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PHYTOTOXICITY AND EFFICACY OF CHLORSULFURON IN WINTER WHEAT

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Abstract: The experiments were carried out in 2001–2004. The aim of the research was to establish such chlorsulfuron dose that would be effective for *Apera spica-venti* control and would not be phytotoxic for winter wheat. Besides, it was performed to identify resistance of *A. spica-venti* biotypes appearing in the experimental fields to chlorsulfuron. The field experiments were conducted in winter wheat that were notably of *A. spica-venti* weedy. The fields belonged to a private farm at Karczyce and Gałów. The cereals had grown there for a long time and winter wheat monoculture together with repeated chlorsulfuron application was used. The experiments were conducted using randomized blocks method with 3 reapplications. Chlorsulfuron (Glean 75 WG) was applied at rates ranging from 1 to 4.5 times higher than the recommend field dose (15–67.5 g a.s./ha). The degree of sensitivity of *A. spica-venti* to chlorsulfuron was established by biological tests in greenhouse conditions. The herbicide was applied at four – leaf stage of development at rates ranging from 1 to 32 times higher than the recommend field dose (11.25–360 g a.s./ha). Poor chlorsulfuron efficacy to control of *A. spica-venti* or its lack might testify for resistance of this species to the herbicide. Chlorsulfuron as an active ingredient was very selective for winter wheat. An application of 67.5 g/ha of the herbicide was not harmful to growth and yielding of winter wheat. Unfortunately, even this dose of the herbicide was ineffective in control of *A. spica-venti*. In fields with a long-term monoculture of winter wheat together with the use of chlorsulfuron, resistance of *A. spica-venti* biotypes to this active ingredient was ascertained. Studies in greenhouse conditions proved that the biotypes were not damaged even when the dose was exceeded 32 times. The above confirmed the resistance of these biotypes to chlorsulfuron.

Key words: chlorsulfuron, phytotoxicity, winter wheat, efficacy, *Apera spica-venti*, resistance, biological tests

INTRODUCTION

One of the factors that determines a high agricultural production is an ability to keep the field free from weeds within the entire vegetation period. Weeds are charac-

terized by long-term seed viability; they grow rapidly and adapt to unfavourable environmental conditions. The influence of weeds on cereal yields varies and depends on the prevalent weeds. Rola (1988) wrote that the one species, among others, that is very competitive with winter wheat was *A. spica-venti*. Dense infestation by this weed (100 panicles per m^2) caused a 30% yield drop of cereals. The author has proved that the threshold for economic damage by infestations of this weed was only 5–10 plants per m^2 in winter wheat fields (Rola and Rola 2002a).

This powerful threat to the basic factors including normal growth and development of field crops requires growers to pursue effective defences. Up to now, an application of selective herbicides has been an effective method for weed control. In cereals protection the new generation agents include sulfonylurea herbicides produced by E. J. Du Pont de Nemorus & Co. Inc. at the end of the seventies. They are used at very low levels in the order of 0.02 kg/ha. The first active substance from that group was chlorsulfuron. Nowadays, in the fields where Glean 75 WG herbicide has been applied many times, poor efficacy of the recommended dose in control of *A. spica-venti* was observed.

It was assumed in the experiments that the herbicide could be effective, when applied in a higher dose. Therefore, the aim of the research was to establish such chlorsulfuron dose that would be effective for *A. spica-venti* control and would not be phytotoxic for winter wheat. However, taking into account data given in the literature regarding the possibility that certain species of weeds became resistant to sulfonylurea herbicides after 5-year an application period (LeBaron 1991), it was also reasonable to identify resistance of *A. spica-venti* biotypes appearing in the experimental fields to chlorsulfuron.

MATERIALS AND METHODS

The field experiments were conducted in 2001–2004 at winter wheat (cultivar Mewa) that were notably of *A. spica-venti* weedy. The fields belong to a private farm at Karczyce and Gałów. The cereals had grown there for a long time and winter wheat monoculture together with repeated chlorsulfuron application was used (Domaradzki and Rola 2002).

