Protection of soybeans against weeds with a two-component herbicide

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Abstract. The article presents information on the effectiveness of a two-component herbicide on soybean crops. The effectiveness of its use at different rates of application and application both with and without adjuvants, as well as species sensitivity to weeds have been studied. The variants of chemical weeding, in which the maximum suppression of weeds was achieved, providing a high yield of soybean grain, were determined.

1. Introduction
Soybean grains are high in protein (up to 50%), fat (up to 27%) and other nutritional components, making it an inexpensive and useful substitute for meat and dairy products. One quintal of soybean grain is equivalent to 4.5-5.0 quintals of grain from crops such as wheat, rye, triticale or barley, suggesting that soy can be used to solve protein shortages in the feeding of farm animals, birds and fish farming. Oil derived from soybeans can be a renewable resource in the production of bio-diesel fuel, and the products of grain processing are used in the production of plastics and other technical products. [1-3]

The benefits of growing and using this peculiar crop are driving the rapid expansion of soybean acreage worldwide and, in particular, in Russia. [4]

Soybean cultivation technology should include elements that ensure optimum conditions for the growth and development of the crop. The main ones are tillage, crop rotation and weed and disease control. [5-9]

Soybean plants grow slowly at the start of their development and, with their shallow roots, are unable to compete with weeds, which can lead to the loss of more than half of the crop if not properly maintained. Weeds that emerge early or simultaneously with the sprouting of soybeans cause the most damage. Annual dicotyledonous weeds and cereal weeds are the most harmful to the crop. Tall weeds such as helleborine, white goosefoot, common goosefoot and others shade soybean plants, resulting in non-simultaneous seed ripening, green hard-to-separate seeds and beans in the heap of harvested grains, which negatively affects the quality of production. [10]

Nowadays, many materials on methods and technologies of soybean weed control can be found both in special literature and on the Internet. In addition, a wide choice of both original preparations and their analogues for weed control is offered by various manufacturing firms and their distributors [11]. Field trials of many of them are conducted quite intensively in scientific institutions of agrarian profile [12-14]. The value of such scientific works is their regional character, binding to the specific soil and climatic conditions of growing crops.
2. Location, object of research
Field trials of two-component herbicide Korsar Super, VRK domestically produced on the basis of active substances bentazon and imazamox were conducted in the laboratory for the study of farming systems of Belgorod State Agricultural University named after V.Y. Gorin in 2018-2020 years.

The test site belongs to the second zone of black soils of the forest-steppe and steppe regions of the Central Black Earth region of crop cultivation. The climate in the Belgorod region is moderately continental with relatively mild winters with snowfalls and thaws and hot summers, often with droughts and dry spells. The average perennial annual temperature is 6.4 °C, the sum of active air temperatures is 2,698 °C, the duration of the warm period is 236 days, and the frost-free period is 153 days.

The soil of the experimental plot is typical black earth of heavy loamy texture with organic matter content equal to 5.2 %, the thickness of humus horizon is 70-90 cm. Reaction of soil solution is slightly acidic, close to neutral.

The subjects were the two-component herbicide Corsair Super, VPK and the adjuvants Galop, J and Adju, J.

The precursor in the experiment was spring barley. The soybean cultivation technology was based on the principles of minimum no-tillage soil loosening. A local soybean variety Lancet was cultivated.

Weather conditions in 2018 were characterised by abnormally hot weather during daytime hours in the first decade of May, intense short-term showers in mid-May, the third decade of June and mid-July, and hot and dry weather in August. In 2019, extreme weather conditions were characterised by intense showers in the second decade of April and the end of the first decade of May, abnormally hot and dry weather in late May and throughout June (on some days the daytime temperature was above 33 °C), and abnormally hot and dry weather in the second decade of August. In 2020, abnormally cold weather was observed in May, with large variations in daily temperatures and intensive rain showers at the end of the month. There was an air and soil drought during the summer.

