THE EFFECT OF SULFONYLUREA HERBICIDES ON GRAIN YIELD AND TECHNOLOGICAL QUALITY OF WINTER RYE CULTIVARS

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Abstract: In the years 2004–2006 with winter rye was conducted the research, both in a field experiment and in laboratory conditions, on the effect of chlorsulfuron (Glean 75 WG) and iodosulfuron methyl-sodium + mesosulfuron methyl (Atlantis 04 WG), used in 3–4 leaf stage in the autumn and plants at full tillering in the spring, on yielding and grain quality of two hybrid cultivars; Fernando F_1 and Stach F_1. The results obtained proved that winter rye, cultivated on black soil of the IIa class, produced high yield regardless plant cultivar, as well as applied herbicides which did not have a phytotoxic effect on plant growth and development.
Neither the yield nor mass of 1000 grains was essentially affected by the use of herbicides or a date of their application. The mentioned parameters varied due to the course of weather conditions during the plant growing season. The examined herbicides did not significantly affect such characteristics as: protein content, falling number, equalization and density of grain.

Key words: rye, herbicides, quality, grain, cultivars

INTRODUCTION

Economic effectiveness of growing grain plant crops is expressed not only by the amount of grain yield, but also by its quality. Requirements established by the European Union have made increasingly more important maintaining technological requirements regarding grain quality (Rothkaehl 2000). The latter requirements also apply to rye, mainly its winter form, still covering a considerable area in Poland – 2350000 ha, which accounts for over 26% of all grain crops and average grain crop amounts to approx. 23 dt/ha. Nearly half of annual yield is destined for fodder purposes and it is also used to a high degree in the milling industry. Rye grain quality is defined by the following parameters: protein content, gluten, falling number and sedimentation index. Starch is an important ingredient of rye flour. Its properties and quality determine the usefulness of flour for bread baking. The falling number is of a significant meaning as it describes the α-amylaze activity in flour. Excessive α-amylaze activity has an adverse effect on the quality of baked products. Those indices are formed as early as at the emergence in specific agrotechnical and weather conditions, but they are also dependent on genetically determined plant properties (Dubis *et al*. 2008; Kraska and Pałys 2002).

According to the literature data (Adamczewski and Urban 2000; Rola *et al*. 2004) some herbicides like chlortoluron, isoproturon, 2.4-D and MCPA, commonly used for weed control in cereal cultures affect cultivated plants. These compounds can temporarily or permanently stop plant growth, as well as cause plant damage and deformation visible during plant growing period. They also worsen some grain quality parameters such as; ear length, the number and mass of the grain in the ear and weight of 1000 grains (WTG) (Rola and Kieloch 2005). This especially refers to winter wheat. However, there have not been available any literature reports concerning the influence of those herbicides on winter rye varieties. The purpose of this work was the assessment of the effect of sulfonylourea herbicides on grain quality of selected winter rye cultivars.

MATERIALS AND METHODS

Two-variable plot experiments using complete block design were conducted in 2004–2006 on the field of an individual farm in Iwiny near Wrocław. The plot was located on black soil, classified as soil IIa of class. Winter wheat served as a preceeding crop. The first experimental factor were herbicides and the second one were winter rye cultivars. Two currently cultivated rye hybrids: Fernando F_1 and Stach F_1 and two herbicides belonging to sulfonylourea group: chlorsulfuron (Glean 75 WG) and iodosulfuron methyl-sodium + mesosulfuron methyl (Atlantis 04 WG) were used. The herbicides were applied in the autumn at 3–4 leaf stage and in the spring at full tillering of winter rye at the doses 20 g/ha and 0.2 kg/ha which

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constituted 15 g s.a./ha and 7.2 g s.a./ha, respectively. The control treatment was not treated with herbicides but weeded manually. The winter rye was sown according to agro-technical recommendations for Lower Silesia region. The herbicides were applied using "Gloria" knapsack sprayer, at a constant pressure of 0.25 Mpa and spray liquid output amounted to 250 l/ha. The harvest of grain was done at full maturity stage and the yield was determined in relation to 14% moisture content. The grain was subjected to laboratory analysis to determine weight of 1000 grains, bulk density of seeds, seed grading, protein content and falling number. Weight of 1000 grains was determined according to Polish Standard No. PN-68/R-74017. The bulk density of seeds, also known as hectoliter weight was determined on the basis of Polish Standard No. PN-ISO 7971-2. Seed grading was established using sieves and determined on the basis of the amount of grain mass remaining on the sieve with mesh dimensions of 2.5 x 25 mm, in relation to the mass of sieved grain. Protein content was determined with INSTALAB 600 device using a near infra-red NIR technique. Falling number was assessed according to Polish Standard No. PN-ISO 3093.

