Sensitivity of Kochia (*Kochia scoparia* [L.] Schrader) from Three Localities to Selected Sulfonylureas, Imazapyr and Atrazine

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Abstract

CHODOVÁ D., MIKULKA J. (2001): **Sensitivity of kochia** (*Kochia scoparia* [L.] Schrader) **from three localities to selected sulfonylureas, imazapyr and atrazine**. Plant Protect. Sci., **37**: 115–120.

The presence of kochia (*Kochia scoparia* [L.] Schrader) was discovered at three new localities with different histories of imazapyr use. At the locality Jihlava, kochia was resistant to imazapyr and cross resistant to nine sulfonylureas after long-term applications of imazapyr. At Žižkov and Karlín most kochia plants were sensitive to all tested sulfonylureas. Plants showed the highest level of resistance to triflusulfuron. Plants of all three populations were sensitive to atrazine. After treatment with all tested herbicides the fresh matter of aboveground parts of the populations at Žižkov and Kolín was reduced in comparison with the untreated control. Treatment with all sulfonylureas and imazapyr caused significant differences in the fresh matter of aboveground parts between the population at Jihlava and those at Karlín and Žižkov.

Keywords: *Kochia scoparia*; sulfonylureas; imazapyr; atrazine; resistance to acetolactate synthase inhibitors

Kochia (*Kochia scoparia* [L.] Schrader) is a weed species introduced to the Czech Republic by railroad transportation. Its occurrence in the environs of railroad stations, ports, factory buildings and other places was described by JEHLÍK (1998), its biology by MIKULKA *et al.* (1999). *Kochia scoparia* var. *trichophylla*, grown as an ornamental annual plant in gardens, often escapes into the wild.

The existence of kochia resistant to imazapyr was reported by CHODOVÁ & MIKULKA (1997). It was the first finding of this weed species showing resistance to the enzyme acetolactate synthase in Europe (CHODOVÁ & MIKULKA 2000a,b; CLAUDE & CORNES 1999). The number of localities where resistant kochia is encountered is increasing. It is very important that this species is spreading, e.g. in Prague, to localities other than those along railroads (crossroads, roads, uncultivated areas).

The fear that this weed species could spread to arable land is justified. The density of Kochia may exceed 2100 seedlings/m^2 and reduce the yield of wheat by more than 20% and that of soybean by over 30%. Further, kochia remains green long after the harvest dates common for these crops, thereby reducing harvest efficiency and clogging combines (WOLF *et al.* 2000).

As kochia was discovered also on arable land (not published yet), its spread is worth studying. Differences were examined between the plants of three recently discovered populations with different applications of acetolactate synthase inhibiting herbicides. The first locality is near a railroad viaduct, the second is a railroad station and the third locality is not in any contact with the railroad. Plants grown from seeds collected at these localities were tested for their sensitivity to imazapyr, for cross-resistance to selected sulfonylureas and atrazine, and fresh and dry matter were determined after herbicide applications.

MATERIAL AND METHODS

Experimental plants

Seeds of kochia (*Kochia scoparia*) were collected in October 1999 at three localities:

Jihlava – railroad tracks and station, irregular applications of imazapyr;

Karlín – border of the main road and on adjacent unkept land, no herbicide applications were identified;

Supported by the National Agency for Agricultural Research (NAZV) project No. QD 1304.

Žižkov – border of the main road near a railroad viaduct, original plants along the railroad may have been treated with herbicides.

The seeds were separated with an air flow separator and kept in a refrigerator at 5°C. The seeds were able to germinate immediately after collection.

Plant cultivation

Seeds were sown into plastic containers 15 × 15 cm in size at an amount of 0.2 g per container. The number of plants was reduced to 10 after emergence; they were grown in a greenhouse (no additional lighting, temperature 20–22° C).

Herbicidal treatment

When plants were 3–5 cm high, herbicides were applied with a hand sprayer, using 50 ml water per m^2. Table 1 shows the herbicides, active ingredients and dosage. Besides the basic dose (B) a twofold dose was used (2 B) to assess the number of resistant plants in a population. Control plants were grown without herbicidal treatment.

