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Effectiveness of herbicides against the volunteer plants of imidazolinone-resistant sunflower in oil flax sowings

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Abstract. In 2020-2021, we conducted research on the effect of herbicides on oil flax productivity and volunteer plants of imidazolinone-resistant sunflower in oil flax sowings. We used the contact herbicide Basagran, AS (a.i. bentazon, 480 g/l) and the systemic herbicides Tifi, WDG (a.i. thifensulfuron-methyl, 750 g/kg), Cleo, WDG (a.i. clopyralid, 750 g/kg), Magnum, WDG (a.i. metsulfuron-methyl, 600 g/kg), Zellek-super, EC (a.i. haloxyfop-P-methyl,104 g/l), Miura, EC (a.i. quizalofop-P-ethyl,125 g/l), Sekator Turbo, OD (a.i. amidosulfuron, 100 g/l + iodosulfuron-methyl-sodium, 25 g/l + mefenpyr-diethyl, 250 g/l). We evaluated the phytotoxicity of the herbicides on the volunteer plants using a 9-point EWRC scale. We found that the of Basagran, AS (4.0 l/ha) + Zellek-super, EC (1.0 l/ha) + Cleo, WDG (0.12 kg/ha) provides the effective control of the volunteer plants and contributes to the stable high indicators of oil flax productivity.

1 Introduction

In today's Russia, oil flax is one of the most dynamically developing crops. If in 1999 its crop acreage did not exceed 16 thousand hectares, since the beginning of the new century it has increased by more than 83 times, amounting to 1.33 million hectares in 2022. Such a snowballing growth of the crop acreage is related to the market demand and the marginality of the crop due to its high consumer value. The relatively low demands to environmental factors and the simplicity of cultivation, the ability to use nutrient elements and soil moisture efficiently, contribute to the area expansion of oil flax cultivation, making it possible to obtain a profitable yield of high-quality seeds in different soil and climatic conditions.

However, the slow growth of the plants during the initial development period reduces their competitiveness against numerous weeds and volunteer plants. Due to the relatively recent cultivation of oil flax on Russian fields, the list of herbicides registered for use on its sowings is comparatively short (25 items), which has a negative impact on the level of weed control and consequently on crop productivity. With the potential yield of the main oil flax varieties exceeding 2.5 t/ha, the actual yield in 2018-2020 in the Russian Federation

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was 0.78-0.83 t/ha and 0.56-0.86 t/ha in the Southern Federal District. As yield losses due to weeds can be up to 25 % or more [1], the issues of ensuring the purity of oil flax sowings are relevant and require a definitive solution.

The problems of herbicide use in sowings of field crops are in the focus of attention of both Russian and foreign scientists [2-8], with special interest in the impact of chemical protection agents on the productivity of oil flax and the quality of its seeds. It was found that in Poland the use of intensive technology with the use of herbicides Linurex 50 WP, Fusilade Forte 150 EC, Glean 75 WP contributed to the increase of flax seed yield by 1.8-2 times compared to herbicide-free technology [9]. Canadian scientists found that the use of herbicide treatments increased the oil seed yield by more than 0.6 t/ha [10].

To control weeds of various species, the flax protection system includes the application of tank mixtures of graminicides and antidicotyledonous preparations, but in some cases such treatment can depress cultivated plants, reducing their yield and seed quality. Negative effects on oil flax have been observed when applying tank mixtures of MCPA with bromoxynil [11], as well as 2M-4X and bromoxynil with topramezone and fluthiacet-methyl [12]. Under the conditions of the Western Ciscaucasia of the Russian Federation, when the graminicide Miura, EC (a.i. chisalofop-P-ethyl) was applied in a mixture with one of the antidicotyledonous preparations Tifi, WDG (a.i. thifensulfuron-methyl) or Magnum, WDG (a.i. metsulfuron-methyl), seed yield was reduced by 40 and 90 kg/ha, and seed oil content by 1.1 and 0.8%, respectively [13].