3. Research Methods
The researches were carried out by field and laboratory methods using the following methods: weed counts by the quantitative weight method on 4 counting sites of 0.25 m² in size on each plot of the experiment [15]. The timing of the counts: 1 - before chemical weeding; 2 - 30 days after treatment; 3 - during the harvesting period.

During the soybean growing season, visual observations of the crop and weeds were carried out after the experiments. Harvesting in the phase of full grain ripeness was carried out using the Terrion SR combine harvesting method in 2010 four replications. The yield was converted to 12 % moisture content. Mathematical processing of the data was done by single-factor analysis of variance [16].

Names of weed species are given according to the "Branch Classifier of Weeds" (Moscow: Rosinformagrotech, 2018) [17].

4. Research results
The infestation of soybean crops before herbicide application varied from year to year, with the predominant annual weed species being Shielded Shield (Amaranthus retroflexus), Chenopodium album, and Echinochloa crusgalli (Table 1).

In 2018, the total number of annual dicotyledonous weeds reached 2 9 specimens/m² and the highest numbers were the backslash and white goosefoot. Perennial dicotyledonous weeds were represented by field thistle and field sow thistle. Field thistle was located in pockets and its number in the distribution over the area of plots was on average 1 specimen/m². Grains in the experiment were represented by common hedgehog and birch broom. Before treatment with herbicide they were in the phase of 1-3 leaves, which made it difficult to identify their species, and therefore their total number was counted, which was 32 ind.² The total number of weeds before the experiment was 64 pcs/m². (Table 1)
Table 1. Species composition, development phase and number of weeds before treatment of soybean crops with herbicide Corsar Super, VRK in 2018-2020.

| Types of weeds      | Latin names          | Phases of weed development | Quantity, ex./m² | 2018 | 2019 | 2020 |
|---------------------|----------------------|----------------------------|------------------|------|------|------|
| Amaranthus retroflexus | 2-4 sheets           | 10                         | 124              | 13   |      |      |
| Amaranthus blitoides  | Cotyledons - 2 leaves | 2                          | 1                | -    |      |      |
| Chenopodium album    | 2-6 leaves           | 13                         | 152              | 24   |      |      |
| Viola arvensis       | Cotyledons - 2-4 leaves | 2                          | 5                | 5    |      |      |
| Stachys annua        | 2-4 sheets           | 2                          | 5                | -    |      |      |
| Persicaria maculosa  | 2-4 sheets           | -                          | 1                | 3    |      |      |
| Malva neglecta       | 2-4 sheets           | -                          | 1                | 1    |      |      |
| Galium aparine       | Stemming             | -                          | -                | 3    |      |      |
| Oberna behen         | 2 sheets             | -                          | 6                | -    |      |      |
| Cirsium arvense      | A rosette of leaves4 | 1                          | -                | -    |      |      |
| Sonchus arvensis     | 2-4 sheets           | 2                          | 1                |      |      |      |
| Echinochloa crusgalli| 1-sheet3             | 32                         | 200              | 170  |      |      |
| Setaria glauca       |                      | -                          | 64               | 496  | 225  |      |

In 2019, the experimental plot was mainly infested with common duckweed, white marigold and tapered needlewort. The Common Elderberry was predominantly in the 2-leaf phase, with some specimens having 3 leaves. On average it reached 200 individuals/m². This species averaged 40% of the total. This was 40% of the total number of weeds. L. cinquefoil was at the 2-4 leaf stage and had an average of 124 individuals/m², while white goosefoot had 4-6 leaves and 152 plants/m². Together these two species accounted for nearly 56% of the total weed infestation in soybeans. The other weed species listed in Table 1 were only a small proportion of the total number of weeds, and were in their early stages of development at the time of the survey. The total number of these weeds was 20 ind/m², which was not more than 4% of the total number of all weeds, of which 496 ind/m² were counted by the pre-treatment herbicide survey.

