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OPPORTUNITIES FOR CHEMICAL CONTROL OF SOME WEEDS IN WHEAT

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Abstract

In 2021 and 2022, a field experiment with the winter wheat variety 'Enola' was conducted. The trial was performed on the experimental field of the Agricultural University of Plovdiv, Bulgaria. The efficacy and selectivity of the following five herbicides was under evaluation - Pontos (240 g/l flufenacet + 100 g/l picolinafen) – applied in three rates, Pallas 75 WG (75 g/l piroxulam), Axial One (45 g/l pinoxaden + 5 g/l florasulam), Atlantis Flexx 20,25 WG (45 g/kg mesosulfuron + 67.5 g/kg propoxicarbazon-potassium + 90 g/kg mefenpir-dietil), and a tank mixture of Biathlon 4 D (714 g/kg tritosulfuron + 54 g/kg florasulam) and Axial 050 (50 g/l pinoxaden). The herbicidal treatments were compared with untreated control. The natural weed infestation was presented by the weeds corn chamomile, common poppy, wild mustard, wild radish, ivy-leaved speedwell, annual raygrass, and wild oat. Biological yield was reported for both years of the experiment. The highest average yield of the two experimental years was found for the variant treated with the tank mixture of Biathlon 4 D + Axial 050- 6.31 t/da.

Key words*: wheat, weeds, herbicides, efficacy, selectivity.*

INTRODUCTION

Ensuring a sufficient amount of food to feed the population is a fundamental concern of mankind. A large part of the food products is procured through the cultivation of agricultural crops (Georgiev et al., 2019; Dimtrova et al., 2019; Nenova, 2019; Nenova et al., 2019; Marinov-Serafimov et al., 2017; Shopova & Cholakov, 2015; Shopova & Cholakov, 2014).
Winter wheat (*Triticum aestivum* L.) is main grain crop in Bulgaria. One of the factors limiting the development of cultivated plants is the annual ubiquitous appearance and development of weed vegetation (Yanev et al., 2014a; Yanev, 2015). The weeds are great competitors of wheat for nutrients, water, space, and light. The weeds can also cause indirect damages because many of them are hosts of harmful insects and diseases (Kalinova et al., 2012). Weeds have become an increasing problem in wheat and some weed species such as *Cirsium arvense*, *Consolida regalis*, *Polygonum aviculare*, *Consolida orientalis*, *Convolvulus arvensis*, *Centaurea cyanus*, *Erodium cicutarium*, and *Bifora radians* (Susuri et al., 2001; Mehmeti et al., 2009; Mehmeti and Demaj, 2010). The high weed infestation can decrease the yields by more than 70% (Atanasova and Zarkov, 2005). Weeds compete for wheat plants with high efficiency for the most critical growth requirements. As a result of this competition, the growth of the crop is weak, which is negatively reflected in the grain yield, as the competition of the weed with the wheat crop has a clear reflection in reducing the yield (Hammood and Safi, 2018; Hamad Al-Mafrajy, 2018; Garakishi, 2020). Yield losses due to weeds have been reported (Oerke and Dehne, 2004; Oerke, 2006; Dangwal et al., 2010).
One of the most frequently applied methods of weed control in cultivated plants is the chemical one. The choice of herbicide is one of the most important and responsible moments in the agrotechnics of the crops. The appropriate herbicide must meet a number of requirements – to be selective for the crop, highly effective against available weeds, its use not lead to the accumulation of residual amounts in the plant production and the soil, not to impair the quality of the production, to be harmless for soil microorganisms and the environment (Goranovska et al., 2022; Yanev, 2021; Yanev, 2020; Yanev & Kalinova, 2020; Mitkov et al., 2020; Neshev et al., 2020; Mitkov et al. 2018; Goranovska & Yanev, 2016; Kostadinova et al., 2016; Hristeva et al., 2015; Kalinova &

Yanev, 2015; Semerdjieva et al., 2015; Hristeva et al., 2014; Yanev et al., 2014b). Successful weed management in wheat depends not only on the proper herbicide choice, but also on the timing and dosage of its application (Abbas et al., 2009; Titiyanov et al., 2015; Petrova, 2017; Titiyanov et al., 2020; Yankova et al., 2020; Shaban et al., 2021; Yanev et al., 2021, Yanev, 2022).

