Productivity and economic efficiency of protection products on spring rape hybrids in the conditions of the Krasnoyarsk forest-steppe

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Abstract. The paper considers the issues of the effectiveness of the integrated use of pesticides on crops of spring rape hybrids and their impact on crop productivity in the conditions of the Krasnoyarsk forest-steppe. The increase in the production of oilseed rape is primarily due to the use of intensive technologies in agriculture due to the limited sown area. The biological characteristics of spring rape require special attention to the means used to protect the culture from harmful organisms. The effect of insecticides, herbicides and fungicides of the “August” Company on the crop structure of 12 rapeseed hybrids was studied, and the biological and economic efficiency of their use was evaluated. The natural and climatic conditions of 2019 contributed to an increase in the number and variety of harmful organisms such as pests and weeds, so the role of the use of “August” Company drugs in the integrated protection of spring rape hybrids has increased. During the study, it was found that the combination of the use of Break, ME and Borey Neo, SK insecticides in pest control reduced their spread and harmfulness in all variants of the experiment to almost zero. The use of the fungicide Kolosal Pro, KME, led to the cleanliness of rapeseed plants from diseases. The highest level of profitability for KL hybrids was in the variant of the combined use of the Paradox, VRK + Grader VGR herbicides, respectively, in hybrids of the Halion and Estock herbicides that are unstable to imidazolinones.

1. Introduction
In recent years, the sowing areas of spring rape and its production have sharply increased in the Krasnoyarsk Territory. According to the Ministry of Agriculture and Trade of the Krasnoyarsk Territory, in 2012, sowing areas under rape was 15,600 hectares, then in 2019 146,000 hectares, over six years they grew by almost 7 times. The area of oilseeds is increasing due to the development of trade relations with Southeast Asia, in particular with Mongolia and China. In 2017, about 20 thousand tons of rape were shipped to these countries for export; in 2018, about 40 thousand tons of this crop were delivered [1]. According to the Ministry of Agriculture and Trade of the Territory, almost 50% of the total agricultural exports are wheat and rapeseed. In 2018, grain was sold at $ 26 million, rapeseed - at $ 6.5 million. According to the information of the Ministry of Agriculture and Trade of the Krasnoyarsk Territory, the volume of rapeseed export in October 2019 increased by 2.7 times compared to the same period in 2018.

Rapeseed consumption is also growing in the Krasnoyarsk Territory itself [1]. Due to the limited resources of arable land, a further increase in the production of spring rape will not be associated with the expansion of the cultivated area (in 2019 - about 130 thousand hectares), but with an increase in its
productivity due to the introduction of new varieties and optimization of plant protection against harmful organisms (weedy plants, pests and diseases). In this regard, there is a need to search for new, more effective means of protection for new varieties and hybrids that form the highest productivity and early ripening in the conditions of the forest-steppe of the Krasnoyarsk Territory.

The questions of studying the effectiveness of the application and assessing the effect of triazole fungicidal preparations, used individually or in combination, on the growth of winter oilseed rape, the development of phoma stem canker, crop wintering and crop yield are considered in the article by Nazanin Zamani-Noor, Jessica Knüfer. Multifactorial field trials were conducted over three cropping seasons (2012–2015). According to them plant height was significantly affected by cultivars and fungicide treatments. Fungicide treatments were more effective in reducing the disease in moderately resistant cultivars than in susceptible ones. The application of fungicides did not significantly impact the different yield parameters with the exception of seed yield [2].

Mitrović P., Marisavljević D. et al studied the application of various herbicides and their combinations for annual and perennial weed species such as Agropyrum repens, Cirsium arvense, Cynodon dactylon in spring rape crops and their effect on the hectoliter mass of seeds and oil and protein content in seeds in the conditions of Serbia [3].

The objective of the work is to assess the biological and economic effectiveness of pesticides in spring rape crops in the conditions of the Krasnoyarsk forest-steppe.

2. Research methodology
The research was carried out on the experimental field of the Borsky Research and Production Enterprise, FSBEI HE Krasnoyarsk State Agrarian University, which is 51 km north of the city of Krasnoyarsk, experiments were conducted and studies were conducted to study the effect of the use of chemical protection from harmful organisms on the yield and the main elements of the structure of spring rape harvest in the conditions of the Krasnoyarsk forest-steppe.

In general, the vegetation period of 2019 can be characterized as abnormal, especially in terms of the extremely uneven distribution of rainfall during the entire period. Combined drought during the growing season affected the growth and development of plants (including weeds), the spread of pests and diseases.

