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INFLUENCE OF NUTRITION BACKGROUND ON THE PRODUCTIVITY OF *Carthamus tinctorius* IN THE CONDITIONS OF SOUTHERN STEPPE OF UKRAINE

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Abstract

The article presents the results of studies conducted in 2017-2019 years on the southern chernozem in the southern Steppe of Ukraine, the studies found that the optimization of nutrition increased the field germination of safflower seeds compared to the control by 1.3-6.2%, due to the maximum indicators for the background of application of $N_{60}P_{60}$ and $N_{60}P_{60}$ + "Organic D-2M" (90.2-91.4%). For optimizing the nutrition much more intense it was the growth of vegetative mass, leaf area, larger formed mass of 1000 seeds, while the seed increases the accumulation of protein and fat. It was found that for cultivation of crops without optimized nutrition, it formed yields in the range of 1.0-1.1 t / ha. With the application of mineral fertilizers in half and full doses, the yield increase was 0.23-0.55 t / ha. Additional treatment of seeds and planting with organic fertilizer "Organic D-2M" on these fertilizer backgrounds provides yields at the levels of 1.55-1.63 t / ha. The maximum yield (1.63 t/ha) was formed due to seed treatment and foliar fertilization with "Organic D-2M" organic fertilizer on the background of application before sowing $N_{60}P_{60}$, its level was slightly lower when using only $N_{60}P_{60}$ – 1.53 t/ha. The conducted studies showed the economic feasibility of using seed treatment and sowing of safflower plants with "Organic D-2M" – organic fertilizer in the rosette phase on the background of applying full $N_{60}P_{60}$ mineral fertilizer.

Key words: *safflower, nutrition background, yield, seed quality, profitability.*

INTRODUCTION

The growing consumption of vegetable fats, the increase in world prices for oilseeds has led to an increase in the area of sunflower cultivation in Ukraine – 6.1 million hectares, which significantly exceeds the scientific standards and causes a decrease in the content of humus, macro-and microelements in soils, and a deterioration of the environmental situation (Melnyk et al., 2017; Zavorotniy and Bilyk, 2017; Kuzmenko et al., 2016).

There is a need to search for new drought-resistant and less demanding crops as a biological mechanism for diversifying production. One of these plants is safflower, which is an oil and dye crop being resistant to extreme conditions and has been widely used in global production in recent years (Ozturk et al., 2008; Faten et al., 2019; Ali et al., 2019; Wood et al., 2018; Oguz et al., 2019, Wei B. et al., 2019). This crop has a great potential: it can be grown in various natural and climatic zones of Ukraine, it is resistant to drought, shedding and lodging of crops, it has phytosanitary properties, it is a good precursor for winter and spring crops, it can provide high profitability of production due to unpretentiousness in cultivation and significant demand for grown products on the world market (Shevchenko et al., 2017; La Bella et al., 2019).

Today, safflower is grown in 60 countries, but the main global producers of raw materials are Mexico, India, Argentina, Kazakhstan and the United States (FAO, 2018). In Ukraine, the area of its crops is still not significant - about 5 thousand hectares in the Kherson region. There are prospects for increasing the acreage to 1 million hectares in Ukraine, since safflower grows even on saline and saline soils in the conditions of steppes and semi-deserts, whose areas grow annually (Shevchenko et al., 2017).

Under favorable growing conditions, the crop forms up to 2.0 t/ha of seeds or more due to the content of up to 40% of oil, which is not inferior to sunflower oil in terms of fatty acid composition (Salvatore et al., 2019). Taking into account the trends of changes in the modern climate with frequent extreme weather anomalies and a gradual increase in average annual temperatures, which negatively affect the yield of most field crops, such qualities of safflower as having drought resistance and unpretentiousness to growing conditions favorably distinguish it from traditional for the zone and well-known for producers of oilseeds (Leus, 2016; He et al., 2018; Sajjad Ali et al., 2017).

The analysis of literary sources has determined that in recent years, mainly, the issues of agricultural techniques for growing safflower on gray forest, chestnut soils of the Kherson region and in the Crimea are covered (Fedorchuk and Filipov, 2013; Vozhehova et al., 2018; Vozhehova et al., 2019; Homina et al., 2017).

The problem of determining the biological productivity of safflower for growing on southern Chernozem depending on the optimization of nutrition conditions remains unexplored.

