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EFFICACY OF SELECTED HERBICIDES IN WEED CONTROL OF MAIZE

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Abstract. Effectiveness of selected herbicides applied pre- and post-emergence in maize was evaluated in 2010–2011. The highest efficiency expressed as the decrease of number and weight of weeds despite of weather conditions, was observed in case of application of Boreal 58 WG in dose of 0.4 kg·ha^{-1} pre-emergence + Mustang 306 SE at 0.6 l·ha^{-1} used in the 3–4 leaf stage. Over 84% of effectiveness expressed as the decrease of total weed weight in both years, was noticed in case of Hector 53.6 + WG + Mocarz 75 WG + Trend 90 EC. In wet 2010 year herbicides: Boreal 58 WG, Adengo 315 SC + Mustang 306 SE, Adengo 315 SC + Mocarz 75 WG, Guardian Complet Mix 664 SE, Afalon Dyspersyjny 450 SC + Dual Gold 960 EC were 100% effective against *Brassica napus*, *Viola arvensis* and *Capsella bursa-pastoris*. The stress of drought in the next year greatly reduced the effectiveness of weed control to the *Chenopodium album* and *Brassica napus*. From the nine weed species, which appeared in 2010 year were dominant: *Viola arvensis* (VIOAR), *Brassica napus* (BRSNA) and *Capsella bursa-pastoris* (CAPBP), while in 2011 *Chenopodium album* (CHEAL) and *Capsella bursa-pastoris* (CAPBP).

Key words: weed control, herbicides, maize, effectiveness

INTRODUCTION

Weeds in maize are very competitive for water, light and nutrients [Gołębiowska and Rola 2008]. It is important to reduce their occurrence already in the early stages of development, i.e. from emergence to 8–10 leaves stage [Hruszka 2003, Sulewska et al. 2008], especially in maize, which is characterized by a slower growth rate in this period [Gąsiorowska and Makarewicz 2008]. Potential yield losses, resulting from competitive weeds, can be significant, and therefore effective chemical treatments are still the most reasonable and cost-effective tillage in corn [Sulewska et al. 2008, Weber and Gołębiowska 2009]. The aim of this study was to evaluate the efficacy of selected herbicides applied pre-and post-emergence for weed control in maize grown for grain.

MATERIALS AND METHODS

The field experiment was conducted in 2010 and 2011 in Experimental Station Swadzim (52°26′ N, 16°45′ E) belonging to the Poznań University of Life Sciences, in randomized block method in four replications. The experiment tested the effectiveness of weed control in maize grown for grain in the application of combinations according to table 1. Two control objects were used: without and mechanical weeding. The characteristics of various herbicides and their dosages are described in table 2. The evaluation of effectiveness of herbicides was performed 4 weeks after

Table 1. Objects under investigation

Number of object	Combination of herbicides
1	Control
2	Mechanical weeding
3	Boreal 58 WG – 0.75 kg·ha^{-1} – T0
4	Boreal 58 WG – 0.4 kg·ha^{-1} – T0 + Mustang 306 SE – 0.6 l·ha^{-1} – T4*
5	Boreal 58 WG – 0.4 kg·ha^{-1} – T0 + Mocarz 75 WG – 0.2 kg·ha^{-1} – T4
6	Adengo 315 SC – 0.33 l·ha^{-1} – T0 + Mustang 306 SE – 0.6 l·ha^{-1} – T4
7	Adengo 315 SC – 0.33 l·ha^{-1} – T0 + Mocarz 75 WG – 0.2 kg·ha^{-1} – T4
8	Dual Gold 960 EC – 1.5 l·ha^{-1} – T0 + Mustang 306 SE – 0.6 l·ha^{-1} – T4
9	Dual gold 960 EC – 1.5 l·ha^{-1} – T0 + Chwastox Turbo 340 SL – 2.0 l·ha^{-1} – T4
10	Guardian Complet Mix 664 SE – 3.5 l·ha^{-1} – T0
11	Guardian Complet Mix 664 SE – 2.5 l·ha^{-1} – T0 + Chwastox Turbo 340 SL – 2.0 l·ha^{-1} – T4
12	Hector 53.6 WG – 80 g·ha^{-1} – T4 + Trend 90 – 0.1% – T4
13	Hector 53.6 WG – 70 g·ha^{-1} + Mocarz 75 WG – 0.2 kg·ha^{-1} + Trend 90 EC – 0.16% – T4
14	Hector 53.6 WG – 70 g·ha^{-1} + Mustang 306 SE 0.6 l·ha^{-1} + Trend 90 EC–0.2% – T4
15	Hector 53.6 WG – 70 g·ha^{-1} + Chwastox Turbo 340 SL – 2.0 l·ha^{-1} + Trend 90 EC – 0.1% – T4
16	Maister 31 OD – 1.25 l·ha^{-1} – T4
17	Elumis 105 OD – 1.2 l·ha^{-1} – T4
18	Afalon Dyspersyjny 450 SC – 2.0 l·ha^{-1} + Dual Gold 960 EC – 1.5 l·ha^{-1} – T0

