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Influence of herbicides and application timing on broadleaf weeds control in maize (*Zea mays* L.)

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Abstract

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During 2018 and 2019 a field plot trial with maize (hybrid Blason Duo) was conducted. The study was situated on the experimental field of the Agricultural University of Plovdiv, Bulgaria. The trial was performed by the randomized block design in 4 replications. The florasulam-containing herbicide products Derby Super, Starane Gold and Kabadex Extra were under evaluation. The studied herbicide products were applied in two phenological stages of maize – BBCH 15 (3rd – 5th true leaf) and BBCH 18 (8th – 9th true leaf). The efficacy of the studied products by the 10-score visual scale of EWRS was reported. The selectivity by the 9-score scale of EWRS was also evaluated. The efficacy of the herbicide was higher after the application in BBCH 15 in comparison to that in BBCH 18. The highest herbicide efficacy against the weeds *Chenopodium album* L., *Amaranthus retroflexus* L., *Xanthium strumarium* L., *Abutilon theophrasti* Medik. and *Solanum nigrum* L. after the application of Kabadex Extra – 0.45 l ha^{-1} in BBCH 15, followed by Derby Super – 33 g ha^{-1} treated in the same stage was recorded. For the treatment with Kabadex Extra – 0.45 l ha^{-1} in BBCH 15 the studied parameters ear length, ear diameter, number of seeds per ear, absolute seed mass and grain yield were the highest. For all treatments accept for Starane Gold in BBCH 15, visual symptoms of phytotoxicity on the 7th day after application were recorded. The symptoms completely disappear on the 28th day after application.

Keywords: weeds, herbicides, efficacy, selectivity, yield

Introduction

The growing population on Earth requires its provision with food and fodder for farm animals (Shopova & Cholakov ,2014; Shopova & Cholakov, 2015; Georgiev et al., 2019; Nenova, 2019; Petrova et al., 2019; Tonev et al., 2019).

Maize (*Zea mays* L.) is the third most important crop on the world after rice and wheat. In 2019 in Bulgaria maize for grain has an area of 560 911 ha and production of 3 990 190 t, and maize for silage and green fodder has an area of 27 500 ha and total production of 588 034 t (MZH, 2020).

Weeds are main limiting factor leading to yield decrease in maize (Tonev, 2000; Tonev et al., 2019). The research findings of a number of authors shows that in dependence of the weed infestation the maize grain yield could be decreased from 24 to 96.7% (Zhalnov & Raykov, 1996; Khan et al., 2003; Oerke & Dehne, 2004; Jat et al., 2012; Mukherjee & Puspajit, 2013; Yakadri et al., 2015; Ehsas et al., 2016; Jagadish et al., 2016; Kakade et al., 2016; Dimitrova et al., 2018).

Depending on the latitudes and the presence of weed seeds in the soil, different weed associations develop in maize fields. Along with the grass weeds, serious problem are the broadleaf weed species. In some fields these weeds dominate over the grass species. In Bulgaria economically important weeds in maize *Amaranthus retroflexus* L., *Datura stramonium* L., *Xanthium strumarium* L., *Solanum nigrum* L., *Chenopodium album*, *Abutilon theophrasti*

L., *Sinapis arvensis* L., *Echinochloa crus gali* L., *Setaria glauca* L., *Sorghum halepense* L., *Convolvulus arvensis* L, *Cinodon dactilon* L. and *Cirsium arvense* L. (Tonev et al., 2010; Hristova et al., 2012; Kalinova et al., 2012; Mitkov et al., 2019).

In studies conducted in Slovakia present that the most widely distributed weeds in maize are *Chenopodium album* L., *Amaranthus spp*., *Echinichloa crus galli* (L.) P. Beauv, *Datura stramonium* (L.), *Fallopia convolvulus* (L.) A. Lôve, *Persicaria spp*., *Cirsium arvense* (L.) Scop, *Elytrigia repens* (L.) P. Beauv, *Avena fatua* (L.), *Abutilon theophrasti* Medik, *Atriplex spp*. and *Setaria viridis* (L.) P. Beauv (Týr & Vereš, 2012; Smatana et al., 2015).