The experiments were conducted using randomized blocks method with 3 reapplications and plot size of 20 m^2. Chlorsulfuron (Glean 75 WG) was applied at rates ranging from 1 to 4.5 times higher than the recommend field dose (15.0–67.5 g a.s./ha). The herbicide was applied in spring time at BBCH 21–22 of *A. spica-venti*.

Three weeks after herbicide treatment, an estimation of phytotoxicity influence on the winter wheat with a valuation method was performed. Plants condition was evaluated in 9-degree scale, where 1 – determines no reaction of crop and 9 – crop damaged.

The influence of chlorsulfuron on winter wheat was established on the ground of yield components. Before harvest on each plot all spikes per 1 m^2 were counted, and 30 spikes of winter wheat were taken and more detailed assessment including length of spike, number of grains in spike and their weight and weight of thousand grains were done.

Five weeks upon the herbicide application the aboveground part of *A. spica-venti* was cut. The weed from 3 randomly chosen places of each plot (3 x 0.25 m^2) was col-

lected. The herbicide efficacy was defined on the basis of the fresh weight reduction in comparison to untreated plants.

Frequency factor of weeds that were not controlled by chlorsulfuron were established by square-frame method. It was determined the number of *A. spica-venti* before and after herbicide application. The plants from 2 indicate places of each plot (2 x 1 m^2) were counted. The measurements were effected 3 times: before herbicide application, 4 weeks after application and at flowering of weeds. On the basis of numbers, difference before and after chlorsulfuron application, the herbicide efficacy was defined.

The degree of sensitivity of *A. spica-venti* to chlorsulfuron was established by biological tests in greenhouse conditions. The seed samples came from fields where the efficacy of chlorsulfuron was unsatisfactory. The seeds were sown in plastic pots containing 2:1 mixture of peat and sand. Chlorsulfuron was applied at the four-leaves stage of development at rates ranging from 1 to 32 times the recommend field dose (11.2–360 g a.s./ha). After 6 weeks upon the application of the herbicide the fresh and dry weight of plants was established. The experiments were conducted using a completely randomized design with 3 reapplications. ED_{90} was used to evaluate the herbicide efficacy. The plants that were weed-controlled to such degree were numbered among the herbicide sensitive ones. At the same time lack of effective weed killing proves resistance of plants to the herbicide.

All data were subjected to the analysis of variance and least significant difference values were calculated at the 5% probability level (LSD 0.05).

RESULTS

In experiment that took place at Karczyce, phytotoxicity influence of chlorsulfuron on winter wheat was not observed. No significant differences in a number of spikes between untreated plants (427 spikes per m^2) and after herbicide application at the doses ranged from 15 to 37.5 g a.s./ha doses were ascertained. The other doses of active substance contributed to significant increase in number of spikes and after application the highest dose 490 spikes per m^2 occurred. Application of chlorsulfuron in 15–22.5 g/ha doses, did not have significant influence on length of spike of winter wheat and weight of grains in spike. Further increase in the active substance doses resulted in significant increase of length of spike and weight of grains. After use of 67.5 g a.s./ha of herbicide, the length of spike reached 6.92 cm and weight of grains – 1.76 g.

Only the recommended dose of the herbicide did not affect the significant increase of number of grains in spike, yield of winter wheat and weight of thousand grains. The yield reached the control plants value and 5.58 t/ha was obtained. Proportionally to the increase of herbicide dose, yield and weight of thousand grains increased too. In an object treated with chlorsulfuron at 67.5 g/ha dose, the yield of winter wheat reached 6.64 t/ha and weight of thousand grains was 49.38 g (Table 1).

Phytotoxic effect of chlorsulfuron application at the highest doses (52.5–67.5 g/ha) was growth retardation of *A. spica-venti* but without any influence on later growth. (Table 2).

In an object where herbicide was not applied, occurrence of 31 plants of *A. spica-venti* per m^2 was ascertained. After application of chlorsulfuron from 15 g/ha to 30 g/ha doses on the winter wheat plantation, there was 76–86% individuals that were not controlled by herbicide. Further increase in the active substance doses caused decrease

of percentage part individuals to about 50% (after application 52.5 g/ha of chlorsulfuron) and to 42% – after application 67.5 g/ha. Herbicide in doses 15–22.5 g/ha decreased fresh weight of plants by about 4–9% in comparison with untreated plants. Increase of the dose to 45 g/ha resulted in decrease of *A. spica-venti* weight by 28%. After application of the highest dose of chlorsulfuron, reduction of fresh weight at 47% of plants followed (Table 2).