* – herbicide applied in T4 phase because of not satisfactory effect of herbicide applied in T0 phase

Table 2. Characteristics of applied herbicides

Name	Dose per ha	Active substance (a.s.)	Content of a.s.
Boreal 58 WG	0.75 kg	flufenacet + isoxaflutole	48% + 10%
Mustang 306 SE	0.6 l	2.4-D + florasulam	300 g·l^{-1} + 6.25 g·l^{-1}
Mocarz 75 WG	0.2 kg	dicamba + tritosulfuron	500 g + 250 g
Adengo 315 SC	0.33 l	isoxaflutole + thiencarbazone methyl	225 g + 90 g
Dual Gold 960 EC	1.5 l	S-metolachlor	960 g·l^{-1}
Chwastox Turbo 340 SL	2.0 l	MCPA + dicamba	300 g·l^{-1} + 40 g·l^{-1}
Guardian Complet Mix 664 SE	3.5 l	acetochlor + terbuthyloazine	450 g·l^{-1} + 214 g·l^{-1}
Hector 53.6 WG	80 g	nicosulfuron + rimsulfuron	42.9% + 10.7%
Maister 31 OD	1.25 l	foramsulfuron+iodosulfuron–methyl-sodium	30 g·l^{-1} + 1 g·l^{-1}
Elumis 105 OD	1.2 l	mesotrione + nicosulfuron	75 g·l^{-1} + 30 g·l^{-1}
Afalon Dyspersyjny 450 SC	2.0 l	linuron	450 g·l^{-1}

application, referring to the results of the control without weeding. Also other basic parameters of infestation such as species composition, number and fresh weight of weeds, which were used to calculate the relative abundance of weeds (Ra) [Jędruszczak and Antoszek 2004] and ecological indicator–dominance (D) [Czacharowski 2004], under which weed species has been assigned to the appropriate class domination, developed by Kasprzak and Niedbała [1981]:

- D5 – eudominants – over 10.0% of all evaluated individuals from taxonomic group,
- D4 – dominants – 5.1 – 10.0%,
- D3 – subdominants – 2.1 – 5.0%,
- D2 - recedents – 1.1 – 2.0%,
- D1 – subrecedents – below 1.0%.

Relative abundance index (Ra) was calculated according to the formula: Ra = (rd + rf)/2, where Ra – means the relative abundance, rd – indicates the relative density of species per m^2, obtained by dividing the number of individuals from the species and number of individuals of all species per area unit, rf – indicates the relative frequency of species per area unit, the number of occurrences of the species in relation to the number of occurrences of all weed species per area unit. Dominance (D) is used for the comparison of the species within the biocenosis, indicating the quantitative part of the test species in the ecosystem, and not only a percentage of the collected material. This ratio was calculated based on the following formula: Di = n/N × 100%, where Di – is the dominance of the i^{th} species, n_i – is the number of the i^{th} species, and N – is the total number of all species. The experiment was conducted in accordance with the applicable standard EPPO PP1/50 (2) [1982] describing the conduct of trials for the efficacy evaluation of herbicides in maize, and compared to the scope of the effectiveness of plant protection products by the Minister of Agriculture and Rural Development [Official Journal of 2004, no. 183, it. 1890].

