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Biological Efficiency of the Application of Herbicides on Spring Barley in the Chernozem Region

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ABSTRACT

In the conditions of the Central Chernozem Region of Russia, a study of the effect of herbicides on the weed component and productivity of barley plants was carried out. We used seeds of spring barley of the Vakula variety and Ballerina Super, Prima, Lancelot, and Ballerina Forte herbicides. Weed counts were carried out following the All-Russian Institute for Plant Protection methodological instructions: before treatment (initial weediness), 15, 30, 45 days after treatment, and before harvesting. Sheaf samples for laboratory analysis were taken at the onset of economic ripeness in all test plots in four replicates. The actual yield of barley was determined using sheaf samples. The obtained results were processed by the method of variance analysis. The research variants were determined as follows: control (no effect of herbicides), Ballerina Super (application of a herbicide), Prima (application of a herbicide), Ballerina Forte (application of a herbicide), Lancelot (application of a herbicide). Studies have shown that perennial and annual dicotyledonous weeds have significant distribution in the crops of spring barley in the Central Chernozem zone. Out of these, in terms of abundance, white goosefoot, drug fumitory, white campion, black-bindweed, field pennycress, field milk thistle, and dog nettle prevail. A comparative analysis of herbicides, both in terms of the biological effectiveness of preparations against weeds and the effect on plant productivity, revealed that the Lancelot, Ballerina Super, and Ballerina Forte herbicides had the biggest effect against a wide range of weeds.

Keywords: Spring barley, Weed component, Herbicides, Ballerina super, Prima, Lancelot.

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INTRODUCTION

The main factors in initiating work to determine the effect of herbicides on the weed component and productivity of barley plants in the Lipetsk area of the Chernozem region were the natural and climatic conditions of the region and the social significance of barley derivatives to ensure the country's food security [1-3].

The purpose of the research

Was to study the effect of herbicides on the weed component and productivity of barley plants in the Lipetsk area of the Chernozem region.

MATERIALS AND METHODS

The objects of research are the following herbicides:

Ballerina Super, Suspo-Emulsion (SE) (2.4-D acid in the form of 2-ethylhexyl ether, 410 g/l, and florasulam, 7.4 g/l) is a post-emergence herbicide of systemic action against annual dicotyledons, including those resistant to 2.4-D and 2-Methyl-4-Chlorophenoxyacetic Acid

(MCPA), and some perennial root-sprouting weeds in grain crops, corn, millet, and sorghum.

Prima, SE (300 g/l 2.4-D to-you + 6.25 g/l of florasulam) is a post-emergence herbicide of systemic action, designed to control annual and some perennial dicotyledonous weeds in crops of grain and corn. It affects weeds that have already sprouted by the time of treatment [4].

Lancelot, Water-Dispersible Granules (WDG) (aminopyralid, 300 g/kg + florasulam, 150 g/kg) is a herbicide for cereal crops used against a wide range of dicotyledonous weeds, including the most dangerous species (yellow thistle, field milk thistle, creeping thistle, chamomile, fallen sunflower seeds, sticky-weed, and others) [5].

Ballerina Forte, SE (complex 2-ethylhexyl ester of 2.4-D acid, 300 g/l, picloram, 37.5 g/l, and florasulam, 10 g/l.) is a herbicide with enhanced action used against perennial dicotyledonous and annual dicotyledonous weeds on grain crops and corn [6-8].

The studies were carried out in 2019 from June to July on the territory of the educational and experimental field of the Yelets State University (YSU) named after I.A. Bunin, Yeletskiy district, Lipetsk area, on the culture of Vakula P4 spring multi-row barley variety. Before barley, winter wheat had been cultivated on the fields. The tillage of the experimental plot consisted of two autumn disking treatments after harvesting the predecessor crop and pre-sowing cultivation. In spring, N_{34} was introduced for cultivation, 100 kg/ha Seeding rate of barley: 170 kg/ha. The sowing was done in rows. The space between the rows was 15 cm. The sowing period was April 30. The treatment of crops with herbicides was carried out on June 4 in the tillering phase. Harvesting was carried out at the stage of full ripeness.

