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CONTROL OF MIXED WEED INFESTATION IN WINTER WHEAT

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Abstract

During 2016-2017 and 2017-2018 a field trial with winter wheat variety "Enola" was performed. The experiment was situated on the experimental field of the Agricultural University of Plovdiv, Bulgaria. Herbicide products with mixed mode of action were evaluated - Osprey Extra, Atlantis WG, Abak and Atlantis Flex. The application of Atlantis WG – 0.50 kg ha^{-1} + 1.00 l ha^{-1} showed the highest control against Anthemis arvensis, Papaver rhoeas and Sinapis arvensis. The highest efficacy against the weeds Lamium purpureum and Avena fatua after the application of Abak + Mero – 0.25 kg ha^{-1} + 1.00 l ha^{-1} was reported. The treatment with Osprey Extra + Biopower – 0.33 kg ha^{-1} + 1.00 l ha^{-1} showed highest efficacy against Lolium rigidum and Galium aparine. The most difficult-to-control weeds were the volunteer of Clearfield® oilseed rape and Veronica hederifolia. The height of the plants, length of the central ear, average number of grains per ear, average grain weight per ear, 1000 grain weight and yields were the highest after the treatment with Atlantis WG – 0.50 kg ha^{-1} + Biopower – 1.00 l ha^{-1} and Abak – 0.25 kg ha^{-1} + Mero – 1.00 l ha^{-1}.

***Key words**: winter wheat, biometry, herbicides, weeds, efficacy introduction.*

INTRODUCTION

The winter wheat (*Triticum aestivum* L.) is main grain crop in Bulgaria. The total harvested area for 2019 are 1 198 682 ha with average yields of 5.141 t ha^{-1} (MZH, 2020). The weeds are main competitors of winter wheat for water, nutrients and light. The weeds also cause indirect damage, as many of the species are hosts of diseases and pests (Kalinova et al., 2012). The high weeds infestation can decrease the yields up to 70% (Atanasova and Zarkov, 2005; Bekelle, 2004).

In the modern agriculture the weed control is mainly performed by the chemical method. A number of authors study the selectivity and efficacy of different herbicides in crops (Marinov-Serafimov and Golubinova, 2016; Marinov-Serafimov and Golubinova, 2015; Rankova and Tityanov, 2015; Rankova et al., 2014; Goranovska and Kalinova, 2014; Hristova, 2007; Atanasaova, 2002).

The choice of a proper herbicide, optimal time and application rate are one of the most important and responsible moments in the wheat management (Petrova, 2017; Penchev and Petrova, 2015; Petrova and Sabev, 2014; Abbas et al., 2009a; Khalil et al., 2008; Sherawat et al., 2005). For graminaceous weeds control in wheat Raffel et al. (2010) recommend application of Tarox (pinoxaden + clodinafop-propargyl). Berca and Horoias (2013) conduct a trial for *Avena fatua* control. The researchers reported that at very high density of the weed - from 600 to 900 specimens per m^2, very good results after the application of Palas 75 WG in rate of 150 g ha^{-1}. For *Alopecurus myosuroides* control in wheat Kierzek et al. (2006) recommend the application of pinoxaden in tank mix with adjuvant in 2nd - 4th leaf stage of the crop and in 1st - 4th leaf stage of the weed. It was found that in the crop rotation of winter wheat with winter oilseed rape the application of propyzamide and pyroxulam the density of *Alopecurus myosuroides* was decreased (Roberts and Jackson, 2012).

For successful control of the resistant to herbicides *Alopecurus myosuroides* in wheat the application soil herbicides in the autumn followed by spring application of mesosulfuron + iodosulfuron is applied (Atlantis) (Gehring and Thyssen, 2014).

