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THE PROBLEMS OF WEED MANAGEMENT BY HERBICIDE SYSTEMS APPLIED IN MAIZE

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Abstract: Detailed recognition of weed infestation state and degree in south-western region of Poland provided the basis for starting field experiment on three types of soils aiming at the assessment of weed control effectiveness by means of suitably selected herbicide systems. High efficiency of weed elimination on alluvial soils was obtained due to herbicide mixture mesotrione + nicosulfuron in split doses. In the experiment established on brown soils the mentioned weed species were most satisfactorily controlled by herbicide mixture applied according to infestation degree: mesotrione + nicosulfuron i rimsulfuron + adjuvant + dicamba applied once in full doses. The mixture rimsulfuron + adjuvant + dicamba showed to be the most efficient regarding the weeds typical for alluvial soils, except for *Elymus repens*, numerously occurring in the experiment, which exhibited medium sesitivity, as well as winter forms of *Anthemis arvensis*. Mixture of rimsulfuron + adjuvant + florasulam +2,4-D allowed to eliminate undesired plants on that soil stand in the most efficient way and to achieve the highest grain yield.

Key words: sulfonylurea herbicides, weed control, soil stands, herbicides mixtures, lowered doses

INTRODUCTION

In the nineties in Poland there took place a change regarding the way of maize utilisation from a silage to grain. Increased interest of growers in this kind of cultivation resulted from advantageous price boom, as well as favourable climate conditions allowing to obtain full grain maturity even for cultivars of FAO 270. That tendency led, within ten years time, to the increase of maize cultivation area by 293%. Herbicide protection accounts only for 5% of direct expenses by farmers (Sulewska and Koziara 2006), yet lack of herbicide treatments when weed infestation amounts to up 75%, and

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inappropriate agrotechnology can cause yield loss up to 90%, which indicates its fully economically justified introduction (Skrzypczak 1996). Triazine withdrawal from the register list of herbicides permitted for use, as well as immunity developed by some weed species (De Prado 1995) resulted in the search for alternative means and methods of their control (Varga *et al*. 2000). As it has been known from the literature, the most effective way of weed control is the application of appropriately composed herbicide mixtures. Mesotrione combined with other herbicides is hoped to provide satisfactory answer (Gołębiowska and Rola 2004). On the other hand, positive results of the investigation carried out in cereals regarding the reduction of herbicide doses (Proven *et al.* 1991; Domaradzki 2006) encourage the scientists to undertake similar research involving maize. It has been assumed that herbicide mixtures prepared according to the state and degree of weed infestation and mininum doses used will allow to maintain weed-free plantation until the harvest. The aim of the investigations was to determine efficiency of herbicides and their mixtures in the condition of weed infestation on three soil stands, using herbicide mixtures in diffrent doses, dates and growth stage of maize plant development.

MATERIALS AND METHODS

In the years 2004–2006 were conducted field experiments on the evaluation of some herbicide mixtures efficacy regarding crop maize. Detailed characteristics of herbicides and their mixtures applied on diffrent soils were presented in Table 1. The layout of the experiments was a complete randomized block design in four replications. The area of each maize plot was 25 m^2. For each system were evaluated selectivity and efficacy of herbicides and their mixtures. The experiments were established on three soil stands the south-western region of Poland, as well as on *chernozems* in the surroundings, *distric cambisols* and *haplic luvisols.* Evaluation of herbicide effectiveness was determined on the basis of quantitative analysis of weed infestation, as well as grain yield using analysis of variance for randomized blocks (AWAR) and half-confidence interval of Tukey's test. Fertilization and plant protection treatments targeted on pests and plant diseases followed current recommendations. On selected soil stands were assessed mezotrione weed control effect, as well as of its mixture with nicosulfuron used once and according to divided doses system in diffrent dates and phases of maize plant development, along with rimsulfuron used with adjuvant and dicamba in a two leaf stage of maize. Weed control effect regarding particular weed occurrence was compared to the application of nicosulfuron and rimsulfuron. On grey brown podsolic soil weed control effectiveness using glyphosat in pre-germination date, as well as florasulam + 2,4-D + rimsulfuron + adjuvant applied after maize germination were additionally investigated.

