Grain yield and disease resistance of winter cereal varieties and application of biological agent in organic agriculture

A. Sliesaravičius, J. Pekarskas, V. Rutkovienė and K. Baranauskis*

Lithuanian University of Agriculture, Studentų 11, Lt-53361, Akademija, Kaunas distr., Lithuania
*Lithuanian Institute of Horticulture, Babtai, LT-54333 Kaunas distr., Lithuania; e-mail: algis.Sliesaravicius@lzuu.lt

Abstract. Field trials with different varieties of winter wheat, rye barley and triticale were carried out at the Agroecology Center of the Lithuanian University of Agriculture from 2003-2005. The biological agent biojodis was tested. The winter wheat varieties 'Baltimor' and 'Residence' were found to be the most resistant to *Septoria tritici* (leaf blotch. The biological agent biojodis increased wheat grain yield for separate varieties by 0.38 – 0.97 t ha^{-1}. No significant differences in disease resistance were found among the triticale and rye varieties tested. Research on the biological agent biojodis revealed that this agent reduced the incidence of fungi in the grain of the winter wheat variety 'Širvinta 1', thus it could diminish the number of mycromicetes species and the fungal infection level.

The grain untreated wtith biojodis was found to be infected with 4 fungi species (Aspergillus oryzae, Fusarium nivale, Fusarium poae, Mycelia sterilia), where the infection level reached 9.0×10^3 cfu (colony forming unit), whereas the grain treated with the agent at a rate of 2 l t^{-1} was found to be infected with 2 species of fungi (Fusarium poae, Fusarium sporotrichiodes) at 5.5×10^3 cfu (colony forming unit) infection level.

Key words: wheat, rye, triticale barley, disease, yield, protein, organic farming, varieties, biological agent

INTRODUCTION

With the growing demand for ecological production the number of ecological farms increases. In Lithuania, as of 2005, there were more than 1800 farms involved in ecological production.. These farms account for 69000 ha of the total agricultural land and use seed produced on conventional (intensive production) farms. This seed needs a transitional period for purification and adaptation to ecological growing conditions. Varieties differ in their response to the change of the cultivation conditions (Ostergard & Jensen, 2004; Strazdina & Bleidere, 2004; Gaile et al., 2004; Strazdina & Opmane, 2005; Vigovskis et al., 2005).

It was found that the new winter wheat varieties 'Zentos' are better suited for ecological cultivation conditions than variety 'Sirvinta 1'(Sliesaravičius & Kučinskas, 2001). The new varieties have to be adapted to ecological farming (Eisele & Kapke, 1997; Lammerts van Bueren et al., 2002; Kalinina et al., 2004; Kokare & Kronberga, 2005). The variety's ability to adjust to different growing conditions and its capacity to effectively utilize nutrients are important characteristics. As a result, not every variety grown on a conventional farm is suited for ecological production farms, so a special approach is needed for testing them. Moreover, plant nitrogen supply is an important factor both for grain yield and protein content. On ecological farms where mineral nitrogen is not applied cereals are often insufficiently supplied with nitrogen, which results in a low grain protein content. Therefore, it it important to test the efficiency of organic agents such as biojodis for ecological seed production..

Fusarium fungi are causing great loss in crop yield, as they are capable of penetrating into any grain tissue or cell, producing strong toxins. In many cases fungous infection strikes plant shoots via infected seeds. Therefore, acquiring healthy grain for seeding is of great importance (Schmidt, 1991; Knudsen et al., 1995).The objective of the present research was to study the response of winter cereal varieties to ecological cultivation conditions and the efficacy of the organic agent biojodis for the grain yield of the different varieties of winter wheat.

MATERIALS AND METHODS

During 2003–2005 field trials were carried out at the Agroecology Centre of the Lithuanian University of Agriculture. The soil of the experimental site was heavy loam, Eutri-Hypogleyic Albeluvisol – PLB – g4 (Endohypogleyic - Eutric Planosol – Ple-gin-W) with neutral reaction (pH 7.1), average humus content (2.25%), phosphorus and potassium contents at 270.0 mg kg $^{-1}$ and 175.0 mg kg $^{-1}$, respectively.

