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ORIGINAL ARTICLE

Energy efficient growing of red beet in the conditions of central forest steppe of Ukraine

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Two varieties of red beet like *Chervona kulia* and *Nosivskyi ploskyi* were used in the investigation. The row scheme with the spacing of 45 cm and the band scheme of 20+50 cm were applied to study the effect of seed sowing on the yield of red beet. In order to determine the effect of the biological preparation we applied the treatment of plants with the solution of Azotobacterin and Phytosporin three times during the vegetation period. The 45 × 14 cm row seed sowing scheme in the varieties and the sample with Azotobacterin application provided the largest weight of 229.1-234.6 g of root-beets. The application of the 45 × 14 cm seed sowing scheme with the total amount of 159,000 plants per hectare provides the yield of 36.4-37.3 t/ha. By applying the bio preparations the yield of root-beets is 31.5-43.5 t/ha. The largest yield of 43.5 t/ha on *Chervona kulia* variety was received due to Azotobacterin application. The yield due to Phytosporin application was also sufficient though it increased the control level only by 7.6 t/ha. The water, electricity, fertilizers energy, as well as the quality of the basic soil cultivation and hand labour significantly affects the energy value accumulated in the root-beets yield. The largest energy value of 74.973 MJ was received on the *Chervona kulia* variety by applying the 45 × 14 cm row scheme together with Azotobacterin application.
Keywords: Scheme; variety; bio preparation; root-beets; yield; profitability

Introduction

The main aim of the vegetable growing development in Ukraine by 2020 is to provide the population with fresh and processed vegetables which quantity is determined by scientifically based consumption standards. The vegetables production has to be increased by the intensity of the industry progress and the expanding of the range of products, by the implementation of science and technology achievements, as well as by the use of production potential (Gorlov et al., 2014; Sas et al., 2010; Vdovenko et al., 2017). In order to expand the use of red beet in the farm enterprises of Ukraine it is required to implement the advanced and fast ripen varieties, develop the ecologically healthy and adapted elements of growing technology, improve the production quality and inform the population about essential therapeutic potential of plants (Soetan, 2008). Among vegetables, the red beet occupies an area of 40-45 thousand hectares, which is mostly concentrated in the western regions-9.9% and placed in one rotation with the carrot. It is required to plant the red beet seeds in several terms: the first time-right after the sowing of early cereals, the second one-in the first half of May. The second term plants almost do not form flowering; the root-beets are more delicate and have a better endurance for winter. The yield of the first term plants is mainly used in the summer-autumn period while of the second term ones-for the storage.

Much attention in the development of the elements of vegetables growing in the open soil is given to the methods of seed sowing and the application of different preparations including biological. These preparations have an effect on the microbial group of rhizosphere, reduce the phytotoxicity of the soil, improve absorption of nitrogen and phosphorus and facilitate early flowering providing an increase of 20-65 % in the yield (Kolomiets et al., 2016; Truba et al., 2012; Kordowska-Wiater, 2011).

The application of growth regulators and biological preparations in the crop farming is one of the most effective measures to increase the productivity of plants and improve their quality. In the research of Duranti et al., the preparations and micro fertilizers increased the yield of lupine and other crops; therefore it is essential to apply these preparations and micro fertilizers at pre-sowing seed treatment and during the vegetation. The application of Azotophyte and Phytosporin during the growing of cucumber seedlings changes the biometry of plants at the phase of flowering and fruiting. The treated seedlings significantly differed from the untreated ones by the length of stalk and their leaf surface increased by 129-192 cm^2. When using the biological preparation at the phase of fruiting, the length of the stalk was by 7.8-9.9 cm longer; the plants formed the larger amount of leaves and their surface increased by 152-184 cm^2. The largest yield of cucumber was received when using Azotophyte-42.7 t/ha (Ternavskiy, 2009). The productivity of tomatoes is also higher when increasing the Azotophyte or

Phytosporin concentration during the seedlings steeping. The steeping of seedlings in the Azotophyte solution shows the increase of tomatoes productivity up to 46.2 t/ha, while the Phytoside solution increases the dry matter content by 4.8%-5.3%, the sugar content-by 15-24% and reduces the nitrates content by 30%.