It is known that one of the most important elements of increasing the yield of agricultural crops, including oilseeds, is the use of fertilizers. Researchers determined that safflower reacted positively primarily to phosphoric and potash fertilizers. Safflower uses 30-35 kg of nitrogen, 20-25 kg of phosphorus, and 35-45 kg of potassium to form 1 ton of seeds and an appropriate amount of vegetative mass. A greater amount of nitrogen and phosphorus is used by the plant in the beginning of stemming, and less potassium is used by the plant during this period. From stemming to flowering, the need to use nitrogen almost does not change, phosphorus decreases, and potassium increases. On southern chernozems, it is recommended to apply mineral fertilizers at a dose of N_{30-45} P_{40-60} K_{15-45} for cold weather, on dark chestnut soils it is recommended N_{45-60} P_{30-45}, and on irrigated lands it is recommended N_{60-90} P_{60-90} (Mohammad et al., 2017; Vozhehova et al., 2019).

At the same time, it was determined that intensive use of mineral fertilizers can cause a number of negative environmental consequences associated with the accumulation of fluorine, heavy metals, radioactive elements and other toxicants in the soil, which leads to eutrophication of the latter, deterioration of the habitat conditions of the ichthyofauna, deterioration of water quality indicators, etc. (Chandini et al., 2019; Savci, 2012; Atikur and Zhang, 2018, Nosheen, 2018).

Foliar nutrition is an integral part of modern crop production technology and the key to obtaining a high yield of good quality (Abo-Sedera et al., 2016; Hamaiunova et al., 2019). The use of organic-mineral fertilizer "Organic D-2M", made on the basis of organic acids, allows you to ensure optimal nutrition of crops, reduce the harmful effects of high doses of NPK, pesticides, pesticides and radionuclides, increase crop yields, including and many oilseeds, indicators of their quality, improve soil fertility and ensure environmental safety (Panfilova & Mohylnytska, 2019; Panfilova & Hamayunova, 2018; Dvoretsky & Glushko, 2016; Gamayunova, 2019).

Therefore, the purpose of the research was to determine the effect of the nutrition background on the level of yield and quality of seeds of safflower for growing on the southern Chernozem in the southern Steppe zone of Ukraine.

MATERIALS AND METHODS

The research was carried out during 2017-2019 yrs in LLC "Zolotoy Kolos" of the Vitovsky district of the Mykolaiv region using generally accepted methods. The object of research was the process of forming the productivity of safflower on the basis of patterns of growth and development of plants in the southern Steppe of Ukraine. Subject of the research was plants of safflower varieties Lagidny, which is entered in the Register of plant varieties of Ukraine since 2011yr, mineral fertilizers (ammonium nitrate, double superphosphate) and organic-mineral fertilizer "Organic D-2M" (presowing treatment of seeds in the rate of 1 l/t and fertilizing of plants in the rosette phase in norm 1 l/ha using a working solution of 200 l/ha sowing Area of the plot is 108 m^2, accounting - 35,0 m^2. The experience was repeated three times.

"Organic D-2M" is organo-mineral fertilizer containing N as 2.0-3.0%, P_2O_5 as 1.7-2.8%, K_2O as 1.3-2.0%, total calcium as 2.0-6.0%, organic matter as 65-70% (in terms of carbon). The variants were placed in the experiment by the method of split plots, the repetition of the experiment was fourfold. Soil of research areas was southern black soil humus, light clay-loam soil on wide slightly drained loess on the watershed plateau, typical for the area of Southern Steppe. The reaction of the soil solution was neutral (pH 6.8-7.2). Their arable layer contains an average of 2.4% humus, light-hydrolyzed nitrogen as 16 mg/kg, mobile phosphorus as 160 mg/kg and exchanged potassium as 187 mg/kg of soil.

The experiment scheme included the following variants:

1. Control (without fertilizers);
2. Treatment of seeds and seeding plants with "Organic D-2M"
3. $N_{30}P_{30}$;
4. $N_{30}P_{30}$ + "Organic D-2M";
5. $N_{60}P_{60}$;
6. N_{60} P_{60}+ "Organic D-2M".

RESULTS AND DISCUSSIONS

During the years of research, weather conditions differed both in temperature and in the amount of precipitation during the growing season of plants. Sowing was carried out in the second decade of April, seedlings appeared after 12-15 days, depending on weather conditions and nutrition background. Higher indicators of field germination of safflower seeds were determined on fertilized sites and for processing seeds before sowing with organic-mineral fertilizer "Organic D-2M". The density of standing plants was close to the normal seeding rate (Table 1).