Table 1. Influence of different chlorsulfuron doses on winter wheat – Karczyce 2001–2004

Object	Dose of chlorsulfuron [g/ha]	Phytotoxicity TRZAW	Number of spikes [No./m^2]	Lenght of spike [cm]	Number of grains in spike	Weight of grains in spike [g]	Weight of thousand grains [g]	Yield [t/ha]
1	–	1	427	6.2	31.7	1.5	45.6	5.6
2	15.0	1	428	6.5	32.8	1.5	46.1	5.6
3	22.5	1	434	6.5	33.8	1.6	46.5	5.9
4	30.0	1	441	6.6	33.9	1.6	47.4	5.9
5	37.5	1	448	6.7	33.9	1.6	47.9	6.0
6	45.0	1	453	6.7	34.4	1.7	48.1	6.1
7	52.5	1	468	6.9	34.5	1.7	48.1	6.3
8	60.0	1	488	6.9	34.9	1.7	49.0	6.6
9	67.5	1	490	6.9	36.3	1.8	49.4	6.6
		LSD (0.05)	21.8	0.3	1.3	0.1	0.7	0.2

TRZAW – *Triticum* spp.

Table 2. Estimation of chlorsulfuron efficacy in control of *Apera spica-venti* – Karczyce 2001–2004

Object	Dose of chlorsulfuron [g/ha]	Phytotoxicity	Per cent of resistant biotypes	Reduction of fresh weight [%]
1	control	9	31*	57.6 **
2	15.0	8	86	4
3	22.5	8	81	9
4	30.0	8	76	18
5	37.5	8	65	22
6	45.0	7	57	28
7	52.5	6	53	35
8	60.0	6	48	37
9	67.5	6	42	47
				LSD (0.05) = 6.1

* number of *A. spica-venti* [No./m^2]
** weight of *A. spica-venti* [g/m^2]

In the winter wheat, that was cultivated at Gałów, phytotoxic influence of chlorsulfuron on crop was observed when the herbicide was used at 67.5 g/ha dose. It revealed inconsiderable growth retardation, but after 2–3 weeks after treatment these symptoms disappeared (Table 3). Significant differences in number of spike per m^2 and length of spike were not observed between the control object and those treated with chlorsulfuron from 15 to 30 g/ha doses. Increase of active substance dose caused significant increase parameter values. After treatment with the highest dose (67.5 g/ha), 426 spikes per m^2 appeared and length of spike increased up to 0.43 cm compared to control plants.

Table 3. Influence of different chlorsulfuron doses on winter wheat – Gałów 2001–2004

Object	Dose of chlorsulfuron [g/ha]	Phytotoxicity TRZAW	Number of spikes [No./m^2]	Lenght of spike [cm]	Number of grains in spike	Weight of grains in spike [g]	Weight of thousand grains [g]	Yield [t/ha]
1	–	1	344	6.6	33.4	1.3	39.6	3.9
2	15.0	1	347	6.6	33.7	1.3	39.7	3.9
3	22.5	1	354	6.7	34.1	1.4	40.1	3.9
4	30.0	1	355	6.8	34.4	1.4	40.6	3.9
5	37.5	1	375	6.9	35.1	1.4	41.1	4.1
6	45.0	1	379	7.0	36.8	1.6	42.0	4.1
7	52.5	1	385	7.0	37.3	1.6	42.6	4.1
8	60.0	1	411	7.0	37.5	1.6	43.0	4.7
9	67.5	1–2	426	7.0	37.6	1.6	43.4	4.8
		LSD (0.05)	15.5	0.2	0.9	0.1	0.7	0.2

TRZAW – *Triticum* spp.

The recommended field dose of chlorsulfuron and 1.5 times higher did not cause significant difference in weight and number of grains in spike. Further increase in the active substance doses increased weight of thousand grains and it was significantly different in comparison with untreated plant. Significant increase of yield of winter wheat was ascertained after application of 67.5 g/ha dose of chlorsulfuron and reached 4.78 t/ha (Table 3).

