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Technologic qualities of sugar beet root crops in foliage application of melafen and trace elements.

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ABSTRACT

The influence of a new generation growth regulator melafen together with non reutilized trace elements (boron, zinc, manganese) in foliage application has been studied in production conditions on technologic qualities of sugar beet root crops and sucrose losses in molasses. As a result of conducted experiments the yielding capacity increased. The reduction of heavy metals content in root crops was also observed. The content of molasses-forming agents (potassium, sodium, alfa-aminonitrogen) diminished which lead to the sucrose loss reduction and ultimately the increase of gross yield of purified sugar.
Keywords: sucrose, technologic qualities, foliage application, non-reutilized trace elements, growth regulator melafen, yielding capacity, ecologic purity.

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INTRODUCTION

The value of root crops depends, first of all, on the sucrose amount in them. Sucrose is accumulated and stored up in root crops of sugar beet during the life activity of the plant. The processes of outflow and accumulation are interrelated with major physiologic processes of a vegetating plant depending on the set of environmental conditions and also on meteorologic factors. Depending on the chemical composition a root cropcan contain various quantitative and qualitative combinations of some dry matter components, different proportions between sucrose and non-sugars, a diverse composition of non-sugars. We consider that the chemical composition of root crops has influence on technologic qualities while processing root crops at the plant, therefore, technologic qualities have an effect significantly on sucrose losses.

Main factors of the yield increase and technologic qualities improvement of sugar beet roots are weather conditions, mineral nutrition with macro- and microelements(especially those which are not reutilized).

There are data in literature pointing to the prospects of applying microfertilizers as top dressings to raise the yield of sugar beet [1-4].

Our studies have established that the application of growth regulators is a factor of raising the yield and quality of roots [5-10].

The purpose of the study was to examine technologic qualities of root crops and sucrose losses in molasses in the process of top dressing with a new generation growth regulator melafen together with non-reutilized trace elements (boron, zinc, manganese) in production conditions.

OBJECTS AND METHODS OF INVESTIGATION

The experiment was conducted in 2012-2015 on the farm «SyapukovE.F.» of the Tsilninsky district in the Ulyanovsk region on the seedlings of the hybrid Manon.

Top dressing with microelements and a growth regulator was carried out 2 times for a vegetation period. The first treatment was conducted in the phase of 5-6 true leaves with the mixture prepared in a container simultaneously with the second herbicide spraying, the second treatment – in the period of root formation. Melafen was applied in the form of a water solution in a concentration $1 \cdot 10^{-7}$%, microelements – in the form of water solutions of their salts: boron (boric acid – H_3BO_3), zinc (zinc sulphate – $ZnSO_4$), manganese (manganese sulphate – $MnSO_4$) in concentrations 0,05%. The soil of the experimental plot was represented by leached black soil, of average thickness with average humus content, average clayloam. The humus content – 4,8-5,3%, phosphorus – 115-160 mg/kg, potassium – 140-200 mg/kg.

The content of microelements in the fields fluctuates in the following ranges: boron – 0,1-0,18 (mean – 0,14 mg/kg), manganese – 4,7-10,9 (mean – 7 mg/kg), zinc – 0,4-0,6 (mean – 0,47 mg/kg). The soils are referred to very poor in relation to boron and zinc, to manganese they are referred to poor ones.

The stand thickness was at the level of 99,3 thousands of plants on 1 ha. Meteorologic conditions of the vegetation periods of 2012–2015 were different. 2013 was a favorable year in the rainfall amount and temperature conditions – very humid, especially in August and September, when the rainfall was 2,5 of a monthly rate, that is why the yield was higher but with a lower sucrose content. The year 2014 was less favorable at the beginning and the end of the vegetation because there was no precipitation. High temperature in August-September contributed to a more intensive outflow of sucrose from the leaves that is why in 2014 the sugar content of root crops was higher in comparison with 2012 and 2013. In 2015 in May-Junethe rainfall amount was less than a monthly norm and in July the precipitation amount was more than a monthly rate in 2 times. In August-September the rainfall amount was less than a monthly rate in 2 times. June and September of 2015 were warmer in contrast to an average rate for many years.