Table 1. The influence of nutrition background on the seed germination of safflower, %

№ п/п	Variant	Years of research			average for 2 yrs
		2017	2018	2019	
1.	Control*	87.2	83.1	85.3	85.2
2.	treatment of seeds and seeding plants with "Organic D-2M"	88.4	85.5	87.0	87.0
3.	N_{30} P_{30}	89.7	86.7	87.9	88.1
4.	N_{30} P_{30}+ "Organic D-2M"	90.8	87.1	88.7	88.9
5.	N_{60} P_{60}	90.9	89.5	90.1	90.2
6.	N_{60} P_{60}+ "Organic D-2M"	92.3	90.4	91.3	91.3
The least significant difference (LSD) at $p<0.05$		2.1	1.9	1.8	

*Control (without fertilizers, treatment of seeds and seeding plants with water)

On average, for three years of research, field germination in the control of seed treatment with water was 85.2%, and organic-mineral fertilizer "Organic D-2M" against the background of $N_{60}P_{60}$, it increased to 91.3%, which exceeded the control by 6.1%. Plants of these variants also had the highest survival rates. The plants of the fertilized areas used their genetic potential to a greater extent and were characterized by a more developed habit and a longer vegetation period. Also, safflower plants formed a much larger number of baskets compared to the crops of the control variant, in which the interphase periods of vegetation were shorter.

During the years of research at the seedling stage, a significant acceleration of root growth and a slow increase in the leaf mass of safflower were noted, which provided better plant survival during dry periods of vegetation. Before the appearance of 10-12 true leaves, low growth rates were observed, after which the formation and lengthening of the stem and branching of plants occurred more intensively.

Due to branching (from 3 to 18 branches, depending on the variant), the plants formed a shrub with a diameter of 20-45 cm, a height of 85-95 cm in less moisture-rich year 2018, in a more favorable year 2017, respectively, 27-53 and 100-110 cm. In 2017, the later stages of budding phases (I decade of June), flowering (III decade of June), and fruiting were observed (Figure 1).

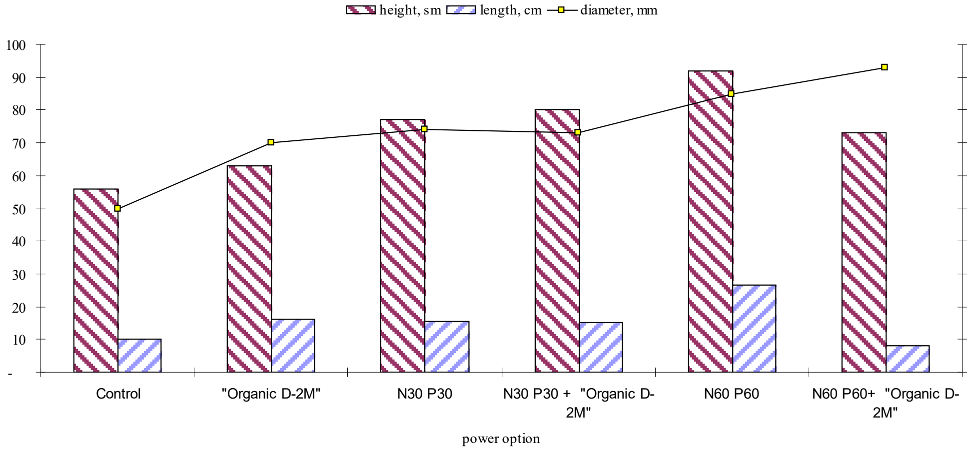

Figure 1. Biometric indicators of the leaf depending on the nutrition background at the beginning of budding (average for 2017-2019), mm

Studies determined that the nutrition background significantly affected the size of the leaves of safflower. Thus, the length of the leaves of this crop when grown on $N_{60}P_{60}$ and $N_{60}P_{60}$+"Organic D-2M" backgrounds increased by 4.1% and 6.8%, respectively, compared to the control

The maximum values of the assimilation area of plants reached in the flowering phase with the joint application if $N_{60}P_{60}$+"Organic D-2M" and amounted to 18.9 thousand m^2/ha, which is more than control by 6.1 thousand m^2/ha (Table 2).