In oil flax production, it is often included in the crop rotation after a late-harvested crop such as sunflower. However, when sunflowers are harvested, there are usually a lot of fallen seeds left on the field, which germinate the following year and contaminate the flax sowings. Currently, much of the world's sunflower is grown using Clearfield technology [14], which involves the application of imidazolinone-group herbicides to imidazolinone-resistant hybrids. The problem of controlling volunteer plants of such sunflower has not yet been solved, as they are tolerant to most of the antidicotyledonous preparations recommended by manufacturers for use in oil flax sowings, and their tank mixtures, used to enhance the herbicidal effect, can have a phytotoxic impact on the crop.

The issues of controlling volunteer plants of imidazolinone-resistant sunflower (hereinafter – the volunteer plants) on oil flax are therefore relevant and timely, and the research results will be applied in agricultural production.

2 Materials and Methods

The aim of the research is to develop a tank composition of herbicides that will enable the destruction of volunteer plants of imidazolinone-resistant sunflower and contribute to the improvement of productivity indicators of oil flax.

The research on leached chernozem was carried out in 2020-2021 in the conditions of the central zone of the Krasnodar region. The object of the research was oil flax (Linum usitatisimum L. (1753)) of the variety FLIZ bred at V.S. Pustovoit All-Russian Research Institute of Oil Crops. We used the contact herbicide Basagran, AS (a.i. bentazon, 480 g/l), the systemic antidicotyledonous herbicides Tifi, WDG (a.i. thifensulfuron-methyl, 750 g/kg), Cleo, WDG (a.i. clopyralid, 750 g/kg), Magnum, WDG (a.i. metsulfuron-methyl, 600 g/kg), Sekator Turbo, OD (a. i. amidosulfuron, 100 g/l + iodosulfuron-methyl-sodium, 25 g/l + mefenpyr-diethyl, 250 g/l) and the systemic graminicides Zellek-super, EC (a.i. haloxyfop-P-methyl, 104 g/l), Miura, EC (a.i. quizalofop-P-ethyl, 125 g/l).

The experiment scheme:

- Control (no herbicide treatment, with manual weeding).
- Basagran, AS (4.0 l/ha).
- Basagran, AS (4.0 l/ha) + Zellek-super, EC (1.0 l/ha).

- Basagran, AS (4.0 l/ha) + Miura, EC (1.2 l/ha).
- Basagran, AS (4.0 l/ha) + Zellek-super, EC (1.0 l/ha) + Tifi, WDG (0.025 kg/ha).
- Basagran, AS (4.0 l/ha) + Zellek-super, EC (1.0 l/ha) + Cleo, WDG (0.12 kg/ha).
- Basagran, AS (4.0 l/ha) + Zellek-super, EC (1.0 l/ha) + Sekator Turbo, OD (0.1 l/ha).
- Basagran, AS (4.0 l/ha) + Zellek-super, EC (1.0 l/ha) + Magnum, WDG (0.01 kg/ha).

The crop was cultivated according to the technology recommended for the region [15]. The oil flax plots were sown using the common row system with a row spacing of 0.15 m. The experimental plots were eight-row plots of 12.0 m^2 and were systematically laid out with 3 replications. To simulate the emergence of volunteer plants of imidazolinone-resistant sunflower, the imidazolinone-resistant hybrid Imidzh was sown in the experimental plots using the wide-row method with a row spacing of 0.7 m.

On the day of the herbicide treatment, the oil flax plants had 5-6 pairs of true leaves, while the sunflower plants that had emerged were at different stages: from cotyledonous leaves to three pairs of true leaves.

The herbicides were applied in the experiment with a backpack sprayer at a working fluid application rate of 300 l/ha. Observations on the condition of the sowings were made throughout the entire growing season of the oil flax. The phytotoxicity of the herbicides on the volunteer plants was evaluated using the 9-point EWRC scale according to the methodological guidelines for registration trials of herbicides in agriculture [16]. Flax was harvested using a Wintersteiger Classic combine and the yield was corrected to standard indicators of purity (100%) and seed moisture (12%). The oil content of the seeds was determined according to the requirements of State Standard R 8.597-2010. The research results were evaluated using the method of analysis of variance [17].

3 Results and Discussion

On the fourth day after herbicide treatment, symptoms of phytotoxicity were observed on volunteer plants of oil flax sowings - imidazolinone-resistant sunflower - in all variants of herbicide application. The nature of these symptoms was different for the different herbicide treatments.

