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ASSESSMENT OF THE EFFICIENCY OF THE APPLICATION OF FUNGICIDES AND MICROFERTILIZERS IN SUGAR BEET GROWING IN THE FOREST STEPPE OF UKRAINE

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Abstract

The results of research on determining the effectiveness of using microfertilizers and fungicides on hybrid sugar beet crops are given. Research was conducted in 2021-2022 at the experimental field of Bila Tserkva National Agrarian University. In the experiment, sugar beet hybrids were studied: Libero and Margarita KWS; Microfertilizers: control without their use, Florenta beet (1.5 l/ha), Intermag beet (2 l/ha); Fungicides: control (without their application), Alto super 330 EC (0.5 l/ha), Amistar Extra 280 SC (0.6 l/ha), Styer 500 (0.5 l/ha). It was established that the highest yield of root crops and the coefficient of energy efficiency (Cee) in the sugar beet hybrids Libero and Margarita KWS was obtained on the variant with the use of the microfertilizer Intermag beet (2 l/ha) and the fungicide Amistar Extra (0.6 l/ha) – 52.1 i 58.3 т/га та 3.2 і 3.6, respectively. The use of fungicides allows you to increase the sugar content by an average of 0.8–1.2%, microfertilizer Florenta beet (1.5 l/ha) by 0.6%, and microfertilizer Intermag beet (2 l/ha) by 0.8%, compared with control variants. The best indicators of the technological qualities of sugar beet root crops were on the variants of combined application of microfertilizers and fungicides, while the conductometric ash content was the lowest, and calculated sugar content and dry matter content were the highest.

Key words: *sugar beet, microfertilizers, fungicides, yield of root crops, sugar content in root crop*

INTRODUCTION

About 30% of the world's sugar production comes from sugar beet *(Beta vulgaris)*, most of which is produced in industrialized countries. The remaining 70% obtained from sugar cane, which is mainly grown in developing countries with tropical climates [3, 10].

The European Union (EU) is a large producer of beet sugar, producing about 50% of the total amount worldwide [34]. From another point of view, sugar beet is also used for ethanol fuel and biogas production [2, 23, 28].

In Ukraine, sugar production is an export-oriented industry [7]. So, during the period 2000–2021, the area planted under sugar beets decreased by 4.02 times from 855.6 thousand hectares in 2000 to 212.6 thousand hectares in 2021.

It should be noted that the gross harvest of root crops decreased by only 1.34 times from 13198.8 thousand tons in 2000 to 9834.6 thousand tons in 2021 [18]. Due to the increase in the yield of sugar beets in recent years, the decrease in the gross harvest of this crop is less noticeable. This became possible due to the improvement of cultivation technology, the selection of higher quality and productive hybrids, adapted to cultivation in conditions of insufficient moisture and resistant to diseases [38].

The efficiency of sugar production largely depends on the integration processes taking place in this field. Due to the compactness of the raw material zones near the sugar mills, a positive effect on the efficiency of sugar production is noted, because the transport costs for the delivery of raw materials are reduced, as well as the loss of root crops and their sugar content. [17].

The advantages of sugar beets are a lower cycle of crop production, higher yield, high tolerance of a wide range of climatic variations, and low water and fertilizer requirements. Compared to sugar cane, sugar beets require 35-40% less water and fertilizer [6]. Since the investments in the sugar industry are long-term and financially demanding, there is a clear need for the use of modern decision support tools and models in order to ensure good decision support before the investment is made [32].

Climate change affects crop production, in particular the cultivation of sugar beets, especially in the southern and eastern parts of Europe. Plant growth, development, and yield are the result of genetic characteristics of hybrids, environmental influences, and the interaction of these factors. The interaction of the genotype with the environment leads to the fact that sugar beet hybrids have different ranks in different environmental conditions [13].

Modern and energy–intensive technologies are being applied in order to increase the yield [24] leading to the 300-400% increase in the energy demand [39]. Therefore, the relationship between energy and agriculture becomes even more important [9].

Effective energy use is one of the requirements for sustainable agricultural production, because it saves money, conserves fossil fuel, and reduces air pollution [15, 25]. Energy consumption in agriculture is increasing as a response to the increasing population, limited supply of arable land and a need for the higher living standards [29].

