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Optimization of Herbicide Doses in Sustainable System of Maize Cultivation

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Abstract

Amendment to the EU standards has considerably reduced the list of biologically active substances of herbicides meeting the criteria of Good Agricultural Practice. The required usage of these substances at their maximum recommended rates ensures their fast action and high efficiency of a treatment with respect to a number of weed species, regardless their susceptibility. However, the herbicides have often been used in excess which has not always been justified by the true necessity of weed control and by their selectivity for the protected crop. The realistic knowledge of the weed infestation hazards in plough–system maize cultures maintaining appropriate crop rotation should enable meeting the most important goal of sustainable agriculture – reducing the rates of chemical pesticides to the indispensable minimum. At low weed infestation levels and at the reduced rates of herbicides it is necessary to assist the herbicide`s active ingredient by the addition of adjuvants. As a consequence, one may expect the improvement in the herbicide efficacy, even if it has been applied at the reduced rate, as well as stabilization of an herbicide performance under unfavorable weather conditions. On haplic phaeozems, it is possible to successfully control monocotyledonous and dicotyledonous weeds with Callisto 100 SC + Milagro 040 SC mixture supplied with Atpolan 80 EC adjuvant and applied in split recommended doses, as well as in the doses reduced by as much as 50%. On haplic cambisols, only sporadic occurrence of Echinochloa crus–galli (L.) P. Beauv and Setaria viridis (L.) P.Beauv. was recorded, but considerable incidence of Chenopodium album L. and Amaranthus retroflexus L., as well as individual plants of Artemisia vulgaris L. had been observed. In case of low infestation by monocot weeds, the satisfactory effect could only be achieved when the mixture was applied at the full recommended doses of its components and supplied with adjuvant. The addition of Atpolan 88 EC adjuvant provided effective control of such species as Viola arvensis Murray, Galium aparine L., Geranium pusillum Burm. f. ex L. and Artemisia vulgaris L., even when the dose was reduced by 1/3.

Keywords: Herbicide systems, Reduced doses, Herbicide mixtures, Maize, Weed control.

Öz

AB standartlarındaki değişiklik, İyi Tarım Uygulamaları kriterleri ile örtüşen herbisitlerin biyolojik aktif maddelerinin listesini dikkat çekici miktarda azalttı. Bu maddelerin maksimum tavsiye edilen oranlarda gerekli kullanımı, bir uygulamanın duyarlılıklarına bakmaksızın bir grup yabancı ot türünde hızlı ve yüksek etkisini sağlar. Bununla birlikte, herbisitler çoğu kez yabancı ot kontrolü için gerçek miktarı ve korunan ürün için seçiciliklerini doğrulamayan aşırı dozlarda kullanılırlar. Uygun toprak rotasyonunun sağlandığı pulluklu mısır kültürleri sisteminde yabancı ot istilaları tehlikelerinin gerçekçi bilginin, kimyasal pestisitlerin gerekli minimum oranlara azaltan sürdürülebilir tarımın en önemli amacıyla buluşmasına olanak verilmelidir. Bu, düşük yabancı ot istilaları ve herbisitlerin azaltılan oranlarında, herbisitlerin aktif maddelerine adjuvant eklenerek yardımcı olmak için gereklidir. Bunun bir sonucu olarak, adjuvant eklenmesi durumunda herbisitin performansının uygun olmayan hava koşullarında stabilizasyonu sağlanmasının yanı sıra azaltılan oranlarda uygulanması durumunda bile etkisinde artış beklenebilir. Haplik phaeozemler üzerinde, Atpolan 80 EC adjuvant ve %50'ye kadar azaltılan dozun yanı sıra, bölünmüş tavsiye edilen dozlarıyla uygulanan Callisto 100 SC + Milagro 040 SC karışımı ile monokodiledon ve dikodiledon yabancı otların başarılı bir şekilde kontrolü olanaklıdır. Haplik cambisoller üzerinde sadece Echinochloa crus–galli (L.) P. Beauv ve Setaria viridis (L.) P.Beauv. fakat Artemisia vulgaris L.'e ait tek tek bitkilerin yanı sıra, önemli oranda Chenopodium album L. ve Amaranthus retroflexus L. gözlemlendi. Monokodiledon yabancı otların düşük istilalarının olması durumunda, yeterli etkiye sadece karışım bileşenlerin önerilen tam dozlarında uygulandığında ulaşıldı ve adjuvantla sağlandı. Atpolan 88 EC adjuvant ilavesi, doz 1/3'e düşürüldüğünde dahi Viola arvensis Murray, Galium aparine L., Geranium pusillum Burm. f. ex L. ve Artemisia vulgaris L. gibi türlerin etkili kontrolünü sağladı.

