Plant Archives Volume 21, No 1, 2021 pp. 1861-1867 *e-ISSN:2581-6063 (online), ISSN:0972-5210*

Plant Archives

Journal home page: www.plantarchives.org

DOI Url: https://doi.org/10.51470/PLANTARCHIVES.2021.v21.no1.257

EFFECT TO CROP ROTATION AND FERTILIZATION SYSTEM IN YIELD AND TECHNOLOGICAL QUALITY IN SUGAR BEET (*BETA VULGARIS* L.)

O. I. Prysiazhniuk[1]*, V. M. Hryhoriev[2], I. V. Svystunova[3], V. Ya. Bukhalo[4], L .M. Karpuk[5], A. I. Kryvenko[6], and A. A. Pavlichenko[5]

[1]Institute of Bioenergy Crops and Sugar Beet NAAS, 25 Klinichna St., Kyiv, 03110, Ukraine

[2]State Agricultural and Engineering University in Podillia, 13 Shevchenka St., Kamianets-Podilskyi, 32300, Ukraine

[3]National University of Life and Environmental Sciences, 15 HeroivOborony St., Kyiv, 03041, Ukraine

[4]Kharkiv national agrarian university named after V.V. Dokuchaev, “Dokuchaevske - 2”, Kharkiv region, Kharkiv district, 62483, Ukraine

[5]BilaTserkva National Agrarian University,pl. 8/1 Soborna, BilaTserkva, 09117, Ukraine

[6]Odessa state agricultural experimental station of NAAS of Ukraine st.Mayakskoe road 24, smt.Khlebodarskoe, Belyaevsky district, Odessa region, 67667, Ukraine

*Email: ollpris@gmail.com

(Date of Receiving-19-01-2021; Date of Acceptance-19-03-2021)

ABSTRACT

he quality of sugar beet roots is estimated by the concentrations of K, Na and α-amino nitrogen in cell fluid since sucrose content in the cell vacuole is the result of a balance of other active osmotic compounds (K and Na ions). Along with the increasing dose of organomineral fertilizers, sugar losses in molasses increase, the thin juice purity decreases, and, accordingly, white sugar yield decreases. Therefore, the optimal dose of fertilizers within the organomineral fertilization system on the typical leached chernozem (in the zone of sufficient soil moisture) was 40 t/ha of cattle manure + $N_{90}P_{110}K_{130}$, which provides sugar yield of 6.37, 6.32, and 6.48 t/ha. Analysis of sugar yield per hectare under the conditions of insufficient soil moisture shows the importance of the right decision on short crop rotation. Thus, the highest sugar yield (5.73 t/ha) was observed in the grain – grass – hoed crop rotation against the background of 25 t/ha of cattle manure + $N_{90}P_{120}K_{90}$. However, increased fertilizer doses, 25 t/ha of cattle manure + $N_{135}P_{180}K_{135}$, causes a reduction in sugar yield and is not efficient in terms of additional input.

Keywords: sucrose content in roots, α-amino nitrogen, potassium content, sodium content, mineral nutrition, organomineral nutrition

INTRODUCTION

Sugar beet (*Beta vulgaris* L.) can grow in a wide range of climates; therefore, this crop is suitable for cultivation in the Europe and the United States (Cooke and Scott, 1993). The potential of sugar beet productivity from northern France to eastern Poland is determined by the climatic conditions of a specific region and ranges between 85 and 95 t/ha root yield (Pidgeon *et al.,* 2001). However, in 2013, the actual root yield was over 85 t/ha in France and 58 t/ha in Poland, and less than 40 t/hain Ukraine. In 2018, the average root yield in France 81.6 t/ha, and in Poland 59.9 t/ha, and in Ukraine 50.8 t/ha (FAOSTAT, 2018).

In Europe, sugar beet is the only source of sugar suitable for the commercial processing (Winner, 1993). At the same time, the abolition of sugar production restrictions in EU in 2017 forced sugar beet growers to improve their competitiveness by optimizing and reducing production costs. Therefore, the introduction of new agronomical practices and the optimization of the use of available resources and conditions become more and more popular and necessary (Petersen and Rover 2005, Koch *et al.,* 2009, Van den Putte *et al.,* 2010).

Traditionally low sugar content and poor quality of roots are the reasons for the high costs of sugar processing. Therefore, high sugar yield is considered a key factor in increasing the economic efficiency of sugar production at factories (Dutton and Huijbregts, 2006). Root quality of is one of the most important indicators of sugar production efficiency and is affected by a genotype (Mahn *et al.,* 2002) and many biotic and abiotic factors (Hoffmann *et al.,* 2005).

