UDC 633.63:631.53.01.006.83:631.547.2/.3
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PHOTOSYNTHETIC PRODUCTIVITY OF SUGAR BEET DEPENDING ON AGROTECHNOLOGICAL TECHNIQUES OF GROWING

Influence of agrotechnological techniques of growing on indexes of photosynthetic productivity of sugar beet it is proved in the article. It is proved that leaf surface area and photosynthetic potential of diploid and triploid biological forms were almost the same. With the density of plants increasing is decreasing leaf surface area. Density of plants increasing from 90–100 to 101–110 thousand/ha does not lead to a leaf surface area reduction. Foliar application use in phase of leaves closure between rows (136 days from sowing) provides an increase of net photosynthetic productivity. Foliar feeding application at all terms is providing photosynthetic productivity increased of both investigated hybrids.
Keywords: *sugar beet, photosynthetic productivity, agritechnological methods of growing*

Introduction. One of the main ways to increase productivity of agricultural crops is to create favorable conditions for the manifestation the high potential productivity of agrophytocenoses. The whole complex of agrotechnological measures should be aimed at providing of optimal conditions passage of the physiological processes that determine the high productivity plants of sugar beet [1]. Complex of agrotechnological techniques in the optimization of sugar beet agrophytocenoses is includes the use of various biological forms of high-productivity hybrids of sugar beet of domestic and foreign origin, optimization of plants density, application of foliar feeding by micronutrient of different types, norms by the different terms of application, which provides an increase of carbohydrates content, vitamins and chlorophyll in the leaves of plants. All this will contribute to strengthening of photosynthetic process passage, increase productivity of root and improving their technological qualities.

Photosynthesis – is a the main process as a result of which are formed organic compounds that make up about 95% of the dry mass the plant. The intensity of the photosynthetic process has a set of external factors such as light, temperature, carbon dioxide, humidity, etc., and biological characteristics of the plants, especially the specificity of their reactions to external influences factors. The photosynthetic process is considered as a result of the interaction of all complex internal and external factors in the life of plants [2].

K.A. Timiriazev [3] wrote that crops yield are ultimately determined not by the amount of moisture and fertilizer, which we can provide the plant, and the quantity and quality of light that enters per unit area of assimilation surface of sowing.

By the researches of scientists [3, 4] is found that the formation of root and accumulation of sugar in it have close relationship with the dynamics of the leaf mass development and growth and sugar beet productivity that depends on field germination largely, plant density, number of leaves per plant and their total assimilation surface.

Photosynthesis process regulation i.e. its productivity increasing – is one of the most effective methods of influence on the sugar beet productivity, and for them - an important means of yield level increasing. In our time is developed a complex of agrotechnological measures that taken ability to influence on the process of photosynthesis.

The aim was to determine the parameters of photosynthetic productivity of sugar beet depending on agrotechnological techniques of growing such as the use of different biological forms of sugar beet hybrids of domestic and foreign origin, optimization of plants density, application of foliar feeding by micronutrient of different types, norms by the different terms of application.

Materials and methods. Field experiments were performed during 2010–2012 in the field conditions of Bila Tserkva National Agrarian University, which is located in the zone of unstable moistening.

Area of sown plots – 64.8 m^2, accounting – 54.0 m^2, repetition – quadruple. The problem of increasing the photosynthetic productivity of sugar beet solving was conducted experiments in which is studied the photosynthetic productivity depending on the different genotypes (diploid hybrids of sugar beet: Ukrainian ChS 72, Leopard, Zoom, triploid hybrids: Umanskyy ChS 97, Orix, Murray); different density of planting plants to harvest from 80-90 to 136-145 thousand pcs/ha with an interval of 10 thousand pcs/ha and types of micronutrients, timing of foliar feeding application and norms of their application. In the experiments were use microfertilizers of Ukrainian production research and production center "Reakom": Reakom R-beet (standard), Reastim-humus-beet and Reakom-plus-beet. Microelements were added in 2 terms: closing leaves in a row phase and one month before harvesting by different norms from 3.0 to 7.0 l/ha. For research it was use hybrid seeds of domestic selection Ukrainian ChS 72.

Determination of the pure productivity of photosynthesis, which is measured in grams of dry matter per square meter of leaf area per day (g dry matter/m2 leaf surface per day) was determined by A.A. Nichiporovich method [5]. The components of the net productivity of photosynthesis are leaf surface area, which is measured in thousands of square meters of leaf area per hectare (thousands m2/ha) and photosynthetic potential (million m2 × day/ha). This experience gives the opportunity to comprehensively assess the effectiveness of this agrotechnological technique.

