Modern approaches to production of high-quality spring rape

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Abstract. Spring rape is the main oilseed crop in the non-chernozem zone of Russia, which includes Ryazan region. The area with the crop has increased to 60 thousand ha in the last five years. Rape, being an important oilseed crop, belongs to feed crops of the region. Sale of oilseeds brings agricultural enterprises high profit from the crop production industry. Clearfield technology of rape growing was studied on gray forest loamy soil in Ryazan region in comparison with conventional oilseed production technology. Clearfield technology is the combined action of Nopasaran herbicide and the use of special hybrids which are resistant to this herbicide. High crop efficiency does not depend largely on weather conditions, mainly due to activity of the two active substances, which determine the novelty and relevance of the studies. According to the research results, the highest average spring rape yield in the experiment was obtained at the first sowing period in the 1st decade of May. It was 20.8 dt/ha for hybrid Salsa KL. The maximum crop yields were observed on options using Clearfield, regardless of the sowing period. On average, the growth, development, yield and its structure of domestic Ratnik variety were not inferior to Ozorno hybrid. Sowing in the first decade of May can be recommended as the most productive one for spring rape in the southern part of the Non-Chernozem Zone of Russia.

1. Introduction
The increased interest in oilseeds is due to the high economic efficiency of production and adaptability to a temperate climate, as well as the relatively good yield of seeds, oil content and the possibility of creating the ideal background for subsequent crops in the crop rotation [1].

The scientific community and agricultural producers have been given an important task of developing and improving the most promising technologies for the cultivation of oilseeds, which contribute to increasing the yield of oilseeds and their quality in the region [2].

The current level of agricultural production and changing agroecological conditions require improvement of cultivation technologies and introduction of new varieties into the technological cycle, fertilizer application and innovative plant protection products [3]. The development and further improvement of the basic elements of agricultural technology of cultivation, adapted to the growing conditions, will contribute to the realization of the potential of oilseeds, which is of great theoretical and practical importance [4].

Spring rape is the main oilseed crop in Ryazan region. The area under the crop has increased to 60 thousand hectares during the last five years. Being an important oilseed crop, it belongs to the food balance and forage crops of the region. Sale of oilseeds brings agricultural enterprises up to 25% profit in the crop production sector [5].
Rape oil and protein make up 65–71 % of the seed weight. Rape protein is characterized by increased albumin fraction for oil fractions (36–48 %), and is characterized by a high ratio of essential amino acids useful for the body, especially lysine. It can be mentioned that the fatty acid composition of rapeseed oil is an energy-intensive product and an important source of linoleic acid, as well as vitamins E and F. The feed value of 1 kg of spring rape meal is equal to 0.9–1.1 feed units, and according to the balanced amino acid composition, the press cake and meal are equal to soybean [6, 7]. Rape products for feeding animals are quite various. Oil and flour can be used as enrichment of grain mixtures, as well as the herbage.

It should be noted that spring rape grows well on any type of soil, but well-fertilized gray forest and chernozem soils, medium loamy in mechanical composition are optimal [8–10]. Winter grain crops, arable crops and legumes can be used as a forecrop for spring rape in the region [11]. A high rape yield is possible after peas and vetch as a forecrop, especially after their treatment with bioorganic fertilizers [12].

Note that when producing high-quality oilseeds, technological methods have their own characteristics, which come down to the fact that any technique should preserve the genotypic properties of the variety [13].

In this moment of agricultural development, the oilseed market offers a large number of new varieties and hybrids, plant protection products. The possibility of their usage has been little studied and requires additional research.

2. Problem statement

Spring rape is a crop that has changed dramatically in recent decades as a result of human activities. This is expressed both in appearance and in chemical composition. At the moment, mainly varieties with double quality or 00-varieties are grown. Rape variety Ratnik, which occupies the largest cultivated area in the European part of Russia among domestic varieties, was selected for the agroecological assessment in these studies. Hybrids of the German selection Ozorno and Salsa KL were also investigated.

Ozorno and Salsa KL are hybrids of a new generation, with high genetics, which are characterized by high-intensity growth, a strong root system, high resistance to diseases and stress factors in the external environment and better adaptability to weather conditions. These hybrids are aimed at high stable yields, thereby showing a high profitability of production. Salsa KL is a hybrid cultivated using the Clearfield system. Clearfield technology is the combined action of Nopasaran herbicide and special hybrids that are resistant to this herbicide. The crop is highly efficient regardless of weather conditions, largely due to two active substances that penetrate rape plants through leaves and soil. Imazomox penetrates through the leaf surface and metazachlor does it through the root system of the crop.