Trial fields of 30 m^2 were used, and each variety was run in three replicates. Protein content was calculated on the basis of total nitrogen content, determined by the Kjeldahl method (multiplying 5.7.).

Sedimentation was measured by the Zeleny method, and gluten was determined by apparatus Glutomatic (Mašauskienė & Cesevičius, 2004). The tests involved 13 varieties of winter cereals: 6 wheat, 3 rye, 2 triticale, and 2 barley varieties. The disease pressure was characterized by disease incidence and disease severity (Žemės ūkio augalų ligos ir jų apskaita , 2003).In field trials, prior to sowing, wheat seed was treated with a water solution of organic agent biojodis (2 l t $^{-1}$), then the plants were sprayed in spring, before resumption of vegetation (3 l ha $^{-1}$) and at heading stage (3 l ha $^{-1}$). Biojodis is a liquid organic fertilizer produced as an aqueous extract of biohumus supplemented by physiologically active iodine, biotransformers and microelements (Table 1). To elucidate the effects of biojodis on wheat seed germination and number of fungi, laboratory analyses were performed in a controlled environment - in a thermostat. Winter wheat variety 'Širvinta 1' seeds were germinated on a filter paper in Petri dishes at 20±2°C temperature. Seed vigour and germination frequency was determined after 3 and 7 days, respectively. Micromicetes were cultivated on Chapek medium. Infected medium was incubated at 26±2°C temperature. Light microscopy was applied to identify fungi by cultural and morphological features. A detection frequency (DF) measure was used to identify dominating fungi genus. DF was calculated by a formula as follows:

$$DF = \frac{B}{C} \times 100\%$$

where, B = number of samples infected by the same fungus; C = total number of examined samples.

Table 1. Composition of biojodis.

Components	Amount
Organic matter	5–8 %
pH	7.1–7.8
Nitrogen (N)	0.85–1.5%
Phosphorus (P)	0.90–1.5 %
Potassium (K)	0.82–1.5 %
Water soluble humates	0.15–0.7 %
CaO	0.40–2.0 %
MeO	0.25–2.0 %
Fe	0.08–0.2 %
Mn	0.002–0.05 %
Cu	0.008–0.01%
Zn	0.002–0.01 %
Co	0.0005–0.002 %
Mo	0.0005–0.002 %
B	0.008–0.02 %
J	0.10–0.75 mg l^{-1}
Sucrose	0.25–10.0 mg l^{-1}
Bacterial microflora	10^7-10^{10} colony units g^{-1}
Patogenic microflora	N/A

Dry and warm weather predominated during the first decade of May 2004. Average temperature during this decade was 5°C greater than during the next two decades. As there were only 6.4 mm of rainfall during the first decade, the soil dried up very quickly, making environmental conditions for the summer crop's seed germination somewhat unfavorable. Average temperatures in June and July were 1.3 and 0.9°C lower, respectively, as compared to the perennial mean, whereas rainfall quantity followed the yearly average. Average temperature in August was greater by 1.2°C than the yearly average. August was also the rainiest month, as with rainfall exceeding the annual average by 28.2 mm; the harvesting of summer crops was delayed. In 2005, as vegetation began, the weather was cool and rainy. During the first decade of May, average air temperature was 5.5°C lower than the same period in 2004, while rainfall quantity increased by a factor of 7. Cool weather dominated during the first decade of June - the average day temperature reached only 21.8°C - while during the 2nd and 3rd decades it increased up to 16.2°C. In general, the average June temperature was greater by 0.5°C and the rainfall quantity, greater by 15.3 mm as compared to annual means.

Acquired data were analyzed and means, standard deviations and LSDs (least significant difference's) were determined by ANOVA for EXCEL v. 3.43 (Tarakanovas & Raudonius, 2003).

RESULTS AND DISCUSSION

Laboratory analyses suggest that, depending on the concentration, biojodis increases wheat seed vigour and germination (Table 2). The highest seed germination was recorded using a concentration of 2 l t $^{-1}$ (Table 2). Biojodis is characterized by fungicidal properties and inhibits fungi growth in winter wheat seed (Table 3), protecting the germinating seed from diseases. The agent biojodis had a positive effect on the grain yield of all winter wheat varieties tested. Agent treatment resulted in the 0.38-0.97 t ha $^{-1}$ grain yield increase (Table 4).