Table 2. The dynamics of growth of leaf area of plants of safflower dye depending on the background of nutrition (average for 2017-2019), thousand m^2/ha

Variant	Phases of growth and development		
	Rosette	budding	flowering
Control*	0.07	7.7	12.8
treatment of seeds and seeding plants with "Organic D-2M"	0.09	9.6	14.6
N_{30} P_{30}	0.11	11.0	16.9
N_{30} P_{30}+ "Organic D-2M"	0.12	11.9	17.3
N_{60} P_{60}	0.13	12.9	17.9
N_{60} P_{60}+ "Organic D-2M"	0.15	14.8	18.9
The least significant difference (LSD) at $p<0.05$	0.03-0.04	0.80-1.40	0.90-1.30

*Control (without fertilizers, treatment of seeds and seeding plants with water)

The area of the leaf surface in the socket phase, depending on the nutrition supply background, was the largest for the use of $N_{60}P_{60}$ and $N_{60}P_{60}$+"Organic D-2M" (0.13 and 0.15 thousand m_2/ha, respectively), which is 0.06 and 0.08 thousand m_2/ha more than the asymmetric surface of plants in the control variant.

During the budding phase, the area of the leaf surface of fertilized plants was determined in the range of 12.9-14.8 thousand m_2 / ha, which exceeded the control by 30.6-31.2%.

We determined the experimental and direct trend lines and the value of the accuracy of the approximation relative to the influence of the nutrition background on the formation of the leaf surface area of plants of safflower. As in the rosette phase, as well as budding and flowering, there was a close relationship between these components: R2 = 0.923; 0.984 and 0.982.

Optimization of nutrition had a positive effect on the number of formed leaves and inflorescences on the plant (Figure 2).

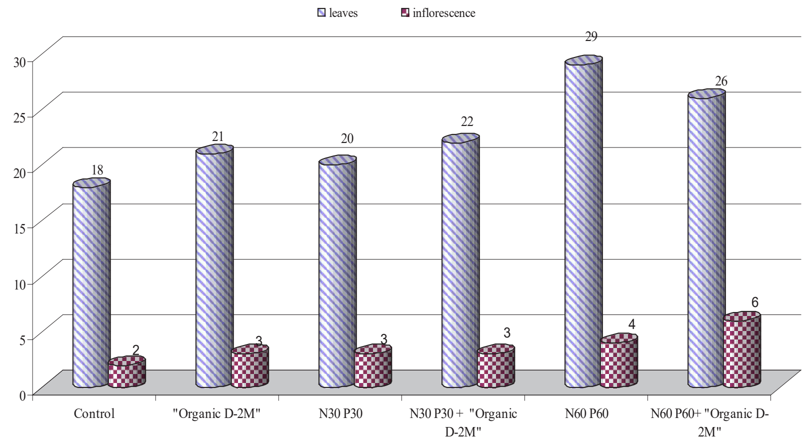

Figure 2. Influence of the nutrition background on the number of leaves and inflorescences on one plant of safflower (average for 2017-2019), PCs.

With a similar dependence, under the influence of the studied factors, there was an increase in the biomass of plants of safflower.

As determined in the course of biometric measurements, the increase in biomass depended on the weather conditions of the year that developed during the growing season of the crop, but it changed significantly under the influence of the nutrition background.

In addition, this dependence was observed not only in the intensity of growth of aboveground plant biomass, but also in the mass of roots (Figure 3).

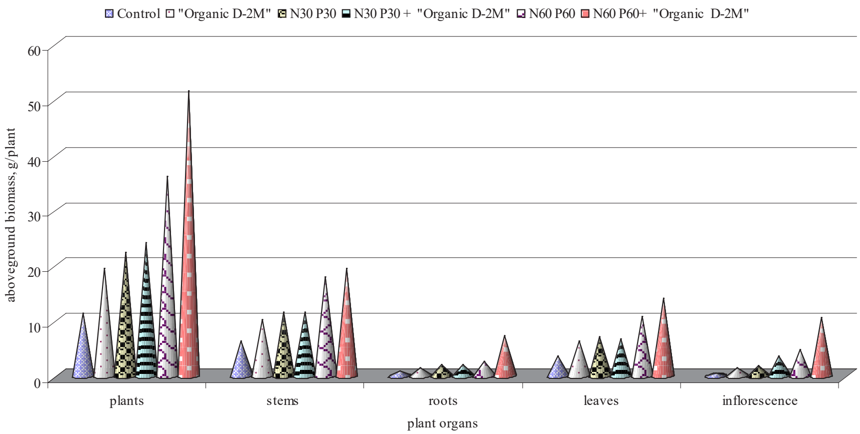

Figure 3. Formation of aboveground biomass of safflower plants at the beginning of the budding phase, depending on the nutrition background (average for 2017-2019), g/plant