Plants analyses and other observations were performed according to existing methods that have been used in domestic practice [6]. Experiment was laid by the method of split plots location repetitions systematically, consistently. Experiments repeated were fourfold.

The statistical data processing was performed on a personal computer by R. Fisher method [7].

Results and discussion. An important index that is characterized photosynthetic productivity is net photosynthetic productivity, so it was important to determine this index depending on biological forms of sugar beet. It is experimentally proved that in average for the three years the leaf surface area of diploid and triploid biological forms of sugar beet was almost the same and was 46,5–47,8 thousand m^2/ha. There was no significant difference of this index and on date of accounting, except for the account on the first of September, where the leaf surface area of triploid form was significantly higher than diploid forms (Table 1).

Table 1

Leaf surface area and productivity of photosynthesis depending on the biological forms of sugar beet (average of 2010–2012)

Biological forms of sugar beet	Date of determination			Average
	1 July	1 August	1 September	
Leaf surface area, thousand m^2 /ha				
Diploids	27,8	52,9	58,7	46,5
Triploids	26,7	52,9	63,8	47,8
Deviations of triploids compared with diploids	– 1,1	0	+ 5,1	+ 1,3
SSD_{05}	3,3	1,1	3,8	2,1
Photosynthetic potential, million. m^2 · days /ha				
Diploids	0,83	1,59	1,76	1,40
Triploids	0,80	1,59	1,91	1,43
Deviations of triploids compared with diploids	– 0,03	0	+ 0,15	+ 0,15
SSD_{05}	0,4	0,8	0,2	0,2
Net productivity of photosynthesis, g dry matter /m^2 leaf surface per day				
Diploids	1,3	6,0	6,0	4,4
Triploids	1,4	6,7	6,3	4,8
Deviations of triploids compared with diploids	+ 0,1	+ 0,7	+ 0,3	+ 0,4
SSD_{05}	0,3	0,7	0,3	0,7

On the first date of the account – 01 July, the index of leaf surface area in diploid forms was higher on 1.1 thousand m^2/ha compared to triploid, due to the intensity of plant growth and development in the early stages. On the second date of accounting – 01 August, the leaf surface area as diploid and triploid forms of beet was the same and amounted to – 52.9 thousand m^2/ha, indicating that during July is formed a powerful leaf mass both biological forms of sugar beet.

On the third date of accounting – September 01, is found a significant increase of the leaf surface area of triploid forms of beet, which was 63.8 thousand m^2/ha and exceeded diploid form on 5.1 thousand m^2/ha (SSD_{05} = 2.1 thousand m^2/ha).

According to A. Nychyporovych [8], sowings are considered good when their photosynthetic potential is 2.2-3.0 million m^2 days/ha, medium – 1.0-1.5 million m^2 days/ha or unsatisfactory – 0.5-0.7 million m^2 days/ha.

Photosynthetic potential on average of three years of both biological forms of sugar beet was almost identical and amounted 1.40-1.43, i.e. sowings are described as medium according to the A. Nychyporovych classification it is established.

In variants where were sown triploid form the net productivity of photosynthesis on average by dates of accounting was slightly higher and amounted – 4.8 g dry matter/m^2 leaf surface per day, and in variants with diploid forms – 4.4 g dry matter/m^2 leaf surface per day. During the most active period of plants growth and development (from 01 of July to 01 of September) there was only a tendency of net productivity of photosynthesis increasing of triploid forms of beet compared with diploid. This is due to the efficiency of the plants leaf surface work with the accumulation of dry matter. The significant difference depending on biological forms beet by the index of net productivity of photosynthesis was not.

One of the main drivers of the net productivity of photosynthesis is the density of planting. The observations of the assimilation surface growth and development of sugar beet plants is showed that leaf surface area depending on the density of plants on average ranged between 37.6–47.2 thousand m^2/ha. Plant density increasing is led to leaf surface area decrease (Table 2).