The sugar content of root crops was determined by the method of hot water digestion on a colorimetric flow-through sugarmeter AP-05 in the research laboratory of the department «Biology, chemistry, technology of storage and produce processing» at the Ulyanovsk State Agricultural Academy. The potassium and sodium content was determined with the use of a lab ionmeter I-160MI applying ionselective electrodesELIS-121Kand ELIS-212Na. To determine α-amino nitrogen the method offered by Stanek and Pavlas which was modified by Wininger and Kubadinov that was based on the measurement of optical density with the use of a spectrophotometerPE-5300V.

Standard sugar losses when molasses was formed were calculated according to Brownshweig's formula [11]:

$$SSL= 0{,}12 \cdot (K + Na) + 0{,}24 \cdot \alpha\text{-amino nitrogen} + 0{,}48, \quad (1)$$

where SSL – standard sugar losses, %; K – potassium content, mmol for 100 gr of the wet weight; Na – sodium content, mmol for 100 gr of the wet weight;α-amino nitrogen – the content of alfa-aminonitrogen, mmol for 100 gr of the wet weight.

The content of purified sugar was equal to the difference between sugar content and standard sugar losses in molasses [11]:

$$SPS = SC – SSL, \quad (2)$$

where CPS – content of purified sugar, %; SC – sugar content, %; SSL – standard sugar losses in molasses, %.

Gross sugar yield was determined as an equation of the yield and sugar content:

$$GSY = Y \cdot SC / 100, \quad (3)$$

where GSY – gross sugar yield, t/ha; Y – yielding capacity of root crops, t/ha; SC – sugar content of root crops, %.

Gross yield of purified sugar was calculated according to the formula:

$$GYPS = Y \cdot PSC/ 100, \quad (4)$$

where GYPS – gross yield of purified sugar, t/ha; Y – yielding capacity of root crops, t/ha; PSC – purified sugar content in root crops, %.

INVESTIGATION RESULTS

The results of the field experiments conducted on the farm mentioned above in 2006-2011 were confirmed in the production conditions in 2012-2015 on large sown areas in 2012-2013 by 225 ha, in 2014 – 300 ha, in 2015 - 500 ha, in 2016 1000 hawas sown (table 1).

Table 1: Yielding capacity of sugar beet in production conditions, t/ha

Variant	Year of production trials				Averageyielding capacity, t/ha	Yield gain	
	2012	2013	2014	2015		t/ha	% tocontrol
Control (non treated crops)	44,6	53,3	34,7	29,1	40,4	-	100
Experimental (treated crops)	49,2	58,9	38,9	32,3	44,8	4,4	110,9

Meteorologic conditions in the years of production sowing (2012-2015 rr.) in the amount rainfall and temperature regime were different – 2014 and 2015 were arid, that is why the yielding capacity in these years was significantly lower– in 1,5 times in comparison with more favorable 2012 and 2013.

The results of production trials show that the use of our technology with two-time top dressing of agrophytocenosis of sugar beet raises the yielding capacity on average for 4 years by 4,4 t/ha (10,9%), with the yield of treated crops 40,4 t/ha.

TECHNOLOGIC QUALITIES OF ROOT CROPS

While processing sugar beet crops at the sugar mill technological qualities have a significant effect on the magnitude of sugar losses. The index of sugar content does not completely identify technologic qualities of beet raw materials that is why it is also important to take into account a soluble part of non-sugars.

Major factor of the yield rise and improvement of technologic qualities of sugar beet root crops is mineral nutrition with macro- and microelements.

The application of growth regulators is an additional factor increasing the sucrose content that raises purity of normal juice and improving major technological qualities of sugar beet.

Major indicators of technological qualities are: sucrose content, juice purity, hydrogen value (pH).

The results of studies show that in the experimental variant the sucrose content increased from 16,85% to 17,75% (table 2).

Table 2: Sugar content values of root crops, in % for the wet weight

Variant	Years of studies				Average sugar content
	2012	2013	2014	2015	
Control	16,5	15,6	17,2	18,1	16,85
Experiment	17,4	16,5	18,2	18,9	17,75

Intensive sugar accumulation takes place regardless of weather conditions under the influence of microelements in all the years of investigation. Technologic parameters, apart from the sucrose content, are normal juice purity and hydrogen value (pH) (tables 3, 4).