One of the research assumptions was to provide people with the red beet production from the open soil when using the ecologically healthy technology and the absence of information regarding the implementation of agro technology elements on the plants productivity. Therefore, the purpose of the article was to investigate the influence of red beet seeds sowing schemes and the application of bio preparations on the plant biometric characteristics and yield.

Materials and methods

The study of the red beet yield in the conditions of right-bank Forest steppe of Ukraine when using seed sowing schemes and bio preparations was carried out in Vinnytsia region during 2015-2016. During the years of research, the climate was moderately continental; the reserves of productive moisture in the soil before the beginning of the spring vegetation and in the layer of 0-100 cm were 136 and 119 mm. The average annual precipitations amount was 471-480 mm, where almost 60-70% of them were in the warm period of the year. The average date of the last and first frosts in the air coincided with the dates of the transition of average daily temperatures higher +10 °C in spring and lower +10° in autumn. This period corresponds to the active vegetation of plants during 155-165 days. The hydrothermal coefficient (IHC) was 1.7-1.8. The content of humus in the soil was average-2.4%, P_2O_5-21.2 mg/100 g of soil, K_2O was low-9.2 mg/100 g of soil. The soil acidity was close to the neutral.

Two varieties of red beet like *Chervona kulia* and *Nosivskyi ploskyi* were used in the investigation and were cultivated by direct sowing according to the recommendations of the Institute of Horticulture and Melon-growing. To study the seed sowing effect on the yield we applied the row scheme of seed sowing with the spacing of 45 cm and further distance of 12 and 14 cm between the plants and the amount of 185 and 159 thousand plants per hectare; and the 20+50 cm band scheme with the spacing of 12 cm between the plants and the amount of 238000 plants per hectare. In addition, to determine the effect of bio preparation on the red beet yield, the plants were separately treated with the solution of Azotobacterin and Phytosporin three times with the interval of 14 days. The preparation was applied for the first time during the phase of the second pair of leaves. The control sample included the scheme of seed sowing with the spacing of 45 cm, the 12 cm distance between the plants and the amount of 185000 plants per hectare, as well as the sample, where the plants were not treated with bio preparations. All the samples were placed through the randomly selected blocks in three replications.

The biometric observations were made during the experiment, the height of the plant, as well as the diameter, length and weight of the food organ were determined. The laboratory-field method was used to monitor the processes of growth, development and production, the method of synthesis-to formulate conclusions, and the statistical, economic-mathematical and bio energetic analyses-to determine the efficiency of the cultivation technology.

Results and discussion

The biometric factor is the main feature in the growing of red beet. The best characteristics are obtained under the optimum cultivation conditions. As a result of using the 50+20 cm band scheme of seed sowing with the distance of 12 cm between the plants and the amount of 238000 plants per hectare, the total amount of leaves in the phase of technical maturity of root-beets was 22-23 per plant in the varieties of *Chervona kulia* and *Nosivskyi ploskyi*, that wasn't lower than the amount of leaves in the control sample. However, the greater amount of 25-26 leaves per plant was obtained under the 45 cm row scheme of seed sowing and the amount of 159000 plants per hectare in the varieties of *Nosivskyi ploskyi* and *Chervona kulia*. The indicated seed sowing scheme and the amount of plants didn't provide the largest length of leaves per variety. Due to the application of 45 × 14 cm seed sowing scheme, the width of the leaf at the phase of technical maturity was not the same and ranged from 8 to 9 cm, respectively (Table 1).

It is known that the amount of leaves, their length and width depends on the type of root-beet. By using the row seed sowing scheme with the formation of 222200 plants per hectare, the varieties with the round shape of root-beets are characterized by the total amount of 25-28 leaves with the length of 13-14 cm and the width of 8.0-8.9 cm. The varieties of red beet in our study were characterized by approximate characteristics in the sample with the spacing of 45 cm, the distance of 14 cm between the plants and the amount of 159000 plants per hectare. But the biometric characteristics are reduced independently of the root-beets shape upon the larger amount of plants per hectare.

