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Improvement of elements of oil flax cultivation technology on gray forest soil

E I Lupova\textsuperscript{1}, E A Vysotskaya\textsuperscript{2} and D V Vinogradov\textsuperscript{1}

\textsuperscript{1}Ryazan State Agrotechnological University Named after P.A. Kostychev, Kostychev st., 1, Ryazan, 390044, Russia
\textsuperscript{2}Voronezh State Agrarian University Named after Emperor Peter I, Michurin st., 1, Voronezh, 394087, Russia

E-mail: vdvrzn@mail.ru

Abstract. The article proposes the results of investigations on agroecological assessment of oil flax varieties depending on the sowing time in the southern part of the Nonchernozem belt of Russia. The experiments took place at the agrotechnological experimental station of Ryazan State Agrotechnological University Named after P.A. Kostychev on gray forest soil typical of the region. It should be noted that the introduction of new varieties into the zone requires a more detailed study of the technology of their cultivation, including the determination of the optimal seeding rate and sowing date for specific weather conditions. The objects of investigations were domestic varieties of flax: Istok, VNIIMK 620, Sunlin and LM 98. Sowing was carried out in two terms - the third decade of April and the first decade of May. According to the results of experiments, it can be concluded that the yield was formed due to the density of planting, largely due to better survival in the second term of sowing. Despite significantly lower yield parameters of the second crop, such as the number of bolls per plant, the mass of 1,000 seeds, the number of seeds per boll, the yield of Sunlin and LM-98 varieties was higher than in the first term of sowing. On average, the maximum productivity was shown by Istok variety when the first sowing period (21.2 dt / ha) and Sunlin variety when the second period of sowing (20.6 dt / ha). During the years of studying varieties, flax oil content was 36.3-46.3 %. There was a decrease in this parameter in all experimental varieties by 1-3.5 % in the second period of sowing.

1. Introduction
For the present-day agriculture, it should be stated that the type of arable flax of the Eurasian subspecies is oil flax or as it is also called crown flax (\textit{Linum usitatissimum L., subs. Eurasiaticum Vav. et Ell.}) adapted in many countries of the world and cultivated in all continents [1]. According to FAO data, over 8 million hectares of flax are planted in the world and cultivated in all continents [2].

The introduction of high-yielding varieties resistant to adverse environmental factors is of great economic importance, since it is an available and inexpensive way to increase the production of agricultural raw materials.

The agricultural market, including the oil industry and the processing industry, imposes strict requirements on the varieties currently cultivated in agriculture [3]. Varieties must be rich in fiber and seeds, have resistance to lodging, uniform maturation, high resistance to diseases and pests, as well as...
meet the manufacturer's requirements for the length of the growing season and other characteristics [4].

The selection of crown flax for the past 40 years has provided a yield increase of 25-30% and current varieties have genetic diversity. Developed and improved methods of biotechnology at the stages of increasing genetic diversity, genetic stabilization of the breeding material, identification and reproduction make possible to solve the problem of increasing the efficiency of the flax breeding process and creating some competitive genotypes [5]. In the Russian Federation, in addition to highly productive domestic varieties some varieties from the Republic of Belarus, Europe and other countries appeared [6].

The advantages of oil flax are drought resistance and short growing season [7]. Oil flax is not inferior in economic profitability to other oilseeds and is a much better predecessor. Considering that in the Nonchernozem belt of Russia there are few pests and diseases of this crop, which reduces the direct costs of pesticides [8], it grows well on all types of soil [9].

At this stage, the most effective way to increase the yield and bulk yield of oil seeds of flax is to introduce into production new high-yielding food-grade varieties and realize their potential by improving agricultural technology for specific soil and climatic conditions of the region.

2. Target setting
In the Russian Federation and in the world, producers' interest in oilseeds has increased due to the high demand and high cost of seeds at processing plants when purchasing raw materials.

Important oilseeds grown in the Nonchernozem belt of Russia are sunflower and spring rape. Oilseed flax is still not sufficiently grown, but in the near future it should become an alternative crop for sunflower for consumption, and for rapeseed for placement in crop rotation in Ryazan region and neighboring regions [10].

The sown area of oil flax in Ryazan region is small - about 3 thousand hectares annually and in the neighboring Tula region in 2018 it amounted to a little over 4.7 thousand hectares. In the conditions of the region, the yield of oil flax can reach up to 2.5-2.8 t/ha.

One of the important issues in agricultural technology of growing crops is the study and selection of highly productive varieties for a particular region [11].

Introduction of new varieties to the belt requires a more detailed study of the technology of their cultivation [12], including the determination of the optimal seeding rate, sowing period, the level of mineral nutrition and the foliar application for specific weather conditions [13].