In general, root quality characteristics include the concentration of sucrose, the content of various non-sugars, molasses-making compounds (sodium, potassium and α-amine nitrogen) (Hoffmann and Märländer, 2005). All these compounds, including K and Na (so-called non-sugars), increase the loss of sucrose in molasses and in this way reduce the efficiency of white sugar recovery from roots during processing (Hoffmann, 2005).

The concentration of Na in sugar beet roots varies from year to year and is significantly affected by growing conditions (Bloch and Hofmann, 2005).It was found that the correlation between Na content and sucrose concentration is often contradictory during the growth and development of sugar beet and quite difficult to investigate (Allison *et al.,* 1994; Bloch *et al.,* 2006). Even more interesting is the interaction between Na and the content of α-amino nitrogen, which has a positive and significant correlation in the case of higher root yield (Mengel and Kirkby, 2001).Other researchers found the Na content of roots significantly fluctuating among the studied hybrids with the average content being 10.2 kg/ha and the smallest 6.3 kg/ha (Subbarao *et al.,* 1999; Subbarao *et al.,* 2003). The content of K in sugar beet roots varies considerably and depends on the biological characteristics of the hybrids under study; however, the average content of K is 4.02% (Voss, 1996; Mengel and Kirkby, 2001).In general, the effect of K on sucrose content can only be explained by the simultaneous interaction of K with Na and the content of α-amino nitrogen. The studies show that there is an antagonism between K and Na (Draycott and Christensen, 2003).

The content of α-amino nitrogen in various sugar beet hybrids varies considerably, but its average values fluctuate around 1.5%. Generally, it is believed that the content of α-amino nitrogen decreases as the sugar beet root matures (Gilmour *et al.,* 2000). However, other studies have found that its concentration increases when roots reach the highest absolute growth rate (Grzebisz *et al.,* 2012). It is believed that the main differences in the content of α-amino nitrogen are determined by the basic biological characteristics of hybrids related to the assimilation of nutrients from the soil. However, other researchers did not find any significant differences between the α-amino nitrogen contents of various sugar beet hybrids (Giardini *et al.,* 1992; Gilmour *et al.,* 1996).

Mineral N affects the concentration of K in roots less than Na and α-amino nitrogen (Tsialtas and Maslaris, 2005). After all, an adequate supply of nitrogen is needed to form sugar in roots, but at the same time, its excess can lead to obtaining roots with lower sucrose content and juice purity (Horn and Fürstenfeld, 2001). At the same time, there are studies that indicate an increase in the root yield and sucrose content of roots as a result of high rates of nitrogen. This may be due to an increase in the size and number of leaves, which leads to an increase in leaf area and activation of photosynthesis processes (Malnou *et al.,* 2008)

Consequently, the agronomical practices ensuring an increase in sugar content of roots and a decrease in the concentration of molasses-makers is an effective mechanism for increasing the efficiency of sugar beet growing and processing.

MATERIAL AND METHODS

The quality of sugar beet roots was studied in different soil and climatic zones of Ukraine. The study aimed at revealing the effect of mineral, organic, organic-mineral fertilization system and crop rotation unit on sugar beet quality.

In the zone of sufficient soil moisture with the average annual rainfall from 600 to 620 mm and an average annual temperature of 7.8°C (Uladivske-Liulyntsi Research Breeding Station), the experiment was carried out in the long crop rotations units. The soil for the experiment was leached chernozem with the following agrochemical characteristics: pH_{Salt} of 6.0, humus content of 4.5%, mobile phosphorus content of 150 mg/kg, and exchange potassium content of 60 mg/kg. The layout of the experiment and the fertilization system for sugar beet in crop rotation units is given in Table 1.

In the zone of insufficient soil moisture with average annual rainfall from 520 to 530 mm and an average annual temperature of 7.8°C (Veselyi Podil Research Breeding Station), the experiment was carried out in the short crop rotations units. The soil for this experiment was typical slightly saline chernozem with the following agrochemical characteristics: pH_{Salt} of 7.0, humus content of 4.5%, the mobile phosphorus content of 50 mg/kg, and exchange potassium content of 110 mg/kg. The layout of the experiment and the fertilization system for sugar beet in crop rotation units is given in Table 3.

Sugar beet fertilization treatments have been designed to enrich the soil with nutrients in a particular soil moisture zone. Growing technology for the experiment was generally accepted in the region except for the studied items.

The experiment was carried out in a randomized plot design with four replications in plots of an area of 100 m^2. The test plots were seeded with a domestic triploid sugar beet hybrid 'Zluka' that is well adapted to cultivation under the conditions of unstable and insufficient soil moisture.

