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The effect of herbicides on technological quality of grain of winter rye cultivars

Krzysztof Marczewski, Henryka Rola, Jolanta Sumisławska, Andrzej Biskupski

Department of Weed Science and Tillage Systems in Wrocław
Institute of Soil Science and Plant Cultivation – National Research Institute in Puławy
Orzechowa 61, 50-540 Wrocław, Poland

Abstract. In the years 2004–2006 a study was carried out based on field experiments and laboratory tests, concerning the effect of iodosulfuron methyl-sodium mezosulfuron (Atlantis 04 WG) applied at 3–4 leaf stage in autumn and at full tillering stage of winter rye in spring, as well as of fluroksypyr + 2,4-D (Aminopielik Gold 530 EW) applied in spring, on yielding and grain quality of three rye cultivars: Walet, Rostockie and Picasso. The results obtained proved that winter rye grown on black earth, which belongs to the IIa valuation class, produced a high yield regardless of cultivar, and that the herbicides applied did not have any phytotoxic effect on the growth or development of plants.

Neither the yield nor the weight of 1000 grains were significantly affected by the use of herbicides or the date of their application. Their effect varied depending on the course of weather in the growing season. The herbicides tested did not significantly affect such characteristics as protein content, falling number, seed grading and bulk density, flour efficiency, volume and overbake of bread and porosity of crumb.

Rye cultivation in Poland occupies a significant acreage – 2350000 ha. It is assumed that more than a half of the rye plantations require herbicide treatment. Therefore the proper selection of an effective and selective herbicide for specific rye variety is of paramount importance.

key words: rye, herbicides, quality grain, cultivars

INTRODUCTION

The requirements set by the European Union has made it increasingly more important to adhere to technological guidelines regarding grain quality (Rothkaehl, 2000). The latter requirement also applies to rye, mainly its winter form, still covering a considerable area in Poland – 2350,000 ha, which accounts for over 26% of all grain crops and average crop ranges approx. to 23 q of grain per hectare. Nearly half of annual yields are destined for fodder purposes and to a high degree it is also used in the milling industry. Rye grain quality is defined by the following parameters: protein content, falling number (Jańczak, 2006). 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 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. Values of these indexes depend on agrotechnical and meteorological conditions as well as on geneticall-y determined plant properties (Dubis et al., 2008; Kraska and Pałys, 2002; Piech and Maciorowski, 2000; Podolska and Grabiński, 2004; Podolska and Sułek, 2010; Sułek and Podolska, 2006; Woźniak and Staniszewski, 2007).

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 grain cultivation, do effect on cultivated plants. These compounds can temporarily or permanently halt plant growth, as well as cause plant damage and deformation that can be seen during the growing season. They also worsen some grain quality parameters such as: ear length, the number and mass of the grain in the ear and MTZ (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 herbicides on grain quality properties of selected winter rye cultivars.

MATERIALS AND METHODS

A trial laid out as a two-factorial randomized block design was conducted in the years 2004–2006 in the field of an individual farm at Iwiny near Wrocław. The trial was established on black earth, classified as IIIa valuation class. Winter wheat was the preceding crop. The first variable

Corresponding author:
Henryka Rola
e-mail: h.rola@iung.wroclaw.pl
tel. +48 71 3638707 ext. 120

