

Effect of herbicides and soil treatments on beet yield

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Purpose. The purpose of the research was to establish the possibility of expanding beardless tillage in the cultivation of beets by combining them with soil herbicides in the Western Forest-Steppe of Ukraine. **Methods.** Field, analytical and statistical. **Results.** We found that the use of herbicides before sowing beets reduced the number of weeds by 4.5-7 times compared to the herbicide-free background. Thus, the use of soil herbicide Goldix on the background of plowing helped to reduce weeds before harvest, while the number of weeds was 4.8 pcs/m² when using beardless cultivation KLD-2.0 - 5.3 pcs/m², and when disking BDP-6.3 - 14.1 pcs m². The highest indicators of potential photosynthetic formation of beet plants variety Bikores were observed during the period of intensive growth (20.07) on variants with the application of pre-germinating herbicides Gladiator and Goldix in combination with plowing PLN 5-35 to a depth of 20-22 cm. They were 1.84 and 1.98 million m²/ha, respectively. Among the systems of basic tillage, the best were the variants with plowing PLN 5-35 to a depth of 20-22 cm and flat-cut tillage KLD-2.0 to a depth of 14-16 cm. Gladiator (5.0-6.0 l/ha) and Goldix (6.0 l/ha) were the most effective soil herbicides of the proposed herbicides, which provide root crop yields at the level of 63.9–64.5 t/ha. The highest content of dry matter in the roots of beets was observed when using the agent Goldix on the background of plowing (PLN 5-35 to a depth of 20-22 cm) and the background of flat-cut tillage (KLD-2.0 to a depth of 14-16 cm) - 11.7%, and 11.8%, respectively. The highest betanin content in the roots was observed in the variant when using the agent Goldix on the background of plowing to a depth of 20-22 cm - 265.1 mg/100 g of raw weight. In the herbicides Gladiator and Dual Gold applications, the betanin content ranged from 234.9 to 257.4 mg/100 g of raw weight. **Keywords:** beets, plowing, flat cultivation, disking, weeding, yield, herbicides.

Introduction

In recent years, a special place in the cultivation of vegetable crops is the primary cultivation; plowing consumes about 40% of total fuel costs, about 40% of material costs, 50% of working time, 25% of labor costs (Bezvikonnyi et al., 2020, Barabash, 1994). Therefore, in terms of increasing the cost of fuel, and hence all the work in crop production, the problem of studying, developing, and implementing in agricultural production resource-saving methods of tillage is put forward (Asyka & Smurov, 1990). The experience of advanced farms shows that using the same tillage system in all soil and climatic zones is impractical. It does not provide reliable protection of soils from erosion, does not promote the efficient use of soil moisture, and most importantly, with a shortage of energy may have excessive energy consumption (Shevchenko et al., 2008). Therefore, at the present stage of agricultural development, more and more attention is paid to the implementation of soil-protective resource-saving systems of basic tillage, which significantly injure the soil and positively affect its water and physical regimes and increase yields (Ivakin, 2012).

It is well known that tillage affects yields, but what it should be for a particular crop is still controversial. The same method can manifest itself differently in different soil and climatic conditions (Iodko & Iodko, 1990).

According to H. Sh. Tarchokov and F. H. Bzhinaev, the positive influence of beardless, minimal, and mouldboard cultivation on the productivity of crops has been found in many scientific institutions. At the same time, minimizing tillage yields not only decreases but also increases with the overall reduction of energy consumption for cultivation (Tarchokov & Bzhinaev, 1998).

At that time, studies have shown that plowing in comparison with surface tillage provides higher yields of crops but leads to a significant reduction in the humus content in the arable layer (Pisarenko et al., 2016).

It is noted that beardless tillage leads to reduced crop yields due to the deterioration of physical soil properties, the temporary weakening of biological activity and nutrient regime, and increased weed growth. Weed growth is one factor hindering their introduction into production (Budionny & Shevchenko, 2006).