The accumulation of dry matter occurred according to the growth of green biomass, the largest amount of it was formed during the flowering-fruiting period and fluctuated within 1.1-2.0 t/ha depending on the variant. On average, over the years of research, it was found that the crops of plants of the control variant, compared with the introduction of mineral fertilizer in a dose of $N_{60}P_{60}$, both separately and together with a biological product ($N_{60}P_{60}$+ "Organic D-2M"), dry biomass accumulated by 0.52 t/ha and 0.65 t/ha, respectively.

Structural analysis of safflower plants was determined by the following indicators: plant height, number of baskets, number of seeds in a basket, weight of seeds per plant (Table 3).

Table 3. Influence of nutrition optimization on indicators of the structure of the safflower crop (average for 2017-2019)

Factor A (variants of nutrition)	Height of plants, cm	Mass of one plant, g	Nuvber of baskets per plant, pcs.	Number of seeds in a basket, pcs.	Mass of seeds from one plant, g
Control *	83.0	46.65	7.0	12.0	3,1
treatment of seeds and seeding plants with "Organic D-2M"	89.0	62.32	10.0	16.0	6,1
N_{30} P_{30}	97.0	72.37	13.0	17.0	8,5
N_{30} P_{30}+ "Organic D-2M"	100.0	77.24	13.0	18.0	9,1
N_{60} P_{60}	111.0	81.91	13.0	23.0	11,7
N_{60} P_{60}+ "Organic D-2M"	114.0	111.74	14.0	25.0	14,0
The least significant difference (LSD) at $p<0.05$	3.0-8.0	2.7-5.3	1.0-2.0	3.0-4.0	1,3-1,7

*Control (without fertilizers, treatment of seeds and seeding plants with water)

The optimal combination of mineral fertilizers and plant growth regulators is an important factor in improving the yield and quality of safflower seeds (Yerenenko O. et al., 2018).

On average, for 2017-2019, the largest values of such structure indicators as the number of baskets per plant, the size of baskets, the weight of 1000 seeds, the weight of seeds in a basket and the weight of seeds from 1 plant were determined when $N_{60}P_{60}$ was used together with the «Organic D-2M» organo-mineral fertilizer. These indicators of the structure of the safflower crop affected the level of crop yield (Table 4).

Table 4. Influence of weather conditions and nutrition background on the yield of safflower seeds in the years of cultivation, t/ha

Factor A (variants of nutrition)	Years of research			Average for 3 yrs
	2017	2018	2019	
Control *	1.20	0.84	0.93	0.99
treatment of seeds and seeding plants with "Organic D-2M"	1.25	0.97	1.08	1.10
N_{30} P_{30}	1.54	1.14	1.26	1.31
N_{30} P_{30}+ "Organic D-2M"	1.69	1.25	1.37	1.44
N_{60} P_{60}	1.73	1.37	1.50	1.53
N_{60} P_{60}+ "Organic D-2M"	1.79	1.47	1.63	1.63
The least significant difference (LSD) at $p<0.05$	0.12	0.11	0.12	

*Control (without fertilizers, treatment of seeds and seeding plants with water)

On average, over three years of research, the yield of safflower seeds was formed as follows: low yield as 0.99 t/ha. it was determined in the control without fertilizers when processing seeds and sowing only with water.

The use of organic-mineral fertilizer "Organic D-2M" for processing and fertilizing without adding mineral fertilizers provided a yield of 1.10 t/ha, which was by 11.1% more than the control. Significantly higher yields were obtained when applying mineral fertilizers to safflower for sowing in half and full recommended doses for this crop, namely on the background of $N_{30}P_{30}$ as 1.31 t/ha, and $N_{60}P_{60}$ as 1.53 t/ha of seeds. The yield increased even more if the pre-sowing treatment of seeds and foliar nutrition with organic-mineral fertilizer "Organic D-2 M" in the rosette phase was carried out on the specified fertilizer backgrounds. On average, over three years, these variants collected 1.44 and 1.63 t/ha, respectively, which indicates an increase in crop yield from the preparation "Organic D-2M" at the level of 0.13 t/ha and 0.10 t/ha compared to the studied variants with doses of mineral fertilizers and within 0.45–0.64 t/ha relative to the control.

