Technological adequacy of sugar beet hybrids for the 2019 harvest in Kursk Region

M I Egorova, L N Puzanova and L Yu Smirnova

Kursk Federal Agricultural Research Center, 70b, Karl Marks str., Kursk, 305021, Russian Federation

E-mail: rniisp@gmail.com

Abstract. 13 hybrids of sugar beet of various breeding types of 3 breeding companies that grow using the same technology in the same conditions in the northeast zone of Kursk Region in 2019 have been studied. The technological adequacy of sugar beets as of September 21 was assessed based on the values of the collection recovery sugar and the natural alkalinity of the juice. The highest collection recovery sugar was shown by Borneo, sugar-type hybrid – 9.68 t/ha, Gunnar, normal type hybrid – 9.02 t/ha, the lowest – Gagarin, sugar-type hybrid – 7.04 %. The optimal natural alkalinity was demonstrated by the hybrids of Tibul, Koala, Gunnar and Cayman, excessive natural alkalinity against the background of a high content of α-amine nitrogen was observed in such hybrids as Recordina KWS, Euphoria KWS, Grimm, Borneo. A comprehensive assessment allowed the availability of technologically adequate sugar beet of Gunnar, normal-type hybrid, Tibul and Koala normal sugar-type hybrids. Having an optimal chemical composition that potentially creates effective processing conditions, they provide for the collection recovery sugar at 9.02, 7.68, 7.09 t/ha with an average of 5.7 t/ha achieved in Russia.

1. Introduction
Sugar beet is one of the dominant crops of Kursk Region. In 2019, the cultivated area of sugar beet in the region amounted to 98,500 hectares, gross harvest – more than 5,000,000 tons with an average harvest of 50.7 t/ha. More than 650,000 tons of sugar was produced from sugar beet in the 2019 harvest. Such results were provided by the use of sugar beet hybrids with high technological qualities. Indeed, modern breeders strive to systematically approach the formation of breeding traits of new hybrids, including the task of improving the chemical composition of sugar beet considering of sucrose and non-sugars such as potassium, sodium, α-amine nitrogen [1]. The content of potassium, sodium and α-amine nitrogen determines the degree of sucrose extraction during sugar production; therefore, it is always taken into account when approving a sort and, in some countries, for sugar beet payment [2].

Researchers from different countries studied the content of alkaline elements and α-amine nitrogen in sugar beet depending on various factors of crop cultivation: type of hybrid, plant density, nutrition background, harvesting time and other factors. Their results contain interesting data and patterns, but they cannot be used for specific decisions of sugar beet manufacturers to choose a hybrid. For testing varietal samples, determining the economic utility of hybrids, the methods are used [3, 4]. In reality, the sugar beet manufacturers are strive to use the most productive hybrids. For sugar producers, the
technological adequacy of sugar beets is important, providing such properties of root-crops which allow them to be processed with maximum efficiency [5].

In 2018, in Kursk Region, 83 sugar beet hybrids were used in industrial crops, of which 10 hybrids accounted for 50% of the sown area. Such a disproportion with a large assortment makes it difficult to make the optimal choice, which is necessary to maintain the profitability of sugar beet production. Therefore, the assessment of hybrids from the standpoint of the predicted sugar yield and the coefficient of sugar extraction from beets [6, 7], technological adequacy as a whole is relevant.

2. Materials and methods
A production experiment was carried out with the use of beet that harvested in 2019 in one of the farms of the north-eastern zone of Kursk Region. Sugar beets were cultivated on a 342-hectare field for the third year of crop rotation after winter wheat according to the standard technology recommended for the Central Black Earth Region. The soil of the site is represented by typical, heavy loamy chernozem with pH_{KCl} 4.9, humus content of 5.7%, total nitrogen – 118 mg/kg of soil, mobile phosphorus – 141 mg/kg of soil, exchange potassium – 115 mg/kg of soil.

In the summer after harvesting the predecessor crop stubble disking was carried out, basic fertilizers P_{90} K_{150} were applied in two stages, followed by deep plowing. The final stage of autumn tillage was harrowing and continuous cultivation to a depth of 10-12 cm. In the spring, the harrowing of the soil was carried out in order to close and retain moisture in it, the introduction of nitrogen fertilizers N_{120}, pre-sowing cultivation.