It is known that crops of the broad-row method require a more extended period of active protection against weeds, which can last on average 50 days after germination (Ivashchenko, 2002). There is a relatively high efficiency of soil herbicides in the cultivation of row crops, especially beets, reducing the first most harmful wave of weeding (Kyryliuk, 2011; Raditska, 2008).

However, to date, very little material has been collected on the effectiveness of combining different tillage methods with herbicides. In addition, one of the main reasons for the low efficiency of beardless cultivation in the cultivation of row crops is the high level of weeding compared to mouldboard cultivation (Shevchenko, 2014).

Therefore, studies to determine the effectiveness of different tillage systems and their combination with the application of herbicides are relevant.

The study aimed to establish the possibility of expanding the use of beardless tillage in the cultivation of beets by combining them with the use of soil herbicides in the Western Forest-Steppe of Ukraine.

Materials and methods

The research was conducted in the Training and Production Center "Podillia" of Podilsk State Agrarian and Technical University during 2017-2019. Bicores variety (Netherlands) was studied. The soil of the experimental field is typical leached black soil, low-humus, medium loamy on forest-like loams. The content of humus (according to the Turin method) in the soil layer 0-30 cm is 3.8%. According to the Cornfield method, the content of easily hydrolyzable nitrogen compounds (according to the Cornfield method) is 118 mg/kg, mobile phosphorus and potassium compounds (according to the Chirikov method) are 153 mg/kg and 164 mg/kg of soil, respectively. The amount of absorbed bases ranges from 163-205 mg eq./kg. Hydrolytic acidity is 17-22 mg eq./kg, the degree of saturation of the bases - 90%. Scheme of the experiment: Factor A: 1. Plowing PLN 5-35 by 20-22 cm. 2. Flat-cut tillage KLD-2.0 by 14-16 cm. 3. Disking BDP-6.3 to a depth of 10-12 cm. Factor B: 1. Control (without herbicides); 2. Application of herbicides Gladiator 5.0-6.0 l/ha, Goldix 6.0 l/ha, and Dual Gold 1.2-1.6 l/ha were carried out before sowing.

The size of the sown area is 20 m², accounting - 15 m², the repetition of the experiment - four times.

Crop weeding in the experiment was determined by quantitative gravimetric method, crop yield - manually from the accounting area. Phenological observations, biometric and physiological-biochemical studies were performed according to the methods (Bondarenko & Yakovenko, 2001; Moiseyenko et al., 1996).

Results

We revealed that in the control variant, the number of weeds were 40.2-55.8 pcs/m², depending on the treatment variant in 2017-2019 (Table 1).

Table 1. Weediness of beet crops depending on tillage and application of herbicides, pcs/m², (average for 2017-2019).

The variant	Herbicides	Average	
		Before sowing	Before harvesting
Plowing PLN 5-35 20-22 cm	Control	40.6	74.0
	Gladiator	0	5.3
	Goldix	0	4.8
	Dual Gold	0	7.5
Flat cutting KLD-2.0 14-16 cm	Control	47.3	79.4
	Gladiator	0	7.6
	Goldix	0	5.3
	Dual Gold	0	8.1
Disking BDP-6.3 10-12 cm	Control	55.8	83.3
	Gladiator	0	17.4
	Goldix	0	14.1
	Dual Gold	0	20.2

With the application of herbicides, weeding was reduced, and before sowing, weeding was not observed in all variants. On average, over the years of research, the use of Gladiator herbicide on the background of tillage reduced weeds compared to the control of 5.3 pcs/m² on the background of plowing, 7.6 pcs/m². In the variant of KLD-2.0 to 17.4 pieces/m² in the variant with the processing of BDP-6.3. The application of Goldix soil herbicide helped to reduce weeds before harvest. Thus, against the background of plowing, the number of weeds was 4.8 pieces/m², when using beardless tillage KLD-2.0 - 5.3 pieces/m², and when disking BDP-6.3 - 14.1 pieces/m².