Weed control was visually assessed on the basis of estimated analysis of weed infestation which took place 4–5 weeks after spraying. Before harvesting was assessed secondary weed infestation using the agrophytosociological method – degree of soil coverage by crop and weeds in % and condition of plants in scale 1 : 9. Maize harvesting was done manuelly in the phase of full maturity, more grain yield and dry matter containing over 15% moisture were determined.

Table 1. Herbicides and their mixtures applied on diffrent soils

IUNG PIB Wrocław 2004–06

Soil type	Active ingredient	Dose per ha [l, kg, g]	Date of application
Chernozems Distric cambisols, Haplic luvisols	mesotrione (100 g/l)	full dose = 100 g	BBCH=15
	mesotrione (100 g/l)	1/2 dose = 50 g	BBCH=13
		1/2 dose = 50 g	BBCH=16
	mesotrione (100 g/l) +nicosulfuron (40 g/l)	full dose = 80 g +40 g	BBCH=15
	mesotrione (100 g/l) +nicosulfuron (40 g/l)	1/2 dose = 40 g +20 g	BBCH=13
		1/2 dose = 40 g +20 g	BBCH=16
	rimsulfuron +isodecyl alcohol ethoxylate (25% + 0.1%) +dicamba (480 g/l)	40 g +0.1% +240 g	BBCH=12
	nicosulfuron (40 g/l)	60 g	BBCH=15
	rimsulfuron +isodecyl alcohol ethoxylate (25% + 0.1%)	60 g +0.1%	BBCH=15
Haplic luvisols	glyphosat (680 g/kg)	680 g	BBCH=00
	rimsulfuron +isodecyl alcohol ethoxylate (25% + 0.1%) +florasulam (6.25 g/l) +2,4-D (452 g/l)	40 g +0.1% +3.12 g +226 g	BBCH=18

RESULTS AND DISCUSSION

Field inspections undertaken by scientific workers of IUNG – Wrocław in the years 2000–2005 in south-western region of Poland enabled to determine characteristic weed communities found in maize stands on typical soils. The following taxons dominated on alluvial soils: *Echinochloa crus-gali*, *Chenopodium album*, *Amaranthus retroflexus*. They were often accompanied by thermophilic late-emerging species: *Aethusa cynapium*, *Setaria* spp., *Solanum nigrum*. On brown soils typically occurred *E. crus-galli*, *S.* spp., *C. album*, *A. arvensis*, as well as *Galium aparine* and *Veronica hedrifolia* which often were winter forms. Grey brown podsolic soils were infested by the following weeds: *E. crus-galli*, *E. repens*, *C. album*, *Galinsoga parviflora*, *Capsella bursa-pastoris*, as well as relatively high amount of *A. arvensis*, *Centaurea cyanus* and *Viola arvensis*. Some weed species showed decreased sensitivity to sulphonylurea herbicides (Gołębiowska and Rola 2004; Rola 2002) (Table 2).

Similar observation regarding communities of maize weeds was performed in Czech Republic (Tyser and Holec 2004). High weed control efficiency regarding the mentioned species was reported for many years for herbicides of sulphonylurea derivatives group (Menck *et al*.1998; Rola 2002). On cultivated fields there can be often met ecotypes characterised by increased tolerance of active ingredients of those herbicides and therefore, difficult to control (Rola and Marczewska 2002; Rola and Rola 2002; Kucharski *et al*. 2004).