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

Meteorological conditions during the experimental period

The weather conditions during the 2003/2004 season was most favourable for winter rye as compared to the whole period of investigation. September of 2003 proved to be a warm, yet a dry month, and October weather was quite typical, with moderate rainfall. This kind of weather was beneficial both for germination and the first stages of plant development. The spring and the summer were relatively warm with sufficient amount of precipitation for rye development. Weather conditions were also favourable for grain harvesting in due time.

The following plant growing season (2004/2005) was characterized by warm September and the first half of October, with an appropriate amount of rainfall. The plants entered the winter resting period while were still in an early tillering stage and without being properly rooted. The spring and the summer were relatively cold and humid for that time of the year, with a total precipitation approx. 210 mm (within 3-month period) which was not favourable for rye growth and grain forming. July was characterized by heavy rainfall which delayed grain harvest.

In the autumn 2005, a slight deficit in soil moisture contributed to worse germination of rye. In the second half of November plant growth was retarded. The winter was long and severe with heavy snow, which, however, did not adversely affect winter rye survival. The spring of 2006 was rather cold at the beginning but it was characterized by appropriate precipitation level. A sudden increase in temperature in the middle of June and a noticeable deficit of water was not favourable for plant growing and grain development, resulting in earlier harvest (Table 1).

Table 1. Weather conditions between September 2003 and August 2006

	Year	Month											
		IX	X	XI	XII	I	II	III	IV	V	VI	VII	VIII
Temperature [°C]	2003–04	20.5	6.0	5.4	2.8	5.4	2.7	3.9	10.5	14.5	18.2	19.9	19.1
	2004–05	15.4	10.8	4.8	2.3	3.7	0.9	1.6	9.1	12.0	18.0	20.3	17.2
	2005–06	16.0	4.3	2.7	0.2	–6.4	–2.5	2.6	10.2	13.7	20.9	24.3	18.2
	1994–04	16.3	10.9	5.6	0.7	–2.0	1.9	4.1	8.4	15.6	17.6	19.6	19.4
Precipitation [mm]	2003–04	20.5	68.2	13.9	26.0	43.0	35.7	47.4	7.0	44.6	39.7	47.8	23.3
	2004–05	15.4	38.8	85.7	13.2	37.8	44.8	8.8	35.0	133.7	55.0	134.4	59.2
	2005–06	34.5	4.3	31.2	99.3	27.2	41.6	1.5	3.2	28.8	52.3	4.8	20.8
	1994–04	59.1	425	34.8	46.6	29.1	28.7	40.5	35.4	39.5	77.8	110.9	69.0

RESULTS AND DISCUSSION

One of the prerequisites to obtain a reasonably high yield from the crop is to maintain it in a weed-free state.

Long-term investigation concerning weed occurrence carried out in Poland (Rola 1975; Rola *et al.* 1981, 1996, 2005) proved that winter rye belongs to considerably weed-infested crops. The list of most commonly found weed species in winter rye includes, among others, *Apera spica-venti, Anthemideae, Agropyron repens, Cirsium arvense, Centaurea cyanus, Convolvulus arvensis, Papaver rhoeas, Vicia hirsute*, while *Anthoxanthum aristatum, Alopecurus myosuroides* occur locally.