Table 1. Biometric characteristics of the red beet at the phase of technical maturity of root- beets depending on the scheme of seed sowing (average for 2015-2016).

Variety (A)	Experimental scheme, cm (B)	Amount of plants, thousand units/ha	Biometric characteristics of the plant		
			Amount of leaves, unit/plant	Length of leaves, cm	Width of leaves, cm
Chervona kulia	45 × 12	185	24	14	9
	45 × 14	159	26	15	9
	50+20 × 12	238	22	10	7
Nosivskyi	45 × 12	185	24	13	8

ploskyi	45 × 14	159	25	14	9
	50+20 × 12	238	23	11	6
LSD 0.05					
(A)			0.9	1.1	0.8
(B)			1.1	1.3	1
(AB)			1.6	1.8	1.4

The application of biological preparations significantly improves the plants characteristics, which is approved by scientists (Yakimenko, 2011; Kolomiets et al., 2016; Vdovenko, 2015). The application of Azotobacterin preparation in the experiment provided intensive growing processes facilitating the formation of the greater amount of leaves than under the application of Phytosporin. When growing the variety of *Chervona kulia* the amount of leaves per plant was 27 and their length of 16 cm exceeded the control under the application of Azotobacterin. At the same time, the indicated preparation didn't increase the leaf width (Table 2).
Due to the application of Phytosporin, the biometric characteristics of the plant were lower in comparison with the application of Azotobacterin. Apparently, the amount of leaves depends on bacterial species used for preparations. The bacteria Azotobacter chroococcum used in the Azotobacterin preparation show the growth-stimulating action for the red beet during the vegetation period, while the bacteria Bacillus subtilis used for the Phytosporin preparation do not provide the greater amount of leaves, their general length and width. Such characteristics are approved by Alamanou, Jigna et al., Kolanta et al., Yakimenko, Buinyi et al.

Table 2. Biometric characteristics of the red beet at the phase of technical maturity of root- beets depending on the biological preparation (average for 2015-2016).

Variety (A)	Experimental scheme (B)	Biometric characteristics of the plant Amount of leaves, units/plant	Length of leaves, cm	Width of leaves, cm
Chervona kulia	Without preparation	24	14	9
	Azotobacterin	27	16	9
	Phytosporin	24	13	8
Nosivskyi ploskyi	Without preparation	24	13	8
	Azotobacterin	26	15	8
	Phytosporin	24	13	8
LSD0.05				
	(A)	0.6	1.1	0.9
	(B)	0.7	1.3	1.1
	(AB)	1	1.8	1.6

The 45 cm row seed sowing scheme or the 20+50 cm band scheme had an impact on obtaining different root-beets. The 45x14 cm row seed sowing scheme with 59000 plants per hectare provided the greatest weight of 234,6 g of root-beets on *Chervona kulia* variety, which is by 28% higher in comparison with the control. The similar positive impact was obtained on *Nosivskyi ploskyi* variety when using the 45 × 14 cm scheme, which increased the control by 353 g. The smallest weight of 150.1-151.1 g of root-beets was obtained by using the 50+20 cm band scheme of seed sowing due to the larger amount of plants per area, which was by 1.2-1.3 times lower in comparison with the control.
The schemes of seed sowing also had an impact on the length of root-beets. The largest length of 15,5 and 15,1 cm of root-beets was obtained by using the 45 × 14 cm row scheme of seed sowing in the studied varieties. The length rate in the other samples was lower or almost close to the control. The diameter of root-beets varied from 6.2 to 8.8 cm. The largest diameter of 8.8 cm was obtained in *Nosivskyi ploskyi* variety by using the 45 cm seed sowing scheme. The other samples did not provide the increase of root-beets in diameter (Table 3).
The examined bio preparations also showed an influence on the root-beets biometry. The root-beets weight varied from 170.4 to 235.2 g and depended mainly on the variety characteristics and the intensity of photosynthesis process resulting from the bacteria influence. The largest weight was received in the variety of *Chervona kulia* with the application of Azotobacterin. The root-beets weight was 235.2 g and exceeded the control by 1-3 times. When growing the *Nosivskyi ploskyi* variety the largest weight was 231.1 g with the application of Azotobacterin. When using Phytosporin, the root-beets weight exceeded the control by 11-29 % in the studied varieties.

