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EFFECT OF ADJUVANTS ON BIOLOGICAL EFFICACY OF SULFOSULFURON AND PROPOXYCARBAZONE-SODIUM FOR WEED CONTROL IN WINTER WHEAT AND CARRYOVER EFFECTS

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Abstract: Biological efficacy of herbicides: propoxycarbazone-sodium (Attribut 70 WG) and sulfosulfuron (Apyros 75 WG) applied with adjuvants was estimated in the field, greenhouse and laboratory experiments. An addition of adjuvants to herbicides Attribut 70 WG and Apyros 75 WG had a positive influence on physical characteristics of tank mixture, herbicidal effect, and the increase of winter wheat grain yield. Ammonium nitrate used as an adjuvant showed the weakest effect. The lowest grain yield was obtained after using the preparations Attribut 70 WG and Apyros 75 WG without adjuvant. The oil adjuvants, Adbios 85 SL, Aero 030 SL, Atpolan 80 EC and Olbras 88 EC influenced in a similar manner the activity of tested herbicides. Obtained herbicidal effect, the amount of yield and elements of yield structure were differentiated after joint application of herbicides with adjuvants. The herbicides protected plantations of winter wheat against couch grass (*Agropyron repens*) during the whole vegetative season. However the herbicide Attribut 70 WG was more effective in controlling regrowth of couch grass after harvest, as compared to Apyros 75 WG. On the other hand, Apyros 75 WG controlled somewhat better broadleaf weeds. Also differences in carryover effect occurred. On the sites after propoxycarbazone–sodium application winter oilseed rape, spring oilseed rape and sugar beet should not be cultivated. On the sites after cereals that were protected against weeds with sulfosulfuron only cultivation of winter oilseed rape should not be recommended, however spring oilseed rape and sugar beet can be grown.

Key words: sulfosulfuron, propxycarbazone-sodium, adjuvants, winter wheat, weed control, carryover effects

INTRODUCTION

Observations on weed infestation in winter cereals reveal on many plantations the mass occurrence of broadleaf as well as grass weeds, mainly *Apera spica-venti* and *Agropyron repens*. In these conditions, for obtaining high grain yield control of both groups of weeds is required. Since twenty years herbicides belonging to sulfonylourea group have been recommended for controlling weeds in winter cereals (Palm and Allison 1980; Adamczewski et al. 1988). In the end of the last century two new sulfonylourea herbicides: sulfosulfuron (Apyros 75 WG) and propoxycarbazone-sodium (Attribut 70 WG) have been introduced into Polish marked. These herbicides are characterized by a high efficacy in controlling grass weeds, including couch grass (*Agropyron repens*), as well as some broadleaf weeds in winter wheat.

Herbicidal effect of the herbicide Apyros 75 WG against grass and broadleaf weeds has been estimated in many field experiments (Dobrovdsky 1995; Parrish et al 1995; Adamczewski et al.1996; Cairns et al. 2001). Also many investigations were conducted on control of various weed species using the herbicide Attribut 70 WG (Adamczewski et al. 2000; Amman and Wellmann 2001; Bell 1999; Santel et al. 2001; Freucht et al. 1999). However, there are no scientific papers presenting a comparison of both herbicides, as well as their carryover effects. Some sulfonylourea herbicides degrade in the soil for quite a long time, and can threaten following crop plants (Adamczewskiet et al. 1998; Paradowski 1994). According to Amman et al. (2000) Attribut 70 WG quick degradation in the soil does not create any threat to following crop plants.

The aim of presented study was to compare herbicidal efficacy in controlling broadleaf weeds, as well as *Apera spica-venti* and *Agropyron repens* with the two herbicides Apyros 75 WG and Attribute 70 WG, used with various adjuvants, and their carryover effect on winter oilseed rape, spring oilseed rape and sugar beet. Experiments were performed in the field and greenhouse conditions. In the laboratory physical characteristics of tank mixture, as well as grain quality of winter wheat obtained from field experiments were assessed.

MATERIAL AND METHODS

In the experiments the following herbicides were compared: Apyros 75 WG, Monsanto Co., containing 75% of sulfosulfuron, and two products of Bayer CropScience Co.: Attribut 70 WG containing 70% of propoxycarbazone-sodium and Attribut Star 57 WG containing 42% of propoxycarbazone-sodium and 15% of tribenuron-methyl. These herbicides were applied in combination with adjuvants: Adbios 85 SL (85% ethoxylated fatty amine), Aero 030 SL (30% ethoxylated coconut amine), Atpolan 80 EC (80% paraffin oil), Olbras 88 EC (88% post refined fatty acids of oilseed rape oil) and 34% ammonium nitrate. Doses of herbicides and adjuvants used in experiments are given in tables illustrating results of estimation of herbicidal activity.

Field experiments. Plot experiments were conducted in the years 2000–2002 in the Agricultural Experimental Farm of Plant Protection Institute in Winna Góra. Experiments were laid out according to randomised block design on podsolic soil of pH 6.7–6.9 in four replications, plot size for harvest 16.5 m^2. Winter wheat

cv. Kobra was sown in the beginning of October at sowing rate of 220 kg/ha. Soil cultivation and other agrotechnical measures and mineral fertilization were conformable with recommendations for this crop plant. Spraying treatments with herbicides were performed in the spring at full tillering stage of winter wheat, BBCH scale 24–26. Treatment with herbicides was performed using plot sprayer Gloria, nozzle type R 110-03, spray volume 200 l/ha, and working pressure 200 kPa. Weed control efficacy against broadleaf weeds was estimated 3–4 weeks after treatment. The number of weeds on untreated plots was assessed using frame method (4 × 0,25 m = 1 m^2). Alternatively, on plots treated with herbicides weed control efficacy was assessed on the basis of whole plot evaluation, as a per cent in comparison to the untreated plots, taking under consideration numerousness of weeds and their condition. Weed control efficacy in relation to grass weeds (*Apera spica-venti* and *Agropyron repens*) was assessed after heading. In 3–4 weeks after harvest regrowth of couch grass was determined. Moreover, from each plot 10 rhizomes were dug out, each being around 10 cm long and placed on moistened filter paper in Petri dish. After 3 weeks the destruction of rhizomes was assessed and regrowth emerging from remaining alive rhizomes enumerated.