The problem of negative effect of weeds on winter rye has not been thoroughly studied so far. According to the common opinion rye is one of the crops least susceptible to weeds (Koch 1970). Due to its fast growing in the autumn and early spring, rye suppresses a wide variety of spring and winter weeds and in the following stages of its development, due to shading, it even restricts the growth of wheat-grass (*Agropyron*) (Tischler 1971). A strong and shallow-reaching rye root system can create unfavourable conditions for weed germination (Rademacher 1964). As it was reported by Rola (1985), *Apera spica-venti* proved to be highly competitive to winter rye, regardless the soil and agrotechnical conditions of rye cultivation. As the number of this weed increases on the field, the rye yield decreases. Crops losses, which occurred as a result of 25–50 and 300–500 panicles per 1m², ranged to 14 and 58%, respectively. The author's own studies (Rola 1992) also confirm a competitive effect of *Cirsium arvense* on winter

rye. The lowest stated level of infestation with this weed species of 5–10 plants per 1m² resulted in 17.3% decrease in rye yield. In care of 50 plants on the same area, yield losses were as much as 51.4%.

A negative correlation was proved between *Cirsium arvense* weed infestation and length of a rye ear, as well as the number of ears per area unit, and the correlation between grain mass per one ear and rye yield.

In the field experiment conducted a large number of weeds was not stated. Rarely occurring weed species such as *Galium aparine, Stellaria media, Veronica hedeifolia, Viola arvensis, Thlaspi arvense* were effectively controlled by the use of herbicides, while on the control treatment they were removed manually. Therefore, the state and degree of weed infestation of a rye field could not have been taken into consideration as a factor affecting the crop and its quality.

Many authors claim that herbicides' effect on cultivated plants can be expressed by morphological changes like suppression of germination, growth and development, colour and leaf necrosis, as well as plant deformation. In extreme cases herbicides can lead to disturbances in plant life processes and in consequence reduce the yield and its quality (Rola *et al*. 2000; Urban 2002; Gabinska and Rola 1985; Nowicka and Rola 1997). Sulfonylourea group active substances belong to a new generation of herbicides and are generally considered to be safer for grain. Reduced yield amount is rarely considered as a result of the application of these herbicides. Just as rarely they cause alterations in plant morphology, particularly in wheat (Nowicka 1993; Rola and Kieloch 2006).

The results of conducted investigation did not indicate any of the above symptoms of herbicide effects as affecting plant morphology of winter rye cultivars, regardless variable weather conditions during the 2005–2006 plant growing seasons.

Weather conditions in particular years affected the amount of rye yield of winter and its quality discriminants characterizing grain technological value. The highest yield was obtained for plant growing season 2003/2004 when the weather was the most favourable for plant development. During that season, Fernando F_1 cultivar gave higher yield than Stach F_1 cultivar, although these differences were not statistically confirmed. The yield of cultivars under investigation was much lower in the following years, although this fact was not of statistical significance.

No proof has been found regarding the dependence between yield and the use of herbicides, nor the fact that there was no significant relation between herbicides and rye cultivars related to the mentioned feature (Table 2).

Average values for weight of 1000 grains indicate significant differences between particular cultivars. Fernando F_1 cultivar was characterized by a significantly higher mass, this being proved statistically. Taking into account all the years of investigation, the lowest quality and amount of winter rye grain, regardless of plant cultivar, was obtained in 2006 during the long-lasting drought accompanied by high temperatures, which were recorded from the second half of June to the harvest. No differences were observed in reference to 1000 grain mass as related to the herbicide used and no interaction was found between the cultivars and applied herbicides (Table 3).

Table 2. Influence of herbicides on grain yield of rye cultivars [t/ha]

Treatment	Term of application	Fernando F_1				Stach F_1			
		2004	2005	2006	mean	2004	2005	2006	mean
Control	–	8.80	6.58	6.29	7.23	8.77	6.19	5.79	6.92
Glean 75 WG	autumn	8.90	6.74	6.29	7.31	8.77	6.16	5.83	6.92
Glean 75 WG	spring	8.94	7.04	6.58	7.52	8.87	5.51	5.68	6.69
Atlantis 04 WG	autumn	8.79	6.62	6.15	7.19	8.89	6.19	6.13	7.07
Atlantis 04 WG	spring	8.87	6.56	6.34	7.26	8.74	5.88	6.08	6.90

LSD (0.05) cultivars – not significant differences
herbicides – not significant differences
cultivars x herbicides – not significant differences

