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SUSCEPTIBILITY OF FIBER FLAX CULTIVARS TO HERBICIDES

Krzysztof Heller[1], *Kazimierz Adamczewski*[2], *Mirosław Nanaszko*[3]

[1]Institute of Natural Fibres, Wojska Polskiego 71b, 60-630 Poznań, Poland
e-mail: khel@inf.poznan.pl
[2]Institute of Plant Protection, Miczurina 20, 60-318 Poznań, Poland
e-mail: K.Adamczewski@ior.poznan.pl
[3]Experimental Station, Bukówka,
76-219 Jezierzyce Słupskie, Poland

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Abstract: The paper presents the results of plot experiments on susceptibility of 4 cultivars of fiber flax: Alba, Belinka, Nike and Wiko to broad-leaved weed herbicides (chlorsulfuron, bentazon + MCPA) and graminicides (haloksylop-R, chizalofop P, and setoxidim), used as single or mixtures. The experiments were conducted on two soil suitability complexes in the years 1994–1996.
The cultivars Alba and Wiko were more susceptible to herbicides than Nike and Belinka. More susceptible Alba and Wiko showed faster phenological development as compared to two other cultivars, especially in the first period of growing season (from germination to the stage of fast growth). Herbicides had more phytotoxic effect on flax plants on light soil than on other ones.
The most phytotoxic effect on tested cultivars, leading to a reduction of scutched fiber yield, was observed for the mixture of haloksylop-R + chlorsulfuron and bentazon + MCPA followed by setoxidim at 7-day interval. Higher yields of most flax cultivars were observed when flax was sprayed with chlorsulfuron herbicides followed by one of the tested graminicides (haloksylop-R, chizalofop P or setoxidim) after seven days from application of chlorsulfuron.
The cultivar Nike has been found to be the most resistant to tested herbicides. Application of chemical methods of weed control for cultivation of this cultivar resulted in an increase of long yield of scutched fiber. The herbicides tested in the experiment usually had a beneficial effect on the quality of flax scutched fiber, especially in case of Alba and Wiko cultivars.

Key words: fiber flax cultivars, herbicides, susceptibility

INTRODUCTION

There are two types of flax (*Linum usitatissimum* L.): fiber flax and oil flax. Fiber flax is a plant of wet moderated climate cultivated mainly for fiber.

The degree and state of weed infestation of fiber flax are decisive for the fiber yield and quality of fiber i.e. divisibility, delicacy, greasy feel, heaviness, strength, color and homogeneity. The efficacy of weed control is therefore indirectly connected with the yield and quality of fiber (Heller 1992; Lapkovskaya and Soroka 1997).

The following herbicides are recommended for protection of flax in Poland: pre-emergence herbicides: linuron, lenacil, and post-emergence herbicides: MCPA, bentazon, chlopyralid, chlorsulfuron, tifensulfuron-methyl, dichlofop-methyl, fluazifop-P-buthyl, setoxidim, haloksifop-R, chizalofop , chizalofop-P-ethyl.

The many-year observations of the infestation of fiber flax in Poland (Heller 1998) showed that the highest threat to this crop is represented by the following weeds: *Chenopodium ablum* L., *Polygonum convolvulus* L., *Viola arvensis* Murr., *Stellaria media* Vill., *Lamium amplexicaule* L., *Thlaspi arvense* L., *Elymus repens* (L.) Gould. and *Polygonum nodosum* Pers. The second numerous group of weeds contains the following species: *Polygonum aviculare* L., *Sinapsis arvensis* L., *Capsella bursa-pastoris* (L.) Med., *Anthemis arvensis* L., *Galium aparine* L., *Echinochloa crus-galli* (L.) P.B. and *Poa annua* L.

Appearance of grass weeds in high numbers [*Elymus repens* (L.) Gould. (L.) Gould., *Echinochloa crus-galli* (L.) P.B. and *Poa annua* L.] very often requires application of broad-leaved weeds control herbicides and graminicides. There is an insufficient information in domestic and foreign bibliography regarding susceptibility of fiber flax cultivars to herbicides. In Poland, the flax cultivars are evaluated prior registration in field experiments for their agricultural value, i.e. yield of straw and seed, fiber efficiency in the straw, fiber quality, growing season length, resistance to diseases (Fusarium wilt) and lodging. But there is a shortage of information referring to the resistance of new cultivars of flax to pesticides, especially to herbicides.

The aim of the research discussed here was a biological assessment of herbicides used in weed control in fiber flax with a special attention paid to the following aspects: susceptibility of 4 cultivars of fiber flax to the mixtures of herbicides used for simultaneous control of dicots and grass weeds; weed control efficacy for particular weed species; the effect of herbicides on flax yield and its quality.

