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ENERGY SUBSTANTIATION OF AGROTECHNICAL MEASURES OF SUGAR BEET CULTIVATION

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The goal of agricultural intensification is to obtain high, stable and sufficiently predictable crop yields. The energy feasibility study of agrotechnical measures helps to optimize the conditions for growing crops. Its task is to realize in practice the possible level of use of solar energy, soil and climatic resources, genetic potential of zoned and promising varieties in order to obtain high crop yields with minimal material, monetary and energy costs The need for energy assessment is due to high prices for energy carriers, mineral fertilizers, and pesticides.

The article presents the results of a study on the impact of agrotechnical measures on changing the energy balance when growing sugar beet under irrigation in the south of Ukraine.

The aim of the research was to assess the bioenergy efficiency of individual elements of sugar beet cultivation technology. To achieve this goal, the method of comparative analysis, as well as calculation and abstract logical methods were used.

The field experiments were conducted in the Kherson region in the Ingulets irrigated area. The soil cover is represented by dark chestnut slightly saline medium loamy soils.

The highest energy intake with the harvest of sugar beet roots – 390.3-396.7 thousand MJ/ha, the maximum total energy consumption – 133.1-134.6 and the highest energy gain – 229.2-234.8 MJ/ha were at both plowing depths, provided that organic-mineral fertilizers were applied at a rate of 40 t/ha of manure + N150P150K60 of the second sowing term and plant density of 110 thousand plants. /ha, and the highest coefficient of energy efficiency on unfertilized – 2.57-2.91 and organic fertilizer backgrounds (2.57-2.79).

Thus, to obtain the highest energy efficiency coefficient for sugar beet cultivation on dark chestnut irrigated soils, we recommend plowing to a depth of 20-22 cm, applying organic and mineral fertilizers at a rate of 40 t/ha of manure + N150P150K60, sowing at a soil temperature of 8-9°C and forming a plant density of 110 thousand/ha.

Key words: *sugar beet, agrotechnical factors, bioenergy analysis, energy input, energy expenditure, energy coefficient.*

Минкін М.В. Енергетичне обґрунтування агротехнічних заходів вирощування буряків цукрових

Метою інтенсифікації землеробства є одержання високих, стабільних і достатньо прогнозованих урожаїв сільськогосподарських культур. Енергетичне обґрунтування агротехнічних заходів сприяє оптимізації умов вирощування культури. Його завданням є практична реалізація можливого рівня використання сонячної енергії, ґрунтово-кліматичних ресурсів, генетичного потенціалу районованих і перспективних сортів з метою одержання високих урожаїв сільськогосподарських культур з мінімальними матеріальними, грошовими й енергетичними затрата Необхідність проведення енергетичної оцінки зумовлена високими цінами на енергетичні носії, мінеральні добрива, пестициди.

У статті наведено результати дослідження щодо вивчення впливу агротехнічних заходів на зміну енергетичного балансу при вирощуванні буряку цукрового за зрошення в умовах півдня України.

Метою наукового дослідження було проведення оцінки біоенергетичної ефективності окремих елементів технології вирощування буряків цукрових. Для реалізації поставленої мети використовували метод порівняльного аналізу, а також розрахунковий та абстрактно-логічний методи.

Польові досліди проводилися в Херсонській області в зоні Інгулецького зрошуваного масиву. Ґрунтовий покрив представлений темно-каштановими слабо солонцевими середньо суглинистими ґрунтами.

Найбільше надходження енергії з урожаєм коренеплодів цукрових буряків – 390,3-396,7 тис. МДж/га, максимальні загальні витрати її – 133,1-134,6 і найвищий приріст енергії – 229,2-234,8 МДж/га були на обох глибинах оранки, за умови внесення органо-мінеральних добрив нормою 40 т/га гною + $N_{150}P_{150}K_{60}$ другого строку сівби й густоти стояння рослин 110 тис./га, а найвищий коефіцієнт енергетичної ефективності на неудобрених – 2,57-2,91 та органічних фонах живлення (2,57-2,79).

Таким чином, рекомендуємо для одержання найвищого коефіцієнта енергетичної ефективності при вирощуванні цукрових буряків на темно-каштанових зрошуваних ґрунтах проводити оранку на глибину 20-22 см, вносити органо-мінеральні добрива нормою 40 т/га гною + $N_{150}P_{150}K_{60}$, проводити сівбу при температурі ґрунту 8-9°С та формувати густоту стояння рослин на рівні 110 тис./га.