Table 2. Decreased sensitivity of some weed species to sulphonylurea herbicides used in maize cultivation

IUNG PIB Wrocław 2003–06

Weed species	Active ingredients of sulphonylurea herbicides		
	foramsulfuron +jodosulfuron +sejfner +adjuvant 300 g/kg + 10 g/kg + 300 g/kg	nicosulfuron 60 g/l	rimsulfuron + adjuvant 60 g + 0.1%
Aethusa cynapium	+++	+++	+++
Amaranthus retroflexus	+++	+++	+++
Chenopodium album,	++	++	+
Echinochloa crus galli	++++	+++	+++
Elymus repens	+++	++++	+++
Galium aparine	+++	+++	+++
Galinsoga parviflora	+++	+++	+
Setaria spp	++	++	+++
Solanum nigrum	+++	++	+
Veronica hedrifolia	+++	++	++
Viola arvensis	++++	+++	++

++++ sensitive species (85–100% weed control), +++ medium-sensitive species (85–70% weed control), ++ medium-resistant species (60–70% weed control), + resistant species (> 60% weed control).

In the experiment established on *chernozems*, weeds community was represented by such species as: *E. crus galli*, *S.viridis*, *Ch. album*, *A. retroflexus*, *V. arvensis*, *Thlaspi arvense* or *S. nigrum* occurring with average intensity. Mesotrione applied at a full dose controlled *E. crus galli*, *S. viridis* and *V. arvensis* was classified as medium sensitive species in 75–80%. Compensation of not controlled weeds remained until harvesting and it did result in decreased grain yield. Nicosulfuron + mesotrione mixture applied once occurred to be insufficiently effective as far as *E. crus-galli* and *S. viridis* were concerned. In divided – applications system, after using the first dose of mesostrione, applied as the only herbicide and in the mixture with nicosulfuron, effectiveness was obtained similar to that of comparative herbicides like nicosulfuron and rimsulfuron + isodecyl alcohol ethoxylate (Table 3). The second dose of those herbicides gave good results of controlling late-emerging weeds – *E. crus-galli*, *S. viridis* and *A. cynapium* and the best results were achieved leavng the plantation clean until harvesting. Grain yields obtained from those objects were significantly higher than single application of mesotrione and sulphonylurea herbicides (Table 3). The results obtained point to further diminishing of herbicide doses on plantations showing low weed infestation, which was also stressed by other authors (Proven *et al*. 1991).

Table 3. Effectiveness of herbicide mixture controlling mono- and dicotyledone weeds occurring on *chernozems*

IUNG PIB Wrocław 2004–06

Herbicides	Dose per ha	dateof application	Efficacy of weed control [%]								Yield of grain [t/ha]
			ECHCG	SETVI	CHEAL	AMARE	THLAR	VIOAR	AETCY	SOLNI	
Untreated*	–	–	27	19	22	11	9	8	6	3	6.15
Mesotrione	full dose = 100 g	BBCH = 15	78	74	100	92	100	80	90	87	10.13
	½ dose = 50 g +½ dose = 50 g	BBCH = 13	82	77	100	100	100	84	88	90	12.83
		BBCH = 16	85	86	100	100	100	100	90	100	
Mesotrione +nicosulfuron	full dose = 80 g +40 g	BBCH = 15	88	83	100	92	96	94	90	93	11.36
	½ = 40 g +20 g +½ =40 g +20 g	BBCH = 13	85	80	100	96	100	93	92	100	12.45
		BBCH = 16	92	95	100	100	100	100	100	100	
Rimsulfuron +isodecyl alcohol ethoxylate +dicamba	40 g + 0.1%+ 240 g	BBCH = 12	86	83	100	93	100	93	90	92	11.56
Nicosulfuron	60 g	BBCH = 15	92	85	75	86	100	90	86	85	10.88
Rimsulfuron +isodecyl alcohol ethoxylate	60 g +0.1%	BBCH = 15	88	88	73	85	100	87	85	78	10.42
								LSD (0.05)			1.032