In 2019, 12 hybrids of spring rape of a new generation were sown for research: Cyclus KL, Tsebra KL, Currie KL, Cultus KL, Contra KL, Solar KL, Salsa KL, Drago, Smilla, Lexus, Lanzia and Lumen. Each hybrid was laid in repetitions, the repetition placement in two blocks was systematic, and the area of one plot was 30 m². Rapeseed hybrids were seeded according to the steam precursor, in the summer at the beginning of budding, rapeseed plants were fed with the microbiological preparation Lignohumate at the rate of 1 l / ha. Protection from harmful organisms (weeds, pests and diseases) was carried out by the preparations of “August” Company according to the scheme presented in table 1.

Table 1. The variants of experiments for the complex protection of spring rape in 2019.

| Variant 5         | Variant 4         | Variant 3         | Variant 2         | Variant 1         |
|-------------------|-------------------|-------------------|-------------------|-------------------|
| Galion, VR + 0.3  | Galion, VR + 0.3  | Galion, VR + 0.3  | Paradox, VRK – 0.35 | Paradox, VRK + 0.4 |
| Haker, VRG + 0.06 | Estok, VDG + 0.025| -                 | Greider, VGR + 0.06 | -                 |
| Adieu, G + 0.2    | Adieu, G + 0.2    | Adieu, G + 0.2    | Galop, G + 0.25    | Galop, G + 0.25   |
| Quickstep, MKE + (0.4) | Quickstep, MKE + (0.4) | Quickstep, MKE + (0.4) | -                  | -                  |
In the control plots before sowing, only preliminary treatment of rapeseed was carried out. The sowing date is May 19, the sowing rate is 70 pcs./m², the depth is 3-4 cm, with the SSFK-7 seeder, after sowing rolling [4].

Weed counts were carried out in accordance with the VIZR guidelines: before treatment (initial weed), 15, 30, 45 days after treatment and before harvesting. At the first count, the number of weeds was calculated; in subsequent - the number and weight of weeds separately by species. The phases of development of weeds during the spraying period, and symptoms of manifestation of herbicidal activity during the growing season (photo-observation of weeds, the dynamics of the manifestation of herbicidal activity of the preparations on the main types of weeds) were noted. Harvested and accounted for separately from each variant.

The disease. The surveys were carried out in accordance with the VIZR guidelines. During the test period, it is necessary to mark the date of the first signs of the disease. The prevalence and degree of development of the disease is recommended to be considered before treatment, subsequent surveys should be carried out with an interval of 10-14 days, continuing until the harvest (at least 4 counts per season). Quantitative and qualitative accounting of the crop should be carried out in the phase of full ripeness by continuous threshing of plants from each experimental plot.

Pests. Cruciferous flea beetles, pollen beetles, diamondback moth, meadow moth, grasshoppers.

Methodology of accounting: surveys were carried out in accordance with the VIZR guidelines. Counting caterpillars of different ages on 20 plants on 50 plants (10 samples of 5 plants), located on the diagonal of each repetition of the production experiment. Dates of accounting: immediately before processing, on the 3rd day after the treatment, on the 7th day after the treatment; 14 days after treatment. Each hybrid was laid in 2 replicates in each block. Placement of repetitions of spring rapeseed hybrids resistant to imidazolinones in two blocks, simple hybrids of two repetitions in three blocks, allocation of plots systematic area of one plot 30 m².

The total area of 1 block of hybrids resistant to imidazolinones 210 m², unstable 150 m². The total sown area was about 0.1 ha.

Accounting for the crop. A week before harvesting, test sheaves were selected from each of four typical 0.25 m² plots of land, in total one square meter to determine crop structure and biological yield. We counted the number of plants, measured the height of the plants, determined the mass of the sheaf as a whole and the seeds separately, counted the number of pods from each plant and selectively 25 pods from each sheaf (a total of 100), and also counted the number of seeds in the fruit. A mass of 1000 seeds was determined after drying and bringing their moisture to standard.

The actual harvest was taken into account on October 7 with the TERRION selection combine. Productivity was brought in accordance with GOST 10583-76 to 12% humidity and 100 percent purity. The cutting height was maximum, so as to completely harvest the entire crop on the branches, but not lower, since the lower part of the stems was still green).