Before harvest 25 ears of winter wheat were taken from each plot and the number of grains per ear was counted. The grain was harvested with a plot combine, and in the laboratory mass of 1000 grains (average from 6 × 250 grains) was assessed. Per cent content of protein and gluten was assessed and Zeleny's sedimentation index was calculated. Analyser Informatic 8100 Parten Co. was used for these studies. This equipment works on the basis of near infrared radiation /NIR/ refraction, wavelength 1400–2500 nm.

Greenhouse experiment. For assessing efficacy of herbicides on couch grass rhizomes additional studies were performed in greenhouse conditions. For this purpose rhizomes of couch grass were dug out from the sites where herbicides were not applied. 10 cm long sections of rhizomes each with five buds were placed in 2.5 L pots filled up to 3/4 volume with the soil, and afterwards covered with 5 cm soil layer. Pots were successively watered. At the 4–6 leaves stage of couch grass plants were sprayed with herbicides with addition of adjuvants, using greenhouse sprayer, nozzles TeeJet 11002 and pressure of 300 kPa. The spray volume used was 250 l/ha. Three weeks after spraying the above ground plant parts were cut off and weighted. For the next four weeks pots were not watered to simulate drought conditions that frequently occur after harvest. After this period of time watering of pots was resumed. When couch grass plants in unsprayed control developed 4–6 leaves, the above ground green mass was cut off and weighted. In addition, rhizomes were taken out of the pots, weighted and alive buds present on rhizomes counted.

Properties of spraying solution. For the determination of physical characteristics of spray mixture of herbicides and adjuvants the following measurements were taken: static surface tension, degree of surface coverage and retention. For assessment of static surface tension stalagmometr was used. It served for counting the number of droplets arising from a constant volume of each spray solution of herbicides with adjuvants, and water. Afterwards, using formula given below static surface tension was calculated:

$$D_c = \frac{d_c n_w}{d_w n_c} D_w [mN/m], \text{ where}$$

D_c – surface tension of spray mixture [m/Nm]
D_w – surface tension of pure water [m/Nm]
d_c – gravity of spray mixture [g/cm^3]
d_w – gravity of pure water [g/cm^3]
n_c – number of spray mixture droplets flowing out of stalagmometr volume
n_w – number of pure water droplets flowing out of stalagmometr volume

For determination of surface coverage by spray droplets water-sensitive strips produced in Switzerland by TeeJet – Spraying System Co. were used. Treatments were performed with greenhouse sprayer being directed on water-sensitive strips positioned against spraying direction horizontally (180°) or vertically (90°), using nozzles TeeJet 11002, 300 kPa pressure, and spray volume 250 l/ha. Treated surface was measured using computer system for image analysis MultiScan v.4.01, collaborating with a video camera Panasonic CCTV type WV-CL 702E. Studies were carried out in two replications. In the studies concerning spray mixture characteristics couch grass (*Agropyron repens*) leaves were used. The experiment was performed on six leaves in three replications ($6 \times 3 = 18$ measurements for each treatment). Violet stain phenylosafranin at 10 mg of stain on 100 ml solution was added to spray mixture. After treatment leaves were washed by dipping 12 times in 15 ml methanol : distilled water solution (1:2). Concentration of phenylosaphranine in each harvested samples was measured by Beckman DU 8 spectrophotometer at wavelength $\lambda = 552$ nm. The values were expressed in ml as the of spray mixture recovered from the leaves. Treated surface was measured using computer system for image analysis MultiScan v.4.01, collaborating with a video camera Panasonic CCTV type WV-CL 702E. The retention was expressed as amount of spray mixture retained per 1 cm^2 leaf area (μl/cm^2) and as per cent of spray volume used.

Influence on cultivation of following crop plants

Field experiments. Plot experiments were performed in the Experimental Station in Krościna Mała. They were laid out according to randomized block design on podsolic soil in four replications, on plots measuring 50 m^2. Tested herbicides were applied on winter wheat in the spring with plot sprayer equipped with nozzle TeeJet 11002 VP, delivering 250 l/ha spray mixture at 250 kPa. Soil cultivation and mineral fertilization were conformable with recommendations for winter wheat. After harvest of winter wheat and carrying out recommended agricultural measures, winter oilseed rape was sown. In winter oilseed rape observations of emergence and plant development were done. After completing the assessment of damage on winter oilseed rape, in the spring shallow ploughing (8–10 cm) was performed and on the same site spring oilseed rape was sown. In spring oilseed rape emergence was assessed, and prior to harvest 30 plants were taken from each plot and length, weight and number of siliques on each plant were determined.

Greenhouse experiment. The greenhouse experiment was laid out as independent experiment in four replications. 5 L pots were filled with a mixture of peat substrate

and sandy soil in proportion 1:1. Afterwards herbicides were applied on the soil surface. Spraying treatment was performed using a greenhouse sprayer equipped with nozzle TeeJet XR 11002, spray volume operated at 200 kPa and 250 l/ha. After spraying, treated soil was covered with 0,5 cm soil layer and pots were protected with non-woven polypropylene cover. All the time, up to the moment of winter oilseed rape sowing soil was maintained at the level of moisture 60–70%. After four months from application of herbicides winter oilseed rape was sown at the rate 25 seeds per pot and covered with 1.0 cm soil layer, soil moisture was maintained at 60–70% of water holding capacity assuring correct emergence. After sowing pots were carried to the plant house. Forty days after emergence plant density and fresh mass of plants was determined. Moreover, visual assessment of morphological changes of oilseed rape plants was performed in relation to the untreated object. After harvest of winter oilseed rape, 10 seeds of spring oilseed rape and 10 seeds of sugar beet were planted in the same pots. In all pots the same level of soil moisture was maintained. One month after emergence number of spring oilseed rape and sugar beet plants as well as fresh mass of plants were determinated.

Statistical analysis. Statistical analysis of data from the field and greenhouse experiments was performed using t-Student's test on the level of probability $\alpha = 0,05$.

RESULTS AND DISCUSSION

There are no published reports on parallel studies carried out in the same experiment on the comparison of herbicidal efficacy of Apyros 75 WG (sulfosulfuron) and Attribut 70 WG (propoxycarbazone-sodium). The estimation of efficacy of both herbicides was assessed in different field experiments. The lack of the parallel comparison poses difficulties in making objective evaluation of biological activity of both preparations. Assessment of activity of the herbicide Apyros 75 WG against broadleaf and grass weeds (*Apera spica-venti*, *Agropyron repens, Avena fatua, Bromus spp*.) was performed by Dobrovdsky (1995), Parrish (1995), Cairns et al. (2001). Studies on the activity of herbicide Attribut 70 WG were done by Bell (1999), Freucht et al. (1999), Amman and Wellman (2001) and Santel et al. (2001).