Phytotoxic influence of chlorsulfuron on *A. spica-venti* biotype showed slight growth retardation of weeds after application the herbicide in 52.5–67.5 g/ha doses. The plants were in a good condition (Table 4).

On the plots where chlorsulfuron was not applied, 56 plants of *A. spica-venti* per m^2 occurred. The application of this compound in recommended dose did not cause significant decrease of this species number. In plantation there were 95% plants that did not respond to the herbicide. The use a preparation from 22.5 to 37.5 g/ha doses proved occurrence of resistance by 70–82% of *A. spica-venti* biotypes. Chlorsulfuron in 15.0–30.0 g/ha doses decreased the fresh weight of weed by 16–33% in comparison with untreated plants. Increase of herbicide dose caused further decrease of fresh weight and application of herbicide at dose 67.5 g/ha caused 50% reduction.

Table 4. Estimation of chlorsulfuron efficacy in control of *Apera spica-venti* – Gałów 2001–2004

Object	Dose of chlorsulfuron [g/ha]	Phytotoxicity	Per cent of resistant biotypes	Reduction of fresh weight [%]
1	control	9	56*	87.3 **
2	15.0	8	95	16
3	22.5	7	82	27
4	30.0	7	74	33
5	37.5	7	70	34
6	45.0	6–7	65	35
7	52.5	6	63	45
8	60.0	6	50	46
9	67.5	6	44	50
				LSD (0.05) = 4.2

* number of *A. spica-venti* [No./m^2]
** weight of *A. spica-venti* [g/m^2]

Taking into consideration poor efficacy of chlorsulfuron in the control of *A. spica-venti* in field experiments, in autumn seed samples of weeds were collected in order to establish their sensitivity to this herbicide in laboratory conditions. The application of chlorsulfuron in the medium recommended dose (11.2 g/ha) did not cause the decrease of fresh weight and in a slight degree decreased dry weight of aboveground part of *A. spica-venti* that occurred in winter wheat at Karczyce. Chlorsulfuron in the highest doses (90–360 g/ha) caused the fresh and dry weight reduction only by 35–40% thereof in comparison with untreated plants (Fig. 1).

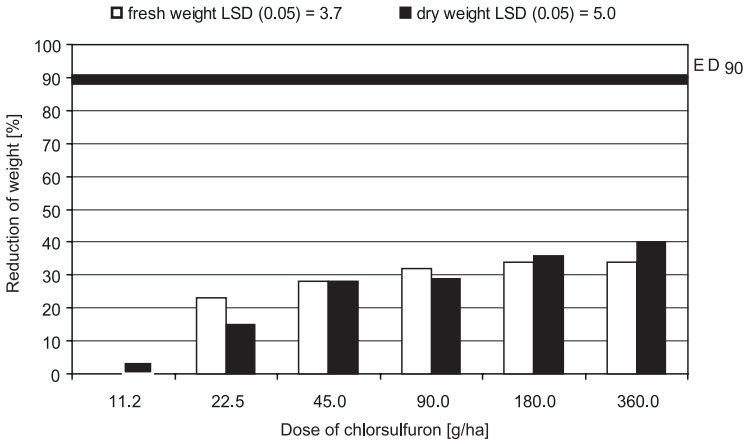

Fig. 1. Influence of different chlorsulfuron doses on fresh and dry weight of *Apera spica-venti* biotype (Karczyce)

After application of chlorsulfuron from 11.2 to 45 g/ha doses of *Apera spica-venti* biotype that occurred in winter wheat at Gałów, reduction of fresh and dry weight of aboveground part of plants in range 10–35% was noticed. The use of higher doses of preparation (90–360 g a.s./ha) contributed to 30–35% decrease of the parameters value (Fig. 2).