Anahtar Kelimeler: Herbisit sistemleri, Azaltılmış doz, Herbisit karışımları, Mısır, Yabancı ot kontrolü.

Introduction

Modern technologies of maize cultivation and fertilization contribute to the increase in agricultural production indices, while, on the other hand, indirectly providing favorable conditions for the development and growth of segetal weeds. Yet the simplified tillage, considerable saturation of crop rotation with cereals and maize cultivation as monoculture do significantly affect the differentiation of quantitative and qualitative composition of the segetal flora (Gołębiowska and Kaus, 2009). The precise and realistic knowledge of the weed infestation hazards in plough–system maize cultures maintaining appropriate crop rotation should enable meeting the most important goal of sustainable agriculture–reducing the rates of chemical pesticides to the indispensable minimum.

Amendment to the EU standards has considerably reduced the list of biologically active substances of herbicides meeting the criteria of Good Agricultural Practice. The required usage of these substances at their maximum recommended rates ensures their fast action and high efficiency of a treatment with respect to a number of weed species, regardless their susceptibility (Sutton et al., 2002; Contiero, 2005; Praczyk and Skrzypczak, 2009). The possibility of combined application of chemical substances in mixtures additionally supported by adjuvants seems to be highly promising as far as weed control is concerned (Woźnica, 2003; Hamouz et al., 2005).

The primary aim of the research was to assess the effectiveness of control of the weed communities on two different types of soil, using the mixture of mesotrione and nicosulfuron, as well as to verify the possibility of their application at the reduced rates. The second study goal involved evaluation of the effect of two oil adjuvants: Actirob 842 EC and Atpolan 80 EC, on that mixture`s herbicidal effectiveness with respect to Echinochloa crus–galli L. P. Beauv. and some of the annual dicotyledonous weeds. The third objective was to evaluate the cost–effectiveness of the treatments.

Materials and Methods

Research on feasibility of the use of Callisto 100 SC + Milagro 040 SC mixture for weed control in maize was conducted in 2007–2009, as a field experiment, involving two localities:

Near Wrocław, on haplic phaeozems, classified as very good and good wheat complex, characterized by 3.6% humus content and pH 6.3; on haplic cambisols featuring 2.3% humus content and pH 5.5, belonging to very good rye complex.

The experiment was established in maize cultivated according to the following crop rotation pattern: winter wheat + white mustard intercrop, maize for grain, spring barley. On the experimental stand the plough system of soil tillage was introduced, with seedbed preparation using standard tools and fertilization following agronomic recommendations.

Herbicide mixture was applied according to the system of split doses: half the dose being applied at 2–3–leaf stage of maize (BBCH 12) against the weeds at their 1 – 5 leaf stage and the other half the dose–at 5–6–leaf stage of maize (BBCH 15) against the weeds at their advanced developmental stages, but before their flowering.

Herbicide mixture efficacy was assessed as the percentage of weed damage relative to the non–treated area, according to methods commonly accepted in herbology (Domaradzki et al., 2001).

Maize harvest in field experiments was performed manually, at full maturity stage and was accompanied by determination of the following yield parameters: cob number and weight, grain yield and the 1000 kernel weight (TKW). The results were compared to those obtained from the non–treated area. The grain yield and the TKW were calculated at the grain moisture level of 15%.