In experiments conducted in the Agricultural Experimental Farm in Winna Góra (Tabs. 1, 2) 10 species of broadleaf weeds and 2 grass weeds occurred. Mass occurrence of *Stellaria media* (STEME) was stated, 38 plants/m^2 being controlled by both herbicides in the range of 90%–100% and *Viola arvensis* (VIOLAR), 36 plants/m^2 being controlled in a considerable lower degree (51%–75%). A better control of *Viola arvensis* gave Apyros 75 WG, especially when applied with adjuvants. Somewhat lower intensity of the occurrence was recorded for *Veronica arvensis* (18 plants/m^2) and *Matricaria inodora* (12 plants/m^2). The occurrence of these species was eliminated by 50% to 80%. Herbicidal efficacy of the herbicide Apyros 75 WG against the above weed species was better than of Attribut 70 WG. The remaining broadleaf species occurred less numerously – from 1 to 4 plants/m^2. Among those weeds *Thlapsi arvense*, *Capsella bursa-pastoris, Papaver rhoeas* and *Brassica napus* volunteers were very well controlled, (almost 100%) by both herbicides applied with adjuvants. *Lamium* spp. and *Centaurea cyanus* were not satisfactory controlled.

Table 1. Influence of herbicides Apyros 75 WG and Attribut 70 WG used with adjuvants on broadleaf weed control in winter wheat – Winna Góra 2000–2002

No.	Hedrbicides and adjuvants	Dose per ha	Per cent of weed control									
			STEME	VIOAR	VERAR	MATIN	PAPRH	BRSNN	CAPBP	LAM sp.	CENCY	THLAR
1	check (no per sq.m.)	–	(38)	(36)	(18)	(12)	(4)	(3)	(3)	(2)	(2)	(1)
2	Apyros 75 WG	26.5 g	92	62	51	65	89	96	95	55	61	80
3	Apyros 75 WG + Adbios 85 SL	26.5 g + 1.5 l	100	73	56	79	100	100	100	70	68	100
4	Apyros 75 WG + Aero 030 SL	26.5 g + 1.5 l	100	75	58	79	100	100	100	64	67	100
5	Apyros 75 WG + Atpolan 80 EC	26.5 g + 1.5 l	100	72	58	80	100	100	100	61	63	100
6	Apyros 75 WG + Olbras 88 EC	26.5 g + 1.5 l	100	73	57	80	100	100	100	64	69	100
7	Apyros 75 WG + ammonium nitrate	26.5 g + 2.5 kg	99	74	54	74	100	98	98	60	65	98
8	Attribut 70 WG	100 g	90	51	50	60	88	98	94	45	43	80
9	Attribut 70 WG + Adbios 85 SL	100 g + 1.5 l	97	57	54	65	100	100	100	60	48	100
10	Attribut 70 WG + Aero 030 SL	100 g + 1.5 l	94	56	55	69	100	100	100	64	52	100
11	Attribut 70 WG + Atpolan 80 EC	100 g + 1.5 l	96	54	53	65	100	100	98	60	50	100
12	Attribut 70 WG + Olbras 88 EC	100 g + 1.5 l	94	60	54	63	100	100	100	60	53	100
13	Attribut 70 WG + ammonium nitrate	100 g + 2.5 kg	93	60	52	59	100	98	94	58	50	96

STEME – *Stellaria media*, VIOAR – *Viola arvensis*, VERAR – *Veronica arvensis*, MATIN – *Matricaria inodora*, PAPRH – *Papaver rhoeas*, BRSNN – *Brasica napus*, CAPBP – *Capsella bursa-pastoris*, LAM – *Lamium* sp., CENCY – *Centaurea cyanus*, THLAR – *Thlaspi arvense*

Table 2. Influence of herbicides Apyros 75 WG and Attribut 70 WG used with adjuvants on grass weed control in winter wheat – Winna Góra 2000–2002

No.	Herbicides and adjuvants	Dose per ha	Per cent of *Apera spica-venti* control	*Agropyron repens*			
				per cent			no of shoot regrowth from alive rhizomes
				control before harvest	regrowth after harvest	rhizomes control	
1	check (no per sq.m.)	–	(27)	(21)	100	0	7.1
2	Apyros 75 WG	26.5 g	100	78	58	21	5.1
3	Apyros 75 WG + Adbios 85 SL	26.5 g + 1.5 l	100	92	24	39	2.9
4	Apyros 75 WG + Aero 030 SL	26.5 g + 1.5 l	100	94	28	41	2.6
5	Apyros 75 WG + Atpolan 80 EC	26.5 g + 1.5 l	100	91	25	35	2.8
6	Apyros 75 WG + Olbras 88 EC	26.5 g + 1.5 l	100	91	27	35	3.0
7	Apyros 75 WG + ammonium nitrate	26.5 g + 2.5 kg	100	83	50	25	3.4
8	Attribut 70 WG	100 g	100	87	18	44	3.9
9	Attribut 70 WG + Adbios 85 SL	100 g + 1.5 l	100	96	6	58	1.5
10	Attribut 70 WG + Aero 030 SL	100 g + 1.5 l	100	97	4	66	1.4
11	Attribut 70 WG + Atpolan 80 EC	100 g + 1.5 l	100	97	6	57	2.1
12	Attribut 70 WG + Olbras 88 EC	100 g + 1.5 l	100	92	5	65	1.6
13	Attribut 70 WG + ammonium nitrate	100 g + 2.5 kg	100	90	15	49	2.5