Ключові слова: *буряк цукровий, агротехнічні фактори, біоенергетичний аналіз, прихід енергії, витрати енергії, енергетичний коефіцієнт.*

Statement of the problem. The technology of sugar beet cultivation is costly due to the application of organic, mineral fertilizers and plant protection products, inter-row tillage, plant density formation, and harvesting. The effectiveness of the use of elements of sugar beet cultivation technology is determined not only by assessing the value of the increase in the production with the cost of cultivation associated with the use of technology, but also by the ratio of renewable energy to non-renewable energy. Therefore, determining the energy efficiency of the elements of sugar beet cultivation technology in the conditions of unstable moisture in the south of Ukraine is relevant.

Analysis of recent research and publications. In modern economic conditions, the intensification of production is accompanied by an increase in the energy intensity of products, so to identify reserves for its reduction, a bioenergy assessment of both individual elements and the technology of growing the crop as a whole is carried out [1-3].

The need for an energy assessment is driven by high prices for energy carriers, mineral fertilizers, and pesticides. For example, 1 kg of nitrogen fertilizers in terms of 100% of nutrients in terms of energy consumption is equal to 61.74 MJ, phosphorus fertilizers – 10.92 MJ and potash fertilizers – 6.72 MJ; 1 kg of herbicides – 348.99 MJ, fungicides – 205.67 MJ; 1 ton of manure – 688.8 MJ. The energy equivalent of 1 kg of gasoline is 54.6 MJ, diesel fuel – 52.92, and live labor per man-hour – 12.0 MJ [5].

Sugar beet is an intensive crop. High yields of sugar beet require an increasing use of labor and energy for production. To create each additional ton of harvest, energy is consumed, which is carried by high-quality pre-sowing seed preparation, formation of an optimal phytocoenosis, foliar fertilization of plants, timing of root crop harvesting and use of various biological forms of sugar beet that actively influence plant growth and development. The energy content of 1 kg of sugar beet roots is 610.5 kcal. The analysis of bioenergy indicators allows to make effective calculations on the optimal use of fertilizers and other biological and technological factors in order to maximize the genetic potential of sugar beet plants. Bioenergy indicators allow all elements of agrotechnology, technical means, resources to be brought to a single indicator – J, and thus to establish the active position of each element of the technological process system [4-7].

Statement of the task. The aim of the research was to assess the bioenergy efficiency of individual elements of sugar beet cultivation technology. To achieve this goal, we used the method of comparative analysis, as well as calculation and abstract and logical methods.

The field experiments were conducted in the Kherson region in the Ingulets irrigated area. The soil cover is represented by dark chestnut slightly saline medium loamy soils.

The following factors and their variants were included in the experimental design:

Factor A – plowing to a depth of 20-22 cm and 28-30 cm seeding rate of similar seeds: 6; 9 and 12 million pcs/ha.

Factor B – fertilizer background: no fertilizers, N150P150K60, Manure 40 t/ha + N150P150K60, Manure 40 t/ha.

Factor C – sowing time: the first term – at a soil temperature at the depth of seeding (4-5 cm) – 6-8 ° C; the second – ten, the third – 20 days after the first term.

Factor D – plant density: 90, 110 and 130 thousand/ha.

Calculations of bioenergy efficiency were carried out according to the methodology of bioenergy assessment of crop production technologies [3, 4].

Summary of the main research material. Thanks to photosynthetic activity, plants are able not only to use but also to accumulate energy in the crop. To increase the yield of agricultural crops, it is necessary to increase energy consumption for fertilization, protection of plants from pests, diseases and crops from weeds, etc. Therefore, the main task of agricultural producers is to increase the yield, which increases the energy supply.

The main task of energy analysis is to find and plan agricultural production methods that ensure the rational use of non-renewable and renewable energy and environmental protection.

The purpose of assessing the bioenergy efficiency of a technology is to determine the payback of the total energy accumulated in the crop or its productive part, as well as to determine the level of energy intensity of the products obtained.

To calculate the energy efficiency of sugar beet cultivation technology, we have drawn up technological maps that indicate the list of activities, as well as the scope and time of their implementation.

Table 1 shows the energy input data, which were calculated according to the sugar beet yield and the total energy content per 1 kg of dry matter.

The least energy was accumulated with the harvest in the variants without fertilizers and plowing to a depth of 20-22 cm (96.8-141.5 thousand MJ/ha). In the plots of deep plowing without fertilizers, slightly more energy was accumulated (113.2-150.2 thousand MJ/ha) than in the plots of shallow plowing. The same pattern was observed in the accumulation of energy with the sugar beet harvest and in fertilized plots where only mineral and only organic fertilizers were applied.

