Formation of the yield of oil crops of the *Brassicaceae* family in the Middle Cis-Urals

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**Abstract.** The article presents data on the study of the formation of the seed yield of spring oil crops in the conditions of the Middle Cis-Urals. The work is based on the results of a two-factor microfield experiment, where factor A - crops - rape and camelina, factor B - varieties of crops - rape Accord and Podmoskovny, camelina Veles and Yubilyar. The relevance of the study is related to the growing interest in oil crops. The research methodology is generally accepted in agronomy. Camelina was characterized by a faster rate of development, its growing season was 89-109 days, rape - 109-147 days. Morphological and biological features of crops were revealed - a large height of rape plants, their damage by blossom weevil and diamondback moth and the associated lower (50%) survival rate of plants during vegetation; lower seed content (by 44 pcs.) and the formation of smaller seeds (the weight of 1000 seeds was 2.08 g inferior to the same indicator of rape) in camelina. With such a yield structure, camelina had an advantage of 18 g/m². The crops did not differ in the content of crude protein and fat in the seeds.

1. Introduction

Oil crops include plants which seeds or fruits contain fatty oil - the main product of their cultivation. In the conditions of the Udmurt Republic, geographically related to the Middle Cis-Urals, plants of different botanical families are cultivated from this group: *Brassicaceae* - rape of spring and winter forms, sinapis, *Linaceae* - crown flax (oil), *Asteraceae* - sunflower. Fatty oil is obtained from the seeds of fiber crops - fiber flax (*Linaceae* family), cannabis (*Cannabaceae* family). There have been attempts to sow other crops of this group on small areas - safflower (*Asteraceae* family), camelina (*Brassicaceae* family), soybean (*Fabaceae* family). Vegetable oil is of great nutritional and technical importance. By-products of seed processing are valuable concentrated animal feed [1, 2]. Seeds and their processed products are used in the food industry [3, 4]. In the structure of the cultivated areas of the region, the advantage remains with plants of the *Brassicaceae* family. According to the research of R. N. Kurbangaliev [5], R. B. Nurlygaynov [6], S. Mannabi [7], V. V. Medvedev [8], E. F. Vafina [9], the attractiveness of plants of the family is associated on the one hand with a high content of fat and protein in their seeds, on the other - with the possibility of growing in moderate climate conditions. In this regard, studies aimed at researching the productivity of plants of this group are relevant.

The purpose of this research was to study the characteristics of the formation of seed yields of spring oilcrop varieties of the *Brassicaceae* family in the conditions of the Middle Cis-Urals. Research objectives: to conduct a comparative assessment of the phenological development of plants of the studied crops, their damage by pests; to determine the yield of seeds of spring rape and spring...
camelina varieties based on morphological analysis of plants and elements of the yield structure; to determine the collection of protein and fat from crop yield.

2. Materials and methods
The study was carried out during two growing seasons in 2019 and 2020 at the experimental field in the UNPC "Agrotechnopark" of the Izhevsk SAA (North-Eastern Non-Chernozem region, Republic of Udmurtia 56°55'6" N, 53°35'24" E). The scheme of the field experiment included two factors. The first crop (A) - spring rape (A1 - control) and spring camelina (A2), the second - varieties (B) of these crops - Accord (A1B1 - control) and Pomoskovny (A1B2), Veles (A2B1 - control) and Yu-bilyar (A2B2). The experience is microfield, the repetition of variants is sixfold, the area of each plot is 1.05 m². The precursor in the experiment is oat, medium-cultivated sod-medium podzolic soil with a humus content of 1.96...2.25% in the arable layer (according to Tyurin), mobile phosphorus and potassium - 166...263 and 273... 300 mg/kg, respectively (according to Kirsanov), pH_KCl - 5.4...5.7. The research was carried out according to the method generally accepted in agronomy [10]. Winter and spring tillage was carried out according to zonal recommendations. Sowing was carried out with seeds treated with insecticide (Celest Top KS (12.5-15.0 l/t) with a seeding rate of rape 3 million pieces, camelina 7 million pieces of germinating seeds per 1 ha in the usual ordinary way to a depth of 1-2 cm. Crop tending included post-sowing rolling, treatment against monocotyledonous and dicotyledonous weeds in the phase of rape rosette with the herbicide Galion VR (0.27...0.31 l/ha), against the blossom weevil in the budding phase with Karate Zeon MKS (0.1...0.3 l/ha), against the diamondback moth with Kungfu KE (0.10–0.15 l/ha). Harvesting was carried out manually when the seeds were fully ripe. The growing season of 2019 was characterized as cool and humid, 2020 - moderately humid and warm.