It is economically unreasonable to use herbicides for control of graminaceous weeds without performing successful control of broadleaf weeds. Mitkov et al. (2017) study Sekator OD and Biathlon 4 D for control of dicotyledonous weeds. The herbicide products were applied in two terms – 1st - 2nd stem node (BBCH 30-32) and flag leaf (BBCH 37-39) of the wheat. The highest efficacy was recorded after the application of Biathlon 4 D + Dash in rate of 0.14 kg ha^{-1} + 1.0 l ha^{-1} applied 1st – 2nd stem node of the crop. Chopra et al. (2008) found that carfentrazone in rate of 20 g ha^{-1} and metsulfuron in rate of 4 g ha^{-1} control the broadleaf weeds 83.7 and 84.1% respectively. For control of the broadleaf weeds Abbas et al. (2009b) recommend the usage of Buktril Super EK - 835 ml ha^{-1} and Starane-M - 875 ml ha^{-1}. WangCang et al. (2016), reported that the combinations of 29% fluroxypyr - 111.31 g ha^{-1} + 5% carfentrazone-ethyl - 3.31 g ha^{-1}, florasulam - 7.50 g ha^{-1} + carfentrazone-ethyl - 15.00 g ha^{-1} had excellent efficacy against *Descurainia sophia*, *Capsella bursa-pastoris* and *Galium aparine*. For the most efficient control of *Galium* sp. fluroxypyr should be applied. High efficacy against *Galium aparine* after the combine treatment of carfentrazone + MCPP, triosulfuron + dicamba, and amidosulfuron + iodosulfuron was recorded (Cirujeda et al., 2008).

Besides differentiated, the control of the mono- and dicotyledonous weeds in wheat could be performed simultaneously. For *Apera spica-venti, Echinochloa crus-galli* and some dicotyledonous weeds, Szemendera et al. (2008) found that Pledge 50 WP (flumioxazine) can be applied. If there is mixed weed infestation with *Apera spica-venti*, *Lolium* sp., *Avena fatua*, *Myosotis arvensis*, *Capsella bursa-pastoris, Thlaspi arvense*, etc. Krato and Raffel (2018) observed that treatment with Avoxa (pinoxadene+pyroxulam + cloquintocet-mexyl) in rate of 1.8 l ha^{-1} may be performed.

The aim of the study is to establish the possibilities for chemical control of mixed weed infestation in winter wheat.

MATERIALS AND METHODS

During the experimental seasons of 2016-2017 a field trial with winter wheat variety "Enola" was performed. The experiment was situated on the experimental field of the department of "Agriculture and herbology" at the Agricultural University of Plovdiv, Bulgaria. The trial was conducted by the randomized block design in 3 replications. The size of the harvesting plot was 20 m². Variants of the trial were: 1. Untreated contol; 2. Osprey Extra (mesosulfuron-methyl + thiencarbazon-methyl + mefenpyr-diethyl) - 166 g ha^{-1} + Biopower (adjuvant) - 1000 ml ha^{-1}; 3. Osprey Extra – 200 g ha^{-1} + Biopower - 1000 ml ha^{-1}; 4. Osprey Extra - 255 g ha^{-1} + Biopower - 1000 ml ha^{-1}; 5. Osprey Extra - 333 g ha^{-1} + Biopower - 1000 ml ha^{-1}; 6. Osprey Extra - 330 g ha^{-1}; 7. Atlantis WG (iodosulfuron-methyl-sodium+ mesosulfuron-methyl + thiencarbazone-methyl) 500 g ha^{-1} + Biopower - 1000 ml ha^{-1}; 8. Abak (pyroxsulame + cloquintocet-mexyl) - 250 g ha^{-1} + Mero (adjuvant) - 1000 ml ha^{-1}; 9. Atlantis Flex (mesosulfuron-methyl + propoxycarbazone-natrium + mefenpyr-diethyl) - 330 g ha^{-1} + Biopower - 1000 ml ha^{-1}. Predecessor of winter wheat during both experimental years was Clearfield® winter oilseed rape (*Brassica napus* L.).

To the whole experimental area before sowing of the winter wheat, fertilization with 300 kg ha^{-1} with NPK (15:15:15) 300 kg ha^{-1} NH_4NO_3 as spring dressing.

Artificial weed infestation with previously collected weed seeds by spreading to the whole area of the trial was performed. The infestation was done with *Anthemis arvensis* L., *Papaver rhoeas* L., *Galium aparine* L., *Sinapis arvensis* L., *Lamium purpureum* L., *Veronica hederifolia* L., *Lolium rigidum* L., *Avena fatua* L., and volunteer Clearfield® *Brassica napus* L.

The application of the herbicide products was done in beginning of spindling stage of the crop (BBCH 30-31) with spraying solution 250 l ha^{-1}. The efficacy of the herbicides was evaluated on the 14th, 28th, and on the 56th day after treatments by the 10-score scale of EWRS. The selectivity of the herbicides was examined on the 7th, 14th, 28th and 56th day after application by the 9-score scale of EWRS (Zhelyazkov et al., 2017).