MATERIALS AND METHODS

The baselines for the research were field experiments conducted in the Experimental Station of INF in Bukówka (pomorskie province) in 1994–1996. The experiments were set out by the simple randomized block design with four replications – in four belts with border plots. The area of plots for harvesting was 10 m^2. The spacing between plots – 0.5 m. The experimental factors were: cultivars of fiber flax: Alba (PL), Belinka (NL), Nike (PL), Wiko (PL); herbicides: controlling broad-leaved weeds, chlorsulfuron – 11.25 g a.i. ha^{-1} (Glean 75 WG, containing containing 75% Du Pont), bentazon + MCPA – 1,020 g + 150 g a.i. ha^{-1} (Basagran M, containing bentazon 340 g a.i. L^{-1} + MCPA 50 g a.i. L^{-1}, BASF); graminicides: haloksylop-R – 104 g a.i. ha^{-1} (Perenal 104 EC, containing 104 g a.i. L^{-1} Dow AgroSciences), chizalofop P – 100 g a.i. ha^{-1} (Targa Super 5 EC, containing 5% a.i. L^{-1} Nissan), setoxidim – 375 g a.i. ha^{-1} (Nabu Plus EC, containing setoxidim – 12.5% a.i. L^{-1} Nippon Soda). During the time when research was carried out six field experiments were conducted: 3 on light and 3 on medium heavy soil. Spraying of herbicides was carried out using an experimental sprayer with a compressed air container of APORO Company from Poznań, applying 300 l/ha of spraying liquid, nozzle type: Tee-Jet XR 110–03, pressure 3 bar. The following observations and measurements were conducted regarding, evaluation of herbicide effect on flax plants, weed control efficacy, structure of flax yield, quantitative and qualitative assessment of fiber. The evaluation of phytotoxic effect of herbicides to flax was conducted 7–14 days after application using 1–9 scale. The yields obtained on the light soil were subjected to technological evaluation in the laboratory of Flax Industry Factory Makop in Malbork. The effect of applied chemical treatments on the yield and quality of fiber was determined as % of long scutched fiber. The quality of long scutched fiber was determined according to organoleptic testing supplemented with application of model controls. Data were subjected to an analysis of variance. Means were compared using Fischer's Least Significant Difference (LSD) Test at the 5 % level (p=0.05).

RESULTS

Efficacy of weed control treatments (Tab. 1)

Chlorsulfuron – 11.25 g a.i. ha^{-1} applied in mixtures with graminicides (haloksylop-R – 104 g a.i. ha^{-1}, chizalofop P – 100 g a.i. ha^{-1}, setoxidim – 375 g a.i. ha^{-1}) was as effective in controlling of broad-leaved weeds as applied separately. The following species were resistant to chlorsulfuron: *Viola arvensis* Murr. and *Fumaria officinalis* L. Bentazon [1,020 g a.i. ha^{-1}] + MCPA [150 g a.i. ha^{-1} applied separately or simultaneously together with setoxidim – 375 g a.i. ha^{-1} usually satisfactory decreased biomass of broad-leaved weeds only on rye strong soil suitability complex.

Table 1. Weed control in flax (average from 3 field trials on 2 soil type and 4 cultivars)

Treatments ($g\ ha^{-1}$)	Weeds control in %	
	Broad-leaved	Grasses
Unweeded control (number per sq.m)	(147)	(14)
chlorsulfuron (11.25)	88	–
chlorsulfuron (11.25) + chizalofop P (100)	87	83
chlorsulfuron (11.25) + haloksylop-R (104)	88	87
chlorsulfuron (11.25) + setoxydim (375)	80	82
chlorsulfuron (11.25) after 7 days chizalofop P (100)	77	92
chlorsulfuron (11.25) after 7 days haloksylop-R (104)	76	94
chlorsulfuron (11.25) after 7 days setoxydim (375)	75	90
bentazon (1,020) + MCPA (150)	95	–
bentazon (1,020) + MCPA (150) + chizalofop P (100)	83	90
bentazon (1,020) + MCPA (150) + haloksylop-R (104)	79	87
bentazon (1,020) + MCPA (150) + setoxydim (375)	82	82
bentazon (1,020) + MCPA (150) after 7 days chizalofop P (100)	95	97
bentazon (1,020) + MCPA (150) after 7 days haloksylop-R (104)	96	90
bentazon (1,020) + MCPA (150) after 7 days setoxydim (375)	91	88

Graminicides – haloksylop-R – 104 g a.i. ha^{-1}, chizalofop P – 100 g a.i. ha^{-1}, setoxidim – 375 g a.i. ha^{-1} applied separately or together with dicodyledonous weed controlling herbicides, generally well destroyed *Elymus repens* (L.) Gould., *Avena fatua L.* and *Lolium perenne* L., while *Poa annua* L. – poorly. The best results of controlling of *Poa annua* were obtained when haloksylop-R was applied – 104 g a.i. ha^{-1} within 7 days after bentazon [1,020 g a.i. ha^{-1}] +*MCPA* [150 g a.i. ha^{-1}].