Evaluation of resistant plants

Every experiment was conducted in three replications; of each experiment 100 plants were evaluated. Plants that did not show any symptoms of wilting or drying within 2 weeks after treatment were considered to be resistant individuals. Some plants were of lower habit than the control ones, with witches' broom branching or light-green in color. Significance of differences was evaluated by *t*-test. Fresh and dry matter (at 75–78°C) was determined 2 weeks after treatment.

Kochia sensitivity to atrazine was verified on the basis of photochemical activity of chloroplasts in the presence of 10^{-5} and 10^{-4} M atrazine, using our own verified methods (KOČOVÁ *et al.* 1988; KÖRNEROVÁ *et al.* 1998).

RESULTS AND DISCUSSION

Kochia which was proved to be resistant to imazapyr possesses a target site of acetolactate synthase resistance (CLAUDE & CORNES 1999; CHODOVÁ & MIKULKA 2000a,c). Unlike in resistant plants, the enzyme acetolactate synthase in sensitive plants is inhibited in the presence of a herbicide, which causes disorders of the biosynthesis of branched-chain amino acids.

As the spread of kochia is of an expansive character in the Czech Republic, it is necessary to monitor the occurrence of sensitive and resistant biotypes at new localities, their spreading, as well as the biological characteristics of both biotypes. With respect to potential eradication of this weed species, an important finding is that the germination rate of the imazapyr resistant biotype within 144 h at 5°C is higher than that of the sensitive biotype, but no such differences were observed at higher temperatures (CHODOVÁ & MIKULKA 2000b).

Taking into account the likely occurrence of this weed on arable land in future, it is desirable to study cross-resistance and biological effects of sulfonylureas on both biotypes.

The paper presents the characteristics of kochia populations from three new localities, including cross resistance to some herbicides, and fresh and dry matter.

Table 1. List of herbicides, active ingredients and dosage per 1 ha

Active ingredient	Active ingredient (g/ha) (B)	Herbicide
Rimsulfuron	15	Titus 25 WG*
Thifensulfuron-methyl + isodecylalcohol-ethoxylat	14.4 + 18	Refine 75 DF
Metsulfuron-methyl	6	Ally DF
Chlorsulfuron	22.5	Glean 75 WG
Sulfosulfuron	19.5	Monitor 75 WDG*
Nicosulfuron	60	Milagro
Triflusulfuron-methyl	15	Safari 50 WG*
Tribenuron	18.0	Granstar 75 WG*
Iodosulfuron-methyl + mefenpyr-diethyl	10 + 24	Husar**
Iodosulfuron-methyl + amidosulfuron + mefenpyr-diethyl	3.75 + 15 + 37.5	Sekator**
Imazapyr	1000	Arsenal
Atrazine	1000	Gersaprim 500 FW
Control		without treatment

B = basic dose, addition of wetting agent: *Trend 0.1%, **Istroekol 1 l/ha

Table 2. Number of kochia (*Kochia scoparia*) plants from three localities resistant to selected sulfonylureas, imazapyr and atrazine. Expressed as percentage of plants before treatment

Active ingredient	Locality Jihlava		Žižkov		Karlín	
	B	2 B	B	2 B	B	2 B
Rimsulfuron	100	100	40	20	0	0
Thifensulfuron -methyl + Isodecylalcohol-ethoxylat	100	100	40	0	10	0
Metsulfuron-methyl	100	100	20	10	20	0
Chlorsulfuron	100	100	20	0	0	0
Sulfosulfuron	100	100	30	20	10	0
Nicosulfuron	100	100	40	20	30	0
Triflusulfuron-methyl	100	100	50	40	50	40
Tribenuron	100	100	20	10	0	0
Iodosulfuron-methyl + mefenpyr-diethyl	100	100	0	0	0	0
Iodosulfuron-methyl + amidosulfuron+ mefenpyr-diethyl	100	100	0	0	0	0
Imazapyr	100	100	30	0	0	0
Atrazine	0	0	0	0	0	0

B = basic dose, 2 B = twofold basic dose (see Table 1)

Table 2 shows the number of kochia plants resistant to selected sulfonylureas, imazapyr and atrazine.