The use of the innovative Clearfield system is aimed at improving a number of agronomic advantages. It reduces weed infestation of crops, including problematic weeds of the cruciferous family: species of mustard, colza, wild radish and drops. When using this technology, there is no decrease in the quality indicators of the obtained crop as for the content of glucosinolates and erucic acid. The use of the system reduces infestation with cereal weeds, including carrion grains. In connection with the foregoing, it can be stated that in order to identify ways to increase the productivity of oilseeds, there is an urgent need for a set of studies in the region, including the study of innovative Clearfield technology. This determined the relevance and novelty of research.

3. Materials and methods

The studies were conducted at the agrotechnological experimental station of Ryazan State Agrotechnological University Named after P.A. Kostychev on gray forest heavy loamy soil. The studies of productivity of spring rape varieties and hybrids at different sowing dates took place in 2016–2019.

The objects of the research were hybrids of foreign selection Salsa KL, Ozorno (Rapool company) and domestic variety Ratnik. The productivity of spring rape was studied at two sowing dates: 1st and
2nd decades of May. The seeding rate of spring rape Ratnik variety was 2.5 million pieces of germinating seeds / ha and that of German hybrids was 1.25 million pcs / ha. The replication was fourfold.

Salsa KL was sown using innovative Clearfield technology and Nopasaran herbicide 1.2 l/ha. The herbicide was used in a tank mixture with adhesive Dush 1.2 l/ha. Nopasaran was used for rape in the phase of 4-6 true leaves, taking into account the early development of weed vegetation and focusing on the vulnerable stages of the most harmful groups of weeds in an agrotechnological experimental station. When growing Ozorno and Ratnik, 0.3 l/ha of herbicide Galion, VR was used. Treatment with Galion, VR was carried out in the phase of 4–6 true leaves, before the crop budding. The operating fluid consumption for rape was 250 l/ha.

The humus content in the tillage horizon was 2.9–3.1 %, which is typical for this type of soil in the region. The reaction of the soil was medium acidic (pH KCl – 5.0). Hydrolytic acidity was low, and did not exceed 2.6 MEq/100 g of soil. The amount of absorbed bases was 15 M-equiv/100 g of soil and the degree of soil saturation with bases was not more than 70 %. The nutrient content in the arable horizon of the soil was as follows: phosphorus (on average 120 mg/kg of soil) and potassium (on average 150 mg/kg of soil) content was increased (class IV), nitrogen content (50 mg/kg of soil) was low (class II).

Agrotechnical measures for the cultivation of spring rape were in accordance with the recommendations adopted in the Non-Chernozem zone of Russia [14].

Winter wheat was the forecrop in all experiments, then autumn plowing was carried out to a depth of 20–22 cm with the help of Peresvet plow PPO-7-35 Almaz + K-744P. In early spring, the soil was harrowed by BZZS-1.0 + MTZ-1221, then cultivated by KPS-4.2 + MTZ-1221 to a depth of 12–14 cm. Pre-sowing cultivation was to a depth of 2-3 cm. Together with the pre-sowing cultivation fertilizers were introduced (RUN-1H + MTZ-1221.2). The introduction of mineral fertilizers was carried out according to experimental schemes. Used Ammonium nitrate, urea and nitrophosphate were used in terms of the active substance. Sowing was carried out with seeder SSNT-16 + MTZ-82.1 to a depth of 2–3 cm.

Spring rape sowing was carried out with pretreated (incrustated) seeds. All rape seeds were treated by Kruiser Rape, KS (mefenoxam 32.3 g/l + thiamethoxam 280 g/l + fludioxonil 8 g/l). Sowing dates and seeding rates were selected according to experimental schemes.

After sowing, seed rolling with 3KKSh-6 + MTZ-1221.2 took place. During the growing season of oilseeds pesticides against pests, diseases and weeds were sprayed with OP-3000 Bulgar, OH-400, OFIII-15-01 sprayers and Kvazar-12 backpack sprayer, depending on the type of treatment. They tried to carry out insecticidal treatments in a tank mixture with herbicides or fungicides. Insecticides were used against major oilseed pests such as cruciferous flea, canola beetle, and cabbage moth. Fastak, KE in a dose of 0.15 l/ha and Bi-58 New, 1 in a dose of 1.2 l/ha were used.