The active ingredients (a.i.) of the tested herbicide mixture belong to different chemical classes, characterized by the different modes of action (MOA). The a.i. of Milagro 040 SC, nicosulfuron, is the amino acid biosynthesis inhibitor, responsible for disrupting the protein synthesis in the plant cells. On the other hand, mesotrione, the a.i. of Callisto 100 SC, inhibits the biosynthesis of carotenoid plant pigments, causing plants whitening and their growth inhibition (Table 1.).

The adjuvants added to the tested mixture also belong to the different groups and as such represent different physical–chemical properties (Table 1.).

Atpolan 80 EC belongs to the oils of mineral origin, i.e. paraffin oils obtained in the process of crude oil refining. Due to the good solubility in them of the active ingredients of herbicides and their ability to penetrate plant cuticle waxes, paraffin oils improve herbicide uptake by the weeds to be controlled. Actirob 842 EC is an adjuvant of the fatty acids methyl esters class, characterized by similar properties to those of mineral oils.

Table 1. Effectiveness of selected herbicides applied in full and reduced doses in the weed control on haplic phaeozems and their effect on maize yield in 2007–2009

Treatment	Dose (l*ha^{-1})		Efficacy (%)								
			ECHCG	SETVI	CHEAL	AMARE	THLAR	VIOAR	AETCY	SOLNI	Other (Antar, Lampu, Steme, Angar)
Untreated	-	-	*17	*8	*22	*11	*6	*8	*6	*9	*11
Milagro 040 SC	0,8 + 1,0	1/1 FD** BBCH 12 + BBCH 15	85	86	92	96	100	92	94	88	100
+ **Callisto 100 SC**	0,53 + 0,67	2/3 FD** BBCH 12 + BBCH 15	85	83	89	93	98	86	92	90	92
	0,40 + 0,50	1/2 FD** BBCH 12 + BBCH 15	80	78	83	90	95	83	78	88	87
Milagro 040 SC	0,8 + 1,0 + 1,5	1/1 FD** BBCH 12 + BBCH 15	98	100	97	99	100	95	95	100	100
+ Callisto 100 SC	0,53 + 0,67 + 1,5	2/3 FD** BBCH 12 + BBCH 15	95	92	93	96	100	87	90	98	93
+ Actirob 842 EC	0,40 + 0,50 + 1,5	1/2 FD** BBCH 12 + BBCH 15	90	87	85	90	96	84	84	85	90
Milagro 040 SC	0,8 + 1,0 + 1,5	1/1 FD** BBCH 12 + BBCH 15	100	100	100	100	100	99	99	100	100
+ Callisto 100 SC	0,53 + 0,67 + 1,5	2/3 FD** BBCH 12 + BBCH 15	95	95	95	97	100	89	94	98	96
+Atpolan 88 EC	0,40 + 0,50 + 1,5	1/2 FD** BBCH 12 + BBCH 15	93	90	90	93	98	86	88	90	93

Number of weeds per m^2, **FD (full dose), 2/3 FD, 1/2 FD (reduced doses) ECHCG Echinochloa crus–galli, SETVI Setaria viridis, CHEAL Chenopodium album, SOLNI Solanum nigrum, AMARE Amaranthus retroflexus, ANTAR Anthemis arvensis, VIOAR Viola arvensis, AETCY Aethusa cynapium, THLAR Thlaspi arvense, LAMPU Lamium purpureum, STEME Stellaria media, ANGAR Anagallis arvensis.

The chemicals subject to examination were applied at three doses: maximum recommended (100%) dose (full dose–FD) and at the reduced doses–1/2 FD and 2/3 FD.

Statistical analysis of the research results was based on the analysis of variance for field and microplot experiments conducted in randomized split plot design. The significance of differences was tested with Tukey confidence semi–interval at significance level p= 0.05, using AWAR 2.0 and Statgraphics v. 1.41 PL software.