Identified Research Variants:

1. Control variant (no herbicide exposure)
2. Ballerina Super, SE (herbicide application: 0.5 l/ha)
3. Prima, SE (herbicide application: 0.6 l/ha)
4. Ballerina Forte, SE (herbicide application: 0.75 l/ha)
5. Lancelot, WDG (herbicide application: 0.033 kg/ha)

Weed counts were carried out following the methodological instructions of the All-Russian Institute for Plant Protection (VIZR) for the determination of weediness (the VIZR method): before treatment (initial weediness), 15, 30, 45 days after treatment, and before harvesting. The number of weeds was verified during the first and subsequent counts. 30 days after treatment, in addition to the number of weeds, the weight was taken into account. After harvesting, the yield of barley was determined. Repetition: fourfold, the number of experimental plants in replication: 25 pcs. Sheaf samples for determination of yield and laboratory analysis were taken at the onset of economic ripeness in all test plots in four replicates. The weight of 1,000 seeds was determined by the arithmetic mean of two samples in fourfold repetition. The obtained results were processed by the method of variance analysis.

To determine the biological effectiveness of herbicides, we used the quantitative weight-related and quantitative methods of weed counting. The biological effectiveness of herbicides shows a decrease in the number of weeds as a result of the use of herbicides as compared with the control variant [9, 10].

RESULTS AND DISCUSSION

As a result of the studies carried out in the crops of barley, we identified 28 species of weeds belonging to 13 families.

The largest number of species included such families as Asteraceae (4 species), Cruciferae (5 species), Polygonaceae (3 species), and Labiatae (3 species), which accounted for 54% of the total number of recorded species. The Leguminosae, Ranunculaceae, Caryophyllaceae families had two representatives each, while Chenopodioideae, Rubiaceae, Violaceae, Geraniaceae, Scrophulariaceae, Amaranthaceae, Convolvulaceae, and Equisetidae had one species each. The biological subtype of annual weeds included 20 species, while the perennial subtype included 9 species.

Analysis of indicators of the abundance of weeds per unit area by the time of herbicide treatments revealed that on average, up to 100 specimens of annual weeds and up to 13-14 specimens of perennial species of different ages and habits were counted per 1 m^2. This made it possible to carry out tests of herbicides at this site (according to the VIZR method).

The most abundant species were the early spring dicotyledonous ones, such as white

goosefoot, white campion, dog nettle, and field pennycress. Wintering species were also noted, namely sticky-weed and scentless chamomile. Among the perennial weeds, representatives of the creeping-rooted group such as field milk thistle and field bindweed dominated in the count. Rhizomatous species (marsh woundwort and field horsetail) had a high occurrence at the survey sites.

Determination of the effectiveness of herbicides concerning certain groups of weeds revealed the following patterns. On the variant with the use of the Ballerina Super, SE, high biological effectiveness was revealed concerning such annual species growing in grain fields as black-bindweed, white goosefoot, sticky-weed, and such perennial species as yellow thistle and field horsetail. No biological effect was observed in the case of white goosefoot and field horsetail treated with Lancelot. The oppressive effect affected only the seedlings of the white goosefoot, while the adult vegetative plants practically did not suffer. Only visual observations of horsetail were carried out. Calculation of effectiveness against horsetail was not included in the experiment.

The study noted a biological effect on field milk thistle and creeping thistle, where the population of the plants did not recover.

Determination of the comparative effectiveness of herbicides in reducing the number of weeds revealed that the death of most of the weeds that fell under herbicidal treatment was noted on the 30 to 40th day. When compared with the control variant, by the 30th day of observation, the total number of weeds in the variant with the use of Ballerina Forte had decreased by 75%. In the variant with the use of Prima the number had decreased by 68%, with Ballerina Super by 56%, and with Lancelot by 8%. By the 45th day of observation, the regularity remained. By harvesting the decrease amounted to 70, 45, 86, and 15%, respectively.

Analysis of the data revealed that the use of Ballerina Super and Ballerina Forte contributed to a decrease in the biological mass of weeds by 88% by the 30th day of observation, the use of Prima by 91%, and the used of Lancelot by 59% **(Table 4)**.

The highest yield of barley grain was obtained in the variant with the use of the Lancelot preparation, amounting to 34.4 c/ha, which is 32% higher than in the control variant **(Table 5)**. The control of weeds with such herbicides as Ballerina Super and Ballerina Forte provided an increase in yield compared to the control variant by 6.4 and 7.8 c/ha, respectively. The use of the Prima herbicide made it possible to obtain 29.6 c/ha of barley grain, which is 14% higher than the control variant. The seeds obtained from the plots treated with Prima were the heaviest, weighing 56.5 g, which is 4 g higher than the control variant. The seed mass in the variants treated with Ballerina Super and Ballerina Forte herbicides was approximately the same (53.2 and 53.8 g, respectively) **(Table 6)**.