* for untreated plots is shown the number of weeds per 1m^2
ECHCG – *Echinochloa crus-galli*, SETVI – *Setaria viridis*, CHEAL – *Chenopodium album*, AMARE – *Amaranthus retroflexus*, THLAR – *Thlaspi arvense*, VIOAR – *Viola arvensis*, SOLNI – *Solanum nigrum*

In the years 2004–2006 were recorded the following taxons on *distric cambisols*: *E. crus-galli* + *Setaria* spp., *Ch. album*, *A. arvensis*, *G. aparine*, *V. arvensis*, *Fumaria officinalis*, *Geranium pussilum*, *Artemisia vulgaris*. That community was most effectively controlled with the use of mesotrione +nicosulfuron and rimsulfuron + adjuvant + dicamba mixtures applied once, except for *G. pussilum* which reacted less desirably to the first mixture, while *F. officinalis* and *V. arvensis* – to the second mixture. Both mixtures effectively controlled monocotyledone species *E. crus-galli* and *S. spp.* (Table 4). Mesotrione applied in full dose reduced weed size, especially *A. vulgaris*, yet *F.officinalis* and *G. aparine* proved to be medium-sensitive species, while *G. pussilum*-medium resistant one, which in a wet year resulted in compensation of that species (Table 4).

Table 4. Effectiveness of herbicide mixture controlling mono- and dicotyledone weeds occurring on *distric cambisols*

IUNG PIB Wrocław 2004–06

Herbicides	Dose per ha	Date of application	Efficacy of weed control [%]									Yield of grain [t/ha]
			ECHC+ SETSS	CHEAL	ANTAR	VIOAR	GALAP	FUMOF	GERPU	ARTVU	OTHER	
Untreated*	–	–	97	14	9	7	6	5	5	3	11	4.27
Mesotrione	full dose = 100 g	BBCH = 15	78	100	96	90	83	84	70	90	98	9.65
	½ dose = 50 g +½ dose = 50 g	BBCH = 13	78	100	100	100	84	88	75	83	100	9.11
		BBCH = 16	83	100	100	100	80	86	75	88	100	
Mesotrione + nicosulfuron	full dose = 80 g +40 g	BBCH = 15	92	100	100	100	92	94	82	87	100	12.11
	½ = 40 g +20 g +½ =40 g +20 g	BBCH = 13	75	89	86	85	80	96	82	78	100	10.25
		BBCH = 16	82	93	92	90	85	95	80	80	100	
Rimsulfuron +isodecyl alcohol ethoxylate +dicamba	40 g+ 0.1%+ 240 g	BBCH = 12	88	95	100	82	100	80	88	77	100	12.05
Nicosulfuron	60 g	BBCH = 15	88	780	86	95	85	88	93	74	100	9.25
Rimsulfuron +isodecyl alcohol ethoxylate	60 g +0.1%	BBCH = 15	82	75	85	96	88	90	95	72	100	9.54
									LSD (0.05)			1.145

* for untreated plots is shown the number of weeds per 1m^2
ECHCG – *Echinochloa crus-galli*, SETSS – *Setaria spp*. CHEAL – *Chenopodium album*, ANTAR – *Anthemis arvensis*, ELYRE – *Elymus repens*, GALAP – *galium aparine*, VIOAR – *Viola arvensis*, FUMOF – *Fumaria officinalis*, GERPU – *Geranium pusillum*, ARTVU – *Artemisia vulgaris*

Segetal plant community on *haplic luvisols* was dominated by monocotyledone species *E. crus-galli* and *E. repens*. Dicotyledone taxons occurred less intensively, involving such species as *Ch. album*, *G. parviflora*, *C. bursa-pastoris*, *C. cyanus*, *V. arvensis*, *A. arvensis* and *V. persica* with its winter forms (Table 5). Application of rimsulfuron +isodecyl alcohol ethoxylate +dicamba mixture eliminated the mentioned species and proved to be an effective solution on that type of soil. Only *E. repens*, numerously occurring in the experiment, was of medium sensitivity, similarly to winter forms of *A. arvensis* and *V. persica* (Table 5). Herbicide mesotrione and mixture of mesotrione +nicosulfuron applied as divided – application system was less effective as compared to full dose use. Also nicosulfuron and rimsulfuron did not give good results and did not protect the plantation from weed infestation. The species like *C. cyanus* and *V. arvensis* turned out to be of medium sensitivity, while *Ch. album* was controlled merely in 65% (Table 5).