Results

Weed control effectiveness by Callisto 100 SC + Milagro 040 SC herbicide mixture on haplic phaeozems:

In the weed community on the haplic phaeozems a considerable proportion of barnyard grass (Echinochloa crus–galli L. P.Beauv), lamb's quarters (Chenopodium album L.) and redroot pigweed (Amaranthus retroflexus L.) was recorded, these weeds being often accompanied by the less numerous thermophilous, late emerging species like fool`s parsley (Aethusa cynapium L.), green bristlegrass (Setaria viridis L. P.Beauv.) and black nightshade (Solanum nigrum L.). The chemical control of weed infestation on that soil stand was carried out in two variants: A) with the exclusive use of Callisto 100 SC + Milagro 040 SC herbicide mixture applied in split full doses and in split doses reduced by 1/3 and by 1/2, B) with the use of the same herbicide mixture supplied with Atpolan 80 EC or Actirob 842 EC adiuvants, also applied in the form of split full and split reduced doses.

Variant A

Two monocotyledonous species were recorded in the botanical composition of the weed community: barnyard grass (17 units/m^2) and green bristle grass (8 units/m^2). The examined herbicide mixture, deployed at full dose, resulted in the weed control ranging between 88% and 86% respectively, while the same preparation used at the dose reduced by 1/3 proved to be less efficient, the resulting weed control amounting to 85% and 83% respectively (Table 1.). Any further dose reduction seemed unreasonable, as the weed species that had not been completely destroyed by the treatment occurred as secondary weed infestation and had affected the obtained grain yield of maize

significantly (Table 2.). As far as the communities of the dicotyledonous species were concerned, the recorded species include the lamb's quarters (22 units/m^2), redroot pigweed (11 units/m^2), field

Table 2. Effectiveness of selected herbicides applied in full and reduced doses in the weed control on haplic cambisols and their effect on maize yield in 2007–2009

Treatment	Dose l*ha^{-1}		Efficacy (%) ECHCG	SETVI	CHEAL	VIOAR	GALAP	GERPU	ARTVU	Other (Antar, Fumof)
Untreated	-	-	*11	*6	*49	*13	*6	*9	*5	*11
Milagro 040 SC + Callisto 100 SC	0,8 + 1,0	1/1 FD** BBCH 12 + BBCH 15	97	95	94	96	93	97	90	100
	0,53 + 0,67	2/3 FD** BBCH 12 + BBCH 15	93	90	86	90	86	89	85	98
	0,40 + 0,50	1/2 FD** BBCH 12 + BBCH 15	85	85	80	83	78	81	76	93
Milagro 040 SC + Callisto 100 SC + Actirob 842 EC	0,8 + 1,0 + 1,5	1/1 FD** BBCH 12 + BBCH 15	100	100	100	100	100	100	92	100
	0,53 + 0,67 + 1,5	2/3 FD** BBCH 12 + BBCH 15	92	95	90	90	88	90	95	95
	0,40 + 0,50 + 1,5	1/2 FD** BBCH 12 + BBCH 15	88	90	88	85	82	84	85	93
Milagro 040 SC + Callisto 100 SC Atpolan 88 EC	0,8 + 1,0 + 1,5	1/1 FD** BBCH 12 + BBCH 15	98	96	96	100	100	100	92	100
	0,53 + 0,67 + 1,5	2/3 FD** BBCH 12 + BBCH 15	92	93	86	92	90	92	94	99
	0,40 + 0,50 + 1,5	1/2 FD** BBCH 12 + BBCH 15	86	88	85	85	84	84	85	96

Number of weeds per m^2, **FD (full dose), 2/3 FD, 1/2 FD (reduced doses)
ECHCG *Echinochloa crus–galli*, SETVI *Setaria viridis*, CHEAL *Chenopodium album*, AMARE *Amaranthus retroflexus*, ARTVU *Artemisia vulgaris*, ANTAR *Anthemis arvensis*, VIOAR *Viola arvensis*, GALAP *Galium aparine*, FUMOF *Fumaria officinalis*, GERPU *Geranium pusillum*.

pennycress (Thlaspi arvense L.) (6 units/m^2), field violet (8 units/m^2), fool`s parsley (6 units/m^2) and black nightshade (9 units/m^2). The mixture of mesotrione and nicosulfuron was a successful means to control these weeds, regarding most of the listed species, both after its application at full dose and at the doses reduced by 1/3 and 1/2. Only the field violet proved to be of medium susceptibility to the application of that mixture at the reduced doses (Table 1.).