The yield was determined plot by plot, followed by calculation per hectare. The sugar content in roots was determined on the technological line Venema by the method of cold digestion.

Dispersion analyses were used to statistically evaluate the results of the field studies.

RESULTS AND DISCUSSION

The experiment carried out under the conditions of sufficient soil moisture (Uladivske-Liulyntsi RBS) demonstrated that thin juice purity significantly affects sugar losses in molasses. This occurs under the action of potassium, sodium and α-amine nitrogen (Table 1, 2).
Increased application dose of mineral fertilizers

($N_{130}P_{160}K_{200}$) resulted in the highest content of potassium in roots in rotation unit with clover, 4.20, while under the medium fertilization dose ($N_{90}P_{110}K_{130}$) its content reached 3.98, and under the high fertilization dose ($N_{180}P_{220}K_{260}$) it was 4.49 mg/equivalent per 100 g of fresh mass.

The content of sodium in the roots increases along with the increase in the dose of mineral fertilizers from medium to high in all rotation units. Thus, in the unit with maize, its content varied from 0.86 to 1.11, with clover from 1.05 to 1.37, and with pea from 0.77 to 1.09 mg/equivalent per 100 g of fresh mass.

Phosphorus-potassium fertilizer $P_{160}K_{200}$ significantly reduced the content of sodium in the fresh mass of roots. It was almost twice less than the with the increased dose of mineral fertilizers ($N_{130}P_{160}K_{200}$) and amounted to 0.57–0.59, while in the unfertilized treatment it was 0.59–0.73 mg/equivalent per 100 g of fresh mass. The content of α-amino N in roots in the unit with clover and pea was 3.05 and 2.19, respectively, that was by 0.15 and 0.58 mg/equivalent per 100 g of fresh mass less than in the unfertilized treatment. However, the content of potassium tended to increase. Respectively with the use of phosphorus-potassium fertilizers, thin juice purity was the highest (94.10%) in the unit with pea, while with the increased dose of fertilizers it was 91.30%.

It was found that the content of α-amino N increased in proportion to the increase in the fertilizer dose and under the effect of legumes as pre-crops of sugar beet. That is why with the introduction of $N_{90}P_{110}K_{130}$, its content in roots was 4.13 in the unit with clover, while in the unit with maize, it was 3.48, and in the unit with pea, 3.46 mg/equivalent per 100 g of fresh mass.

In the treatment with 40 t/ha of cattle manure + $N_{90}P_{110}K_{130}$, the content of α-amino N in roots was 3.83 and 3.76 in the units with maize and pea, respectively, and 4.58 mg/equivalent per 100 g of fresh mass in the unit with clover. This occurred due to the different availability of nitrogen to plants. By increasing the dose of organic fertilizers to 40 t/ha of cattle manure + $N_{180}P_{220}K_{260}$, the content of α-amino N in the unit with clover reached 5.49 mg/equivalent per 100 g of fresh mass.

Thin juice purity decreases along with the increase in mineral fertilizer dose. To illustrate, with $N_{90}P_{110}K_{130}$ it was 92.6% in the unit with maize and bean mixed sowing, 92.2% in the unit with clover and 92.1% in the unit with pea, which was by 1.3, 0.6 and 1.0% lower than the control treatment (Table 2).

When planning an effective sugar beet growing technology, it is necessary to provide enough nitrogen to obtain the best yield and quality of sugar at the lowest production costs (Lobell, 2007).

A high rate of mineral fertilizers ($N_{180}P_{220}K_{260}$) decreased thin juice purity compared to the control treatment. Thus, in the unit with maize, it decreased by 2.6%, in the unit with clover by 2.1, and in the unit with pea by 0.6%. Accordingly, sugar recovery in the unit with maize was 13.4%, with clover 13.7%, and with pea 13.2%. Sugar losses in molasses were the highest in the unit with clover (3.06%) and with pea (3.17%), while in the unit with maize they amounted to 2.58% due to the increased content of mineral nitrogen compounds in soil.

Analysis of data on the biomass accumulation by sugar beet roots indicates a negative effect of Na on cell size, which in turn reduces the potential for sucrose accumulation in roots. At the same time, sufficient supply of both K and Na ensures the formation of optimum size root cells, in this way contributing to the effective accumulation of sucrose (Tsialtas and Maslaris, 2009).