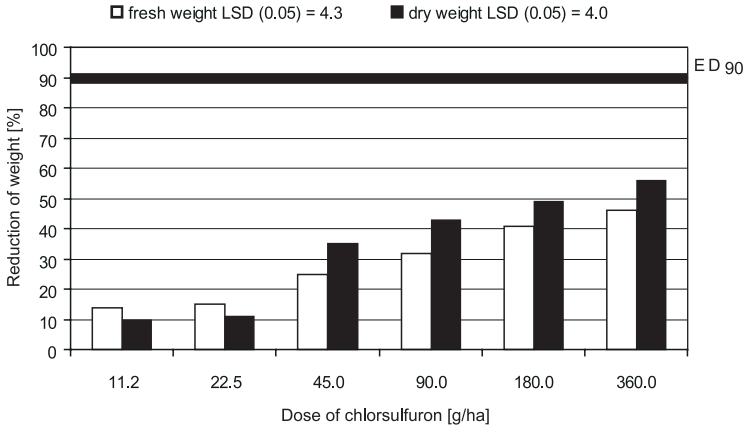

Fig. 2. Influence of different chlorsulfuron doses on fresh and dry weight of *Apera spica-venti* biotype (Gałów)

The results of biological tests may thus indicate the occurrence of resistance of *A. spica-venti* to chlorsulfuron. Biotype o ccurring at Gałów showed lower level of resistance to the herbicide than biotype occurring at Karczyce. Nevertheless, none of chlorsulfuron doses caused 90% reduction of aboveground part of plants.

DISCUSSION

Proper choice of a herbicide should be based on the knowledge of weed level in the plantation which will allow keeping of weed-free condition of the field until the crop harvest. Favourable effect of the herbicide is indicated by its high effectiveness with respect to weed infestation reduction, limitation of the weed threat, increase of crop yield, lowering of plant care expenditure and higher effectiveness of integrated plant protection methods (Adamczewski 1988).

The effect of herbicides in field conditions is connected with a number of factors which include, among others: air temperature, air and soil humidity, soil type, crop and weed plant development stages. Effectiveness of these preparations results also from the tillage system in the given area (proper crop rotation) and herbicides rotation connected with this. Simplifications in the tillage system combined with using of active substance belonging to the same chemical group for many years may have serious, negative effects for agriculture practice.

The results presented in the paper confirm the above observations. The field experiments were conducted on winter wheat plantations in the fields located at Karczyce and Gałów where winter wheat had been grown for many years in the monoculture system and weeds had been removed using chlorsulfuron (Glean 75 WG) in the recommended dose. Recently, poor effectiveness of this preparation in control of

A. spica-venti has been observed in these locations. The application of chlorsulfuron at the level of 15 and 22.5 g/ha caused reduction of fresh weight of the aboveground part of this biotype appearing in the experimental field at Karczyce only by 4–9%. From 81 to 86% biotypes not destroyed by this herbicide remained on the plantation (Table 2). A similar situation occurred in the second experiment on the winter wheat plantation at Gałów. There the recommended dose of chlorsulfuron in the field (15 g/ha) reduced the growth of *A. spica-venti* by 16% versus the untreated plants with the herbicide and there were 95% plants left on the plantation which did not react to this active substance (Table 4). This result may indicate that the compensation of this species of weed took place in these locations. The research of Pawłowski et al. (1987, 1991), Zawiślak and Adamiak (1994) proved that a noticeable increase of *A. spica-venti* number occurs in crop rotations with high share of winter cereals and monoculture of these plants. Furthermore, Chodova (1997), Gressel (1983), Rola (1988), Domaradzki and Rola (2002) agreed that intensive and prolonged usage of herbicides from the same chemical group in the same location led to the compensation of specific species in weed association and to selection and occurrence of resistant weed biotypes that up till now were deemed susceptible.

The results of biological tests presented in this paper proved that biotypes of *A. spica-venti* resistant to chlorsulfuron appeared in winter wheat at Karczyce and Gałów. The application of the herbicide even at the level 32 times higher than the recommended one (360 g/ha) practically did not limit the plant growth in 90% cases in comparison with untreated plant – which could be the basis to assume that the given species was susceptible to the applied substance (Figure 1, 2). In the world literature numerous studies have appeared which confirm occurrence of resistance to chlorsulfuron, but the researches on the reaction of *A. spica-venti* to this active substance could be regarded as pioneering.

A. spica-venti is a species very threatening to the winter wheat. Results of the researches (Rola 2002a) indicated that the occurrence of 100 *A. spica-venti* panicles per m^2 causesd approximately 30% decrease of winter wheat yield.

