Environmental testing of Linum usitatisimum L. varieties in the steppe zone

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Abstract. The research was conducted from 2017 to 2019 in the steppe zone of southern Russia. In all three years of research, the average annual air temperature exceeded the annual average value by 1.9, 2.1 and 2.2 in 2017, 2018 and 2019, respectively. During the growing season of oil flax, 82.7 mm of precipitation fell in 2017, 225 mm in 2018 and 241 mm in 2019. The following oil flax varieties were tested in the experiment: Fliz (control), VNIIMK 620, Chibis, Solnyshko, Pestrik, and Uralsky. Analysis of the sheaf material showed that the number of bolls on one plant was greater for the varieties Solnyshko and Pestrik (2.6 and 2.7 pieces on one plant, respectively) than on the control variety of Fliz. The average number of seeds in one boll in all studied varieties for three years was the same. The height of Chibis and Pestrik oil flax plants was 2.7 and 2.1 cm higher than the control variant, respectively. The average weight of seeds from one plant over three years was greater for Chibis and Solnyshko varieties and amounted to 0.43 and 0.52 grams, respectively. In terms of yield, the control variant exceeded only VNIIMK 620 variety by 0.04 t/ha. At the same level with the control variety were Chibis, Pestrik and Uralsky. The Solnyshko variety gave significantly lower yields. There was no exceeding of the oil content in flax seeds as compared to the control variety. VNIIMK 620 variety was on par with the Fliz variety with an oil content of 44.82%.

1. Introduction

Oil flax (Linum usitatisimum L.) was one of the first crops consciously grown by man since ancient times. This oldest plant belongs to the flax family and includes more than two hundred species from herbaceous to shrubby plants [1–3].

Oilseed flax seeds contain from 30 to 50% of fatty quick-drying oil, which is of great economic importance [4]. The flaxseed cake remaining after squeezing the oil serves as a valuable fodder [5].

In recent years, in Russia there has been an increase in interest in this culture, due to industry lacking raw materials. The average yield over the last twenty years of cultivation of oil flax in the Russian Federation is 1.0 t/ha and varies from year to year from 0.32 (dry years in southern Russia) to 1.8 t/ha (years favorable for precipitation) [2, 6]. It should be noted that flax is a good precursor to winter wheat which is the main food crop in Russia [5].

The steppe zone is characterized by droughts with a long, rainy season and a decrease in the relative humidity of air and soil, as well as with an increase in the average daily temperature when the...
hydrothermal coefficient varies from 0.44 to 0.47 and the typical plant need for precipitation is not satisfied. Therefore, in this zone it is necessary to grow drought-tolerant varieties [2, 6, 7].

When placing crops in new regions, plants, although they have the ability to adapt to changing environmental conditions within the limits of its genotypes, can react negatively to changes that do not correspond to their biological characteristics, including reducing productivity and product quality [5].

Currently, new varieties of oil flax are cultivated along with the well-known ones. In addition, a number of varieties of foreign origin are entered in the register. While previously several varieties that did not differ significantly from each other were sown, nowadays it is difficult to choose the most adapted to the conditions of a particular region with unique environmental characteristics (climate, soil, rainfall during the growing season, groundwater level) [2, 6].

Selection develops and the registry is supplemented with new varieties. However, recently no series of new varieties of Linum usitatisimum L. have been tested in the steppe zone in comparison with the control variety. In this regard, the goal of our research was to conduct an environmental test of various varieties of Linum usitatisimum L. in the steppe zone of southern Russia.

2. Methodology and research conditions

Scientific research was conducted from 2017 to 2019 in the experimental field of the field crop department of the Crimean Agricultural Research Institute, which is located in the center of the republic and belongs to the risky farming zone. The experiment was established according to the method of B.A. Dospekhov [8]. The soil cover of the experimental field was represented by chernozem southern micellar-carbonate low humus on loesslike clays. The thickness of the humus horizon did not exceed 42 centimeters. The organic matter content was 2.1–2.3%, with 4.1–4.3 of mobile phosphorus, and about 42 mg per 100 g of soil of exchange potassium [9]. The climate of the experiment area is continental. Summer is hot and arid. The average annual air temperature is 10.4 °C, over the past 33 years it has increased by 2 °C. The long-term average annual precipitation was exactly 419 mm, and the hydrothermal coefficient was 0.4–0.6. The distribution of precipitation is uneven. The years with an increased amount alternate with periods of acute deficit. During the growing season, soil droughts and dry winds are observed annually [10].