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were herbicides and the second one were winter rye cultivars. The study involved three currently grown cultivars: Walet, Rostockie, Picasso as well as two herbicides: iodosulfuron methyl-sodium + methyl mezosulfuron (Atlantis 04 WG), and fluroxypyr + 2,4-D (Aminopielik Gold 530 EW). Atlantis was applied in autumn in 3–4 leaf stage and in spring at full tillering stage of winter rye at a rate of 0.2 kg ha^{-1} which was equivalent to 7.2 g s.a. ha^{-1}. Aminopielik Gold was used in spring at 1,25 l ha^{-1}, equivalent of 662 g s. a. ha^{-1}. In the control treatment no herbicides were applied and the plots were weeded manually. The winter rye was sown according to the crop management recommendations for the Lower Silesia region. The herbicides were applied with the use of "Gloria" knapsack sprayer, at constant pressure of 0.25 MPa and speed of 3.6 km h^{-1}, to produce spray volume of 250 l ha^{-1}. The harvest of grain was done at full grain maturity and the yield was expressed by converting it to 14% of moisture content. The grain was subjected to laboratory analysis to determine weight of 1000 grains, determination of bulk density in a poured state, seed grading, the amount of protein and the falling number. The weight of 1000 grains was determined according to Polish Standard No. PN-68/R-74017. The determination of bulk density in poured state, also known as a "hectoliter mass" was determined on the basis of Polish Standard No. PN-ISO 7971-2. Seed grading was established by the method of sifting through sieves and determined based on the proportion of the weight of the grain remaining on a 2.5 x 25 mm mesh sieve to the total weight of sieved grain. Protein count was determined with INSTALAB 600 device using a near infrared NIR technique. Falling number was measured according to Polish Standard No. PN-ISO 3093.

Flour efficiency determination, bread volume from 100 g of flour, overbake of bread, porosity of the crumb – were done with the aid of common methods used in baker/baking-laboratories (Jakubczyk and Haber, 1983).

The results were analyzed statistically following two -factor analysis of variance in non-orthogonal system. The smallest significant differences were calculated for a significance level of P = 0.05.

Meteorological conditions during the research period (Table 1)

The weather conditions during the 2003/2004 season were the most favorable for winter rye growing within the whole period of investigation. September 2003 proved to be a warm, yet a dry month and October weather was quite typical, with large rainfalls. That kind of weather was beneficial both to germination and to the first stage of plant development. The spring and the summer were relatively warm with sufficient amounts of precipitation for rye development. Weather conditions were also favorable for grain harvesting in due time.

The following plant growing season (2004/2005) featured cold September and the first half of October, with an appropriate amount of rainfall. The plants entered the winter resting stage while 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 very favorable for rye growing and grain forming. July was characterized by heavy rainfalls which delayed grain harvesting.

In the autumn of 2005, a slight deficit in soil moisture contributed to worse germination of rye. In the second half of November plant growth was inhibited. The winter was long and severe with heavy snowfall, which, however, did not adversely affect winter rye survival. The spring of 2006 was rather cold at the beginning and practical without precipitation in March and April. A sudden increase in temperature in the middle of June and a noticeable deficit in water was not favorable for plant growth and grain development, resulting in earlier harvesting.

RESULTS AND DISCUSSION

One of the prerequisites to obtain a reasonably high yield from a particular cultivar is to maintain the cultivated winter rye in a weedless state.

The field in which the experiment was laid out was not overgrown with weeds heavily. Small numbers of *Galium*

Table 1. Weather conditions between September 2003 and August 2006.

Parameter	Year	Month											
		IX	X	XI	XII	I	II	III	IV	V	VI	VII	VIII
Temperature [^{0}C]	2003–04	14.0	6.0	5.4	2.8	5.4	2.7	3.9	10.5	14.5	18.2	19.9	19.1
	2004–05	14.8	10.8	4.8	2.3	3.7	0.9	1.6	9.1	12.0	18.0	20.3	17.2
	2005–06	16.2	4.3	2.7	0.2	-6.4	-2.5	2.6	10.2	13.7	20.9	24.3	18.2
	1994–2004	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	27.1	68.2	13.9	26.0	43.0	35.7	47.4	7.0	44.6	39.7	47.8	23.3
	2004–05	16.9	38.8	85.7	13.2	37.8	44.8	8.8	35.0	133.7	55.0	134.4	59.2
	2005–06	31.1	4.3	31.2	99.3	27.2	41.6	1.5	3.2	28.8	52.3	4.8	20.8
	1994–2004	59.1	42.5	34.8	46.6	29.1	28.7	40.5	35.4	39.5	77.8	110.9	69.0

aparine, *Stellaria media*, *Veronica hederifolia*, *Viola arvensis* and *Thlaspi arvense* species were effectively killed with herbicides, while in the control treatment the weeds were removed manually. That is why the condition and degree of weed infestation in the rye canopy could not be considered as a factor influencing the yield and its quality.