6 days after herbicide application in all variants of the experiment, there was a noticeable change in the color of the leaves of the volunteer plants. In the variants № 2, 3, 5, 6, and 7, we observed necrosis on most of the sunflower plants caused by the tissue death.

20 days after spraying of sowings, we observed the partial death of the herbicide-treated sunflower plants in all variants. At the same time, new sunflower plants that were not directly treated by pesticides emerged on the experimental plots. These plants were not counted and were subsequently removed.

As for the type of damage to volunteer plants, it was most severe in variant No. 6, where sunflower plants were deformed and twisted. In variants No. 5 and No. 8, in addition to damage to volunteer plants, we noted signs of phytotoxic action of herbicides on oil flax plants: change in color and damage to leaves, slowing of plant growth.

30 days after herbicide treatment, variants No. 2, 3, 4, 5 and 7 showed partial recovery of the previously damaged external appearance of the sunflower. In variants No. 6 and 8 we observed the death of a significant part of the damaged sunflower plants. In addition, in variant № 6, these plants were severely deformed and lacked reproductive organs. Variant No. 8 had the highest herbicide efficacy on sunflower, but there were signs of a strong phytotoxic effect on oil flax: discoloration of the plants and slowing of their growth, yellowing of some leaves.

At the beginning of the maturity stage of oil flax in variants No. 2, 3, 4, 5 and 7 there were a lot of sunflower plants, which significantly hindered mechanized harvesting of the crop. Combine harvesting of oil flax in these variants was possible only after manual removal of sunflower plants from the experimental plots.

In variants No. 6 and 8, we observed only isolated volunteer plants, which did not hinder combine harvesting of oil flax.

We found that the treatment of oil flax sowings with the tank composition of herbicides (variant No. 6) Basagran, AS (4.0 l/ha) + Zellek-super, EC (1.0 l/ha) + Cleo, WDG (0.12 kg/ha) had a strong phytotoxic effect on the volunteer plants, which was 79.6 % on average for 2020-2021, and gave the highest yield of oil flax - 1.57 t/ha, seed oil content - 46.1 % and oil yield - 0.64 t/ha (Table 1).

Table 1. Phytotoxicity to the volunteer plants of imidazolinone-resistant sunflower and oil flax productivity under herbicide application (VNIIMK, 2020-2021).

Variant	Phytotoxicity to the volunteer plants, %			Yield, t/ha			Oil content of seeds, %			Oil yield, t/ha		
	2020	2021	on average over two years	2020	2021	on average over two years	2020	2021	on average over two years	2020	2021	on average over two years
Variant 1 (control)	-	-	-	1.19	1.80	1.50	45.5	46.3	45.9	0.48	0.73	0.60
Variant 2	57.4	27.1	42.3	0.81	1.69	1.25	44.4	46.7	45.6	0.32	0.69	0.50
Variant 3	57.3	26.6	42.0	0.94	1.59	1.27	44.8	46.6	45.7	0.37	0.65	0.51
Variant 4	60.1	25.3	42.7	1.30	1.76	1.53	45.2	47.0	46.1	0.52	0.73	0.62
Variant 5	70.9	30.1	50.5	1.09	1.50	1.30	44.5	45.9	45.2	0.43	0.61	0.52
Variant 6	87.0	72.3	79.6	1.33	1.81	1.57	45.8	46.4	46.1	0.54	0.74	0.64
Variant 7	67.6	36,3	52.0	1.30	1.56	1.43	44.5	45.8	45.1	0.51	0.63	0.57
Variant 8	90.0	77.2	83.6	0.67	1.61	1.14	44.4	45.4	44.9	0.26	0.64	0.45
LSD_{05}	-	-	16.5	0.18	0.29	0.40	1.0	0.4	1.0	0.07	0.12	0.16

Source: Compiled by the authors

The lowest productivity of oil flax was obtained when using tank mixture of herbicides Basagran, AS (4.0 l/ha) + Zellek-super, EC (1.0 l/ha) + Magnum, WDG (0.01 kg/ha) in variant No. 8, where the average yield in 2020-2021 was 1.14 t/ha, seed oil content - 44.9 %, which led to the minimum oil yield in the experiment - 0.45 t/ha.