RESULTS AND DISCUSSION

Years of conducting the trial characterized by significant differences in weather conditions. More favorable weather conditions were in 2010, which had higher amount of rainfall during the period from April to June. Maize plants, although characterized by slow growth, in such circumstances managed to quickly cover the spacing, which significantly reduced the number of weeds. In 2011 the weather conditions were not favorable for maize growing. In the period from March to June there was a large water deficit, which limited the normal development of plants and limited the effectiveness of herbicides. In the years of research it was found the presence of nine weed species in maize plots: *Brassica napus* L., *Viola arvensis* Murray, *Polygonum aviculare* L., *Fallopia convolvulus* (L.), *Chenopodium album* L., *Capsella bursa-pastoris* (L.) Medik., *Convolvulus arvensis* L., *Euphorbia* L., *Echinochloa crus-galli* (L.) Beauv. Dominant species in the community in a number of these taxa were in 2010: *Capsella bursa-pastoris*, *Brassica napus* and mostly *Viola arvensis*. In 2011, prevailed only eudominants: *Brassica napus* and *Chenopodium album* (Fig. 1.). Other species occurred at low intensity. A clear dominance of *Viola arvensis* weed in 2010, and *Chenopodium album* in 2011, confirmed weed used in the assessment of the relative abundance index (Ra) (Tab. 3), indicates a high competitive ability of weed species, both in control object – *Viola arvensis* (Ra = 0.986), *Chenopodium album* (Ra = 0.843) and in conditions of stress induced by herbicide treatment – *Viola arvensis* (Ra = 0.571), *Chenopodium album* (Ra = 0.971).

A similarly high values of indices of relative abundance for *Viola arvensis* (Ra = 0.753) reported Idziak et al. [2007], Sekutowski and Domaradzki [2009] (Ra = 0.242) in the cultivation of wheat, and Szulc and Dubas [2008] (Ra = 0.553) in maize. In addition, the study of Szulc and Dubas [2008] for long-term weed infestation in maize monoculture shows that *Chenopodium album* is the second major species among the weeds in maize (Ra = 0.410). The burden of these two species, warned in his earlier works Majchrzak et al. [2003], Gołębiowska [2006], which further reinforces the belief that we are dealing with the escalating phenomenon of compensa-

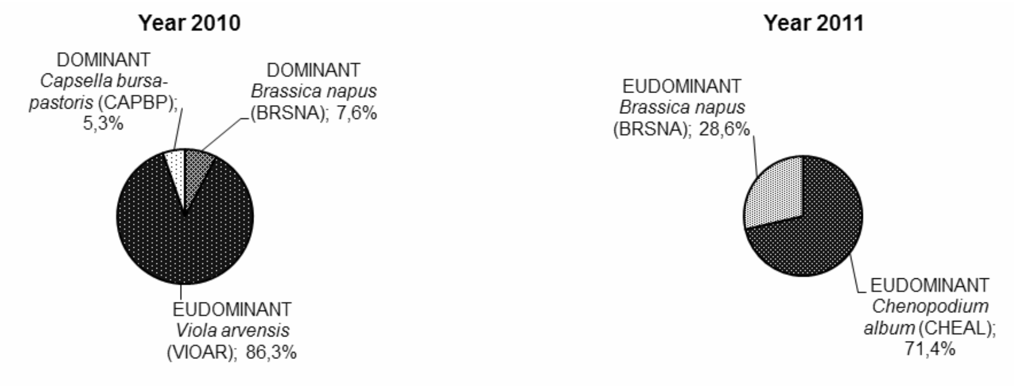

Fig. 1. The share of dominating weeds in 2010 and 2011 assigned to the category of dominance on the base of calculated indicator of the dominance (D)

Table 3. Share of dominant weed species (%) and their abundance depending on the combination of herbicides in the years 2010 and 2011