The selection of herbicides suitable for wheat is determined by species diversity and weed density. Most herbicides control only a specific group of weeds, and to provide more broad-spectrum weed control, the use of herbicide combinations is recommended (Bostrom and Fogelfors, 2002; Walia et al., 2000). According to Chaudhry et al. (2008) when mixing anti-grain and anti-broadleaf herbicides, the density of wheat and broadleaf weeds decreased significantly (by 96.3% and 97.6%, respectively), and grain yield compared to their application alone increased by 15%. Several researchers have shown that tribenuron-methil and bifenox herbicides can control weeds in wheat (Brzozowska et al., 2008). Some investigators found positive effect for the interaction between cultivars and weed control treatments on weeds and yield of wheat crop (Abusteit et al., 1991; Singh and Singh, 1996). In some earlier studies of herbicide efficacy in wheat, Sinapis arvensis and Chenopodium album had also been found highly susceptible to fluroxypyr, 2.4-D, tribenuron-methyl and amidosulfuron (Elezović et al., 1994; Stanković-Kalezić et al., 1998; Radivojević et al., 2001). Galium aparine was the species that proved resistant to tested herbicides: Secator OD, Lintur 70 WG, Granstar 75WG, Mustang, Kambio, Starane-250, Arat and Kerto (Radivojević et al., 2006). The best weed control was accomplished by Safener 15 WP 2 (247 g/ha) as significantly lower weed counts per m (11.0) and higher percent weed control (73.4%). Based on better weed control and wheat yield, Safener 15WP (395.2 ml/ha) and Puma super 69EW (1250 ml/ha) were proved to be better in areas where wheat fields are predominantly infested by monocot weeds. Safener 15 WP and Puma super 69 EW were found effective against Avena fatua, less effective against Phalaris minor and ineffective against Poa annua (Mehmood et al., 2014). Therefore, the chemical method is one of the easiest and cheapest ways to control the weed, due to the tremendous economic returns resulting from the use of herbicides for their high effectiveness and speed of impact. These herbicides have been used to control wheat weeds in large areas of the world despite the emergence of environmental and health problems resulting from their use, which led to increased productivity, sometimes reaches more than 50% (Montazeri et al., 2005; Al-Aqidi, 2010; Gopal et al., 2017; Kaur et al., 2020).

The purpose of the study is to establish some possibilities for chemical control of individual weeds in common wheat variety "Enola".

MATERIALS AND METHODS

In 2021 and 2022, a field experiment with winter wheat variety “Enola” was carried out in the Educational and Experimental Field of the Department of Agriculture and Herbology at the Agricultural University - Plovdiv, Bulgaria. The experiment was carried out according to the block design in 4 replications with a size of the working plot of 20 m².

A preliminary inspection of the experimental field was performed. In the reporting field nine types of weeds, typical for the crop were identified. The average weed density in the two experimental years, per 1 m² was as follows: *Anthemis arvensis* L. - 5.5 specimens; *Papaver rhoeas* L. - 10 specimens; *Sinapis arvensis* L. - 7 specimens, *Raphanus raphanistrum* L. - 5 specimens, *Veronica hederifolia* L. - 9 specimens; *Lolium rigidum* L. - 34.5 specimens; *Avena fatua* L. - 36.5 specimens.