Variant B

The highest effectiveness, providing nearly 100% weed control, in mono– and dicotyledonous weed community, was obtained after application of Callisto 100 SC + Milagro 040 SC mixture with the addition of Atpolan 88 EC adiuvant at full dose, which, eventually, allowed to obtain the highest grain yield size. The reduction in the mixture dose by 1/3 and 1/2 did not decrease its effectiveness and all weed species observed in the experiment showed control levels ranging between 85% and 100%. The treatment allowed sustaining the maize stand without weed infestation until harvest time. As a result of the high effectiveness of that mixture, the high yield was achieved of the maize grain of considerable size and weight, amounting to 10.8 and 10.2 t ha^{-1} respectively, which proved significantly higher than the yield of the non–treated area (Table 1. and Table 2.). Comparable effectiveness of weed control in that stand and high grain yields were also obtained after using that

same mixture assisted with Actirob 842 EC adjuvant. Only in the case of field violet and fool`s parsley the weed control showed less satisfactory, amounting to 84% (Table 1.).

Application of the reduced doses of herbicide mixture supported by the addition of both adjuvants allowed to ensure satisfactory effectiveness of weed control in the case of barnyard grass, green bristle grass, lamb's quarters, redroot pigweed, field pennycress, and black nightshare. Less satisfactory results of weed control were observed in the case of field violet and fool`s parsley, both species showing medium susceptibility to the herbicide mixture with Actirob 842 EC at the reduced doses.

Weed control effectiveness of Callisto 100 SC + Milagro 040 SC herbicides mixture on haplic cambisols:

The haplic cambisols site was predominantly infested by the lamb's quarters. Apart from that weed, a considerable degree of infestation was observed by such species as field chamomile (Anthemis arvensis L.), stickywilly (Galium aparine L.), field violet and small geranium (Geranium pusillum Burm. f. ex L.). In that plant community the species diversity was recognized as lower, compared to haplic phaeozems. Among the monocotyledonous species, barnyard grass and green bristlegrass occured late, with small intensity and they were accompanied by sporadically growing quack grass (Elymus repens (L.) Gould).

Similarly to the haplic phaeozems site, the herbicides were applied in two variants – A and B.

Variant A

In the growing seasons 2007–2009, the weed community on haplic cambisols was controlled with the exclusive use of Callisto 100 SC + Milagro 040 SC herbicide mixture at full dose, as well as at the doses reduced by 1/3 and 1/2.

These treatments reduced the incidence of barnyard grass and green bristlegrass to an acceptable degree, although in that stand their number was rather low anyway–a total density of the two taxons amounted 17 units/. In each one of the herbicide treatments, both after application of full and reduced doses, the achieved control of the monocotyledonus weeds exceeded 85% compared to the non–treated area (Table 3.).

The best control of the dicotyledonous species was provided by the mixture applied at full dose and at the dose reduced by 1/3. In the case of intensive infestation by the lamb's quarters (49 units/m^2), field violet (13 units/m^2), stickywilly (6 units/m^2) and small geranium (9 units/m^2), as well as in the presence of common wormwood (Artemisia vulgaris L.) (5 units/m^2), the reduction of the herbicide dose by 1/2 proved to be ineffective (Table 2.).

Variant B

The effectiveness of weed control on haplic cambisols was also estimated for Calisto 100 SC + Milagro 040 SC mixture supplemented with Actirob 842 EC and Atpolan 88 EC adjuvants, at full and at reduced doses.