The technology of growing flax, like other agricultural crops, is a complex of interrelated activities and the role of each of them is not only functionally related to each other, but also depends entirely on the biological characteristics of the crop and variety. Proceeding from this, we studied the main elements of the agrotechnology of cultivating a crop, to the greatest extent determining its yield, and these are the choice of optimal periods for sowing and the introduction of the most promising varieties that have proven themselves in other agro-climatic zones of the Russian Federation. The study of the influence of agrotechnological elements on the cultivation of oil flax in specific soil and climatic conditions is very relevant, which is the basis of our research.

3. Materials and methods
Our investigations took place the agrotechnological experimental station of Ryazan State Agrotechnological University Named after P.A. Kostychev in 2017-2018 on gray forest soils.

The meteorological conditions of vegetation periods over the years of experiments: 2017 and 2018 were characterized by increased moistening and normal temperature conditions (HTC - 1.5). The precipitation during the years of investigations prevailed in the second half of the growing season of oil flax: end of July - first half of August.

Studies have been conducted on gray forest soil, characterized by the following agrochemical parameters: pH Сі 5.1-5.5; humus content of 1.9-3.3%, mobile phosphorus (P₂O₅) – 195-252 mg / kg (high), potassium (К₂О) 123-133 mg / kg.
The two-factor experiment scheme included factor A (sowing dates): the sowing periods were the third decade of April and the second decade of May and factor B (varieties): VNIIMK-620, Sunlin, Istok, LM 98. The sown area of the plot was 30 m² and the registration plot was 20 m². The replication was fourfold.

Variety Istok, bred by Penza Agricultural Research Institute, is included in the State Register of the Russian Federation in the Middle Volga (7) region. It is characterized by a short stem, yellow seeds and maturation 2-6 days later than the standard. During the years of field tests, no disease was observed.

Variety VNIIMK 620 was originated by Federal Research Center "All-Russian Scientific Research Institute of Oilseeds Named after V.S. Pustovoit". It is included in the register for the North Caucasus (6) region. The seeds are brown; the variety has medium ripeness and is resistant to lodging and Fusarium wilt disease.

The applicant of variety LM 98 is the All-Russian Flax Research Institute. It is included in the State Register of the Middle Volga (7) region. The variety is vigorous. Seeds are yellow. The variety is mid-season, resistant to lodging and shattering.

The applicant of variety Sunlin is "Ecolen" Limited Liability Company, Tver. The variety is included in the State Register of the Middle Volga (7) region. It is low. Seeds are yellow, and the variety is food-grade. It is of average ripeness. Over the years of field trials in region 7, slight anthracnose damage has been noted.

The flax varieties selected for the experiments meet all the criteria for food-grade ones, with high characteristics of vegetable oil, including a high content of oleic acid.

Agrotechnical measures were according to the recommendations adopted in the Nonchernozem belt of Russia. It included fall tillage to a depth of 20–22 cm, early spring harrowing, then cultivation to a depth of 12-14 cm and pre-sowing cultivation to a depth of 1.5-2 cm. Mineral fertilizers in a dose of N90(PK)60 active ingredient / ha were applied under pre-sowing cultivation. Ammonium nitrate and nitrophoska were applied in terms of active ingredient.

Sowing was in an ordinary way with the help of selection seeder SSNT-16, and the seeding rate in the experiment was 8 million pieces of germinating seeds / ha.

Herbicide Fenizan, VR, 0.2 l / ha, with the active substance of 360 g / l dicamba acid + 22.2 g / l chlorsulfuron acid was used in the experiment against annual dicotyledonous weeds and some perennial dicotyledonous weeds. The herbicide treatment in the phase of "herringbone" was carried out by OH-400 in an aggregate with an MTZ-1221 tractor in a tank mix with insecticide Fastak, K.E. in a dose of 0.15 l / ha.

The harvesting took place when reaching full ripeness of oil flax by direct combining with combine TERRION-SAMPO SR2010. When full ripeness of flax, all leaves fell, stems and bolls became brown.

It should be noted that all agrotechnical techniques were carried out in the maximum approximate optimal time.

Hydrological and soil assessments in research, were carried out through appropriate systems and methods [14], [15].

Observations, records and analyses were carried out according to generally accepted methods and GOST. Mathematical data processing was carried out by the method of variance analysis according to R. Fisher in the presentation of B.A. Dospekhov (1985) [16] on a PC. Agrochemical studies were performed in laboratories of the State Station of the Agrochemical Service "Ryazanskaya".

4. Results and discussion
The flax has the poor root system, and the first phases of growth and development proceed rather slowly. In our studies, phenological observations showed that the duration of the main phases of growth and development of oil flax plants was different in terms of sowing.
When sowing in the first decade of May, the vegetation period of the crop was 94-115 days. When sowing in the second decade of May, it was 89-107 days. The planting dates had a significant impact on the temperature and water regime of oil flax plants during the whole growing season.