From data published by scientists from India, the most aggressive weeds in maize are *Polygonum* (*P. pensylvanicum, P. persicaria, P. orientale*), *Stellaria media, Stellaria aquatica, Oldelandia diffusa, Oldenlandia umbellate, Physalis minima, Solanum nigrum*. In Belgaum district of Karnataka, India, the most distributed weeds are *Cynodon dactylon, Dinebra retroflexa, Echinochloa colonum, Eleusine indica, Cyperus rotundus, Parthenium hysterophorus, Commelina benghalensis, Portulaca oleracea, Cynotis cuculata, Phyllanthus niruri* and *Amaranthus viridis* (Haji et al., 2012; Mukherjee & Puspajit, 2013).

In maize fields in Mashhad, Iran the most common weeds are *Amaranthus retroflexus* L., *Chenopodium album* L., *Portulaca oleracea* L. and *Solanum nigrum* L. (Baghestani et al., 2007).

One of the main methods for weed control is conducted by herbicide application (Tonev, 1986; Pannacci & Covarelli, 2009; Skrzypczak et al., 2011; Muhammd et al., 2012; Dimitrova et al., 2013b; Goranovska & Kalinova, 2014; Koprivlenski et al., 2015; Sevov et al., 2015; Umesha et al., 2015; Janak et al., 2016; Goranovska et al., 2017; Goranovska & Kalinova, 2018).

Against the annual grass and broadleaf weeds very high efficacy after the application of Gardoprim plus gold 500 SK – 4.00 l ha^{-1} (99%), Lumax 538 SK – 4.00 l ha^{-1} (97%), Wing – 4.00 l ha^{-1} (97%) and Merlin flex – 0.42 l ha^{-1} (94.6%) was recorded (Dimitrova et al., 2013a).

The application of Merlin Duo in rates of 1.00 l ha^{-1} to 2.00 l ha^{-1} after sowing before germination of maize controls *Abuthilon theophrasti* L. and *Solanum nigrum* L. The highest efficacy against *Chenopodium album* L. after the application of Merlin Duo in the rates of 1.25, 1.5 and 2.00 l ha^{-1} was reported (Mitkov et al., 2018).

Pannacci (2016) found that the application of *foramsulfuron* in dose of 20,3 g ai/ha showed 95% efficacy against *Amaranthus retroflexus* L., *Setaria viridis* (L.) Beauv., *Sinapis arvensis* L. and *Solanum nigrum* L.

For control of *Sorghum halepense* L., *Convolvulus arvensis* L., *Echinochloa crus gali* L., *Chenopodium album* L., *Amaranthus retroflexus* L. and *Abutilon theophrasti* L. in maize it is recommended to apply Stomp 33 EK + Mistral 4 SK in rates of 3.00 l ha^{-1} + 1.30 l ha^{-1} (Kalinova et al., 2000).

Acording to Kierzek et al. (2012) the best control of mixed weed infestation in maize after the application of the mixture *s-metolachlor* + *terbuthylazine* + *mesotrione*, followed by foliar application of *nicosulfuron* with adjuvant Atpolan Bio 80 SL.

In the maize fields, Tonev et al. (2016) recorded high efficacy against broadleaf and grass weed species as *Sorghum halepense* L. *Convolvulus arvensis* L. and *Cirsium arvense* L. after application of the herbicide combination Flurostar 200 EK + Nishin 4 OD in rates of 0.70 l ha^{-1} + 1.30 l ha^{-1}. If there is high infestation with *Chenopodium album* L. the combination of Mustang 306.25 SK and Nishin 4 OD in doses of 0.60 l ha^{-1} + 1.30 l ha^{-1} in tank mixture is recommendable**.**

For control of *Xanthium strumarium, Amaranthus retroflexus, Datura stramonium* and *Chenopodium album* in maize Damalas et al. (2018) established efficacy from 92 to 100% after the alone treatment of *tembotrione* at 100 g ai/ha and three mixtures of *tembotrione* with: *rimsulfuron* at 10 g ai/ha, *nicosulfuron* at 40 g ai/ha and *foramsulfuron* at 60 g ai/ha.