3. Results
The development of the studied plants during the years of research took place in different meteorological conditions. In 2019, rape seedlings appeared after 10 days, during the sowing – germination period, the HTC was 2.7 with an average daily air temperature of 14.3°C and a precipitation of 29 mm (Figure 1). During the formation of the leaf rosette, relatively favorable conditions were observed, 43 mm of precipitation fell at an air temperature of 14.0°C. During the period of intensive growth (rosette – shooting), plants developed with a small amount of precipitation (5 mm) and an average daily temperature of 14.7°C. The laying of generative organs in rape plants occurred at an average daily air temperature of 20.3°C and no precipitation. Precipitation (158 mm) that fell during the flowering - green pod period, a low average daily air temperature of 10.0°C in the phase of the green pod - full ripeness of the seeds delayed the ripening of rape seeds. The duration of rape growing season was 147 days. Camelina plants developed at a faster pace, the period of rosette formation and periods of intensive plant growth and bud laying took place at a lower air temperature of 9.8°C and 16.5°C, which positively affected the formation of seed yield. During the period of filling and ripening of camelina seeds, less precipitation fell (63 mm), and the average daily air temperature (17.1°C) was higher relative to similar indicators of rape development periods. The growing season of the camelina lasted 109 days. In 2020, rape and camelina plants in the initial periods from sowing to shooting developed under relatively identical conditions. In rape, the buds are laid, in camelina, flowering occurred in the absence of precipitation. More precipitation fell during the period flowering - green pod in both crops. In general, the duration of the growing season decreased in comparison with 2020 and amounted to 109 days for rape, 89 days for camelina. Under such weather conditions, the yield of spring camelina seeds was inferior to the same indicator obtained in 2019. The yield of rape in 2020, on the contrary, exceeded the yield obtained in 2019. In both years of the study, there were no differences in the development of plants of different varieties of the studied crops.
Figure 1. Weather conditions for the development phases of oil crops of the *Brassicaceae* family, 2019-2020.

The differences between rape and camelina plants in height by vegetation phases were revealed (Figure 2). Starting from the rosette phase, rape plants that were 2 cm taller than camelina plants had an advantage. In the shooting phase, the height difference was 40 cm, in the flowering phase - 34 cm, in the green pod phase - 38 cm. These differences are significant.

* - LSD$_{0.05}$ by factor A = 0.7 cm; ** - LSD$_{0.05}$ by factor A = 1.5 cm; 
*** - LSD$_{0.05}$ by factor A = 2.5 cm; **** - LSD$_{0.05}$ by factor A = 5.1 cm

Figure 2. Dynamics of the height of oilseed plants of the *Brassicaceae* family (average 2019-2020).
The formation of yields in the years of research in the studied crops occurred in various ways. Due to the different seeding rate, the crops differed in the number of seedlings - 556 pcs./m² in camelina and 234 pcs./m² in rape with LSD₁₀ of main effects by factor A 14 pcs./m² (Table 1). The field germination of seeds of both crops did not differ significantly and amounted to 76-79%. By harvesting, the standing density of productive camelina plants significantly exceeded by 328 pcs./m² the number of productive rape plants. In the spring camelina variety Veles, by 27 pcs/m² more productive plants were formed for harvesting relative to the similar indicator of the Yubilyar variety. There were no differences between rape varieties.