Table 3. The influence of herbicides on weight of 1000 grains of rye cultivars [g]

Treatment	Term of application	Fernando F_1				Stach F_1			
		2004	2005	2006	mean	2004	2005	2006	mean
Control	–	42.3	47.1	32.6	40.7	38.3	38.1	30.2	35.5
Glean 75 WG	autumn	42.9	44.5	33.2	40.2	38.9	41.5	30.2	36.9
Glean 75 WG	spring	44.6	49.3	32.6	42.2	36.9	38.0	30.5	35.1
Atlantis 04 WG	autumn	44.0	46.1	32.6	40.9	38.6	39.8	31.0	36.4
Atlantis 04 WG	spring	43.3	46.1	35.1	41.5	39.8	39.5	31.8	37.0

LSD (0.05) cultivars – 4.62
herbicides – not significant differences
cultivars x herbicides – not significant differences

The content of protein reveals the baking quality characteristics of the grain, destined for flour manufacturing for baking purposes, and it should be at least 11.5% of this component. These data were obtained for Fernando F_1 and Stach F_1 rye cultivars in 2006, independent of herbicides used. Also, differences were not proved between these cultivars. Significantly lower values of this indicator in 2004 and 2005 can be considered as a proof of the influence of the weather conditions, though it was not proved statistically (Table 4).

Falling number is another quality parameter, which characterizes the state of amylolytic enzymes in grain and baking usability of flour. At the same time the latter feature determines its storage durability. In order to guarantee that rye flour has an appropriate falling number for the baking process for milling purposes grain should be used of falling number not below 110 seconds. The results similar to the desired ones were obtained in case of Stach F_1 grain, and slightly better for Fernando F_1 cultivar in 2005, harvested from the control treatments as well as from those treated with herbicides. During 2004 and 2006, falling number determined for the examined cultivars, regardless a herbicide used, exceeded the minimum permissible norm almost twice and three times. In spite of that fact, the significance of differences for grain of both cultivars, as well as for the herbicides and the interaction between the studied factors were not statistically proved (Table 5).

One of the crucial rye grain meal quality attributes is seed grading, which means the relation of remaining sieved grain on a particular sieve (mesh measurements 2.5 by 25 mm) to the whole mass of sieved grain. Permissible norm of 85% for rye was achieved only once, in 2005, regardless of the cultivar examined (Table 6).

It can be assumed that the above results were possible due to the weather conditions in the turn of the spring and summer season, as it was relatively cold for this time of the year and considerable precipitation was recorded as well (358.1 mm from April to July). Although the results for the remaining years achieved quite even levels, the grain of Fernando F_1 and Stach F_1 cultivars did not conform the required norm. Sulfonylurea herbicides such as Glean 75 WG and Atlantis 04 WG used in the experiment did not prove to affect the quality determinant. Statistical analysis of the results did not confirm the significance of differences in relation to grain cultivars and herbicides, nor did it prove interaction between them.

Test weight, which determines grain mass in kg/hl should be minimum around 68 kg/hl for rye in a sieved state. The data presented in table 7 shows that none of the studied factors in the experiment significantly affected the rye grain quality of the studied varieties, which was confirmed by statistical analysis (Table 7).

Table 4. The influence of herbicides on protein content of rye cultivars [%]

Standart > 11.5%

Treatment	Term of application	Fernando F_1				Stach F_1			
		2004	2005	2006	mean	2004	2005	2006	mean
Control	–	7.9	10.4	12.1	10.1	8.4	11.0	11.6	10.3
Glean 75 WG	autumn	7.6	10.6	11.5	9.9	7.8	10.7	11.7	10.0
Glean 75 WG	spring	7.8	10.4	12.2	10.1	7.8	10.7	11.7	10.0
Atlantis 04 WG	autumn	7.7	10.6	11.8	10.0	8.0	11.0	11.6	10.2
Atlantis 04 WG	spring	7.5	10.3	11.6	9.8	8.3	10.3	11.5	10.0

LSD (0.05) cultivars – not significant differences
herbicides – not significant differences
cultivars x herbicides – not significant differences

Table 5. The influence of herbicides on falling number of rye cultivars [s]