After the usage of *foramsulfuron* and *nicosulfuron* applied in tank-mixture with *2,4-D* + *MCPA* the weeds *Amaranthus retroflexus* L. and *Chenopodium album* L. can be controlled from 78 to 100% in dependence of the herbicide dose (Sarabi et al., 2018).

The aim of the study is to determine the influence of some herbicides and their application timing for control of broadleaf weeds in maize.

Materials and Methods

In 2018 and 2019 a field plot trial with the maize hybrid "Blason Duo" was conducted. The experiment was situated on the experimental field of the agricultural University of Plovdiv, Bulgaria. The study was performed by the randomized block design in 4 replications with size of trial plot 28 m^2.

The research included herbicide treatment in two phenological stages of maize – BBCH 15 (3^{rd} – 5^{th} true leaf) and BBCH 18 (8^{th} – 9^{th} true leaf). Variants of the trial were: 1. Untreated control; 2. Derby Super (150.2 g/kg *florasulam* + 300.5 g/kg *aminopyralid)* – 33 g ha^{-1} (BBCH 15); 3. Derby Super – 33 g ha^{-1} (BBCH 18); 4. Starane Gold (100.0 g/l *fluroxypyr* + 1.0 g/l *florasulam*) – 1.20 l ha^{-1} (BBCH 15);

5. Starane Gold – 1.20 l ha^{-1} (BBCH 18); 6. Kabadex Extra (16.7 g/l *florasulam* + 267 g/l *mesotrione*) – 0.45 l ha^{-1} (BBCH 15); 7. Kabadex Extra – 0.45 l ha^{-1} (BBCH 18). The size of the spraying solution was 250 l ha^{-1}.

The hybrid "Blason Duo" is from FAO Group 450, tolerant to the herbicide *cycloxidim.*

In both experimental years the maize was grown on the same area as monoculture. The plants were irrigated by drop irrigation system.

On the whole field combined fertilization with 250 kg ha^{-1} with N:P:K (15:15:15), followed by deep ploughing was done. Before sowing of the crop, disking on the depth of 15 cm and two harrowings on 8 cm of depth as well as spring dressing with 250 kg ha^{-1} NH_4NO_3 was also performed.

For removing the influence of the grass weeds the whole experimental area was treated with Stratos Ulra (100 g/l *cycloxidim*) at rate of 2.00 l ha^{-1}. The treatment with Stratos Ultra was done in BBCH 15 of maize.

The efficacy of the studied herbicide rates against the weeds by the 10 score scale of EWRS (European Weed Research Society) on the 14th, 28th and 56th day after application was studied. The selectivity of the herbicide by the 9 score scale of EWRS was also evaluated (Zheliazkov et al., 2017).

Identified and analyzed are the parameters ear length, number of seeds per ear, ear diameter, absolute seed mass and maize grain seed yield. The reported biometric indicators are processed with a software package of SPSS 19 program by using Duncan's multiple range test.

Results and Discussion

On the trial field, the application of Stratos Ultra during maize vegetation in both experimental years, only annual broadleaf weeds were reported.

The species were from the group pf the late-spring weeds – *Chenopodium album* L., *Amaranthus retroflexus* L., *Xanthium strumarium* L., *Abutilon theophrasti* Medik. and *Solanum nigrum* L.

On the 14th day after treatments, for both years of the study, the highest efficacy against *Ch. album* after the application of Kabadex Extra – 0.45 l ha^{-1} (BBCH 15) – 60% was recorded. After the application of this herbicide product in the late stage of maize – BBCH 18, the efficacy against *Ch. album* was significantly lower – 20% in 2018 and 25% in 2019. In 2018, on the 14th day after treatments 0% efficacy against *Ch. album* after the application of Derby Super – 33 g ha^{-1} and Starane Gold – 1.20 l ha^{-1} in BBCH 18 was recorded. The probable reason for these results may be that the weed was in stage of development not appropriate for herbicide application. We have obtained close efficacy results in both experimental years. The efficacy was the highest on the last reporting date. That statement could be explained with the fact that there was enough time for the herbicide products to express their potential.