In many papers the authors report that the influence of herbicides on cultivated plants can manifest itself by morphological changes such as inhibition of emergence, growth and development, hyperchromatism and necrosis of leaves as well as deformation of habit. In extreme cases it leads to disturbance in the vital processes of plants, and in consequence to decreased yields and deteriorated crop quality (Rola et al., 2004; Urban, 2002; Gabińska and Rola, 1985; Nowicka and Rola, 1997). Winter rye sown in Lower Silesia in the years 2004–2006 on optimum dates each year emerged uniformly, developed regularly and in late autumn reached the stage of full tillering.

In our investigation we did not observe any of the above symptoms of herbicide action on the morphology of winter rye cultivars, irrespective of variable weather conditions in the growing seasons of 2005–2006. Herbicides appeared not to have influence on the growth and development of those cultivars, either. The coverage of soil by all the cultivars, as observed before harvest, was uniform. However, the atmospheric conditions in particular years of the research differentiated the yields of winter rye and influenced the qualitative discriminants characterizing the technological value of grain.

In the 2003/04 season the yields obtained were the highest, the course of weather having been the most favourable to vegetation of plants (Table 2). In that season the cultivar Picasso gave a much higher yield than did Walet and Rostockie, however statistically not significant (cultivars x years n.s.). The yields of the cultivars in following years were lower, but statistically the difference was unimportant. Similarly, the yields were not proved to have been dependent on herbicides, nor was any significant interaction of herbicides and cultivars found to influence that quality. Płoszyński et al. (1991) in his research into the influence of herbicides on the yield of spring triticale grain obtained similar results. That author as well as others (Witek, 1979; Kuś and Siuta, 1995; Krzymuski and Laudański, 1996; Krasowicz and Nieściór, 2001) maintain that the yielding of rye is most influenced by natural factors, crop management and the sowing material.

The cultivars tested varied for the weight of 1000 grains but to a small degree (Table 3). Notwithstanding insignificant differences, there was noticed a better shapeliness of the Picasso cultivar grain. In the years of the study the least shapely grain of winter rye, irrespective of the cultivar, was obtained in 2006, when a prolonged drought with high temperatures occurred from the second half of June to the harvest-time. No differences were observed in

Table 2. Influence of herbicides on grain yield [t ha^{-1}] of rye cultivars.

Herbicide	Term	Walet				Rostockie				Picasso			
		2004	2005	2006	mean	2004	2005	2006	mean	2004	2005	2006	mean
Check		8.38	6.01	5.25	6.55	8.43	6.88	5.48	6.93	9.75	7.37	6.06	7.73
Iodosulfuron methylsodium + mesosulfuron methyl	autumn	8.39	6.01	5.35	6.58	8.27	6.46	5.58	6.77	9.66	7.23	6.13	7.67
	spring	8.41	5.36	5.39	6.39	8.14	6.50	5.25	6.63	9.78	6.74	6.24	7.59
Fluroxypyr +2,4-D	spring	8.48	5.37	5.08	6.31	8.21	6.31	5.63	6.72	9.56	6.50	5.19	7.08
Mean		8.42	5.69	5.27	6.46	8.26	6.54	5.49	6.76	9.69	6.96	5.91	7.52

LSD(0.05) for: cultivars – 0.416; herbicides – n.s.; years – 0.416; interactions: cultivars x herbicides – n.s.; cultivars x years – n.s.; herbicydes x years – n.s.
n.s. – not significant

Table 3. Influence of herbicides on on weight 1000 grain (g) of rye cultivars.