The weather conditions for the years of Linum usitatisimum L. research are shown in Table 1 in comparison with the long-term average values. In all three years of the studies, the average annual air temperature exceeded the average long-term indicator by 1.9; 2.1 and 2.2 in 2017, 2018 and 2019, respectively. During the growing season of oil flax, 82.7 mm of precipitation fell in 2017; 225 mm in 2018 and 241 mm in 2019.

Agromethods for growing oil flax in experiments. Given the high culture requirements for clean fields and soil fertility, crops of Linum usitatisimum L. were planted after the predecessor—winter barley. We took into account that flax on the same field should not be planted for 6–7 years, due to flax sickness. To significantly reduce field contamination, bastard fallow was implemented. In the fall, 30 kg/ha of P₂O₅ were introduced during the main treatment. In spring, pre-sowing cultivation of 5–6 cm was carried out. 10 kg of P₂O₅ in the form of superphosphate were introduced with sowing by an ordinary seeder SN-16 with row spacing of 15 cm and a sowing rate of 45 kg/ha to a depth of 4–5 cm. Sowing was carried out in all three years in the first decade of March. After sowing the field was rolled. Sowing care consisted of post-emergence harrowing to control weeds at the seedling stage and prevent formation of soil crust to preserve moisture. Harvesting was carried out by Sampo-500 combine during the phase of full maturation of the bolls (in all three years it was the month of July) that acquired a yellow-brown color [6].
Table 1. Weather conditions for years of field experiments on oilseed flax in comparison with long-term average indicators, 2017-2019

| Month   | Average daily air temperature [°C] | Total precipitation [mm] |
|---------|-----------------------------------|--------------------------|
|         | Long-term average annual           |                          |
|         | 2017     | 2018     | 2019     | 2017     | 2018     | 2019     |
| January | -1.20    | -1.90    | 0.97     | 1.03     | 32.2     | 30.0     | 37.8     | 48.6     |
| February| -0.50    | 0.60     | 1.4      | 1.60     | 30.1     | 18.6     | 42.3     | 5.10     |
| March   | +3.10    | 7.00     | 4.6      | 5.80     | 31.4     | 22.1     | 22.8     | 11.7     |
| April   | +10.0    | 9.30     | 13.2     | 9.80     | 28.1     | 3.9      | 3.10     | 26.9     |
| May     | +15.7    | 15.7     | 19.0     | 17.7     | 42.0     | 23.6     | 15.6     | 14.4     |
| June    | +19.9    | 21.4     | 22.7     | 23.8     | 59.1     | 20.5     | 46.3     | 120      |
| July    | +22.2    | 23.8     | 24.1     | 23.1     | 42.0     | 12.6     | 137      | 68.2     |
| August  | +21.5    | 25.1     | 25.1     | 23.7     | 32.4     | 53.2     | 4.30     | 7.80     |
| September | +16.6  | 20.5     | 18.8     | 18.2     | 33.4     | 0.10     | 88.8     | 21.2     |
| October | +10.5    | 12.2     | 13.2     | 13.3     | 27.0     | 24.8     | 20.1     | 18.0     |
| November| +5.90    | 6.60     | 4.8      | 8.50     | 33.3     | 24.0     | 51.2     | 22.6     |
| December| +1.90    | 7.20     | 2.0      | 4.90     | 39.1     | 18.4     | 84.0     | 39.4     |
| Average annual* / Total annual** | 10.4*   | 12.3*    | 12.5*    | 12.6     | 430**    | 288**    | 553**    | 407**    |

The following oil flax varieties were tested in the experiment: Fliz (control), VNIIMK 620, Chibis, Solnyshko, Pestrik, and Uralsky.

When calculating the indicators of growth and development parameters, state methods of variety testing of agricultural crops were used [11, 12].

Analysis of variance was calculated using the method of B.A. Dospekhov [8].

3. Research results.

Table 2 presents the dates of the onset of the main phenological phases of the development of Linum usitatissimum L. of all studied varieties for 2018 and the date of harvesting.