On average for both years of the study, on the 56th day after treatments 90% efficacy against *Ch. album* for the treatment with Kabadex Extra – 0.45 l ha^{-1} (BBCH 15) was found (Table 1).

In comparison to the herbicidal control of the weed *Ch. album*, for the control of *A. retroflexus* the studied herbicide products examined in two application timings showed higher efficacy results. The recorded efficacy during both experimental years was lower on the first evaluation date on increased in time.

On the 14th day, in 2018 the highest efficacy against this weed for Derby Super – 33 g ha^{-1} (BBCH 15) and Starane Gold – 1.20 l ha^{-1} (BBCH 15) was found – 75%.

The results were approximately the same in 2019 for all treatments.

The efficacy was 100% for Derby Super – 33 g ha^{-1} (BBCH 15) and Kabadex Extra – 0.45 l ha^{-1} (BBCH 15) (Table 2).

Regarding the control of the weed *Xanthium strumarium* L. the evaluated herbicides showed approximately the same efficacy as for *A. retroflexus*. The average results on the 56th day after treatments showed 100% efficacy after the application of Derby Super – 33 g ha^{-1} (BBCH 15) and Kabadex Extra – 0.45 l ha^{-1} (BBCH 15).

Table 1. Efficacy of the studied herbicides against *Ch. album*, %

Variants / days after treatments	2018			2019			Average		
	14th	28th	56th	14th	28th	56th	14th	28th	56th
1. Untreated control	–	–	–	–	–	–	–	–	–
2. Derby Super – 33 g ha^{-1} (BBCH 15)	20	50	65	25	55	60	23	53	63
3. Derby Super – 33 g ha^{-1} (BBCH 18)	0	10	10	5	10	15	3	10	13
4. Starane Gold – 1.20 l ha^{-1} (BBCH 15)	10	35	40	15	30	40	13	33	40
5. Starane Gold – 1.20 l ha^{-1} (BBCH 18)	0	10	15	0	5	10	0	8	13
6. Kabadex Extra – 0.45 l ha^{-1} (BBCH 15)	60	80	90	60	80	90	60	80	90
7. Kabadex Extra – 0.45 l ha^{-1} (BBCH 18)	20	45	65	25	45	65	23	45	65

For the conditions of the trial the lowest efficacy after the application of Derby Super – 33 g ha^{-1} (BBCH 18) was recorded – 75% (Table 3).

The biological efficacy against *A. theophrasti* in 2018 was the highest for Derby Super – 33 g ha^{-1} (BBCH 15) and Kabadex Extra – 0.45 l ha^{-1} (BBCH 15) 75% and 65% respectively. On the 28th day after the herbicide application 85% efficacy against the weed for these two herbicide products was observed. On the 56th day after treatments the efficacy for Kabadex Extra – 0.45 l ha^{-1} (BBCH 15) it reached 100%. The tendency was kept in 2019 also.

The average efficacy results on the 56th day after the treatments showed the highest control of *A. theophrasti* Medik. for Kabadex Extra – 0.45 l ha^{-1} (BBCH 15) – 100% was recorded (Table 4).

The highest herbicide efficacy against *S. nigrum* after the application of Starane Gold – 1.20 l ha^{-1} (BBCH 15) was recorded. In 2018 the efficacy of this treatment on the 14th day was 80%, and in 2019 it was 75%.

Average for both experimental years 100% control of *S. nigrum* for the treatment of Starane Gold – 1.20 l ha^{-1} (BBCH 15) and Kabadex Extra – 0.45 l ha^{-1} (BBCH 15) was established. High control of the concrete weed species was after the application of Derby Super – 33 g ha^{-1} (BBCH 15) also found – 95% (Table 5).

Herbicides as xenobiotics are "foreign" substances for the plants. When the tolerance of cultivated plants to the absorbed herbicide is not enough to destroy the crop, the result is herbicide stress (Vischetti et al., 2002).

The visual phytotoxicity is presented on table 6. The obtained data regarding the phytotoxicity results after the herbicide application are unidirectional in both years of the experiment.