During the growing season spring rape crops were treated with fungicide Pictor, KS in a dose of 0.5 l/ha at the first signs of damage to pathogens of Alternaria blight, Sclerotinia disease, Phoma rot, white rot and as a precautionary measure.

Treatment was carried out no later than one month before the expected harvest for rape and two months for sunflower. Treatment of agrocenoses was carried out before the flowering of crops. Harvesting was carried out at full ripeness of crops directly with TERRION-SAMPO SR 2010 combine.

Rape was harvested when drying at least 75 % of the pods and humidity of not more than 10–11 %, followed by drying. The cut height of rape plants was at the level of 8–10 cm.

4. Results and discussion

During the experiment with the study of varieties and hybrids at different sowing dates, rape plants grew slowly and developed a more powerful root system in the first month of the growing season. In the second half of the growing season, an intensive growth of leaf-stem mass was noted, where the average daily increase in herbage was 0.4–0.6 t/ha. Note that in a short time interval, the crop is able to form large yields against the background of low heat supply.
The duration of the phenological phases depended on sowing dates and on moisture and air temperature (Table 1).

**Table 1. Phenological periods of spring rape plants development, depending on the sowing dates, average for 2016–2019**

| Sowing date | Variety / hybrid | Sowing – seedlings | Seedlings start flowering | Phenological periods, days | Sowing – seeds harvest | Shoots – seeds harvest |
|-------------|------------------|--------------------|-------------------------|---------------------------|-----------------------|-----------------------|
| 1st decade of May | Ratnik 9.2 | 9.2 | 42.7 | 24.5 | 27.0 | 103.4 | 94.1 |
| | Salsa KL 9.2 | 9.2 | 42.2 | 24.7 | 28.0 | 104.1 | 94.9 |
| | Ozorno 9.2 | 9.2 | 42.0 | 23.5 | 27.7 | 102.4 | 93.2 |
| 2nd decade of May | Ratnik 8.7 | 8.7 | 38.2 | 21.0 | 26.5 | 94.4 | 84.7 |
| | Salsa KL 8.7 | 8.7 | 40.5 | 21.5 | 27.5 | 98.2 | 89.5 |
| | Ozorno 8.7 | 8.7 | 37.5 | 19.5 | 25.5 | 91.2 | 82.5 |

The formation of real rape leaves was noted on the 6th–9th day from germination, when the first and second sowing dates. Initially, a rosette formed and the sixth-twelfth leaves appeared. Active branching of plants began after the height of rape plants was 25–30 cm. All studied varieties and hybrids passed the first phases of growth and development quite equally. Before the budding phase of the crop, on average, about 35–38 days passed when the first sowing period and 32–34 days when the second sowing period.

The beginning of rape flowering occurred, when an average daily temperatures in the amount of 740–790 °C. The flowering phase of the studied rape was different and depended on the variety or hybrid, as well as on the sowing time. It occurred 37–43 days after germination. Soon, 7–9 days later, the massive flowering of rape began.

Differences in ripening between the varieties and hybrids of spring rape were not noted at the 1st sowing date. On average it was 94–95 days. According to the results of the experiment, when sowing in the second term Ozorno hybrid was more fast-ripening. Its vegetation period was 83 days, that was 7 days less than in the case with Salsa KL hybrid (86 days).

The field germination rate of rape in the years of research varied and depended mainly on the temperature and humidity of the seed soil layer. So, at the first sowing date, increased moisture reserves were observed. When the second sowing date, optimal soil and air temperature for the crop were observed. The research showed that spring rape did not experience any lack of moisture in the first half of development. The exception was 2019, when the sowing and seedling period was prolonged and amounted to 9-10 days, due to an abnormally dry hot May and the first half of June. It hindered the germination and development of rape in the first half of the growing season and affected the survival of plants.