Table 1. Formation of the density of the productive plant stand of oil crops of the Brassicacea family (average 2019-2020).

| Variety (B)      | Number of seedlings, pcs./m² | Plants for harvesting, pcs./m² | Survival rate for the growing season, % |
|------------------|------------------------------|---------------------------------|-----------------------------------------|
|                  | Spring rape (A1)             |                                 |                                         |
| Accord (k)       | 234                          | 112                             | 49                                      |
| Podmoscovny      | 233                          | 116                             | 51                                      |
| Average          | 234                          | 114                             | 50                                      |
|                  | Spring camelina (A2)         |                                 |                                         |
| Veles (k)        | 555                          | 456                             | 83                                      |
| Yubilyar         | 556                          | 429                             | 78                                      |
| Average          | 556                          | 442                             | 80                                      |
| LSD₁₀ main ef.   |                              | fr. of dif.                     | main ef. fr. of dif. main ef. fr. of dif.|
| A                | 14                           | 20                              | 17                                       |
| B                | F₁ < F₀₅ 9                   | F₁ < F₀₅ 13                   | F₁ < F₀₅ F₁ < F₀₅                        |

The different density of productive plant standing is associated not only with the different seeding rate of crops, but also with the survival of plants during the growing season. Spring camelina varieties had a significantly higher given indicator of 78-83% relative to the survival rate of rape plants of 49-51%. The survival of plants was affected by their damage by pests. T. Ya. Prakhova [11] considers: "In evolutionary terms, the genus Camelina (camelina) developed in a different way than other species of the Brassicaceae family. Camelina plants have acquired a whole range of useful features, including higher resistance to harmful objects compared to rape and sinapis. Nevertheless, in some years unstable weather conditions (drought, uneven precipitation of large amounts of precipitation) during the growing season of the crop can contribute to the manifestation of diseases on camelina". The most dangerous pests of cole crops are blue fleas. They are especially dangerous in dry and hot weather. Rape blossom weevil is called rape pest No. 2. Its beetles damage the buds before they bloom, eating out the stamens, pistils and petals. In recent years, diamondback moth has been of particular importance in terms of harmfulness. The number of blue fleas on rape crops did not exceed the economic threshold of harmfulness, pests were not detected in camelina crops (Figure 3).
Figure 3. Colonization of rape and camelina plants by pests, pcs./plant.

This is due to the sowing of seeds treated with insecticide. Rape blossom weevil damaged rape and camelina crops. More damage was detected in rape crops – 10 pcs. per plant, 1 pc. on camelina. The sowings of both crops were treated with insecticide. The number of diamondback moth caterpillars on rape plants exceeded their number on camelina plants by 2.5 times.

The morphological features of the studied crops are associated with the formation of elements of plant productivity. Thus, the camelina has smaller pods (silicules), fewer seeds are formed in its fruits. According to T. Ya. Prakhova [12], E. L. Turin [13] the formation of 14-18 seeds is possible in a camelina pod. In the rape pod, according to studies in the Udmurt Republic and neighboring regions, from 12 to 40 [14, 15, 16]. According to our data, a smaller number of pods were formed on rape plants – regardless of the variety, 26 pcs., camelina plants had 80 pods (Table 2). Rape had the advantage in terms of the number of seeds on the plant. The difference between crops by plant seed content is 44 pcs. with LSD_{0.05} of main effects by factor A - 40 pcs., by weight of 1000 seeds 2.08 g with LSD_{0.05} of main effects by factor A - 0.04 g.

| Variety (B)          | Pods per plant, pcs. | Seeds per plant, pcs. | Weight of 1000 seeds, g |
|----------------------|-----------------------|------------------------|-------------------------|
|                      | Spring rape (A1)      |                        |                         |
| Accord (k)           | 26                    | 336                    | 3.16                    |
| Podmoscovny          | 25                    | 325                    | 3.21                    |
| Average              | 26                    | 330                    | 3.18                    |
|                      | Spring camelina (A2)  |                        |                         |
| Veles (k)            | 79                    | 279                    | 1.11                    |
| Yubilyar             | 81                    | 293                    | 1.10                    |
| Average              | 80                    | 286                    | 1.10                    |
| LSD_{0.05} main ef.  | fr. of dif. main ef.  | fr. of dif. main ef.  | fr. of dif.             |
Plants of the Cruciferae family are characterized by a high content of fat and protein. According to the results of chemical analysis, it was revealed that in the 2019-2020 harvest, the seeds of the studied crops and varieties had the same crude protein content (Table 3).