The following parameters of the winter wheat were determined: Height of the plants at the end of the vegetation, length of the dental ear, number of grains per ear, mass of the grain per ear, 1000 grain weight and grain yield. The obtained data were processed by the statistical software SPSS 19.

RESULTS AND DISCUSSIONS

On the experimental field only annual weeds during both vegetation seasons of the winter wheat were observed. The weeds were presenters of three biological weed groups. The highest population was from the group of the early-spring weeds - *Galium aparine* L., *Sinapis arvensis* L., *Lamium purpureum* L. and *Avena fatua* L., followed by the group of the winter spring weeds - *Anthemis arvensis* L., *Papaver rhoeas* L. and *Lolium rigidum* L. and one presenter of the ephemerals - *Veronica hederifolia* L.
On the field the Clearfield® oilseed rape volunteer *Brassica napus* L. was also reported. The efficacy of the studied herbicide products is presented on average for bot experimental years on Tables 1, 2 and 3.
The highest efficacy 14 days after herbicide application against *A. arvensis* (38.3%), *P. rhoeas* (30.0%), *G. aparine* (35.0%), *S. arvensis* (58.3%) and *L. purpureum* (46.6%) for Atlantis WG (500 g ha^{-1} + Biopower - 1000 ml ha^{-1}) was reported.
Lower efficacy was reported against *G. aparine, S. arvensis* and *L. purpureum* after the application of Atlantis Flex - 330 g ha^{-1} + Biopower - 1000 ml ha^{-1} (variant 9). The efficacy obtained was 31.6%, 35.0% and 31.6% respectively. For the treatment with Abak - 250 g ha^{-1} + Mero - 1000 ml ha^{-1} the efficacy against *A. arvensis* was only 25% average for both years of the study.

Table 1. Efficacy of the studied herbicide products on the 14th day after application average for 2017 and 2018, %

Treatments	*A. arvensis*	*P. rhoeas*	*G. aparine*	*S. arvensis*	*V. hederifolia*	*L. purpureum*	*L. rigidum*	*A. fatua*	*B. napus CL*
1. Untreated contol	-	–	–	–	–	–	–	–	–
2. Osprey Extra - 166 g ha^{-1} + Biopower - 1000 ml ha^{-1}	6.6	10.0	10.0	21.6	13.3	10.0	8.3	0.0	0.0
3. Osprey Extra - 200 g ha^{-1} + Biopower - 1000 ml ha^{-1}	10.0	11.6	13.3	28.3	11.6	21.6	11.6	0.0	0.0
4. Osprey Extra - 255 g ha^{-1} + Biopower - 1000 ml ha^{-1}	10.0	11.6	13.3	25.0	11.6	20.0	16.6	5.0	0.0
5. Osprey Extra - 333 g ha^{-1} + Biopower - 1000 ml ha^{-1}	25.0	25.0	21.6	28.3	18.3	26.6	10.0	1.6	0.0
6. Osprey Extra - 330 g ha^{-1}	18.3	21.6	25.0	30.0	20.0	26.6	5.0	5.0	0.0
7. Atlantis WG - 500 g ha^{-1} + Biopower - 1000 ml ha^{-1};	38.3	30.0	35.0	58.3	25.0	46.6	8.3	3.3	0.0
8. Abak - 250 g ha^{-1} + Mero - 1000 ml ha^{-1}	25.0	0.0	5.0	26.6	10.0	21.6	10.0	5.0	0.0
9. Atlantis Flex - 330 g ha^{-1} + Biopower - 1000 ml ha^{-1}	21.6	20.0	31.6	35.0	30.0	31.6	8.3	5.0	10.0

On the first reporting date the highest efficacy against *V. hederifolia* after the application of Atlantis Flex - 330 g ha^{-1} + Biopower - 1000 ml ha^{-1} - 30.0% average for the period was observed.
The efficacy against *L. rigidum* and *A. fatua* was very low after the treatments of all herbicide products. The Clearfield oilseed rape volunteer (*B. napus*) was the most difficult-to-control weed in our experiment. Only 10.0% efficacy was recorded after the application of Atlantis Flex - 330 g ha^{-1} + Biopower - 1000 ml ha^{-1} (Table 1).
In previous our study the Clearfield® oilseed rape volunteer also appeared to be a very resistant to chemical control "weed". The highest efficacy for the conditions of the study after the treatment with thifensulfuron-methyl

+ fluroxypyr (750 ml ha^{-1}) was recorded - 40% (Mitkov et al., 2018).