Visual phytotoxicity was not observed when the herbi-

Table 2. Efficacy of the studied herbicides against *A. retroflexus*, %

Variants / days after treatments	2018			2019			Average		
	14th	28th	56th	14th	28th	56th	14th	28th	56th
1. Untreated control	–	–	–	–	–	–	–	–	–
2. Derby Super – 33 g ha^{-1} (BBCH 15)	75	90	100	80	90	100	78	90	100
3. Derby Super – 33 g ha^{-1} (BBCH 18)	30	50	70	35	50	70	33	50	70
4. Starane Gold – 1.20 l ha^{-1} (BBCH 15)	75	85	95	70	90	95	73	88	95
5. Starane Gold – 1.20 l ha^{-1} (BBCH 18)	40	55	70	40	60	70	40	58	70
6. Kabadex Extra – 0.45 l ha^{-1} (BBCH 15)	60	85	100	65	85	100	63	85	100
7. Kabadex Extra – 0.45 l ha^{-1} (BBCH 18)	40	60	85	40	65	85	40	63	85

Table 3. Efficacy of the studied herbicides against *Xa. strumarium*, %

Variants / days after treatments	2018			2019			Average		
	14th	28th	56th	14th	28th	56th	14th	28th	56th
1. Untreated control	–	–	–	–	–	–	–	–	–
2. Derby Super – 33 g ha^{-1} (BBCH 15)	85	95	100	80	90	100	83	93	100
3. Derby Super – 33 g ha^{-1} (BBCH 18)	30	55	75	35	55	75	33	55	75
4. Starane Gold – 1.20 l ha^{-1} (BBCH 15)	80	90	95	75	90	95	78	90	95
5. Starane Gold – 1.20 l ha^{-1} (BBCH 18)	40	65	85	40	60	85	40	63	85
6. Kabadex Extra – 0.45 l ha^{-1} (BBCH 15)	85	95	100	80	90	100	83	93	100
7. Kabadex Extra – 0.45 l ha^{-1} (BBCH 18)	40	65	80	40	60	85	40	63	83

Table 4. Efficacy of the studied herbicides against *A. theophrasti*, %

Variants / days after treatments	2018			2019			Average		
	14th	28th	56th	14th	28th	56th	14th	28th	56th
1. Untreated control	–	–	–	–	–	–	–	–	–
2. Derby Super – 33 g ha^{-1} (BBCH 15)	75	85	90	75	85	90	75	85	90
3. Derby Super – 33 g ha^{-1} (BBCH 18)	30	55	65	40	60	65	35	58	65
4. Starane Gold – 1.20 l ha^{-1} (BBCH 15)	45	70	85	40	70	85	43	70	85
5. Starane Gold – 1.20 l ha^{-1} (BBCH 18)	40	60	75	40	65	75	40	63	75
6. Kabadex Extra – 0.45 l ha^{-1} (BBCH 15)	65	85	100	70	90	100	68	88	100
7. Kabadex Extra – 0.45 l ha^{-1} (BBCH 18)	40	65	80	45	65	80	43	65	80

Table 5. Efficacy of the studied herbicides against *S. nigrum*, %

Variants / days after treatments	2018			2019			Average		
	14th	28th	56th	14th	28th	56th	14th	28th	56th
1. Untreated control	–	–	–	–	–	–	–	–	–
2. Derby Super – 33 g ha^{-1} (BBCH 15)	65	85	95	60	80	95	63	83	95
3. Derby Super – 33 g ha^{-1} (BBCH 18)	30	55	75	35	55	75	33	55	75
4. Starane Gold – 1.20 l ha^{-1} (BBCH 15)	80	95	100	75	90	100	78	93	100
5. Starane Gold – 1.20 l ha^{-1} (BBCH 18)	40	60	75	45	60	70	43	60	73
6. Kabadex Extra – 0.45 l ha^{-1} (BBCH 15)	70	90	100	70	85	100	70	88	100
7. Kabadex Extra – 0.45 l ha^{-1} (BBCH 18)	40	65	80	45	65	85	43	65	83

cide Starane Gold was applied in the rate of 1.20 l ha^{-1} in BBCH 15. The phytotoxicity score was 0.