Agriculture and energy are fundamental components of the economic development of mankind because they support economic activity and improve the quality of life of people [3]. In modern agricultural production, there are still not enough measures to optimize energy consumption, which leads to high energy consumption [1]. One of the ways to optimize energy consumption is to determine the effectiveness of the technologies used to grow certain crops [31] .

It is important to increase the productivity of sugar beets to reduce the impact of harmful organisms, which affects the reduction of product losses. Therefore, the control of diseases of the leaf apparatus of sugar beets is an important aspect in the technology of growing and increasing the yield potential of this crop [19].

According to S. Kostyuchko [22] the highest yield of sugar beets was obtained with the application of fungicides Falcon (0.8 l/ha) + Abacus (1.5 l/ha) + Rex Duo (0.6 l/ha) – 72.1 t/ha. The yield increase from the application of Falcon fungicide (0.8 l/ha) – 6.4 t/ha, Falcon fungicides (0.8 l/ha) + Abacus (1.5 l/ha) – 14.1 t/ha and from fungicides Falcon (0.8 l/ha) + Abacus (1.5 l/ha) + Rex Duo (0.6 l/ha) – 23.4 t/ha, compared to control. With the use of fungicides, an increase in the sugar content of sugar beet roots by 1.7–2.1% was noted.

But according to the results obtained in Denmark, no significant effect of the use of fungicides before the appearance of visible disease symptoms on sugar collection was noted. The increase in the yield of root crops was significant only in one of 16 cases of fungicide application [16].

An effective method of applying microfertilizers to agricultural crops was to apply them in foliar feeding on vegetative plants. During foliar fertilization, nutrients are delivered directly to the leaf blade, which increases the intensity of the photosynthesis process, activates the action of enzymes, enhances the synthesis of sucrose, and promotes the outflow of mono- and disaccharides to the root crop. Activation of biochemical and physiological processes in plants promotes more intensive use of nutrients from the soil and ensures the achievement of maximum plant productivity. This allows you to reduce the doses of fertilizers without reducing the productivity of the crop [20]. Foliar nutrition with chelated compounds of microelements enhances metabolism, respiration, absorptive and excretory functions of the root system [40].

The use of microfertilizer "Reacom-r-beet" prolonged the life cycle of sugar beet leaves, increased the content of dry matter in leaves and root crops, increased the accumulation of sugars, increased yield and improved the technological quality of root crops [41].

According to M. Kharchenko [21] the use of Combibor microfertilizer in the phase of 6-8 true leaves of sugar beets contributed to an increase in the yield of root crops by 5.4 t/ha, sugar content by 0.7%, which made it possible to obtain an additional 1.1 t/ha of sugar, compared to the control.

Using a mixture of microfertilizers Ca+micro + Boron+Molybdenum + Micro Beetroot and the fungicide Falcon yielded 66.7 t/ha of root crops. A similar scheme of microfertilizers with the use of Alto super fungicide provided a yield of 68.0 t/ha. The use of Alto super fungicide contributed to an increase in sugar yield by 12.1-14.8 t/ha [4].

According to the data received by O. P. Strilec' [35] the use of microfertilizers and fungicides in one technological operation in foliar fertilization increased the yield of root crops by 2.6–3.9 t/ha, their sugar content by 0.5–0.7%, and sugar collection by 0.7–1.0 t/ha ha, compared to the control. The combination of microfertilizer "Reacom-r-beet" in a dose of 5 l/ha and fungicide Impact 0.25 l/ha was determined to be the most effective - the yield of root crops was 47.5 t/ha. At the same time, the content of "harmful" nitrogen in root crops decreased, compared to the control without fungicides, by 0.70–0.85 mg-eq./100 g of raw mass, and the quality of normally purified juice increased by 0.2–1.0% , sugar losses in molasses decreased by 0.26–0.35%, and sugar output at the plant increased by 0.76–1.05%.

One of the possibilities of increasing the economic and energy efficiency of sugar beet production is the use of effective measures in the cultivation technology. One of these measures is the application of fungicides and macro- and microelements in the necessary periods of growth and development of sugar beet plants [5].

The purpose of the research was to determine the effectiveness of using microfertilizers and fungicides on hybrid sugar beet.