The average field germination of rape was observed at the level of 89.1–91.0 % at the first sowing period and 82.5–84.7 % at the second one. An adverse combination of hydrothermal conditions, a high degree of weed contamination, as well as the degree of damage by numerous crop pests such as cruciferous flea, rapeseed beetle and cabbage moth influenced rape preservation. Young rape plants damaged by pests sharply reduced the growth of biomass or simply died. When high weed contamination of fields, the decrease in crop yield reached 30 % or more. Weed vegetation in cultural agrocenoses reduces soil fertility due to the consumption of moisture and nutrients. It also inhibits agricultural crops, shading them. That results in a shortage of crops and reduced product quality.

When planning the first sowing period in late April – early May, the soil temperature in Ryazan region is almost always lower and the majority of weeds do not germinate. Weed contamination of Clearfield variants was low and all weed groups died or were strongly inhibited (Table 2).
Table 2. Weed contamination of spring rape crops before harvesting, depending on the sowing dates, average for 2016–2019

| Variety / hybrid | The number of weeds, pcs/m² | Wet weight of weeds, g/m² | The mass of one weed, g |
|------------------|-----------------------------|---------------------------|------------------------|
|                  | perennial       | annual       | total       |                           |
| Ratnik           | 5.0             | 74.3         | 79.3        | 285.4                   | 3.6 |
| Salsa KL         | 3.0             | 33.3         | 36.3        | 39.9                    | 1.1 |
| Ozorno           | 4.5             | 60.1         | 64.6        | 187.3                   | 2.9 |
|                  | Seeding time 1  |              |             |                         |     |
| Ratnik           | 4.7             | 68.3         | 73.0        | 248.2                   | 3.4 |
| Salsa KL         | 2.5             | 27.6         | 30.1        | 24.1                    | 0.8 |
| Ozorno           | 4.1             | 62.7         | 66.8        | 187.0                   | 2.8 |

Weed vegetation begins to sprout simultaneously with shoots of spring rape with access to the first tier. Taking into account the biology of the crop, rape is in the stage of slow growth and is heavily overgrown with weeds at this time.

Spring rape is sensitive to weeds in the first 25–35 days of the growing season. Further, when the budding phase begins, the root system is already quite well developed. Rape has intensive growth of the aerial vegetative mass and the crop is able to compete with and suppress weed vegetation successfully.

At the beginning of budding and subsequent phases, the total amount of weed vegetation steadily decreased, while at the same time their mass continued to increase. Harm from weeds depends quite strongly on groups and species diversity, which did not change much in the experiment. The preceding grain drops had a negative effect.

The sowing dates affected weed contamination of the crop. A higher amount of weed vegetation was noted when the first sowing date. High weed contamination was noted by early germinating weeds, in particular by numerous dawny hemp nettle and sandweed. When the second sowing date, the number of weeds decreased, in many respects, due to later pre-sowing cultivation and sowing. A longer rape growing season made it possible for weeds to develop well and compete effectively with crops. In many respects, due to the later pre-sowing cultivation, it does not allow weeds to compete effectively for the best growing conditions. Often, when early stages of sowing, additional use of herbicide treatment of rape is recommended. On variants using the Clearfield system, optimization of the debris reduction process depended on just one treatment with Nopasaran herbicide.

By the time of harvesting, the homogeneous crops of Salsa KL hybrid, its uniform ripening, low weed contamination and a compact pod facilitated harvesting, thereby reducing seed loss to a minimum.

The herbicidal screen prevented the development of subsequent waves of weed vegetation throughout the growing season. The Clearfield system was very efficient, regardless of weather and soil conditions. The need for long-term use of the herbicidal treatment after the sprouting phase and before budding, makes it possible to vary the time of the use of the agrochemical against weeds and to apply it at the optimum time.

An important indicator in the structure of the crop is the number of plants per unit area when harvesting. This indicator is one of the most important elements of the productivity of agrophytocenoses, which is formed from the initial stages of plant development and is determined by many factors during the growing season of the crop (Table 3).

Plants of variety Ratnik and hybrids Salsa KL and Ozorno had different development intensities and German hybrids had a high compensatory ability. In this connection, during the growing season, various temperature, light and water conditions developed in the agrocenoses.
The maximum indices of the structure of the spring rape crop were observed on variants using the Clearfield system. Successful cultivation of Salsa KL using the Clearfield system is possible in fields heavily contaminated with problematic weeds, including cruciferous ones.