When the crops were treated with herbicides at the end of the first decade of June 2020, most annual dicotyledonous weeds were in the 2-4 leaf phase, while some, in particular, white meadowsweet and field broom in the stem phase, unnoticed milkcress had just begun to form the first leaves. The perennial dicotyledonous weeds found on the experimental plot were Field Sow Thistle. Total infestation of the soybean crop consisted of 225 weeds per 1 m² with 75% of them being common dwarf milk thistle. (Table 1)

The experiment scheme in 2018 provided for the use of herbicide Korsar Super, VPK at a rate of 1.5 l/ha in a tank mixture with adjuvant Galop, J (0.5 l/ha) in the soybean germination phase and determination of its effectiveness in relation to the control variant without chemical weeding.

According to the results of biological efficacy tests, 30 days after treatment the annual and perennial dicotyledonous weeds were completely eliminated by the tested herbicide. Only single plants of common hedgehog and common broomstick survived. (Tables and23)

At the time of yield counting on the control variant of the experiment, the dominant weeds in terms of development were white goosefoot, tapered broom, common hedgehog and broom broomstick. At the plots treated with a tank mixture of herbicide Corsar Super, VPK with adjuvant Galop, G were present sporadic weeds of Common Headwort and Common Bunting. (Table 3)
Table 2. Effect of herbicide Corsair Super, VRK on the total weed infestation of soybean crops in 2018.

| Options for experience | Dates accounts | Number of weeds* | Weight of weeds* |
|------------------------|----------------|------------------|-----------------|
|                        |                | pcs./m²          | decline, % of control | g/m² | decline, % of control |
|                        |                | UD F MD S OPC    | UD F MD S OPC    | UD F MD S OPC |
| 1. Corsar Super, VPK + Galop, G - 1.5 l/ha + 0.5 l/ha | 19.06 | 0 0 2 | 10 0 | 100 94.7 | 0 0 | 49 100 100 94.3 |
| 2. Control - without treatment | 31.08 | 2 0 2 | 96.4 | 100 92.0 | - - - - - | - - - - - |

* ODF - annual dicotyledonous weeds, MDS - perennial dicotyledonous weeds, OCA - annual cereal weeds

Table 3. Effect of herbicide Corsair Super, VRK on selected weed species in soybean crops in 2018.

| Options for experience | Dates accounts | Reduced number of weeds, % to control |
|------------------------|----------------|------------------------------------|
|                        |                | Tucked back pinecone | Duckweed stingrays | Marais white | Field violet | Pistachio annual | Field Hemlock | Yellow thistle | Elderberry | Bristlecone blue |
| 1. Corsar Super, VPK + Galop, G - 1.5 l/ha + 0.5 l/ha | 19.06 | 100 | 100 | 100 | 100 | 100 | 96.3 | 90.9 |
| 2. Control - without treatment | 31.08 | 91.7 | 100 | 100 | 100 | 100 | 98.9 | 100 |

Chemical weeding of soybean crops in the phase of primordial leaves under agroclimatic conditions 2018 led to a significant increase in its grain productivity relative to the control. Due to suppression of weeds, the crop yield reached 3.35 t/ha, which was 1.08 t/ha higher than the control or in relative terms by 47.6 %. (Table 4)

Table 4. Soybean yields as a function of herbicide treatment with Corsair Super, VRK in 2018.

| Options for experience | Yield, t/ha | Deviation from control in t/ha | Deviation from control in % |
|------------------------|-------------|--------------------------------|------------------------------|
| 1. Corsar Super, VPK + Galop, G - 1.5 l/ha + 0.5 l/ha | 3.35 | 1.08 | 47.6 |
| 2. Control - without treatment | 2.27 | - | - |

In 2019, the test scheme was expanded to include three uses of the herbicide Corsair Super, VPC in the primordial leaf phase and a control without chemical weeding (Table 5).
Table 5. Scheme of experience in 2019.

| Options for experience | Consumption rate | Multiplicity |
|------------------------|------------------|--------------|
| 1. Corsair Super, VRK + Adju, G | 1.4 l/ha + 0.2 l/ha | 1 |
| 2. Corsair Super, VRK + Adju, G | 1.6 l/ha + 0.2 l/ha | 1 |
| 3. Corsair Super, VRK | 1.6 l/ha | 1 |
| 4. Control | Untreated | - |

In 30 days after treatment with herbicides weed infestation of soybean in all experimental variants, except the control, compared with the results of the preliminary accounting decreased by 94-99 %. In contrast, the number of weeds in the control during this period increased from 620496 to 6202. (Tables 1 and 6).