The use of cattle manure for sugar beet at an application dose of 40 t/ha contributes to the increase in potassium content in the fresh mass of roots compared to the mineral fertilization $N_{200}P_{100}K_{240}$. The content of sodium in the roots showed a tendency to increase in the unit with pea, where its content increased by 0.21, while in the unfertilized treatment it was 0.73 mg/equivalent per 100 g of fresh mass. The content of α-amino N was lower compared to the mineral fertilization system. It ranged from 3.1 to 3.46 mg/equivalent per 100 g of fresh mass. Sugar losses in molasses were small. In the unit with maize, they increased by 0.33%, with clover by 0.38%, and with pea by 0.76% compared to the unfertilized treatment. Therefore, thin juice purity in the rotation units was 92.9, 92.8, and 92.6%, and sugar recovery was 14.9, 15.1, and 14.2%, respectively.

The studies conducted under the conditions of insufficient soil moisture (Veselyi Podil RBS) have shown that crop rotations and fertilizer treatments significantly affect the working quality of sugar beet roots. After all, the white sugar recovery and thin juice purity significantly affect sugar losses in molasses, depending on the effects of potassium, sodium, and α-amino N (Table 3, 4).

Similarly, in the experiment carried out in another zone of soil moisture, it was shown that the content of potassium and sodium in roots grows along with increasing fertilizer dose. Thus, with an increased dose of fertilizers (25 t/ha of cattle manure + $N_{135}P_{180}K_{135}$), the highest content of potassium in roots was observed in the units of grain-fallow rotation, 4.83, while with medium fertilizer application dose it reached 4.78 mg/equivalent per 100 g of fresh mass.

The content of sodium in the roots increases with the increase in the dose of organic fertilizers from medium to high in all crop rotation units. Thus, in the units of

Table 1. Effect of crop rotation unit and fertilizers on sugar beet root quality, Uladivske- Liulyntsi RBS, 2014–2019

Treatment	K (mg/ eq per 100 g of fresh mass)			Na (mg/ eq per 100 g of fresh mass)			α-amino N, (mg/ eq per 100 g of fresh mass)			Sugar losses in molasses (%)		
	I	II	III	I	II	III	I	II	III	I	II	III
No fertilizers	3.78	4.04	3.81	0.59	0.71	0.73	2.50	3.22	2.77	1.62	2.00	2.19
$N_{90}P_{110}K_{130}$ (average fertilizer dose)	3.90	3.98	3.80	0.86	1.05	0.77	3.48	4.13	3.46	2.18	2.52	2.17
$N_{130}P_{160}K_{200}$ (increased fertilizer dose)	4.01	4.20	3.85	1.09	1.03	0.95	3.94	4.29	3.71	2.47	2.69	258
$N_{180}P_{220}K_{260}$ (high fertilizer dose)	4.25	4.49	3.83	1.11	1.37	1.09	4.12	4.88	4.34	2.58	3.06	3.17
20 t/ha of cattle manure + $N_{130}P_{160}K_{200}$	4.00	4.70	4.12	1.04	1.28	1.09	4.21	5.02	3.61	2.64	3.15	3.21
40 t/ha of cattle manure + $N_{90}P_{110}K_{130}$	4.00	4.73	4.39	0.74	2.49	0.96	3.83	4.58	3.76	2.40	2.88	3.24
40 t/ha of cattle manure + $N_{130}P_{160}K_{200}$	4.34	4.55	4.22	1.07	1.21	1.30	4.11	5.21	4.50	2.58	3.27	3.56
40 t/ha of cattle manure + $N_{180}P_{220}K_{260}$	4.48	4.59	4.31	1.28	1.19	1.33	5.80	5.49	4.78	3.63	3.64	3.44
40 t/ha of cattle manure	4.19	4.47	4.14	0.69	0.82	0.94	3.10	3.40	3.46	1.95	2.38	2.95
$P_{160}K_{200}$	4.15	4.49	4.09	0.57	0.59	0.57	2.39	3.05	2.19	1.71	2.23	2.23
$N_{130}K_{200}$	4.01	5.04	3.60	0.93	1.25	0.97	3.87	5.28	3.60	2.43	3.01	2.91
$N_{130}P_{160}$	3.37	4.27	2.97	0.64	0.83	0.92	3.86	4.77	4.02	1.83	2.14	2.40
$LSD_{0.05}$	0.15	0.18	0.20	0.06	0.04	0.07	0.15	0.14	0.17	0.12	0.15	0.17

Note: I - in the unit with maize; II - in the unit with clover; III - in the unit with pea

Table 2. Effect of crop rotation unit and fertilizers on the thin juice purity and technological white sugar yield, Uladivske-Liulyntsi RBS, 2014–2019