The effect of herbicides on fiber flax (Tab. 2)

The most visible changes in emergence of flax plants on both soil suability complexes were visible when the mixtures of herbicides were applied: chlorsulfuron or bentazon + MCPA with graminicides – especially with haloksylop-R and chizalofop P. Additionally, on the good rye complex, the damages of plants caused by herbicides were observed on the plots where graminicides were applied 7 days after herbicides bentazon + MCPA. The flax cultivars evaluated in the experiment showed

Table 2. Flax cultivars susceptibility to herbicides (average from 3 field trials)

Treatments (g ha^{-1})	Flax cultivars susceptibility to herbicides*							
	Alba		Belinka		Nike		Wiko	
	medium heavy soil	light soil	medium heavy soil	light soil	medium heavy soil	light soil	medium heavy soil	light soil
Unweeded control	1	1	1	1	1	1	1	1
chlorsulfuron (11.25)	1	1	1	1	1	1	1	1
dctlparchlorsulfuron (11.25) + chizalofop P (100)	1–2	1–2	1–2	1–2	1	1	2	2
chlorsulfuron (11.25) + haloksylop-R (104)	4–5	4–5	3–4	3–4	2–3	2–3	3–4	3–4
chlorsulfuron (11.25) + setoxydim (375)	1–2	1–2	1–2	1–2	1	1	1–2	1–2
chlorsulfuron (11.25) after 7 days chizalofop P (100)	1	1	1	1	1	1	1	1
chlorsulfuron (11.25) after 7 days haloksylop-R (104)	1	1	1	1	1	1	1	1
chlorsulfuron (11.25) after 7 days setoxydim (375)	1	1	1	1	1	1	1	1
bentazon (1,020) + MCPA (150)	1	1	1	1	1	1	1–2	1–2
bentazon (1,020) + MCPA (150) + chizalofop P (100)	1–2	1–2	1–2	1–2	1–2	1–2	1–2	1–2
bentazon (1,020) + MCPA (150) + haloksylop-R (104)	2–3	1	1	1	1	1	1	1
bentazon (1,020) + MCPA (150) + setoxydim (375)	1	1	1	1	1	1	1	1
bentazon (1,020) + MCPA (150) after 7 days chizalofop P (100)	1	2–3	1	2–3	1	1	1–2	1–2
bentazon (1,020) + MCPA (150) after 7 days haloksylop-R (104)	1	2–3	1	2–3	1	2–3	1–2	2–3
bentazon (1,020) + MCPA (150) after 7 days setoxydim (375)	1	2–3	1	2–3	1	2–3	1–2	1–2

*According to 1–9 scale, where: 1 – no injury, 9 – total damage different degree of resistance to applied herbicides: Alba – on both soil complexes strongly reacted by a chlorosis and inhibition of growth when the herbicide chlorsulfuron was used together with graminicides (especially with haloksylop-R). The damage factor reached 4–5 in 9-degree scale (Tab. 1). The cultivar Alba similarly reacted on soils of good wheat complex in treatments: bentazon + MCPA + haloksylop-R and bentazon + MCPA + chizalofop *P*. On a poorer soil (good rye complex) strong damages of flax were observed in treatments where graminicides were applied 7 days after herbicides bentazon + MCPA. Cultivar Belinka on both soil complexes, the yellow tincture was visible of leaf blade caused by joint application of graminicides (especially haloksylop-R) with chlorsulfuron and also as a result of application of the mixture bentazon + MCPA + chizalofop P. Moreover, on lighter soil, like in case of Alba, the damages of plants caused by graminicides applied 7 days after bentazon + MCPA were observed (damage factor: 2–3). Nike was the most resistant to herbicides among tested cultivars. On both soil complexes the symptoms of damage were noted in the following treatments: chlorsulfuron + haloksylop-R and bentazon + MCPA + chizalofop P. Furthermore, on the light soil the phytotoxic effect of weed control chemicals was observed as a result of application of first bentazon + MCPA, followed by graminicides haloksylop-R or setoxidim 7 days after. Wiko unlike other cultivars was susceptible to the mixtures of herbicides including bentazon + MCPA. Slight symptoms of phytotoxic effect of those plant protection products (1–2 degrees in a 9-degree scale) – a transient tincture and twisting of leaf blade – had no negative effect on yields of this cultivar. Summarize up, it can be said that among tested cultivars of fiber flax Alba and Wiko were more susceptible to herbicides than Nike and Belinka.

Structure of yields

The effect of herbicides and soil type on flax stem technical length (Tab. 3)

The technical length of stems is a non-branched part of stem measured from the base of cotyledon to the first branching at the top. There is a strong correlation between the technical length of stems and the efficiency and quality of the fiber. The most important in processing of straw into fiber is the non-branched part of stems, containing the highest amount and the best quality of fiber. The stem longer and the rank higher of flax straw in classification system. In comparative experiments conducted on the two soil suitability complexes, the stronger shortening of technical length of the stem, caused by phytotoxic effect of herbicides was observed on lighter soil. The shortening of technical length of the stem was observed for all tested cultivars: on both soil suitability complexes – as a result of phytotoxic effect of a mixture of chlorsulfuron + haloksylop-R (the straw shorter by 2.9–5.5 cm than of a control); on lighter soil – as a result of joint application of herbicides chlorsulfuron or bentazon + MCPA with graminicides (shortening of the technical length of stems by 1.1–6.9 cm) and also on the plots sprayed with graminicides where graminicides were applied 7 days after application of mixture of bentazon + MCPA (the straw shorter by 3.4–7.9 cm as compared with the control). Among tested cultivars the most susceptible to the mixtures of herbicides was Wiko. The most favorable effect of herbicides on technical length of the straw was observed for Nike.