Table 6. Effect of herbicide Corsair Super, VRK on total weed infestation of soybean crops in 2019.

| Options for experience | Dates accounts | Number of weeds* | Weight of weeds* |
|------------------------|----------------|------------------|------------------|
|                        |                | pcs./m²          | decline, % of control | g/m² | decline, % of control |
|                        |                | DS | OPC | DS | OPC | DS | OPC | DS | OPC |
| 1. Corsair Super, VPK + Adew, W - 1.4l/ha + 0.2 l/ha | 22.06 | 10 | 53 | 97.3 | 78.4 | 123 | 118 | 88.5 | 85.6 |
|                        | 22.08 | 27 | 55 | 93.2 | 74.4 | - | - | - | - |
| 2. Corsair Super, VPK + Adew, W - 1.6l/ha + 0.2 l/ha | 22.06 | 3 | 46 | 99.2 | 81.2 | 20 | 117 | 98.1 | 85.7 |
|                        | 22.08 | 5 | 50 | 98.7 | 76.7 | - | - | - | - |
| 3. Corsair Super, VRK - 1.6l/ha | 22.06 | 7 | 79 | 98.1 | 67.8 | 33 | 327 | 96.9 | 60.1 |
|                        | 22.08 | 18 | 102 | 95.5 | 51.2 | - | - | - | - |
| 4. Control - without treatment | 22.06 | 375 | 245 | - | - | 1069 | 820 | - | - |
|                        | 22.08 | 399 | 215 | - | - | - | - | - | - |

*DC - dicotyledonous weeds, OCA - annual cereal weeds

The predominant weeds in the soybean crops of the control were common hedgehog, tapered broom, and white goosefoot. The proportion of these species in the total number of weeds was 39.5%, 26.9% and 28.2%, respectively. Test plots where we applied the tested herbicide were mostly infested by common aphid, which comprised from 70 % to 95 % of the total number of weeds, depending on the test variant. (Table 7)

Table 7. Effect of herbicide Corsair Super, VRK on selected weed species in soybean crops in 2019.

| Options for experience | Dates accounts | Reduced number of weeds, % to control |
|------------------------|----------------|-------------------------------------|
|                        |                | Tucked back pinecone | Duckweed stingray | Marais white | Pistachio annual | St. John’s wort | The manger unnoticed | Lily of the valley | Field violet | The common firecracker | Elderberry |
| 1. Corsair Super, VPK + Adew, W - 1.4l/ha + 0.2 l/ha | 22.06 | 99.4 | 100 | 97.1 | 90.9 | 75.0 | 100 | 100 | 0 | 100 | 78.4 |
|                        | 22.08 | 90.4 | 100 | 97.1 | 80.0 | 100 | 100 | 100 | 0 | 100 | 74.9 |
| 2. Corsair Super, VPK + | 22.06 | 99.4 | 100 | 98.9 | 100 | 100 | 100 | 0 | 100 | 100 | 81.2 |
In this count, the total number of annual cereal and dicotyledonous weeds in the 1st and 2nd experiment variants with herbicide Korsar Super, VPK with adjuvant Adju, W, respectively, was 63 and 49 indivisible plants/m², which was 9.8 and 12.47 times less than in the control. Plots in the 3rd experiment variant with tested herbicide without adjuvant were more weedy than with this adjuvant. Here the total number of weeds was 1.868 times more than in Variant 2 but 7.2 times less than in the control. It should also be noted that without adjuvant the effectiveness of herbicide Korsar Super, VPK against cereal weeds was significantly lower, as evidenced by an increase in their numbers and wet weight compared with the variants, where the tested herbicide was used in a tank mixture with Adju, G. (Table 6)

On the control variant the total crude weight of weeds reached 1889 grams. Where the crops were treated with herbicide Korsar Super, VRK at the rate of 1.6 l/ha without adjuvant, the weight of weeds was 5.2 times lower than on the control. At the same time when using the preparation together with surfactant at the rate of its application 1.4 l/ha the weight of weeds in relation to the variant without treatment was 7.8 times less, and at the rate of 1.6 l/ha - 13.8 times less. At the same time, in comparison with the third variant, where it was applied in a pure form, the weight of weeds was lower by 1.5 times and 2.6 times, respectively.