100% control of *Apera spica-venti* (APESV) was obtained in all spraying treatments regardless adjuvants used (Tab. 2). Estimation performed during the vegetative season showed that couch grass (*Agropyron repens*) was controlled by Attribut 70 WG applied with adjuvants by 90%–97%. Also Apyros 75 WG used with adjuvants controlled this perennial weed by 83%–94%. Estimation performed at that time showed little differentiation in efficacy of both herbicides in controlling couch grass. During estimation performed 3–4 weeks after harvest on the plots treated with Apyros 75 WG a more intensive regrowth of couch grass was stated than on the plots treated with Attribut 70 WG. This indicates that Attribut 70 WG more effectively controlled not only above ground part of couch grass, and also grass rhizomes than Apyros 75 WG. Estimation performed at that time also indicates, that ammonium nitrate was the weakest adjuvant. On the plots where Apyros 75 WG with oil adjuvants was applied 24%–28% regrowth of couch grass occurred, while on the plots treated with Attribut 70 WG regrowth amounted to only 5%–6%. The laboratory analysis of destruction of couch grass (*Agropyron repens*) rhizomes taken from experimental plots revealed once again a higher efficacy of the preparation Attribut 70 WG (44%–65% destruction) as compared to the preparation Apyros 75 WG (21%–41% destruction). In both cases the weakest effect was recorded in treatments ith addition of ammonium nitrate as an adjuvant. The analysis of alive buds of couch grass revealed their higher number (2.6 to 5.1) in treatments where Apyros 75 WG was used.

To confirm the results obtained in field experiments appropriate greenhouse experiments were carried out, results of which are presented in table 3. The reduction of green mass of above ground parts of couch grass after three weeks from spraying treatment was from around 34% after the application of the herbicide Apyros 75 WG without adjuvants and 47%–57% in the case of application with adjuvants. The herbicide Attribut 70 WG controlled couch grass to a much higher degree. The reduction of green mass was from 55% when Attribut 70 WG was used without adjuvants, to 80%–91% when used with adjuvants. After cutting off the above ground parts of couch grass pots were not watered for 4 weeks to simulate drought conditions frequently occurring after harvest. Afterwards pot watering was resumed and when couch grass plants developed 4–6 leaves, the above – ground plant parts were cut off and weighted. The performed analysis of green mass regrowth, mass of alive rhizomes and number of buds present on rhizomes confirmed earlier results. In every case the best effects were stated after spraying treatments with herbicides to which adjuvants were added, but ammonium nitrate proved to be the least useful adjuvant. Differences between remaining adjuvants were much smaller. For the herbicide Apyros 75 WG the best adjuvant proved to be Adbios 85 SL. However for the herbicide Attribut 70 WG differentiation between oil adjuvants was not significant.

Mass of 1000 grains and number of grains per ear was lower on control plots as compared to treated with herbicides plots (Tab. 4). In the control object mass of 1000 grains amounted to 45.0 g, and in the remaining objects it was higher. In treatments with the preparation Apyros 75 WG it ranged from 45.6 to 46.7 g, and in the treatments with Attribut 70 WG it amounted to 45.2–45.8 g. The lowest number of grains per ear was recorded in the control object (27.3 grains).

Table 3. Influence of herbicides Apyros 75 WG and Attribut 70 WG used with adjuvants on *Agropyron repens* control in % (greenhouse experiment)

No.	Herbicides and adjuvants	Dose per ha	Green mass	Green mass of shoot regrowth	Mass of living rhizomes	Buds on rhizomes
1	check	–	(12.5 g/pot)	(2.9 g/pot	(14.4 g/pot)	(22.3 no/pot)
2	Apyros 75 WG	26.5 g	34.4	41.8	31.3	33.6
3	Apyros 75 WG + Adbios 85 SL	26.5 g + 1.5 l	51.2	80.5	77.8	78.4
4	Apyros 75 WG + Aero 030 SL	26.5 g + 1.5 l	54.4	78.3	75.0	75.3
5	Apyros 75 WG + Atpolan 80 EC	26.5 g + 1.5 l	56.8	75.0	70.2	70.9
6	Apyros 75 WG + Olbras 88 EC	26.5 g + 1.5 l	56.0	75.9	70.4	71.7
7	Apyros 75 WG + ammonium nitrate	26.5 g + 2.5 kg	47.2	69.5	61.1	50.7
		LSD (0.05)	13.12	11.32	9.37	8.33
1	check	–	(13.2 g/pot)	(3.0 g/pot)	(12.3 g/pot)	(23.7 no/pot)
2	Attribut 70 WG	100 g	55.3	60.0	70.1	56.1
3	Attribut 70 WG + Adbios 85 SL	100 g + 1.5 l	90.2	96.3	90.3	91.1
4	Attribut 70 WG + Aero 030 SL	100 g + 1.5 l	90.9	96.6	90.4	92.0
5	Attribut 70 WG + Atpolan 80 EC	100 g + 1.5 l	90.7	96.8	90.2	91.1
6	Attribut 70 WG + Olbras 88 EC	100 g + 1.5 l	90.1	96.6	90.3	92.4
7	Attribut 70 WG + ammonium nitrate	100 g + 2.5 kg	80.0	83.3	76.4	88.6
		LSD (0.05)	9.59	7.75	5.64	6.12

Table 4. Influence of herbicides Apyros 75 WG and Attribut 70 WG used with adjuvants on winter wheat grain yield and grain quality – Winna Góra 2001–2002

No.	Herbicides and adjuvants	Dose per ha	Weight of 1000 seeds (g	No. of seeds per ear	Yield (t/ha)	Protein (%)	Gluten (%)	Sedimentation index
1	check	–	45.0	27.3	5.01	11.43	22.35	25.01
2	Apyros 75 WG	26.5 g	46.7	29.5	6.07	11.33	23.31	26.25
3	Apyros 75 WG + Adbios 85 SL	26.5 g + 1.5 l	46.3	30.0	6.51	11.85	24.28	30.01
4	Apyros 75 WG + Aero 030 SL	26.5 g + 1.5 l	46.5	30.8	6.43	11.81	24.23	30.25
5	Apyros 75 WG + Atpolan 80 EC	26.5 g + 1.5 l	45.9	29.9	6.48	11.73	23.88	29.51
6	Apyros 75 WG + Olbras 88 EC	26.5 g + 1.5 l	46.1	30.1	6.56	11.38	22.38	26.51
7	Apyros 75 WG + ammon. nitrate	26.5 g + 2.5 kg	45.6	30.1	6.26	11.33	22.23	26.01
8	Attribut 70 WG	100 g	45.7	29.7	6.09	10.63	21.01	23.01
9	Attribut 70 WG + Adbios 85 SL	100 g + 1.5 l	45.8	29.0	6.45	11.08	22.65	24.25
10	Attribut 70 WG + Aero 030 SL	100 g + 1.5 l	45.2	29.5	6.56	10.61	21.43	24.01
11	Attribut 70 WG + Atpolan 80 EC	100 g + 1.5 l	45.3	30.7	6.48	10.85	21.65	24.75
12	Attribut 70 WG + Olbras 88 EC	100 g + 1.5 l	45.6	29.8	6.43	11.28	22.35	24.25
13	Attribut 70 WG + ammon. nitrate	100 g + 2.5 kg	45.8	30.3	6.28	10.91	22.01	24.75
	LSD (0.05)				0.313	0.762	ns	3.921