The sowing-shoots period of flax depending on the time of sowing was different. It was established that with an increase in average daily air temperature, the interphase periods of plant growth and development decreased. Shoots of flax appeared on the 6-7th day after sowing, had small cotyledonary leaves and a bud between them, from which a stem with real leaves, flowers and bolls developed. The budding phase was noted when the first bud appeared on the main stem. It lasted for 18-23 days in studies. The height growth of plants was 3-5 cm per day.

On average, flowering lasted for 24-27 days with the first sowing season and 20-21 days with the second sowing period, depending on the flax variety. In experiments, the growth of plants at the beginning of the phase noticeably weakened, and at the end it completely stopped.

Sowing oil flax in the second term contributed to better preservation of plants. This pattern was traced in all varieties.

The herringbone stage came in 25-30 days after the sowing. Flax plants reached a height of 5-10 cm or more and had 6-8 pairs of true leaves. This stage was characterized by the slow growth of stems in height and the rapid development of the root system.

Starting from the herringbone stage, there was a 2-4 days’ increase in the interstage period of the herringbone - budding and a 2-4 days’ increase in the interstage period of flowering - green ripeness in Istok variety. As a consequence, the lengthening of the vegetation period of this oil flax variety for 4-8 days took place.

The duration of the ripening phase was 15-22 days, depending on the factors of the experiment. It can be divided into green, early yellow and full ripeness.

In 2017, the oil flax of the first sowing period had secondary flowering on varieties Sunlin and VNIIMK-620. Secondary flowering is often noted at a time when the hot period is replaced by abundant precipitation, especially in the second period of growth and development. Secondary flowering is a genetic sign of early plant development, due to the fact that flax also has perennial species. Due to the biology of the crop when a large amount of precipitation, flowering of flax is more intense. In this case, additional bolls appear, which, unfortunately, do not have time to fully mature. In connection with this, when the crop is threshed by a combine, flax heap has high humidity and many seeds unevenly ripen or do not ripen completely. As a result, the yield and seed quality decrease. In studies, secondary flowering was observed when the first sowing period on the above varieties of oil flax, during the first half of August.

**Table 1.** Field germination, planting density, plant survival and elements of the yield structure of oil flax varieties at different sowing time.

| Sowing time | Variety | Field emergence, % | Planting density, full shoots, pcs / m² | Survival, % | Number of bolls, pcs / plant | Seeds in a boll, pcs | Weight of 1,000 seeds, g |
|-------------|---------|-------------------|----------------------------------------|-------------|-----------------------------|---------------------|------------------------|
| 1st decade of May | VNIIMK 620 | 83.5 | 668.0 | 90.9 | 18.4 | 5.9 | 6.2 |
| | Istok | 83.0 | 664.0 | 95.4 | 19.8 | 6.3 | 6.1 |
| | LM 98 | 79.4 | 635.6 | 89.5 | 16.4 | 6.7 | 5.8 |
| | Sunlin | 82.3 | 658.4 | 94.7 | 18.3 | 6.7 | 6.6 |
| 2nd decade of May | VNIIMK 620 | 87.8 | 734.6 | 92.4 | 16.5 | 5.7 | 6.1 |
| | Istok | 88.6 | 708.8 | 96.5 | 17.2 | 6.2 | 6.2 |
| | LM 98 | 84.2 | 674.0 | 94.3 | 16.7 | 5.9 | 5.7 |
| | Sunlin | 91.9 | 735.2 | 97.7 | 15.9 | 6.2 | 6.4 |

Flax bolls formed as a result of secondary flowering gave shrunk and abortive seeds.
The field germination of the crop from the studied varieties practically changed and depended on the amount of moisture content in the sowing layer of the soil, temperature factors and sowing time (Table 1).

Field emergence and the survival rate of plants of the second term of sowing was higher, which can be explained by better conditions for crop growth. The parameter of the number of bolls per 1 m² of crop is one of the determining factors in the formation of the crop. On average, the largest number of bolls was observed on variety Istok (17.2-19.8 pieces / plant) of two sowing periods. It should be noted that the parameter of the yield structure of the crop is often a genetic parameter inherent in varieties, and it also depends on the elements of agronomy.