The study included the following treatments: 1. Untrated control; 2. Pontos (240 g/l flufenacet + 100 g/l picolinafen) - 0.5 l ha^{-1}; 3. Pontos - 0.75 l ha^{-1}; 4. Pontos - 1.00 l ha^{-1}; 5. Palas 75 WG (75 g/l pyroxulam) - 0.20 kg ha^{-1}; 6. Palas 75 WG - 0.25 kg ha^{-1}; 7. Axial One (45 g/l pinoxaden + 5 g/l florasulam) - 1.00 l ha^{-1}; 8. Atlantis Flex (45 g/kg mesosulfuron + 67.5 g/kg propoxicarbazon-natrii + 90 g/kg mefenpir-dietil) - 0.25 kg ha^{-1}; 9. Axial 050 (50 g/l pinoxaden) + Biathlon 4D (54 g/kg florasulam + 714 g/kg tritosulfuron) - 0.90 l ha^{-1} + 0.05 kg ha^{-1}. The herbicidal products were applied in the spring, in the tillering stage of the crop (BBCH 21-25).

The herbicide spraying was accomplished via electrical backpack sprayer SOLO model 417 (Solo, Germany) with a volume of the working solution 200 l ha^{-1}.

The predecessor of wheat was oilseed rape. The preparation of the area was carried out by plowing to a depth of 20 cm, as well as by two cultivations. Pre-sowing fertilization with NPK 15:15:15 at the rate of 300 kg ha^{-1} was accomplished. Sowing was done at the optimal time for wheat with a seed drill for crops with a fused surface at a row spacing of 12 cm, with a density of 450 pcs. germinating seeds per m^2. Spring dressing was carried out in March with ammonium nitrate 300 kg ha^{-1}). The herbicide efficacy evaluations were performed 14, 28, and 56 days after the herbicidal application. The 10-score scale of EWRS (European Weed Research Society) for visual rating was used. For herbicidal selectivity, the 9-score scale of EWRS was used.

The results of the conducted research with the software package of SPSS 17 program of one- and two-factorial analysis of variance were processed.

RESULTS AND DISCUSSIONS

Against *Anthemis arvensis* L., the results of the herbicide products used are presentend in Table 1. When counting the 14th day after the treatment with the herbicides, the efficacy varies widely, from the 10 to 75%. On the 28th day after the treatment, the efficacy increases progressively in all tested variants and reaches 30 - 90%.

Table 1. Efficasy of the studied herbicides against *A. arvensis* avarage fort the period (%)

Treatments	Days after treatments		
	14	28	56
1. Untreated control	-	-	-
2. Pontos - 0.5 l ha^{-1}	10	30	50
3. Pontos - 0.75 l ha^{-1}	25	45	65
4. Pontos - 1.00 l ha^{-1}	40	60	75
5. Palas 75 WG - 0.20 kg ha^{-1}	40	60	75
6. Palas 75 WG - 0.25 kg ha^{-1}	60	80	90
7. Axial Edno - 1.00 l ha^{-1}	70	85	95
8. Atlantis Flex - 0.25 kg ha^{-1}	60	80	90
9. Axial 050 + Biathlon 4 D – 0.90 l ha^{-1} + 0.05 kg ha^{-1}	75	90	100

Aproximately complete weed cotrol was reported on the 56th day after treatment (90 - 100%) only in the variants treated with the products Pallas 75 WG in rate of 25 kg ha^{-1}, Axial One, Atlantis Flex and from the combined application of Axial 050 + Biathlon 4 D. For the other treatments, the efficacy was unsatisfactory and varied from 50 to 75%.

Table 2 shows the dynamics of the herbicidal efficacy against *P. rhoeas* L. reported on the 14th, 28th and 56th days after treatment with the different products. It is noteworthy that no herbicidal effect (0%) was reported for Pallas 75 VG on all three reporting dates. In the remaining treatments of the experiment, a relatively low herbicidal efficiency of 20 to 70%, at the first reporting date was found. However, the efficacy reaches the maximum 100% at the last reporting date only for variant 9 (Axial 050 + Biathlon 4 D - 0.90 l ha^{-1} + 0.05 kg ha^{-1}). This proves that, regardless of the slower mechanism of action, the tank mixture of Axial 050 + Biathlon 4 D has excellent efficacy against weeds. The variant treated with the herbicide Axial One also had an approximately excellent effect on the 56th day after treatment (95%). Except for the highest tested rate of the herbicide Pontos, its variants with lower applied doses as well as Atlantis Flex had unsatisfactory efficacy at the last reporting date.