Dual Gold herbicide (1.2-1.6 l/ha) was less effective than Gladiator and Goldix herbicides. Thus, in the variant (BDP-6.3) the herbicide Gladiator proved to be more effective by 14%, and Goldix by 30% compared with Dual Gold. Before sowing beets reduces the number of weeds by 4.5-7.0 times compared to the herbicide-free background. Among the main tillage systems, the best were the variants with plowing PLN 5-35 to a depth of 20-22 cm and flat-cut tillage KLD-2.0 to a depth of 14-16 cm, which significantly reduces weeds compared to disking BDP-6.3 to a depth of 10-12 cm. When analyzing data on crops weediness during the period of active growth and development of plants, it was found that the number and weight of weeds changed over the years (Table 2).

The study results showed that in 2018 the dry weight of weeds was significantly lower compared to 2017 and 2019. On average, for three years, the highest dry weight of weeds was under control when disking the soil by 10-12 cm - 226.5 g/m² before harvesting. In the variants with plowing PLN 5-35 to a depth of 20-22 cm and flat-cutting tillage KLD-2.0 to a depth of 14-16 cm, the dry weight of weeds was lower and was 194.9 and 194.9 g/m², respectively. The dry weight of weeds increases with increasing clogging. The use of Gladiator, Goldix, and Dual Gold against the background of natural weed control (weed control) helped to reduce the dry weight of weeds compared to the control (with weeds, without pesticides). Thus, the lowest dry weight of weeds was when applying the soil herbicide Gladiator on the variant with plowing PLN 5-35 was 24.7 g/m²; it was slightly higher when applying the herbicide Goldix - 25.7 g/m².

After analyzing the total dry weight of weeds in the variants with the introduction of Gladiator, Goldix, and Dual Gold, it should be noted that the use of the herbicide Dual Gold contributed to the growth of the total dry weight of weeds in beet crops.

Table 2. The dry weight of weeds depending on tillage and action of soil herbicides, g/m².

Variant of tillage	Herbicides	2017		2018		2019		Average for 2017-2019	
		Before sowing	Before harvest ing	Before sowing	Before harvest ing	Before sowing	Before harvest ing	Before sowing	Before harvest ing
Plowing PLN 5-35 20–22 cm	Control	25.4	194.7	18.5	185.0	27.5	198.5	23.8	192.7
	Gladiator	0	28.8	0	17.7	0	27.5	0	24.7
	Goldix	0	27.3	0	20.0	0	29.9	0	25.7
	Dual Gold	0	29.8	0	27.8	0	32.3	0	30.0
Flat cutting KLD-2.0 14–16 cm	Control	31.6	200.4	21.6	186.8	29.9	197.5	27.7	194.9
	Gladiator	0	31.8	0	17.0	0	38.6	0	29.1
	Goldix	0	28.3	0	16.7	0	36.5	0	27.2
	Dual Gold	0	39.4	0	29.2	0	40.9	0	36.5
Disking BDP-6.3 10–12 cm	Control	26.7	219.2	29.6	209.2	33.3	251	29.9	226.5
	Gladiator	0	40.6	0	53.3	0	62.9	0	52.3
	Goldix	0	39.5	0	50.0	0	60.3	0	49.9
	Dual Gold	0	48.3	0	58.8	0	66.3	0	57.8

Thus, the combination of Gladiator and Goldix pre-germinating herbicides with plowing to a depth of 20–22 cm and flat cultivation to a depth of 14–16 cm is an effective means of reducing the number of weeds and their dry weight in the agrophytocenosis. It was found that obtaining a high yield of beetroots is proportional to the intensity of photosynthesis, which largely depends on the size of the leaf surface and photosynthetic potential (Table 3). The largest leaf surface area of beet plants was found in the variant of treatment with soil herbicide Goldix on the background of fallow plowing PLN 5-35 to a depth of 20-22 cm - 62.36 thousand m²/ha, which is 55.7% more than in control. In the variants where soil herbicides Dual Gold and Gladiator were applied, the level of this indicator was in the range of 56.30 and 60.88 thousand m²/ha, respectively. The formed leaf surface area on the variant with flat-cut tillage KLD-2.0 (14–16 cm) under the condition of applying the soil herbicide Goldix exceeded the corresponding control indicator (without herbicides - 39.87 thousand m²/ha) by 20.74 thousand m²/ha.