Treatment	Thin juice purity (%)			Sugar recovery (%)			Sugar yield (t/ha)		
	I	II	III	I	II	III	I	II	III
No fertilizers	93.9	92.8	93.1	15.6	15.8	14.8	5.67	5.31	5.18
$N_{90}P_{110}K_{130}$ (average fertilizer dose)	92.6	92.2	92.1	14.3	14.6	13.3	6.13	6.13	5.69
$N_{130}P_{160}K_{200}$ (increased fertilizer dose)	91.8	91.8	91.3	13.8	14.8	13.8	6.54	6.54	6.25
$N_{180}P_{220}K_{260}$ (high fertilizer dose)	91.3	90.7	92.5	13.4	13.7	13.2	6.57	6.57	6.23
20 t/ha of cattle manure + $N_{130}P_{160}K_{200}$	91.5	90.6	92.1	13.4	13.8	13.8	6.24	6.24	6.52
40 t/ha of cattle manure + $N_{90}P_{110}K_{130}$	92.3	91.1	91.7	13.9	14.2	13.6	6.32	6.32	6.48
40 t/ha of cattle manure + $N_{130}P_{160}K_{200}$	91.5	90.4	89.9	13.8	13.7	12.2	6.34	6.34	6.94
40 t/ha of cattle manure + $N_{180}P_{220}K_{260}$	88.9	89.9	90.1	11.9	13.2	12.5	6.28	6.28	5.18
40 t/ha of cattle manure	92.9	92.8	92.6	14.9	15.1	14.2	6.44	6.44	6.17
$P_{160}K_{200}$	93.9	92.3	94.1	15.8	15.8	14.9	6.49	6.49	5.97
$N_{130}K_{200}$	92.0	89.8	91.8	13.8	13.3	13.6	4.93	4.93	5.82
$N_{130}P_{160}$	92.5	91.3	92.3	13.5	13.0	13.7	4.98	4.98	5.63
$LSD_{0.05}$	4.5	4.2	4.4	3.7	3.6	3.4	-	-	-

Note: I - in the unit with maize; II - in the unit with clover; III - in the unit with pea

Table 3. Effect of crop rotation unit and fertilizers on sugar beet root quality, Veselyi Podil RBS, 2014–2019

Treatment	K (mg/eq per 100 g of fresh mass)	Na (mg/eq per 100 g of fresh mass)	α-amino N (mg/eq per 100 g of fresh mass)	Sugar losses in molasses (%)
Esparcet – fescue grass – winter wheat – sugar beet (grain – grass – hoed crop rotation)				
No fertilizers	3.84	0.75	2.70	2.20
25 t/ha of cattle manure + $N_{90}P_{120}K_{90}$	4.10	1.10	4.23	2.30
25 t/ha of cattle manure + $N_{135}P_{180}K_{135}$	4.30	1.20	4.78	2.30
Silage maize – winter wheat – sugar beet (hoed crop rotation)				
No fertilizers	3.81	0.63	2.53	2.20
25 t/ha of cattle manure + $N_{90}P_{120}K_{90}$	4.05	1.10	4.10	2.30
25 t/ha of cattle manure + $N_{135}P_{180}K_{135}$	4.10	1.15	4.23	2.20
Bare fallow – winter wheat – sugar beet (grain – fallow crop rotation)				
No fertilizers	4.10	0.73	2.82	2.20
25 t/ha of cattle manure + $N_{90}P_{120}K_{90}$	4.78	1.30	4.34	2.30
25 t/ha of cattle manure + $N_{135}P_{180}K_{135}$	4.83	1.34	4.98	2.20
Winter wheat – winter wheat – sugar beet (grain – hoed crop rotation)				
No fertilizers	3.89	0.67	2.79	2.10
25 t/ha of cattle manure + $N_{90}P_{120}K_{90}$	4.33	1.22	4.20	2.30
25 t/ha of cattle manure + $N_{135}P_{180}K_{135}$	4.47	1.27	4.75	2.30
$LSD_{0.05}$	0.17	0.05	0.14	0.12

Table 4. Effect of crop rotation unit and fertilizers on thin juice purity and white sugar recovery, Veselyi Podil RBS, 2014–2019

