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Impact of Different Adjuvants and Modes of Application on Efficacy of Rimsulfuron in Maize

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SUMMARY

Field studies were conducted in order to investigate the efficacy of herbicide rimsulfuron in maize with three various commercial products (WG and OD formulations), in combination with three different nonionic adjuvants (Extravon, Trend 90 and Break-Thru S240). The investigation was carried out at two different locations during two years. The application of products in combination with adjuvants was done in one and two steps. The efficacy was evaluated on five weed species. The results demonstrated that the addition of any of the adjuvants improved the efficacy of rimsulfuron, but that there were no significant differences between products of different producers in the case of same or different formulation of rimsulfuron. Two different modes of application had no impact on efficacy.

Keywords: Rimsulfuron; Formulations; Adjuvants; Efficacy; Maize

INTRODUCTION

Rimsulfuron (chemical name: N-((4,6-dimethoxypyrimidin-2-yl)aminocarbonyl)-3-(ethylsulfonyl)-2-pyridibesulfonamide) is a post-emergence sulfonylurea herbicide which controls most annual and perennial grass weeds and several broadleaf weeds in maize, and it has been in use for a long time. Like many other herbicides, it requires an adjuvant for effective weed control (Green and Green, 1993; Green, 1996).

Adjuvants are used with herbicides in most of applications. An effective adjuvant should enhance weed control, while leaving the crop unaffected. Nonionic surface active agents and various oils are the most frequently used adjuvants. Nonionic surfactants are the most common type of surfactants and they are usually compatible

with any material because they are not likely to react chemically with other substances (Green et al., 1992; Stock and Briggs, 2000; Knowles, 2006; Green and Beestman, 2007; Wang and Liu, 2007).

Research on adjuvant and formulation technology for agrochemicals has advanced and the results of that is a large number of adjuvants and pesticide products on the market. Choosing the best adjuvant is difficult (Bunting, et al. 2004; Kudsk and Mathiassen, 2007), as growers must choose from thousands of commercial products. Also, one active substance can be formulated in different ways; typically rimsulfuron can be found on the market formulated as WG (water dispersible granules) and recently as OD (oil dispersion). The type of pesticide formulation, and in some cases the choice of product of the same formulation type, can markedly affect the results obtained in practical use. It is known that type of formulation can influence pesticide performance altogether with the mode of application.

The objective of this study was to investigate the influence of three different nonionic adjuvants on biological efficacy of a selected herbicide. Using the active ingredient rimsulfuron, herbicide/adjuvant tank-mixtures (tree different herbicidal products) were applied to maize. Two types of formulations were used, WG and OD, in order to determine if the formulation type affects the efficacy and if there are any differences in effectiveness if the adjuvant is built in formulation (Tiger 25OD) or added to tank-mixes. Also, the intention was to find out if the mode of application influences the performance of products.

MATERIAL AND METHODS

Field trials were carried out on maize crops in 2008 and 2009, at two locations: Bavanište (JPC coordinates: 7488607, 4967456, elevation: 94m a.s.l.) and Glogonjski Rit (JPC coordinates: 7461181, 4981089, elevation: 60m a.s.l.).

The soil at Bavanište locality had the following physiochemical characteristics: pH 7.8, organic matter content 3.1%, sand 1.8%, silt 61.8%, clay 36.4%. The seeding of maize grains Pionir R 10 took place on April 12, 2008 and April 13, 2009.

The soil at Glogonjski Rit locality had the following physiochemical characteristics: pH 7.65, organic matter content 2.7%, sand 50.4%, silt 18.6%, clay 31%. The seeding of maize grains PR36R10 (Pioneer Hi-Bred., USA) took place on April 13, 2008 and April 11, 2009.

The trial plots were laid out in randomized complete block design in four replications. The herbicide efficacy was evaluated by OEPP/EPPO method (2004). The size of the main plot was 25 m^2. On two locations within each experimental unit, the quantity of each weed species was determined using the 1.0 x 1.0 m frame. Efficacy percentage for each weed species was calculated.