**Table 3.** The content of crude protein, fat in the seeds of rape and camelina varieties, collection of raw protein, fat.

| Variant          | Content of protein in seeds, % | Collection of protein, g/m² | Fat content in seeds, % | Collection of fat, g/m² |
|------------------|--------------------------------|------------------------------|-------------------------|-------------------------|
| Rape Accord      | 22.8                           | 25.2                         | 44.2                    | 48.9                    |
| Rape Podmoskovny | 22.9                           | 25.8                         | 44.0                    | 50.0                    |
| Camelina Veles   | 23.2                           | 30.0                         | 43.8                    | 58.2                    |
| Camelina Yubilyar| 23.4                           | 29.2                         | 43.7                    | 56.7                    |
| LSD₀⁵ for main effects A (crop) | –     | 3.4                          | –                       | 6.6                     |

With the harvest, rape sowings provided 25.2-25.8 g/m² of crude protein, camelina - 23.2-23.4 g/m². On average, according to factor A (crop), a higher collection of crude protein from 1 ha was detected in camelina with LSD₀⁵ of the main effects of factor A - 3.4 g/m². The differences between the varieties of each crop are insignificant. The fat content in plant seeds of Cruciferae family varieties was 43.7-44.2%. Differences in the gross fat collection are significant between the studied crops: camelina has a gross fat collection of 57.4 g/m², which is higher than this indicator of rape of 49.4 g/m² with LSD₀⁵ of the main effects on factor A - 6.6 g/m². Rape and camelina varieties did not differ in fat collection.

4. Discussion
The conducted research makes it possible, based on the peculiarities of meteorological conditions, plant development, and their morphology, to justify obtaining different yields of crop seeds. In the conditions of 2019, the yield advantage of 30 g/m² (LSD₀⁵ of the main effects by factor A - 27 g/m²) was established for spring camelina (Table 4).

**Table 4.** Yield of varieties of oil crops of the *Brassicaceae* family, g/m².

| Variety (B)     | 2019 | 2020 | Average 2019-2020 |
|-----------------|------|------|-------------------|
| Accord (k)      | 101  | 120  | 110               |
| Podmoskovny     | 107  | 119  | 113               |
| Average         | 104  | 120  | 112               |
| Veles (k)       | 136  | 128  | 132               |
| Yubilyar        | 131  | 126  | 128               |
| Average         | 134  | 127  | 130               |
| LSD₀⁵ main ef.  |      |      |                   |
| A               | 27   | 38   | Fₜ < F₀⁵          |
| B               | Fₜ < F₀⁵ | Fₜ < F₀⁵ | Fₜ < F₀⁵ | 15   | 21   |

The differences between the varieties of each crop are insignificant.
Rape and camelina varieties did not differ significantly in yield. In 2020, rape formed a yield of 20 g/m² higher than the yield of 2019. There were no significant differences between the crops and their varieties in the data of the year of research. On average for 2019-2020, the yield of camelina seeds exceeded the yield of rape by 18 g/m² with LSD₀₅ of the main effects by factor A of 15 g/m². A comparative assessment of the formation of rape and camelina yields showed that with the leading position of the first one currently in the region, the second also has prospects. Camelina plants are characterized by faster development, less damage by pests and crop productivity that is not inferior to the yield of rape.

5. Conclusion
In the conditions of the Middle Cis-Urals, the spring camelina had shorter separate periods of development (for 2-5 days), as well as a shorter growing season relative to the development of spring rape. Faster development allowed (among other things) camelina plants to reduce the infestation of the blossom weevil by 9 pcs./m², diamondback moth by 3 pcs./m² in comparison with similar indicators of rape. The studied crops had morphological differences. The height of camelina plants during the growing season was less than the height of rape plants by 2-40 cm; seeds on camelina plant were also created by 44 pcs., respectively; larger seeds with a weight of 1000 pcs. 3.18 g were formed by rape (in camelina varieties, on average, 1.10 g). At the same time, the plant stand density before harvesting was higher in camelina crops by 328 pcs./m². Thus, rape had higher plant productivity indicators, camelina was distinguished by a large number of productive plants per unit area. On average, for two years of research, the advantage in yield was the camelina, which provided its value at the level of 130 g/m², which significantly exceeded the yield of rape seeds by 18 g/m². A higher yield of camelina seeds with an almost equal content of crude protein and fat in them (relative to rape) provided a greater yield of these indicators from 1 square meter - 29.2-30.0 g/m² and 56.7-58.2 g/m².

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