The highest effectiveness of weed control, considered all the weed species at this site, was achieved by the mixture applied at full dose, with the addition of both Actirob 842 EC and Atpolan 88 EC adiuvants. The treatment allowed sustaining maize stand without weed infestation until harvest and obtaining the highest grain yield in the amount of 8,53 and 8,68 t*ha^{-1} respectively, that proved significantly higher compared to the non–treated area (Table 2. and table 3.). On the same soil site, the application at the dose reduced by 1/3 supplemented by Atpolan 88 EC brought about a positive effect, particularly in the control of such species as field violet, field bedstraw, small geranium and common wormwood. However, the addition of another adjuvant, Actirob 842 EC, proved to be ineffective in the control of field violet and common wormwood.

The cost of Calisto 100 SC + Milagro 040 SC herbicide mixture application for weed control in maize on different soil sites makes up, at the current maize grain price in Poland, an equivalent of 0,68 – 0,75 tons of grain, assumed that it is the barnyard grass and dicotyledonous annual weeds that are the actual problem (Table 3.). Considered the continuous emerging of new weed species, a single application of this mixture does not provide the effective control of monocotyledonous or dicotyledonous weeds within the whole plant growing period, particularly on haplic cambisols. On the contrary, such effective control can be achieved by the addition of adiuvants, substances which improve effectiveness, and by deploying the examined mixture in the system of split doses. High

effectiveness of this treatment on haplic phaeozems, especially when the application of herbicide mixture was combined with Atpolan 88 EC, ensured profitable yield of grain, even after its application at the reduced doses (Table 3.).

Table 3. Average yield of maize depending on calculation costs with use chemicals systems of weed control in field experiments.

Herbicide Dose per ha	Dose l*ha^{-1}	Costs of herbicides in grain/ha	Yield of grain t*ha^{-1} Location	
			haplic phaeozems	haplic cambisols.
Untreated	-	-	6,3	4,76
Milagro 040 SC + Callisto 100 SC	0,8 + 1,0	0,68–0,74	+ 3,4	+ 3,50
	0,53 + 0,67	0,46–0,50	+ 2,2	+ 2,15
	0,40 + 0,50	0,34–0,37	+ 2,0	+ 0,89
Milagro 040 SC + Callisto 100 SC + Actirob 842 EC	0,8 + 1,0 + 1,5	0,77–0,80	+ 4,4	+ 3,77
	0,53 + 0,67 + 1,5	0,52–0,54	+ 4,0	+ 3,02
	0,40 + 0,50 + 1,5	0,39–0,4	+ 3,3	+ 1,35
Milagro 040 SC + Callisto 100 SC Atpolan 88 EC	0,8 + 1,0 + 1,5	0,73–0,75	+ 4,7	+ 3,92
	0,53 + 0,67 + 1,5	0,49–0,50	+ 4,5	+ 3,27
	0,40 + 0,50 + 1,5	0,36–0,38	+ 3,9	+ 1,69
	NIR, LSD $_{(p=0,05)}$		0,998	1,061

Costs of application of micstures of herbicides on 1ha-550 PLN = 130 EUR
PRICE OF 1T GRAIN OF MAIZE–715 PLN= 175 EUR.

Discussion

For many years already, plant protection preparations have been recommended for maize cultures that, apart from their herbicidal action, bring about some adverse effects on the environment or may exhibit a phytotoxic activity on the crops to follow (EPPO, 1995). Therefore, by the decision of the European Union countries, the EU Parliament Directive 91/414/EWG has been issued within the framework of the Plant Protection Act, in force since 2003, which aims at elimination or maximum reduction of application of substances that pose a hazard to the agricultural environment. These initiatives led to considerable curtailment of the list of active substances used for plant protection, starting since 2007 (Matyjaszczyk, 2007).