The weather conditions of the research in 2020 and 2021 affected the effectiveness of herbicide treatments and the productivity of oil flax. Thus, in 2020, under the deficit of soil moisture at the beginning of the crop vegetation, the herbicide composition of the variant No. 8 - Basagran, AS (4.0 l/ha) + Zellek-super, EC (1.0 l/ha) + Magnum, WDG (0.01 kg/ha) had the highest phytotoxic impact on the volunteer plants (90.0%). However, treatment of crops with this mixture had a negative effect not only on the volunteer plants, but also on oil flax. This led to a decrease in crop yield and seed oil content to 0.67 t/ha and 44.4 %, respectively, which is significantly lower than the control - 1.19 t/ha and 45.5 %. Good results were obtained in the variant № 6 using a tank mixture of Basagran, AS (4.0 l/ha) + Zellek-super, EC (1.0 l/ha) + Cleo, WDG (0.12 kg/ha), the application of which had a significant phytotoxic effect on the sunflower – 87.0 % and contributed to the highest yield of oil flax, seed oil content and oil yield – 1.33 t/ha, 35.8 %, and 0.54 t/ha, respectively.

In 2021, oil flax vegetation took place under relatively favorable conditions of abundant moisture and heat. Although herbicide phytotoxicity was lower than in 2020, oil flax productivity was higher. As in 2020, the highest values of phytotoxicity to sunflower were obtained in variants No. 8 and 6 - 77.2 and 72.3 %, respectively. The variant № 8 showed the relatively low yield of oil flax was obtained - 1.61 t/ha and the lowest seed oil content in the experiment - 45.4%, and the variant No. 6 had the highest yield of the crop - 1.81 t/ha with a relatively high seed oil content - 46.4%, which provided the maximum value of oil yield in the experiment - 0.74 t/ha.

In both years of the research, the herbicides applied in the variants No. 2, 3, 4, 5, and 7 did not provide the necessary effectiveness, and by the time of oil flax maturing, we observed a high number of volunteer plants on the experimental plots. Therefore, these variants were not suitable for practical use.

4 Conclusion

The conducted research revealed differences in the effectiveness of the influence of herbicides and their tank mixtures on the volunteer plants of imidazolinone-resistant sunflower and indicators of oil flax productivity.

We found that in the conditions of the central zone of the Krasnodar region on leached chernozem the use of herbicide Basagran, AS (4.0 l/ha) and tank mixtures of Basagran, AS (4.0 l/ha) + Zellek-super, EC (1.0 l/ha), Basagran, AS (4.0 l/ha) + Miura, EC (1.2 l/ha), Basagran, AS (4.0 l/ha) + Zellek-super, EC (1.0 l/ha) + Tifi, WDG (0.025 kg/ha), and Basagran, AS (4.0 l/ha) + Zellek-super, EC (1.0 l/ha) + Sekator Turbo, OD (0.1 l/ha) does not provide the necessary effectiveness of control of the volunteer plants of imidazolinone-resistant sunflower in oil flax sowings and is not recommended for use.

The tank mixtures of Basagran, AS (4.0 l/ha) + Zellek-super, EC (1.0 l/ha) + Cleo, WDG (0.12 kg/ha) and Basagran, AS (4.0 l/ha) + Zellek-super, EC (1.0 l/ha) + Magnum, WDG (0.01 kg/ha) had the highest phytotoxic effect on the volunteer plants of imidazolinone-resistant sunflower, which provided the necessary conditions for the combine harvesting of oil flax. However, despite high effectiveness against the volunteer plants, the tank mixture Basagran, AS (4.0 l/ha) + Zellek-super, EC (1.0 l/ha) + Magnum, WDG (0.01 kg/ha) contributed to a significant decrease in oil flax productivity and is not recommended for use.

The tank mixture of Basagran, AS (4.0 l/ha) + Zellek-super, EC (1.0 l/ha) + Cleo, WDG (0.12 kg/ha) provides the effective control of the volunteer plants of imidazolinone-resistant sunflower and maintains consistently high oil flax productivity indicators. Based on the results of the research, we can recommend the herbicides Basagran, AS and Zellek-super, EC for inclusion in the regulatory Catalogue [18] that allows the use of chemical plant protection products in oil flax cultivation in Russia.

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