Assessment of productivity and adaptability of *Camelina Sativa* varieties

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Abstract. The aim of this research is to assess the varieties of winter camelina in terms of productivity and adaptability in a contrast agroclimatic environment of the Middle Volga region and the region of steppe Crimea in 2016–2018. The climate of the Middle Volga region is moderately continental. The precipitation varies from 350 to 750 mm a year. The average year temperature is 5.3 °C. The climate of the steppe Crimea region is continental. The average year temperature here is 15.1 °C and the precipitation varies between 350 and 450 mm a year. In average the yield of different camelina varieties fluctuated between 1.59 and 1.83 t/ha, depending on the environment condition index (Ii -0.19–0.46). In the Penza region, the Kozir and Baron varieties gave the biggest yield with the productivity of crops equal to 1.80 and 1.83 t/ha respectively. In Crimea, the biggest yield was given by the Dikiy variety (1.74 t/ha). The variability of productivity is low at 7.4–10.1% and medium at 11.5–13.2%. The Baron variety has a low variation factor (7.4 and 11.5%) regardless of a cultivation region. All varieties had a high stability which was 1.20–1.25 and 1.30–1.46 depending on a region. The Baron and Kozir varieties had the highest stability reaching 1.46 and 1.25 respectively. All varieties had a high index of stability for this crop, equal to 0.50–0.59. Camelina is tolerant of all stress factors and forms a stable yield in different cultivation conditions. All varieties showed a great ecological adaptability and flexibility with the bi values equal to 1 and varying between 0.92–1.07. The most stable and flexible variety in the case of the Penza region is Baron (bi= 0.92; σdr²= 0.07) while in the region of Crimea it is Kozir (bi= 0.99; σdr²= 0.07). The Dikiy variety has high adaptivity parameters in both regions (bi= 0.93–0.97; σdr²= 0.06). The variance analysis showed that the share of “variety” factor influence is from 38.4% (the Penza region) to 39.2% (Crimea). In the variety–region relationship the influence of a variety is 40.6%. The share of “years” factor influence is 21.7–24.6%, depending on a region.

1. Introduction
Camelina (*Camelina sativa* L.) is an oil crop that belongs to the Brassicaceae family. The processing of its oilseeds is perspective in terms of food and technical purposes, producing biodiesel and remediating the toxicity of soils.

Camelina is highly adaptable to a moderate climate, has early maturation and can bear soil and air drought [4–5]. The main value of camelina from the ecological point of view is its ability to form a high potential yield in a great variety of weather and climate conditions [6].
Due to its flexibility and tolerance for the cultivation methods, the popularity of camelina is growing in many regions both in Russia and abroad [2, 7–9].

However, wider use of the crop, an increase in cultivation area and formation of stable harvest depend on genetic diversity of existing varieties adapted to the conditions of cultivation as well as the genotype–environment relationship [10].

A variety plays the most important role in increasing the yield of a particular culture. That’s why it is necessary to develop the concept of introducing such varieties that can effectively use local conditions for growth and development (warmth, moisture, nutritional substances, etc.), have broad adaptive capabilities in providing a stable harvest in different regions and years. Also, it is necessary to ensure the agronomic balance between productivity and stability of a variety [11].

The aim of our research is to assess the yield and main parameters of the camelina varieties adaptability to limiting environmental factors in contrast agroclimatic regions.

2. Methods and conditions
The object of the research is the varieties and a selected example of camelina created in Penza Research Institute of Agriculture. The investigation is carried out in contrast conditions of the Middle Volga region and the region of steppe Crimea in 2016–2018.

The climate of the Middle Volga region is moderately continental. The precipitation varies from 350 to 750 mm a year. The average year temperature is 5.3 °C. The soils of the experimental plot are represented by bleached black soils with the content of humus equal to 6.0–7.0%. The agro-climatic conditions in the research years were different in the degree of moisturization. The best year in terms of moisture was 2017 with a hydrothermal factor reaching optimal value and achieving 1.1.

The hardest conditions of very dry weather for camelina growth and development were in 2018 when the hydrothermal factor reached 0.3 points. The 2016 year was dry with the hydrothermal factor of 0.7 points. The climate of steppe Crimea is moderately cold, medium-dry, continental, with big year and daily fluctuations of temperature. The average year temperature is 15.1 °C with 350–450 mm of precipitation a year. The soils are represented by black soils above fulvic loessoid light clays. The content of humus is 2.29%. The meteorological conditions in the research years were different from the long-term average annual data on the amount of precipitation and temperature scenario.

The driest year was 2018 with a hydrothermal factor equal to 0.23 points with long-term average annual of 0.59. The average daily temperatures in the period of vegetation were higher than long-term average annual data by 3.7–5.3 °C. The year 2017 was insufficiently moistened with a hydrothermal factor reaching 0.61 points. The most appropriate year in terms of water availability was 2016. However, the moisturising was still insufficient with a hydrothermal factor of 0.82. The evaluation of camelina yield was made based on the methodology for oil crops [12]. The share of factors in forming the yield and the coefficient of variation were determined based on two-factor variance analysis using B.A. Dospekhov methodology [13]. The ecological stability of varieties was determined based on the methodology of A.A. Rossielle and J. Hamblin (by $Y_{\text{max}}$–$Y_{\text{min}}$ equation) [14].

