Weed control of oil flax in the area of unstable moistening in the south of Russia

V M Lukomets, A S Bushnev and G I Orekhov
V.S. Pustovoit All-Russian Research Institute of Oil Crops, 17 Filatova street, Krasnodar, 350038, Russia
E-mail: vniimk-agro@mail.ru

Abstract. The work aimed at determining the optimal methods of using herbicides that ensures the control of gramineous and dicotyledonous weeds when growing oil flax in the conditions of unstable moistening of the south of Russia. A single treatment with a pre-emergence herbicide Dual Gold after sowing a crop against monocotyledonous gramineous or with a foliar Tifi at the stage of true leaves development of flax against dicotyledonous weeds contributed to the of 0.07-0.09 t/ha higher yield than in the control with manual weeding. However, the sequential introduction of these preparations led to a decrease in crop yield by 0.14 t/ha on one plot. We noted a slight increase in yield (+0.04 t/ha) under the separate application of Miura graminicide and anti-dicotyledonous herbicide Sekator Turbo, and a decrease in yield (-0.16 t/ha) and seed oil content (-0.8 %) under application of their tank mixture. The separate foliar herbicide treatments should be a priority in weed control of oil flax.

1. Introduction
A steady increase in the production of vegetable oils is a strategic challenge facing the domestic agriculture. Due to data published by the Federal Service of State Statistics, the main producers of vegetable oil are sunflower, soybean and rapeseed; they occupy 10.6, 3.6, and 1.9% of crop acreage in Russia, respectively. Oil flax (crown flax) can supplement and partially replace these crops, its processed products are raw materials for many industries. As an agricultural crop of an early sowing period, it efficiently uses the accumulated soil moisture deposits, developing high yields even in regions with unstable and insufficient moistening. Russian agricultural producers appreciated the potential of this crop, which is clearly demonstrated by the increase in its acreage more than 93 times – from 8.7 to 814.7 thousand hectares for the period from 2001 to 2019. In 2020, it kept growing and increased by 26.3 % to 1029.2 thousand hectares.

With the increase of the crop acreage, there is also a noticeable increase in the number of herbicides allowed for use on oil flax sowings. By the end of 2020, their list reached 21 items, and while back in 2012 there was only one. As a rule, the application of pre-emergence herbicides in the protection system of most agricultural crops allows avoiding the first wave of weeds. This also applies to oil flax, but the first pre-emergence herbicide (Egida, SC, a.i. mesotrione) was registered on the crop only in 2020. It should also be noted that the role of herbicides in the crops cultivations is incredibly significant, since a low level of weed control always leads to a decrease in the potential yield, which for flax is 2.5 t/ha and higher and may be one of the reasons for the insufficient harvest, which in 2017-2019 in the Russian Federation was 0.78-1.09 t/ha, and 0.56-1.15 t/ha in the Southern Federal District.
Internationally, the problems of herbicide application in plant growing draw great attention [1-5], including the issues of their effect on the productivity of flax sowings. For example, in Canada, the herbicide application in flax cultivation provided an increase in crop yield to almost 0.62 t/ha with a decrease in weed biomass by 0.05 t/ha [6]. Studies conducted by S. Andrusczak, U. Gawlik-Dziki, P. Kraska, E. Kwiecinska-Poppe, K. Rozylo and E. Palys in the conditions of Eastern Poland have established a positive effect of the use of intensive cultivation technology with herbicide application (Linurex 50 WP, Fusilade Forte 150 EC, Glean 75 WP) on the flax productivity, with an increase in seed yield by 80-102 % compared to the herbicide-free technology [7]. In the occurrence of gramineous and broad-leaved weeds, a tank mixture of an anti-dicotyledonous preparations and graminicide is used to protect flax sowings, but in some cases this method can have a phytotoxic effect on the crop. For example, in the northeastern part of the USA, H. Karimmojeni, A.G. Pirbaloti, P. Kudsk, V. Kanani and A. Ghafori [8] revealed a negative effect of the tank mixture of MCPA with bromoxynil or bentazone on oil flax, leading to a decrease in its yield. Similar consequences were noted after application of a tank mixture of dichlorprop-R with mecoprop-R and MCPA. At the same time, M.E. Kurtenbach, E.N. Johnson, R.H. Gulden and C.J. Willenborg did not reveal a negative effect of preparations based on flutiacet-methyl, pyroxasulfone, topramezone and their tank mixtures on the crop yield, but noted the phytotoxic effect of tank mixtures of MCPA with flutiacet-methyl and topramezone [9]. J. Mankowski, K. Pudelko, J. Kolodziej and T. Karas established the positive effect of chlorsulfuron on the productivity and quality of flax along with good weed control, but bentazone, despite its high herbicidal effect, decreased the quantity and quality of the crop yield [10]. In the south of Russia, the separate application of anti-dicotyledonous herbicides Tifi, WDG (0.025 kg/ha) (thifensulfuron-methyl) or Magnum, WDG (0.01 kg/ha) (metsulfuron-methyl) and graminicide Miura, EC (1.2 l/ha) (quizalofop-P-ethyl) contributed to the high productivity of oil flax, and their tank mixtures led to a decrease in yield by 0.04 and 0.09 t/ha and seed oil content by 1.1 and 0.8 %, respectively [11].