The tillage methods were characterized by the variantvariant characterized the lowest indicators of the leaf surface area among the methods of tillage with disk BDP-6.3 to a depth of 10–12 cm. One of the most critical parameters, which is closely related to the level of beets yield, given the productivity of the leaf apparatus, is the photosynthetic potential.

Accounts conducted during the study period showed that the use of pre-germinating herbicides Gladiator, Goldix, and Dual Gold combined with high-quality basic tillage has a positive effect on the formation of the photosynthetic apparatus of plants.

Thus, the highest indicators of potential photosynthetic formation of beet plants of the variety Bikores were observed during the period of intensive growth (20.07) on variants with pre-germinating herbicides Gladiator and Goldix in combination with plowing PLN 5-35 to a depth of 20-22 cm and amounted to 1.84 and 1.98 million m²/ha. These indicators of beet plants exceeded the control variant by 37.3% and 47.7%, respectively.

In the experiment variants, which used flat-cut tillage KLD-2.0 to a depth of 14–16 cm combined with the herbicides Gladiator, Goldix, and Dual Gold, the value of photosynthetic potential was 1.79, respectively; 1.83 and 1.65 million m²/ha.

It should be noted that the indicators of photosynthetic potential in the variants with BDP-6.3 disking to a depth of 10–12 cm in combination with herbicides were the lowest.

Thus, in the conditions of the Western Forest-Steppe of Ukraine, the formation of the photosynthetic potential of Bikores beet largely depended on the studied factors.

The dependence of the photosynthetic potential on the leaf surface area of beets in the variety Bicores is described by the following regression equation $y = 0.182 + 0.0271 * x$ and explains 97% of the variation of the variable $r = 0.969$, $R^2 = 0.93$ (Fig. 1).

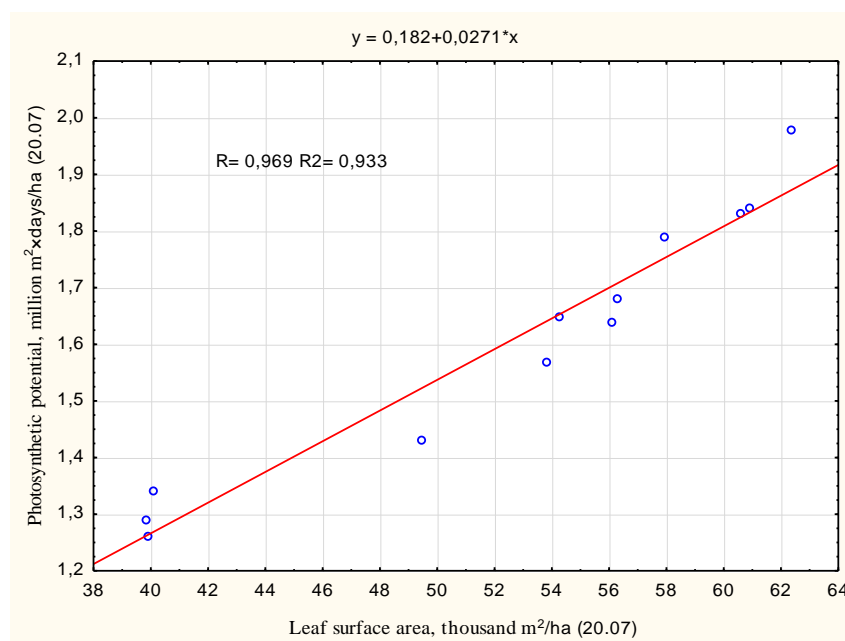
Experimental studies have shown (Fig. 2) that the yield of root crops is correlated with the photosynthetic potential and has a straightforward character: $y = -3.9609 + 36.5249 * x$. The linear correlation coefficient indicates a high positive direct strong correlation relationship between total yield and photosynthetic potential ($R = 0.94$). The coefficient of determination shows that the variation in total root yield is due to the variation of photosynthetic potential by 88%. This indicates a close correlation between the studied indicators.