By the harvesting period for the variants with herbicide Corsar Super, VPK, during the time after the previous survey there was an increase in weed infestation by 12.2 % to 39.5 %. In the control plots, the number of weeds remained approximately the same as in the previous count. (Tables 6 and 7)

In soybean crops, the main weeds on the control variant were common hedgehog, white gooseberry, and tapered needlewort, which comprised 35 %, 28 %, and 31 % of all weeds, respectively.

At the time of harvesting the lowest weed infestation of soybean crops, 55 ex/m², was on the plots of the second option, where the rate of application of 1.6 l/ha of Korsar Super, VRK mixed with adjuvant was applied. It was 11 times less than the control. On plots of the 1st variant, where Corsar Super, VPK was used with the application rate of 1.4 l/ha in mixture with Adju, G, weeds at this time relative to the second variant were 27 more ex/m², and relative to the control 7.5 times less. In the third experiment variant, where herbicide Corsar Super, VPK in a pure form with the norm of application of 1.6 l/ha, the infestation was 120 ex/m² or 5.1 times lower than in the control, but it was 52% higher than in variant 2, where the rate of herbicide was the same, but when applying adjuvant was added.

The following yield data shows that the lowest yield of soybeans was obtained on the control and was 0.90 t/ha (Table 8).

Table 8. Soybean yield as a function of treatment with herbicide Corsair Super, VRK in 2019

| Options for experience | Yield, t/ha | Deviation from control in t/ha | in % |
|------------------------|------------|--------------------------------|------|
| 1. Corsar Super, VPK + Adew, W - 1.4l/ha + 0.2 l/ha | 2.15 | 1.25 | 138.9 |
| 2. Corsar Super, VPK + Adew, W - 1.6l/ha + 0.2 l/ha | 2.22 | 1.32 | 146.7 |
| 3. Corsar Super, VRK - 1.6l/ha | 2.04 | 1.14 | 126.7 |
| 4. Control - without treatment | 0.90 | - | - |
The variants of herbicide Korsar Super, VRK tested in the experiment in all cases significantly increased the yield of soybean in relation to the control. The variants of chemical weeding differed insignificantly in terms of yield. Thus, the use of the studied preparation without adjuvant in the 3rd experiment variant provided grain productivity of soybean equal to 2.04 t/ha. Compared to it, the grain yield in variants with tank mixtures of herbicide Corsar Super, VPK and Adjuvent, J was slightly higher, although the increase did not go beyond the smallest significant difference of experience.

At the rate of the tested herbicide equal to 1.6 l/ha in a mixture with an adjuvant the yield was 2.22 t/ha, which was 0.18 t/ha more than the variant with the use of Corsair Super, VPK in the same dosage, but without it. Reducing the herbicide application rate to 1 l/ha with the tank mixture with adjuvant did not significantly affect the value of soybean grain yield, relative to the second option, its reduction was 0.07 t/ha.

In 2020, the deadline for chemical weeding of soybeans with herbicide Corsar Super, VPK, unlike in previous years of testing, was postponed to the time when the crop has formed its first triple leaf. The herbicide application rate was 1,6 l/ha and the adjuvant Galop, J 0.25 L/ha.