Table 2

Leaf surface area and productivity of photosynthesis depending on the density of plants (average of 2010-2013)

Density of plants, thousand/ha	Date of determination			Average
	1 July	1 July	1 July	
Leaf surface area, thousand m^2 /ha				
80–90	25,5	52,7	57,2	45,1
91–100 (контроль)	26,3	55,6	59,8	47,2
101–110	27,6	55,7	58,0	47,1
111–120	22,8	51,4	57,8	44,0
121–135	22,7	45,2	52,9	40,3
136–145	20,2	42,3	50,2	37,6
SSD_{05}	4,6	7,8	6,4	3,1
Photosynthetic potential, million. m^2 · days /ha				
80–90	0,76	1,58	1,71	1,35
91–100 (контроль)	0,79	1,63	1,79	1,40
101–110	0,83	1,67	1,74	1,41
111–120	0,68	1,54	1,74	1,32
121–135	0,68	1,36	1,59	1,21
136–145	0,61	1,27	1,51	1,13
SSD_{05}	0,2	0,3	0,3	0,1
Net productivity of photosynthesis, g dry matter /m^2 leaf surface per day				
80–90	1,4	7,6	6,1	5,0
91–100 контроль	1,1	7,5	6,9	5,2
101–110	1,4	7,9	6,6	5,3
111–120	1,2	7,0	6,6	4,9
121–135	1,2	7,3	5,9	4,8
136–145	0,8	7,3	6,3	4,7
SSD_{05}	0,7	1,0	0,9	0,4

Between density of plants and leaf surface area it is established close inverse correlation, which is shown as a graph in Fig. 1.

Character of the point's location on the charts is shows that by the density of plant increasing the leaf surface area is decreases. The relationship between the declared values is linear, correlation is strong, inverse, and correlation coefficient is - 0.87. The developed regression equation that describes this relationship: y = 0.1615 x + 62.386. The value of the reliability of the approximation is 0.764.

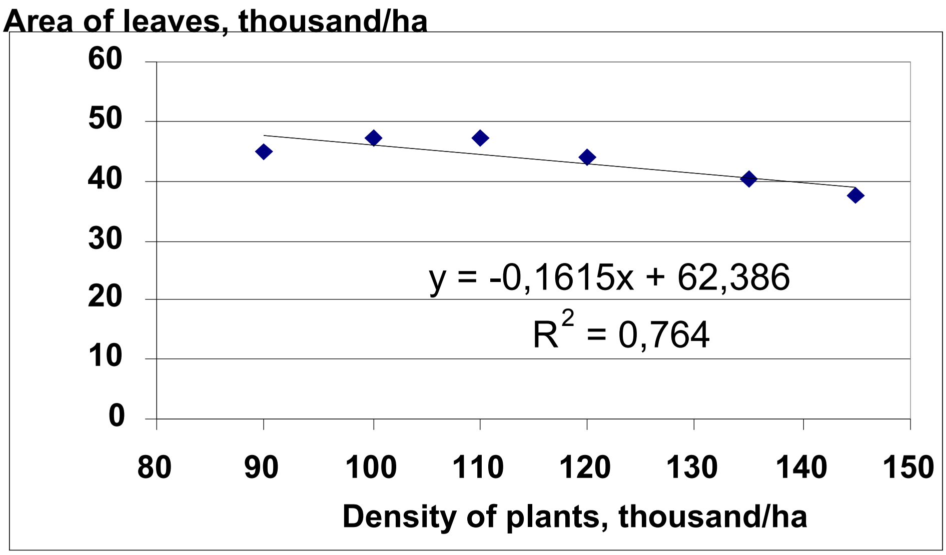

Fig. 1. The leaf surface area depending on the density of plants

According to the A. Nychyporovych classification [8], we can note that on the variants with the given finite density of plants, photosynthetic potential on the 01 of July was unsatisfactory and was within 0,61–0,83 million m^2 days/ha. On the 1 of August index of photosynthetic potential was within between the middle and the best – 1.27–1.58 as on the 01of September was slightly better and was 1.51–1.79 million m^2 days/ha. The index of photosynthetic potential of sowing is decreasing, due to poor development and operation of their leaf surface.

The highest net productivity of photosynthesis was by the density of 101–110 thousand/ha – 5.3 g dry matter/m^2 of leaf surface per day. There is no significant difference of net productivity of photosynthesis by the density of plants of 101–110 and control – 90–100 thousand/ha. Below its value is obtained by the density of 136–145 thousand plants/ha – 4.7 g dry matter/m^2 leaf surface per day.

Earlier research works were established [3] that microelements that should be applied in the komplekson form (chelate) of metal, as a result is observed an increase of their solubility and bioavailability for the sugar beet plants [9].