Mathematical processing of the obtained data was carried out according to the method of B.A.Dospekhov [6]. The results of the study were processed by methods of dispersive and correlation-regression analyses [7].

| Brek, ME, 0.05 | Borey Neo, SK, 0.2 + Colosal Pro, KME 0.6 Raps | Brek, ME, 0.05 | Borey Neo, SK, 0.2 + Colosal Pro, KME 0.6 Raps | Brek, ME, 0.05 | Borey Neo, SK, 0.2 + Colosal Pro, KME 0.6 Raps | Brek, ME, 0.05 | Borey Neo, SK, 0.2 + Colosal Pro, KME 0.6 Raps |
|----------------|-----------------------------------------------|----------------|-----------------------------------------------|----------------|-----------------------------------------------|----------------|-----------------------------------------------|
| Break, ME, 0.05 Break, ME, 0.05 Break, ME, 0.05 Break, ME, 0.05 Break, ME, 0.05 | Borey Neo, SK, 0.2 + Borey Neo, SK, 0.2 + Borey Neo, SK, 0.2 + Borey Neo, SK, 0.2 + | Colosal Pro, KME 0.6 Colosal Pro, KME 0.6 Colosal Pro, KME 0.6 Colosal Pro, KME 0.6 | Raps Raps Raps Raps (KL) Raps (KL)
3. Results
In the course of the research, rapeseed hybrids were evaluated by the main elements of the crop structure (table 2). The assessment showed that the survival of plants to harvest was better for the hybrid Tsebra KL and Lumen, with a seeding rate of 70 pcs. per square meter, 68 pieces left for harvesting – this is about 96%, the lowest survival was in hybrids Salsa KL, Drago and Smilla and amounted to about 60%.

**Table 2.** Crop structure and biological productivity of oilseeds of spring rape hybrids in 2019.

| Hybrids     | Plants for harvest pcs. m² | Fruits per plant, pcs. | Seeds in a pod, pcs. | 1000 seed weight, g | biological productivity of oilseeds, t / ha |
|-------------|-----------------------------|-------------------------|----------------------|---------------------|-------------------------------------------|
| Cyclus KL   | 64                          | 130                     | 25                   | 3.8                 | 78.0                                      |
| Tsebra KL   | 68                          | 156                     | 29                   | 3.2                 | 86.3                                      |
| Currie KL   | 64                          | 164                     | 32                   | 3.0                 | 99.2                                      |
| Cultus KL   | 56                          | 143                     | 31                   | 2.5                 | 61.6                                      |
| Contra KL   | 52                          | 209                     | 22                   | 3.6                 | 86.8                                      |
| Solar KL    | 48                          | 244                     | 32                   | 3.3                 | 124.0                                     |
| Salsa KL    | 40                          | 240                     | 27                   | 2.3                 | 59.6                                      |
| Drago       | 40                          | 110                     | 34                   | 3.3                 | 49                                        |
| Smilla      | 40                          | 133                     | 31                   | 3.5                 | 57                                        |
| Lexus       | 56                          | 129                     | 36                   | 2.1                 | 53                                        |
| Lanzia      | 48                          | 126                     | 36                   | 2.3                 | 49                                        |
| Lumen       | 68                          | 129                     | 24                   | 3.4                 | 72                                        |

By the number of fruits per one plant, the Solar KL hybrid stood out. There were more seeds in the pod from the Lexus hybrid. According to the mass of 1000 seeds, the Cyclus KL hybrid stood out; its mass of 1000 seeds was 3.8 g.

It should be noted that the mass of 1000 seeds obtained on hybrids in 2019 is lower than in 2018 for all hybrids (figure 1).

![Figure 1. Mass of 1000 seeds of spring rape hybrids.](image)

The assessment of biological productivity by the main elements of the crop structure shows that it varies in hybrids and varies greatly from 49 kg / ha in the Drago hybrid to 124 centners in the Solar hybrid. To determine the effect of crop structure elements on crop, a correlation analysis was performed using the Microsoft Excel package. A correlation analysis of the dependence of crop on alimony of the crop structure showed that the crop had a significant high correlation with the number of fruits per plant (the correlation coefficient was +0.79). The mean significantly negative relationship was between the number of seeds in the pod and the weight of 1000 seeds (-0.47).
The assessment of spring rape hybrids by the actual harvesting yield (table 3), carried out by us using the combine harvester method, showed that ripening at the end of the growing season did not take place simultaneously, although by external signs (the seeds in the pods were black) it looked as if everyone had ripened the same way. However, the moisture content of the seeds during harvesting showed that hybrids were the fastest to ripen, which according to varietal characteristics, published on the producer’s website and according to the State Register of Selection Achievements allowed for use, are included in later ripeness groups by vegetation duration, such as Currie and Cultus (table 4). The moisture content of the seeds of these hybrids during harvesting was the lowest.