Thus, in the variants of shallow plowing, depending on the timing of sowing and plant density, 224.6-352.4 thousand MJ/ha were received with the harvest on the background of N150P150K60, and 163.0-240.6 thousand MJ/ha on the background of organic fertilizers, while in the areas of deep plowing – 232.8-361.5 and 170.7-246.5 thousand MJ/ha, respectively. Against the background of the use of organic-mineral fertilizers, a different pattern was observed, i.e., in the variants of shallow plowing, 0.6-2.7% more energy was accumulated than in the variants of deep plowing.

Fertilizers provided a significant increase in energy supply. The first place in energy accumulation with the harvest was taken by the variant with the use of organic-mineral fertilizers, the second – mineral and the third – organic.

The timing of sowing also influenced the energy supply with the harvest. The least energy was received with the crop in all variants of the experiment when sowing in the third term, and the most – in the second term of sowing sugar beet. Thus, without the use of fertilizers, depending on the depth of plowing and plant density, 96.8-126.5 thousand MJ/ha were received in the third sowing term. MJ/ha, in the second – 121.0-150.2; against the background of mineral fertilizers – 224.6-290.3 and 289.0-361.5; against the background of organic-mineral – 247.4-303.1 and 331.0-396.7 and against the background of organic fertilizers – 163.0-194.9 and 213.6-246.5 thousand MJ/ha, respectively.

Table 1

Energy input depending on the studied factors, thousand MJ/ha

Power supply background	Sowing period	Plant density, thousand/ha		
		90	110	130
Plowing to a depth of 20-22 cm				
Without fertilizers	First.	116,0	120,5	108,2
	Second.	131,9	141,5	121,0
	Third.	107,3	110,9	96,8
$N_{150}P_{150}K_{60}$	First.	242,9	282,6	261,1
	Second.	289,0	352,4	323,2
	Third.	224.6	280,7	255,6
Manure 40 t/ha + $N_{150}P_{150}K_{60}$	First.	272,5	325,0	293,0
	Second.	334,2	336,7	359,3
	Third.	248,8	303,1	278,5
Manure 40 t/ha	First.	165,7	197,2	178,9
	Second.	213,6	240,6	220,9
	Third.	163,0	186,3	171,6
Plowing to a depth of 28-30 cm				
Without fertilizers	First.	131,0	131,5	115,5
	Second.	147,9	150,2	128,3
	Third.	122,3	126,5	113,2
$N_{150}P_{150}K_{60}$	First.	247,9	293,5	263,4
	Second.	296,7	361,5	327,3
	Third.	232,8	290,3	262,0
Manure 40 t/ha + $N_{150}P_{150}K_{60}$	First.	265,7	317,3	290,8
	Second.	331,0	390.3	353,8
	Third.	247,4	296,7	271,2
Manure 40 t/ha	First.	172,6	205,0	184,9
	Second.	219,1	246,5	226,4
	Third.	170,7	194,9	178,9

Comparing the density of sugar beet plants, it should be noted that an increase in the number of plants from 90 to 110 thousand/ha led to an increase in energy intake on all nutrition backgrounds, and an increase in the number of plants from 90 to 130 thousand/ha on variants without fertilizers led to a decrease in energy, and on fertilized ones – to an increase in energy.

The highest energy intake was with sugar beet roots in all variants at a planting density of 110 thousand/ha.

Energy consumption is directly related to energy intake: the more energy is supplied, the more it is consumed, which is associated with additional costs for deepening plowing and fertilizer application (Table 2). While plowing to a depth of 20-22 cm consumes 1224 MJ per hectare, deep plowing consumes 1416 MJ.

Only fertilizer application increases energy consumption: mineral fertilizers – by 51244 MJ/ha; organic fertilizers – by 21122, and organic-mineral fertilizers – by

72366 MJ/ha. Energy costs also increase due to the additional harvesting of sugar beets, with 68.52 MJ consumed per centner of root crops.

In the structure of energy costs, the highest costs are for gasoline and diesel fuel, which, depending on the experimental variant, range from 5766 to 23637 and from 7329 to 17344 MJ/ha, respectively.

In our experiments, the lowest energy consumption for sugar beet cultivation was observed in the variants without fertilizers at both plowing depths at the third sowing term and plant density of 130 thousand/ha – 43.5-46.1 thousand. MJ/ha, and the highest – against the background of organo-mineral fertilizers at a rate of 40 t/ha of manure + N150P150K60 at the second sowing term and plant density of 110 thousand/ha – 161.1-161.9 MJ/ha, which is mainly due to the level of yield in these variants.