Treatment	Thin juice purity(%)	Sugar recovery (%)	Sugar yield (t/ha)
Esparcet – fescue grass – winter wheat – sugar beet (grain – grass – hoed crop rotation)			
No fertilizers	91.6	14.0	4.18
25 t/ha of cattle manure + $N_{90}P_{120}K_{90}$	91.3	14.0	5.73
25 t/ha of cattle manure + $N_{135}P_{180}K_{135}$	91.6	13.4	5.47
Silage maize – winter wheat – sugar beet (hoed crop rotation)			
No fertilizers	90.9	13.7	3.84
25 t/ha of cattle manure + $N_{90}P_{120}K_{90}$	91.4	13.8	5.19
25 t/ha of cattle manure + $N_{135}P_{180}K_{135}$	91.4	13.6	5.52
Bare fallow – winter wheat – sugar beet (grain – fallow crop rotation)			
No fertilizers	91.5	13.5	4.02
25 t/ha of cattle manure + $N_{90}P_{120}K_{90}$	89.9	13.2	5.65
25 t/ha of cattle manure + $N_{135}P_{180}K_{135}$	90.8	13.0	5.61
Winter wheat – winter wheat – sugar beet (grain – hoed crop rotation)			
No fertilizers	91.5	13.7	2.84
25 t/ha of cattle manure + $N_{90}P_{120}K_{90}$	91.5	13.6	5.31
25 t/ha of cattle manure + $N_{135}P_{180}K_{135}$	90.9	13.2	5.07
$LSD_{0.05}$	0.5	0.6	-

hoed crop rotation, its content varied from 1.10 to 1.15, in grain-fallow crop rotation from 1.30 to 1.34, and grain-hoed crop rotation from 0.77 to 1.09 mg/equivalent per 100 g of fresh mass.

It was found that the content of α-amino N increased in proportion to the increase in the application dose of fertilizers, and it was the highest for the use of 25 t/ha of cattle manure + $N_{135}P_{180}K_{135}$ regardless of rotation. However, it is noteworthy that the high values of α-amino N content in roots were observed in grain-fallow rotation, which is most likely due to the significant mineralization of the organic matter of the soil in the field with bare fallow.

Sugar losses in molasses did not depend on the type of short crop rotation. Accordingly, they increased on fertilized backgrounds and varied from 2.1 to 2.3%.

Under the conditions of insufficient soil moisture, crop rotation makes a significant contribution to the formation of thin juice purity. Thus, the maximum values were observed in the unfertilized treatment in the grain – grass – hoed crop rotation (91.6%), grain-fallow crop rotation (91.5%) and grain-hoed crop rotation (91.5%); however, in the hoed crop rotation worse indicators were obtained compared to fertilized treatment. We believe that such differences are probably due to the rather intensive use of mineral fertilizers for maize, which under the conditions of insufficient soil moisture can be used by after-crops (Table 4).

Organo-mineral fertilization system with 25 t/ha of cattle manure + $N_{90}P_{120}K_{90}$ resulted in a slight decrease in thin juice purity in crop rotatory system by 0.3%, and in a strong decrease in the grain-fallow rotation by 1.6%. In grain-hoed crop rotation, thin juice purity was at the level of the control treatment without fertilizers, 91.5 %. In the hoed crop rotation, thin juice purity increased by 0.4% compared to control treatment and equalled 91.4%. By increasing fertilizer doses to 25 t/ha of cattle manure + $N_{135}P_{180}K_{135}$, thin juice purity decreased only in the grain-hoed crop rotation (90.9%).

The highest white sugar recovery (14%) was obtained from the roots grown in the grain – grass – hoed crop rotation with the use of 25 t/ha of cattle manure + $N_{90}P_{120}K_{90}$. However, with the increase in the fertilizer doses to 25 t/ha of cattle manure + $N_{135}P_{180}K_{135}$, the lowest values of white sugar recovery were obtained regardless of crop rotation.

The largest value of sugar yield per hectare (5.73 t/ha) was obtained in grain – grass – hoed crop rotation against the background of 25 t/ha of cattle manure + $N_{90}P_{120}K_{90}$, which was by 1.57t/ha higher than the unfertilized control treatment, then in the hoed crop rotation and in the grain-hoed crop rotation. Sugar yield in these rotations amounted to 5.19, 5.61, and 5.31 t/ha, respectively. Increasing the fertilizer doses to 25 t/ha of cattle manure + $N_{135}P_{180}K_{135}$ causes the reduction of sugar yield to a greater extent in crop rotatory system.

CONCLUSIONS

Increased fertilizer dose in both mineral and organo-mineral fertilization formula leads to an increased content of K, Na and α-amino N in roots, which subsequently leads to the losses of sugar in molasses.

The optimum dose of fertilizers within the organo-mineral fertilization formula on the typical leached chernozem (for the zone of sufficient soil moisture) is 40 t/ha of cattle manure + $N_{90}P_{110}K_{130}$, and in conditions of insufficient soil moisturethe highest sugar yield was observed in grain – grass – hoed crop rotation, and fertilizer doses, 25 t/ha of cattle manure + $N_{90}P_{120}K_{90}$.