Sowing was carried out in technologically ripe well-warmed soil (+10 °C) on April 21-24 with the seeds of sugar beet hybrid Veda (STRUBE RUS), a sugar-type, early ripe type. At the same time, on plantation plots with six rows and 0.085 ha each by different breeding companies the following hybrids were successively sown: KWS – Euphoria KWS, universal normal-yielding type; Constance KWS, universal normal-type; Recordina KWS, mid-late ripening normal-yielding-type; Bravissima KWS, early-mid ripening sugar-type; STRUBLE – Veda, early sugar-type; Gagarin, early sugar-type; Grimm, mid-early normal-sugar type; Gunnar, mid-ripening normal-type; Malkin, mid-early sugar-type; Tibul, mid-late normal-sugar type; Sesvanderhave – Koala, mid-late normal-sugar type; Borneo, mid-ripening sugar-type; Cayman, mid-ripening sugar-type.

A month later, the plant stand density per 1 hectares ranged from 103,000 (Malkin hybrid) up to 130,000 plants (Gagarin hybrid) up to 130,000 plants (Gagarin hybrid), including up to 110,000 plants observed in two hybrids (Malkin, Tibul); from 111,000 to 120,000 plants in two hybrids (Constance, Bravissima); from 121,000 to 125,000 plants in four hybrids (Recordina, Euphoria, Gunnar, Borneo); four hybrids had a standing density of 126,000 to 130,000 plants (Veda, Grimm, Koala, Gagarin).

Meteorological conditions in 2019 were favorable for sugar beet growth and development. The average daily temperature of the sugar beet vegetation period (April-September) was 15.8 °C, i.e. was 1.3 °C higher than the long-term average; the amount of precipitation was 246.3 mm with an average long-term of 323 mm.

During the vegetation period, a complex of herbicides, insecticides and pesticides with a liquid flow rate of 200 l/ha was used (Biceps-Garant 1.5 l/ha; Triceps 0.01 kg/ha; Biceps 22 1.5 l/ha; Lontrel 300 0.4 l/ha; Centurion 0.4 l/ha; Break 0.1 l/ha; BIS-300 0.3 l/ha; Break 0.1 l/ha; Borey Neo 0.12 l/ha; Pilot 1.75 l/ha). The humic preparation Rostock 0.2 l/ha, microfertilizer Microvit-7 Boron 1.0 l/ha (in the phase of 4-6 true leaves, then after 20 days and in the closing phase of the leaves in the aisle) were added. Top-dressing with nitrogen fertilizers (ammonium nitrate 100 kg/ha) was carried out in the closing phase of the leaves in a row. After the detection of single plants affected by root rot, in the first ten days of August crop was treated with the Colosal Pro fungicide 0.5 l/ha.

The sugar beet was harvested on September 21 by the Ropa Tiger beet harvester. Productivity was determined by the weight of root crops of each collected hybrid.

The sugar content of root crops was determined by the methods ICUMSA GS6-1. α-amine nitrogen was determined by the methods ICUMSA GS6-5 [8]. The content of sodium and potassium was determined by potentiometric ion-selective electrodes according to the methods described in [9].
which was adjusted according to the results of authors’ own studies. So, according to ICUMSA GS6-1, to 26 g of sugar beet gruel should be added so much water that the total volume of water and juice in the sample amount 200 cm$^3$. This volume varies depending on the content of pulp in beets and ranges from 177 cm$^3$ to 179.3 cm$^3$, being the subject of national agreements, in Russia and the CIS countries it is accepted to add 178.2 cm$^3$ of water to 26g of sugar beet gruel, according to the methods GOST R 53036-2008. The authors [9] recommend that for this sample the volume of water in the form of two portions was 178.2 cm$^3$, in addition, in the calculation formula indicate that to obtain 1 dm$^3$, the weight of the sugar beet gruel was 65 g, which is a mistake. The indicated aspects of sample preparation and calculation of the results were used to determine the content of sodium and potassium in sugar beets.

