Weed control in oil flax sowings

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Abstract. The conducted research was aimed at studying new systems of weed plants control during cultivation of oil flax. We carried out the field studies in the south of Russia in the Krasnodar region on leached chernozem during 3 years. We found that the application of preemergent herbicides Frontier Optima, EC (1.2 l/ha) and Dual Gold, EC (1.6 l/ha) provides an efficient weed control, contributes to higher crop productivity and cost-effectiveness indicators compared to the used in the production method of spraying vegetative plants with a tank mixture of herbicides. The application of preemergent herbicides will increase the competitiveness of oil flax cultivation and help receiving good economic effect. The herbicide Gardo Gold, SC (4.0 l/ha) and a tank mixture of herbicides Dual Gold, EC (1.6 l/ha) + Gezagard, SC (3.5 l/ha) are not recommended for application on oil flax due to the phytotoxic effect on the crop, which decreases the yield and oil content of seeds.

1. Introduction
Recently, the production of oil flax has increased significantly due to its high consumptive qualities and demand on the agricultural market. From 2007 to 2018, the crop acreage in the Russian Federation increased 4.8 times (from 110.1 to 524.8 thousand ha), while gross yield of seeds increased almost 8.8 times (from 73.12 to 551.0 thousand tons). However, the oil flax yield obtained in the conditions of agricultural enterprises is much lower than its potential capabilities and varies widely depending on the region. Thus, in 2017, in a number of constituent entities of the Southern and North Caucasian federal districts of Russia, flax yield was 1.5-1.8 times lower than in neighboring constituents. Such a large yield gap depends on a number of factors, including the efficiency of weed control. One of the biological characteristics of oil flax is the slow grow of plants in the initial stages of its development. The presence of weeds in sowings during this period can significantly reduce the crop yield as the weeds are competing with plants for light, moisture and nutrition. The earlier the measures for flax protection from weed begin, the more likely it is to increase its productivity. One of the ways of weed control in the early period of development of cultivated plants is the application of preemergent herbicides. This method has high efficiency, as it allows for a prolonged suppression of weeds in the development phases of cultivated plants that are most susceptible for infestation. However, in Russia the preemergent herbicides on oil flax are not registered, which does not allow their use in the cultivation of this valuable crop.

2. Literature References
The issues of herbicides application have been studied in sowings of various crops [1-5]. A number of Russian and foreign scientists were engaged in the development of flax cultivation technologies [6-10]. Research on various combinations of the sowing period and seeding rate, cultivar height and the
availability of chemical plant protection products, conducted by M.E. Kurtenbach, E.N. Johnson, R.H. Gulden, S. Duguid, M.F. Dyck and C.J. Willenborg in western Canada showed that the application of herbicides in the cultivation tall-growing cultivar of flax contributed to an increase in seed yield up to 0.6 t/ha while reducing the biomass of aboveground weeds by 50 kg/ha but it did not affect the productivity of weed seeds [11]. Research on flax tolerance to flutiacetmethyl, pyroxasulfone and topramezone showed that no herbicide or combination of herbicides had a significant effect on yield. However, mixing flutiacetmethyl and topramezone with MCPA and bromoxynil is not recommended due to increased damage to sowings [12]. S.S. Acharya, R.B. Nirala, A. Roychowdhury, M. Ghosh and M. Haque found that in the conditions of the Indo-Gangetic plain of Bihar, the application of pendimethalin and isoproturon provides the most effective weed control [13]. H. Karimmojeni, A.G. Pirbaloti, P. Kudsk, V. Kanani and A. Ghafori concluded that the tank mixtures of bentazone and bromoxynil with a non-ionic surfactant or 2,4-D with MCPA protect the yield by providing a satisfactory weed control with acceptable levels of crop phytotoxicity and are good options for the chemical control of broadleaf weeds in flax sowings [14]. In Russia, in 2018, 15 herbicides were registered on oil flax for application in the phase of leaf development and at the early stages of weed plants growth [14]. The preemergent soil herbicides were not registered.