On the second reporting date the highest efficacy against *A. arvensis*, *P. rhoeas, S. arvensis* and *L. purpureum* again from Atlantis WG (500 g ha^{-1} + Biopower - 1000 ml ha^{-1}) was found - 86.6%, 88.3%, 91.6% and 90.0% respectively (Table 2). Efficacy reaching 90.0% against of *L. purpureum* for the treatment of Abak - 250 g ha^{-1} + Mero - 1000 ml ha^{-1} was observed. For *G. aparine* control, the highest results for the treatment with Osprey Extra - 333 g ha^{-1} + Biopower - 1000 ml ha^{-1} was reported. Against *V. hederifolia* and *B. napus* the higest efficacy on the 28th day after treatments with Atlantis Flex - 330 g ha^{-1} + Biopower - 1000 ml ha^{-1} - 50 and 23.3% respectively was observed (Table 2).

Table 2. Efficacy of the studied herbicide products on the 28th day after application average for 2017 and 2018, %

Treatments	*A. arvensis*	*P. rhoeas*	*G. aparine*	*S. arvensis*	*V. hederifolia*	*L. purpureum*	*L. rigidum*	*A. fatua*	*B. napus CL*
1. Untreated contol	-	–	–	–	–	–	–	–	–
2. Osprey Extra - 166 g ha^{-1} + Biopower - 1000 ml ha^{-1}	45.0	53.3	35.0	73.3	18.3	60.0	31.6	35.0	0.0
3. Osprey Extra - 200 g ha^{-1} + Biopower - 1000 ml ha^{-1}	58.3	63.3	55.0	81.6	26.6	76.6	41.6	53.3	0.0
4. Osprey Extra - 255 g ha^{-1} + Biopower - 1000 ml ha^{-1}	56.6	70.0	65.0	81.6	28.3	85.0	48.3	56.6	0.0
5. Osprey Extra - 333 g ha^{-1} + Biopower - 1000 ml ha^{-1}	60.0	83.3	78.3	85.0	38.3	85.0	61.6	68.3	0.0
6. Osprey Extra - 330 g ha^{-1}	70.0	80.0	66.6	86.6	26.6	85.0	50.0	65.0	0.0
7. Atlantis WG - 500 g ha^{-1} + Biopower - 1000 ml ha^{-1};	86.6	88.3	71.6	91.6	38.3	90.0	63.3	70.0	0.0
8. Abak - 250 g ha^{-1} + Mero - 1000 ml ha^{-1}	78.3	0.0	45.0	90.0	20.0	90.0	71.6	83.3	0.0
9. Atlantis Flex - 330 g ha^{-1} + Biopower - 1000 ml ha^{-1}	63.3	75.0	41.6	81.6	50.0	78.3	58.3	70.0	23.3

The efficacy on the 56th day after treatments kept the tendency observed on the first two reporting dates.

It is worth noting that the herbicide efficacy was the highest on the third reporting date.

Atlantis WG - 500 g ha^{-1} + Biopower - 1000 ml ha^{-1} showed the highest results against *A. arvensis*, *P. rhoeas* and *S. arvensis* - 96.6, 91.6 and 100%, respectively.

Against *S. arvensis* 100% efficacy after the spraying with Abak - 250 g ha^{-1} + Mero - 1000 ml ha^{-1} followed by treatments 5, 6 and 9 where the efficacy reached 98.3% (Table 3). Excellent efficacy against *L. purpureum* and *A. fatua* of Abak - 250 g ha^{-1} + Mero - 1000 ml ha^{-1} was observed - 100% and 98.3%, respectively.

The highest efficacy against *L. rigidum* and *G. aparine* on the 56th day after application for the treatment with Osprey Extra - 333 g ha^{-1} + Biopower - 1000 ml ha^{-1}, 93.3% and 86.6% respectively was recorded.

During both experimental years the lowest and unsatisfactory efficacy was observed for the volunteer *B. napus*. Among all treatments with the exception of Atlantis Flex - 330 g ha^{-1} + Biopower - 1000 ml ha^{-1} the control was 0% (Table 3).