Thus, when using mineral fertilizers and Organic D-2M together, the seed yield was significantly higher, and the total dose of $N_{60}P_{60}$ was the maximum, where the average for 2017-2019 it was 1.63 t/ha of seeds, which was by 64.6% higher than the control.

It should be noted that the studied factors significantly affected the main indicators of the quality of safflower seeds. So, plants of fertilized variants, on average, formed something weighty grain over the years of research, the weight of 1000 seeds in them prevailed by 1.0-2.9 g. The highest value of this indicator was determined by the combined use of the full dose of mineral and organic-mineral fertilizer "Organic D-2M", where the weight of 1000 seeds on average over the years of research was 40.1 g (Table 5).

Table 5. Influence of nutrition background on the main indicators of quality of safflower seeds (average for 2017-2019)

Factor A (variants nutrition)	Mass of 1000 seeds, g	Content of protein, %	Content of fat, %
Control *	37.2	19.1	38.1
treatment of seeds and seeding plants with "Organic D-2M"	38.2	20.2	38.5
N_{30} P_{30}	38.6	20.4	39.6
N_{30} P_{30}+ "Organic D-2M"	39.1	20.5	40.2
N_{60} P_{60}	39.0	20.6	39.4
N_{60} P_{60}+ "Organic D-2M"	40.1	20.6	39.9
The least significant difference (LSD) at $p<0.05$	1.3-1.8	0.2-0.3	0.3-0.6

*Control (without fertilizers, treatment of seeds and seeding plants with water)

We determined that the protein content in the seeds of safflower was dependent on the weather conditions of the growing year and the nutrition background. More protein 20.2-20.6% was contained in the seeds of the fertilized variants, while in the control-19.1 %, it was by 5.5-7.3% less percentage points.

More fat in safflower seeds as 38.5 up to 40.2% also accumulated in order to optimize nutrition and exceeded the control by 0.4-2.1%. We defined a conditional collection (yield) of oil that could be removed from safflower seeds collected from a unit area. On average, over the years of studies with wind control, this indicator was 0.38 t/ha, when processing seeds and sowing plants with organic-mineral fertilizer "Organic D-2M" it was 0.42 t/ha; when growing crops on the background of $N_{30}P_{30}$ application it was 0.52 t/ha; on the background of $N_{60}P_{60}$ it was 0.60 t/ha, and the joint application of these backgrounds of fertilizer also processing seeds and sowing plants of safflower preparation "Organic D-2M", respectively, 0.58 t/ha and 0.65 t/ha of oil, which exceeded the control by 52.6% and 71.1%, or the conditional yield of oil for the combination of mineral fertilizers with organo-mineral fertilizer "Organic D-2M" significantly increased. The positive effect of the combined use of mineral fertilizers with growth-regulators on the main indicators of the quality of oilseeds is important in their cultivation, as the seeds are usually used for the production of oil. Moreover, it is desirable that it is of high quality.

CONCLUSIONS

Thus, the conducted researches found that the optimization of nutrition increases the field germination of the seeds of safflower dye compared with the control by 1.3-6.2%, with the maximum indicators against the background of application of $N_{60}P_{60}$ and $N_{60}P_{60}$ + "Organic D-2M" (90.2-91.4%). With the optimization of nutrition, the vegetative mass of plants, the area of the leaf surface is much more intense, the mass of 1000 seeds is formed, while the accumulation of protein and fat increases in the seeds. The maximum yield (1.63 t/ha) was formed by seed treatment and foliar feeding of "Organic D-2M" organic-mineral fertilizer on the background of $N_{60}P_{60}$ sowing, slightly lower than its level when using only $N_{60}P_{60}$ - 1.53 t/ha. The conducted studies have proved the economic feasibility of using the treatment of seeds and plants of safflower dyestuff organo-mineral fertilizer "Organic D-2M" in the phase of the socket against the background of the introduction of complete mineral fertilizer $N_{60}P_{60}$.

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