It was assumed in the programme of the research that reduction of the occurrence of *A. spica-venti* in winter wheat on the plantations was possible by applying higher dose of chlorsulfuron, providing that this species had enzymatic resistance that a suitable herbicide dose may interrupt (Rola 2002b). Therefore, the influence of high chlorsulfuron doses on growth and yield of winter wheat was also investigated in the field experiments. Lack of significant differences in the yield of this plant after application of the active substance in the recommended dose was correlated with poor weed control. After application of the highest doses of the herbicide (60 and 67.5 g/ha) the first symptoms of phytotoxic influence became visible in form of growth retardation of winter wheat at Gałów (Table 3).

Chlorsulfuron selectivity in winter wheat was the subject of several scientific papers. The details regarding the reaction of cereals to chlorsulfuron were contradictory. The herbicide was recommended for weed control in cereals in doses below 20 g/ha (Cornwell and Lane 1981). Hegeman and Behrens (1981), Cornwell and Lane (1981) did not ascertain changes in growth of wheat even after application of the substance in 75 and 125 g/ha doses. Results of the researches by Wicks et al. (1987) proved that changes in the development of winter wheat might take place under the influence of chlorsulfuron in 70 g/ha dose. Results showing differentiated reaction of winter wheat to the active substance were presented also in the research by Dastgheib and Field (1990).

The results of the experiments described in the paper confirmed the possibility of using chlorsulfuron in winter wheat at the doses up to 67.5 g/ha which were safe for the field crop.

CONCLUSIONS

Chlorsulfuron was a very selective for winter wheat as an active ingredient. The application of 67.5 g/ha of the herbicide was not harmful for growth and yielding of winter wheat. Unfortunately, even this dose of the herbicide was ineffective in control of *A. spica-venti*. In fields with a long-term monoculture of winter wheat together with the use of chlorsulfuron, the resistance of *A. spica-venti* biotypes to this active substance was ascertained. The research in greenhouse conditions proved that the biotypes were not controlled even after application of chlorsulfuron at the dose 32 time higher than recommended one. That confirms occurrence of the resistance to chlorsulfuron in these biotypes.

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POLISH SUMMARY

FITOTOKSYCZNOŚĆ I SKUTECZNOŚĆ CHLOROSULFURONU W PSZENICY OZIMEJ

Badania wykonano w latach 2001–2004. Celem ich było ustalenie dawki chlorosulfuronu skutecznej dla *Apera spica-venti* i nie wykazującej fitotoksycznego działania na pszenicę ozimą. Ponadto dokonano identyfikacji stopnia odporności na chlorosulfuron biotypów tego gatunku chwastu występujących na polach doświadczalnych.

Doświadczenia polowe prowadzono na plantacjach pszenicy ozimej silnie zachwaszczonej *A. spica-venti*, należących do gospodarstw indywidualnych w Karczycach i Gałowie. Na tych stanowiskach uprawiano przez wiele lat zboża, w tym pszenicę ozimą w monokulturze w połączeniu z wielokrotnym stosowaniem chlorosulfuornu. Zastosowano metodę losowanych bloków w 3 powtórzeniach. Chlorosulfuron aplikowano w dawkach od zalecanej do 4,5-krotnie wyższej (15 do 67,5 g s.a./ha).

Stopień wrażliwości *A. spica-venti* na chlorosulfuron ustalano testem biologicznym w warunkach szklarniowych, w których zastosowano ten środek, w dawkach od średniej zalecanej (11,25 g/ha), nawet do 32-krotnie od niej wyższej (360 g/ha).

Chlorosulfuron okazał się substancją wysoce selektywną w stosunku do pszenicy ozimej. Aplikacja jego w dawce 67,5 g/ha nie wpłynęła ujemnie na wzrost i rozwój rośliny uprawnej, jak również na jej plonowanie. Nawet w tej dawce środek okazał się nieskuteczny w niszczeniu *A. spica-venti*. Badania w warunkach kontrolowanych wykazały, że biotypy te również nie uległy zniszczeniu po aplikacji preparatu w dawce 32-krotnie wyższej od zalecanej, co potwierdza występowanie u nich odporności na chlorosulfuorn.