MATERIALS AND METHODS

Research was conducted in 2021-2022 at the experimental field of Bila Tserkva National Agrarian University. The experiment was conducted according to the following scheme: Factor A. Sugar beet hybrids. 1. Libero; 2. Margarita KWS. Factor B. Microfertilizers. 1. Control without microfertilizers; 2. Florenta beet (1.5 l/ha); 3. Intermag beet (2 l/ha). Factor C. Fungicides. 1. Control (without the use of fungicides); 2. Alto super 330 EC, concentrate emulsion (0.5 l/ha); 3. Amistar Extra 280 SC, concentrate suspension (0.6 l/ha); 4. Styer 500, concentrate emulsion (0.5 l/ha).

The area of sown plots was 156 m^2, accounting area – 124 m^2. Repetition – three times, placement of repetitions and plots was consistent, systematic. The technology of growing sugar beets is generally accepted for the forest-steppe of Ukraine, except for the techniques that were studied. Fungicides were applied at the beginning of the appearance of diseases on plants in the phase of 3-4 pairs of leaves in sugar beets, subsequent treatments were carried out after 14-16 days. Spraying with microfertilizers was carried out before closing the leaves of sugar beets in the interrows together with the last fungicide application. Consumption of the working solution during the application of fungicides and microfertilizers was 230 l/ha.

Mineral fertilizers $N_{90}P_{90}K_{90}$ (nitroamofoska) were applied during the main tillage (autumn), and nitrogen fertilizers N_{30} (ammonium nitrate) were applied before sowing sugar beet. Harvesting of sugar beets was carried out with a combine harvester from the entire area of the accounting plot with subsequent calculation per 1 ha. Mathematical processing of the received research results using the dispersion method using Statistica 12.

Technological indicators of the quality of sugar beet root crops (dry matter, conductometric ash) and sugar content were

carried out in the laboratory of the Salivonkiv Sugar Factory of the Kyiv Region (Ukraine).
Determination of the energy efficiency of sugar beet cultivation was carried out according to Yu. Tarariko et al. [36]. We took into account the energy value of sugar beet root crops, energy consumption for their cultivation. Coefficient energy efficiency (Cee) is calculated as the ratio of the energy content in the obtained yield of sugar beets to the energy expenditure for its production.

RESULTS AND DISCUSSIONS

On average, over two years, the hybrid Margarita KWS had a 6.0 t/ha higher yield root crop compared to the hybrid Libero (Table 1).

The use of fungicides significantly affected the yield of root crops of sugar beet hybrids. On average, in two years, the hybrids Libero and Margarita KWS, when using Alto super 330 EC increased the yield of root crops by 5.8–6.9 and 6.6–7.5 t/ha, compared to the control. When using the fungicide Amistar Extra this increased in the range of 7.2-8.3 and 7.7-9.1 t/ha and the fungicide Styer – 6.7-7.9 and 7.2-8.4 t /ha.
The increase in the yield of root crops with the use of microfertilizers was less than with the options with the use of fungicides. Thus, the used of microfertilizers Florenta beet and Intermag beet provided an increase in yield by 2.1 and 4.3 t/ha and 3.4 and 5.5 t/ha, respectively, in the hybrids Libero and Margarita KWS.

Table 1. Yield of root crops of hybrids sugar beet, t/ha

Hybrid (A)	Microfertilizers(B)	Fungicides (C)	2021	2022	Average
Libero	Control (without microfertilizer)	Control	43.3	36.6	40.0
		Alto super	50.5	43.1	46.8
		Amistar Extra	51.5	43.7	47.6
		Styer	51.1	43.1	47.1
	Florenta beet	Control	46.7	38.1	42.4
		Alto super	53.8	42.8	48.3
		Amistar Extra	55.1	44.3	49.7
		Styer	54.7	43.8	49.3
	Intermag beet	Control	48.5	39.4	44.0
		Alto super	56.4	45.0	50.7
		Amistar Extra	57.7	46.5	52.1
		Styer	57.5	46.0	51.8
Margarita KWS	Control (without microfertilizer)	Control	47.8	41.5	44.7
		Alto super	55.8	46.9	51.4
		Amistar Extra	57.2	47.8	52.5
		Styer	56.4	47.2	51.8
	Florenta beet	Control	51.4	43.9	47.7
		Alto super	60.3	49.2	54.8
		Amistar Extra	61.4	50.5	56.0
		Styer	60.7	50.3	55.5
	Intermag beet	Control	53.6	45.1	49.4
		Alto super	62.3	51.1	56.7
		Amistar Extra	63.9	52.7	58.3
		Styer	63.4	52.1	57.8
SD_{05}, t/ha		A	3,5	3.0	
		B	1.4	1.1	
		C	0.6	0.8	
		ABC	5.1	4.7	

Source: Authors own results.