Table 2. Phenological observations in the ecological varietal test of oil flax in 2018

| Varieties   | Development phases / Dates |
|-------------|----------------------------|
|             | sowing  | seedlings | herringbone | flowering | ripening | full ripening | harvest |
| Fliz        | 28.03.  | 10.04.    | 17.04.      | 14.05.    | 12.06.    | 02.07.        | 12.07.  |
| VNIIMK 620  | 28.03.  | 10.04.    | 17.04.      | 14.05.    | 12.06.    | 02.07.        | 12.07.  |
| Chibis      | 28.03.  | 10.04.    | 17.04.      | 14.05.    | 12.06.    | 02.07.        | 12.07.  |
| Solnyshko   | 28.03.  | 10.04.    | 17.04.      | 14.05.    | 12.06.    | 02.07.        | 12.07.  |
| Pestrik     | 28.03.  | 10.04.    | 17.04.      | 14.05.    | 12.06.    | 02.07.        | 12.07.  |
| Uralsky     | 28.03.  | 10.04.    | 17.04.      | 14.05.    | 12.06.    | 02.07.        | 12.07.  |

Table 3 presents the dates of the onset of the main phenological phases of development of all studied oil flax varieties for 2019 and the date of harvesting. This year, flax seeds reached full ripeness in all studied varieties 18 days later than in 2018 due to precipitation during this period.
Table 3. Phenological observations in the ecological varietal test of oil flax in 2019

| Varieties   | Development phases / Dates               |
|------------|----------------------------------------|
|             | sowing | seedlings | herringbone | flowering | ripening | full ripening | harvest |
| Fliz        | 19.03. | 04.04.    | 29.04.      | 21.05.    | 27.06.    | 30.07.        | 30.07.  |
| VNIIMK 620  | 19.03. | 04.04.    | 29.04.      | 24.05.    | 27.06.    | 30.07.        | 30.07.  |
| Chibis      | 19.03. | 04.04.    | 29.04.      | 24.05.    | 27.06.    | 30.07.        | 30.07.  |
| Solnyshko   | 19.03. | 08.04.    | 06.05.      | 27.05.    | 27.06.    | 25.07.        | 30.07.  |
| Pestrik     | 19.03. | 04.04.    | 29.04.      | 27.05.    | 27.06.    | 30.07.        | 30.07.  |
| Uralsky     | 19.03. | 04.04.    | 29.04.      | 24.05.    | 27.06.    | 30.07.        | 30.07.  |

The growth and development parameters of the studied varieties of oil flax are presented in Table 4. As shown by the analysis of sheaf material, the number of bolls on one plant was more on the varieties Solnyshko and Pestrik (2.6 and 2.7 pieces on one plant, respectively) than on the control variety Fliz (LSD<sub>05</sub> = 1.20 pieces). The quantity of seeds in one box in all studied varieties on average over three years was the same (LSD<sub>05</sub> = 0.41 pieces). The height of Chibis and Pestrik oil flax plants was 2.7 and 2.1 cm higher than the control variant, respectively (LSD<sub>05</sub> = 1.96 cm). The average weight of seeds from one plant over three years was greater for Chibis and Solnyshko varieties and amounted to 0.43 and 0.52 g, respectively (LSD<sub>05</sub> = 0.02 g).

Table 4. Growth and development parameters in the environmental testing of different varieties of oil flax (average for 2017–2019)

| Varieties   | Parameters                  |
|------------|-----------------------------|
|             | No. of bolls per 1 plant [pcs] | No. of seeds in 1 boll [pcs] | Plant height [cm] | Mass from 1 plant [g] |
| Fliz        | 6.8                         | 7.8                         | 39.9              | 0.40               |
| VNIIMK 620  | 7.3                         | 7.9                         | 39.0              | 0.36               |
| Chibis      | 8.0                         | 7.9                         | 42.6              | 0.43               |
| Solnyshko   | 9.4                         | 8.1                         | 40.4              | 0.52               |
| Pestrik     | 9.5                         | 7.9                         | 42.0              | 0.38               |
| Uralsky     | 6.3                         | 6.8                         | 39.8              | 0.34               |
| LSD<sub>05</sub> | 1.20                      | 0.41                        | 1.96              | 0.02               |

The density of plants before harvesting was obtained more from VNIIMK 620, Chibis and Solnyshko flax varieties with 33, 106 and 36 pieces per 1 m², respectively, as compared to the Fliz control variety (Table 5) with LSD<sub>05</sub> = 24.5 pieces per 1 m². The weight of 1000 seeds was greatest for the VNIIMK 620, Chibis and Uralsky varieties with 1.58, 0.58 and 1.07 g, respectively (LSD<sub>05</sub> = 0.28 g).