After the application of Derby Super – 33 g ha^{-1} and Kabadex Extra – 0.45 l ha^{-1} in BBCH 15 phytotoxicity score 1 was recorded. On the 7th day the expressed symptoms were slight twisting of the leaf blade.

For these two variants on the 14th day after treatments the visual symptoms of the caused herbicide stress completely disappeared.

On the 7th day the variants were the herbicides Derby Super, Starane Gold and Kabadex Extra were applied in BBCH 18 higher phytotoxic symptoms were recorded. The phytotoxiciyty score by the EWRS scale was 2. The visible symptoms were crimping and stronger twisting of the leaf blades. Also slight growth retardation was reported.

For these treatments on the 14th day the phytotoxicity score decreased to 1. This was probably due to the overcome herbicide stress.

On the last reporting date visual phytotoxicity was not observed for any of the studied herbicides and their application timing (Table 6).

During the two years of the study, the influence of the studied herbicide products on some biometrical parameters as well as on the maize grain seed yields was evaluated.

In 2018 the highest ear length was recorded for the treatment of Kabadex Extra – 0.45 l ha^{-1} (BBCH 15) – 16.40 cm, followed by Derby Super – 33 g ha^{-1} (BBCH 15) – 15.49 cm and Starane Gold – 1.20 l ha^{-1} (BBCH 15) – 15.47 cm. The lowest values for this parameter for the untreated control were recorded – 12.88 cm. The tendency was kept in the next experimental year (2019).

Average for both experimental years the highest results for the herbicide products applied in BBCH 15 for the ear length was established.

All treatments with applied herbicide application surpass the untreated control in level of significance gD = 5% as the values are with proved differences (Table 7).

For the parameter number of seeds per ear statistically proved differences of the data between the untreated control and the variants with applied herbicides was observed.

The lowest results were found to be for the untreated control 334.73 (in 2018) and 419.62 (in 2019) seeds per ear. Average for the period the highest seed number per maize ear was recorded after the application of Kabadex Extra – 0.45 l ha^{-1} (BBCH 15) – 522.00 seeds, followed by the treatments with Derby Super – 33 g ha^{-1} (BBCH 15) – 495.90 and Starane Gold – 1.20 l ha^{-1} (BBCH 15) – 483.15 seeds per ear. After statistical processing of the data, it was found that there is no statistically proved differences between these three treatments.

It is noteworthy that there are no significant differences in seed numbers between the treatments received late herbicide application (Table 8).

Regarding the obtained data for the indicator ear diameter it was established that when the studied herbicides are

Table 6. Visual phytotoxicity of the studied herbicides for maize, scores by EWRS

Variants / days after treatments	2018			2019		
	7th	14th	56th	7th	14th	28th
1. Untreated control	–	–	–	–	–	–
2. Derby Super – 33 g ha^{-1} (BBCH 15)	1	0	0	1	0	0
3. Derby Super – 33 g ha^{-1} (BBCH 18)	2	1	0	2	1	0
4. Starane Gold – 1.20 l ha^{-1} (BBCH 15)	0	0	0	0	0	0
5. Starane Gold – 1.20 l ha^{-1} (BBCH 18)	2	1	0	2	1	0
6. Kabadex Extra – 0.45 l ha^{-1} (BBCH 15)	1	0	0	1	0	0
7. Kabadex Extra – 0.45 l ha^{-1} (BBCH 18)	2	1	0	2	1	0

applied in BBCH 15 higher values in comparison to the late spraying in BBCH 18 are recorded.

Average for both trial years the highest ear diameter for the treatments with Derby Super, Starane Gold and Kabadex Extra was found – 4.47, 4.40 and 4.32 cm respectively. The lowest ear diameter was recorded for the plants of the untreated control – 3.88 cm.

From the comparative analysis of maize for the studied indicator, significant differences were reported between the untreated control and the other variants (Table 9). These results shows that in this case high weed infestation reducing the diameter of the ear of maize plants could expected.

The absolute seed mass of 1000 seeds is a very important indicator of the grain's quality. The seeds with bigger values of the indicator have a higher price. According to a lot of authors this indicator has crucial for the formation of the yields (Georgiev et al., 2014). The results obtained in the resent study are presented in table 10.