The highest productivity of sugar beets was obtained with the combined combination of the fungicide Amistar Extra 280 SC and microfertilizer Intermag beet – 52.1 and 58.3 t/ha, respectively in hybrids Libero and Margarita KWS.
It should be noted the unreliable difference between the third and fourth options for the

use of fungicides, which in the years of research was in the range of 0.2–0.5 t/ha (SD_{05} = 0.6 in 2021, SD_{05} = 0.8 in 2022).

On average, during the years of research, the sugar content of the roots of the sugar beet hybrids Libero and Margarita KWS was 17.4 and 17.6 % (Fig. 1). That is, there was no significant difference between the hybrids. The minimum values of this indicator were obtained on the control variants without the use of fungicides and microfertilizers of 16.2 and 16.3 %, respectively, in the hybrids Libero and Margarita KWS.

The use of the fungicide Alto super 330 ES increased the sugar content of root crops by 0.8–1.0%, Amistar Extra 280 SC by 1.0–1.2 %, and Styer 500 by 0.9–1.1%, compared to the control.

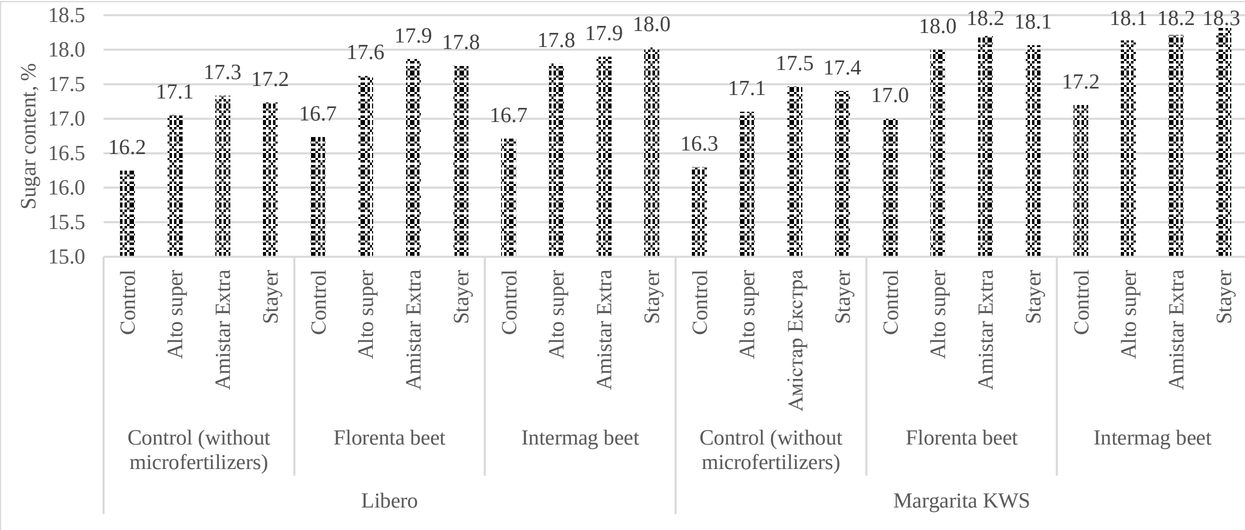

Fig. 1. Sugar content in sugar beet roots (average for 2021–2022), %
Source: Authors own results.

An important factor affecting the technological processes of sugar production is the technological quality of sugar beet roots. Technological indicators include chemical, biological and physical indicators of root crops after storage and in fresh form, they determine the level of losses and the amount of output of crystalline white sugar at the sugar factory [27].

The sugar beet root consists of 75% water and about 25% dry matter, which includes approximately 17.5% sugar and 7.5% non-sugars. Non-sugars are divided into those not soluble in water (5%), which are called pulp, and soluble non-sugars (2.5%). The pulp consists of cell wall components and a small amount of other substances that are not soluble in water. The composition of the pulp includes the following components: pectin substances – 2.4 %, hemicellulose – 1.1 %, fiber – 1.2 %, proteins 0.11 %, saponins – 0.1 %, ash – 0.1 % [40].