Productivity is the most important effective indicator of crop production and agricultural production in general. The level of productivity reflects the impact of economic and income conditions in which agricultural production is carried out, and the quality of the organizational and economic activity of each enterprise. In our studies, the calculation was carried out at 12% moisture content of flax seeds. In terms of yield, only the VNIIMK 620 variety exceeded the control variant by 0.04 t/ha (LSD<sub>05</sub> = 0.03 t/ha). At the same level with the control were Chibis, Pestrik and Uralsky varieties. The Solnyshko flax variety gave significantly lower yields.
Table 5. Plant density, mass of 1000 seeds and yield in an environmental test of different varieties of oil flax (average for 2017–2019)

| Varieties    | Parameters       | Plant density [pcs/m²] | Mass of 1000 seeds [g] | Yield at 12% moisture [t/ha] |
|--------------|------------------|------------------------|------------------------|-----------------------------|
| Fliz         |                  | 399                    | 4.67                   | 0.62                        |
| VNIIMK 620   |                  | 432                    | 6.25                   | 0.66                        |
| Chibis       |                  | 505                    | 5.25                   | 0.64                        |
| Solnyshko    |                  | 435                    | 4.08                   | 0.48                        |
| Pestrik      |                  | 349                    | 4.83                   | 0.61                        |
| Uralsky      |                  | 419                    | 5.74                   | 0.62                        |
| LSD₀₅        |                  | 24.5                   | 0.28                   | 0.03                        |

The oil content in flax seeds of the studied varieties is presented in Table 6 (the last row presents values from GOST 30623). The excess of this parameter above the control option was not recorded in our experiments. The VNIIMK 620 variety was equal to Fliz variety with an oil content of 44.82% (LSD₀₅ = 2.10%). All other studied varieties contained significantly less oil. Also, Table 6 presents the results of fatty acid composition analysis. The amount of palmitic, palmitoleic, stearic, oleic, linoleic was determined.

Table 6. Content of fatty oil and fatty acid composition in oil flax varieties (average for 2017–2019)

| Varieties          | Oil mass fraction [%] | Palmitic | Palmitic oleic | Stearic | Oleic | Linoleic |
|--------------------|-----------------------|----------|----------------|---------|-------|----------|
| Fliz               | 45.16                 | 2.03     | 0.07           | 3.22    | 16.53 | 14.44    |
| VNIIMK 620         | 44.82                 | 6.25     | 0.23           | 4.12    | 16.06 | 16.10    |
| Chibis             | 39.29                 | 5.22     | 0.05           | 3.94    | 17.46 | 18.06    |
| Solnyshko          | 37.99                 | 6.00     | 0.06           | 3.80    | 14.73 | 15.92    |
| Pestrik            | 38.08                 | 6.23     | 0.10           | 2.58    | 18.71 | 12.55    |
| Uralsky            | 41.18                 | 5.79     | 0.14           | 4.17    | 15.90 | 11.74    |
| LSD₀₅              | 2.10                  | 0.28     | 0.01           | 0.20    | 0.90  | 0.87     |
| GOST 30623         | 3.6-7.2               | up to 0.2| 2.5-5.5       | 11.3-24.0 | 10.4-18.7 |

Table 7 presents the content of linolenic, arachinic, gondoic, behenic and erucic fatty acids.

Table 7. The content of fatty acid composition in oil flax varieties (average for 2017–2019)

| Varieties          | Linoleic | Arachinic | Gondoic | Behenic | Erucic |
|--------------------|----------|-----------|---------|---------|--------|
| Fliz               | 43.89    | 0.11      | 0.28    | 0.17    | 0.1    |
| VNIIMK 620         | 51.92    | 0.31      | 0.14    | 0.11    | 0.4    |
| Chibis             | 45.05    | 0.19      | 0.12    | 0.13    | 0.1    |
| Solnyshko          | 18.81    | 0.16      | 0.10    | 0.18    | 0.2    |
| Pestrik            | 48.18    | 0.10      | -       | 0.13    | 0.2    |
| Uralsky            | 34.76    | 0.11      | -       | 0.10    | 0.2    |
| LSD₀₅              | 2.33     | 0.01      | 0.01    | 0.01    | 0.02   |
| GOST 30623         | 48.5-68.5| up to 0.3 | up to 0.3| up to 0.2| up to 0.6 |
4. Conclusions
1. The average yield of VNIIMK 620 oil flax over the years of research was 0.04 t/ha which exceeded that of the control variant. At the same level with the control were Chibis, Pestrik and Uralsky varieties. The Solnyshko flax variety gave significantly lower yields.
2. The excess of the oil content above the control option was not recorded in our experiments. The VNIIMK 620 variety was equal to Fliz variety with an oil content of 44.82%. All other studied varieties contained significantly less oil.

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