Table 2. Efficasy of the studied herbicides against *P. rhoeas* avarage fort the period (%)

Treatments	Days after treatments		
	14	28	56
1. Untreated control	-	-	-
2. Pontos - 0.5 l ha^{-1}	20	40	60
3. Pontos - 0.75 l ha^{-1}	35	55	75
4. Pontos - 1.00 l ha^{-1}	50	70	85
5. Palas 75 WG - 0.20 kg ha^{-1}	0	0	0
6. Palas 75 WG - 0.25 kg ha^{-1}	0	0	0
7. Axial Edno - 1.00 l ha^{-1}	55	75	95
8. Atlantis Flex - 0.25 kg ha^{-1}	35	55	75
9. Axial 050 + Biathlon 4 D – 0.90 l ha^{-1} + 0.05 kg ha^{-1}	70	85	100

From Table 3, it is clear that all applied herbicides in the experiment had excellent herbicidal efficacy against *S. arvensis* L. reported on the 56th after application of the products. Despite the lower efficacy rates at day 14 after treatment, the weed was relatively easy-to-contol by the different evaluated herbicides in the trial.

Table 3. Efficasy of the studied herbicides against *S. arvensis* L. avarage fort the period (%)

Treatments	Days after treatments		
	14	28	56
1. Untreated control	-	-	-
2. Pontos - 0.5 l ha^{-1}	75	85	95
3. Pontos - 0.75 l ha^{-1}	80	90	100
4. Pontos - 1.00 l ha^{-1}	85	95	100
5. Palas 75 WG - 0.20 kg ha^{-1}	80	90	95
6. Palas 75 WG - 0.25 kg ha^{-1}	85	95	100
7. Axial Edno - 1.00 l ha^{-1}	80	90	100
8. Atlantis Flex - 0.25 kg ha^{-1}	75	90	100
9. Axial 050 + Biathlon 4 D – 0.90 l ha^{-1} + 0.05 kg ha^{-1}	85	95	100

With the exception of the products Pontos applied in its lowest tested rate and Pallas 75 BG tested at the rate of 0.20 kg ha^{-1} against *R. raphanistrum* L. the efficacy of the other variants was 95 - 100%, reported on the 56th day after treatment (Table 4).

Table 4. Efficasy of the studied herbicides against *R. raphanistrum* L. avarage fort the period (%)

Treatments	Days after treatments		
	14	28	56
1. Untreated control	-	-	-
2. Pontos - 0.5 l ha^{-1}	70	80	90
3. Pontos - 0.75 l ha^{-1}	75	85	95
4. Pontos - 1.00 l ha^{-1}	80	90	100
5. Palas 75 WG - 0.20 kg ha^{-1}	70	80	90
6. Palas 75 WG - 0.25 kg ha^{-1}	80	90	100
7. Axial Edno - 1.00 l ha^{-1}	75	90	100
8. Atlantis Flex - 0.25 kg ha^{-1}	70	85	100
9. Axial 050 + Biathlon 4 D – 0.90 l ha^{-1} + 0.05 kg ha^{-1}	80	90	100

Already on the first date, the percentages ranged from 70 to 80% after the application of the differnt herbicides in the experiment. At the last reporting dtae for treatments 4, 6, 7, 8 and 9 an efficacy of 100 percent was recorded. The efficacuy for treatment 2 and 5 an efficacy of 90% was found. For treatment 3 the efficacy was 95%.