Table 3. The effect of herbicides and soil type on flax stem technical length (average from 3 field trials)

Treatments (g ha^{-1})	Stem technical length [cm]							
	Alba		Belinka		Nike		Wiko	
	medium heavy soil	light soil	medium heavy soil	light soil	medium leavy soil	light soil	medium heavy soil	light soil
Unweeded control	85.4	75.3	85.9	73.1	86.5	77.5	86.9	76.7
chlorsulfuron (11.25)	87.1	73.7	84.4	72.3	85.9	75.6	86.3	75.0
chlorsulfuron (11.25) + chizalofop P (100)	85.6	71.5	84.5	70.3	88.9	70.7	85.0	69.8
chlorsulfuron (11.25) + haloksylop-R (104)	78.5	71.7	79.8	68.2	81.8	72.5	81.4	73.8
chlorsulfuron (11.25) + setoxydim (375)	84.4	72.3	84.2	71.2	86.9	75.5	84.3	71.7
chlorsulfuron (11.25) after 7 days chizalofop P (100)	87.7	72.8	86.5	71.8	90.8	72.1	88.5	72.5
chlorsulfuron (11.25) after 7 days haloksylop-R (104)	87.6	74.4	87.9	73.3	87.6	75.4	86.4	75.4
chlorsulfuron (11.25) after 7 days setoxydim (375)	85.9	74.0	85.7	72.8	89.2	77.2	86.5	76.2
bentazon (1,020) + MCPA (150)	86.9	72.9	88.4	71.6	90.3	74.8	88.1	75.0
bentazon (1,020) + MCPA (150) + chizalofop P (100)	85.7	72.2	84.6	72.0	88.4	74.6	86.2	74.5
bentazon (1,020) + MCPA (150) + haloksylop-R (104)	85.7	71.9	86.6	68.7	87.9	71.9	87.7	72.9
bentazon (1,020) + MCPA (150) + setoxydim (0.375)	86.6	70.8	89.2	68.9	90.9	72.3	88.6	72.2
bentazon (1,020) + MCPA (150) after 7 days chizalofop P (100)	85.3	71.5	85.2	68.9	87.2	72.3	86.8	73.3
bentazon (1,020) + MCPA (150) after 7 days haloksylop-R (104)	87.6	70.6	88.2	68.2	89.2	69.6	89.0	73.0
bentazon (1,020) + MCPA (150) after 7 days setoxydim (375)	85.7	69.8	87.8	66.4	88.6	70.8	86.1	70.6

	LSD (0.05)	**LSD** (0.01)
Medium heavy soil	1.27 cm	1.68 cm
Light soil	2.00 cm	2.63 cm

The yield of raw threshed straw (Tab. 4)

The decrease of raw threshed straw yield was observed: on light soil for all cultivars sprayed with bentazon + MCPA followed after 7 days by graminicides (especially haloksylop-R) (the straw yield lower by 2.57–8.36 dt ha^{-1} as compared with the control) and additionally for Alba when chlorsulfuron was applied alone or together with a graminicide setoxidim (yield decrease by 3.50–4.73 dt ha^{-1}); on medium heavy soil on plots with Alba in treatments: chlorsulfuron + haloksylop-R and bentazon + MCPA + haloksylop-R (the straw yield lower by 5.43 dt ha^{-1} and 3.23 dt ha^{-1}, respectively).

Table 4. The effect of herbicides on fibre flax straw yield (average from 3 field trials)