In the zone of sufficient soil moisture, the dose of phosphorus fertilizer within the mineral fertilization system on the leached chernozem may be reduced by 30%, while on the typical slightly saline chernozem in the zone of insufficient soil moisture it may be reduced by 50%. The dose of potassium may be decreased by 10 and 20%, respectively. The dose of nitrogen in the organo-mineral fertilization system on leached chernozem should not exceed N_{130}, while on typical slightly saline chernozem it should not exceed N_{90}.

REFERENCES

Allison, M.F., Jaggard, K.W.,&Armstrong, M.J. (1994). Time of application and chemical form of potassium, phosphorus, magnesium and sodium fertilizers and effects on the growth, yield and quality of sugar beet. *Journal of Agricultural Science, Cambridge 123*, 61-70. http://dx.doi.org/10.1017/S0021859600067782

Bloch, D.,&Hoffmann, C. (2005). Seasonal Development of Genotypic Differences in Sugar Beet (*Beta Vulgaris* L.) and Their Interaction with Water Supply. *Journal of Agronomy and Crop Science, 191*: 263-272. http://dx.doi.org/10.1111/j.1439-037X.2005.00150.x

Bloch, D., Hoffmann, C.,&Märländer, B. (2006). Solute Accumulation as a Cause for Quality Losses in Sugar Beet Submitted to Continuous Temporary Drought Stress. *Journal of Agronomy and Crop Science, 192:* 17-24. http://dx.doi.org/10.1111/j.1439-037X.2006.00185.x

Cooke, D.A.,&Scott, R.K. (1993). *The Sugar Beet Crop. Sciencient Practice*. Chapman and Hall, London http://dx.doi.org/10.1007/978-94-009-0373-9

Draycott, A. P.,&Christenson, D. R. (2003). *Nutrients for Sugar Beet Production. Soil-Plant Relationships.* CABI Publishing, Wallingford, pp. 242. http://dx.doi.org/10.1079/9780851996233.0000

Dutton, J., &Huijbregts, T. (2006). Root quality and processing. p. 409-442. In A.P. Draycott (ed.) *Sugar beet.* Blackwell Publ., Oxford, UK. http://dx.doi.org/10.1002/9780470751114.ch16

Food and Agriculture Organization Corporate Statistical Database. (2018). The Agricultural Production domain: Produced quantities, harvested area, yield per hectare.

Giardini, L., Pimpini, F., Borin, M.,&Gianquinto, G. (1992). Effects of poultry manure and mineral fertilizers on yield of crops. *Journal of Agricultural Science, Cambridge 118*, 207-213. http://dx.doi.org/10.1017/S0021859600068805

Gilmour, J.T., Clark, M.D.,&Daniel, S.M. (1996). Predicting long-term decomposition of biosolids with a seven-day test. *Journal of Environmental Quality 25*, 766-770. http://dx.doi.org/10.2134/jeq1996.00472425002500040016x

Gilmour, J.T., Cogger, C.G., Jacobs, L.W., Wilson, S.A., Evanylo, G.K.,&Sullivan, D.M. (2000). Estimating Plant-available Nitrogen in Biosolids. *Water Environment Research Foundation, Alexandria, Virginia*. 174 p. http://dx.doi.org/10.2175/193864700785378149

Grzebisz, W., Pepliński K., Szczepaniak W., Barłóg, P.,&Cyna, K. (2012). Impact of nitrogen concentration variability in sugar beet plant organs throughout the growing season on dry matter accumulation patterns. *Journal of Elementology, 17*: 389-407. http://dx.doi.org/10.5601/jelem.2012.17.3.03

Hoffmann, C. (2005). Changes in N composition of sugar beet varieties in response to increasing N supply. *J. Agron. Crop Sci., 191*: 138-145. http://dx.doi.org/10.1111/j.1439-037X.2004.00149.x

Hoffmann, C. M, Kenter, C., &Bloch, D. (2005). Marc concentration of sugar beet (*Beta vulgaris* L) in relation to sucrose storage. *Journal of the Science of Food and Agriculture. 85*:459–465 http://dx.doi.org/10.1002/jsfa.2002

Hoffmann, C. M.,&Märländer, B. (2005). Composition of harmful nitrogen in sugar beet (*Beta vulgaris* L.) – amino acids, betaine, nitrate – as affected by genotype and environment. *European Journal of Agronomy, 22*: 255-265. http://dx.doi.org/10.1016/j.eja.2004.03.003