According to the research results (Table 4), in the control variant, where no herbicides were applied, the yield of beets on the background with plowing to a depth of 20–22 cm was 42.3 t/ha, on the background of beardless tillage KLD-2, 0 by 0.7 t/ha less - 41.6 t/ha, and against the background of soil disking BDP-6.3 to a depth of 10–12 cm - 38.6 t/ha.

When using herbicides, the yield of beets increases. Thus, when using the herbicide Gladiator (5.0-6.0 l/ha) the average yield over the years of research was 63.9 t/ha on the background of plowing (PLN 5-35 to a depth of 20-22 cm), on the background of flat-cut tillage (KLD-2.0 to a depth of 14–16 cm) - 60.7 t/ha, and against the background of disking (BDP-6.3 to a depth of 10–12 cm) - 55.7 t/ha.

Table 3. Biological parameters and productivity of beets depending on tillage and application of herbicides (average for 2017-2019).

Variants	Herbicides	Leaf surface area, thousand m ² /ha (20.07)	Photosynthetic potential, million m ² × days/ha (20.07)
Plowing PLN 5-35 20–22 cm	Control	40.06	1.34
	Gladiator	60.88	1.84
	Goldix	62.36	1.98
	Dual Gold	56.30	1.68
	Control	39.87	1.26
Flat cutting KLD-2.0 14–16 cm	Gladiator	57.95	1.79
	Goldix	60.61	1.83
	Dual Gold	54.25	1.65
	Control	39.83	1.29
Disking BDP-6.3 10–12 cm	Gladiator	53.81	1.57
	Goldix	56.12	1.64
	Dual Gold	49.44	1.43
LSD ₀₅		7.53	0.12

**Fig. 1.** The relationship between the photosynthetic potential and the leaf area of beets (average for 2017-2019).

The highest yield of beetroots was obtained using the soil herbicide Goldix (6.0 l/ha). The yield of beetroots with the joint action of plowing the soil with the herbicide was 64.5 t/ha, with no-tillage - 60.4 t/ha, and in the variant with disking - 56.1 t/ha. Compared to the two previous herbicides, the soil herbicide Dual Gold (1.2–1.6 l/ha) was less effective.

The combination of basic tillage systems with herbicides in beet crops reduces the negative impact of unwanted vegetation due to a significant reduction in its number. With the combined action of tillage with herbicides, the yield of beetroots increases significantly during plowing (PLN 5-35 to a depth of 20-22 cm) and without beardless cultivation (KLD-2.0 to a depth of 14-16 cm).

The results of our studies showed (Table 5) that the elements of cultivation technology affected the quality of beetroots. There is a positive effect of pre-germinating herbicides on the increase of dry matter content in fruits in all studied variants. Thus, the highest dry matter content in the roots of beets was observed when using the agent Goldix on the background of plowing (PLN 5-35 to a depth of 20-22 cm) and the background of flat-cut tillage (KLD-2.0 to a depth of 14-16 cm) – 11.7%, and 11.8%, respectively. A significant decrease in the dry matter content in the roots was observed in the variants (without the use of herbicides), regardless of the methods of tillage - 10.8-10.9%.