The average amount of weeds in the crops of oil flax varieties was in the range of 105.8-131.5 pieces / m². With a later sowing period, the number of weeds and the wet weight of weeds by 1m² decreased, while the weight of one weed increased. So, during the first sowing time, the total number of weed plants per 1m² decreased, on average, by 15.3 pieces. When recording, which took place immediately before the treatment with herbicides, the main weeds in the crops were pigweed, wild spin, field bindweed, milkweed, field sow thistle and barnyard grass. It should be noted that one herbicidal treatment with Fenizan, VR, 0.2 l / ha was enough to cope with most weeds. As a result of the treatment, the herbicide effectively fought annual dicotyledonous and some perennial dicotyledonous weeds.

Analyzing the crop yield, it was noted that the highest yield of flax seeds was obtained on variants with Istok and Sunlin varieties (Table 2).

Table 2. Yield of oil flax varieties depending on the time of sowing.

| Sowing time      | Variety         | Yield, centners / ha |
|------------------|-----------------|----------------------|
|                  | 2017            | 2018                 | average |
| 1st decade of May| VNIIMK 620      | 22.3                 | 16.6    | 19.4  |
|                  | Istok           | 23.8                 | 18.6    | 21.2  |
|                  | LM 98           | 19.5                 | 17.1    | 18.3  |
|                  | Sunlin          | 22.5                 | 18.1    | 20.3  |
| 2nd decade of May| VNIIMK 620      | 21.4                 | 16.6    | 19.0  |
|                  | Istok           | 23.1                 | 17.9    | 20.5  |
|                  | LM 98           | 20.4                 | 17.6    | 19.0  |
|                  | Sunlin          | 22.5                 | 18.8    | 20.6  |
| SSD<sub>05</sub> |                 | 1.35                 | 1.71    |

The yield was formed due to the density of planting, largely thanks to better survival in the second time of sowing. Despite significantly lower yield parameters of the second crop, such as the number of bolls per plant, the weight of 1,000 seeds and the number of seeds per boll, the yield of Sunlin and LM-98 varieties was higher than in the first time of sowing.

On average, variety Istok had maximum productivity in the 1<sup>st</sup> sowing period (21.2 centners / ha) and Sunlin variety in the 2<sup>nd</sup> sowing period (20.6 centners / ha).

During the years of studying varieties, flax oil content was 36.3-46.3 %. There was a decrease in this parameter in all experimental varieties by 1-3.5 % in the second sowing period. The highest oil content was recorded for VNIIMK 620 (42.7-44.4 %) and Sunlin (42.0-46.3 %) varieties. The maximum oil yield was observed in 2017 on Istok variety of the 1st sowing period and amounted to 1,023 kg / ha, mainly due to the high crop yield.

Under different conditions of ripening of flax varieties, the content of lipids, including tocopherols, sterols and carotenoids in oil changes. In the first half of the growing season of the crop and in the early stages of maturation of oilseeds, chlorophyll is included in the oil pigments, the amount of which is reduced by the time of harvest. It should be noted that there is an inverse relationship between the content of chlorophyll and oil in the seeds: the higher the post-harvest ripening of seeds, the more chlorophyll decreases or disappears altogether.
Abortive seeds contain a large amount of linamarine glycoside depending on the oil flax variety, the degree of ripeness of seeds and their oil content. In the studies, as we have already noted, the seeds of the first sowing period had an insignificant glycoside content, due to the secondary flowering.

5. Conclusion

Thus, according to the research results, the possibility of obtaining high and stable yields of oil flax food varieties VNIIMK 620, Sunlin, Istok and LM 98 (2.5 or more tons / ha) in the soil and climatic conditions of the Nonchernozem belt of Russia on gray forest medium-cultivated soils is proved.

According to the results of research, it can be concluded that the yield was formed due to the density of planting, largely due to better survival in the second term of sowing. Despite significantly lower yields of the second crop, such as the number of bolls per 1 plant, the weight of 1,000 seeds and the number of seeds per boll the yield of Sunlin and LM-98 varieties was higher than in the first term of sowing.

On average, the maximum productivity was shown by variety Istok of the 1st sowing period with a yield of 21.2 centners / ha and Sunlin variety of the 2nd sowing period with 20.6 centners / ha. During the years of studying varieties, flax oil content was 36.3-46.3 %. There was a decrease in this parameter in all experimental varieties by 1-3.5 % in the second sowing period.

The maximum profitability in the experiment was when sowing oil flax in the third decade of April (variety Istok - 125.8 %). All developed elements of agrotechnology for the cultivation of oil flax provided high economic effect.

As a recommendation, we offer to introduce high-grade technology for obtaining a crop of 2.0-2.5 tons / ha and more of oil flax varieties Sunlin, VNIIMK 620, Istok and LM 98 on gray forest soils of Ryazan region. All the studied varieties showed high adaptation to the zone of sowing, having proved to be highly resistant to lodging, shedding of seeds, as well as varieties with a low susceptibility to fusarium wilt, anthracnose and other crop diseases.

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