Three different commercial plant protection products were used: Tiger 25OD (GAT Microencapsulation AG, Austria), Amurg 25WG (Biesterfeld International GmbH, Germany) and Tarot 25WG (DuPont International, Switzerland). The three adjuvants investigated in this study were Extravon (Syngenta-Agro, Switzerland), Trend 90 (Du Pont International, France) and Break-Thru S240 (Goldschmidt GmbH, Germany). Adjuvants were added to tank mixes (herbicide tank-mixtures) in the case of both WG formulations, in the field, just before application (0.1%). The formulation Tiger 25OD already contained adjuvant. Herbicides were applied at full recommended rate of 60 g/ha, as well as in split application 30+30 g/ha.

All treatments were applied with a handheld backpack boom sprayer "Solo", equipped with Tee Jet XR 110/03. The quantity of water was 400 L/ha. Modes and times of application are given in Table 1.

The first evaluation of herbicide efficacy was done 3 weeks after the treatment (3WAT), and the second one 6 weeks after the treatment (6WAT).

Statistical evaluation: the obtained data were analyzed separately for each trial using ANOVA and the means were separated by Duncan's multiple range test. In all analyses the level of significance was at least $P< 0.05$.

RESULTS AND DISCUSSION

The weed communities in agro ecosystems, especially in crops such as maize, are very dynamic and fast-shifting, the predominant weed species being *Solanum nigrum, Datura stramonium, Xanthium strumarium, Chenopodium album, Amaranthus retroflexus, Cirsium arvense, Convonvulus arvensis* (Vrbničanin et al., 2004; Simić and Stefanović, 2006). In maize crops, broadleaf weeds dominate in terms of distribution and density, but weeds from *Poaceae* family should also be mentioned, with *Sorghum halepense* as the most important.

Table 1. Mode, time and frequency of application and meteorological data

Locality	Bavanište		Glogonjski Rit	
Mode of application	Single application			
Year	2008	2009	2008	2009
Date of application	16.05.2008	12.05.2009	19.05.2008	15.05.2009
Stage of maize	5-6 leaves	5 leaves	6 leaves	5-6 leaves
Stage of weeds	2-6 leaves	2-6 leaves	4-6 leaves	2-6 leaves
Temperature	20°C	21°C	24°C	19°C
Wind	0 m/s	0 m/s	0 m/s	0 m/s
Cloud cover	0%	0%	0%	60%
Mode of application	Split application			
First application				
Date of application	08.05.2008	05.05.2009	12.05.2008	07.05.2009
Stage of maize	3-4 leaves	3-4 leaves	4-5 leaves	4 leaves
Stage of weeds	2-4 leaves	2-4 leaves	2-6 leaves	2-4 leaves
Temperature	18°C	16°C	23°C	19°C
Wind	1 m/s	0 m/s	0 m/s	1 m/s
Cloud cover	0%	100%	40%	0%
Second application				
Date of application	16.05.2008	12.05.2009	19.05.2008	15.05.2008
Stage of maize	5-6 leaves	5 leaves	6 leaves	5-6 leaves
Stage of weeds	2-6 leaves	2-6 leaves	4-6 leaves	2-6 leaves
Temperature	20°C	21°C	24°C	19°C
Wind	0 m/s	0 m/s	0 m/s	0 m/s
Cloud cover	0%	0%	0%	40%

Thus, the increased population of *Sorghum halepense* can be noticed in the wider territory, which is most likely the result of the several-decade long use of triazine herbicides, especially atrazine. An increasing emergence of annual weed species *Datura stramonium* has also been noticed in recent years. The selection of Bavanište and Glogonjski Rit locations for conducting of trials was based on the fact that five out of seven very important weed species were found in maize crops at these localities.

As majority of herbicides, rimsulfuron also requires use of adjuvants for foliage-applied treatments. A well-selected type of adjuvant, as well as its higher application rate enhance the efficacy of rimsulfuron from practically useless to fully effective in weed control. The recommended application rate of adjuvant for use with rimsulfuron is 0.25% (v/v) in the USA and 0.1% in Europe (Green, 1996).

The results of investigation are shown in Tables 2 and 3. The results are average efficacy values for two years (2008/2009).