### Table 3. The yield of rapeseed in 2019, kg / ha.

| Hybrid Name | Biological yield | Actual yield |
|-------------|------------------|--------------|
| Cyclus KL   | 78.0             | 62           |
| Tsebra KL   | 86.3             | 79.2         |
| Currie KL   | 99.2             | 87.3         |
| Cultus KL   | 61.6             | 57           |
| Contra KL   | 86.8             | 75.9         |
| Solar KL    | 124.0            | 106.0        |
| Salsa KL    | 59.6             | 49.8         |
| Drago       | 49               | 45.6         |
| Smilla      | 57               | 53.2         |
| Lexus       | 53               | 40.0         |
| Lanzia      | 49               | 36.0         |
| Lumen       | 72               | 68.0         |

Actual oilseed yields of spring rape hybrids are reduced to 12 percent moisture and 100 percent physical seed purity. The highest seed yield in 2019 was formed by the Solar hybrid, the actual yield, which amounted to 106 c / ha.

An assessment of the economic efficiency of spring rape varieties was carried out taking into account all the costs of complex protection, including variants with their different combinations.

Economic efficiency was determined by the following indicators: yield (with allocation of yield of early and late varieties); yield of standard oilseeds from 1 ha; labor costs per 1 centner of spring rape (early or late); own cost of production; profit per 1 ha of sown area; the level of profitability of production as a whole.

The data in table 4 on the example of all experiment variants of plant protection show that the cost-effectiveness options are distinguished using the full range of protection in new spring rape hybrids. An economic assessment by the level of profitability showed that the best option was protection with the combined use of Paradox and Grader, the profitability of which on spring rape hybrids from the KL group was 333 percent with a yield level of 72 kg / ha.

### Table 4. Evaluation of spring rape hybrids by economic efficiency indicators in 2019 according to experiment variants.

| Indicators                  | Variant 1 | Variant 2 | Variant 3 | Variant 4 | Variant 5 | Control |
|-----------------------------|-----------|-----------|-----------|-----------|-----------|---------|
| Yield, c / ha               | 49        | 72        | 49        | 57        | 53        | 14      |
| Selling price, rub. / ha    | 2200      | 2200      | 2200      | 2200      | 2200      | 2200    |
| Revenues from sales, rub. / ha | 107800   | 158400    | 107800    | 125400    | 116600    | 30800   |
| Cost per 1 hectare, rub.    | 34968     | 36534     | 34998     | 36233     | 35989     | 23827   |
| Own cost, c / rub.          | 713       | 507       | 714       | 636       | 978       | 1701    |
| Profit per 1 c / rub.       | 1486      | 1692      | 1485      | 1564      | 1522      | 498     |
| Level of profitability %    | 208       | 333       | 208       | 246       | 224       | 29      |
In the protection variants of spring rape hybrids unstable to imidazolinones, the highest level of profitability was shown by the variant with the addition of herbicide Estok 246 percent at a yield level of 57 c / ha. Moreover, in the control variant, where the seeds were only pickled, the profitability level was positive and amounted to 29% with a yield of 14 c / ha.

4. Conclusion
As a result of the study, it was found that in the conditions of 2019, when there was an increase in the number and variety of harmful organisms, such as pests and weeds, the role of the application of “August” Company in the integrated protection of spring rape hybrids increases.

The combination of the use of the insecticides Break, ME and Borey Neo, SK in pest control, in 2019 on spring rape hybrids, reduced their spread and harmfulness in almost all variants of the experiment to almost zero.

The use of the fungicide Colosal Pro, KME led to the cleanliness of rapeseed plants from diseases.

The highest seed yield in 2019 was formed by the Solar hybrid, the yield of which was 106 c / ha, the smallest hybrid Lanzia was 36 c / ha.

The level of profitability was highest for KL hybrids in the case of the complex application of the herbicides Paradox, VRK + Grader, VGR, respectively, for hybrids of the herbicides Galion, VR + Estok, VDG, which are unstable to imidazolinones.

The profitability level in the protection option with the combined use of Paradox, VRK + Grader, VGR on spring rape hybrids from the KL group was 333% with a yield of 72 c / ha.

In the variants of spring rape hybrids protection unstable to imidazolinones, the highest level of profitability was shown by the variant with the addition of Estok herbicide, VDG - 246% with a yield level of 57 c / ha. Moreover, in the control variant, where the seeds were only pickled, the profitability level was positive and amounted to 29% with a yield of 14 kg / ha.

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