Herbicide	Term	Walet				Rostockie				Picasso			
		2004	2005	2006	mean	2004	2005	2006	mean	2004	2005	2006	mean
Check		45.3	41.5	27.6	38.1	49.5	35.9	25.7	37.0	41.2	41.4	34.2	38.9
Iodosulfuron methylsodium + mesosulfuron methyl	autumn	46.9	38.2	29.1	38.0	49.0	38.1	25.3	37.5	41.9	41.2	34.1	39.0
	spring	43.9	34.3	30.7	36.3	47.3	38.8	26.3	37.5	42.7	38.8	32.0	37.8
Fluroxypyr +2,4-D	spring	44.8	38.4	31.5	38.2	47.2	38.7	27.5	37.8	42.3	40.7	34.1	39.0
Mean		45.2	38.1	29.7	37.7	48.3	37.9	26.2	37.5	42.0	40.5	33.6	38.7

LSD(0.05) for: cultivars – n.s.; herbicides – n.s.; years – 2.29; interactions: cultivars x herbicides - n.s.; cultivars x years – 3.36; herbicydes x years – n.s.
n.s. – not significant

the weight of 1000 grains which could have depended on the herbicide applied. Neither did any interaction appear between the cultivars and the herbicides.

The milling quality of rye grain is assessed mainly by its seed grading, i.e. by the ratio of the grain left after sieving through a determined sieve (mesh size 2,5 x 25 mm) to the total weight of the grain sieved. In each of the cultivars tested the seed grading of grain was below the norm admissible for rye, i.e. 85%. The highest seed grading of grain was found in the cultivars Walet and Picasso. Analysis of variance did not show any significant variation for seed grading as depending on the herbicide applied (Table 4).

A very important feature of quality is the falling number, characterizing the state of amylolytic enzymes in grain, which determines the baking usefulness of flour and at the same time gives information about its storage capability. To obtain rye flour with the falling number level appropriate for the baking process one should use grain with the falling number within the interval of 110–190 s. In the grain of the cultivars tested this parameter was above the expected norm (Table 5). The highest index of this feature was reached in grain of the cultivar Picasso (277 s). However the effect of herbicide was found to be statistically insignificant.

The determination of bulk density, determining its bulk in pouring state, in case of rye should keep at the level of 71–73 kg hl^{-1}. In this respect, the cultivars differed significantly from one another (Table 6). The lowest density was that in the cultivar Rostockie. Herbicides influenced bulk density of rye but to a small degree. Results obtained by other investigators (Świętochowski and Sienkiewicz, 1954; Szymczak et al., 1982; Domańska et al., 1985) concerning the influence of herbicides applied in the production of cereals on the quality of grain and flour were not univocal and the differences observed were mostly insignificant (Kieloch and Rola, 2009; Kieloch et al., 2010). The authors think that the effect of substances applied in early stages of growth and development of cereals is imperceptible when assessing the value of food products. This question calls for further investigation of the physiological processes occurring in the stage of heading and infusion of grain.

One of the important technological qualities of grain is its percentage of protein. That value informs us about the baking quality of grain intended for production of baking flour. It has been accepted that the protein content in rye grain should keep at the level of about 11%. Domańska et al. (1985) and Płoszyński et al. (1991) proved a significant decrease in the protein content in spring triticale grain after application of herbicides in all experimental treatments as compared with the control. However, they pointed out that the value of that character was greatly influenced by the weather conditions. Andruszczak et al. (2009) obtained the best parameters of grain, i.e. the content of protein, gluten and sedimentation index, when applying herbicides in

Table 4. Influence of herbicides on seed grading [%] of rye cultivars.