The obtained results again show that there is a statistically proven difference between the control and the treated variants. Average for the years of the research the highest results for the treatments of Kabadex Extra – 0.45 l ha^{-1} in BBCH 15 were recorded – 368.68 g. This treatment surpass the other variants and there was proved differences at gD = 5%. These results are followed by the treatments with Derby Super – 33 g ha^{-1} (BBCH 15) and Starane Gold – 1,20 l ha^{-1} (BBCH 15), where the absolute seed mass was 338.69 and 331.44 g respectively.

For the treatments with late herbicide application the differences of the obtained data were with not proved differences.

Table 7. Ear length, cm

Variants / days after treatments	2018	2019	Average
1. Untreated control	11.90 d	13.70 d	12.80 d
2. Derby Super – 33 g ha^{-1} (BBCH 15)	16.48 ab	19.28 ab	17.88 ab
3. Derby Super – 33 g ha^{-1} (BBCH 18)	14.50 c	16.76 c	15.63 c
4. Starane Gold – 1.20 l ha^{-1} (BBCH 15)	16.18 abc	18.20 abc	17.19 abc
5. Starane Gold – 1.20 l ha^{-1} (BBCH 18)	14.56 c	17.30 bc	15.93 c
6. Kabadex Extra – 0.45 l ha^{-1} (BBCH 15)	17.14 a	19.94 a	18.54 a
7. Kabadex Extra – 0.45 l ha^{-1} (BBCH 18)	15.20 bc	17.78 bc	16.49 bc

The values with different letters are with proved difference according to Duncan's multiple range test ($p < 0.05$)

Table 8. Number of seeds per ear

Variants / days after treatments	2018	2019	Average
1. Untreated control	334.73 f	419.62 e	377.18 e
2. Derby Super – 33 g ha^{-1} (BBCH 15)	472.12 ab	519.67 b	495.90 ab
3. Derby Super – 33 g ha^{-1} (BBCH 18)	409.67 e	445.35 d	427.51 d
4. Starane Gold – 1.20 l ha^{-1} (BBCH 15)	456.65 bc	509.64 b	483.15 abc
5. Starane Gold – 1.20 l ha^{-1} (BBCH 18)	429.35 de	452.87 d	441.11 cd
6. Kabadex Extra – 0.45 l ha^{-1} (BBCH 15)	481.43 a	562.57 a	522.00 a
7. Kabadex Extra – 0.45 l ha^{-1} (BBCH 18)	438.23 cd	488.14 c	463.19 bcd

The values with different letters are with proved difference according to Duncan's multiple range test ($p < 0.05$)

Table 9. Ear diameter, cm

Variants / days after treatments	2018	2019	Average
1. Untreated control	3.66 e	4.09 e	3.88 e
2. Derby Super – 33 g ha^{-1} (BBCH 15)	4.16 ab	4.48 bc	4.32 ab
3. Derby Super – 33 g ha^{-1} (BBCH 18)	3.85 d	4.29 d	4.07 d
4. Starane Gold – 1.20 l ha^{-1} (BBCH 15)	4.18 ab	4.62 ab	4.40 ab
5. Starane Gold – 1.20 l ha^{-1} (BBCH 18)	3.95 cd	4.34 cd	4.15 cd
6. Kabadex Extra – 0.45 l ha^{-1} (BBCH 15)	4.28 a	4.66 a	4.47 a
7. Kabadex Extra – 0.45 l ha^{-1} (BBCH 18)	4.07 bc	4.48 bc	4.23 bc

The values with different letters are with proved difference according to Duncan's multiple range test ($p < 0.05$)