Table 3. Efficacy of the studied herbicide products on the 56th day after application average for 2017 and 2018, %

Treatments	*A. arvensis*	*P. rhoeas*	*G. aparine*	*S. arvensis*	*V. hederifolia*	*L. purpureum*	*L. rigidum*	*A. fatua*	*B. napus CL*
1. Untreated contol	-	–	–	–	–	–	–	–	–
2. Osprey Extra - 166 g ha^{-1} + Biopower - 1000 ml ha^{-1}	50.0	60.0	45.0	85.0	24.0	80.0	78.3	90.0	0.0
3. Osprey Extra - 200 g ha^{-1} + Biopower - 1000 ml ha^{-1}	63.3	70.0	61.6	95.0	38.3	95.0	90.0	95.0	0.0
4. Osprey Extra - 255 g ha^{-1} + Biopower - 1000 ml ha^{-1}	68.3	76.6	68.3	96.6	45.0	96.6	88.3	95.0	0.0
5. Osprey Extra - 333 g ha^{-1} + Biopower - 1000 ml ha^{-1}	83.3	91.6	86.6	98.3	55.0	98.3	93.3	91.6	0.0
6. Osprey Extra - 330 g ha^{-1}	83.3	81.6	73.3	98.3	55.0	98.3	91.6	93.3	0.0
7. Atlantis WG - 500 g ha^{-1} + Biopower - 1000 ml ha^{-1};	96.6	91.6	83.3	100	46.6	98.3	90.0	96.6	0.0
8. Abak - 250 g ha^{-1} + Mero - 1000 ml ha^{-1}	95.0	0.0	78.3	100	45.0	100	90.0	98.3	0.0
9. Atlantis Flex - 330 g ha^{-1} + Biopower - 1000 ml ha^{-1}	85.0	75.0	70.0	98.3	63.3	96.6	81.6	96.6	50.0

The boxplot of the biometrical data is presented on Figure 1. Regarding the indicator central stem height we found that the plants from treatment 7 (Atlantis Flex + Biopower - 500 g + 1000 ml ha^{-1}) were the highest. From the figure is seen that the stem height vary in the narrow extend, so we concluded that the plans of the concrete treatment were the most uniformed. According to the next parameter - the central ear length, with the highest and uniformed values were the plants from treatment 7 also.

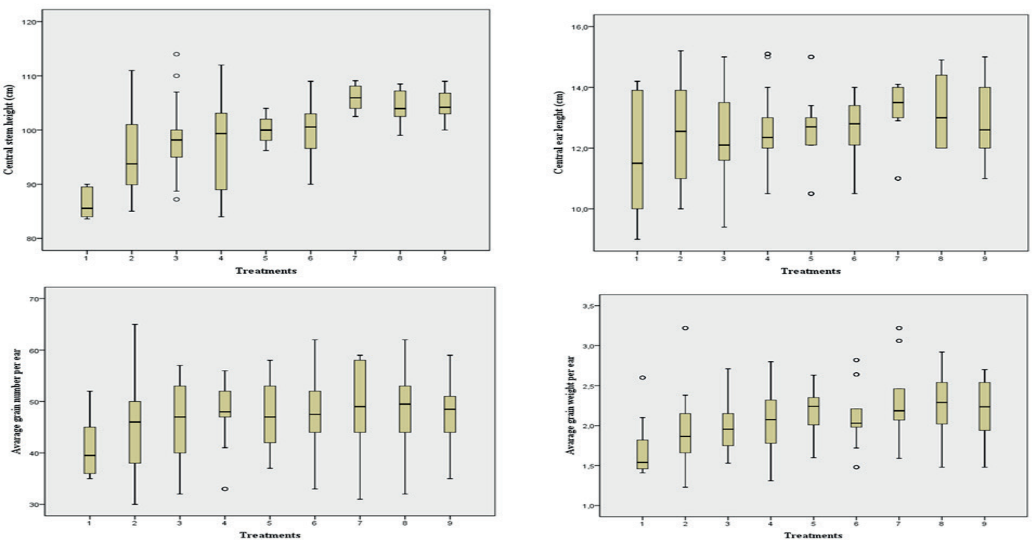

Figure 1. Boxplot of the biometrical data

The highest grain number per ear was found for treatment 7, and the lowest for the untreated control was recorded. The average grain weight per ear was for the treatments 5, 8, 9 and 7.