3. Materials and methods

The aim of research is to study the possibility of application of preemergent soil herbicides in the cultivation of oil flax in southern Russia in the conditions of the Krasnodar region. We conducted the research in 2017-2019 on the fields of V.S. Pustovoit All-Russian Research Institute of Oil Crops (VNIIMK), Krasnodar. The object of the research was popular modern preemergent herbicides: Frontier Optima (ai dimethenamid-P), EC (1.2 l/ha), Dual Gold (ai S-Metolachlor), EC (1.6 l/ha), Gardo Gold (ai S-Metolachlor + terbutylazine), SC (4.0 l/ha) and the tank mixture of herbicides Dual Gold, EC (1.6 l/ha) + Gezagard (ai prometrin), SC (3.5 l/ha). We tested herbicides against the background of two controls: without treatment and with manual weeding. We chose the variant used in production conditions for oil flax cultivation for comparison: the spraying of sowings with the tank mixture of herbicides Sekator Turbo (ai amidosulfuron + iodosulfuron-methyl-sodium + mefenpyr diethyl), OD (0.1 l/ha) + Miura (ai quizalofop-P-ethyl), EC (1.2 l/ha).

We applied herbicides manually using a backpack sprayer: preemergent – after sowing of flax, tank mixture of Sekator Turbo, OD (0.1 l/ha) + Miura, EC (1.2 l/ha) – in the phase of leaf development. In control variants, we did not apply preparations. We carried out the infestation recording, assessment of the biological efficiency of herbicides and their phytotoxicity (by EWRC scale) according to the guidelines of FSBSI VIZR [15]. The number and species composition of weeds was recorded twice: the first time after 20-30 days of herbicides application, the second time – after 40-60 days. Using a small-sized harvester, the crop was harvested and tended to 100 % purity and 12 % seed moisture. We determined he oil content in seeds of oil flax by nuclear magnetic resonance analysis on an AMV-1006M analyzer according to GOST 8.597-2010 [16].

4. Results

In 2017, in the presowing period, the accumulated precipitation from October to March was less than the long-term average values (325.0 mm) – 312.0 mm; 2018 and 2019 were characterized by a significant precipitation in the same period: 472.9 and 352.5 mm, respectively (Table 1).

| Year | Amount for October-March | Month | Amount for April-July |
|------|--------------------------|-------|-----------------------|
| Long-term average | 325.0 | 48.0 | 57.0 | 67.0 | 60.0 | 232.0 |
| 2017 | 312.0 | 43.5 | 116.0 | 63.4 | 86.7 | 309.6 |
| 2018 | 472.9 | 17.6 | 86.0 | 11.0 | 119.2 | 233.8 |
| 2019 | 352.5 | 45.5 | 120.0 | 41.5 | 73.5 | 280.5 |
The amount of precipitation that fell during the growth season of oil flax was characterized by an uneven distribution: a significant excess of the level of precipitation above the norm during budding and ripening (in May and July), and the lack of precipitation during active growth and in the flowering stage (in April and June). In June, the air temperature during the years of research was significantly higher (by 1.6-5.0 °C) that the long-term annual average value (20.4 °C), which negatively affects the indicators of crop productivity (Table 2).

**Table 2.** Daily average air temperature of the growth period of oil flax, °C.

| Year   | Month IV | Month V | Month VI | Month VII | Average | Departure from long-term annual average, °C ± |
|--------|----------|---------|----------|-----------|---------|---------------------------------------------|
| 2017   | 10.9     | 16.8    | 20.4     | 23.2      | 17.8    | -                                          |
| 2018   | 13.5     | 19.0    | 23.5     | 26.3      | 20.6    | 2.8                                         |
| 2019   | 11.0     | 21.8    | 25.4     | 23.4      | 20.4    | 2.6                                         |

The infestation of oil flax sowings during the growth period was low (up to 16 pcs./m²) and represented by annual cereal (*Setaria glauca* L.) and dicotyledonous weeds (*Ambrosia artemisiifolia* L., *Chenopodium album* L., *Abutilon theophrasti* Medicus). The preemergent herbicides had different effects on weeds. The Frontier Optima preparation showed the utmost biological effectiveness at the time of all three recordings: 31.0, 40.5 and 66.7 %, respectively, which is comparable with the biological effectiveness of the tank mixture of herbicides Sekator Turbo + Miura: 58.6, 56.8 and 50.0 % (Table 3).