Standard > 110 s

Treatment	Term of application	Fernando F_1				Stach F_1			
		2004	2005	2006	mean	2004	2005	2006	mean
Control	–	286	160	325	257	225	113	297	212
Glean 75 WG	autumn	266	112	314	230	230	109	302	214
Glean 75 WG	spring	318	190	319	276	229	111	298	213
Atlantis 04 WG	autumn	301	151	326	259	230	118	299	216
Atlantis 04 WG	spring	296	127	325	249	245	112	314	224

LSD (0.05) cultivars – not significant differences
herbicides – not significant differences
cultivars x herbicides – not significant differences

Table 6. The influence of herbicides on seed grading of rye cultivars [%]

Standard > 85%

Treatment	Term of application	Fernando F_1				Stach F_1			
		2004	2005	2006	mean	2004	2005	2006	mean
Control	–	59.6	92.7	72.6	75.0	60.7	93.6	76.7	77.0
Glean 75 WG	autumn	57.6	93.7	75.8	75.7	58.9	93.7	72.1	74.9
Glean 75 WG	spring	53.7	94.2	63.7	70.5	58.4	95.3	69.3	74.3
Atlantis 04 WG	autumn	57.9	95.2	69.4	74.2	59.5	94.0	67.9	73.8
Atlantis 04 WG	spring	53.6	93.6	76.7	74.6	59.2	95.2	75.6	76.7

LSD (0.05) cultivars – not significant differences
herbicides – not significant differences
cultivars x herbicides – not significant differences

Table 7. The influence of herbicides on test weight of rye cultivars [kg/ hl]

Standard > 68 kg/hl

Treatment	Term of application	Fernando F_1				Stach F_1			
		2004	2005	2006	mean	2004	2005	2006	mean
Control	–	75.2	69.0	70.1	71.4	75.4	68.8	69.4	71.2
Glean 75 WG	autumn	75.4	68.2	71.4	71.6	76.2	69.0	69.6	71.6
Glean 75 WG	spring	74.6	69.2	69.0	71.0	75.8	69.2	68.7	71.2
Atlantis 04 WG	autumn	75.0	69.0	69.8	71.3	76.6	68.4	68.9	71.3
Atlantis 04 WG	spring	75.8	68.8	70.8	71.8	77.2	69.0	69.5	71.9

LSD (0.05) cultivars – not significant differences
herbicides – not significant differences
cultivars x herbicides – not significant differences

CONCLUSIONS

1. Weather conditions in the years of investigation 2003/2004 –2005/2006 diversified the yield of winter rye cultivars Fernando F_1 and Stach F_1.
2 The yield, mass of 1000 seeds and the examined quality determinants such as: protein content, falling number, equalisation and density of grain were not affected by the Glean 75 WG and Atlantis 04 WG herbicides applied during winter rye growing period.

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POLISH SUMMARY

WPŁYW HERBICYDÓW SUFONYLOMOCZNIKOWYCH NA PLON I JAKOŚĆ TECHNOLOGICZNĄ ZIARNA ODMIAN ŻYTA OZIMEGO

Przedstawiono wyniki badań przeprowadzonych w latach 2004–2006, w warunkach doświadczeń polowych i laboratoryjnych nad wpływem herbicydów Glean 75 WG i Atlantis 04 WG, stosowanych w fazie 3–4 liści (jesienią) i w fazie pełnego krzewienia żyta ozimego (wiosną) na plonowanie i jakość ziarna dwóch odmian mieszańcowych Fernando F_1 i Stach F_1. Wykazano, że żyto ozime uprawiane na czarnej ziemi, zaliczanej do klasy bonitacyjnej IIa, niezależnie od odmiany plonowało wysoko, a stosowane herbicydy nie działały fitotoksycznie na jego wzrost i rozwój. Wysokość plonowania oraz masa 1 000 ziaren nie zależały istotnie od herbicydów ani też terminu ich aplikacji. Wpływ na żyto ozime różnicował przebieg pogody w sezonie wegetacyjnym. Badane herbicydy nie wywarły istotnego wpływu na oznaczane cechy takie jak: zawartość białka, liczbę opadania, wyrównanie i gęstość ziarna.