The collecting sugar per hectare was calculated as a product of sugar beet yield and sugar content. The projected sugar yield was determined as purified sugar content according to the Braunschweig formula [11] and the recovery of sugar from beet indicator as extractable sugar. The calculated natural alkalinity, % CaO, was determined by the formula:

$$H_{af} = \frac{0.014 \times \alpha-N \times [(K+Na) - \alpha-N+0.37]}{(K+Na)},$$

(1)

where, $\alpha-N$ is the content of $\alpha$-amino-nitrogen, mmol/kg; $K$ is the content of potassium, mmol/kg; $Na$ is the content of sodium, mmol/kg.

The technological adequacy of hybrids was assessed by the amount of collection of refined sugar while observing the optimal value of natural alkalinity.

3. Discussion of the results
In general, the hybrids showed different results, which manifested themselves as follows. The chemical composition of sugar beets studied hybrids, shown in table 1, varied.

| Hybrids       | Sucrose content, % | Content of sodium, mmol/kg | Content of potassium, mmol/kg | Content of $\alpha$-amino-nitrogen, mmol/kg |
|---------------|--------------------|----------------------------|-------------------------------|--------------------------------------------|
| Veda          | 21.10              | 10.85                      | 35.32                         | 5.77                                       |
| Euphoria KWS  | 21.03              | 21.18                      | 37.03                         | 11.76                                      |
| Constance KWS | 20.98              | 13.67                      | 37.03                         | 7.69                                       |
| Recordina KWS | 20.09              | 16.81                      | 57.33                         | 12.20                                      |
| Bravissima    | 21.02              | 12.45                      | 41.54                         | 6.48                                       |
| Gagarin       | 19.87              | 8.82                       | 27.44                         | 5.44                                       |
| Grimm         | 20.61              | 9.67                       | 38.76                         | 8.52                                       |
| Gunmar        | 19.94              | 9.91                       | 44.51                         | 3.52                                       |
| Malkin        | 20.45              | 9.67                       | 44.51                         | 6.15                                       |
| Tibul         | 20.07              | 9.24                       | 20.34                         | 2.20                                       |
| Koala         | 20.23              | 11.11                      | 24.47                         | 3.74                                       |
| Borneo        | 21.69              | 10.62                      | 31.51                         | 10.00                                      |
| Cayman        | 19.85              | 13.05                      | 33.76                         | 4.12                                       |

Sugar content ranged from 19.85 % to 21.69 %: in general, it was higher than 20.00 % for the sugary hybrids (with the exception of the Gagarin hybrid – 19.87 %), lower for the normal-type hybrids (with the exception of the Constance KWC hybrid – 20.98 %), intermediate types of the hybrids showed average results.

From the point of view of technological adequacy, for sugar beet along with sugar content, the level and ratio of non-sugars – sodium, potassium, $\alpha$-amine nitrogen are important, which determine the amount of sucrose loss in molasses and the degree of sucrose extraction from raw materials. The sodium content in root crops differed 2.4 times and varied from 8.82 mmol/kg to 21.18 mmol/kg, the
highest indicator was in hybrids of normal-yielding type. At the same time, in STRUBE hybrids, regardless of type, the accumulation of sodium did not exceed 10 mmol/kg. The potassium content was 2.8 times different and ranged from 20.34 mmol/kg to 57.33 mmol/kg. No dependence on the type of hybrid or affiliation with a particular breeding company was observed. The ratio of potassium and sodium in hybrids ranged from 4.6:1 to 1.7:1 with the considered optimal 3:1. The closest approximation to the optimal ratio was observed for the Borneo (3:1) and Gagarin (3.1:1) sugar-type hybrids. Extreme values differed in the Malkin sugar-type hybrid (4.6:1) and the Euphoria KWC (1.8:1) normal-yielding type hybrid. The content of α-amine nitrogen in root crops differed 5.5 times, varying from 2.20 mmol/kg to 12.20 mmol/kg. No dependence of the content on the type of hybrid was observed, although the STRUBE and Sesvanderhave hybrids showed consistently lower values (with the exception of the Borneo hybrid, 10.00 mmol/kg).

On the whole, the minimum contents of sodium, potassium, and α-amine nitrogen were shown by the normal-sugar type hybrids of Tibul and Koala and the sugar-type of Gagarin, in which the contribution of molasses non-sugars to the loss in molasses is the smallest (from 0.84 % to 1.05 %). The maximum content of molasses-forming non-sugars was observed in the Recordina KWS, Euphoria KWS normal-yielding type hybrids with a maximum contribution of 1.66 % and 1.45 % to the sucrrose loss in molasses.