The application of herbicides that provide weed control in the absence of phytotoxicity on oil flax in the south of Russia has been little studied. Currently, these studies are relevant, and their results will be of use practically.

The aim of the research is to study the effect of various variants of herbicide application on the productivity of oil flax in the area of unstable moistening in the south of Russia.

2. Materials and methods

We carried out the studies in 2018-2020 on leached chernozem of Western Ciscaucasia in the area of unstable moistening at V.S. Pustovoit All-Russian Research Institute of Oil Crops (Krasnodar, Russia) during the cultivation of oil flax variety FLIZ. The object of study was the methods of weed control in the sowings of Linum usitatisimum L. with modern herbicides: pre-emergence herbicide of soil action Dual Gold (a.i. S-Metolachlor) and foliar graminicide Miura (a.i. quizalofop-P-ethyl); anti-dicotyledonous Tifi (thifensulfuron-methyl) and Sekator Turbo (a.i. amidosulfuron + iodosulfuron-methyl sodium + mefenpyr-diethyl).

The scheme of experiment included the following variants for the herbicide application on oil flax:

- Control, manual weeding;
- Pre-emergence application of Dual Gold, EC (1.6 l/ha);
- Spraying of sowings with Tifi, WDG (0.025 kg/ha) at the stage of true leaves development of crop;
- Pre-emergence application of Dual Gold, EC (1.6 l/ha), spraying of sowings with Tifi, WDG (0.025 kg/ha) at the stage of true leaves development of crop;
- Sequential separate application of preparations Miura, EC (1.2 l/ha) and Sekator Turbo, OD (0.1 l/ha) at the stage of true leaves development of crop;
- Spraying of sowings with a tank mixture of Miura, EC (1.2 l/ha) + Sekator Turbo, OD (0.1 l/ha) at the stage of true leaves development of crop.
We applied herbicides with a working fluid consumption rate of 300 l/ha: pre-emergence – on the day after sowing the crop, the rest – at the stage of true leaves development of flax. The record area was 12.0 m$^2$, the number of replications was four, the plots placement was randomized. We used the cultivation technology of flax recommended for the region, except for the studied variants. The yield was harvested by direct combining and normalized to 100 % of purity and the standard moisture content of seeds (12 %). We determined the oil content in seeds by nuclear magnetic resonance in accordance with State Standard R 8.620-2006.

3. Results
In the process of work, we obtained the results on the yield and oil content of oil flax seeds under various methods of herbicide application and the range of their variability in the years of research (table 1).

### Table 1. Productivity and oil content of oil flax seeds under various variants of herbicide application.

| Variant | Herbicide | Application method | Productivity (t/ha) | Oil content of seeds (t/ha) |
|---------|-----------|--------------------|---------------------|-----------------------------|
|         | control, manual weeding | -                  | 1.33 (1.31–1.35)    | 45.9 (45.5–46.2)            |
|         | Dual Gold, EC (1.6 l/ha) | pre-emergence      | 1.42 (1.34–1.52)    | 45.6 (44.8–46.4)            |
|         | Tifi, WDG (0.025 kg/ha) | foliar             | 1.40 (1.20–1.60)    | 45.6 (44.9–45.9)            |
|         | Dual Gold, EC (1.6 l/ha), Tifi, WDG (0.025 kg/ha) | pre-emergence foliar | 1.19 (1.04–1.42)    | 45.4 (44.6–46.1)            |
|         | Miura, EC (1.2 l/ha), Sekator Turbo, OD (0.1 l/ha) | separate foliar    | 1.37 (1.34–1.40)    | 45.4 (44.6–45.9)            |
|         | Miura, EC (1.2 l/ha) + Sekator Turbo, OD (0.1 l/ha) | tank mixture foliar | 1.17 (1.12–1.24)    | 45.1 (44.0–45.7)            |
| HMD_05  |           |                    | 0.20                | 0.53 (-)                    |

The productivity and oil content of seeds allowed determination of the oil yield of oil flax in the studied variants (figure 1).