It is established that on the efficiency of photosynthesis of sugar beet is significantly affect timing of micronutrients foliar feeding, types and norms of their application (Table 3).

Observations by the growth and development of assimilation surface of sugar beet plant on September 1 by the microelements application in the closing leaves in a row phase have shown that the leaf surface area, depending on the term, type and application norm of micronutrients, on average, ranged from 34.5 to 46 6 thousand m^2/ha.

On the control variant (without feeding), average for research years, the leaf surface area was 34.5 thousand m2/ha and its higher value was obtained in the variant of Reakom-plus-beet application in the norm of 7 l/ha – 46.6 thousand m2/ha, that is caused by optimal area of plant nutrition and the best leaf surface assimilation apparatus formation. The smallest value of the leaf surface index, relative to the control, was obtained in the areas with Reastim-humus-beet and Reakom-plus-beet micronutrients application in the norm of 3 l/ha, respectively, 37.5 and 35.5 thousand m^2/ha. With the norms increasing of 3 to 5 and 7 liters/ha is increased leaf surface area as compared with the control and with the standard. Foliar application of Reakom-plus-beet micronutrient fertilizers in norms 5 and 7 liters/ha is provided the biggest area of leaf surface. That is, on leaf surface increasing a significant influence had as a form of micronutrients and the norm of application.

Table 3

Leaf surface area and photosynthetic productivity depending on the types, norms and terms of microelements applying in feeding on September 1 (average of 2010–2012)

Type of microfertilizers (factor B)	Application norm, l/ha (factor C)	Leaf surface area, thousand m^2/ha	Photosynthetic potential, million m^2 × days/ha	Pure photosynthesis productivity, g dry matter/m^2 of leaf area per day
Phase of closing leaves in a row (factor A)				
Without feeding (control)	-	34.5	1.03	5.48
Reakom R-beet (standard)	5.0	38.4	1.15	5.67
Reastim-humus-beet	3.0	37.5	1.12	5.61
	5.0	42.7	1.28	5.96
	7.0	44.5	1.34	6.26
Reakom-plus-beet	3.0	35.5	1.06	5.88
	5.0	44.6	1.34	6.50
	7.0	46.6	1.40	6.61
Closing leaves between rows (136 days from sowing) (factor A)				
Without feeding (control)	-	32.1	0.96	4.65
Reakom R-beet (standard)	5.0	36.5	1.09	5.29
Reastim-humus-beet	3.0	33.9	1.02	5.54
	5.0	41.0	1.23	5.67
	7.0	45.0	1.35	5.73
Reakom-plus-beet	3.0	37.6	1.13	5.37
	5.0	44.9	1.35	5.97
	7.0	50.6	1.52	6.31

According to the research results on the variants with the application of various types of micronutrients with different norms, on the first of September the photosynthetic potential was average and was within 1.03-1.40 million m^2 × days/ha. High indicators of photosynthetic potential were obtained in variants with Reastim-humus-beet and Reakom-plus-beet microfertilizers application in the norms of 5 and 7 l/ha. In comparison with the application norm of 3 l/ha these indicators were increased on 0.06–0.34 million m^2 × days/ha.

Reakom R-beet, Reastim-humus-beet and Reakom-plus-beet microfertilizers foliar feeding application amid a general background of fertilizer is establishing appropriate conditions for the photosynthetic process intensity increasing, especially pure photosynthetic productivity. The most favorable were areas in which the feeding was carried out in closing leaves in a row phase with the norm of micronutrients application of 5 and 7 l/ha. At Reakom R-beet application in the recommended norm of 5 l/ha for the production the pure photosynthetic productivity was 5.67 g of dry matter/m2 leaf area per day, at Reastim-humus-beet application in the norms of 5 – 5.96 and 7 l/ha – 6.26 g dry matter/m^2 leaf area per day respectively. After Reakom-plus-beet application in the norms of 5 and 7 l/ha, the pure photosynthetic productivity was respectively – 6.50 and 6.61 g dry matter/m^2 leaf area per day. Given that in these variants there was a high photosynthetic potential (1.15–1.40 million m2 × days/ha) and has created a favorable physiological background for productive work of each plant cell by the expense of micronutrients application, it were created the necessary conditions for a high level of photosynthesis process passing.