ns – not significant difference

The lowest statistically grain yield was obtained for control plots (5.01 t/ha). However after using herbicides the increase of grain yield was 1.06 t/ha for the herbicide Apyros 75 WG to 1.55 t/ha for Apyros 75 WG + Olbras 88 EC and Attribut 70 WG + Aero 030 SL. Ammonium nitrate added to both herbicides influenced the grain yield increase, but differences were not statistically significant. In the literature there are some data concerning the influence of tested herbicides on the grain yield, presented data deal mainly with herbicidal effect of these preparations. Only Bell (1999) states in his paper that the herbicide Attribut 70 WG increased winter wheat grain yield.

Qualitative analysis showed that the content of protein in wheat grain in the control object amounted to 11.43%. The grain obtained from plots on which the herbicide Apyros 75 WG was used had a similar protein content as stated for the control. Moreover, it can be remarked that protein content in grain from plots sprayed with Attribut 70 WG was distinctly lower than in the remaining objects. The content of gluten was in the control object lower than the norm, and amounted to 23.35% (the norm 26.0%). In the remaining treatments the content of gluten ranged from 21.01% to 24.28% and there were no statistically significant differences between treated objects and untreated control. A minimal value of Zeleny's sedimentation index for grain was exceeded in all experimental objects. In the control object it amounted to 25.01, while the required minimum is 20.0–25.0. For treated objects sedimentation index ranged from 23.01 to 30.25. A definitely better sedimentation index was obtained for grain where the herbicide Apyros 75 WG was applied (26.01–30.25), than for objects treated with Attribut 70 WG (23.01–24.75).

The efficacy of plant protection products is in a considerable degree related to characteristics of water used for spraying treatments. Its parameters can be changed for more favourable by adding adjuvants to spray mixture. In the laboratory experiments comparative studies were performed on characteristics of spray mixture containing two active ingredients (Tab. 5). Surface tension of pure water was 72.5 mN/m. When the two tested herbicides were used alone, they showed a lower surface tension amounting to 58,4 mN/m for the herbicide Attribut 70 WG and 63.6 mN/m for the herbicide Apyros 75 WG. The addition either of four oil adjuvants decreased surface tension. Stronger effects were stated using adjuvants with the herbicide Attribut 70 WG; surface tension dropped to 24.7–37.2 mN/m. For the herbicide Apyros 75 WG these values were somewhat higher. The addition of ammonium nitrate increased surface tension of spray mixture of both herbicides. The analysis of number of falling droplets on horizontal and vertical water-sensitive strips correlated with used herbicides and added adjuvants. Moreover, the number of droplets was correlated with coverage degree of leaf surface. The number of retained droplets on horizontal and vertical surface ranged from 1:6 to 1:10. Analogically, smaller differences were stated for the degree of coverage, proportions of which ranged from 1:5 to 1:8. The addition of ammonium nitrate to both herbicides did not have a marked effect on retention. All remaining adjuvants increased spray retention, but observed results were variable, with no correlation with the activity. Adbios 85 SL and Aero 030 SL used with the herbicide Apyros 75 WG showed the highest retention and were the only that caused retention above 50 %. The same

Table 5. Influence of herbicides Apyros 75 WG and Attribut 70 WG used with adjuvants on physical characteristcs of spray volume

No.	Herbicides and adjuvants	Dose per ha	Surface tension [mN/m]	No. drops per sq.cm		Degree of coverage [%]		Retention	
				horizontal surface	vertical surface	horizontal surface	vertical surface	ml/cm^2	% of spray volume
1	check (water)	–	72.5	–	–	–	–	–	–
2	Apyros 75 WG	26.5 g	63.6	116	16	21.0	4.6	0.85	33.9
3	Apyros 75 WG + Adbios 85 SL	26.5 g + 1.5 l	41.3	129	22	29.6	5.1	1.22	52.7
4	Apyros 75 WG + Aero 030 SL	26.5 g + 1.5 l	36.0	131	18	26.2	5.4	1.12	50.7
5	Apyros 75 WG + Atpolan 80 EC	26.5 g + 1.5 l	38.0	124	22	28.7	5.8	1.03	44.3
6	Apyros 75 WG + Olbras 88 EC	26.5 g + 1.5 l	33.9	120	20	37.0	6.1	1.19	47.7
7	Apyros 75 WG + ammonium nitrate	26.5 g + 2.5 kg	71.5	100	13	24.3	3.9	0.81	32.2
8	Attribut 70 WG	100 g	58.4	90	11	22.6	4.7	0.84	33.5
9	Attribut 70 WG + Adbios 85 SL	100 g + 1.5 l	37.2	142	14	25.9	5.2	0.96	36.0
10	Attribut 70 WG + Aero 030 SL	100 g + 1.5 l	27.4	137	15	25.9	4.2	1.02	40.7
11	Attribut 70 WG + Atpolan 80 EC	100 g + 1.5 l	30.8	137	15	23.8	3.9	1.04	41.6
12	Attribut 70 WG + Olbras 88 EC	100 g + 1.5 l	24.7	129	17	28.8	3.6	1.11	43.9
13	Attribut 70 WG + ammonium nitrate	100 g + 2.5 kg	64.2	102	12	24.3	3.3	0.87	34.8

Table 6. Influence of herbicides Apyros 75 WG, Attribut 70 WG and Attribut Star 57 WG on carryover effect on oilseed rape (field experiment) – Krościna Mała

No.	Herbicides	Dose per ha	Oilseed rape						
			Winter (2002)			Spring (2003)			
			emergence, no. of plants per sq.m (date)			emergence, no. plants per sq.m	heigh in cm	wieght of 1 plant in g	of hulls per 1 plant
			20.09.	10.10.	25.10.				
1	Check	–	54	54	54	84	98	81	49
2	Attribut 70 WG	100 g	22	4	0	82	72	65	2
3	Attribut Star 57 WG	125 g	35	17	0	84	85	69	10
4	Attribut Star 57 WG + Atpolan 80 EC	125 g + 1.5 l	26	7	0	74	85	89	6
5	Apyros 75 WG + Atpolan 80 EC	26.5 g + 1.5 l	48	48	48*	85	96	85	51

* Plant inhibition as compared to untreated plot

adjuvant used with the preparation Attribut 70 WG proved to be Olbras 88 EC, which also very well retained spraying solution when used with the herbicide Apyros 75 WG.