Table 1. Biological Effectiveness of Herbicides Used Against Dicotyledonous Weeds 15 Days after Treatment (by the Number of Weeds)

Weed species	Control variant	Ballerina Super		Prima		Ballerina Forte		Lancelot	
	pcs/m^2	pcs/m^2	effectiveness, %	pcs/m^2	effectiveness, %	pcs/m^2	effectiveness, %	pcs/m^2	effectiveness, %
Dicotyledonous annual plants									
Lady's thumb	1.0	1.0	0.0	0.0	100.0	0.0	100.0	0.0	100.0
Field violet	3.0	1.0	66.7	3.0	0.0	0.0	100.0	0.0	100.0
White campion	1.0	13.0	-1200.0	6.0	-500.0	1.0	0.0	1.0	0.0
White goosefoot	9.0	5.0	44.4	3.0	66.7	0.0	100.0	6.0	33.3
Dog nettle	12.0	1.0	91.7	2.0	83.3	0.0	100.0	0.0	100.0
Field pennycress	1.0	0.0	100.0	1.0	0.0	1.0	0.0	0.0	100.0
annual plants	27.0	21.0	22.2	15.0	44.4	2.0	92.6	7.0	74.1

Dicotyledonous perennial plants									
Field bindweed	3.0	2.0	33.3	1.0	66.7	0.0	100.0	0.0	100.0
total	30.0	23.0	23.3	16.0	46.7	2.0	93.3	7.0	99.8

Table 2. Biological Effectiveness of Herbicides Against Dicotyledonous Weeds 30 Days after Treatment (by the Number of Weeds)

Weed species	**Control variant**	**Ballerina Super**		**Prima**		**Ballerina Forte**		**Lancelot**	
	pcs/m²	**pcs/m²**	**effectiveness, %**	**pcs/m²**	**effectiveness, %**	**pcs/m²**	**effectiveness, %**	**pcs/m²**	**effectiveness, %**
Dicotyledonous annual plants									
Black-bindweed	1.0	0.0	100	0.0	100.0	0.0	100.0	1.0	0.0
Lady's thumb	2.0	0.0	100	1.0	50.0	0.0	100.0	0.0	100.0
Field violet	4.0	1.0	75	2.0	50.0	2.0	50.0	2.0	50.0
White campion	4.0	3.0	25	12.0	-200.0	22.0	-450.0	34.0	-750.0
Drug fumitory	1.0	2.0	-100	2.0	-100.0	1.0	0.0	2.0	-100.0
White goosefoot	10.0	1.0	90	0.0	100.0	0.0	100.0	7.0	30.0
Dog nettle	13.0	2.0	84.6	0.0	100.0	0.0	100.0	1.0	92.3
Red-root amaranth	1.0	1.0	0	0.0	100.0	0.0	100.0	0.0	100.0
Field pennycress	2.0	0.0	100.0	0.0	100.0	0.0	100.0	0.0	100.0
annual plants	38.0	10.0	73.7	17.0	55.3	25.0	34.2	47.0	-23.7
Dicotyledonous perennial plants									
Field milk thistle	1.0	1.0	0	0.0	100.0	0.0	100.0	0.0	100.0
Field bindweed	3.0	3.0	0	1.0	66.7	0.0	100.0	3.0	0.0
perennial	4.0	4.0	0	1.0	75.0	0.0	100.0	3.0	25.0
Total	42.0	14.0	66.7	18.0	57.1	25.0	40.5	50.0	-19.0

Table 3. Biological Effectiveness of Herbicides Used Against Dicotyledonous Weeds 45 Days after Treatment (by the Number of Weeds)