The use of high doses of mineral fertilizers reduces the sugar content of root crops, sharply increases the content of conductometric ash in them. This causes an increase in sugar losses in molasses, an increase in the MB factor, a decrease in the quality of normally purified juice and the yield of crystallized sugar at the sugar factory [26]. Increased doses of nitrogen fertilizers significantly increase the content of non-protein nitrogen in root crops [11]. The use of organic fertilizers helps to increase the yield of sugar at the sugar factory, improves the technological qualities of root crops and reduces the content of non-protein nitrogenous substances [14].

The use of microfertilizers and fungicides affected the technological qualities of sugar beet root crops (Table 2). Application of microfertilizers Florenta beet and Intermag beet to foliar fertilization increased the dry matter content in root crops by 0.4-1.0%, the estimated sugar yield by 0.7-1.2%, and also contributed to the reduction of conductometric ash by 0.07-0.09% and molasses by 0.4-0.6%, compared to the control.

An increase in the sugar content of root crops by 0.9-1.3%, the content of dry matter by 0.2-0.7%, as well as a decrease in the content of conductometric ash by 0.01-0.02% and molasses by 0.1-0, 2% when using fungicides on sugar beet crops. This is also confirmed by the data obtained by A. Shamsutdinova [33] which notes that the application of microfertilizers reduced the content of non-protein nitrogen, phosphorus and potassium in the roots of sugar beets and allowed to obtain a factory output of sugar – 12.8 t/ha.

The hybrid Margarita KWS had a higher content of dry matter and at the same time lower indicators of the estimated sugar content, compared to the hybrid Libero. It was established that the best indicators of the technological qualities of sugar beet roots were obtained with the simultaneous application of fungicides and microfertilizers, while the calculated sugar content and dry matter content were the highest and the conductometric ash was the lowest.

Table 2. Technological indicators of the quality of root crops of hybrids sugar beet (average for 2021–2022)

Hybrid	Microfertilizers	Fungicides	Dry matter content, %	Conductometric ash, %	Output of molasses, %	Estimated sugar content, %
Libero	Control (without microfertilizer)	Control	20.7	0.604	4.4	13.0
		Alto super	21.1	0.587	4.3	13.9
		Amistar Extra	21.0	0.574	4.2	14.2
		Styer	21.2	0.576	4.2	14.1
	Florenta beet	Control	21.2	0.534	3.9	13.7
		Alto super	21.6	0.521	3.8	14.7
		Amistar Extra	21.6	0.516	3.8	14.9
		Styer	21.7	0.526	3.8	14.8
	Intermag beet	Control	21.3	0.519	3.8	13.8
		Alto super	21.8	0.511	3.7	14.9
		Amistar Extra	22.0	0.508	3.7	15.0
		Styer	21.9	0.506	3.7	15.1
Margarita KWS	Control (without microfertilizer)	Control	21.0	0.588	4.3	13.1
		Alto super	21.5	0.577	4.2	13.9
		Amistar Extra	21.5	0.568	4.2	14.3
		Styer	21.7	0.575	4.2	14.2
	Florenta beet	Control	21.6	0.52	3.8	14.1
		Alto super	22.0	0.508	3.7	15.1
		Amistar Extra	22.0	0.506	3.7	15.3
		Styer	22.2	0.516	3.8	15.1
	Intermag beet	Control	21.7	0.507	3.7	14.3
		Alto super	21.9	0.496	3.6	15.3
		Amistar Extra	22.1	0.502	3.7	15.3
		Styer	22.1	0.493	3.6	15.5

Source: Authors own results.

Another factor addressed to evaluate the efficiency of sugar beet production is the energy consumption. Data collected from 146 sugar beet farms in Tokat (Turkey) revealed that the profit–cost ratio of farms was 1.17. The highest energy cost items were labor, land renting, depreciation and fertilizers [8]. Analyses of input and output energies in the production of agricultural products are usually based on the determination of energy consumption and environmental impacts of production systems. This data is used to compare different cropping systems and to determine how best to use energy [30].

According to the results of research conducted in Iran, it was found that the total energy costs for growing sugar beets were about 58487.80 MJ ha−1. Among these energy costs, the largest share falls on mineral fertilizers (24.5%), electricity (23.62%) and water (22.45%). Of the total energy consumption, 77.39% were non-renewable Benefit-to-cost ratio was calculated in sugar beet 1.05 fields and production productivity was calculated 9.15 kg $^{-1}$ [12]. Based on data touching 1400 farms of Slovakia, sugar beet helps those farms to increase their productivity rates and to scale up the wages [37].