Table 10. Absolute seed mass of 1000 air-dry maize seeds, g

Variants / days after treatments	2018	2019	Average
1. Untreated control	262.24 d	282.56 d	272.40 d
2. Derby Super – 33 g ha^{-1} (BBCH 15)	325.91 b	351.47 b	338.69 b
3. Derby Super – 33 g ha^{-1} (BBCH 18)	279.92 c	297.81 c	288.87 c
4. Starane Gold – 1.20 l ha^{-1} (BBCH 15)	320.10 b	342.77 b	331.44 b
5. Starane Gold – 1.20 l ha^{-1} (BBCH 18)	282.65 c	299.87 c	291.26 c
6. Kabadex Extra – 0.45 l ha^{-1} (BBCH 15)	359.87 a	377.49 a	368.68 a
7. Kabadex Extra – 0.45 l ha^{-1} (BBCH 18)	284.90 c	307.90 c	296.40 c

The values with different letters are with proved difference according to Duncan's multiple range test ($p < 0.05$)

Table 11. Maize grain seed yield, t ha^{-1}

Variants / days after treatments	2018	2019	Average
1. Untreated control	3.53 f	4.73 e	4.13 e
2. Derby Super – 33 g ha^{-1} (BBCH 15)	7.17 b	7.76 b	7.47 b
3. Derby Super – 33 g ha^{-1} (BBCH 18)	5.18 e	6.33 d	5.76 d
4. Starane Gold – 1.20 l ha^{-1} (BBCH 15)	6.85 c	7.75 b	7.30 b
5. Starane Gold – 1.20 l ha^{-1} (BBCH 18)	5.31 e	6.67 cd	5.99 d
6. Kabadex Extra – 0.45 l ha^{-1} (BBCH 15)	8.19 a	8.55 a	8.37 a
7. Kabadex Extra – 0.45 l ha^{-1} (BBCH 18)	6.32 d	7.00 c	6.66 c

The values with different letters are with proved difference according to Duncan's multiple range test ($p < 0.05$)

The lowest results for the absolute seed mass of 1000 air-dry maize seeds for the untreated control were established – 272.40 g average for both years of research.

From research findings from different authors around the globe as well as from our previous studies it is found that the yield could be decreased to different extend in dependence of weed infestation (Tonev, 1986; Imoloame & Omolaiye, 2016; Sevov et al., 2015 Tonev et al., 2016, Mitkov et al., 2018; Mitkov et al., 2019, Mitkov, 2020).

On table 11 are the results for the maize grain yield of the resent study. The obtained results showed that for the treated variants there is a positive correlation between their efficacy results and the biometrical parameter as well as grain yields.

As a result of the high weed infestation the grain yield of the untreated control was – 4.13 t ha^{-1} average for the period. The highest yields after the application of Kabadex Extra – 0.45 l ha^{-1} (BBCH 15) was recorded 8.37 t ha^{-1} on average. The yield is with proved difference in comparison to the other treatments.

Among the treated variants the lowest yields for the application of Derby Super and Starane Gold sprayed in BBCH 18 were found. For treatment 3 the yield was 5.76 t ha^{-1}, and for variant 5 – 5.99 t ha^{-1} average for both years of the trial. In all treated variants, the obtained yield is higher than that of the untreated control, and its increase is statistically proven at a level of significance gD = 5%.

Conclusions

The highest herbicide efficacy and control against the weeds *Chenopodium album* L., *Amaranthus retroflexus* L., *Xanthium strumarium* L., *Abutilon theophrasti* Medik. and *Solanum nigrum* L. after the application of Kabadex Extra – 0.45 l ha^{-1}, followed by Derby Super in BBCH 15 was found.

From the analysis of the biometric indicators of the studied maize hybrid "Blason Duo" the highest results for the ear length, number of seeds per ear, ear diameter, absolute seed mass of 1000 air-dry maize seeds as well as grain seed yield after the treatment with Kabadex Extra – 0.45 l ha^{-1} in BBCH 15 were recorded.

Visual phytotoxicity was not recorded when the herbicide Starane Gold was applied in BBCH 15. After the late herbicide application the phytotoxicity score increased independently the studied herbicide product. On the last reporting date there were no visual phytotoxic symptoms from any of the evaluated herbicides, but the herbicide stress caused by the late treatment had negative influence on the performance and yielding of maize.

The application of the herbicides in the beginning of the maize vegetation (BBCH 15) showed higher efficacy and respectively higher grain yields in comparison to the herbicide treatment later in time (BBCH 18).

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