Table 5 shows the effect of the applied herbicides on *Veronica hederifolia* L. Except for the highest tested rate of Pontos and the tank mixture of the herbicides Axial 050 and Biathlon 4D, the weed was very poorly controlled by all other variants in the experiment. On the 56th day after the treatment, the recorded efficacy of Pontos was 80%, and 85% from the combined treatment with Axial 050 + Biathlon 4 D. In all other variants of the trial, herbicide control varied from 40 to 65% on the last reporting date.

Table 5. Efficasy of the studied herbicides against *V. hederifolia* L. avarage fort the period (%)

Treatments	Days after treatments		
	14	28	56
1. Untreated control	-	-	-
2. Pontos - 0.5 l ha^{-1}	10	30	45
3. Pontos - 0.75 l ha^{-1}	20	45	65
4. Pontos - 1.00 l ha^{-1}	40	60	80
5. Palas 75 WG - 0.20 kg ha^{-1}	5	25	40
6. Palas 75 WG - 0.25 kg ha^{-1}	10	30	50
7. Axial Edno - 1.00 l ha^{-1}	15	35	55
8. Atlantis Flex - 0.25 kg ha^{-1}	10	35	55
9. Axial 050 + Biathlon 4 D – 0.90 l ha^{-1} + 0.05 kg ha^{-1}	40	65	85

Against the annual, monocotyledonous weed *Lolium rigidum* L., an increase in the herbicidal effect with an increase in the rates of the herbicidal product Pontos (Table 6) was observed.

Table 6. Efficasy of the studied herbicides against *L. rigidum* L. avarage fort the period (%)

Treatments	Days after treatments		
	14	28	56
1. Untreated control	-	-	-
2. Pontos - 0.5 l ha^{-1}	10	35	55
3. Pontos - 0.75 l ha^{-1}	25	50	70
4. Pontos - 1.00 l ha^{-1}	40	60	80
5. Palas 75 WG - 0.20 kg ha^{-1}	30	50	70
6. Palas 75 WG - 0.25 kg ha^{-1}	40	65	85
7. Axial Edno - 1.00 l ha^{-1}	65	85	95
8. Atlantis Flex - 0.25 kg ha^{-1}	30	50	70
9. Axial 050 + Biathlon 4 D – 0.90 l ha^{-1} + 0.05 kg ha^{-1}	70	90	100

On the 14th day after treatment, the efficacy varied only from 10 to 40% for the individual herbicide rates. On the 56th day, the herbicide control was increased and reached from 55 (0.50 l ha^{-1}) to 80% (1.00 l ha^{-1}). A satisfactory herbicidal effect from the herbicide Pallas 75 VG and Atlantis Flex at the last reporting date was reported. The highest efficacy in the variants treated with Axial One (95%) and from the combined usage of Axial 050 + Biathlon 4 D (100%) on the same reporting date was found. In these two variants, the effect is entirely due to the active substance pinoxaden contained in the products Axial One and Axial 050, which have a higher herbicidal efficacy against weeds compared to other grass weed contoling herbicides.

From Table 7, can be conclude that the tested herbicide Pontos has a very low efficacy against *Avena fatua* L., recorded on the 14th day after its application, ranging from 5 to 20%. Gradually, at the following reporting dates, the effect increases, and on the 56th day after treatment, it reaches 35-60%, which is unsatisfactory. From Atlantis Flex a satisfactory efficacy of 85% at the same reporting date was recorded. At the two tested rates of Pallas 75 WG, the herbicidal efficay reached 90-95%. Excellent control was reported for the seventh and ninth variants, at the last reporting date, which is due to the Axial One and Axial 050 products.

Visible signs of phytotoxicity were not observed in any of the variants.