4. Discussion
The weather conditions during the growth season of oil flax in the years of research were not stable. The amount of precipitation between October 2017 and 2018 to March 2018 and 2019 exceeded the average long-term norm by 45.5 and 8.5 %, respectively, which characterized these years as sufficient in terms of the accumulation of moisture deposits. The amount of precipitation during the growth season of the crop in 2018 was at the normal level, and in 2019 it exceeded it by 20.9 %. These conditions contributed to the normal growth and development of flax. In 2020, there were dry conditions for oil flax – the initial moisture deposits in the soil and the amount of precipitation of the growth season were only 59.5 and 86.8 % of the average long-term values. The average daily temperature from April to August was above the norm for all three years of research, exceeding it by 3-5 °C in the summer months, which had a negative effect on crop productivity.

The infestation of the experimental plot was low – on average, over three years it was 12.2 plants per 1 m$^2$, with the presence of monocotyledonous (Setaria glauca L.), annual dicotyledonous (Amaranthus retroflexus L., Chenopodium album L., Xanthium strumarium L., Solanum nigrum L.,
Fallopia convolvulus L.) and perennial (Linaria vulgaris (L.) Mill., Barbarea vulgaris R.Br., Convolvulys arvensis L., Sonchus arvensis L.) weeds.

Figure 1. The oil yield of oil flax depending on the variants of herbicide application.

The pre-emergence application of Dual Gold, EC (1.6 l/ha) suppressed the development of the first wave of weeds, ensuring normal growth and development of plants starting from the oil flax emergence. Due to this, on average for 2018-2020, we obtained the highest crop yield – 1.42 t/ha. The foliar treatment at the stage of true leaves development of oil flax with the herbicide Tifi, WDG (0.025 kg/ha) allowed to obtain a yield of 0.07 t/ha higher than the control. However, the combined application of these preparations led to a decrease in crop yield by 0.14 t/ha.

The comparison of two methods of application of foliar herbicides graminicide Miura, EC (1.2 l/ha) and anti-dicotyledonous Sekator Turbo, OD (0.1 l/ha) showed the advantage of their separate application (increase in yield by 0.04 t/ha compared to the control) over combined in the form of tank mixtures. The narrow range of yield variability in this variant (1.34-1.40 t/ha) indicates the possibility of obtaining a high effect both in years with favorable weather conditions and with a moisture deficit. The tank mixture of these herbicides had a phytotoxic effect on flax plants, decreasing the yield by 0.16 t/ha and the oil content of seeds by 0.8 % compared to the control. Moreover, the difference in yield between these methods of herbicide application averaged 0.20 t/ha or 15 % over three years, which indicates the high importance of the correct algorithm of actions when choosing a method for implementing this technological procedure (Table 1).

The pre-emergence treatment of flax with herbicide Dual Gold, EC (1.6 l/ha), foliar treatments at the stage of true leaves development of flax with Tifi, WDG (0.025 kg/ha), separate application of Miura, EC (1.2 l/ha) and Sekator Turbo, OD (0.1 l/ha) contributed to an increase in oil yield compared
with the control by 0.4, 0.3 and 0.2 t/ha, respectively. It is worth mentioning that we determined the most stable oil yield in terms of variability, close to the control, in the variants with pre-emergence application of Dual Gold, EC (1.6 l/ha) and foliar separate application of Miura, EC (1.2 l/ha) and Sekator Turbo, OD (0.1 l/ha) at the stage of true leaves development of flax (Figure 1).

5. Conclusion
As a result of the research, we established the effective methods of herbicide application on oil flax in the area of unstable moistening in the south of Russia, which allow to obtain a high and quality yield:

- The pre-emergence application of the soil herbicide Dual Gold, EC (1.6 l/ha) – in the presence of monocotyledonous gramineous and certain dicotyledonous weeds, mainly in a high soil fertility;
- The foliar treatment at the stage of true leaves development of oil flax with herbicide Tifi, WDG (0.025 kg/ha) in the presence of dicotyledonous, including MCPA-resistant weeds;
- The foliar separate application of herbicides Miura, EC (1.2 l/ha) in the presence of perennial (dog’s grass) and annual gramineous weeds and Sekator Turbo, OD (0.1 l/ha) in the presence of annual weeds, including those resistant to 2M-4X, and some perennial dicotyledonous weeds. This method is universal, since it can be used with a mixed type of infestation, it ensures stable obtaining of high yields both in years with favorable weather conditions and with a moisture deficit.

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