Table 2

Energy consumption for growing sugar beet roots depending on the studied factors, thousand MJ/ha

Power supply background	Sowing period	Plant density, thousand/ha		
		90	110	130
Plowing to a depth of 20-22 cm				
Without fertilizers	First.	46,3	47,0	45,2
	Second.	48,7	50,2	47,1
	Third.	45,0	45,6	43,5
$N_{150}P_{150}K_{60}$	First.	116,5	122,6	119,4
	Second.	123,6	133,1	128,7
	Third.	113,9	122,3	118,9
Manure 40 t/ha + $N_{150}P_{150}K_{60}$	First.	143,2	151,1	146,4
	Second.	152,5	161,9	156,2
	Third.	139,6	147,8	144,1
Manure 40 t/ha	First.	75,9	80,6	77,9
	Second.	83,1	87,2	84,2
	Third.	75,5	79,0	76,8
Plowing to a depth of 28-30 cm				
Without fertilizers	First.	48,8	48,8	46,5
	Second.	51,3	51,7	48,4
	Third.	47,5	48,1	46,1
$N_{150}P_{150}K_{60}$	First.	117,6	124.4	119,9
	Second.	124,9	134,6	129,5
	Third.	115,3	123,9	119,7
Manure 40 t/ha + $N_{150}P_{150}K_{60}$	First.	142,4	150,1	146,1
	Second.	152,2	161,1	155,6
	Third.	139,6	147,9	143,2
Manure 40 t/ha	First.	77,1	82,0	79,0
	Second.	84,1	88,2	85,2
	Third.	76,9	80,5	78,1

Energy consumption is directly related to energy intake: the more energy is supplied, the more it is consumed, which is associated with additional costs for deepening plowing and fertilizer application.

An important indicator in bioenergy assessment is the energy efficiency coefficient, which is determined by the ratio between the amount of energy accumulated by the crop and the amount of energy used for production.

The calculations of the efficiency factor are shown in Table 3.

Table 3

Energy efficiency factor of sugar beet cultivation depending on the factors under study

Power supply background	Sowing period	Plant density, thousand/ha		
		90	110	130
Plowing to a depth of 20-22 cm				
Without fertilizers	First.	2,51	2,56	2,39
	Second.	2,71	2,82	2,57
	Third.	2,38	2,43	2,23
$N_{150}P_{150}K_{60}$	First.	2,08	2,31	2,19
	Second.	2,34	2,65	2,51
	Third.	1,98	2.30	2.15
Manure 40 t/ha + $N_{150}P_{150}K_{60}$	First.	1,90	2,15	2,00
	Second.	2,19	2,45	2,30
	Third.	1,78	2,05	1,93
Manure 40 t/ha	First.	2,18	2,45	2,30
	Second.	2,57	2,76	2,62
	Third.	2,16	2,36	2,23
Plowing to a depth of 28-30 cm				
Without fertilizers	First.	2,68	2,69	2,48
	Second.	2,88	2,91	2,65
	Third.	2,57	2,63	2,46
$N_{150}P_{150}K_{60}$	First.	2,11	2,36	2,20
	Second.	2,38	2,69	2,53
	Third.	2,02	2,34	2,19
Manure 40 t/ha + $N_{150}P_{150}K_{60}$	First.	1,87	2,11	1,99
	Second.	2,17	2,42	2,27
	Third.	1,77	2,01	1,89
Manure 40 t/ha	First.	2,24	2,50	2,34
	Second.	2,61	2,79	2,66
	Third.	2,22	2,42	2,29

The lowest coefficients (1.77-1.78) were obtained when sugar beet was grown on an organic-mineral nutrition background, at the third sowing term and plant density of 90 thousand/ha, and the highest – without fertilizers and on the background of organic fertilizers – 2.57-2.91 and 2.57-2.79, respectively, at the second sowing term. On the mineral and organic-mineral fertilizer backgrounds, the energy efficiency coefficients were lower compared to the unfertilized and organic fertilizer backgrounds.

This is due to the fact that the application of mineral and organic-mineral fertilizers increases energy consumption for their application and harvesting of additional crops.

Conclusions. Thus, the calculations of the bioenergy assessment of sugar beet production allow us to draw the following conclusions.

The highest energy supply with the harvest of sugar beet roots – 390.3-396.7 thousand MJ/ha, the maximum total energy consumption – 133.1-134.6 and the highest energy gain – 229.2-234.8 MJ/ha were at both plowing depths, provided that organic-mineral fertilizers were applied at a rate of 40 t/ha of manure + N150P150K60 of the second sowing term and plant density of 110 thousand plants. /ha, and the highest coefficient of energy efficiency on unfertilized – 2.57-2.91 and organic fertilizer backgrounds (2.57-2.79).

Thus, to obtain the highest energy efficiency coefficient for sugar beet cultivation on dark chestnut irrigated soils, we recommend plowing to a depth of 20-22 cm, applying organic and mineral fertilizers at a rate of 40 t/ha of manure + N150P150K60, sowing at a soil temperature of 8-9°C and forming a plant density of 110 thousand/ha.

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