The parameters of a common adaptive capacity (bi) and stability ($S^2d_1$) were defined based on the methods by A.V. Kilchevskiy and L.V. Khotilev using variance and regression analysis [15].

The index of environment conditions was determined based on the methodology of S.A. Eberhart and W.A. Russel [16]. The index of stability and the rate of variety stability were determined based on the methodology, described by E.D. Nettevich [17].

3. Results
The meteorological conditions during the period of vegetation in the research years were characterized by the variability regardless of a natural and climatic zone. The index of environmental conditions varied between −0.28 and 0.46 points in the case of Crimea and between −0.19 and 0.32 in the case of Penza.

The most stressful conditions for the growth and development of camelina were in 2018 in the Middle Volga region and in the region of steppe Crimea. The index of environmental conditions reached −0.19 and −0.28 respectively.
In the region of Penza, the most optimal conditions for development was in 2017 ($I_i = 0.32$). However, in Crimea the most optimal year was in 2016 with an environmental conditions index is 0.46.

The average yield of camelina varieties varied with respect to environmental conditions.

In average the yield of camelina varieties in 2016–2018 varied between 1.59 and 1.83 tonnes per hectare (Table 1).

The research identified the decrease in the average yield of camelina varieties in the direction from the Middle Volga region to the steppe Crimea, seemingly caused by harder meteorological conditions.

**Table 1. The average variation of camelina varieties yield in 2016–2018.**

| Varieties | Average yield t/h | The variation in yield, Cv, % | The index of stability (IS) | The level of growth stability |
|-----------|-------------------|-------------------------------|----------------------------|-----------------------------|
| Crimea    |                   |                               |                            |                             |
| Penzyak   | 1.64              | 13.2                          | 0.52                       | 1.20                        |
| Kozir     | 1.68              | 12.3                          | 0.55                       | 1.25                        |
| Baron     | 1.59              | 11.5                          | 0.53                       | 1.21                        |
| Dikiy     | 1.74              | 12.4                          | 0.59                       | 1.24                        |
| Penza     |                   |                               |                            |                             |
| Penzyak   | 1.71              | 9.7                           | 0.54                       | 1.32                        |
| Kozir     | 1.80              | 8.8                           | 0.50                       | 1.36                        |
| Baron     | 1.83              | 7.4                           | 0.55                       | 1.46                        |
| Dikiy     | 1.75              | 10.1                          | 0.53                       | 1.30                        |
| Crimea    |                   |                               |                            |                             |
| The least significant difference (0.5) | 0.18 |                               |                            |                             |
| The index of environmental conditions, ($I_i$) | -0.28...0.46 |                               |                            |                             |
| Penza     |                   |                               |                            |                             |
| Penzyak   | 1.71              | 9.7                           | 0.54                       | 1.32                        |
| Kozir     | 1.80              | 8.8                           | 0.50                       | 1.36                        |
| Baron     | 1.83              | 7.4                           | 0.55                       | 1.46                        |
| Dikiy     | 1.75              | 10.1                          | 0.53                       | 1.30                        |
| Crimea    |                   |                               |                            |                             |
| The least significant difference (0.5) | 0.11 |                               |                            |                             |
| The index of environmental conditions, ($I_i$) | -0.19...0.32 |                               |                            |                             |

In the Penza region, the Kozir and Baron varieties gave the biggest yield with the productivity of crops equal to 1.80 and 1.83 t/ha respectively. In Crimea, the biggest yield was given by the Dikiy variety (1.74 t/ha), which didn’t significantly surpass other varieties. The Baron variety had the lowest yield (1.59 t/ha). The variation in the yield of varieties, grown in the region of Penza is weak and accounts for 7.4–10.1%. The variation of the yield in Crimea is 11.5–13.2%. The Baron variety has a low variation factor (7.4 and 11.5%) regardless of a cultivation region, which indicates its genetic resistance against a complex of stress factors.

The assessment of varieties based on their stability of growth showed that it was quite high and accounted for 1.20–1.25 and 1.30–1.46 depending on the region.

The highest growth stability in terms of yield and reaction to environmental conditions were shown by Baron (growth stability = 1.46) and Kozir (growth stability = 1.25).

Another important parameter that characterizes the stability of varieties reaction on different environmental conditions is the index of stability.

All varieties had a high index of stability for this crop equal to 0.50–0.59. In both optimal and extreme growing conditions (growth and excessive water availability) camelina is tolerant of all stress factors and forms a stable yield.
The highest index equal to 0.55–0.59 belonged to the Baron, Kozir and Dikiy varieties, which shows its adaptability to particular environmental conditions.

The assessment of varieties in terms of ecological stability showed that the lowest of such an indicator belonged to the Dikiy variety both in the region of Penza and Crimea, accounting for -0.19 and -0.25 respectively, which shows a broader range of stress factors it can adapt to (Table 2).