**Table 3.** The effect of herbicides on the infestation of oil flax sowings.

| Variant                                      | Recording* | The number of weed plants | The mass of weed plants at the time of second recording |
|----------------------------------------------|------------|---------------------------|------------------------------------------------------|
|                                              |            | pcs./m² | decrease, % against control | g/m² | decrease, % against control |
| Control, without treatment                   | 1          | 7.3     | -                          | 35.7 | -                          |
|                                              | 2          | 9.3     | -                          |       |                            |
|                                              | 3          | 3.0     | -                          |       |                            |
| Frontier Optima, EC (1.2 l/ha)              | 1          | 5.0     | 31.5                       | 1.1   | 96.9                       |
|                                              | 2          | 5.5     | 40.9                       |       |                            |
|                                              | 3          | 1.0     | 66.7                       |       |                            |
| Dual Gold, EC (1.6 l/ha)                     | 1          | 5.0     | 31.5                       | 1.3   | 96.4                       |
|                                              | 2          | 7.0     | 24.7                       |       |                            |
|                                              | 3          | 3.0     | 0.0                       |       |                            |
| Gardo Gold, SC (4.0 l/ha)                    | 1          | 5.6     | 23.3                       | 1.3   | 96.4                       |
|                                              | 2          | 8.1     | 12.9                       |       |                            |
|                                              | 3          | 2.9     | 3.3                       |       |                            |
| Dual Gold, EC (1.6 l/ha) + Gezagard, SC (3.5 l/ha) | 1          | 6.4     | 12.3                       | 1.7   | 95.2                       |
|                                              | 2          | 7.8     | 16.1                       |       |                            |
|                                              | 3          | 3.0     | 0.0                       |       |                            |
| Sekator Turbo, OD (0.1 l/ha) + Miura, EC (1.2 l/ha) | 1          | 3.0     | 58.6                       | 0.4   | 98.9                       |
|                                              | 2          | 4.0     | 56.8                       |       |                            |
|                                              | 3          | 1.5     | 50.0                       |       |                            |

* 1 – 20-30 days after treatment; 2 – 40-60 days after treatment; 3 – before harvesting.
The tank mixture of Dual Gold + Gezagard had a relatively weak herbicidal effect compared to other variants: the mass of weeds at the time of the second recording decreased by 95.2%; the decrease in the number of weeds was insignificant.

In addition to low biological activity against weeds, the herbicide Gardo Gold and the tank mixture of Dual Gold + Gezagard had a phytotoxic effect on oil flax, which was expressed in plant depression, tissue necrosis and destruction of single specimens (Figures 1, 2).

![Figure 1. The manifestation of phytotoxicity of the herbicide Gardo Gold on oil flax plants (orig.).](image1)

![Figure 2. The manifestation of phytotoxicity of the tank mixture of herbicides Dual Gold + Gezagard on oil flax plants (orig.).](image2)

By the EWRC scale (European Weed Research Council), the phytotoxicity of herbicide Gardo Gold, SC (4.0 l/ha) was 43.1%, and the phytotoxicity of the tank mixture of herbicides Dual Gold, EC (1.6 l/ha) + Gezagard, SC (3.5 l/ha) was 35.7%. 11.1 and 5.6%, of oil flax plants, respectively, were completely destroyed, which negatively affected the planting density and contributed to decrease in crop productivity.