Table 2. Efficacy of rimsulfuron at locality Bavanište (2008/2009)

Herbicides	Rate g/ha, ml/ha, %	Efficacy (%)									
		3WAT					6WAT				
		DATST	HELAN	SOLNI	SORHA	XANST	DATST	HELAN	SOLNI	SORHA	XANST
Single application											
Control	0.0	0.0 a	0.0 a	0.0 a	0.0 a	0.0 a	0.0 a	0.0 a	0.0 a	0.0 a	0.0 a
Amurg	60	32.8 bc	69.4 b	40.2 b	73.0 b	21.9 b	18.5 ab	65.1 b	46.0 b	67.6 b	19.1 b
Amurg+ Extravon	60+0.1	36.9 c	99.0 c	71.3 c	92.4 c	35.2 bc	39.8 bc	99.3 c	70.9 c	92.8 c	53.9 cd
Amurg+ Trend	60+0.1	45.2 c	95.8 c	63.0 c	94.9 cd	43.2 cd	27.2 bc	100.0 c	69.0 c	94.1 cde	45.1 c
Amurg+ Break Thru	60+0.1	22.7 b	99.0 c	63.6 c	99.5 d	28.5 bc	41.0 bc	99.0 c	67.7 c	99.5 e	58.8 d
Tarot+ Trend	60+0.1	65.2 d	98.4 c	63.4 c	97.7 d	42.4 cd	44.4 c	100.0 c	66.4 c	98.5 de	60.8 d
Tiger	60	44.7 c	100.0 c	68.2 c	96.9 cd	57.2 d	48.31 c	100.0 c	68.8 c	93.3 ce	53.4 cd
LSD 5%		10.5	7.9	9.1	3.6	14.7	13.1	3.5	6.6	5.2	11.9
Split application											
Control	0.0	0.0 a	0.0 a	0.0 a	0.0 a	0.0 a	0.0	0.0 a	0.0 a	0.0 a	0.0 a
Amurg	(30+30)	28.7 b	65.5 b	49.2 b	64.6 b	31.2 b	18.4 ab	72.9 b	51.1 b	64.4 b	35.6 b
Amurg+ Extravon	(30+0.1)+ (30+0.1%)	48.7 c	97.4 c	67.5 c	97.1 cd	60.2 d	36.2 bc	100.0 c	62.6 c	97.6 c	46.7 c
Amurg+ Trend	(30+0.1)+ (30+0.1%)	38.9 bc	97.2 c	66.5 c	96.7 cd	38.1 bc	46.4 c	99.3 c	69.0 d	97.9 c	61.6 d
Amurg+ Break Thru	(30+0.1)+ (30+0.1%)	28.4 b	99.0 c	66.4 c	99.1 d	36.7 bc	41.2 bc	99.3 c	62.8 c	98.6 c	47.3 c
Tarot+ Trend	(30+0.1)+ (30+0.1%)	32.6 b	95.3 c	68.0 c	93.1 c	54.9 d	30.2 bc	100.0 c	71.9 d	96.1 c	58.1 d
Tiger	(30+30)	37.6 bc	99.0 c	68.6 c	98.3 d	48.1 cd	53.2 c	99.3 c	72.6 d	96.1 c	61.2 d
LSD 5%		10.9	5.6	7.1	4.7	11.6	16.5	3.0	5.0	4.7	8.1

DATST-*Datura stramonium*, HELAN-*Helianthus annuus*, SOLNI-*Solanum nigrum*, SORHA-*Sorghum halepense*, XANST-*Xanthium strumarium,* Means in the same column followed by the same letter do not differ (P<0.05) according to Duncan's multiple range test

Table 3. Efficacy of rimsulfuron at locality Glogonjski Rit (2008/2009)