Table 5. Efficiency of herbicide mixture in the control of mono- and dicotyledone weeds occurring on grey-brown *haplic luvisols*

IUNG PIB Wrocław 2004–06

Herbicides	Dose per ha	Date of application	Efficacy of weed control [%]										Yield of grain [t/ha]
			ECHCG	ELYRE	CHEAL	GASPA	VERPE	CAPBP	ANTAR	CE NCY	VIOAR	OTHER	
Untreated*	–	–	172	57	33	21	11	13	9	7	4	9	4.27
Mesotrione	full dose = 100 g	BBCH = 15	74	78	100	95	86	100	98	93	95	100	9.66
	½ dose = 50 g +½ dose = 50 g	BBCH = 13	70	68	100	93	82	93	96	90	93	100	9.65
		BBCH = 16	78	75	100	98	85	100	84	96	98	100	
Mesotrione +nicosulfuron	full dose = 80 g +40 g	BBCH = 15	92	80	88	72	80	100	74	70	85	100	9.11
	½ = 40 g +20 g +½ =40 g +20 g	BBCH = 13	84	83	90	85	78	100	80	80	90	100	9.11
		BBCH = 16	88	85	95	87	84	100	85	82	95	100	
Rimsulfuron +isodecyl alcoholetho-xylate +dicamba	40 g+ 0.1%+ 240 g	BBCH = 12	92	80	100	90	86	96	85	97	100	100	12.05
Nicosulfuron	60 g	BBCH = 15	96	87	82	100	84	100	96	84	85	100	10.05
Rimsulfuron +isodecyl alcohol ethoxylate	60 g +0.1%	BBCH = 15	93	90	65	100	86	100	88	82	80	100	10.11
								LSD (0.05)					0.987

* for untreated plots is shown the number of weeds per 1m^2
ECHCG – *Echinochloa crus-galli*, ELYRE – *Elymus repens*, CHEAL – *Chenopodium album*, GASPA – *Galinsoga parviflora*, VERPE – *Veronica persica*, CAPBP – *Capsella bursa-pastoris*, ANTAR – *Anthemis arvensis*, CENCY – *Centaurera cyanus*, VIOAR – *Viola arvensis*

Table 6. Efficiency of mono- and dicotyledone weed control on *haplic luvisols* in pre-germination phase

IUNG PIB Wrocław 2003–06

Herbicides	Dose per ha	Date of application	Efficacy of weed control [%]								Yield of grain [t/ha]
			ECHCG	ELYRE	CHEAL	GASPA	CAPBP	ANTAR	CENCY	VIOAR	
Untreated*	–	–	172	57	33	21	13	9	7	4	4.27
Gliphosate	680 g/kg	BBCH = 00	88	92	100	78	100	92	83	92	10.25
Rimsulfuron +adjuvant +florasulam +2,4-D	0.15 +0.1% 3.12 +226 g	BBCH = 18	100	100	100	100	100	100	100	100	11.56
								LSD (0.05)			1.287

* for untreated plots is shown the number of weeds per 1m^2
ECHCG – *Echinochloa crus-galli*, ELYRE – *Elymus repens*, CHEAL – *Chenopodium album*, GASPA – *Galinsoga parviflora*, CAPBP – *Capsella bursa-pastoris*, ANTAR – *Anthemis arvensis*, CENCY – *Centaurera cyanus*, VIOAR – *Viola arvensis*

