The yield of new varieties of lentil *Lens culinaris* Medik

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**Abstract.** During 2014 – 2019, in the conditions of the Oryol region, the study of yield indicators and protein content in grain in four varieties of lentils created by various methods was carried out. Rauza and Aida were obtained by classical breeding methods. When creating the Vostochnaya variety, the wildlife species *L. orientalis* was used, and the Flamenco variety - *L. tomentosus*. the Flamenco variety had the best yield, with an average yield of 2.27 t/ha over 6 years. The lowest yield of 1.84 t/ha was shown by the Rauza variety. Aida and Vostochnaya with yields of 2.04 and 1.93 t/ha, took an intermediate position. The coefficient of yield regression on the index of environmental conditions in all varieties is close to 1, and deviations from the regression line are insignificant, which indicates their stability. The protein content varied over the years, and the maximum accumulation of protein in the grain was observed in years with low yields. Differences in varieties are less expressed. The average protein content of the Rauza variety was 26.6%, Aida – 26.7%, Vostochnaya – 26.8%, Flamenco - 27.3%. A new variety of Flamenco lentils, with high yield and protein content, remained stable with a regression coefficient for environmental conditions equal to 1. The use of germ plasma of wildlife relatives in breeding new varieties did not affect negatively their response to environmental conditions and the ability to accumulate high protein content in the grain.

1. **Introduction**

Due to the high content of protein, trace elements, and bioactive compounds, lentils have recently been classified as functional foods [1]. Today, consumers are re-evaluating their diet in favor of a balanced diet for a healthy lifestyle [2]. Therefore, lentil production in the world is increasing annually, reaching 6.3 million tons in 2018, according to FAO data [3].

The yield of lentils remains low in comparison with other crops and averages 1.04 t/ha. [3]. It is believed that purposeful breeding work with lentils began late, only in the 80s of the last century [4], which may be one of the reasons for the low yield of the crop. The goals of breeding this crop are determined by high and stable yield, resistance to diseases and pests, high temperatures, drought, improvement of protein quality, and broad adaptability [5].

Russia is a pioneer in lentil breeding, the first varieties were created at experimental stations at the beginning of the last century. Some varieties of Russian origin can be found in the lineage of foreign, in particular, Canadian varieties [6].

Breeding work with lentils in the Oryol region was revived in the early 90s [7]. Using the K-508 sample, the varieties Rauza (2003) and Svetlaya (2008) were created [8]. In 2010, the Aida variety created by artificial mutagenesis was zoned. In 2017, the state register included the varieties Orlovskaya krasnozernaya, obtained with the participation of the Canadian sample K-2846 [9], and Vostochnaya, bred by introgressive hybridization with the wildlife species *L. orientalis*. In 2019, a
new variety of Flamenco lentils created with the participation of the wildlife species *L. tomentosus* was transferred to the State variety testing.

The aim of our research was to compare the indicators of yield and protein content in grain in lentil varieties selected by the Federal Scientific Center for Legumes and Cereals (FSC LC), created by various methods.

2. Materials and methods
The research was carried out in 2014 – 2019 in the breeding crop rotation of the FRC LC, located in the Oryol district of the Oryol region. The soil of the experimental site is dark gray forest. Lentils were sown using a narrow-row method with a row spacing of 15 cm and a seeding rate of 2.5 million germinating seeds per hectare. The area of plots is 15 m$^2$, the replication is 4 times.

The total nitrogen content was determined using the Kjeldahl method with a nitrogen-protein conversion factor of 6.25. For protein analysis, a mixture of seeds from all replications was taken.

Statistical data processing was performed using Microsoft Office Excel 2010 and STATISTICA 7 programs.

3. Results

3.1. Weather conditions during the growing season
Lentils were usually sown in late April and harvested in late July and early August. Shoots appeared in early May. In 2016, due to heavy rainfall, lentils were sown on May 8. The growing season of lentils from germination to harvesting covered 3 months - May, June, July. When harvesting was late, maturation was delayed until the beginning of August. Weather conditions in almost all years of lentil cultivation were characterized by slightly elevated temperatures over the entire growing season (table 1). The exception was 2017, where the average temperature was at or below the multi-year level. Increased temperatures in May - June 2019, combined with a lack of moisture, led to early maturation, and harvesting was carried out on July 15.

| Months | Precipitation, mm |
|--------|-------------------|
| May    | 53                |
| June   | 61                |
| July   | 80                |
| August | 67                |

The distribution of precipitation by month was uneven in different years. As a rule, crops suffered due to the May or June drought. In July, more than normal precipitation could fall, so due to heavy July rains, the timing of lentil harvesting in 2017 shifted to August 7. This is the latest harvesting period in the experiment. Although the years of testing were characterized by different weather conditions, in general, they ensured the normal development of lentil plants and the formation of the crop.
3.2. Grain yield
The best yields for lentils were in 2016 and 2019 with an average grain yield of 2.44 and 2.53 t/ha, respectively (table 2). The worst results were shown in 2014 and 2017 with yields of 1.59 and 1.55 t/ha. The maximum value of 2.92 t/ha was obtained for the Flamenco variety in 2016, and the minimum value of 1.27 t/ha for the Rauza variety in 2017. Among the varieties, the best yield was Flamenco, the average value for 6 years was 2.27 t/ha, the lowest yield of 1.84 t/ha was shown by the Rauza variety. Aida and Vostochnaya with yields of 2.04 and 1.93 t/ha, took an intermediate position.