Horn, D.,&Fürstenfeld, F. (2001). Nitrogen fertilizer recommendation for sugar beet according to the EUF soil testing system. In: Horst, W.J., M.K. Schenk, A. Bürkert, N. Claassen, H. Flessa, W.B. Frommer, H. Goldbach, H.W. Olfs, V. Römheld, B. Sattelmacher, U. Schmidhalter, S. Schubert, N.V. Wirén and L. Wittenmayer (eds.), *Plant Nutrition, Vol. 92*, pp: 746–747. http://dx.doi.org/10.1007/0-306-47624-X_362

Koch, H.J., Dieckmann, J., Büchse, A., &Märländer, B. (2009): Yield decrease in sugar beet caused by reduced tillage and direct drilling. *European Journal of Agronomy, 30*: 101-109. http://dx.doi.org/10.1016/j.eja.2008.08.001

Lobell, B.D. (2007). The cost of uncertainty for nitrogen fertilizer management: A sensitivity analysis. *Field Crops Res. 100*:210-217. http://dx.doi.org/10.1016/j.fcr.2006.07.007

Mahn, K., Hoffmann, C.,&Märländer, B. (2002). Distribution of quality components in different morphological sections of sugar beet (*Beta vulgaris* L.). *European Journal of Agronomy, 17*: 29-39. http://dx.doi.org/10.1016/S1161-0301(01)00139-3

Malnou, C.S., Jaggard, K.W.,&Sparkes, D.L. (2008). Nitrogen fertilizer and the efficiency of the sugar beet crop in late summer. *European J. Agron., 28*: 47-56 http://dx.doi.org/10.1016/j.eja.2007.05.001

Mengel, K. &Kirkby, E.A. (2001). Principlesof Plant Nutrition. International Potash Institute, Worblaufen-Bern, Switzerland, 593 pp. http://dx.doi.org/10.1007/978-94-010-1009-2

Petersen, J., &Rover, A. (2005): Comparison of sugar beet cropping systems with dead and living mulch using a glyphosate-resistant hybrid. *Journal of Agronomy and Crop Science, 191*: 55-63. http://dx.doi.org/10.1111/j.1439-037X.2004.00134.x

Pidgeon, J. D., Werker, A. R.,&Jaggard, K. W. (2001). Climatic impact on the productivity of sugar beet in Europe 1961-1995 *Agricultural and Forest Meteorology 109(1)*, 27-37. http://dx.doi.org/10.1016/S0168-1923(01)00254-4

Subbarao, G. V., Ito, O., Berry, W. L.,& Wheeler, R. M. (2003). Sodium – A Functional Plant Nutrient. *Critical Reviews in Plant Sciences, 22:* 391-416. http://dx.doi.org/10.1080/07352680390243495

Subbarao, G.V., Wheeler, R.M., Stutte, G.W.,& Levine, L.H. (1999). How far can sodium substitute for potassium in red beet? *Journal of Plant Nutrition 22(11),* 1745-1761. http://dx.doi.org/10.1080/01904169909365751

Tsialtas, J. T.,& Maslaris, N. (2009). Selective Absorption of K over Na in Sugar Beet Cultivars and its Relationship with Yield and Quality in Two Contrasting Environments of Central Greece. *Journal of Agronomy and Crop Science, 195:* 384-392. http://dx.doi.org/10.1111/j.1439-037X.2009.00379.x

Tsialtas, J.T., &Maslaris, N. (2005). Effect of N fertilization on sugar yield and non-sugars impurities of sugar beet (*Beta vulgaris*) grown under Mediterranean conditions. *J. Agron. Crop Sci. 191:*330-339. http://dx.doi.org/10.1111/j.1439-037X.2005.00161.x

Van den Putte, A., Govers, G., Diels, J., Gillijns, K., &Demuzere, M. (2010). Assessing the effect of soil tillage on crop growth: A meta-regression analysis on European crop yields under conservation agriculture. *European Journal of Agronomy, 33:* 231-241. http://dx.doi.org/10.1016/j.eja.2010.05.008

Voss, J. (1996). Input and offtake of nitrogen, phosphorus and potassium in cropping systems with potato as a main crop and sugar beet and spring wheat as subsidiary crops. *European Journal of Agronomy 5,* 105-114. http://dx.doi.org/10.1016/S1161-0301(96)02013-8

Winner, C. (1993). History of the crop. In: Cooke, D.A. and Scott R.K. (eds) *The Sugar Beet Crop*. Chapman & Hall, London, pp. 6-7. http://dx.doi.org/10.1007/978-94-009-0373-9_1