The results regarding the biometrical parameters and yields are presented on Table 4. For the indicator central ear length, statistical difference in the results between the untreated control and the treated variants were found. The lowest values for the untreated control - 11.86 cm were found, and the highest - 13.28 cm for the treatment Atlantis WG + Biopower. For the parameter average grain number per ear, statistically proved differences for the treatments with herbicide application were found. The average grain number per ear varied between 46.43 to 48.90. Lower average grain number per ear was recorded for treatment 2 (Osprey Extra + Biopower)– 45.00.

The untreated control had the lowest average grain weight per ear - 1.70 g. This result is statistically proven at a level of significance of 5%. The highest average grain weight per ear for treatment 7 was found.

The results for the 1000 grain weight showed that there is statistically proved difference between the treated variants and the untreated control. The untreated control had the lowest results - 38.23 g, and the highest for treatment 7 was recorded - 46.20 g.

Data on wheat yield confirms that there is a positive correlation between the effect of herbicides on weeds and the yield obtained from the crop. As a result from the high weed infestation very low average yield for the untreated control was achieved - 2.54 t ha^{-1}. At treatments 7 and 8 the highest yield was obtained - 5.15 t ha^{-1} and 5.05 t ha^{-1} respectively. The variants 2, 3 and 4 treated with Osprey Extra in rates of 166, 200 250 g ha^{-1} Biopower - 1000 ml ha^{-1} also deserve attention. In these tretments, the increase in yield compared to the untreated control is also statistically proved. The lower results regarding the yields of these treatments could be explained with the lowest efficacy of the herbicide product applied in the concrete rates.

Table 4. Parameters and yields of the winter wheat, average for 2017 and 2018

Treatmens	Central stem height, cm	Central ear length, cm	Average grain number per ear	Average grain weight per ear, g	1000 grain weight, g	Yield, t ha^{-1}
1.	86.43 a	11.86 a	41.23 a	1.70 a	38.23 a	2.54 a
2.	96.10 b	12.53 b	45.00 b	1.94 b	40.12 b	3.31 b
3.	97.89 bcd	12.54 b	46.43 bc	2.00 bc	41.72 c	3.54 bc
4.	97.43 bc	12.57 b	47.50 bc	2.08 bcd	42.18 cd	3.80 c
5.	100.01 d	12.67 bc	47.10 bc	2.17 cde	42.96 ef	4.57 d
6.	99.72 cd	12.65 bc	47.10 bc	2.10 bcd	42.62 de	4.48 d
7.	105.91 e	13.28 c	48.70 bc	2.32 e	46.20 h	5.15 e
8.	104.48 e	13.18 bc	48.90 c	2.27 de	44.14 g	5.05 e
9.	104.36 e	12.97 bc	47.50 bc	2.19 cde	43.66 fg	4.60 d
	$gD_{5\%} = 2.5512$	$gD_{5\%} = 0.6675$	$gD_{5\%} = 3.7087$	$gD_{5\%} = 0.2010$	$gD_{5\%} = 0.7436$	$gD_{5\%} = 44.6512$

CONCLUSIONS

Atlantis WG + Biopower in rates of 500 g ha^{-1} + 1000 ml ha^{-1} showed the highest efficacy against the weeds *Anthemis arvensis*, *Papaver rhoeas* and *Sinapis arvensis*.

The highest herbicide control of *Lamium purpireum* and *Avena fatua* was achieved after the application of Abak + Mero in rates of 250 g ha^{-1} + 1000 ml ha^{-1}.

Osprey Extra + Biopower applied in rates of 333 g ha^{-1} + 1000 ml ha^{-1} showed good efficacy against *Lolium rigidum* and *Galium aparine*.

The most difficult-to-control-weeds were the volunteer Clearfield *Brassica napus* and *Veronica hederifolia*. The highest efficacy against these weeds on the 56th day after application of Atlantis Flex + Biopower in rates of 330 g ha^{-1} + 1000 ml ha^{-1} - 50 and 63.3% respectively was reported.

There were no visible signs of phytotoxicity to the crop caused by any of the examined herbicide products.

The lowest results regarding the central stem height, central ear length, Average grain number per ear, average grain weight per ear, 1000 grain weight as well as the yield for the untreated control was found. Statistical differences have been identified in favour of herbicide-treated variants.

The highest results for all evaluated biometrical parameters as well as yield after the application of Atlantis WG + Biopower in rates of 500 g ha^{-1} + 1000 ml ha^{-1} and Abak + Mero in rates of 250 g ha^{-1} + 1000 ml ha^{-1} were obtained

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