Kochia plants from Jihlava showed cross-resistance to nine sulfonylureas and imazapyr. The percent of resistant plants at the other two localities was low (Table 2). Cross-resistance of kochia to triflusulfuron, nicosulfuron, tribenuron and prosulfuron + primisulfuron was demonstrated in our previous papers. Similar to those results (CHODOVA & MIKULKA 2000b), kochia was demonstrated to be most resistant to triflusulfuron, and newly resistant to rimsulfuron, thifensulfuron, metsulfuron, iodosulfuron and iodosulfuron + amidosulfuron (Table 2). Kochia populations in the U.S.A. were resistant to the same sulfonylureas (proved e.g. by KWON & PENNER [1995] and THOMPSON *et al.* [1994]), while resistance to sulfosulfuron has not been described yet. We suppose the imazapyr resistant populations occurring in this country have a certain level of resistance to all acetolactate synthase inhibitors. On the basis of all available results we believe it more likely that kochia resistance was evoked by long-term applications of acetolactate synthase inhibitors than by direct introduction of a resistant biotype. It is also supported by a finding of atrazine-resistant kochia at two localities with intensive treatment. This type of multiple resistance in kochia is quite unique throughout the world.

As resistance of kochia to atrazine has already been demonstrated (CHODOVÁ & MIKULKA 2000b), resistance to this herbicide was verified on the basis of Hill's reaction activity. The results are given in Table 3. Unlike the control, sensitivity to this herbicide is confirmed by the inhibition of photochemical activity of chloroplasts in the presence of atrazine.

Table 3. Photochemical activity of chloroplasts in kochia from two localities after atrazine applications. The values are percent of the control

Locality	Atrazine 10^{-4}	Atrazine 10^{-5}	Reaction to atrazine
Žižkov	4	23	sensitive
Karlín	4	24	sensitive

Control Žižkov = 18.9 mmol O_2/kg chlorophyll per s
Control Karlín = 22.6 mmol O_2/kg chlorophyll per s

Fresh matter of the aboveground parts of kochia from three localities after applications of imazapyr, selected sulfonylureas and atrazine is listed in Table 4. Table 5 shows these values expressed as percent of the untreated control and an evaluation of the significance of differences between the localities.

Following the treatment with all sulfonylureas, imazapyr and atrazine, fresh matter at localities with sensitive plants was lower than in the control. After resistant plants were treated, fresh matter was higher or identical with the control (except atrazine and imazapyr application).

The results (Table 5) showed that there were no differences in kochia fresh matter between the three populations in the control variant and after atrazine treatment. This is explained by the fact that kochia from all localities was sensitive to atrazine. There were highly significant differences in fresh matter after applications of sulfonylureas and imazapyr between the population from Jihlava (kochia resistant to all target herbicides) and those

Table 4. Fresh matter of the above-ground parts of three kochia (*Kochia scoparia*) populations after herbicidal treatment. The values are in mg per plant

Active ingredient	Jihlava $\bar{x} \pm s_{\bar{x}}$	Žižkov $\bar{x} \pm s_{\bar{x}}$	Karlín $\bar{x} \pm s_{\bar{x}}$
Rimsulfuron	364.4 ± 31.5	68.5 ± 8.2	53.5 ± 8.2
Thifensulfuron	357.2 ± 44.1	98.5 ± 17.8	68.1 ± 8.3
Metsulfuron	346.9 ± 36.8	114.3 ± 20.0	70.7 ± 11.0
Chlorsulfuron	423.7 ± 39.8	173.2 ± 22.6	144.0 ± 22.1
Sulfosulfuron	464.8 ± 47.4	212.5 ± 35.1	56.3 ± 6.5
Nicosulfuron	437.2 ± 39.2	123.0 ± 18.1	119.8 ± 15.2
Triflusulfuron	418.9 ± 46.0	178.8 ± 23.1	97.7 ± 13.9
Tribenuron	370.3 ± 32.5	127.6 ± 18.2	113.9 ± 15.0
Iodosulfuron	373.3 ± 32.8	143.0 ± 30.0	107.4 ± 15.3
Iodosulfuron + amidosulfuron	431.4 ± 44.9	127.9 ± 12.8	71.0 ± 12.6
Imazapyr	241.8 ± 33.2	53.3 ± 7.4	98.2 ± 15.2
Atrazine	29.8 ± 2.3	22.3 ± 2.1	33.2 ± 2.8
Control	359.4 ± 41.4	316.6 ± 40.6	391.5 ± 36.0

