

The effect of fertilizer on the use of soil moisture and the productivity of sugar beet in short crop rotations

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Purpose. To establish conditions of stable moisture supply and to achieve high productivity of sugar beet in short crop rotations by optimizing their structure and fertilization system. **Methods.** Long-term field and analytical. **Results.** The results of research on the influence of organic-mineral fertilization on soil moisture availability and biological productivity of sugar beet in short grain-beet crop rotations are presented. It was found that at the beginning of the growing season of sugar beet, high reserves of productive moisture were accumulated in the 1.5 m layer of the soil, which amounted to 225-270 mm. The crop rotation structure had a greater influence on soil moisture than the fertilization system. Under the mineral fertilization (N48.8P45K55 per 1 ha of crop rotation), moisture reserves in 1.5 m layer of soil in crop rotations with predecessors of barley-peas and peas-vetch-oats were higher than in crop rotation with two soybean fields - by 25-38 mm/ha. The combined application of organic and mineral fertilizers increased the reserves of productive moisture in the 1.5 m soil layer at the beginning of the sugar beet vegetation by 5-27 mm compared to the mineral fertilization system. It was established that sugar beet more effectively used soil moisture under the combined application of mineral fertilizers, by-products and green mass of the intermediate crop of white mustard in the crop rotations of barley-pea-winter wheat-sugar beet and soybean-soybean-winter wheat-sugar beet. It was found that the highest biological productivity of sugar beet in short grain-beet crop rotations under conditions of sufficient moisture provided the application of N48.8P45K55 + green manure + by-products per 1 ha of crop rotation, while the structure of crop rotations had less effect on productivity indicators. **Conclusions.** In crop rotations with barley-peas and peas-vetch-oats, the reserves of productive moisture in 1.5 m layers of soil at the beginning of the growing season were 15-17 mm higher than in crop rotation with soybean. Application of N48.8P45K55 + green manure + by-products in crop rotations of barley-peas-winter wheat-sugar beet and soybean-soybean-winter wheat-sugar beet ensured the lowest moisture consumption for the formation of a biological yield of sugar beet - 305 m³/t with a decrease to the background of mineral fertilization by 24-31 m³. The highest biological productivity of sugar beet was achieved in the rotation of barley - peas - winter wheat - sugar beets with the application of N48.8P45K55 + green manure + by-products per 1 ha of the crop rotation: sugar yield - 13.2 t/ha with exceeding the background of mineral fertilization - by 1.8 t/ha, exceeding the similar options in crop rotations with soybean and peas- vetch-oats – by 0.6 t/ha.

Key words: *moisture supply, crop rotation, sugar beet, productivity.*

Introduction. Optimizing the structure of crop rotation and the fertilisation system are the most effective means of influencing the productivity of sugar beet [1]. Obtaining stable yields of sugar beet in conditions of a total shortage of manure and warming requires the application of alternative organic-mineral fertilisation systems, which include the use of by-products of agricultural crops as fertiliser, and under conditions of sufficient moisture, additionally the use for fertiliser a green manure of intermediate crops [2], [3]]. Enriching the soil with an organic component contributes to the formation of humus, stabilization of the soil structure, improvement of nutrient and water regimes, conditions are created that can provide plants with a sufficient amount of moisture and nutrients during the growing season [4], [5].

In the conditions of warming and increasing aridity of the climate, measures aimed at preserving soil moisture and optimizing the nutrient regime are the foundation for obtaining high and stable yields in the long term [6], [7].

The question of the sustainability of sugar beet cultivation becomes especially relevant with the transition to short-rotational crop rotations. The absence of perennial leguminous grasses and the minimization of manure application in crop rotations with a short rotation requires agrochemical measures capable of saturating the soil with organic matter, increasing the mobility of nutrients, increasing soil moisture reserves, which together form a favourable trophic environment for the stable cultivation of sugar beet [8], [9]. The effectiveness of these measures depends on the soil and climatic conditions, and therefore research on this topic is quite relevant in the sugar beet cutting area [10].

The aim of the research was to create conditions for a stable moisture supply and to achieve high productivity of sugar beet in short-rotation crop rotations by optimizing their structure and fertilisation system.

Research materials and methods. Scientific research was conducted during 2019-2022 in a long-term field experiment on leached chernozem of the Uladovo-Lyulynets research and selection station of the IBC&SB.

The area of the sowing plot is 200 m², the accounting area is 100 m². Placement of options in experiments is systematic and sequential, repeated three times.