Weed species	**Control variant**	**Ballerina Super**		**Prima**		**Ballerina Forte**		**Lancelot**	
	pcs/m²	**pcs/m²**	**effectiveness, %**	**pcs/m²**	**effectiveness, %**	**pcs/m²**	**effectiveness, %**	**pcs/m²**	**effectiveness, %**
Dicotyledonous annual plants									
Black-bindweed	1.0	0.0	100.0	0.0	100.0	0.0	100.0	0.0	100.0
Lady's thumb	1.0	0.0	100.0	0.0	100.0	0.0	100.0	0.0	100.0
Field violet	12.0	2.0	83.3	1.0	91.7	1.0	91.7	2.0	83.3
Tufted vetch	2.0	0.0	100.0	0.0	100.0	0.0	100.0	0.0	100.0
White campion	5.0	7.0	-40.0	15.0	-200.0	1.0	80.0	17.0	-240.0
Drug fumitory	2.0	0.0	100.0	1.0	50.0	2.0	0.0	1.0	50.0
White goosefoot	7.0	0.0	100.0	0.0	100.0	0.0	100.0	13.0	-85.7
Dog nettle	2.0	1.0	50.0	0.0	100.0	0.0	100.0	0.0	100.0
Annual yellow woundwort	2.0	6.0	-200.0	4.0	-100.0	3.0	-50.0	2.0	0.0
annual plants	34.0	16.0	52.9	21.0	38.2	7.0	79.4	35.0	-2.9

Dicotyledonous perennial plants									
Field bindweed	8.0	1.0	87.5	2.0	75.0	0.0	100.0	2.0	75.0
Creeping thistle	1.0	0.0	100.0	0.0	100.0	0.0	100.0	0.0	100.0
Field milk thistle	2.0	1.0	50.0	2.0	0.0	0.0	100.0	2.0	0.0
Marsh woundwort	1.0	0.0	100.0	0.0	100.0	0.0	100.0	0.0	100.0
perennial	12.0	2.0	83.3	4.0	66.7	0.0	100.0	4.0	66.7
total	46.0	18.0	60.9	25.0	45.7	7.0	84.8	39.0	15.2

Calculation of the biological effectiveness of herbicides 15 days after treatment showed that the maximum percentage of death of dicotyledonous weeds (both annual and perennial) was caused by the use of the Ballerina Forte (93.3%) and Lancelot (99.8%) preparations **(Table 1)**.

On the 30th day after treatment **(Table 2)**, Ballerina Forte showed 100% biological effectiveness against perennial dicotyledonous weeds. For annual weeds, for this period the best effect was shown by Ballerina Super (73.7%) and Prima (55.3%). These herbicides have shown 100% effectiveness in the control of field pennycress and black-bindweed. The number of drug fumitory plants in these variants was higher than in the control variant, however, the calculation of the effectiveness of the preparations by the weight of weeds showed a result of 84 and 88%, respectively. This indicates the suppressive effect of these preparations on these weeds.

According to the results of calculating the effectiveness of herbicides on the 45th day after treatment **(Table 3)**, it was found that:

- Creeping thistle and marsh woundwort in barley crops had been destroyed by all preparations;
- Field milk thistle was more resistant to the effect of Prima and Lancelot herbicides;
- In general, in the group of dicotyledonous perennial weeds, Ballerina Forte (100%) and Ballerina Super (83.3%) showed a greater effect;
- From annual dicotyledonous plants, lady's thumb, black-bindweed, tufted vetch, dog nettle responded to the effects of all preparations. The Lancelot, WDG herbicide is less effective against white goosefoot. Presumably, other herbicides are more effective because of the 2.4 D ether that is included in their composition and better overcomes wax deposits.

On the 45th day after treatment, there was an increase in the number of certain weeds in all variants due to the emergence of new shoots.

Table 4. The Effect of Herbicides on the Weight of Weeds by Species in Barley Crops on Day 30 after Treatment, g/m^2

Weed species	**Control variant**	**Ballerina Super**		**Prima**		**Ballerina Forte**		**Lancelot**	
	pcs/m^2	**pcs/m^2**	**effectiveness, %**	**pcs/m^2**	**effectiveness, %**	**pcs/m^2**	**effectiveness, %**	**pcs/m^2**	**effectiveness, %**
Dicotyledonous annual plants									
Black-bindweed	0.55	0.0	92.7	0.0	100.0	2.0	-263.6	0.5	12.7
Lady's thumb	1.7	0.0	100.0	0.7	60.0	0.0	100.0	0.1	92.9
Field violet	1.2	0.1	91.7	0.8	36.7	0.6	46.7	0.1	90.0
Tufted vetch	3.1	0.0	100.0	0.0	100.0	0.0	100.0	1.1	65.2
White campion	15.54	0.8	94.6	3.5	77.6	5.2	66.3	9.8	37.2
Drug fumitory	2	0.3	84.0	0.2	88.0	0.2	90.0	0.7	64.0
White goosefoot	3	0.2	93.3	0.4	86.7	0.0	100.0	4.6	-52.0
Dog nettle	3.15	1.4	54.3	0.1	98.1	0.1	97.5	0.8	74.6
Red-root amaranth	0.3	0.4	-20.0	0.0	100.0	0.0	100.0	0.0	100.0