Treatments (g ha^{-1})	Flax cultivars straw yield (kg ha^{-1})							
	Alba		Belinka		Nike		Wiko	
	medium heavy soil	light soil	medium heavy soil	light soil	medium heavy soil	light soil	medium heavy soil	light soil
Unweeded control	7033	4803	6793	4310	6790	4530	6847	4460
chlorsulfuron (11.25)	7467	4453	7120	4797	7447	4933	7633	4343
chlorsulfuron (11.25) + chizalofop P (100)	7620	4510	7190	4223	7513	4473	7247	4343
chlorsulfuron (11.25) + haloksylop-R (104)	6490	4720	6693	4383	7040	4707	6580	4867
chlorsulfuron (11.25) + setoxydim (375)	7407	4330	7097	4683	8270	4873	7770	4457
chlorsulfuron (11.25) after 7 days chizalofop P (100)	7777	5080	7490	5140	7533	4323	7607	4917
chlorsulfuron (11.25) after 7 days haloksylop-R (104)	7683	4810	7333	4767	6983	4780	7413	4807
chlorsulfuron (11.25) after 7 days setoxydim (375)	7765	4983	6883	4773	7407	5033	7383	5117
bentazon (1,020) + MCPA (150)	7457	4743	7180	4293	7220	4767	6823	4383
bentazon (1,020) + MCPA (150) + chizalofop P (100)	7157	4633	6820	4630	7050	4803	7053	4817
bentazon (1,020) + MCPA (150) + haloksylop-R (104)	6710	4733	6700	4400	7460	4423	6987	4313
bentazon (1,020) + MCPA (150) + setoxydim (0.375)	7503	4517	7237	4010	7807	4547	7530	4151
bentazon (1,020) + MCPA (150) after 7 days chizalofop P (100)	7027	4267	6937	3713	7543	4273	7143	4067
bentazon (1,020) + MCPA (150) after 7 days haloksylop-R (104)	7773	4137	6977	3863	7503	4160	6887	4057
bentazon (1,020) + MCPA (150) after 7 days setoxydim (375)	6883	3967	7143	3793	7033	4077	6773	4207

	LSD (0.05)	**LSD** (0.01)
Medium heavy soil	213	282
Light soil	258	340

When chlorsulfuron was applied solely or in combination with graminicides, keeping the 7-day break between treatments, the considerable straw yield increased for Belinka, Nike and Wiko was observed.

The yield of seeds (Tab. 5)

Tested herbicides usually showed favorable effect on the yield of seeds: for Alba and Nike on both soil suitability complexes; for Belinka and Wiko on lighter soil. The herbicides tested in the experiment modified the percentage of total scutched fiber in the yield of straw, the cultivar-born feature, to a very limited degree. Only Alba and Belinka responded with a significant decrease of percentage of long scutched fiber in the straw to application of a mixture chlorsulfuron + haloksylop-R also in treatments where bentazon + *MCPA* was followed by setoxidim after 7 days.

Table 5. The effect of herbicides on fibre flax seed yield (average from 3 field trials)

Treatments (g ha^{-1})	Flax cultivars seed yield (kg ha^{-1})							
	Alba		Belinka		Nike		Wiko	
	medium heavy soil	lightsoil	medium heavy soil	light soil	medium heavy soil	light soil	medium heavy soil	light soil
Unweeded control	717	410	887	433	874	426	956	340
chlorsulfuron (11.25)	1032	353	744	514	1018	448	1046	303
chlorsulfuron (11.25) + chizalofop P (100)	973	384	843	417	966	457	789	394
chlorsulfuron (11.25) + haloksylop-R (104)	834	439	954	449	981	457	752	382
chlorsulfuron (11.25) + setoxydim (375)	990	379	914	522	1271	546	1111	367
chlorsulfuron (11.25) after 7 days chizalofop P (100)	902	426	888	615	987	385	765	432
chlorsulfuron (11.25) after 7 days haloksylop-R (104)	946	370	655	477	919	499	684	392
chlorsulfuron (11.25) after 7 days setoxydim (375)	765	521	655	526	901	440	741	476
bentazon (1,020) + MCPA (150)	947	478	797	542	991	567	769	473
bentazon (1,020) + MCPA (150) + chizalofop P (100)	789	472	794	501	920	494	652	405
bentazon (1,020) + MCPA (150) + haloksylop-R (104)	799	375	682	510	995	464	791	408
bentazon (1,020) + MCPA (150) + setoxydim (375)	844	407	793	435	1074	483	867	372
bentazon (1,020) + MCPA (150) after 7 days chizalofop P (100)	842	348	823	375	963	433	800	382
bentazon (1,020) + MCPA (150) after 7 days haloksylop-R (104)	1032	346	837	470	895	433	834	371
bentazon (1,020) + MCPA (150) after 7 days setoxydim (375)	766	383	796	538	933	449	777	363

	LSD (0.05)	**LSD** (0.01)
Medium heavy soil	68	90
Light soil	30	39

The yield of long scutched fiber (Tab. 6)

The yield of long scutched fiber was determined according to the yields of raw threshed straw and percentage of fiber in the straw. The differences in the yields of long scutched fiber of the tested cultivars, induced by herbicides are caused first of all by statistically proven effect of weed control chemicals on the yield of the straw. Applied herbicides modified the percentage of fiber in the straw to a low extent. The highest phytotoxic effect on tested cultivars, causing decrease of scutched fiber yields was shown by the mixture of herbicides chlorsulfuron + haloksylop-*R* and also by bentazon + MCPA, followed after 7 days by setoxidim (the decrease of long fiber yield by 1.31–3.61 dt ha^{-1}). For the most tested cultivars sprayed with chlorsulfuron and after 7 days with one of the tested graminicides (haloksylop-R, chizalofop P or setoxidim) the increased yields of long scutched fiber were ob-