The yield and projected productivity indicators of sugar beet are presented in table 2.

### Table 2. Indicators of productivity and technological adequacy of sugar beet

| Hybrids      | Root yield, t/ha | Collecting sugar, t/ha | Estimated sugar yield, % | Recovery of sugar from beet indicator | Collecting recovery sugar, t/ha | Estimated natural alkalinity, % CaO |
|--------------|------------------|------------------------|--------------------------|--------------------------------------|-------------------------------|-----------------------------------|
| Veda         | 42.3             | 8.93                   | 19.03                    | 0.90                                 | 8.05                          | 0.08                              |
| Euphoria KWS | 47.8             | 10.05                  | 18.67                    | 0.89                                 | 8.92                          | 0.16                              |
| Constance KWS| 47.1             | 9.88                   | 18.81                    | 0.90                                 | 8.86                          | 0.11                              |
| Recordina KWS| 50.4             | 10.13                  | 17.43                    | 0.87                                 | 8.78                          | 0.17                              |
| Bravissima   | 45.9             | 9.65                   | 18.84                    | 0.90                                 | 8.65                          | 0.09                              |
| Gagarin      | 39.3             | 7.81                   | 17.92                    | 0.90                                 | 7.04                          | 0.08                              |
| Grimm        | 38.8             | 8.00                   | 18.44                    | 0.89                                 | 7.15                          | 0.12                              |
| Gunnar       | 50.6             | 10.09                  | 17.82                    | 0.89                                 | 9.02                          | 0.05                              |
| Malkin       | 47.6             | 9.73                   | 18.27                    | 0.89                                 | 8.70                          | 0.09                              |
| Tibul        | 41.9             | 8.41                   | 18.34                    | 0.91                                 | 7.68                          | 0.03                              |
| Koala        | 38.6             | 7.81                   | 18.36                    | 0.91                                 | 7.09                          | 0.05                              |
| Borneo       | 49.5             | 10.74                  | 19.56                    | 0.90                                 | 9.68                          | 0.12                              |
| Cayman       | 41.4             | 8.22                   | 17.81                    | 0.90                                 | 7.37                          | 0.06                              |

As of September 21, 2019, hybrids showed different yields from 38.6 t/ha (Grimm, sugar-type hybrid) to 50.6 t/ha (Gunnar, normal-type hybrid), including 7 hybrids that showed yields of more than 45 t/ha. The average yield decreased in a row by the type of hybrids: normal-yielding, normal, sugary, normal-sugary. Due to differences in sugar content, the highest predicted sugar yield was demonstrated by sugar-type hybrids: Borneo – 19.56%, Veda – 19.03%. The lowest predicted sugar yield was observed for hybrids: Recordina KWS (17.43 %), normal-yielding type; Cayman (17.81 %) and Gunnar (17.82 %), normal type. Due to the different sugar content and different composition of non-sugars, the highest collection of refined sugar was observed for the Borneo sugar type hybrid – 9.68 t/ha, for the rest – from 7.04 t/ha (Gagarin sugar-type hybrid) to 9.02 t/ha (Gunnar normal type hybrid), but no regularity by type of hybrid has not traced.

Considered non-sugar also determines the value of the natural alkalinity of the first saturation juice, which should ensure the precipitation of calcium salts during juice purification, stabilization of the pH of the solutions in the process stream. In technological beet, the natural alkalinity is 0.02...0.04 % CaO. For the evaluated hybrids, the value of the estimated natural alkalinity calculated according to
equation (1) varied from 0.03 % CaO to 0.17 % CaO, varying 5.7 times. The natural alkalinity close to the optimal value was demonstrated by the Tibul and Koala normal-sugar type hybrids, the Gunnar and Cayman normal-type hybrids, while too high natural alkalinity against the background of a high content of α-amine nitrogen was observed in the Recordina KWS and Euphoria KWS normal-productive type hybrids, the Grimm normal-sugar type hybrid, the Borneo sugar-type hybrid. Such a chemical composition of sugar beet during processing will determine the drop in the pH of the semi-finished products, contribute to the occurrence of a sugar amine reaction and a melanoidin formation reaction, leading to an increase in the color of the semi-finished products and sugar.