Field pennycress	0.11	0.0	100.0	0.0	100.0	0.0	100.0	0.0	100.0
Annual yellow woundwort	0.1	0.0	60.0	0.0	100.0	0.0	100.0	0.0	100.0
minor	30.75	3.3	89.1	5.6	81.7	8.2	73.5	17.6	42.6
Dicotyledonous perennial plants									
Field bindweed	25.9	4.2	83.6	0.2	99.1	1.0	96.3	3.8	85.3
Creeping thistle	15.34	0.0	100.0	0.0	100.0	0.0	100.0	5.3	65.6
Field milk thistle	5	0.8	84.0	0.8	84.0	0.1	97.6	5.0	-0.8
Marsh woundwort	0.95	0.7	24.2	0.2	78.9	0.0	100.0	0.0	100.0
perennial	47.19	5.8	87.8	1.2	97.4	1.1	97.7	14.1	70.1
total	77.94	9.1	88.3	6.86	91.2	9.24	88.1	31.76	59.3

Table 5. Barley Yield Depending on the Use of Herbicides, c/ha

Variant	Yield	+/- to the control variant	
		abs.	%
Control variant	25.9		
Ballerina Super	32.3	6.4	24.7
Prima	29.6	3.7	14.3
Ballerina Forte	33.7	7.8	30.1
Lancelot	34.4	8.5	32.8
Least Significant Difference (LSD)05 of particular differences		**3.5**	

According to the 2019 crop accounting data, all herbicides made it possible to obtain a significant increase in yield compared to the control variant, except for the Prima herbicide. There was no significant difference between the herbicide applications **(Table 5)**.

Table 6. Weight of 1,000 Barley Seeds Depending on the Use of Herbicides, g

Variant	Weight of 1,000 pieces, g	+/- to the control variant	
		abs.	%
Control variant	52.5	-	-
Ballerina Super	53.2	0.7	1.3
Prima	56.5	4.0	7.6
Ballerina Forte	53.8	1.3	2.3
Lancelot	51.2	-1.3	-2.3

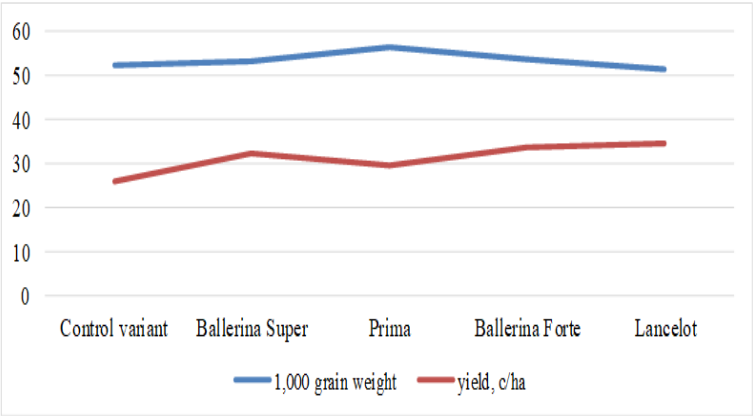

Figure 1. The dependency of 1000 grain weight on yeild

It is noted that in herbicidal variants, the higher the yield, the lower the weight in the variants of herbicide use, see Graph 1. For the control variant, both a lower mass of 1,000 grains and a lower yield are noted compared to the treated variants.

CONCLUSION

Studies have shown that perennial and annual dicotyledonous weeds have significant distribution in the crops of spring barley in the Central Chernozem zone. Out of these, in terms of abundance, white goosefoot, drug fumitory, white campion, black-bindweed, field pennycress, field milk thistle, and dog nettle prevail.

All herbicides were effective against such weeds as creeping thistle, field milk thistle, black-bindweed, lady's thumb, violet, dog nettle and allowed controlling the field bindweed. By the end of the growing season, there was an increase of seedlings of annual dicotyledonous weeds, especially white campion, in all variants, which somewhat reduced the numeric effectiveness values. At the same time, weeds were located in the lower tier and did not have a significant effect on the development of the crops.

The yield when counted by the combine harvester method and the experimental variants exceeded the control variant by 3.7-8.5 c/ha. The difference between herbicide applications was significant.

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