Table 6. The effect of herbicides on long fiber yield on the light soil (average from 3 field trials)

Treatments ($g\ ha^{-1}$)	Long fiber yield [$kg\ ha^{-1}$]			
	Alba	Belinka	Nike	Wiko
Unweeded control	1281	1275	1205	1047
chlorsulfuron (11.25)	1180	1289	1408	998
chlorsulfuron (11.25) + chizalofop P (100)	1315	1380	1452	1210
chlorsulfuron (11.25) + haloksylop-R (104)	918	996	1315	884
chlorsulfuron (11.25) + setoxydim (375)	1049	1150	1497	1156
chlorsulfuron (11.25) after 7 days chizalofop P (100)	1471	1301	1408	1425
chlorsulfuron (11.25) after 7 days haloksylop-R (104)	1342	1371	1392	1571
chlorsulfuron (11.25) after 7 days setoxydim (375)	1422	1064	1382	1148
bentazon (1,020) + MCPA (150)	1218	1138	1380	1205
bentazon (1,020) + MCPA (150) + chizalofop P (100)	1144	1181	1144	1085
bentazon (1,020) + MCPA (150) + haloksylop-R (104)	1238	1092	1500	1092
bentazon (1,020) + MCPA (150) + setoxydim (375)	1291	1294	1324	1118
bentazon (1,020) + MCPA (150) after 7 days chizalofop P (100)	1250	1072	1417	1156
bentazon (1,020) + MCPA (150) after 7 days haloksylop-R (104)	1325	1125	1370	1078
bentazon (1,020) + MCPA (150) after 7 days setoxydim (375)	922	934	1074	805

served. Among tested cultivars of fiber flax, the most resistant one to herbicides was Nike. The application of chemical weed control methods in cultivation of that cultivar caused an increase of long scutched fiber yields in most of the treatments.

The effect of herbicides on the quality of long scutched flax fiber

Generally, tested herbicides had a favorable effect on the quality of long scutched flax fiber of tested cultivars, especially in case of Alba and Wiko. The cultivars Belinka and Nike sometimes reacted with a reduction of quality of long scutched fiber as a result of herbicides application, for instance: Belinka yielded worst fiber in the following treatments: chlorsulfuron + haloksylop-R, chlorsulfuron followed after 7 days by haloksylop-R, bentazon + MCPA followed after 7 days by chizalofop P and bentazon + MCPA followed after 7 days by haloksylop-R. On the plots with cultivar Nike with graminicides chizalofop P or setoxidim, applied 7 days after chlorsulfuron, the fiber was inferior to the control.

DISCUSSION

The research on susceptibility of fiber flax cultivars began in middle 1950s. According to Krzyształowska (1963; 1968) was the first one to observe differences in susceptibility of flax cultivars to herbicides. Later, many experiments have been conducted on resistance to herbicides of cultivars of some crops: winter wheat

(Adamczewski and Urban 2000; Landes 1990; Baylan and Malik 1992; Rola et al. 1997), barley (Landes 1990; Adamczewski et al. 1995), maize (Rola et al. 1997; Doohan et al. 1998; O'Sullivan et al. 1998), spring rapes (Rola and Franek 1995), potato (Love and Haderlic 1991) and fiber flax (Kloczkov and Biełkiewicz 1962; Kloczkov and Ulianova 1964; Krzyształowska 1963 and 1968) oil flax (Kightley et al. 1997). Lupton and Oliwer (1976), reported that cultivar resistance to herbicides is connected with the presence of certain genes which cannot be found in vulnerable cultivars. Those genes are crucial for biochemical mechanisms of herbicide inactivation in the plant. Hanson and Nickell (1986) showed that resistance of cultivars to metribuzine in soybean is triggered by a susceptibility gene, recessive to the dominant gene of resistance. Cultivars Altona and Tracy, having only the recessive gene of susceptibility, were damaged by the metribuzine, while cultivars Centura and Sprite, having the dominant resistance gene, tolerated this herbicide. Similarly, Swantek et al. (1998) observed that a single gene of resistance triggers resistance of soybean cultivars Manolin, Northrup and King S 5960 to the sulfentrazon herbicide. Not only genetic conditions influence the susceptibility of cultivars to herbicides. Also important are time of the treatment (Landes 1990; Love and Haderlic 1991), the dose of a compound (Pereira 1989) and environmental conditions. The most frequently mentioned elements of the latter are: pH (Newson and Shaw 1992) and soil textural group (Popescu 1995; Krzyształowska 1968), the weather during vegetation (Kloczkov and Biełkiewicz 1962; Gabińska 1984; Krzyształowska 1968), the level of agricultural technology (Nowicka and Rola 1993) and the status and degree of crop infestation with weeds (Krzyształowska 1968).