Herbicides	Rate g/ha, ml/ha, %	Efficacy (%)									
		3WAT					6WAT				
		DATST	HELAN	SOLNI	SORHA	XANST	DATST	HELAN	SOLNI	SORHA	XANST
Single application											
Control	0.0	0.0 a	0.0 a	0.0 a	0.0 a	0.0 a	0.0 a	0.0 a	0.0 a	0.0 a	0.0 a
Amurg	60	28.4 b	74.4 b	36.3 b	73.2 b	40.2 b	20.8 b	71.1 b	37.3 b	71.0 b	26.2 b
Amurg+ Extravon	60+0.1	43.9 bc	81.9 c	61.4 c	94.3 cd	61.1 cd	27.3 bc	90.3 c	64.9 d	93.8 c	56.6 c
Amurg+ Trend	60+0.1	61.0 c	93.0 d	76.7 c	92.9 c	48.5 bc	33.0 bc	92.0 c	65.7 d	98.9 d	55.9 c
Amurg+ Break Thru	60+0.1	45.0 bc	92.8 d	64.2 c	99.4 e	67.6 de	23.5 bc	90.8 c	47.9 bc	96.3 cd	51.7 c
Tarot+ Trend	60+0.1	49.8 c	94.9 d	64.8 c	92.6 c	82.0 e	35.7 c	95.5 c	62.1 cd	95.4 cd	56.2 c
Tiger	60	48.5 c	98.1 d	71.0 c	97.7 de	85.3 e	24.8 bc	95.5 c	57.2 cd	93.7 c	61.9 c
LSD 5%		11.9	6.7	13.9	3.5	18.3	11.0	4.6	12.9	2.9	14.7
Split application											
Control	0.0	0.0 a	0.0 a	0.0 a	0.0 a	0.0 a	0.0 a	0.0 a	0.0 a	0.0 a	0.0 a
Amurg	(30+30)	29.6 b	72.4 b	36.0 b	73.2 b	51.3 bc	34.3 b	71.4 b	38.0 b	71.5 b	33.8 b
Amurg+ Extravon	(30+0.1)+ (30+0.1%)	39.2 b	88.9 cd	55.4 bc	97.8 c	71.8 c	32.3 b	90.1 c	75.0 cd	97.7 cd	64.5 d
Amurg+ Trend	(30+0.1)+ (30+0.1%)	32.8 b	87.6 cd	64.4 c	99.4 c	44.2 b	28.8 b	91.6 c	71.2 cd	95.2 c	69.9 d
Amurg+ Break Thru	(30+0.1)+ (30+0.1%)	42.5 b	92.3 de	53.7 bc	98.6 c	57.3 bc	34.5 b	88.1 c	79.1 d	100.0 d	41.7 bc
Tarot+ Trend	(30+0.1)+ (30+0.1%)	40.7 b	81.7 c	57.4 c	99.4 c	66.6 bc	25.0 b	89.7 c	55.8 bc	99.1 d	59.4 cd
Tiger	(30+30)	39.2 b	97.7 e	71.7 c	99.4 c	51.2 bc	36.6 b	92.5 c	74.8 cd	98.9 d	58.4 cd
LSD 5%		10.3	6.4	15.7	3.2	20.6	13.1	5.6	16.4	3.3	15.7

DATST-*Datura stramonium*, HELAN-*Helianthus annuus*, SOLNI-*Solanum nigrum*, SORHA-*Sorghum halepense*, XANST-*Xanthium strumarium,* Means in the same column followed by the same letter do not differ (P<0.05) according to Duncan's multiple range test

Datura stramonium

At the Bavanište locality, the lowest efficacy of 18% against Datura stramonium was shown by Amurg 25WG applied at the rate of 60 g/ha and 30+30g/ha 6WAT, as well as by the combinations Amug 25WG+Trend 90 and Amurg 25WG+Break-Thru S240 (60 g/ha + 0.1%) 6 WAT and 3WAT, while the most effective was Tarot 25WG+Trend 90 (65.2%) 3WAT applied at the same rate. In all other cases, the efficacy varied between 32.6.8% and 53.2% (Table 2).

At the Glogonjski Rit locality, the lowest efficacy of 20.8 % against *Datura stramonium* was shown by Amurg 25WG applied at the rate of 60 g/ha and 30+30g/ha 6WAT, while the most effective was Amurg 25WG+Trend 90 (61.0%) 3WAT applied at the same rate. In all other cases, the efficacy varied between 25.0% and 49.8% (Table 3).

The efficacy of rimsulfuron against *Datura stramonum*, depending on the applied dose, ranged from 13% (9 g/ha) to 55 % (70 g/ha), and against *Xanthium strumarium* from 98% to 100% for all application rates (9, 18, 27, 35, 70 g/ha) (Robinson et al., 1996).