Objects*	2010						2011			
	BRSNA		VIOAR		CAPBP		CHEAL		BRSNA	
	(%)	Ra	(%)	Ra	(%)	Ra	(%)	Ra	(%)	Ra
1	7.7	0.434	86.9	0.504	5.4	0.123	71.4	0.594	28.6	0.313
2	–	–	–	–	–	–	100.0	0.406	–	–
3	–	–	–	–	–	–	93.3	0.563	6.7	0.156
4	–	–	–	–	–	–	87.5	0.344	12.5	0.156
5	66.7	0.375	33.3	0.015	–	–	91.0	0.438	9.1	0.156
6	–	–	–	–	–	–	72.7	0.375	27.3	0.218
7	–	–	–	–	–	–	58.3	0.344	41.7	0.281
8	1.0	0.156	99.0	0.534	–	–	100.0	0.469	–	–
9	–	–	100.0	0.600	–	–	83.3	0.281	16.7	0.156
10	–	–	–	–	–	–	90.0	0.406	10.0	0.156
11	100.0	0.188	–	–	–	–	87.5	0.344	12.5	0.156
12	–	–	100.0	0.347	–	–	100.0	0.688	–	–
13	–	–	100.0	0.311	–	–	100.0	0.437	–	–
14	–	–	100.0	0.478	–	–	100.0	0.469	–	–
15	–	–	100.0	0.644	–	–	100.0	0.250	–	–
16	–	–	100.0	0.466	–	–	100.0	0.531	–	–
17	–	–	100.0	0.245	–	–	71.4	0.593	28.6	0.312
18	–	–	–	–	–	–	100.0	0.312	–	–
Average for herbicide objects	43.9	0.288	91.9	0.414	5.4	0.123	89.2	0.436	19.4	0.206

BRSNA – *Brassica napus*, VIOAR – *Viola arvensis*, CAPBP – *Capsella bursa-pastoris*, CHEAL – *Chenopodium album*
* – according to table 1

tion of weeds that may result from the isolation of the biotypes susceptible to the effects of some preparations, as pointed out in previous studies Idziak et al. [2007]. Our study confirms the thesis of Woźnica and Idziak [2011], that can inhibit this phenomenon using a mixture of herbicides, composed of two or more active substances, which in turn increases the effectiveness of weed control. The overall effectiveness of herbicidal formulations used in the experiment ranged from 49.9 to 93.7%. Of the 16 respondents herbicide combinations (Tab. 4) proved the

Table 4. The effectiveness of herbicides in reducing weed fresh weight (%) depending on herbicides applied in the years 2010 and 2011

Year	2010				2011		
Objects*	BRSNA	VIOAR	CAPBP	Sum	CHEAL	BRSNA	Sum
1**	546	533	84	1163	2982	921	3903
2	100.0	100.0	100.0	100.0	58.7	100.0	69.2
3	100.0	100.0	100.0	100.0	38.6	93.1	44.9
4	100.0	100.0	100.0	100.0	83.8	97.7	87.4
5	75.8	97.7	100.0	91.5	58.3	97.2	67.3
6	100.0	100.0	100.0	100.0	71.3	78.6	70.0
7	100.0	100.0	100.0	100.0	62.8	91.0	69.0
8	92.5	23.2	100.0	60.3	68.1	100.0	74.7
9	100.0	19.2	100.0	51.3	77.9	97.6	81.0
10	100.0	100.0	100.0	100.0	64.2	75.0	61.5
11	93.0	100.0	100.0	95.6	48.5	83.7	49.5
12	100.0	44.9	100.0	76.3	18.7	100.0	23.5
13	100.0	63.0	100.0	85.2	78.6	100.0	84.3
14	100.0	37.9	100.0	73.7	69.7	100.0	77.5
15	100.0	16.8	100.0	58.4	84.3	100.0	89.0
16	100.0	22.8	100.0	65.1	50.0	100.0	59.7
17	100.0	80.4	100.0	92.2	2.3	75.0	9.5
18	100.0	100.0	100.0	100.0	82.4	100.0	86.7
$LSD_{0.05}$				17.3			32.5

BRSNA – *Brassica napus*, VIOAR – *Viola arvensis*, CAPBP – *Capsella bursa-pastoris*, CHEAL – *Chenopodium album*
* – according to table 1, ** – weed weight from control object ($g \cdot m^{-2}$)