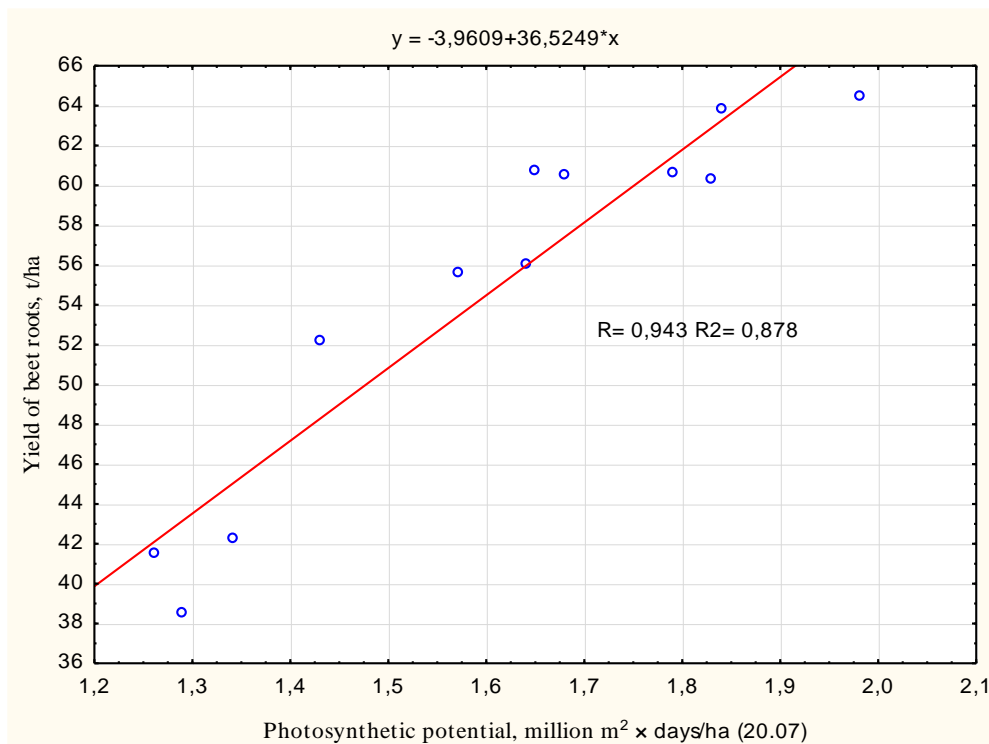


Fig. 2. Relationship between photosynthetic potential and yield of beetroots (average for 2017-2019).

Table 4. Yield of beet roots depending on tillage and application of herbicides, t/ha.

Variants	Herbicides	Year of research			Average for three years
		2017	2018	2019	
Plowing PLN 5-35 20–22 cm	Control	40.6	42.9	43.4	42.3
	Gladiator	60.2	65.2	66.3	63.9
	Goldix	64.1	64.5	64.8	64.5
	Dual Gold	57.9	61.7	62.3	60.6
Flat cutting KLD-2.0 14–16 cm	Control	41.1	41.9	41.9	41.6
	Gladiator	57.6	62.1	62.5	60.7
	Goldix	57.2	61.5	62.4	60.4
	Dual Gold	59.5	61.7	61.3	60.8
Disking BDP-6.3 10–12 cm	Control	38.5	39.2	38.0	38.6
	Gladiator	53.4	56.7	57.0	55.7
	Goldix	54.1	58.7	55.4	56.1
	Dual Gold	52.0	53.7	51.0	52.2
	LSD ₀₅	4.52	5.34	5.71	

An essential indicator of the quality of the roots is the content of sugars, which ensure their taste and positively affect the duration of storage. The highest content of total sugars was characterized by roots of Bikores variety - 9.0% in the variant of application of Goldix herbicide against the background of flat-cut tillage to a depth of 14–16 cm. In the variants without herbicides, the sugar content was the lowest, 8.0-8.1%. Among the methods of tillage, the best variants were plowing and flat tillage.

Betanin is one of the critical chemical indicators of the composition of beetroot content. The analysis results showed that the highest content of betanin in the roots was observed in the variant when using the agent Goldix on the background of plowing to a depth of 20-22 cm - 265.1 mg/100 g of raw weight. In the herbicides Gladiator and Dual Gold applications, the betanin content ranged from 234.9 to 257.4 mg/100 g of raw weight.

The research results showed a positive reaction of the studied beet variety to herbicides. In all variants of soil herbicides use, the content of nitrates in the roots of beets increased, but the value of this indicator did not exceed the MDR (1400 mg/kg of raw weight). In our opinion, the increase in nitrate content in root crops is an indirect confirmation of microbiological processes strengthening that occurs in the plant when applied pre-germinating herbicides.