The first research on susceptibility of fiber flax to herbicides in Poland were conducted by Krzyształowska (1968) who assessing the selective action of preparations MCPA and MCPA + DNOC on 4 cultivars of fiber flax, showed that more susceptible to herbicides were Wiera and Swietocz while cultivars Lazur and Swadzimski were characterized by higher resistance to applied products. This research proved the decisive role of genetic conditions of flax cultivars susceptibility to MCPA and DNOC and also significant effect of environmental factors (temperature and air humidity, soil textural group, level of infestation) on morphological structure of flax plants and hence on their resistance to plant protection products. According to Krzyształowska (1968), the thickness of cuticle and size of leaf area are significant factors for flax susceptibility to herbicides. The author is reporting who claimed that the resistance of fiber flax to herbicides was conditioned by difference in morphology between cultivars (posture and number of leaves, dry weight of plants). The fiber flax (*Linum usitatissimum* L.) belongs to plants susceptible to herbicides. Recommended doses of herbicides are lower than for other crops. For instance sulfonyl-urea herbicide (75% of chlorsulfuron) is used in flax in amount to 10–15 g/ha while for small grains (e.g. winter wheat), the dose of this herbicide is 20–25 g/ha. Also other herbicides are used in flax at lower doses as compared to other crops. Moreover, as showed by Heller (1992; 1995) and Padenov (1994), graminicides (haloksylop-R, chizalofop P, setoxidim), applied in mixtures with herbicides to control broad-leaved weeds (MCPA, chlorsulfuron, bentazon), sometimes have phytotoxic effect on flax. In field of flax infested with grass and broad-leaved weeds twice repeated treatments are recommended: first against broad-leaved weeds and second one, applied 5–7 days later against grasses. Despite the biological evaluation of herbicides conducted in Poland and abroad, there is very little information on resistance of fiber flax cultivars to herbicides. The aim of fiber flax breeding is obtaining early maturing, resistant to diseases (mainly Fusarium wilt), pests, herbicides and lodging cultivars giving high yields of good quality (good spinnability) fiber (Marshal 1992). In Canada, leading producer and exporter of oil flax seeds (cultivation area 600,000 ha), there is a problem of susceptibility of this crop to soil residues of sulfonyl-urea herbicides (chlorsulfuron, triasulfuron, metsulfuron) (Mc Hughen and Holm 1991; 1995; Dixon 1995). The main precondition of hydrolytic decomposition of sulfonylurea compounds is acid reaction of the soil, rich sorption complex of the soil and well moisturized soil (Sabadie 1992; Sarmah et al. 1999). Despite the fact that flax belongs to plants resistant to on-leave application of chlorsulfuron, and triasulfuron, it is damaged by residues of sulfonyl-urea herbicides applied to forecrops remaining in the soil in conditions of low precipitation and alkaline reaction of the environment. In Canada and the USA the breeding research is conducted, using genetic engineering methods, on obtaining transgenic cultivars of oil flax, resistant to sulfonyl-urea herbicides. Mc Hughen and Holm (1991; 1995) were the first to obtain modified transgenic flax cultivar Norlin (FP967) using the modified gene of acetic-laccid synthetase with the help of *Agrobacterium tumefaciens*. This cultivar is resistant to residues of sulfonyl-urea herbicides' chlorsulfuron and triasulfuron in the soil. The research conducted showed that efficacy of herbicides' chlorsulfuron and bentazon + MCPA in controlling broad-leaved weeds was satisfactory. The effectiveness of graminicides on grasses in the experiments was good as well. In experiments conducted at Bukówka (1994–1996) the chlorsulfuron was more effective than bentazon + MCPA. Only *Fumaria officinalis* L. and *Viola arvensis* Murr. were resistant to these herbicides. Bentazon + MCPA showed unsatisfactory efficacy in controlling *Viola arvensis* Murr., *Polygonum aviculare* L., *Fumaria officinalis* L., *Chenopodium ablum* L. (especially on light soils), *Capsella bursa-pastoris* (L.) Med., *Veronica arvensis* L. (lighter soils), *Thlaspi arvense* L. (lighter soils), *Raphanus raphanistrum* L. In ours research the chlorsulfuron applied in mixtures with graminicides (chizalofop P, haloksylop-R or setoxidim) was usually as effective in controlling broad-leaved weeds as applied separately. Bentazon + MCPA applied jointly with graminicides chizalofop P or haloksylop-R showed satisfactory effectiveness only on good rye soils complex. Graminicides chizalofop P, haloksylop-R and setoxidim applied separately or in mixtures with weeds for broad-leaved herbicides usually well controlled *Elymus repens* (L.) Gould., *Lolium temulentum* L. and *Avena fatua L.* but were ineffective on *Poa annua* L. The selectivity of herbicides in tested cultivars was determined according to visual evaluation of damages of flax during the period of 7–14 says after herbicide application and according to morphological evaluation of flax straw, flax plant density and % of thinning, as well as yield of straw, seed fiber and quality of obtained raw material. The most visible changes in flax appearance (phytotoxic tincture, twisted leaves and growth inhibition) on both soil suitability complexes were observed where mixtures of herbicides with graminicides were applied (chlorsulfuron or bentazon + MCPA – especially with haloksylop-R). The inhibition of growth effected on the length of flax straw and yields and quality of straw and fiber. According to Heller (1992; 1995) sulfonyl-urea products applied in a mixture with graminicides usually show a phytotoxic effect on flax. Relatively safe for flax are mixtures of chlorsulfuron + chizalofop P. It is emphasized in many publications that two sprayings should be carried out on flax plantations endangered by grass and broad-leaved weeds: first herbicides for broad-leaved weeds should be used and next, after 5–7 days – graminicides. Those recommendations are more the effect of risk of plant damaging than lower efficacy of discussed herbicides in weed control. In conditions of the experiments conducted at Bukówka (1994–1996) the highest yields of straw (on both soil types) were obtained for cultivar Alba. Additionally, on the medium heavy soil the cultivars Wiko, Belinka and Nike showed significantly higher yield of seed than Alba. Our results showed that the cultivars Alba and Wiko were more susceptible to herbicides than Nike and Belinka. These more susceptible cultivars were characterized by a faster growth and phenological development, especially at the beginning of the growing season (from sowing to blooming) as compared to remaining cultivars. The differences in susceptibility of flax to herbicides may not only be caused by the genetic factors but also different growth rates at the "herring bone" stage, when the weed control chemicals are applied. Krzyształowska (1968) evaluating the susceptibility of flax cultivars to DNOC and MCPA in pot and plot experiments found that differences in susceptibility were observed in pot experiments where the side effects had been eliminated – weeds, variability of atmospheric and soil conditions. According to this author, the environmental conditions (atmospheric conditions and weed infestation status) had the effect on the cultivars' reaction to herbicides and, undoubtedly, weakened the reaction of flax and camouflaged differences between cultivars. Holly and Blackman (1954) were the first to report that the flax resistance to herbicides is a heritable feature and that all the most susceptible cultivars of fiber flax come from the Concurrent cultivar. In our research a clear effect of the environment (soil complex) was observed on the susceptibility of cultivars to herbicides. The evaluated herbicides showed stronger phytotoxic effect on flax on weaker soils, especially in objects with graminicides applied 7 days after bentazon + MCPA. In our experiments applied herbicides usually had no significant effect on the efficiency of fiber of tested cultivars. The differences found in yields of tested cultivars as the result of herbicides' application were caused by the statistically proven effect of weed control on yield of threshed straw. Krzyształowska (1968), testing the effect of MCPA and DNOC on 5 cultivars of fiber flax, found that environmental conditions showed stronger effect on fiber formation in flax than herbicides applied in recommended doses. Heller (1992) proved a beneficial effect of herbicide application on flax fiber yield. According to him, the weed control chemicals are crucial for the straw yield, on the other hand they have no effect on the fiber content in the straw. The herbicides tested in experiments generally showed positive effect on the quality of flax scutched fiber, especially in case of Abla and Wiko. According to Krzyształowska (1968) only high doses of herbicides may cause worse quality of flax fiber.