### Table 3. The structure of the spring rape yield depending on the sowing dates, the average for 2016–2019

| Sowing date        | Variety / hybrid | Population density before harvesting, pcs/m² | Plant height, cm | Maximum leaf area, thousand m²/ha | Number of pods per 1 plant, pcs. | Weigh of 1,000 seeds, g | Yield, dt/ha |
|--------------------|------------------|---------------------------------------------|-----------------|-----------------------------------|----------------------------------|------------------------|-------------|
| 1st decade of May  | Ratnik           | 215.2                                       | 101.6           | 31.9                              | 90.7                             | 2.4                    | 19.0        |
|                    | Salsa KL         | 121.9                                       | 112.4           | 33.3                              | 105.6                            | 3.4                    | 20.8        |
|                    | Ozorno           | 105.7                                       | 106.9           | 30.9                              | 101.3                            | 2.8                    | 19.5        |
| 2nd decade of May  | Ratnik           | 207.6                                       | 95.7            | 28.6                              | 80.1                             | 2.3                    | 18.4        |
|                    | Salsa KL         | 115.8                                       | 103.2           | 31.7                              | 96.0                             | 3.2                    | 20.1        |
|                    | Ozorno           | 104.4                                       | 96.5            | 27.9                              | 83.5                             | 2.7                    | 18.0        |

LSD<sub>05</sub> yield, dt/ha,
AB interactions 2016 – 1.63; 2017 – 1.78; 2018 – 1.67; 2019 – 1.47
by factor A (sowing date) 2016 – 0.94; 2017 – 1.03; 2018 – 0.97; 2019 – 0.85
by factor B (variety / hybrid) 2016 – 1.15; 2017 – 1.26; 2018 – 1.18; 2019 – 1.04

Salsa KL was characterized by intensive growth, especially at the initial stages of development. The hybrid had a deeply penetrating root system and possessed resistance to stressful weather conditions, which led to the formation of a good crop.

The developed deeply penetrating root system made it possible to withstand the stressful conditions of the growing season. The maximum number of pods in the structure of the crop is noted on variant Salsa KL 96.0–105.6 pcs/1 plant.

Variety Ozorno in our studies was characterized as a hybrid with high resistance to stress factors, which can be traced to the unfavorable periods of 2018 and 2019.

Variety Ozorno had healthy and strong stems, which provided high resistance to lodging. It had a great pod with an average 83.5–101.3 pcs/1 plant.

A high yield of spring rape is closely dependent on the nature of the plants development, which is associated with providing them with favorable growth conditions. In hot and dry years, rape plants reduced the number of pods on the plant, but their ripening rate increased, compared with wet years.

When early sowing at the end of April – the first decade of May, rape developed at a still short day and a relatively low temperature, and with subsequent sowing dates in the second half of May it developed with long days and higher average daily temperatures.

At the same time, when sowing in the second half of May, the sowing layer of the soil often withers, which leads to a decrease in the field germination of rape seeds like it was in abnormally dry and hot 2019. When rainfall, the seedlings density increases. Soil moisture has a decisive effect on this indicator when sowing in the 2nd and 3rd decades of May. And in early stages of sowing the temperature regime has a decisive effect on rape growth, given sufficient moisture. All this influenced the development of all experimental hybrids and varieties. In studies, rape plants in the first term developed better because of a longer growing season and, as a result, had a higher yield than when sown in the second term.

### 5. Conclusion

Thus, on average, the highest yield of spring rape (20.8 dt/ha) in the experiment was obtained from Salsa KL when the first sowing date is in the first decade of May. The maximum yield (24.8 dt/ha) was obtained from the same variant in 2016. The maximum yield of spring rape was observed on variants using Clearfield, regardless of the sowing period. On average, the growth, development, yield structure and yield of domestic variety Ratnik were not inferior to values of hybrid Ozorno.
The sowing date influenced weed contamination of crops. A larger amount of weed vegetation was noted in the first term of sowing. High weed contamination was caused by early germinating weeds, in particular by numerous dawny hemp nettle and sandweed. When the second sowing date, the number of weeds decreased, largely due to the later pre-sowing cultivation and sowing. Variants with the Clearfield system showed high efficiency in weed control, where the optimization of the process of reducing weed depended on the only treatment with Nasoparan herbicide in combination with Dash adhesive.

In conditions of the southern part of the Non-Black Earth Zone of Russia, sowing in the first decade of May, as the most productive for spring rape, is recommended.

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