Table 5. Influence of tillage and application of herbicides on biochemical parameters of beetroots (average for 2017-2019).

Variants	Herbicides	Dry matter,%	Sugars,%	Betanine mg/100 g of raw weight	Nitrates mg/kg
Plowing PLN 5-35 20–22 cm	Control	10.9	8.1	221.5	843
	Gladiator	11.4	8.7	257.4	856
	Goldix	11.7	8.9	265.1	850
	Dual Gold	11.2	8.5	249.9	858
Flat cutting KLD-2.0 14–16 cm	Control	10.9	8.0	221.8	843
	Gladiator	11.6	8.8	245.3	866
	Goldix	11.8	9.0	253.2	858
	Dual Gold	11.2	8.5	240.1	870
Disking BDP-6.3 10–12 cm	Control	10.8	8.1	221.6	844
	Gladiator	11.2	8.3	237.8	906
	Goldix	11.5	8.6	250.7	889
	Dual Gold	11.2	8.1	234.9	916
LSD ₀₅		0.11	0.09	4.27	128

Note: MDR N-NO³⁻ = 1400 mg/kg

Conclusion

The application of Goldix soil herbicide helped to reduce weeds before harvest. Thus, against the background of plowing, the number of weeds was 4.8 pieces/m², when using beardless tillage KLD-2.0 - 5.3 pieces/m², and when disking BDP-6.3 - 14.1 pieces/m².

2. In the variants with plowing of PLN 5-35 to a depth of 20–22 cm and flat-cut tillage of KLD-2.0 to a depth of 14–16 cm, the dry weight of weeds was lower and was 194.9 and 194.9 g/m², respectively. Combining Gladiator and Goldix pre-germinating herbicides with 20–22 cm deep plowing and 14–16 cm deep cultivation is an effective way to reduce weeds and dry matter agrophytocenosis.

3. The largest leaf surface area of beet plants was found in the variant with treatment with soil herbicide Goldix on the background of fallow plowing PLN 5-35 to a depth of 20-22 cm - 62.36 thousand m²/ha, which is 55.7% more, than on control. In the variants where soil herbicides Dual Gold and Gladiator were applied, the level of this indicator was in the range of 56.30 and 60.88 thousand m²/ha, respectively.

4. The highest indicators of potential photosynthetic formation of beet plants of the variety Bikores were observed during the period of intensive growth (20.07) on variants with the application of pre-germinating herbicides Gladiator and Goldix in combination with plowing PLN 5-35 to a depth of 20-22 cm and were 1.84 and 1.98 million m²/ha, respectively. These indicators of beet plants exceeded the control variant by 37.3% and 47.7%, respectively.

5. It is established that the yield of root crops is correlated with the photosynthetic potential and has a rectilinear character: $y = -3.9609 + 36.5249 * x$. The linear correlation coefficient indicates a high positive correlation between total yield and photosynthetic potential ($R = 0.94$).

6. Among tillage methods, the highest yields are obtained in the variants with plowing and flat cultivation. Among the proposed herbicides, the soil herbicides Gladiator (5.0-6.0 l/ha) and Goldix (6.0 l/ha) were the most effective, which provide root yields at the level of 63.9–64.5 t/ha.

7. The highest content of dry matter in the beetroots was observed when using the agent Goldix on the background of plowing (PLN 5-35 to a depth of 20-22 cm) and on the background of flat-cut tillage (KLD-2.0 to a depth of 14-16 cm) – 11.7%, and 11.8%, respectively. The highest content of betanin in the roots was observed in the variant when using the agent Goldix on the background of plowing to a depth of 20-22 cm - 265.1 mg/100 g of raw weight. In the herbicides Gladiator and Dual Gold applications, the betanin content ranged from 234.9 to 257.4 mg/100 g of raw weight.

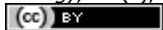
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