One month after chemical weeding the number of weeds on the protected plots decreased significantly. Only single plants of white maria and field violet survived, and the biological effectiveness of the herbicide-adjuvant tank mixture against annual dicotyledonous weeds was equal to 98.4% and 70.0% for the cereal weed. The weed mass of cereal weeds was 172 g/m² which was 82.9% lower compared to the control plants. Field thistle was completely eliminated by the tested herbicide. (Tables 9 and 10)

### Table 9. Effect of herbicides on total soybean weed infestation in 2020.

| Options for experience | Dates accounts | Number of weeds* | Weight of weeds* |
|------------------------|----------------|-----------------|-----------------|
|                        |                | pcs./m² | decrease, % to | g/m² | decline, % of control |
|                        |                | UD MD OP UD MD OP UD MD OP UD MD OP |
|                        |                | F S C F S C F S C F S C |
| 1. Corsar Super, VRK + Galop, G - 1.6 l/ha + 0.4 l/ha | 09.07 | 2 0 145 98.4 100 70.0 1.1 0 172 99.8 100 82.9 | 02.09 | 2 0 63 95.1 100 1.6 - - - - - - |
| 2. Control* | 09.07 | 124 2 483 - - 710 37 100 3 - - - - - - | 02.09 | 41 2 64 - - - - - - - - - - - - |
| * - ODF - annual dicotyledonous weeds, MDS - perennial dicotyledonous weeds, OCA - annual cereal weeds |

### Table 10. Effect of herbicides on selected weed species in soybeans in 2020.

| Options for experience | Dates accounts | Reduced number of weeds, % to control |
|------------------------|----------------|--------------------------------------|
|                        |                | Moro’s white | Buckwheat | Lily of the valley | Field parsley | St. John’s Wort | Malva | Field violet | Milk thistle | Elderberry |
| 1. Corsar Super, VRK + Galop, G - 1.6 l/ha + 0.4 l/ha | 09.07 | 97.4 | 100 | 100 | 100 | 100 | 100 | 90.9 | 100 | 70.0 |
| 2. Control* | 09.07 | 38 | 32 | 6 | 24 | 8 | 5 | 11 | 2 | 483 |
The control shows the number of weeds, ex./m²

Before harvesting soybeans, plots protected with herbicide Corsar Super, VPK, were mostly infested with common aphid in numbers close to those of the control. There were also sporadic plants of white marigold. (Tables 9 and 10).

Table 11. Yields of the soybean variety Lancet in experiments with herbicides in 2020

| Options for experience | Yield, t/ha | Deviation in t/ha | Deviation in % |
|------------------------|------------|-------------------|----------------|
| 1. Corsar Super, VRK + Galop, G - 1.6 l/ha + 0.4 l/ha | 1.70 | 1.04 | 157.6 |
| 2. Control without processing | 0.66 | - | - |
| NDS05 | 0.22 | 33.4 |

As the results of the yield record showed, the low efficiency of herbicide eradication of the cereal weed on the background of its wide distribution in the experimental area, led to a soybean grain yield of 1.70 t/ha at the plots with chemical weeding. This was 2.6 times higher compared to the control or 1.04 t/ha more in physical terms. (Table 11)

5. Conclusion
As a result of three-year tests it should be recognized that the herbicide Korsar Super, VPK is a quality and effective product for controlling weeds in soybeans. Under the species composition of weeds, observed in the culture, it is advisable to apply with the norms of making from 1.4 l/ha to 1.6 l/ha in a tank mixture with adjuvants, as it improves the destruction of dicotyledonous weeds, and most importantly, significantly increases the effectiveness of suppression of annual grass weeds. It should be noted that the best results in eliminating weeds were obtained at the rate of Galop, W equal to 0.5 l/ha.

Treatment of soybean with two-component herbicide Corsar Super, VRK, both in the phase of primordial leaves and during the formation of the first triple leaf, was safe for the protected crop. The elimination of competitors for the main factors of life in the form of weeds from its sowing made it possible to almost fully realize the yield potential inherent in the variety, limited only by weather conditions during the growing season. Chemical weeding with the herbicide studied reduced yield losses by more than %87 on average over three years, harvesting 3.32 t/ha in 2018, 2.22 t/ha in 2019 and 1.70 t/ha of soybean in 2020.

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