Table 2. Seed yield of lentil varieties in Orel region, 2014-2019 years, t/ha.

| Lentil varieties | 2014   | 2015   | 2016   | 2017   | 2018   | 2019   | Mean value per variety |
|------------------|--------|--------|--------|--------|--------|--------|------------------------|
| Rauza            | 1.39   | 1.96   | 2.06   | 1.27   | 1.93   | 2.42   | 1.84                   |
| Aida             | 1.73   | 2.04   | 2.44   | 1.42   | 1.98   | 2.65   | 2.04                   |
| Vostochnaya      | 1.54   | 1.84   | 2.35   | 1.55   | 1.95   | 2.37   | 1.93                   |
| Flamenco         | 1.70   | 2.37   | 2.92   | 1.94   | 2.03   | 2.68   | 2.27                   |
| Mean value per year | 1.59   | 2.05   | 2.44   | 1.55   | 1.97   | 2.53   |                        |
| LSD05            | 0.33   | 0.47   | 0.26   | 0.43   | 0.44   | 0.25   |                        |

The relationship between yield and environmental conditions is shown by the yield regression lines on the environment index shown in the figure.

The linear regression equations for the studied varieties have the following form: Rauza = 1.8367 + 1.0036 x; Aida = 2.0415 + 1.0722 x; Vostochnaya = 1.9319 + 0.879 x; Flamenco = 2.2716 + 1.061 x. Accordingly, the maximum height in the figure is the line of the high-yielding Flamenco variety, and the minimum height is that of the Rauza variety. The lines are located almost parallel, without intersecting. The regression coefficient for three varieties is equal to 1, and for the Vostochnaya variety it is slightly less – 0.88. The graph shows that deviations from the regression line are insignificant for all varieties.
3.3. Grain protein content

The protein content of lentil grains over the years of research has changed from a minimum value of 24.5% in the Rauza variety in 2019 to a maximum value of 29.3% in the Flamenco variety in 2014 (table 3). In the years with low yields, 2014 and 2017, the average protein content was the highest 28.2 and 28.5%, respectively. If we compare the varieties, the differences in the average value for 6 years were less significant. The average protein content of the varieties varied from 26.6% in the Rauza variety to 27.3% in the Flamenco variety.

Table 3. Protein content in seeds of lentil varieties, 2014-2019 years, %.

| Lentil varieties | 2014 | 2015 | 2016 | 2017 | 2018 | 2019 | Mean value per variety |
|------------------|------|------|------|------|------|------|------------------------|
| Rauza            | 27.3 | 26.2 | 27.3 | 28.89| 25.5 | 24.5 | 26.6                   |
| Aida             | 27.9 | 25.9 | 26.9 | 28.4 | 26.0 | 25.2 | 26.7                   |
| Vostochnaya      | 28.2 | 25.8 | 27.6 | 28.2 | 25.4 | 25.5 | 26.8                   |
| Flamenco         | 29.3 | 26.6 | 28.4 | 28.5 | 25.6 | 25.4 | 27.3                   |
| Mean value per year | 28.2 | 26.1 | 27.6 | 28.5 | 25.6 | 25.1 |                        |

4. Discussion

We analyzed the dependence of yield and protein content in grain on environmental conditions in 4 varieties of lentils of Oryol breeding created by different methods. The Rauza variety was created by intraspecific hybridization, Aida by breeding from a mutant population. In the process of creating Vostochnaya and Flamenco varieties, exotic germ plasm of wild life species L. orientalis and L. tomentosus was attracted. It was interesting to compare whether the adaptive responses of new varieties change to environmental conditions. We showed that the coefficient of yield regression on the index of environmental conditions in all varieties is close to 1, and deviations from the regression line are insignificant, which, according to Eberhart and Russell [10], indicates their stability. This means that the varieties selected by the FSC LC will produce consistently high yields under favorable environmental conditions. The latter applies to both old and new varieties. We confirmed our earlier conclusion using the example of other years of testing [11]. This study includes a new Flamenco variety that has the highest yield of 2.27 t/ha in 6 years and a regression coefficient for the environment index of 1.06. The use of the genome of a wild species did not affect the adaptive response of the variety.

The protein content varied over the years, and the maximum accumulation of protein in the grain was observed in years with low yields. Differences in varieties are less expressed. However, the highest-yielding Flamenco variety had the highest protein content. When selecting for high yield, we managed to maintain a high protein content in the grain, although there is often an inverse relationship between these indicators. It is known that wild-growing species have higher protein content in grain in comparison with cultivated varieties [12], which, in particular, can explain the high value of this indicator in varieties created with the participation of wild-growing species.

5. Summary

As a result of a 6-year study in years with different climatic conditions, a high ecological stability of Lentil varieties selected by the FRC LC was revealed. The new Flamenco variety, with the highest yield, maintained high stability with a regression coefficient for environmental conditions equal to 1. Flamenco and Vostochnaya varieties had the highest protein content. Thus, the use of germ plasm of wildlife relatives in breeding new varieties did not have a negative impact on their response to environmental conditions and the ability to accumulate a high protein content in the grain.
6. References

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