Table 3: Normal juice purity of sugar beet, cond.u.*

Variant	Years of studies				Average purity
	2012	2013	2014	2015	
Control	85,8	83,3	87,1	86,5	85,68
Experiment	86,7	84,9	90,0	90,9	88,13

*Conditional unit – a unit that shows the number of sucrose parts containing in 100 parts of sugar beet juice, the rest parts are composed of pectin, fibre, invert sugar and non-sugars.

Table 4:Hydrogen value (pH) of normal juice

Variant	Year of studies				Mean value
	2012	2013	2014	2015	
Control	6,1	6,5	6,3	6,5	6,4
Experiment	6,2	6,3	6,1	6,7	6,3

The results (table 3) show that the purity of normal juice increases on average for 4 yearsby 2,45 cond.u. The most stable indicator is hydrogen value.

The content of potassium in root crops which is one of the molasses-forming agents is referred to important technologic qualities. The higher this indicator is, the lower the quality of beet raw materials is. In our experiments the potassium content (table5) decreased from 5,46 mmol for 100 g of the wet weight of root crops in the control group to 3,60 mmol in the experimental group.

Table5: Potassium content in root crops, mmolfor 100 grof the beet wet weight

Variant	Year of studies				Average content
	2012	2013	2014	2015	
Control	5,53	5,57	5,48	5,25	5,46
Experiment	3,68	3,71	3,62	3,40	3,60

Sodium is also a molasses-forming agent, the content of which worsens the extraction of crystallized sugar. The study results (table 6) revealed that the sodium content in all the years in the control group was – 1,55 mmol for 100 g of the wet weight, in the experimental – 0,69 mmol.

Table6: Sodium content in beet, mmolfor 100 grof the beet wet weight

Variant	Year of studies				Average content
	2012	2013	2014	2015	
Control	1,51	1,64	1,57	1,48	1,55
Experiment	0,66	0,77	0,70	0,62	0,69

The most harmful molasses-forming agent among nitrogenous compounds is alfa-amino nitrogen playing a negative role while extracting sugar.

Table 7: Alfa-amino nitrogen content in beet, mmolfor 100 gr of the beet wet weight

Variant	Year of studies				Average content
	2012	2013	2014	2015	
Control	5,8211	5,9281	5,7676	5,5002	5,7543
Experiment	5,3932	5,3932	4,7513	2,2907	4,4571

On average for the years of studies the greatest content of alfa-amino nitrogen in beet declines from 5,75 mmol for 100 g of the wet weight in the control group to 4, 46 mmol in the experimental group (table7).

Sugar losses in the control group were 2,70%. They were connected with a high content of molasses-forming substances especially potassium and alfa-amino nitrogen. With foliage application of microelements and a growth regulator the standard sugar losses in molasses reduced to 2,06% (table 8).

The content of purified sugar in beet was in inverse relation to standard sugar losses in molasses. The content in the control group was 16,34%, in the experimental group - 14,15%.

Table8: Sugar beet productivity values

Variant	Year of studies				Mean value
	2012	2013	2014	2015	
Standardsugar losses, %					
Control	2,72	2,77	2,71	2,61	2,70
Experiment	2,30	2,31	2,14	1,51	2,06
Content of purified sugar, %					
Control	13,78	12,83	14,49	15,49	14,15
Experiment	15,80	15,29	16,46	17,79	16,34
Gross sugar yield, t/ha					
Control	7,0	8,3	4,9	4,9	6,4
Experiment	9,9	12,0	6,3	6,3	8,7
Gross yield of purified sugar, t/ha					
Control	5,8	6,9	4,1	4,2	5,3
Experiment	8,6	10,5	5,6	5,8	7,7

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Gross sugar yield is one of the integral sugar beet productivity values. In foliage application with microelements and a growth regulator the sugar yield increased and reached a maximum value (8,7 t/ha) when they were applied concurrently.

Gross yield of purified sugar – this is the final amount obtained after processing beets at the sugar mill. On average we managed to obtain7,7 t/ha of purified sugar in the experimental group in comparison with the control – 5,3 t/ha.