Helianthus annuus

At the Bavanište locality, the efficacy of Amurg 25WG against *Helianthus annus* applied at the rate of 60 g/ha 3WAT and 6WAT ranged between 69.4% and 65.1%, while in combination with adjuvants Extravon, Trend 90 and Break-Thru S240, its efficacy increased to 95.8-100%. The efficacy of the combination Tarot 25WG+Trend 90 was 98.4% (3WAT) and 100% (6WAT), while the herbicide Tiger 25WG was 100% efficient. When the applied rate of Amurg 25WG was 30+30 g/ha, the efficacy was 65.5 and 72.9%, respectively. In combination with adjuvants Extravon, Trend 90 and Break-Thru S240, the efficacy was 97.2-100%. Combination Tarot 25WG+Trend 90 exhibited the efficacy of 95.3% (3WAT) and 100 (6WAT), while the efficacy of Tiger 25OD herbicide was 99% (Table 2).

At the Glogonjski Rit locality, the efficacy of Amurg 25WG against *Helianthus annus* applied at the rate of 60 g/ha 3 WAT and 6WAT was higher than 70%, while in combination with adjuvants Extravon, Trend 90 and Break-Thru S240, its efficacy increased to 81.9-93.0%. Efficacy of the combination Tarot 25WG+Trend 90 was about 95%, while the efficacy of the herbicide Tiger 25OD was higher than 95%. When the applied rate of Amurg 25WG was 30+30 g/ha, the efficacy was over 70%. The combinations of Amurg 25WG with adjuvants Extravon, Trend 90 and Break-Thru S240 resulted in the efficacy of 87.6-92.3%. The combination Tarot 25WG+Trend 90 demonstrated the efficacy of 81.7% (3WAT) and 92.5% (6WAT), while the efficacy of Tiger 25-OD was 97.7% and 92.5% (Table 3).

Solanum nigrum

At the Bavanište locality, the efficacy of Amurg 25WG against *Solanum nigrum* applied at the rate of 60 g/ha as well as 30+30 g/ha 3WAT and 6WAT achieved the efficacy of 40.2-51.1%, while in combination with the tested adjuvants, its efficacy significantly increased to 62.6-71.3%. Under the same conditions, the combination Tarot 25WG+Trend 90 showed the efficacy of 63.4-71.9%, and Tiger 25OD herbicide 68.2-72.6% (Table 2).

At the Glogonjski Rit locality, the efficacy of herbicide Amurg 25WG against *Solanum nigrum* applied at the rate of 60 g/ha and 30+30 g/ha 3WAT and 6WAT was about 36%, while in combination with the tested adjuvants its efficacy significantly increased to 47.9-79.1%. Under the same conditions, the combination Tarot 25WG+Trend 90 showed the efficacy of 55.8-64.8%, and Tiger 25OD herbicide 57.2-74.8% (Table 3).

Sorghum halepense

At the Bavanište locality, the efficacy of Amurg 25WG against *Sorghum halepense* applied at the rate of 60 g/ha and 30+30 g/ha 3WAT and 6WAT was 64.4-73.0%, while in combination with the tested adjuvants its efficacy significantly increased to 92.4-99.5%. Under the same conditions, the combination Tarot 25WG+Trend 90 showed the efficacy of 93.1-98.5%, and Tiger 25OD herbicide 93.3-98.3% (Table 2).

At the Glogonjski Rit locality, the efficacy of herbicide Amurg 25WG against *Sorghum halepense* applied at the rate of 60 g/ha and 30+30 g/ha 3WAT and 6WAT was slightly higher than 70%, while in combination with the tested adjuvants its efficacy significantly increased to 92.9-100%. Under the same conditions, the combination Tarot 25WG+Trend 90 showed the efficacy of 92.6-99.4%, and Tiger 25OD herbicide 93.7-99.4% (Table 3).

The similar experimental results were obtained by Green and Green (1993) and Green (1996) who discovered that the efficacy of rimsulfuron against *Setaria faberi*, which belongs to the same family as *Sorghum halepense*, increased from 23% to over 90% when an adjuvant was added (at different application rates and

by adding the surface active agents from the homologue series of liner alchocol ethoxylates, and rimsulfuron application at the rate of 2 g/ha).