Table 3. Biometrical characteristics of root-beets depending on the applied scheme of seed sowing (average for 2015-2016).

Variety (A)	Experimental scheme, cm (B)	Amount of plants, thousand units/ha	Weight of root-beets, g	Length of root-beets, cm	Diameter of root-beets, cm

Chervo-na kulia	45x12	185	183.4	13.5	6.8
	45x14	159	234.6	15.5	7.5
	50+20x12	238	151.1	13.6	6.2
Nosivskyi ploskyi	45x12	185	193.8	14.8	8.4
	45x14	159	229.1	15.1	8.8
	50+20x12	238	150.1	13.2	7.5
		$LSD_{0.05}$			
	(A)		5	0.3	0.5
	(B)		6.1	0.4	0.7
	(AB)		8.7	0.6	0.9

As the result of the application of bio preparations the root-beets length and their diameter changed. When using Azotobacterin in *Chervona kulia* variety, the root-beets length exceeded the control sample by 1.9 cm and the diameter by 1 cm. When using Phytosporin the length of root-beets exceeded the control by 9% and the diameter-by 7%. The positive influence of bio preparation was also observed on *Nosivskyi ploskyi* variety (Table 4).

Table 4. Biometrical characteristics of root-beets depending on the applied bio preparation (average for 2015-2016).

Variety (A)	**Experimental scheme (B)**	**Weight of root-beets, g**	**Length of root-beets, cm**	**Diameter of root-beets, cm**
Chervona kulia	Without preparation	182.1	14.8	6.8
	Azotobacterin	235.2	16.7	7.8
	Phytosporin	223.5	16.2	7.3
Nosivskyi ploskyi	Without preparation	170.4	14.4	7.5
	Azotobacterin	231.1	15.4	8.7
	Phytosporin	190.3	15.2	8.4
		$LSD_{0.05}$		
	(A)	7.7	0.5	0.4
	(B)	9.4	0.6	0.5
	(AB)	13.3	0.9	0.7

The positive impact of bio preparations on the biometric characteristics of the plant is approved by Kolomiets et al., Arya et al., Ternavskiy, Truda et al., Maluszynska et al. The application of preparations, based on the bioagents activity, has an impact on the germination ability of seeds and significantly improves the biometric characteristics. The data are partially confirmed in our studies.

Timely taken technological measures contribute to the process of photosynthesis and the high yield of crops. The yield of root-beets in the researches was 33.9-37.3 t/ha. It was different during the years of growing: in 2015 the yield was reduced when using different schemes of seed sowing and in 2016 it was the same or exceeded the control. The 45 cm seed sowing scheme with the 14 cm distance between the plants provided the increase of 7.7 and 4.8 t/ha in the yield of varieties in 2016. The 45 × 14 cm and 50+20 × 12 cm seed sowing schemes had a positive impact on the yield increase of *Chervona kulia* variety. The yield of root-beets in such samples was 37.3 and 36.0 t/ha respectively and exceeded the control by 3.4 and 2.1 t/ha (Table 5).

Table 5. Yield of red beet in the research depending on the scheme of seed sowing, t/ha.