Herbicide	Term	Walet				Rostockie				Picasso			
		2004	2005	2006	mean	2004	2005	2006	mean	2004	2005	2006	mean
Check		50.9	92.2	62.3	68.5	46.4	95.2	63.4	68.3	57.3	92.1	67.0	72.1
Iodosulfuron methylsodium + mesosulfuron methyl	autumn	52.6	93.6	65.6	70.6	40.3	93.5	58.7	64.1	58.7	94.5	66.3	72.5
	spring	52.9	91.9	60.5	68.4	41.9	92.6	51.3	61.9	58.7	94.5	66.3	73.2
Fluroxypyr +2,4-D	spring	55.1	88.5	75.0	72.9	46.2	93.3	62.8	67.4	58.5	90.8	61.5	70.3
Mean		52.9	91.6	65.9	70.1	43.7	93.7	59.1	65.5	58.3	93.0	65.3	72.2

LSD(0.05) for: cultivars – 2.97; herbicides – n.s.; years – 2.97; interactions: cultivars x herbicides – n.s.; cultivars x years – 4.36; herbicydes x years – n.s.
n.s. – not significant

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

Herbicide	Term	Walet				Rostockie				Picasso			
		2004	2005	2006	mean	2004	2005	2006	mean	2004	2005	2006	mean
Check		267	95	308	223	272	92	301	222	298	154	346	266
Iodosulfuron methylsodium + mesosulfuron methyl	autumn	263	102	317	227	260	82	306	216	305	181	346	277
	spring	260	102	303	222	266	99	296	220	296	152	329	259
Fluroxypyr +2,4-D	spring	239	109	298	215	267	96	316	226	306	171	310	262
Mean		257	102	307	222	266	92	305	221	301	165	333	266

LSD(0.05) for: cultivars – 11.0; herbicides – n.s.; years – 11.0; interactions: cultivars x herbicides – n.s.; cultivars x years – n.s.; herbicides x years – n.s.
n.s. – not significant

Table 6. Influence of herbicides on determination of bulk density [kg hl^{-1}] of rye cultivars.

Herbicide	Term	Walet				Rostockie				Picasso			
		2004	2005	2006	mean	2004	2005	2006	mean	2004	2005	2006	mean
Check		76.6	71.3	70.0	72.6	75.2	69.4	69.6	71.4	75.2	68.8	69.6	71.2
Iodosulfuron methylsodium + mesosulfuron methyl	autumn	77.4	70.2	70.9	72.8	75.0	69.4	69.4	71.3	75.4	69.2	69.8	71.5
	spring	76.6	70.7	70.8	72.7	74.8	70.4	69.1	71.3	74.6	68.8	70.0	71.1
Fluroxypyr +2,4-D	spring	76.6	69.0	70.6	72.0	75.0	69.4	65.7	70.0	74.8	69.4	69.9	71.4
Mean		76.8	70.3	70.6	72.6	75.0	69.7	68.5	71.1	75.0	69.1	69.8	71.3

LSD(0.05) for: cultivars – 0.91; herbicides – n.s.; years – 0.91; interactions: cultivars x herbicides – n.s.; cultivars x years – n.s.; herbicides x years – n.s.
n.s. – not significant

Table 7. Influence of herbicides on protein content [%] of rye cultivars.

Herbicide	Term	Walet				Rostockie				Picasso			
		2004	2005	2006	mean	2004	2005	2006	mean	2004	2005	2006	mean
Check		8.9	10.8	13.1	10.9	9.3	10.9	13.3	11.2	8.2	9.7	11.8	9.9
Iodosulfuron methylsodium + mesosulfuron methyl	autumn	8.8	9.4	13.2	10.5	8.9	10.6	13.3	10.9	7.8	9.6	12.2	9.9
	spring	9.3	9.3	12.7	10.4	9.2	11.1	13.2	11.2	8.0	9.5	12.3	9.9
Fluroxypyr +2,4-D	spring	9.3	9.8	13.8	11.0	8.6	10.7	13.3	10.9	8.0	9.8	13.0	10.3
Mean		9.1	9.8	13.2	10.7	9.0	10.8	13.3	11.0	8.0	9.7	12.3	10.0

LSD(0.05) for: cultivars – 0.907; herbicides – n.s.; years – 0.907; interactions: cultivars x herbicides – n.s.; cultivars x years – n.s.; herbicydes x years – n.s.
n.s. – not significant

Table 8. Influence of herbicides on flour efficiency [%] of rye cultivars.