Xanthium strumarium

At the locality Bavanište, the lowest efficacy against this weed species was shown by Amurg 25WG, applied at a rate of 60 g/ha and 30+30 g/ha. When Amurg 25WG was combined with adjuvants, the efficacy significantly improved and reached 35.2-61.6%. The similar results were obtained for the herbicide Tiger 25OD, as well as for the combination Tarot 25WG+Trend 90 (42.4-61.2%) (Table 2).

At the locality Glogonjski Rit, the highest efficacy in control of *Xanthium strumarium* was demonstrated by Amurg 25WG+Trend 90 (split application) 6WAT and it was 69.9%, while the least effective was Amurg 25WG (60 g/ha) 6WAT with 26.2% In all other cases, the efficacy ranged between 41.7% and 64.5% (Table 3).

Some statistically significant differences were observed between the trial varieties (for *Datura stramonium, Solanum nigrum* and *Xanthium strumarium*), but the efficacy rate did not reach the level that would make any of them cost-effective (cost-effective).

Many researchers have investigated the effects of adjuvants on effectiveness of herbicides against weed species. Thus, the possibilities for suppression of *Muhlenbergia frondosa* by application of foramsulfuron and adjuvant HastenTM were investigated. The test results have shown that this adjuvant enhances uptake of foramsulfuron through waxy cuticle on a leaf. Also, HastenTM increases the coverage of treated plants, by improving the wettability and distribution of active ingredient, which enhances its absorption and uptake by plant, that is, improves the efficacy of herbicide (Sikkema et al., 2007). The similar results were obtained by Bunting et al. (2004), who demonstrated the importance of proper selection of adjuvant for foramsulfuron, in accordance with the weed species existing in maize crops. Their findings indicate that the best adjuvant for foramsulfuron applied against *Echinoclhloa crus-galli, Setaria faberi* and *Abutilon theophrasti* is methylated seed oil, in comparison to Herbimax (crop oil concentrate) and X-77 (nonionic adjuvant). It has also been demonstrated that adjuvants Cornbelt®Premium Crop Oil Concentrate and Cornbelt®Methylated Soy-Stik increase the efficacy of this saflufenacil in control of *Cirsium arvense, Lacuca serriola, Thlaspi arvense* and *Coniysa canadensis* (Knežević et al., 2010).

Our studies indicated that none of the tested adjuvants showed significant advantages over other adjuvants included in trials. However, certain differences in efficacy of rimsulfuron were noticed when it was applied together with an adjuvant (Tables 2 and 3), but although those differences were statistically significant, they did not make any of the combinations cost-effective (cost-effective). As already known, and as confirmed by our experimental results, the efficacy of rimsulfuron significantly increases when applied together with adjuvants, especially against weed species *Helianthus annuus* and *Sorghum halepense*. But, statistically significant differences at both locations and in both years of trials were observed only between untreated control and all herbicide treatments, with or without adjuvants.

Some manufacturers recommend two applications of rimsulfuron product in order to improve its results. That is why we tried to find out in our trials whether the mode of application (single or split application) affects the product efficacy. By analysing the obtained results, it was concluded that mode of application in no way affected the efficacy, which implies that single application is a far more desirable solution from the aspect of cost-effectiveness.

Regarding the impact of formulation type (WG, OD) on efficacy of a product (that is, of active substance in it), as well as the application of adjuvants by adding it to the tank-mix (Amurg 25WG, Tarot 25WG), or using the product that already contains adjuvant (Tiger 25OD), there were no significant differences in either group of trials. It can be said that only in two single cases Tiger 25 OD showed somewhat higher efficacy and those were: at Glogonjski Rit location, against *Helanthus annuus*, after split applications (Table 3, 3 WAT); then, at Bavanište, against *Xanthium strumarium* after single application (Table 2, 3 WAT). In both cases, there were some statistically significant differences in efficacy in comparison to other two, but from the aspect of cost-effectiveness, they are not important. It should be noted here that all tested products were applied under the same conditions (with the same application equipment), so that the differences in physico-chemical characteristics between treatment tank-mixtures were probably not such to affect substantially the efficacy of products, as opposed to the results of some other studies where the use of different application equipment (nozzles) resulted in different efficacy levels depending on type of formulation (Miller and Butler, 2000).