Table 7. Efficasy of the studied herbicides against *A. fatua* L. avarage fort the period (%)

Treatments	Days after treatments		
	14	28	56
1. Untreated control	-	-	-
2. Pontos - 0.5 l ha^{-1}	5	20	35
3. Pontos - 0.75 l ha^{-1}	10	30	50
4. Pontos - 1.00 l ha^{-1}	20	40	60
5. Palas 75 WG - 0.20 kg ha^{-1}	60	80	90
6. Palas 75 WG - 0.25 kg ha^{-1}	65	85	95
7. Axial Edno - 1.00 l ha^{-1}	70	90	100
8. Atlantis Flex - 0.25 kg ha^{-1}	45	65	85
9. Axial 050 + Biathlon 4 D – 0.90 l ha^{-1} + 0.05 kg ha^{-1}	80	90	100

Table 8 presents the results of yields obtained on average for the two years of the experiment. The differences in yields are determined by the herbicidal efficacy of the products and by their ability to control the weeds present in the experiment. The natural background of weeding with highly competitive weed species resulted in a lower mean yield than the untreated control (3.28 t ha^{-1}).

According to the degree of mathematical proof, six separate groups of herbicides are distinguished here (a, b, c, d, e, f,). It is also observed here that variant 9 (Axial One + Biathlon 4 E) is from group (f), the most distant from the group of the untreated control (a), that is, with the highest yield followed by variant 7 (Axial One). Due to the fact that the herbicides Pallas 75 BГ (0.25 kg ha^{-1}), Pontos (1.00 l ha^{-1}) and Atlantis Flex control less available weeds in the experiment, their yield decreases compared to that of the above-mentioned product. At the lower tested rate of Pallas (0.20 kg ha^{-1}), the biological yield decreased more severely. Compared to all other treated variants, the lowest reported yields were from the herbicide Pontos applied in rates of 0.75 and 0.50 l ha^{-1}.

Table 8. Avearge wheat grain seed yield, t ha^{-1}

Treatments	Yelds
1. Untreated control	3.28 a
2. Pontos - 0.5 l ha^{-1}	3.87 *b
3. Pontos - 0.75 l ha^{-1}	4.00 *b
4. Pontos - 1.00 l ha^{-1}	5.20 *d
5. Palas 75 WG - 0.20 kg ha^{-1}	4.58 *c
6. Palas 75 WG - 0.25 kg ha^{-1}	5.19 *d
7. Axial Edno - 1.00 l ha^{-1}	5.76 *e
8. Atlantis Flex - 0.25 kg ha^{-1}	5.24 *d
9. Axial 050 + Biathlon 4 D – 0.90 l ha^{-1} + 0.05 kg ha^{-1}	6.31 *f

CONCLUSIONS

The number of dairy cows has continuously Herbicidal products Axial 050 and Biathlon 4 D applied in a tank mixture showed excellent efficacy against *Anthemis arvensis* L., *Papaver rhoeas* L., *Sinapis arvensis* L, *Raphanus raphanistrum* L., *Lolium rigidum* L. and *Avena fatua* L.

The product Axial One is superior in efficiency to the herbicides Pallas 75 VG and Atlantis Flex compared to *Papaver rhoeas* L. and *Lolium rigidum* L..

The herbicides Pallas 75 WG, Atlantis Flex, Axial One and Pontos applied in doses of 0.50 and 0.75 l ha^{-1} had a low herbicidal efficay against *Veronica hederifolia* L. (from 45 to 65%).

Against *Lolium rigidum* L., the efficacy of the herbicides Pontos applied in doses .50 and 0.75 l ha^{-1}, Pallas 75 WG (0.20 kg ha^{-1}) and Atlantis Flex was unsatisfactory (from 55 to 70%).

During the entire vegetation period of wheat, variety "Enola", no visible signs of phytotoxicity were recorded in any of the variants, which indicates the high selectivity of the tested products.

The highest average yield was obtained from the variant with the combined use of Axial 050 + Biathlon 4 D (6.31 t ha^{-1}).

Of all variants treated with herbicides, the yield of Pontos tested at a dose of 0.50 l ha^{-1} was the lowest - 3.87 t ha^{-1}.

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