Variety (A)	**E × perimental scheme, cm**	**Amount of plants, thousand units/ha**	**Yield, t/ha**		**Average for years**	**+ to the control**	
			2015	**2016**		**t/ha**	**%**
Chervona kulia	45 × 12	185	35.6	32.2	33.9	–	–
	45 × 14	159	34.8	39.9	37.3	3.4	10
	50+20 × 12	238	32	40	36	2.1	6
Nosivskyi ploskyi	45 × 12	185	34.7	37	35.8	–	–
	45 × 14	159	31	41.8	36.4	0.6	2
	50+20 × 12	238	33.4	38	35.7	-0.1	-0.3

LSD0.05		
(A)	2.8	1.2
(B)	3.4	1.5
(AB)	4.8	2.1

The insignificant increase of 2% in the yield was observed when using the 45 × 14 cm seed sowing scheme and 159000 plants per hectare in the growing of *Nosivskyi ploskyi* variety. Analysing the influence of factors on increasing the yield of root-beets, the greatest influence of the factor "seed sowing scheme" with the value of 40% was established. The factor "variety x seed sowing scheme" with the value of 28% had the smaller impact, while the factor "grade" with the value of only 24% was the smallest.
According to Peltzer et al. (2002), when establishing the standards and the scheme of sowing, the germinating ability of seeds and their resistance to harmful organisms must be taking into consideration. Thereby, the detection of changes in the density of crops has a significant impact on technological aspects, provides an increase in the individual productivity of the plant that is confirmed by the data of the research.
While using the bio preparations the yield varied from 31.5 to 43.5 t/ha, pests and diseases agents did not affect the plants, root-beets met the requirements of the standard and were harvested at the phase of technical maturity. The largest yield of 43.5 t/ha was provided on *Chervona kulia* variety with the use of Azotobacterin preparation. The increase of the yield was 29%, while with the use of Phytosporin the yield exceeded the control by 7.6 t/ha (Table 6).

Table 6. Yield of red beet depending on the bio preparation, t/ha.

Variety (A)	Experimental scheme (B)	Yield, t/ha		Average for years	+ to the control	
		2015	2016		t/ha	%
Chervona kulia	Without preparation	36.3	31.2	33.7	–	–
	Azotobacterin	47.1	39.9	43.5	9.8	29
	Phytosporin	43.7	38.9	41.3	7.6	22
Nosivskyi ploskyi	Without preparation	33.9	29.1	31.5	–	–
	Azotobacterin	45.6	39.8	42.7	11.2	35
	Phytosporin	36.3	34.2	35.2	3.7	12
LSD0.05						
(A)		2.1	2.2			
(B)		2.5	2.7			
(AB)		3.6	3.8			

When growing the *Nosivskyi ploskyi* variety and the use of Azotobacterin preparation, the yield of 42.7 t/ha also exceeded the control value. When applying Phytosporin the yield exceeded the control only by 12%. On the basis of the statistical analysis the factor "bio preparation" increased the yield by 29.8%, while the mutual influence of the factors "variety & bio preparation" provided the yield increase by 44.8% and the factor "variety" was only 24.9%.
The efficiency of bio preparations use deems to be appropriate since they provide a significant increase in the yield together with the protection against pathogenic microflora and obtaining the environmentally healthy production (Ternavskiy, 2009). The treatment of plants with certain bio preparations allows increasing the yield of Brussels sprouts by 46% and raising the content of total sugar, dry solid, ascorbic acid and betanin, while the nitrates content does not exceed the generally accepted concentration (Kutz & Paramonova, 2015). However, according to Vdovenko et al. (2016) data, the factor "variety" has the greater influence on the yield of leeks, while the "bio preparation" factor provides the yield increase by 36%. The yield of red beet is partially approved by the increase due to the application of the bio preparation.
In the conditions of the market economy scientific results will be interesting only when after the application of agro technological measures there will be an economic income and a significant increase in the yield. With the use of row and band schemes of seed sowing the profitability of products varied widely. The level of profitability in the growing of *Chervona kulia* variety was 96.3% when using the 45 × 14 cm sowing scheme while the less income was obtained at the same sowing scheme on the variety of *Nosivskyi ploskyi*. The lower index of 61.7% of the profitability level was examined on the variety of *Chervona kulia* with the use of 20+50 × 12 cm sowing scheme, while it was 60.3% on Nosivsky ploskiy variety. Simultaneously, the different influence of the bio preparation on the characteristics of economic efficiency was determined. When using Azotobacterin preparation on *Chervona kulia* variety the profitability was 81.8%. When using Phytosporin the profit was larger than without the preparation.
According to Tananaki (2002) and Drakos et al. (2007), the foliage application is recognized as a means of managing the biochemical plants composition and the market quality of crop production. The given element of cultivation technology is economically feasible, that is confirmed by the results of the research. The plants accumulate the particular value of energy, nutrients and chemical compounds through the process of photosynthesis. A significant influence on the amount of energy accumulated in the crop during the red beet production is done by the energy of water, electricity and fertilizers, as well as