Herbicide	Term	Walet				Rostockie				Picasso			
		2004	2005	2006	mean	2004	2005	2006	mean	2004	2005	2006	mean
Check		43.0	30.5	35.8	36.4	46.0	35.0	35.8	38.9	37.5	32.0	34.9	34.8
Iodosulfuron methylsodium + mesosulfuron methyl	autumn	41.0	32.5	34.0	35.8	43.5	34.5	33.5	37.1	38.0	30.5	31.6	33.3
	spring	41.0	32.5	35.4	36.3	42.5	33.5	34.6	36.8	36.0	30.5	32.1	32.8
Fluroxypyr +2,4-D	spring	40.5	33.0	33.5	35.6	42.0	33.5	33.5	36.3	36.0	30.0	31.6	32.5
Mean		41.4	32.1	34.7	36.1	43.5	34.1	34.4	37.3	36.9	30.8	32.6	33.4

LSD(0.05) for: cultivars – 0.33; herbicides – n.s.; years – 0.33; interactions: cultivars x herbicides – n.s.; cultivars x years – 0.48; herbicydes x years – n.s.
n.s. – not significant

doses decreased by half. In our investigation lower parameters of protein content were obtained than those stipulated by the norm (Table 7). The protein content closest to the requirement was found in the cultivar Rostockie (11,0%), while its highest values in rye were obtained in 2006, irrespective of the herbicides applied. Much lower contents of protein in 2004 and 2005 may testify to a significant effect of weather conditions in those years. The herbicides applied appeared to have no influence on the protein content in grain.

Previous research conducted by these authors using herbicides: Aminopielik Gold and Maraton aiming to determine their effect on winter rye quality showed that some rye quality features like: weight of 1000 grains, protein content, filling number seed grading and determination of bulk density did not depend on the herbicide used (Rola et al., 2008, 2009).

Flour efficiency differed significantly over cultivars and years (Table 8). The cultivar Rostockie was characterized by a higher flour efficiency than the other varieties under test. Flour efficiency was the highest in the first experimental year irrespective of herbicides applied.

Herbicides did not affect bread volume of 100 g flour, as testified to by insignificant differences between the con-

Table 9. Influence of herbicides on bread volume from 100 g of flour [cm^3] of rye cultivars.

Herbicide	Term	Walet				Rostockie				Picasso			
		2004	2005	2006	mean	2004	2005	2006	mean	2004	2005	2006	mean
Check		440	452	353	415	408	467	353	409	425	444	388	419
Iodosulfuron methylsodium + mesosulfuron methyl	autumn	407	455	360	407	470	465	358	431	455	469	398	440
	spring	445	472	382	433	460	480	357	432	430	450	393	424
Fluroxypyr +2,4-D	spring	428	458	357	414	433	462	367	420	442	469	385	432
Mean		430	459	363	417	443	469	359	424	438	458	391	429

LSD(0.05) for: cultivars – r.n.; herbicides – n.s.; years – 35.3; interactions: cultivars x herbicides – n.s.; cultivars x years – n.s.; herbicydes x years – n.s.
n.s. – not significant

Table 10. Influence of herbicides on overbake of bread [%] of rye cultivars.

Herbicide	Term	Walet				Rostockie				Picasso			
		2004	2005	2006	mean	2004	2005	2006	mean	2004	2005	2006	mean
Check		46.9	44.7	57.0	49.5	51.6	46.1	57.7	51.8	48.2	49.8	59.9	52.6
Iodosulfuron methylsodium + mesosulfuron methyl	autumn	49.2	45.1	59.5	51.2	46.4	46.1	58.8	50.4	50.0	48.7	61.6	53.4
	spring	50.2	48.4	58.2	52.2	46.2	45.8	58.3	50.1	52.0	50.6	62.4	55.0
Fluroxypyr +2,4-D	spring	48.7	49.6	56.5	51.6	46.7	46.0	57.7	50.1	50.2	49.3	61.9	53.8
Mean		48.8	47.0	57.8	51.2	47.7	46.0	58.1	50.6	50.1	49.6	61.4	53.7

LSD(0.05) for: cultivars – 1.63; herbicides – n.s.; years – 1.63; interactions: cultivars x herbicides – n.s.; cultivars x years – n.s.; herbicydes x years – n.s.
n.s. – not significant

Table 11. Influence of herbicides on porosity of the crumb [Mohs] of bread of rye cultivars.