Up-to-date research works described in literature concern the efficacy of individual herbicides in field conditions. The herbicide Apyros 75 WG was evaluated in four doses, alone and with the adjuvant Adbios 85 SL by Adamczewski et al. (1996). Similar studies were conducted by Dobrovdsky (1995) who used five doses and the adjuvant Hyspray 80 SL. Cairns et al. (2001) assessed herbicidal effect of sulfosulfuron against broadleaf weeds while studying new generation wetting agents (monolautate, allopurinol). Similar experiments were conducted with preparation Attribut 70 WG (Adamczewski et al. 2000) applying it with adjuvants Adbios 85 SL, Atpolan 80 EC and Olbras 88 EC, and Sogan et al. (1999) presented evaluation of the influence of adjuvants on efficacy of these herbicides in drought conditions. A number of technical data concerning sulfosulfuron were published by Parrish et al. (1995), but this information is not full. Mathiassen and Kudsk (2004) studied in greenhouse conditions uptake of propoxycarbazone-sodium alone and its mixtures by *Apera spica-venti* in dependence on growth stage of this weed.

There is little research on the influence of sulfosulfuron and propoxycarbazone-sodium on following crop plants. There are recognized experiments on the influence of Attribut 70 WG on the environment (Amman et al. 2000). First noticed deformation symptoms of spring and winter oilseed rape leaves were like those caused by sulfonylourea compounds (Paradowski 1994). However not all sulfonylourea compounds exhibit a negative carryover effect as shown by Adamczewski et al. (1998), while estimating carryover effect of tribenuron-methyl on winter oilseed rape. These experiments enabled to exclude a negative carryover effect on oilseed rape of tribenuron-methyl present in the preparation Attribut Star 57 WG. Together with propoxycarbazone-sodium, tribenuron-methyl is a second component of this herbicide. Sulfonylourea preparations cause growth repression, fast dying of growth apex and deformation and thickening of leaf blades. Similar symptoms were stated after the application of propoxycarbazone-sodium. In plot experiments (Tab. 6) a negative effect of propoxycarbazone-sodium on oilseed rape was very high and reduced its emergence by 32 seedlins/m^2. After some time all emerged plants died. Emergence of spring oilseed rape cultivated after winter oilseed rape was uniform. Only in treatment where the herbicide Attribut Star 57 WG + Atpolan 80 EC was used emergence was lowered by 11%. Plants in herbicidal treatments were shorter by 11–26 cm than in untreated control. Weight of one plant from plots where lower emergence was recorded was similar to that stated on control plots, in the remaining herbicidal treatments weight of one plant was lower by 13–16 g. The highest negative effect was stated while recording the number of siliques on a single plant. It was lower by 43–47 siliques per plant. Sulfosulfuron (Apyros 75 WG + Atpolan 80 EC) applied in this experiment only slightly reduced growth of winter oilseed rape as compared to the control, but did not cause any negative symptoms on spring oilseed rape.

In the greenhouse experiment (Tab. 7) observations showed the best emergence in the control object (20.5 plants/pot). A relatively high plant density was also re-

Table 7. Influence of Attribut 70 WG, Attribut Star 57 WG and Apyros 75 WG on carryover effect on winter oilseed rape (greenhouse experiment)

No.	Herbicides	Dose per ha	No plants per pot	Fresh weight of plants in g per pot	Weight of 1 plant in g	% of plant control
1	check	–	20.5	71.3	3.5	–
2	Attribut 70 WG	60 g	17.5	39.7	2.3	44.2
3	Attribut 70 WG	100 g	15.8	32.6	2.1	54.2
4	Attribut 70 WG	140 g	15.3	20.1	1.3	71.9
5	Attribut Star 57 WG	100 g	16.5	43.5	2.6	38.9
6	Attribut Star 57 WG	125 g	15.5	29.5	1.9	58.6
7	Attribut Star 57 WG	150 g	12.8	18.5	1.5	74.1
8	Apyros 75 WG	26.5 g	19.0	42.9	2.3	39.8
9	Apyros 75 WG + Atpolan 80 EC	26.5 g + 1.5 l	20.0	60.8	3.1	14.7
		LSD (0.05)	1.41		0.25	

Time of application: 06.12.2002; sowing: 12.04.2003; emergence: 17.04.2003; evaluation: 28.05.2003

Table 8. Influence of Attribut 70 WG, Attribut Star 57 WG and Apyros 75 WG on carryover effect on spring oilseed rape and sugar beet (greenhouse experiment)

No.	Herbicides	Dose per ha	No plants per pot		Fresh weight of plants in g per pot		Weight of 1 plant in g		% of plant destruction	
			rape	sugar beet	rape	sugar beet	rape	sugar beet	rape	sugar beet
1	check	–	9.5	9.0	22.1	31.4	2.3	3.5	–	–
2	Attribut 70 WG	60 g	7.3	8.0	7.8	24.8	1.1	3.1	65.0	20.9
3	Attribut 70 WG	100 g	7.3	7.8	2.0	22.0	0.3	2.8	90.8	29.8
4	Attribut 70 WG	140 g	6.5	7.5	1.0	7.8	0.2	1.0	95.4	75.3
5	Attribut Star 57 WG	100 g	9.0	8.5	6.4	25.4	0.7	3.0	71.0	18.9
6	Attribut Star 57 WG	125 g	7.5	8.0	2.7	22.8	0.4	2.8	87.9	27.4
7	Attribut Star 57 WG	150 g	7.0	7.5	1.6	12.2	0.2	1.6	92.8	61.2
8	Apyros 75 WG	26.5 g	9.5	8.8	20.3	30.6	2.1	3.5	8.4	2.3
9	Apyros 75 WG + Atpolan 80 EC	26.5 g+1.5 l	9.8	9.0	20.3	29.8	2.1	3.3	7.6	4.9
		LSD (0.05)	1.26	0.75			0.17	0.39		