CONCLUSIONS

There is a correlation between the rate of growth of fiber flax plants and their resistance to herbicides. The cultivars showing faster growth rate at the beginning of the growing season (e.g. Alba) are more susceptible to herbicides than cultivars growing more slowly in that period (e.g. Nike).

The susceptibility of flax herbicides depends on the soil suitability complex. The stronger phytotoxic effect of herbicides and their less beneficial effect on yield and quality of obtained raw material were observed on lighter soils (light soil).

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POLISH SUMMARY

WRAŻLIWOŚĆ ODMIAN LNU WŁÓKNISTEGO NA HERBICYDY

W pracy przedstawiono wyniki doświadczeń polowych wykonanych w latach 1994–1996, w których oceniano wrażliwość 4 odmian lnu włóknistego: Alba, belinka, Nike i Wiko na herbicydy zwalczające chwasty dwuliścienne (chlorsulfuron, bentazon + MCPA) i graminicydy (haloksylop-R, chisalofop P, setoksydim). Odmiany Alba i Wiko były bardziej wrażliwe na herbicydy niż odmiany Nike i Bielinka. Odmiany wrażliwe charakteryzowały się szybszym wzrostem w początkowym okresie wegetacji. Herbicydy wykazały większą fitotoksyczność na rośliny lnu na glebie lekkiej. Największy ujemny wpływ fitotoksyczny na odminy lnu oraz oraz redukcja włókna długiego wystąpiła po zastosowaniu mieszaniny herbicydów: chlorsulfuronu + haloksylop-R i bentazonu + MCPA i zastosowaniu 7 dni później setoxidimu. Największy plon uzyskano po zastosowaniu chlorsulfuronu a po 7 dniach graminicydów (haloksylop-R, chisalofop P i setoxidimu). Odmiana Nike okazała się najbardziej odporna na badane herbicydy. Badane herbicydy miały korzystny wpływ na jakość włókna w słomie lnu, szczególnie miało to miejsce w odmianach Alba i Wike.