All varieties studied in the contrast areas of research showed a great ecological adaptivity and flexibility with the bi values almost equal to 1 and varying between 0.92–1.07.

The most stable and flexible variety in the case of the Penza region is Baron (bi= 0.92; σdr²= 0.07) while in the region of Crimea it is Kozir (bi= 0.99; σdr²= 0.07).

**Table 2. The adaptivity of camelina varieties in terms of the yield.**

| Varieties | Ecological adaptivity bi | Stability S²d₁ | Ecological stability |
|-----------|--------------------------|----------------|----------------------|
|            | Crimea                   |                |                      |
| Penzyak    | 1.05                     | 0.09           | -0.46                |
| Kozir      | 0.99                     | 0.07           | -0.44                |
| Baron      | 1.01                     | 0.09           | -0.48                |
| Dikiy      | 0.97                     | 0.06           | -0.25                |
|            | Penza                    |                |                      |
| Penzyak    | 1.07                     | 0.09           | -0.36                |
| Kozir      | 0.99                     | 0.08           | -0.24                |
| Baron      | 0.92                     | 0.07           | -0.21                |
| Dikiy      | 0.93                     | 0.06           | -0.19                |

**4. Conclusion**

The Dikiy variety has high adaptivity parameters in both regions (bi= 0.93–0.97; σdr²= 0.06). It can give high yield not only in favourable conditions but also show high productivity when influenced by unfavourable and stress factors.

Different genotypes react on one and the same environment in a different way which influences the whole phenotypic variance of productivity indexes.

In the Middle Volga region and the region of steppe Crimea where weather conditions vary from year to year, it is necessary to evaluate the genotype–environment relationship in the system of variety–years, because of a climatic factor in the period of vegetation that influences on yield.

The analysis of variance showed that studied factors significantly influenced the productivity of camelina varieties (F_{fac}>F_{theory}) regardless of a natural and climatic region (Table 3).

The assessment of the share of factors showed that the “variety” factor accounted for 38.4% (Penza) and 39.2% (Crimea). In the variety–region relationship the influence of a variety is 40.6%.

The share of “years” factor influence is 21.7–24.6%, depending on a region.

When the factors of variety–years and variety–region the share of which accounts for 30.3–30.4% interact, the influence of the environment on yield is increasing while the influence of a genotype is decreasing.

Thus, the complex assessment of camelina in terms of yield and adaptivity showed that all varieties form high and stable productivity in contrast conditions regardless of a region. However, the best in terms of ecological adaptability and stability were the Baron (Penza) and Kozir (Crimea) varieties with the parameters of adaptability equal to bi= 0.92-0.99; σdr²= 0.07 with the average productivity of 1.83 and 1.68 tonnes per hectare respectively.

Dikiy variety has high adaptivity (bi= 0.93–0.97; σdr²= 0.06) in both regions with average yield equal to 1.74–1.75 t/ha. The factor that influences the yield most of all regardless of the climatic conditions is the variety factor which accounts for 40.6%.
Table 3. The variance analysis and the share of factors that influence the productivity of camelina

| The source of variation                              | $F$ criterion | The share of factor’s influence | The least significant difference$_{(0.5)}$ | The effect of interaction |
|-----------------------------------------------------|---------------|---------------------------------|------------------------------------------|--------------------------|
|                                                     | fact          | theory                          |                                          |                          |
|                                                     | Corrected     | Corrected                       |                                          |                          |
| Crimea                                             |               |                                 |                                          |                          |
| A factor (years)                                    | 5.39          | 3.98                            | 21.7                                     | 0.11                     | -0.17                    |
| B factor (varieties)                                | 6.78          | 3.59                            | 39.2                                     | 0.16                     | 0.09                      |
| The interaction of A and B                          | 4.85          | 3.09                            | 33.8                                     | 0.13                     | 0.12                      |
| random factors                                      | -             | -                               | 5.3                                      | -                        | -                         |
| Penza                                               |               |                                 |                                          |                          |
| A factor (years)                                    | 6.60          | 3.98                            | 24.6                                     | 0.16                     | -0.06                     |
| B factor (varieties)                                | 8.21          | 3.59                            | 38.4                                     | 0.14                     | 0.11                      |
| The interaction of A and B                          | 7.42          | 3.09                            | 30.3                                     | 0.11                     | 0.13                      |
| random factors                                      | -             | -                               | 6.7                                      | -                        | -                         |
| The genotype–environment interaction               |               |                                 |                                          |                          |
| A factor (region)                                   | 5.27          | 4.49                            | 20.3                                     | 0.17                     | 0.22                      |
| B factor (varieties)                                | 7.69          | 3.23                            | 40.6                                     | 0.12                     | 0.17                      |
| The interaction of A and B                          | 6.42          | 3.23                            | 34.4                                     | 0.14                     | 0.16                      |
| random factors                                      | -             | -                               | 4.7                                      | -                        | -                         |

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