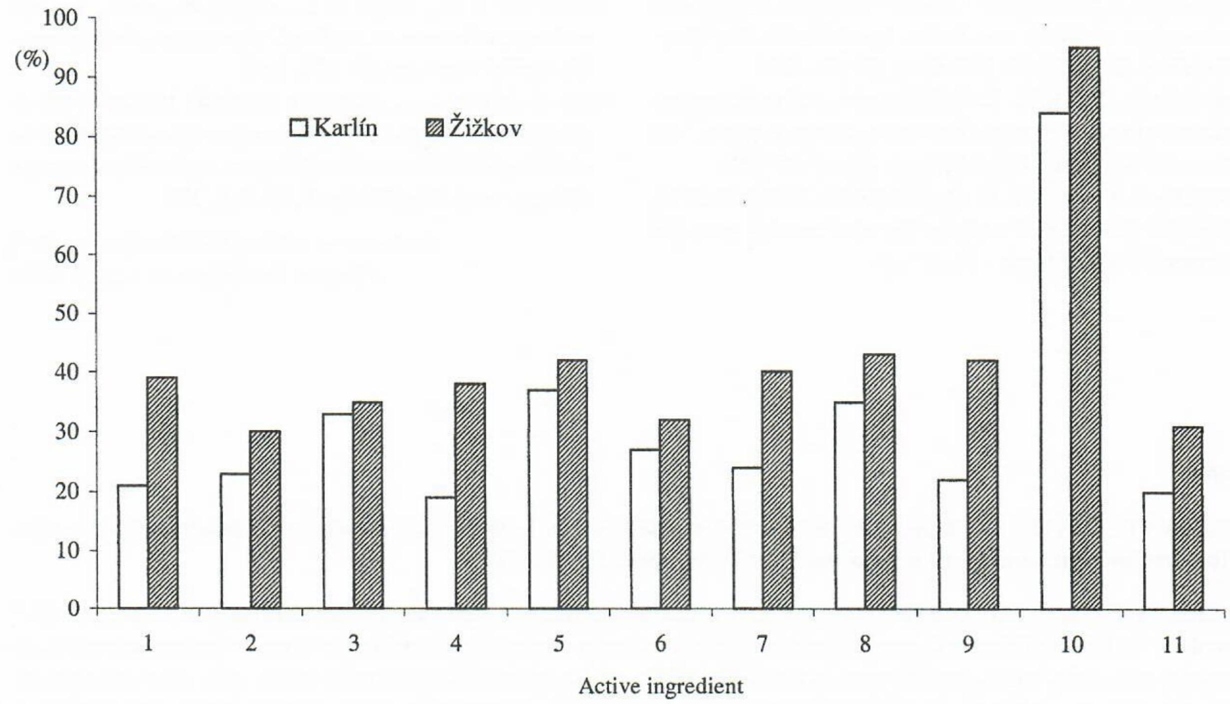
from Žižkov and Karlín. A comparison of plants from Žižkov and Karlín indicated lower fresh matter at Karlín after treatment with metsulfuron, chlorsulfuron, sulfosulfuron, triflusulfuron, iodosulfuron, iodosulfuron + amidosulfuron and rimsulfuron, thifensulfuron, nicosulfuron and tribenuron (insignificant difference).

Dry matter content in plants from localities with sensitive individuals was lower after treatment with all herbicides. The Jihlava population had the lowest dry matter content after tribenuron treatment, which is in agreement with previous results (CHODOVÁ & MIKULKA 1998, 2000b) determined at localities with a high proportion of imazapyr resistant plants. When dry matter content is given as percent of the resistant population (Jihlava), dry matter content ranges from 31–95% in the Žižkov population, and from 19–84 % of the control in the Karlín population (Fig. 1). After treatments with sulfonylureas and imazapyr, differences between the active ingredients are larger for fresh matter than for dry matter.

