomic efficiency in sugar beet cultivation. *Agronomy for Sustainable Development*, 38(1): 5.

Kadar, I., and E. Kiss. 2000. Mineral fertilisation of sugarbeet (*Beta vulgaris* L.) on calcareous loamy chernozem soil. *Növénytermelés*, 49(6): 677-690.

Khasanov, E., I. Gabitov, S. Mudarisov, R. Khamaletdinov, Z. Rakhimov, I. Akhmetyanov, I. Farkhutdinov, I. Masalimov, and R. Musin. 2019. Justification of parameters of seed treater with an eccentrically fixed drum influencing the motion character and seed treatment modes. *Bulgarian Journal of Agricultural Science*, 25(Suppl. 2): 119-128.

Komissarov, A. V., O. A. Lobovikova, I. V. Shul'gina, V. S. Kostyuchenko, E. G. Abramova, O. A. Volokh, N. V. Sinitsyna, V. A. Demchenko, A. S. Fes'kova, and A. K. Nikiforov. 2021. Labeling of immunobiological drugs, produced by the Russian research an-ti-plague institution "microbe" of the Rospotrebnadzor (review). *Drug Development & Registration*, 10(3): 115-130.

Kukhar, V.N., A.P. Chernyavsky, L.I. Chernyavskaya, and Yu.A. Mokanyuk. 2019. Nitrogenous substances of sugar beet and sugar production products and express methods for their determination. *Sugar*, 40: 42-59.

Lamichhane, J. R., J. Boiffin, H. Boizard, C. Dürr, and G. Richard. 2021. Seedbed structure of major field crops as affected by cropping systems and climate: Results of a 15-year field trial. *Soil & Tillage Research*, 206: 104845.

Lamichhane, J. R., J. Constantin, J. N. Aubertot, and C. Dürr. 2019. Will climate change affect sugar beet establishment of the 21st century? Insights from a simulation study using a crop emergence model. *Field Crops Research*, 238: 64-73.

Lubova, T. N., D. R. Islamgulov, K. R. Ismagilov, R. R. Ismagilov, A. M. Mukhametshin, R. R. Alimgafarov, R. I. Enikiev, A. U. Bakirova, A. A. Kamilanov, and O. Y. Lebedeva. 2018. Economic efficiency of sugar beet production. *Journal of Engineering and Applied Sciences*, 13(S8): 6565-6569.

Maerlaender, B., C. Hoffmann, H. J. Koch, E. Ladewig, M. Niemann, N. Stockfisch, M. Varrelmann, and A. K. Mahlein. 2018. Sustainable intensification-a quarter century of research towards higher efficiency in sugar beet cultivation. *Sugar Industry/Zuckerindustrie*, 143(4): 200-217.

Mohammadi-Ahmadmahmoudi, E., R. Deihimfard, and O. Noori. 2020. Yield gap analysis simulated for sugar beet-growing areas in water-limited environments. *European Journal of Agronomy*, 113: 125988.

Petkeviciene, B. 2009. The effects of climate factors on sugar beet early sowing timing. *Agronomy Research*, 7(spec.1): 436-443.

Racca, P., J. Kakau, B. Kleinhenz, and C. Kuhn. 2015. Impact of climate change on the phenological development of winter wheat, sugar beet and winter oilseed rape in Lower Saxony, Germany. *Journal of Plant Diseases and Protection*, 122(1): 16-27.

Rimaz, H. R., S. Zand-Parsa, M. Taghvaei, and A. A. Kamgar-Haghighi. 2020. Predicting the seedling emergence time of sugar beet (*Beta vulgaris*) using beta models. *Physiology and Molecular Biology of Plants*, 26(12): 2329-2338.

Rother, B. 1998. The technical quality of sugar beet under the influence of various cultivation factors. *Dissertation*, 8: 1-135.

Šarauskis, E., F. Godlinski, A. Sakalauskas, M. Schlegel, N. Kanswohl, K. Romaneckas, A. Jasinskas, and V. Pilipavičius. 2010. Effects of soil tillage and sowing systems on sugar beet production under the climatic conditions of Lithuania. *Landbauforschung Völkenrode*, 60(2): 101-110.

Schnepel, K., and C. M. Hoffmann. 2016. Effect of extending the growing period on yield formation of sugar beet. *Journal of Agronomy and Crop Science*, 202(6): 530-541.

Shpaar, D., D. Draeger, and A. Zakharenko. 2006. *Sugar Beet (Growing, Cleaning, Storage)*. Moscow: DLV Agrodelo.

Silva, J. V., T. R. Tenreiro, L. Spätjens, N. P. Anten, M. K. van Ittersum, and P. Reidsma. 2020. Can big data explain yield variability and water productivity in intensive cropping systems? *Field Crops Research*, 255: 107828.

Steinmetz, K., R. Buczys, and K. Buchholz. 1998. The quality of frost-damaged sugar beet. *Zuckerindustrie*, 123: 933-942.

Trimpler, K., N. Stockfisch, and B. Märländer. 2017. Efficiency in sugar beet cultivation related to field history. *European Journal of Agronomy*, 91: 1-9.

Varga, I., M. Antunović, and D. Iljkić. 2017. Sugar beet root development with different nitrogen fertilization rate. *Listy Cukrovarnické a Reparské*, 133(4): 138.

Varga, I., Z. Lončarić, M. Pospišil, M. Rastija, and M. Antunović. 2020. Changes of nitrate-nitrogen in sugar beet petioles fresh tissue during the season concerning nitrogen fertilisation and plant population. *Listy Cukrovarnické a Reparské*, 136(5-6): 198-204.

Wieninger, L., and N. Kubadinov. 1971. Beziehungen zwichen Rübenanalysen und technischer Bewertung von Zuckerrüben. *Zucker*, 24(19): 599-604.

Yuhin, I. P. 2014. *Development history and main scientific research results on sugar beet in Bashkortostan*. Ufa: Mir Pechati.

Zagorulko, Y. Y., and E. Y. Zagorulko. 2020. Features of hyaluronic acid solutions for intra-articular introduction and recent trends in their development (review). *Drug Development & Registration*, 9(2): 45-54.