ECOLOGIC ASPECTS OF TECHNOLOGY APPLICATION

To determine ecological cleanliness of beet raw materials the heavy metals content was identified (table 9).

Under the influence of the used factors a decline of the heavy metals amount in beet is observed in the experimental group.

Table 9: Heavy metals content in sugar beet, mg/kg (average for 2012-2014)

Variant	Cu	Zn	Pb	Cd	Ni
Control	6,663	27,000	0,595	0,213	1,405
Experiment	5,763	19,500	0,445	0,121	0,985

The copper content decreases by 0,9mg/kg, the zinc content fell by 7,5 mg/kg, lead – by 0,15mg/kg, cadmium – by 0,092 mg/kg, nickel content dropped by 0,42mg/kg.

In sugar beet plants that were treated additionally with microelement solutions, as may supposed, additional barriers were created preventing heavy metals from penetrating into plants from the soil and their transformation in a plant organism.

ECONOMIC EFFICIENCY

The described technology is directed towards the industrial method of cultivating sugar beet: manual work abandonment, maximum use of highly efficient machinery, application of growth regulators especially of a new generation, as for example, polyfunctional melafen as an antidepressant, microelements and other innovative techniques that ensure high yields with good technological indicators of beet while processing it at a sugar mill.

The technology developed by us has been put into production since 2013 at the Agro-industrial complex «Novotimersyansky» annually on the sown areas of 250 ha, making possible to get high yields.

The application of growth regulators and boric acid as a top dressing contributed to the improvement of economic indicators when sugar beet was cultivated according to the technology proposed by us (table 10).

Table10: Economic efficiency of cultivating sugar beet in production conditions (2012-2015)

Variant / Indicator	Yield, t/ha	Produce cost, rub./t from harub.	Productionexpenses for1 ha, rub.	Labor expensesman-hourfor 1 ha on 1 t	Cost of production1 t, rub.	Conditionalnet profit, rub./ha	Level of costeffectiveness, %
Control	40,4	1737 59589	25835	14,42 0,38	696,6	33325,2	135,9
Experiment	44,8	1737 66079	26757	15,14 0,37	647,9	39322	159,4

The analysis of the table shows that on average for the years of studies when our technology was applied the economic efficiency in monetary terms increases from 59589 to 66079 rub./ha. Labor expenses fluctuate from 0,37 to 0,38. Production expenses changed depending on the level of yield and application of preparations.

Production cost of beet while using top dressings goes up by 7%. The level of cost effectiveness rises from 135,9 to 159,4%. Thus, top dressing of agrophytocenosis of sugar beet with microelements and growth regulator melafen is economically advantageous in the sugar beet technology.

CONCLUSIONS

The application of the developed technology for sugar beet cultivation and processing enables us to make the following conclusions:

1. Under the action of melafen and non-reutilized microelements sucrose biosynthesis becomes intensified, the draught resistance increases in unfavorable years.
2. While applying the preparation for treating vegetating plants the yielding capacity of sugar beet rose by 3,2-5,6 t/ha, on average for 4 years by 4,4 t/ha that amounts to 10,9% in relation to the level in the control group.
3. At the expense of this technology the beet sugar content increased up to 0,9%, the purity of normal juice improved on average by 2,45 cond. u.
4. In our experiments the content of such molasses-forming agents as potassium and sodium declined by 1,86 and 0,86 mmol respectively for 100 gr of the beet wet weight.
5. Under the influence of our technology the decline of harmful alfa-amino nitrogen took place on average for the years of studies by 1,2972 mmol for 100 gr of the beet wet weight. Thus favorable conditions are created to raise the amount of extracted sucrose.
6. Gross yield of purified sugar in the experimental group amounted to 7,7 t/ha, in comparison with the control group – 5,3 t/ha.
7. This cultivation technology contributes to the improvement of ecological cleanliness of beet raw materials at the expense of the pesticide load reduction and heavy metals transformation.
8. With the use of our technology in monetary terms the economic efficiency goes up from 59589 to 66079 rub./ha. The cost of beet production with top dressings increases by 7%. The level of cost effectiveness rises from 135,9 to 159,4%. Thus, top dressing of sugar beet agrophytocenosis with microelements and growth regulator melafen is economically profitable in the sugar beet technology.

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