On average for three years of research, the maximum yield of oil flax (1.30-1.36 t/ha) was obtained in the variants with application of herbicides Frontier Optima and Dual Gold (Table 4). In all years of research we did not observe the signs of phytotoxicity during application of these preparations, and crop productivity was almost always higher than during the sowings treatment with tank mixture of Sekator Turbo + Miura. Moreover, the yield increase in the variant with Frontier Optima application was at a considerable significance value annually. The slight differences in productivity in the control variants without treatment (1.14 t/ha) and with manual weeding (1.22 t/ha) are due to the low degree of sowings infestation and low competition of crop with weeds.

The application of herbicide Gardo Gold and the tank mixture of Dual Gold + Gezagard negatively affected the flax productivity in 2017 and 2019, and positively affected it in 2018. The effect ambiguity of these preparations on the crop productivity is explained by the various consequences of the manifestation of phytotoxicity under unequal moistening conditions. In 2017 and 2019, at the period of budding and flowering, thinned sowings developed significantly fewer additional branches than the same sowings but in favorable weather conditions of 2018, characterized by an abundance of available moisture.

| Variant                      | Productivity, t/ha | Oil content of seeds, % |
|------------------------------|--------------------|-------------------------|
|                              | 2017  | 2018  | 2019  | on average for three years | 2017  | 2018  | 2019  | on average for three years |
| Control, without treatment   | 1.03  | 1.24  | 1.16  | 1.14                         | 45.9  | 46.2  | 44.9  | 45.7                         |
We observed the highest oil content in the control variant without treatment (45.7 %) with application of herbicides Dual Gold (45.7 %) and Frontier Optima (45.6 %). We observed the decrease of oil content in other variants: up to 45.2 % under the spraying of sowings with the tank mixture of Sekator Turbo + Miura, up to 41.1 and 44.9 %, respectively, under the preemergent application of Gardo Gold and Dual Gold + Gezagard.

The preemergent application of herbicides contributed to a high net profit during crop cultivation. On average, during the research period, we observed the highest net profit under application of Frontier Optima (15758.0 rub/ha) and Dual Gold (14842.5 rub/ha). The same variants provided the highest cost-effectiveness: 90.0 and 86.5 %, respectively (Table 5). In other variants, the level of cost-effectiveness was lower than in the control variant without sowings treatment with herbicides.

Table 5. The economic effectiveness of herbicides application.

| Variant                                      | Net profit, rub/ha | Cost-effectiveness, % |
|----------------------------------------------|--------------------|-----------------------|
| Control, without treatment                   | 13419.0            | 103.5                 |
| Frontier Optima, EC (1.2 l/ha)               | 15758.0            | 90.0                  |
| Dual Gold, EC (1.6 l/ha)                     | 14842.5            | 86.5                  |
| Gardo Gold, SC (4.0 l/ha)                    | 10010.0            | 51.5                  |
| Dual Gold, EC (1.6 l/ha) + Gezagard, SC (3.5 l/ha) | 6117.5             | 28.5                  |
| Sekator Turbo, OD (0.1 l/ha) + Miura, EC (1.2 l/ha) | 12350.0            | 72.0                  |

5. Summary
The conducted research showed that in the conditions of southern Russia, the application of the preemergent soil herbicides Frontier Optima, EC (1.2 l/ha) and Dual Gold, EC (1.6 l/ha) provides an effective weed control on oil flax sowings and contributes to higher crop productivity compared to the used in the production method of spraying vegetative plants with a tank mixture of herbicides Sekator Turbo, OD (0.1 l/ha) + Miura, EC (1/6 l/ha). Applying these herbicides, the producers will receive a reliable method of weed control, which will increase the competitiveness of sowings and indicators of the economic effectiveness of oil flax cultivation. The other variants, studied during our research, have a phytotoxic effect on oil flax plants, which affects its productivity and oil content of seeds, and should not be applied on the crop.

6. References
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