In assessing the technological adequacy of sugar beet of the hybrids under consideration, we consider it necessary to exclude those hybrids in which the natural alkalinity exceeded 0.05 % CaO, since such a value is undesirable in the processing of raw materials. Then such hybrids as Gunnar (normal-type), Tibul and Koala (normal-sugar type) should be classified as technologically adequate sugar beets.

The results obtained are most likely due to the genetic characteristics of hybrids, which, with other conditions remaining the same, are reflected in the amount of nutrients consumed from the soil, during the synthesis of plastic substances of plants, and the accumulation of the minerals.

As a result, two hybrids – Recordina KWS of the normal-yielding type and Gunnar of the normal-type showed the highest and very close results in terms of yield and sugar content, sugar collection per hectare. However, the quantitative composition of the non-sugars formed in them turned out to be different. It was it that influenced the fact that the predicted sugar yield was 0.4 % higher, and the natural alkalinity was optimal for the Gunnar hybrid. In the Recordina KWS hybrid, the composition of non-sugars was less preferable for processing. At the same time, having demonstrated one of the lowest collection values of refined sugar, the Tibul and Koala the normal-sugar type hybrids in terms of their chemical composition and non-sugar ratio were more preferable for processing than other hybrids with a high value collection of refined sugar. And the sugar beet hybrid Borneo of the sugar type with the highest collection of refined sugar due to the non-optimal ratio of non-sugars during processing may be accompanied by negative consequences in the form of an increase in the color of semi-finished products and sugar.

At the same time, the indicated results could well have changed in the later calendar terms of harvesting, since weather conditions contributed to the continued formation of technologically adequate raw materials due to the occurrence of synthesis reactions.

4. Conclusion

During the growing season of 2019, in the northeast zone of Kursk Region as of September 21, hybrids of sugar beet Gunnar, Tibul, Koala proved to be technologically adequate. Their optimal chemical composition provides effective processing conditions and allows one to obtain the collection of refined sugar 9.02, 7.68, 7.09 t/ha with an average of 5.7 t/ha achieved in Russia.

Therefore, the right choice of sugar beet hybrids for cultivation, taking into account the technological adequacy of raw materials, makes it possible to maintain the competitiveness and profitability of sugar beet and sugar producers.

References

[1] Melnik A Ya and Korneeva M O 2012 Evaluation of technological quality of sugar beet hybrids 
(Beta vulgaris L.) on the content of α-amine nitrogen Plant Varieties Studying and Protection 2 19–22

[2] Hoffmann Christa M 2010 Root Quality of Sugarbeet Sugar Tech 12 (3-4) 276–287

[3] Apasov I V, Putilina L N, Bartenev I I, Smirnov M A and Podvigina O A 2017 To the question of a technique of production tests of sugar beet hybrids Sugar beet 10 14–18

[4] Putilina L N, Bartenev I I and Smirnov M A 2018 Practical realization of the sugar beet hybrids’ evaluation procedure Sugar beet 3 12–15
[5] Egorova M I, Puzanova L N, Hlyupina S V and Smirnova L Y 2018 Evaluation of technical adequacy of sugar beet for sugar production *Agrarian science* **7-8** 50–54

[6] Putilina L N, Kulneva N G, Selivanova G A and Zemlyanuhina O A 2016 Technological scoring of sugar beets which were infected by the pathogen of the vascular bacteriosis during vegetation period *Proceedings of VSUET* **3** 239–246

[7] Shpaar D 2004 *Sugar beet (Cultivation, harvesting, storage)* (Minsk: Oreh)

[8] Kuhar V N, Chernyavsky A P et al. 2019 Nitrogenous substances of sugar beet and sugar products and express methods for their determination *Sugar* **4** 42–59

[9] Kuhar V N, Chernyavsky A P et al. 2019 Methods of assessing the technological qualities of sugar beet using indicators of potassium, sodium and α-amino nitrogen content defined in beets and products of its processing *Sugar* **1** 18–36

[10] Buchholz K, Märländer B, Puke H, Glatkowski H and Thielecke K 1995 Neubewerbung des technischen Wertes von Zuckerrüben *Zuckerindustrie* **2 (120)** 113–121