In the near future, however, the use of herbicides for elimination and reduction of weed infestation will be still the fastest and the most effective means of maintaining plantation in a weed-free state. It will therefore remain an indispensable element of cultivation technology. In 2011 there came into force new EU regulations about marketing of crop protection preparations: the regulation by the EU Parliament and by the EU Council no 1107/2009, repealing the Directive 91/414/EWG, as well as the EU Parliament and EU Council Directive no 2009/128/WE, both establishing the frames of community action aiming at sustainable use, registration and marketing of plant protection preparations in three areas of cooperation (northern, central and southern) (Matyjaszczyk, 2007; Surawska and Rzeźnicki, 2010).

Assumptions for the new act on the plant protection meeting the requirements of sustainable agriculture will enforce, to a considerable degree, the development of chemical weed control systems making use of the minimum necessary doses of plant protection preparations, assisted, in order to improve their efficacy, with substances such as adiuvants, safeners or synergists (Woźnica, 2003). That has already been in progress in many research and development centers (Gerhards et al., 2002; Contiero, 2005; Hamouz et al., 2005; Domaradzki, 2006).

In the case of low level of weed infestation and while taking a decision about herbicide application at the reduced doses, it is necessary to protect against adverse factors affecting their performance, by the addition of adiuvants. As a consequence, one can expect the improvement in herbicide effectiveness, even if they are used at reduced doses, as well as some stabilization of herbicide preformance under unfavourable weather conditiions (Skrzypczak et al., 1995; Kapusta et al., 1996; Nalewaja et al., 1998).

Research on the assessment of herbicide mixture Callisto 100 SC and Milagro 040 SC recommended in agricultural practice, which has aimed at obtaining higher herbicide effectiveness by their combination with adjuvants Actirob 842 EC and Atpolan 80 EC, also followed the assumptions mentioned above.

On haplic phaeozems, it is possible to successfully control monocolyledonous and dicotyledonous weeds with Callisto 100 SC + Milagro 040 SC mixture supplied with Atpolan 80 EC adjuvant and introduced according to the method of split recommended doses, as well as doses reduced even by 50%. Positive results of the present experiments may become the foundation to further investigation on reduction of herbicide doses in crops with low weed infestation, which was also stressed by other authors (Domaradzki, 2006; Gołębiowska, 2008). On haplic cambisols, only sporadic occurrence of barnyard grass and green bristle grass was recorded, but considerable incidence of lamb's quarters and redroot pigweed as well as individual plants of common wormwood had been observed. In case of low infestation by monocot weeds and high incidence of monocotyledonous species, the satisfactory herbicidal effect could only be achieved when the mixture was applied at the full recommended doses of its components and supplied with adjuvant. Moreover, the addition of Atpolan 88 EC adjuvant provided another positive effect: the effective control of such species as field violet, field bedstraw, small geranium and common wormwood, even at the dose reduced by 1/3.

Conclusion

The assessment of weed infestation of maize cultivated on haplic phaeozems points to its low intensity as well as to the low diversity of plant species. High efficiency of weed control was obtained applying mesotrione + nicosulfuron mixture in the split doses system, with the addition of Atpolan 88 EC adiuvant. Such treatment variant resulted in the higher yield than the one obtained from the untreated area, and also higher compared to the area in which mesotrione and nicosulfuron were applied separately. Effective weed control effect was also achieved when that mixture was used in the dose reduced by 1/2.

On haplic cambisols, low intensity of Echinochloa crus–galli L. P.Beauv and Setaria viridis L. Beauv. was observed, but relatively high infestation by Chenopodium album L. and Amaranthus retroflexus L. were recorded. Furthermore, Artemisia vulgaris L. proved to be a troublesome, perennial weed in that stand. The species were most effectively controlled by the mixtures of mesotrione + nicosulfuron herbicides at their full recommended doses, supplied with Actirob 842 EC, or at the dose reduced by 1/3, supplied with Atpolan 88 EC, both applied as single treatment. Grain yields obtained from those objects were also the highest and this result was statistically significant.

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