Some researchers, such as Sun et al. (1996), studied the impact of organosilicone adjuvants Silwet L-77®,

Silwet® 408, and Sylgard® 309 on rainfastness of primisulfuron on the foliage of *Abutilon theophrasti*. Primisulfuron was applied at the rate of 40 g/ha, alone or with organosilicone adjuvants. The obtained results indicated that organosilicone adjuvants increased significantly the rainfastness of primisulfuron on the foliage of *Abutilon theophrasti* if the rainfall occurred 0.25 h, 0.5 h, and 1h after the treatment, but when the rain started 2 h after the treatment, there were no significant differences in comparison to treatment with primisulfuron alone. The authors presumed that organosilicone surfactants enhanced the uptake of primisulfuron through stomas, which resulted in faster uptake of herbicide and elimination of possibility to be washed away by rain. Our investigations that included trials with three nonionic adjuvants under favourable weather conditions and absence of precipitation showed that the increased efficacy of rimsulfuron did not refer to all weed species at the locality, but only *Helianthus annuus* and *Sorghum halepense*.

Abouziena et al. (2009) studied the impact of different application rates of bentazon without or with an adjuvant (ammonium sulphate, nonionic adjuvant-Induce 0.25% and organosilicone adjuvant-Kinetic 0.1%) against *Xanthium strumarium, Solanum nigrum* and *Abutilon theophrasti*. The efficacy in suppression of *Solanum nigrum* was not higher than 55% in any of the combinations; efficacy against *Xanthium. strumarium* was 100% regardless of the adjuvant type, while against *Abutilon theophrasti*, it was 97-100%, depending on the used adjuvant. The data obtained by their investigations indicate that bentazon is inefficient in control of *Solanum nigrum*, which can be the result of fast detoxication of this herbicide in *Solanum nigrum* plants, as well as the morphological structure of their leaves. The findings of this group of authors is consistent with our investigation results which demonstrated that the efficacy of rimsulfuron, when combined with various adjuvants, significantly increases against the species *Helianthus annuus* and *Sorghum halepense* (even up to 100%), while it remains insufficiently efficient in the control of *Datura stramonium, Xanthium strumarium* and *Solanium nigrum*, although applied under the same conditions.

The results of our investigations confirmed once again the necessity of using the adjuvants in order to enhance the efficacy of rimsulfuron. By adding adjuvants to the products containing this active substance, their activity is expanded to a larger number of weed species and their efficacy is significantly increased, which is consistent with the conclusions of other researchers (Green, 1996). Concerning the selection of adjuvant, it has been concluded that its chemical structure and other physiochemical properties do not have a significant impact on the efficacy of the product (at least in cases included in our investigations), which differs from the data found in literature (Green and Green, 1993).

The obtained results also indicate that the formulation type (WG, OD) does not significantly influence the efficacy, as well as the fact whether the adjuvant is already included in formulation or later added to the treatment solution. Also, the treatment in one-step or two-step applications does not significantly improve the efficacy of products. The field trials were carried out at two locations with different physiochemical characteristics of the soil, and we also investigated if the soil properties could indirectly affect the efficacy of rimsulfuron despite the fact that it belongs to foliage-applied herbicides. The obtained results indicated that soil properties have no impact on efficacy of rimsulfuron (with or without adjuvants) in control of the tested weed species.

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Uticaj različitih okvašivača i načina primene na efikasnost rimsulfurona u kukuruzu

REZIME

U poljskim uslovima ispitivana je efikasnost različitih komercijalnih proizvoda rimsulfurona (WG i OD formulacije) u kombinaciji sa tri različita nejonska okvašivača (Extravon, Trend 90 and Break-Thru S240) u suzbijanju korova u kukuruzu. Ispitivanja su obavljena na dva lokaliteta u toku dve godine. Primena herbicida u kombinaciji sa okvašivačima obavljena je jednokratno i dvokratno. Efikasnost rimsulfurona je praćena na pet odabranih korovskih vrsta. Rezultati istraživanja su pokazali da svaki od ispitavnih okvašivača povećava efikasnost rimsulfurona, ali da nije bilo značajne razlike između različitih komercijalnih preparata, kao ni različitih formulacija rimsulfurona. Takođe, dva različita načina primene nisu uticala na efikasnost ovog herbicida.

Ključne reči: Rimsulfuron; formulacije; okvašivači; efikasnost; kukuruz