On September 1, at the second period of micronutrients application were also determined the indicators of photosynthesis productivity. It should be noted that the indicators of leaf surface area in all variants were almost in a par, as in the variants after the first term of micronutrients foliar feeding were in the range of 32.1 to 50.6 thousand m^2/ha. Photosynthetic potential value (0.96–1.52 million $m^2 \times$ days/ha) and pure photosynthetic productivity (4.65–6.31 g dry matter/m^2 leaf area per day) were lower in comparison with the first period of micronutrient application.

Summing up it should be noted that foliar feeding application in closing leaves in a row phase is delivers the productivity of photosynthesis increasing, particularly in variants where used Reakom R-beet microfertilizer at application norm of 5 l/ha, Reastim-humus-beet at application norms of 5 and 7 l/ha and the Reakom-plus-beet at the same norms, which resulted the high indicators of leaf area from 38.4 to 46.6 thousand m2/ha , the photosynthetic potential of 1.15 to 1.40 million $m^2 \times$ days/ha and pure photosynthetic productivity from 5.67 to 6.61 g dry matter/m ^{2} leaf area per day, and this in turn is impact on sugar beet final productivity. On net photosynthetic indicators productivity it is possible to predict the sugar beet productivity depending on the norms and types micronutrient application in feeding.

For the sugar beet plant growth and development the great value has provide micronutrients within the set terms of the growing season.

Researches have established that the introduction of microelements in set phase of sugar beet plants growth and development is positively influences on the processes of photosynthesis passage. Thus, foliar feeding conducting of sugar beet triploid hybrid Umanskyy ChS 97 of national selection in phase of leaves closure in rows is ensured of leaf surface area formation on 1 September – 34.7 thousand m^2/ha, and by the two times of feeding the leaf surface area is increased to 38.7 thousand m^2/ha, or was higher than on the control – 0.9 and 4.9 thousand m^2/ha respectively (Table 4).

On the second date of accounting (30 October) the leaf surface area for all variants was slightly lower compared with the accounting on the first of September, that due to the biological characteristics of culture and was within 30.3–34.9 thousand m^2/ha.

Leaf surface area was significantly higher as compared with control and with variants where were spent foliar application in phase of closing leaves in rows by two times of feeding – in closing leaves in a row phase and in the closing phase of the leaves in rows (for 136 days after sowing) which amounted to 34.9 thousand m^2/ha (SSD_{05} factor B – fertilization = 2.6 thousand m^2/ha).

For Oryx triploid hybrid of foreign selection is received similar results. On the first date of accounting the leaf surface area was higher by the all terms of foliar feeding and ranged from 33.4 to 40.6 thousand m^2/ha. It was significantly higher compared with the control by the two time of foliar feeding. On the second date of accounting (October 30) the leaf surface area was within 30.0-34.9 thousand m^2/ha, which is on 1.5-6.4 thousand m^2/ha above than control variant. Thus, as in the variant with Umanskyy ChS 97 is significantly higher values of leaf surface area (34.9 m^2/ha thousand) is received on two time variant of micronutrients application – in closing leaves in a row phase + in the closing leaves phase in rows (for 136 days after sowing). That is, on the increase of leaf surface area is significantly influenced the terms of microelements application.

Comparing the leaf surface area depending on the varietal characteristics it should be noted that significant differences in this index neither on the first, nor on the second date of the accounting in all terms of micronutrients application were not.

Foliar feeding application amid a general background of fertilizer is establishing appropriate conditions for the photosynthetic process intensity increasing, especially pure photosynthetic productivity. Net photosynthetic productivity was significantly higher in all variants with foliar feeding, compared with controls. Terms of foliar feeding application is also influence on the level of this index.

Net productivity of photosynthesis was significantly higher by the two time feeding of plants – during the closing leaves in a row phase + in the phase of closing leaves between rows (for 136 days after sowing) and single – in the phase of closing leaves in rows (for 136 days after sowing) as a hybrid Umanskyy ChS 97 and Oryx hybrid.