The soil of the experimental field is leached light loamy chernozem, has the following agrochemical and physicochemical characteristics of the 0-30 cm layer: saline pH - 6.0-6.3, hydrolytic acidity by Kappen - 1.12-1.28 mg-equiv./100 g of soil, the amount of absorbed bases by Kappen-Ghilkovits – 24.2-27.5 mg-equiv./100 g of soil, humus content by Tyurin – 3.9-4.1%, alkaline hydrolyzed nitrogen – 119-128 mg/kg of soil, mobile phosphorus and potassium by Chirikov - 161-174 and 67-86 mg/kg of soil, respectively.

In the experiments, the Boruta sugar beet hybrid, manufactured by Hilleshög (Germany), was sown. The hybrid has a potential yield of 100 t/ha, is characterized by intensive initial growth and high productivity, is resistant to rhizomania and cercosporosis. Mineral fertilisers were applied in autumn under plowing: ammonium nitrate (34.5% N), simple granulated superphosphate (19.5% P₂O₅) and potassium chloride (60% K₂O). Agricultural technology for growing sugar beet corresponded to the generally accepted Ukrainian intensive technology for the forest-steppe zone.

To determine the reserves of productive moisture, soil samples were taken to a depth of 1.5 m with an interval of 10 cm. After drying for 6 hours at a temperature of 120 °C, the moisture content of the soil samples was determined and the reserves of productive moisture in 1.5 layers were calculated.

Harvesting and recording of the harvest was carried out by the method of trial plots, followed by weighing and conversion to an area of 1 ha. The research results were processed by the method of dispersion and correlation analyses.

Research results and their discussion. The research results showed that, on average, during the research years (2019-2022), at the beginning of the sugar beet growing season, high reserves of productive moisture, which amounted to 225-270 mm, were accumulated in the 1.5 m layer of the soil. With the application of mineral fertilisers (N48.8P45K55 per 1 ha of crop rotation) in crop rotations with predecessors of barley-peas and pea-vitch-oats, moisture reserves in 1.5 soil layers

were higher than in crop rotations with two soybean fields - by 25-38 mm /ha (Table 1).

Table 1

Consumption of productive moisture from 1.5 m soil layer during the growing season of sugar beet depending on crop rotation and fertilisation, ULDSS, 2019-2022.

No. var	Fertilizers were applied per 1 ha crop rotation	Productive moisture during germination, mm	Precipitation during the growing season, mm	Productive moisture at the time of harvesting, mm	Moisture consumption during the growing season, m ³ /ha	Biological productivity, t/ha of dry matter	Planting density, thousands of units/ha	Moisture consumption per 1 plant, m ³	Moisture consumption per 1 ton of biological crop, m ³
Soybean-soybean-winter wheat-sugar beet									
1	N48.8P45K55	225	386	73	5380	16,35	108	0,050	329
2	N48.8P45K55 + by-products	251	386	68	5690	17,53	103	0,055	325
3	N48.8P45K55 + green manure + by-products	245	386	67	5640	18,52	108	0,052	305
4	N48.8P45K55 + 10 t/ha of manure	252	386	65	5730	18,60	110	0,052	308
Barley-peas-winter wheat-sugar beet									
5	N48.8P45K55	263	386	82	5670	16,87	110	0,052	336
6	N48.8P45K55 + by-products	268	386	75	5790	17,44	109	0,053	332
7	N48.8P45K55 + green manure + by-products	265	386	73	5780	18,93	112	0,052	305
8	N48.8P45K55 + 10 t/ha of manure	270	386	73	5830	18,82	111	0,053	310
Peas-vetch-oats-winter wheat-sugar beet									
9	N48.8P45K55	250	386	74	5620	16,00	109	0,052	351
10	N48.8P45K55 + by-products	266	386	75	5770	17,23	112	0,051	335
11	N48.8P45K55 + green manure + by-products	260	386	72	5740	18,41	108	0,053	312
12	N48.8P45K55 + 10 t/ha of manure	264	386	74	5760	18,77	109	0,053	307

With the combined application of mineral fertilisers and by-products (N48.8P45K55 + by-products per 1 ha of crop rotation), the specified regularity was preserved: moisture reserves in the 1.5 m soil layer in the crop rotation with predecessors of barley-peas – 268 mm, peas-vetch-oats – 266 mm, while in crop rotation with soybeans - 251 mm. The predecessor of soybean under the alternative organic-mineral fertilisation system reduced the accumulation of moisture in 1.5 layers of soil at the beginning of the sugar beet vegetation compared to the predecessors of barley-peas and peas-vetch-oats - by 15-17 mm. With the combined application of N48.8P45K55 + green manure + by-products and N48.8P45K55 + 10 t of manure per 1 ha of crop rotation, the reserves of productive moisture in the 1.5 m soil layer were comparable to the option where the only by-products were applied.