Therefore, the most effective proved to be control system based on glyphosate, targeted on the species occurring before maize germination and in the phase of 7–8-leaf of plants, when secondary infestation became a fact, the mixture of rimsulfuron +isodecyl alcohol ethoxylate +dicamba was the most succesful (Table 6). The results obtained in the experiments conducted on diffrent types of soil point to the possibility of effective weed control using doses indispensable for reducing segetal plant communities. In the case of their low intensity the use of herbicides according to split – applications system or herbicide mixture to appropriety meet the state of weed infestation can be introduced (Drexler *et al*. 1998; Dobrzański and Adamczewski 2001; Domaradzki 2006).

CONCLUSIONS

1. The assessment of weed infestation of maize cultivated on *chernozems* points to low diversity of plant species, as well as to its low intensity. High efficiency of weed control was obtained applying mesotrione +nicosulfuron in divided doses which resulted in statistically higher yield than those in the objects untreated with herbicides and than the yield obtained when mesotrione, rimsulfuron and nicosulfuron were used separately
2. High weed control effect was also obtained for half of this mixture dose (Table 3).
3. On *distric cambisols* was observed high intensity of *E. crus-galli*, *Setaria* spp., *Ch. album* and *A. retroflexus* occurrence. *A. vulgaris* proved to be a perennial, trublesome weed. The mentioned species were most effectively controlled by herbicide mixtures composed of mesotrione + nicosulfuron and rimsulfuron + adjuvant + dicamba applied once in full dose.For those objects there were obtained significantly the highest grain yields (Table 4).

4. Weed community found on *haplic luvisols* was mainly composed of *E. crus-galli*, *E. repens*, *Ch. album*, *G. parviflora*, *A. arvensis*, as well as *V. persica* with its winter forms. The mixture rimsulfuron + adjuvant + dicamba proved to be the most effective in elimination of these species,except for *E. repens* numerously occurring in the experiment whichwas medium-sensitive, as well as winter forms of *A. arvensis* and *V. persica* (Table 5).
5. The system of weed control using glyphosate in the case of the species overwintering and germinating before a cultivated plant and additional secondary weed control in 7–8 leaf maize phase with the mixture of rimsulfuron + adjuvant + florasulam + 2,4-D allowed to eliminate undesired plants on that soil stand in the most efficient way and to achieve the highest grain yield (Table 6).

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POLISH SUMMARY

PROBLEMY W REGULACJI ZACHWASZCZENIA SYSTEMAMI HERBICYDOWYMI W KUKURYDZY

Dokładne rozpoznanie stanu i stopnia zachwaszczenia w południowo-zachodnim rejonie Polski dało podstawę do założenia doświadczeń na trzech typach gleb, mające na celu ocenę efektywności niszczenia zbiorowisk chwastów odpowiednio dobranymi systemami herbicydowymi. Wysoką skuteczność ich niszczenia na madach uzyskano po zastosowaniu mieszaniny mesotrione + nicosulfuron w dawkach dzielonych. W doświadczeniu założonym na glebach brunatnych gatunki te najefektywniej niszczyły, odpowiednio dopasowane do stanu zachwaszczenia mieszaniny herbicydów mesotrione + nicosulfuron i rimsulfuron + adjuvant + dicamba aplikowane jednorazowo, w pełnych dawkach. Mieszanina rimsulfuron + adjuvant + dicamba najskuteczniej eliminowała występujące na glebach płowych gatunki chwastów, jedynie *Elymus repens* licznie występujący w doświadczeniu był średniowrażliwy, podobnie jak formy ozime *Anthemis arvensis.* Mieszanina rimsulfuron + adjuvant + florasulam + 2,4-D pozwoliła najskuteczniej eliminować roślinność niepożądaną na tym stanowisku glebowym i uzyskać wysoki plon ziarna.