In our researches, was noted an increase in energy expenditure by 1.6-3.0 GJ ha^{-1} and by 3.1-3.3 GJ ha^{-1} in the options with the use of fungicides and microfertilizers, compared to the control options (Table 3). Due to fungicides, an increase in the energy intensity of the sugar beet crop was noted by 37.1-54.8% and due to microfertilizers by 13.8-33.0%, compared to the control options.

There was no significant difference in energy efficiency between the fungicidal protection options. Thus, when using Alto super 330 EC, the energy intensity of the crop and the coefficient of energy efficiency (Cee) were in the range of 226.1-298.3 GJ ha^{-1} and 2.9-3.4, Amistar Extra 280 SC – 231.2-312, 0 GJ ha^{-1} and 3.0-3.6, Styer 500 – 226.4-307.0 GJ ha^{-1} and 2.9-3.5.

Table 3. Energy efficiency of using microfertilizers and fungicides in sugar beet (average for 2021–2022)

Hybrid	Microfertilizers	Fungicides	The energy intensity of the crop, GJ ha^{-1}	Energy expenditure, GJ ha^{-1}	Coefficient of energy efficiency (Cee)
Libero	Control (without microfertilizer)	Control	189.0	76.1	2.5
		Alto super	226.1	77.9	2.9
		Amistar Extra	231.2	78.3	3.0
		Styer	226.4	77.7	2.9
	Florenta beet	Control	202.5	78.7	2.6
		Alto super	236.7	81.1	2.9
		Amistar Extra	244.5	81.5	3.0
		Styer	244.0	81.2	3.0
	Intermag beet	Control	214.4	79.0	2.7
		Alto super	250.1	81.3	3.1
		Amistar Extra	258.6	81.5	3.2
		Styer	254.2	81.5	3.1
Margarita KWS	Control (without microfertilizer)	Control	225.3	81.7	2.8
		Alto super	266.5	84.4	3.2
		Amistar Extra	275.8	84.9	3.2
		Styer	270.1	84.7	3.2
	Florenta beet	Control	242.7	85.0	2.9
		Alto super	288.9	87.1	3.3
		Amistar Extra	297.2	87.7	3.4
		Styer	294.4	87.5	3.4
	Intermag beet	Control	252.2	85.3	3.0
		Alto super	298.3	87.6	3.4
		Amistar Extra	312.0	87.8	3.6
		Styer	307.0	87.5	3.5

Source: Authors own results.

The use of microfertilizer Florenta beet provides an increase in the coefficient energy efficiency by 0.2 and 0.3%, and Intermag beet by 6.1 and 7.5%, respectively in hybrids Libero and Margarita KWS.

The hybrid Margarita KWS has a energy intensity of the crop (277.5 GJ ha^{-1}) and Cee (3.2) compared to the hybrid Libero (231.5 GJ ha^{-1} and 2.9).

CONCLUSIONS

The maximum yield of root crops in the hybrids sugar beet Libero and Margarita KWS was 52.1 and 58.3 t/ha in the variant with the used of the fungicide Amistar Extra (0.6 l/ha) and microfertilizer Intermag beet (2 l/ha). At the same time, the difference between the options used the fungicides Amistar Extra (0.6

l/ha) and Styer (0.5 l/ha) was unreliable in the years of research. The hybrid Margarita KWS exceeded the hybrid Libero by 5.5 t/ha in root crop yield.

The sugar content in the root crop of hybrids Libero and Margarita KWS was 17.4 and 17.6%. The use of fungicides increases the sugar content by an average of 0.8-1.2%, microfertilizers Florenta beet (1.5 l/ha) and Intermag beet (2 l/ha) by 0.6 and 0.8%, compared to the control options

The indicators of the technological qualities of the root crops of sugar beet hybrids were the best with the simultaneous application of fungicides and microfertilizers while the sugar content and dry matter content were the highest and the conductometric ash was the lowest. From the energy vision, the best option was the combined application of the microfertilizer Intermag beet (2 l/ha) and the fungicide Amistar Extra 280 SC (0.6 l/ha). The coefficient of energy efficiency (Cee) was 3.2 and 3.6, respectively in hybrids Libero and Margarita KWS.

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