Table 4

Leaf surface area and photosynthetic productivity depending on the terms of microelements application in feed (average of 2010-2012)

Time of feeding (factor B)	Leaf surface area, thousand m^2/ha		Photosynthetic potential, million. m2 • days /ha		Net productivity of photosynthesis, g dry matter /m2 leaf surface per day	
	01.09	30.10	01.09	30.10	01.09	30.10
Umanskyy ChS 97 (factor A)						
Without feeding (control)	33,8	28,6	1,01	0,86	4,97	2,81
In the closing leaves in a row phase	34,7	30,3	1,04	0,91	5,10	3,08
In the phase of closing leaves between rows (for 136 days after sowing)	36,9	31,0	1,11	0,93	5,32	3,18
In the closing leaves in a row phase + in the phase of closing leaves between rows (for 136 days after sowing)	38,7	34,9	1,16	1,05	5,43	3,29
Orix (factor A)						
Without feeding (control)	36,7	28,5	1,10	0,85	5,02	2,90
In the closing leaves in a row phase	33,4	30,0	1,00	0,90	5,08	3,15
In the phase of closing leaves between rows (for 136 days after sowing)	39,0	35,0	1,17	1,05	5,49	3,49
In the closing leaves in a row phase + in the phase of closing leaves between rows (for 136 days after sowing)	40,6	34,9	1,22	1,05	5,56	3,56
SSD_{05} factor general	2,7		0,2		0,3	
SSD_{05} factor A (hybrid)	1,6		0,1		0,3	
SSD_{05} factor B (feeding)	2,6		0,1		0,1	

Conclusions. It is proved that the leaf surface area of diploid and triploid biological forms of sugar beet was almost the same and was 46,5–47,8 thousand m^2/ha, and respectively photosynthetic potential was almost the same – within 1.40-1.43. The significant difference depending on biological forms beet by the index of net productivity of photosynthesis was not.

With the density of planting increase is reduced leaf surface area. Density of plants is increasing from 90-100 to 101-110 thousand/ha does not lead to leaf surface area reduction. A similar dependence is obtained by the photosynthetic potential determining. A further increase of density as far as 136-145 thousand/ha is resulted in the reduction of leaf surface area, photosynthetic potential, and respectively – to net photosynthesis decrease, productivity and yield of sugar beet roots.

Foliar application use in phase of closing leaves between rows (136 days after sowing) is provides an increase of net productivity of photosynthesis in comparison with sugar beet feeding in closing leaves phase in rows, and especially by foliar application of new micronutrient Reastim-Humus-beet and Reakom-plus-beets by the application norms of 5 and 7 liters/ha as compared to the control (without feeding), and with the introduction of Reakom-R-beet fertilizers in the norm of 5 l/ha (standard).

Foliar feeding conducting in all time is providing increased of productivity of photosynthesis of both hybrids, due to higher indexes of leaf surface area, photosynthetic potential increasing – 0.85–1.05 million m^2 • day/ha and net productivity of photosynthesis – 2.81–3.56 g dry matter / m^2 leaf surface per day.

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Анотація

Карпук Л.М.

Фотосинтетична продуктивність цукрових буряків залежно від агротехнологічних прийомів вирощування

У статті досліджено вплив агротехнічних прийомів вирощування на показники фотосинтетичної продуктивності цукрових буряків. Доведено, що площа листкової поверхні і фотосинтетичний потенціал диплоїдних та триплоїдних біологічних форм цукрових буряків були майже однаковими. Зі збільшенням густоти насадження зменшується площа листкової поверхні. Підвищення густоти рослин з 90-100 до 101-110 тис./га не призводить до зменшення площі листкової поверхні. Використання позакореневого підживлення в фазу змикання листків у міжряддях (136 днів від сівби) забезпечує зростання чистої продуктивності фотосинтезу. Проведення позакореневого підживлення в усі строки забезпечує зростання продуктивності фотосинтезу обох досліджуваних гібридів.

Ключові слова: *цукрові буряки, фотосинтетична продуктивність, агротехнологічні прийоми вирощування*

Аннотация

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Фотосинтетическая продуктивность сахарной свеклы в зависимости от агротехнических приемов выращивания

В статье исследовано влияние агротехнологических приемов выращивания на показатели фотосинтетической продуктивности сахарной свеклы. Доказано, что показатели площади листовой поверхности и фотосинтетического потенциала *диплоидных и триплоидных биологических форм сахарной свеклы были почти одинаковыми. С увеличением густоты насаждения уменьшается площадь листовой поверхности. Повышение густоты растений с 90-100 до 101-110 тыс./га не приводит к уменьшению площади листовой поверхности. Использование внекорневой подкормки в фазу смыкания листьев в междурядьях (136 дней от посева) обеспечивает рост чистой продуктивности фотосинтеза. Проведение внекорневой подкормки во все сроки обеспечивает рост продуктивности фотосинтеза обеих исследуемых гибридов.*

Ключевые слова*: сахарная свекла, фотосинтетическая продуктивность, агротехнологические приемы выращивания*