Herbicide	Term	Walet				Rostockie				Picasso			
		2004	2005	2006	mean	2004	2005	2006	mean	2004	2005	2006	mean
Check		9	8	9	8.6	8	6	8	7.3	9	7	8	8.0
Iodosulfuron methylsodium + mesosulfuron methyl	autumn	7	8	9	8.0	7	5	10	7.3	7	6	7	6.6
	spring	8	8	9	8.3	9	5	9	7.6	8	8	7	7.6
Fluroxypyr +2,4-D	spring	7	8	8	7.6	6	5	10	7.0	8	7	7	7.3
Mean		7.8	8.0	8.8	8.2	7.5	5.3	9.3	7.3	8.0	7.0	7.3	7.4

LSD(0.05) for: cultivars – 0.8; herbicides – n.s.; years – 0.8; interactions: cultivars x herbicides – n.s.; cultivars x years – 1.2; herbicides x years – n.s.
n.s. – not significant

trol and the herbicide treatments (Table 9). The mean volumes of bread baked from the flour of the analysed rye cultivars treated with different weed-killing agents did not differ significantly, either. The cultivar Picasso tended to have a slightly higher volume of bread. Significant differences in the bread volume were found to have been year-dependent. The highest parameters were obtained in the second year of investigation, while the lowest ones in 2006.

The flour of the cultivar Picasso gave a high overbake of bread, while low values of that quality were obtained with Rostockie, Walet having given intermediate values (Table 10). Definitely positive effect on that quality was observed in the last year of the investigation.

Irrespective of the herbicides and dates of their application, the cultivar Walet was conspicuous for its best porosity of crumb measured on the Mohs scale (8.2). In the other cultivars that parameter was worse than in Walet. No effect of the herbicides applied was found on the size of pores in the crumb of bread of rye cultivars (Table 11). High values of porosity were obtained with the flour of the cultivars Walet and Rostockie in 2006, while cv. Picasso performed best in 2004.

In literature contradictory reports are found concerning the influence of herbicides on the baking properties of bread. Domańska et al. (1985) said only little increase was found in bread volume of flour coming from the treatments with the use of herbicides as compared with the control. According to Buchner's results (1969) herbicides brought about a drop in the volume of bread. Gil et al. (2008) think that the milling and baking values of wheat flour depend more on the genetic characters of cereal cultivars than on the plant pesticides applied. Herbicides appeared to have influenced the efficiency of flour and its usefulness for baking purposes to only a small extent.

CONCLUSIONS

1. No significant influence of herbicides (Atlantis 04 WG and Aminopielik Gold 530 EW) was found on the yield of crops or other technological qualities of grain rye.
2. From among the rye cultivars the highest yield was obtained from the cultivar Picasso, while significantly lower from Walet and Rostockie. Favourable weather conditions in 2003 contributed to the highest increase in yields of all the grain rye cultivars in 2004, as compared with the other years.
3. The rye cultivars differd for a considerable majority of the traits tested. Good seed grading of grain was in the cultivars Picasso and Walet. Adequate falling number and high protein content and flour efficiency were found in the cultivars Rostockie and Walet. High determination of bulk density in a poured state and good crumb porosity characterized Walet, while the best overbake was that of the flour of the cultivar Picasso. No significant influence of cultivars was found on the weight of 1000 grains and on the volume of bread.
4. Proved were significant differences among the cultivars in particular years of the investigation. High weight of 1000 grains, determination of bulk density and flour efficiency were recorded in 2004, and seed grading, low falling number and bread volume in 2005. The year 2006 appeared favourable to such characters as protein content, bread overbake and crumb porosity.

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