Time of application: 06.12.2002; sowing of sugar beet: 30.05.2003; sowing of spring oilseed rape: 02.06.2003; emergence: 07.06.2003; evaluation: 10.07.2003

corded in treatments where the herbicide Apyros 75 WG and Apyros 75 WG + Atpolan 80 EC were used (19.0 and 20 plants/pot). In treatments where higher doses of Attribut 70 WG and Attribut Star 57 WG were used a lower plant density was stated, as compared to the control. The lowest plant density was recorded in the object treated the highest dose (150 g/ha) of the herbicide Attribut Star 57 WG (12.8 plants/pot). It was found that the increase of the dose of herbicides Attribut 70 WG and Attribut Star 57 WG has an unfavourable influence on winter oilseed rape plant density. In treated objects lowering of oilseed rape plant density as compared to the untreated control, was statistically significant. Symptoms of a negative effect of herbicides on winter oilseed rape were: repression of plant growth, leaf deformation, ragged (ribbonlike) leaves, deformation of growth apex, developing on a single plant of several growth apices. The degree of deformation depended on applied doses of herbicides. The strongest damage occurred in the case of earlier application of Attribut 70 WG at the dose of 140 g/ha and Attribut Star 57 WG at the dose 150 g/ha. Some plant damage was recorded in the objects where Apyros 75 WG (with or without adjuvants) was applied. Fresh mass of winter oilseed rape plants was inversely proportional to the used dose of herbicides Attribut 70 WG and Attribut Star 57 WG. The lowest fresh mass (18.5 g/pot) was collected from the experimental object where Attribut Star 57 WG at the highest dose was applied. Analysis of per cent damage of oilseed rape plants shows, that the least plant damage occurred in the object treated with the herbicide Apyros 75 WG with adjuvant (14.7%). Attribut 70 WG at the dose 60 g/ha highly unfavourably affected oilseed rape plants, causing over 44.2% of destruction. Herbicides Attribut 70 WG and Attribut Star 57 WG used at the highest doses destroyed oilseed rape in the range of 71.9% to 74.1%.

Analysis of fresh mass of one plant indicates, that activity of the herbicides Attribut 70 WG and Attribut Star 57 WG resulted in statistically significant decrease of a single plant mass as compared to the control. As doses of the herbicides Attribut 70 WG and Attribut Star WG increased, fresh mass of a single plant decreased.

After harvest of winter oilseed rape to the same pots spring oilseed rape and sugar beet were sown. Sugar beet was sown 3 days earlier than spring oilseed rape to assure a parallel emergence of both plant species. Results obtained in this experiment are presented in table 8. Estimation of emergence of spring oilseed rape and sugar beet indicates, that in all experimental objects where Attribut 70 WG and Attribut Star 57 WG was used at higher doses, there was a decrease of average plant density in the pots, plant stand amounted to from 6.5 to 7.5 of plants/pot for spring oilseed rape and 7.5 to 8.5 plants/pot for sugar beet. In all experimental objects where Attribut 70 WG and Attribut Star 57 WG were applied, the decrease of plant density was statistically significant as compared to the control. Only in the case of Attribiut Star 57 WG application at the lowest dose of 100 g/ha significant decrease of spring oilseed rape and sugar beet stand was not observed. Fresh mass of spring oilseed rape as well as sugar beet was inversely proportional to applied doses of the herbicides Attribut 70 WG and Attribut Star 57 WG. The lowest fresh mass was harvested from the objects where the highest doses of the herbicides Attribut 70 WG and Attribut Star 57 WG were used. Analysis of the amount of fresh mass

shows, that the activity of all herbicides resulted in a statistically significant decrease of fresh mass of a single plant of spring oilseed rape. As doses of herbicides increased, fresh mass of a single plant decreased. The amount of fresh mass of sugar beet plants was related to the applied dose of herbicides Attribut 70 WG and Attribut Star 57 WG. The increase of doses of this preparations resulted in the decrease of sugar beet fresh mass. The lowest amount of sugar beet fresh mass was collected in the objects where the highest doses of the herbicides Attribut 70 WG and Attribut Star 57 WG were applied (7.8 and 12.2 g/pot, respectively). Analysis of the amount of fresh mass shows that the activity of herbicides Attribut 70 WG and Attribut Star 57 WG resulted in a statistically significant decrease of fresh mass of one sugar beet plant harvested from all objects treated with these herbicides. Analysis of per cent destruction of plants shows, that the least damaged were plants harvested from the objects treated with Apyros 75 WG without and with adjuvants (8.4% and 7.6 % for spring oilseed rape, and 2.3% and 4.9% for sugar beet).

The herbicides Attribut 70 WG and Attribut Star 57 WG to a higher degree negatively affected spring oilseed rape plants than sugar beet plants. Attribut 70 WG at the does 60 g/ha strongly negatively affected spring oilseed rape plants causing 65% of their injury. The highest unfavourable effect in relation to spring oilseed rape was stated in the objects where the herbicides Attribut 70 WG and Attribut Star 57 WG were used in the highest dose (95.4% and 92.8% destruction). However the herbicides Attribut 70 WG and Attribut Star 57 WG used at the lowest doses caused respectively 20.9% and 18.9% destruction of sugar beet plants. The strongest unfavourable carryover effect in relation to sugar beet was recorded for the objects where herbicides Attribut 70 WG and Attribut Star 57 WG at the highest doses were used (75.3% and 61.2%, respectively).