most effective combination of Boreal 58 WG + Mustang 306 SE, whose effectiveness in reducing the fresh weight of weeds dominant in both years exceeded 87%, which according to the scope of the effectiveness of plant protection products referred to the Regulation of the Minister of Agriculture and Rural Development, provides a sensitivity of weeds to these herbicides. In 2010, this measure has demonstrated full efficacy (100%) against *Brassica napus, Viola arvensis* and *Capsella bursa-pastoris*. However, in 2011, this herbicide combination fought to a lesser extent *Chenopodium album*. Especially noteworthy are: Boreal 58 WG, Adengo 315 SC + Mustang 306 SE, Adengo 315 SC 75 WG + Mocarz, Guardian Complet Mix 664 SE, 450 SC Afalon Dyspersyjny + Dual Gold 960 EC, which fought against all weed species in 100% of 2010. Unfortunately, in the dry year 2011 showed a much lower efficiency. The high efficiency of weed control Boreal 58 WG formulation reported in previous studies Waligóra et al. [2008]. The studies of Paradowski and Kierzek [2009] and Gąsiorowska and Makarewicz [2011] showed high efficacy in destroying weeds by Mustang 306 EC formulation, applied after emergence of maize plants. Relatively high efficiency, over 84% in both years showed Hector 53.6 + WG + Mocarz + Trend 90 EC. However, according to the range of effectiveness [Journal of Laws of 2004 No 183, it. 1890], the weeds were intermediately susceptible to the active substances contained in the given herbicides. In previous studies, the reduction of weed corn was higher than presented because more than 95% effective in reducing total weed weight was achieved using Calaris 400 SC [Sulewska et al. 2008]. Grain yields of maize (Tab. 5) with all combina-

Table 5. Maize grain yield. its moisture and yield components depending on herbicide combination applied in years 2010 and 2011

Object*	Yield ($t \cdot ha^{-1}$)		Moisture (%)		TKW (g)		No of kernels in ear (pcs)		Ear volume (cm^3)	
	2010	2011	2010	2011	2010	2011	2010	2011	2010	2011
1	5.2	7.6	37.8	28.4	260.0	280.7	413	414	185	414
2	8.3	11.6	37.7	26.3	278.6	299.1	470	549	212	549
3	8.0	11.7	37.4	26.4	269.2	299.8	454	536	216	536
4	8.3	12.5	37.6	25.8	275.8	313.4	469	524	218	524
5	8.6	11.8	37.7	27.1	280.1	298.5	469	525	220	525
6	8.9	12.7	37.8	25.2	278.5	302.7	475	535	228	535
7	8.3	12.4	37.9	25.9	285.2	302.3	462	535	234	535
8	7.7	12.1	37.9	26.1	277.8	294.0	461	505	196	505
9	7.0	11.3	37.7	25.6	271.3	302.3	419	499	184	499
10	8.3	12.5	37.9	26.4	281.1	286.8	466	517	216	517
11	8.4	11.8	37.8	25.9	285.5	294.4	452	507	213	507
12	7.9	11.3	37.8	26.5	274.5	292.0	414	515	193	515
13	7.4	11.6	37.7	25.5	277.3	284.1	468	509	217	509
14	7.4	12.1	37.7	26.0	270.1	300.0	469	533	234	533
15	6.9	11.3	37.8	25.8	263.0	300.4	436	488	206	488
16	7.5	11.7	37.8	26.3	279.6	305.5	445	535	223	535
17	8.1	8.3	37.8	27.1	271.0	285.6	448	431	198	431
18	8.7	12.8	37.7	26.4	263.1	310.1	479	547	222	547
$LSD_{0.05}$	0.7	0.8	n.s.	1.2	n.s.	18.5	40	42	n.s.	42

* – according to table 1, n.s. – non significant differences

tions of treatments where herbicide was applied were significantly higher yields compared with the control object. The highest yields in both 2010 and 2011 as obtained on the protected object herbicide Adengo 315 SC at a dose of 0.33 $l \cdot ha^{-1}$ + Mustang 306 SE at 0.6 $l \cdot ha^{-1}$ (2010 – 8.9 $t \cdot ha^{-1}$, 2011 – 12.7 $t \cdot ha^{-1}$) and Afalon Dyspersyjny 450 SC at a dose of 2.0 $l \cdot ha^{-1}$ + Dual Gold 960 EC in dose of 1.5 $l \cdot ha^{-1}$ (2010 – 8.7 $t \cdot ha^{-1}$, 2011 – 12.8 $t \cdot ha^{-1}$). There were no significant differences in grain moisture harvested in 2010. The following year showed significantly lowest moisture of corn grain harvested from the object where Adengo 315 SC + Mustang 306 SE was applied.