At harvest, the reserves of productive moisture in the 1.5 m layer of the soil under the mineral fertilisation system in crop rotation with barley-peas amounted to 82 mm, peas-vetch-oats – 74 mm, soybeans – 73 mm; under alternative organic-mineral fertilisation systems – 73-75, 72-75 and 65-68 mm, respectively, which was at the level of the mineral fertilisation. The reduction of moisture reserves in the soil at the end of the growing season is a consequence of the use of moisture by plants and unproductive losses of moisture from the soil in the process of evaporation.

During the vegetation period under the mineral fertilisation system (N48.8P45K55 per 1 ha of crop rotation), moisture consumption from the soil in the crop rotation with barley-peas was 5670 m³, peas-vetch-oats - 5620, soybeans - 5380, moisture consumption per plant 0.052, 0.052 and 0.050 m³, for the formation of 1 ton of biological harvest - 336, 351 and 329 m³, respectively. Under the mineral fertilisation system, sugar beet most efficiently used moisture from the soil to form 1 ton of biological yield in the rotation with soybeans and barley-peas, while the moisture consumption was higher in the rotation with peas-vegetable-oats.

With the combined application of N48.8P45K55 + by-products per 1 ha of crop rotation, the specified regularity was preserved. The use of moisture for the formation of 1 ton of biological harvest in the link with barley-peas amounted to 332 m³, peas-vetch-oats - 335 m³, soybeans - 325 m³. The predecessor of soybean under the alternative organic-mineral fertilisation system reduced the use of moisture for the

formation of 1 ton of biological harvest compared to the predecessors of barley-peas and peas-vetch-oats - by 7-10 mm.

The highest efficiency of moisture use for the formation of 1 ton of biological yield of sugar beet was achieved with an alternative fertiliser system enriched in the organic component (N48.8P45K55 + green manure + by-products per 1 ha of crop rotation) in crop rotations with a predecessor of soybeans and barley-peas - 305 m³, in crop rotation with peas-vetch-oats - the use of moisture was slightly higher - 312 m³.

Therefore, the application of N48.8P45K55 + green manure + by-products per 1 ha of crop rotation in the barley-pea-winter wheat-sugar beet and soybean-soybean-winter wheat-sugar beet crop rotations ensured the most effective use of moisture by sugar beet plants for the formation of 1 t of biological harvest - 305 m³ with a decrease in moisture consumption compared to the mineral fertilizers by 24-31 m³.

The fertilization system and crop rotation structure significantly influenced the productivity of sugar beet. On average, for 2019-2022, the yield of roots in short-rotation grain-beet crop rotations under the mineral fertilisation system was 60.4-63.0 t/ha, sugar content 18.1-18.4%. In the crop rotation with peas -vetch-oats, the sugar content in root crops was higher than in the crop rotation with soybeans - by 0.2%, barley-peas - by 0.3%. For the introduction of N48.8P45K55 per 1 ha of crop rotation, the highest sugar yield was obtained in the crop rotation of barley-peas-winter wheat-sugar beet - 11.4 t/ha with an increase compared to the crop rotation with soybeans - by 0.2 t/ha, crop rotations with peas-vetch-oats by 0.3 t/ha (Table 2).

A significant increase in the productivity of sugar beet was achieved with the use of alternative organic-mineral fertilisation systems. With the application of N48.8P45K55 + by-products per 1 ha of crop rotation, the yield of roots in the crop rotation with soybeans was 65.8 t/ha, barley-peas – 64.9, peas-vetch-oats – 64.3, which compared to the mineral fertilisation system was higher by 4.3, 1.9 and 3.9 t/ha, respectively. The use of organic-mineral fertilisation systems in short-rotation crop rotations increased the sugar content in roots by 0.1-0.2% compared to the mineral fertilisation system. With the application of N48.8P45K55 + by-products per

1 ha of crop rotation, the collection of sugar in crop rotations was comparable and ranged from 11.8 to 12.0 t/ha.