CONCLUSION

Obtained results confirmed a high herbicidal effect of tested herbicides against couch grass (*Agropyron repens*). The effectiveness of herbicidal treatments eliminated couch grass competition up to the end of vegetative period of winter wheat. Field and laboratory experiments showed that after the application of herbicides with adjuvants not all rhizomes are killed and they preserve the ability of regeneration. Results obtained in the experiments revealed that a better protection against couch grass regrowth in relation to following crop plants can be obtained after treatments with the herbicide Attribut 70 WG used jointly with oil adjuvants. Definitely the lowest effect on the increase of herbicidal activity was obtained in the case of ammonium nitrate addition as an adjuvant. During the performed studies a very high susceptibility of *Apera spica-venti* to applied herbicides was stated. Also a very high or high herbicidal effect against some broadleaf weed species was recorded. Apart of herbicidal efficacy of sulfosulfuron, such activity was also shown for propoxycarbazone-sodium, generally regarded as destroying only grass weeds. In the performed studies a considerable herbicidal effect was obtained in destroying broadleaf weeds, such as: *Stellaria media, Papaver rhoeas, Capsella bursa-pastoris, Lamium ssp., Thlapsi arvense,* and oilseed rape volunteers, and growth repression was recorded for the following weed species: *Viola arvensis, Veronica spp., Matricaria inodora* and *Lamium spp*. Joint application of the

herbicides Apyros 75 WG and Attribut 70 WG with adjuvants did not cause an increased risk of damage to winter wheat plants. Only a slight inhibition of winter wheat growth was noticed after the application of propoxycarbazone-sodium in the season characterized by drought. However this did not affect grain yield. The application of herbicides with adjuvants influenced grain yield increase. Grain yield increases were statistically significant in some of the treatments. The least favourable effect was recorded in the case of ammonium nitrate used as an adjuvant. Elements of yield structure such as mass of 1000 grains and number of grains per ear were not essentially different from those recorded for control objects. A negative effect of adjuvants on winter wheat grain quality was not stated. Protein and gluten content in some treatments and also in the control object were lower as compared to standard values. Statistically significant differences were not stated for these treatments and this excludes a negative effect of using adjuvants. Zeleny's sedimentation index in all treatments including control fullfilled a required minimum.

In the laboratory studies addition of adjuvants Adbios 85 SL, Aero 030 SL, Atpolan 80 EC, and Olbras 88 EC to spraying solution containing the herbicide Apyros 75 WG or Attribut 70 WG resulted in the decrease of surface tension as compared to the preparations used without adjuvants as well as pure water. As a result, the number of spraying solution droplets and retention increased. An addition of ammonium nitrate as an adjuvant did not improve characteristics of spraying solution.

Results of field experiments showed a very strong carryover effect of propoxycarbazone-sodium on winter oilseed rape. Reduced number of emerged plants as related to the control, which later died in a month time, and a negative effect on spring oilseed rape that was sown in the spring after winter oilseed rape, was demonstrated mainly by a high reduction of silique setting on experimental plants. This indicates on a relatively slow propoxycarbazone-sodium degradation in the soil.

In the conducted greenhouse experiments where propxycarbazone-sodium was earlier used, a distinct reduction of plant density was stated, as well as damage to winter oilseed rape plants, this being dependent on used herbicide dose. Additionally, unfavourable carryover effect of propoxycarbazone-sodium was visible on spring oilseed rape and sugar beet plants that were sown in pots after harvest of winter oilseed rape. Moreover, it was stated that the increase of negative effect observed on spring oilseed rape and sugar beet plants was conditioned by the application of higher doses of propoxycarbazone-sodium. A negative carryover effect of the lowest doses of the herbicides Attribut 70 WG and Attribut Star 57 WG on sugar beet plants was lower as compared to carryover effect on spring oilseed rape plants. A negative carryover effect of sulfosulfuron on spring oilseed rape and sugar beet plants was insignificant.

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POLISH SUMMARY

WPŁYW ADIUWANTÓW NA SKUTECZNOŚĆ DZIAŁANIA SULFOSULFURONU I PROPOKSYKARBAZONU SODOWEGO W ZWALCZANIU CHWASTÓW W PSZENICY OZIMEJ ORAZ DZIAŁANIE NASTĘPCZE

Przedmiotem badań była biologiczna ocena sulfosulfuronu (Apyros 75 WG) i propoksykarbazonu-sodowego (Attribut 70 WG) stosowanych z adiuwantami: Adbios 85 SL, Aero 030 SL, Atpolan 80 EC, Olbras 88 EC i saletrą amonową. Badania przeprowadzono w warunkach polowych, szklarniowych i laboratoryjnych. Doświadczenia polowe wykonano w latach 2000–2002 w Pracowni Doświadczalnictwa Polowego w Winnej Górze oraz w Stacji Oceny

Odmian Krościna Mała. Analizując doświadczenia polowe, szklarniowe i laboratoryjne można stwierdzić, że dodatek adiuwantów do herbicydów Attribut 70 WG i Apyros 75 WG wpływa dodatnio na podniesienie cech fizycznych cieczy użytkowej, na efekt chwastobójczy i przyrost plonu ziarna pszenicy. Spośród pięciu adiuwantów najsłabsze działanie wykazała saletra amonowa, która w małym stopniu wpłynęła na zwiększenie skuteczności chwastobójczej badanych herbicydów w stosunku do chwastów dwuliściennych, a najmniej na zwalczanie perzu właściwego. Również w mniejszym stopniu wpłynęła na przyrost plonu ziarna pszenicy ozimej. Pozostałe adiuwanty, Adbios 85 SL, Aero 030 SL, Atpolan 80 EC i Olbras 88 EC działały podobnie. Uzyskiwany efekt chwastobójczy, wysokość plonu, i elementy struktury plonu po łącznym zastosowaniu herbicydów z adiuwantami były w małym stopniu zróżnicowane, a analizy statystyczne na ogół nie wykazywały istotnych różnic. Nie wykazano ujemnego wpływu, łącznego stosowania adiuwantów na jakość wypiekową ziarna. Oba herbicydy zabezpieczały skutecznie pszenicę ozimą przed perzem właściwym w całym sezonie wegetacyjnym. Jednak Attribut 70 WG zwalczał w lepszym stopniu także rozłogi perzu, dlatego stanowisko po uprawę następnej rośliny jest lepiej zabezpieczone niż po oprysku herbicydem Apyros 75 WG. Z kolei Apyros 75 WG charakteryzował się nieco szerszym zakresem zwalczanych gatunków dwuliściennych. Działanie następcze jest bardziej ograniczone w przypadku zastosowania propoxykarbazonu sodowego. Na stanowiskach, na których był stosowany propoksykarbazon sodowy nie powinno się uprawiać rzepaku ozimego, rzepaku jarego i buraka cukrowego. Na stanowiskach po zbożach odchwaszczanych sulfosulfuronem nie należy uprawiać rzepaku ozimego, natomiast można uprawiać rzepak jary i burak cukrowy.