Thousand grain weight in 2010 the feature at the same level, while in 2011, significantly highest thousand grain weight were characterized by corn ears harvested from object where Afalon Dyspersyjny 450 SC + Dual Gold 960 EC were used. In both years, the number of kernels in the ear was different, but in fact the highest value of the feature was found in plants harvested from object where Afalon Dyspersyjny 450 SC + Dual Gold 960 EC were used, and in 2011 also from object where weed control was done manually. Volume of the ears determined the yield level, and in 2011, as in the case of the yield, it was the highest value of this characteristic with the combination of herbicides: Afalon Dyspersyjny 450 SC + Dual Gold 960 EC and Adengo 315 SC + Mustang 306 SC, as well as in case of mechanical weed control.

CONCLUSIONS

1. The effectiveness of herbicides in weed control in maize was in the years of the study varied. The highest efficiency, regardless of the weather, limiting the number and total weight of weeds was achieved after Boreal 58 WG at a dose of 0.4 $kg \cdot ha^{-1}$ pre-emergence + Mustang 306 SE at 0.6 $l \cdot ha^{-1}$ used in the 3–4 leaf stage.
2. The effectiveness of herbicide preparations used was dependent on the prevailing meteorological conditions, primarily moisture. Herbicides: Boreal 58 WG, Adengo 315 SC + Mustang 306 SE, Adengo 315 SC + Mocarz 75 WG, Guardian Complet Mix 664 SE, Afalon Dyspersyjny 450 SC + Dual Gold 960 EC were 100% effective against *Brassica napus* (BRSNA), *Viola arvensis* (VIOAR) and *Capsella bursa-pastoris* (CAPBP) in wet year. In 2011, the stress of drought greatly reduced the effectiveness of weed control relative to the dominant weeds, which were *Chenopodium album* (CHEAL) and *Brassica napus* (BRSNA).
3. Of the nine species of weeds present in the field in 2010 were dominant: *Viola arvensis* (VIOAR), *Brassica napus* (BRSNA) and *Capsella bursa-pastoris* (CAPBP), while in 2011 *Chenopodium album* (CHEAL) and *Brassica napus* (BRSNA).
4. Applied in both years of the study combinations of herbicides Adengo 315 SC + Mustang 306 SE and Afalon Dispersyjny 450 SC + Dual Gold 960 EC resulted in a significant increase in corn yields and ear volume. Additionally, objects where it were used Afalon Dyspersyjny 450 SC + Dual Gold 960 EC had significantly high thousand grain weight and number of kernels in the ear.

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SKUTECZNOŚĆ WYBRANYCH HERBICYDÓW W ODCHWASZCZANIU KUKURYDZY

Synopsis. Skuteczność wybranych herbicydów zastosowanych przed i powschodowo oceniano w latach 2010–2011. Najwyższą skuteczność, niezależnie od przebiegu pogody, w ograniczaniu liczby i masy chwastów ogółem osiągnięto po zastosowaniu Boreal 58 WG w dawce 0,4 kg·ha^{-1} przedwschodowo + Mustang 306 SE w dawce 0,6·ha^{-1} zastosowany w fazie 3-4 liści. Ponad 84% skuteczność w obu latach wykazał środek Hector 53,6 WG + Mocarz + Trend 90 EC. W wilgotnym 2010 roku herbicydy: Boreal 58 WG, Adengo 315 SC + Mustang 306 SE, Adengo 315 SC + Mocarz 75 WG, Guardian Complet Mix 664 SE, Afalon Dyspersyjny 450 SC + Dual Gold 960 EC były w 100% skuteczne względem *Brassica napus* (BRSNA), *Viola arvensis* (VIOAR) i *Capsella bursa-pastoris* (CAPBP). Stres związany z suszą następnego roku znacznie obniżył ich efektywność chwastobójczą względem chwastów dominujących, jakimi były *Chenopodium album* (CHEAL) oraz *Brassica napus* (BRSNA). Spośród 9 gatunków chwastów występujących na polu dominującymi w 2010 roku były: fiołek polny, samosiewy rzepaku oraz tasznik pospolity, natomiast w 2011 roku komosa biała i samosiewy rzepaku.

Słowa kluczowe: odchwaszczanie, herbicydy, kukurydza, skuteczność