the energy of the main soil cultivation, pre-sowing and the manual labour energy. Its largest value of 74,973 MJ was obtained on the *Chervona kulia* variety with the 45 × 14 cm row sowing scheme, while its smallest value was when using the 45 × 12 cm seed sowing scheme. The bio energy efficiency coefficient when using seed sowing schemes varied from 2.9 to 3.5. The highest value was obtained on *Chervona kulia* and *Nosivskyi ploskyi* varieties, when using the 45 × 14 cm seed sowing scheme; and the lowest value of 3.5 was on *Chervona kulia* variety with the application of 45 × 12 cm sowing scheme.

When using bio preparations, the energy accumulated in the crop was not constant and ranged from 63,315 MJ to 87,435 MJ. Its highest indicator was observed when cultivating the *Chervona kulia* variety with the use of Azotobacterin preparation, while the *Nosivskyi ploskyi* variety was characterized by the approximate value with the use of Azotobacterin preparation. The lowest indicator of 63,315 MJ was obtained on the *Nosivskyi ploskyi* variety without the use of biological preparation. The use of Phytosporin provided more energy than in the control sample, but it was less than in the sample with the use of Azotobacterin preparation.

The energy used in the production of red beet was 96,569 MJ regardless of the variety and the yield, while the bio energy efficiency was 3.3-4.5. Its highest value of 4.4-4.5 was observed in *Nosivskyi ploskyi* and *Chervona kulia* varieties with the application of Azotobacterin preparation. The *Nosivskyi ploskyi* variety was characterized by the lowest value of only 3.3 in the sample where the bio preparations were not used.

Bio preparations have low cost and are technologically harmless to humans and the environment. The use of the activity of tuber bacteria, fixing the nitrogen of the air and mobilizing the hard-to-reach forms of soil phosphorus, increases the soil fertility, while the use of biological preparations during vegetable growing provides the protection from pathogenic microflora allowing to realize the biological potential of plants (Eviner & Chapin 1997; Lapinskas, 1998; Ayana1 et al., 2014; Vdovenko, 2016). When growing tomatoes, the coefficient of bio energy efficiency depends on the yield. Its larger value of 1.7 was obtained by using Azotophyte. However, during the growing of red beet and the use of Phytosporin or Azotobacterin preparations, the coefficient may increase to 4.3-4.5.

Conclusions

On the basis of the obtained results we can make the following conclusions:

1. The amount of 159000 plants per hectare by using the 45 × 14 cm row seeds sowing scheme increases the amount of leaves, their length, as well as the weight of root-beets on *Nosivskyi ploskyi* and *Chervona kulia* varieties.
2. The application of the 45 × 14 cm seeds sowing scheme when growing *Nosivskyi ploskyi* and *Chervona kulia* varieties allows providing the total yield of 36.4-37.3 t/ha of root-beets.
3. Azotobacterin and Phytosporin preparations have a favourable effect on biometrical characteristics and the yield of red beet. When using Azotobacterin preparation, the weight of root-beets increases up to 235.2 g, and their length can be 16.7 cm, while the yield increases up to 42.7-43.5 t/ha on *Nosivskyi ploskyi* and *Chervona kulia* varieties.
4. The highest income is observed by using the 45 × 14 cm sowing scheme on *Chervona kulia* variety with the profitability indicator of 96.3% and the bio energy efficiency coefficient of 3.9.
5. The profitability level on *Chervona kulia* variety with the use of Azotobacterin preparation is 81.8%, while the bio energy efficiency coefficient is 4.5.

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