Table 2

Productivity of sugar beet depending on crop rotation and fertilization, ULDS, 2019-2022, t/ha

No. var	Crop rotations (factor A)	Fertilizers were applied per 1 ha crop rotation (factor B)	Yield, t/ha	Sugar content, %	Sugar harvest, t/ha
1	Soybean-soybean-winter wheat-sugar beet	N48.8P45K55	61,5	18,2	11,2
2		N48.8P45K55 + by-products	65,8	18,4	12,0
3		N48.8P45K55 + green manure + by-products	69,2	18,2	12,6
4		N48.8P45K55 + 10 t/ha of manure	69,4	18,2	12,7
5	Barley-peas-winter wheat-sugar beet	N48.8P45K55	63,0	18,1	11,4
6		N48.8P45K55 + by-products	64,9	18,2	11,8
7		N48.8P45K55 + green manure + by-products	70,9	18,6	13,2
8		N48.8P45K55 + 10 t/ha of manure	69,6	18,5	12,9
9	Peas-vetch-oats-winter wheat-sugar beet	N48.8P45K55	60,4	18,4	11,1
10		N48.8P45K55 + by-products	64,3	18,5	11,9
11		N48.8P45K55 + green manure + by-products	68,5	18,4	12,6
12		N48.8P45K55 + 10 t/ha of manure	69,7	18,5	12,9
LSD 05 (factor A)			1,3	0,1	-
LSD 05 (factor B)			2,8	0,3	-
LSD 05 (factor A+B)			3,9	0,4	-

The fertilisation system, which used of green mass of white mustard as fertiliser combined with by-products and mineral fertilizers, was determined to be quite effective under conditions of sufficient moisture. With the application of N48.8P45K55 + by-products + green manure per 1 ha of crop rotation, the yield of roots in the crop rotation with soybeans was 69.2 t/ha, in the crop rotation with barley-peas – 70.9, peas-vetch-oats – 68.5 with an increase compared to mineral fertilisers by 7.7, 7.9 and 8.1 t/ha, respectively. The sugar content in roots was determined to be the highest in the barley-pea rotation - 18.6%, while in the pea-

vetch-oats rotation - 18.4%, soybeans - 18.2%. In the crop rotation of barley-peas-winter wheat-sugar beet, the alternative fertilisation system enriched with an organic component had the highest efficiency - sugar collection was 13.2 t/ha with an excess of 0.6 t/ha compared to crop rotations with the soybeans and pea-vetch-oats.

The use of a traditional manure-based fertilisation system in short-rotation crop rotations was equal in effectiveness to an alternative organic-mineral system with the application of by-products and green manure. With an application of N48.8P45K55 + 10 tons of manure for 1 ha of crop rotation, the yield of roots in crop rotation with soybeans was 69.4 t/ha, in crop rotations with barley-peas – 69.6, peas-vetch-oats – 69.7, sugar content – 18,2%, 18.5% and 18.5%, sugar collection – 12.7, 12.9 and 12.9 t/ha, respectively. The traditional organic-mineral fertilisation system increased the collection of sugar compared to the background of mineral fertilisers by 1.5-1.8 t/ha.

CONCLUSIONS

1. At the beginning of the sugar beet growing season, high reserves of productive moisture were accumulated in the 1.5 m layer of soil, which amounted to 225-270 mm. With organic-mineral fertilisation systems, the reserves of productive moisture in a 1.5 m soil layer were 5-27 mm higher than with the application of mineral fertilisers. In crop rotations with barley-peas and peas-vetch-oats the accumulation of the moisture was 15-17 mm more than in crop rotation with soybeans.

2. For the formation of a biological yield of sugar beet, soil moisture was the most effectively used when applying N48.8P45K55 + green manure + by-products in crop rotations of barley-peas-winter wheat-sugar beet and soybean-soybean-winter wheat-sugar beet: moisture consumption - 305 m³/t with reduction compared to the mineral fertilisers by 24-31 m³.

3. In conditions of sufficient moisture, the use of organic-mineral fertilisation systems in short-rotation grain-beet rotations increased the yield of sugar beet compared to the mineral fertilisation system - by 1.9-9.3 t/ha, sugar content - 0.1-0.5%, sugar collection - 0.4-1.8 t/ha.

4. The highest biological productivity of sugar beet was achieved in the

rotation of barley-peas-winter wheat-sugar beet with the application of N48.8P45K55 + green manure + by-products per 1 ha of the crop rotation: sugar collection - 13.2 t/ha with exceeding of the mineral fertilisation - by 1.8 t/ha, in the similar options in crop rotations with soybeans and peas-vetch-oats – by 0.6 t/ha.

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