Table 5. Fresh matter of the above-ground parts of kochia (*Kochia scoparia*) plants expressed as percent of untreated control

Active ingredient	Fresh matter as percent of the control			Significance of differences between the localities		
	Jihlava	Žižkov	Karlín	Karlín/Jihlava	Karlín/Žižkov	Jihlava/Žižkov
Rimsulfuron	101	22	13	**	–	**
Thifensulfuron	99	31	17	**	–	**
Metsulfuron	96	36	18	**	**	**
Chlorsulfuron	118	55	37	**	**	**
Sulfosulfuron	130	67	14	**	**	**
Nicosulfuron	122	39	30	**	–	**
Triflusulfuron	116	56	25	**	**	**
Tribenuron	103	40	29	**	–	**
Iodosulfuron	104	45	27	**	**	**
Iodosulfuron + amidosulfuron	120	40	18	**	**	**
Imazapyr	67	17	25	**	–	**
Atrazine	8	7	8	–	–	–
Control	100	100	100	–	–	–

$N = 4$, **$P < 0.01$ (highly significant difference); *$P < 0.05$ (significant difference); – $P > 0.05$ (insignificant difference)



The values are percent of the resistant biotype

Control in mg per plant: Jihlava 47.3; Žižkov 44.0; Karlín 46.1

1 = Rimsulfuron, 2 = Thifensulfuron, 3 = Metsulfuron, 4 = Chlorsulfuron, 5 = Sulfosulfuron, 6 = Nicosulfuron, 7 = Triflusulfuron, 8 = Iodosulfuron, 9 = Iodosulfuron + Amidosulfuron, 10 = Tribenuron, 11 = Imazapyr

Fig. 1. Dry matter content in the aboveground parts of kochia (*Kochia scoparia*) after herbicidal treatment

The new kochia population from Jihlava was found to possess resistance to imazapyr and cross-resistance to sulfonylureas. This is in agreement with our finding that imazapyr resistant kochia is also resistant to other acetolactate synthase inhibitors (MIKULKA & CHODOVÁ 2000a,b). The Karlín population consists mostly of sensitive plants, the Jihlava population only of resistant plants. The Žižkov and Karlín populations had decreased contents of fresh and dry matter not only against the control but also against the Jihlava population.

After the spread of resistant weeds has been prevented, their monitoring and application of suitable diagnostic methods are important. As kochia is cross-resistant to a broad spectrum of sulfonylureas, it is necessary to seek other alternative herbicides for its control. Bladex 50 SC with the active ingredient cyanazine was found effective in our trials.

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Received for publication November 14, 2000
Accepted for publication July 20, 2001

Souhrn

CHODOVÁ D., MIKULKA J. (2000): **Citlivost bytelu metlatého** (*Kochia scoparia* [L.] Schrader) **ze tří lokalit vůči vybraným sulfonylmočovinám, imazapyru a atrazinu.** Plant Protect. Sci., **37**: 115–120.

Na třech lokalitách s odlišným způsobem a dobou používání imazapyru se nově vyskytl bytel metlatý (*Kochia scoparia* [L.] Schrader). Na lokalitě Jihlava s dlouhodobým používáním imazapyru vykazoval bytel metlatý rezistenci vůči imazapyru a cross rezistenci vůči devíti sulfonylmočovinám. Na lokalitách Žižkov a Karlín byla většina rostlin citlivá vůči všem zkoumaným sulfonylmočovinám, přičemž nejvyšší rezistence byla prokázána vůči triflusulfuronu. Vůči atrazinu byly citlivé rostliny ze všech tří populací. U rostlin z lokality Jihlava na rozdíl od lokalit Žižkov a Karlín nebyla proti kontrole po ošetření sulfonylmočovinami snížena hmotnost čerstvé biomasy a sušina. Byly zjištěny průkazné rozdíly mezi lokalitou Jihlava v porovnání s lokalitami Karlín a Žižkov v hmotnosti čerstvé biomasy nadzemních částí po ošetření všemi herbicidy ze skupiny sulfonylmočovin a imazapyrem.

Klíčová slova: *Kochia scoparia*; sulfonylmočoviny; imazapyr; atrazin; rezistence vůči inhibitorům acetolaktatsyntasy; hmotnost čerstvé biomasy; sušina

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