Table 2. Vigour and germination of the seed of winter wheat variety 'Širvinta I' as affected by treatment with biojodis. LUA, 2005

Treatment	Seed vigour, %	Germination, %
Control (untreated with biojodis)	88.2	91.0
Biojodis 1 l $^{-1}$t	87.4	90.3
Biojodis 2 l $^{-1}$t	90.3	95.4
Biojodis 3 l $^{-1}$t	91.6	92.2
LSD_{05}	4.5	3.6

Table 3. The effect of biojodis on the amount of fungi in the seed of the winter wheat variety 'Širvinta I'. LUA, 2005.

Seed treatment	Amount of mycromicetes colony forming units	Number and name of isolated fungi species
Control (untreated with biojodis)	9.0×10^3	4 (Aspergillus oryzae, Fusarium nivale, Fusarium poae, Mycelia sterilia)
Biojodis 1 l $^{-1}$t	6.0×10^3	3 (Aspergillus oryzae, Aspergillusflaus, Fusarium pooe)
Biojodis 2 l $^{-1}$t	5.5×10^3	2 (Fusarium poae, Fusarium sporotrichividis)
Biojodis 3 l $^{-1}$t	6.1×10^3	3 (Fusarium poae, Mycelia sterilia, Aspergillus oryzae)
LSD_{05}	1.8×10^3	

Table 4. The effect of biojodis on the grain yield of different winter wheat varieties.
LUA, Agroecology Centre, 2004–2005

Variety	Yield t ha $^{-1}$ without biojodis		Mean 2004-2005	Yield t ha $^{-1}$ with biojodis		Mean 2004-2005 t ha $^{-1}$	Average yield increase t ha $^{-1}$
	2004	2005		2004	2005		
'Alma'	3.54	4.36	3.95	3.89	504	4.46	0.51
'Ada'	4.18	5.53	4.85	4.99	5.86	5.42	0.57
„Širvinta I'	3.78	3.40	3.59	4.53	4.36	4.44	0.85
'Baltimor'	4.38	5.01	4.69	4.73	5.01	4.87	0.49
'Milda'	4.10	4.95	4.52	4.72	6.26	5.49	0.97
'Residence'	4.53	5.62	5.52	5.40	6.40	5.90	0.38
LSD_{05}	0.50	0.68	0.61	0.57	0.70	0.65	

Table 5. Grain chemical composition of winter wheat varieties with and without biojodis treatment. LUA, Agroecology Centre, 2004-2005.

Variety	Protein %				Gluten %				Sedimentation ml			
	2004		2005		2004		2005		2004		2005	
	without biojodis	with biojodis	without biojodis	with biojodis	without biojodis	with biojodis	without biojodis	with biojodis	without biojodis	with biojodis	without biojodis	with biojodis
‘Alma’	10.4	10.6	13.4	13.7	26.3	27.1	26.5	26.7	29.0	30.0	38.0	39.8
’Ada‘	10.2	10.5	12.2	12.6	17.6	18.4	21.7	23.2	26.0	27.0	32.4	33.3
‚Širvinta I‘	9.6	9.8	12.1	12.7	18.2	19.1	21.3	23.1	23.0	24.3	31.8	33.5
‘Baltimor’	8.3	9.0	9.5	9.8	13.6	13.7	16.7	16.9	22.0	29.2	23.4	24.2
‘Milda’	9.6	9.7	12.2	13.1	17.9	18.9	23.1	26.1	26.0	27.0	32.7	35.6
‘Residence’	8.3	8.4	10.5	11.4	16.1	16.9	18.3	18.9	17.0	18.1	27.6	28.1
LSD05	0.5	0.6	0.8	0.7	3.4	4.2	3.8	4.5	5.3	4.8	7.5	8.2

Table 6. Septoria tritici and Dreschlera tritici repentis on winter wheat varieties. LUA, Agroecology Centre, 2004-2005.

Variety	Septoria tritici incidence and severity %				Dreschlera tritici repentis incidence and severity %			
	2004		2005		2004		2005	
	incidence	severity	incidence	severity	incidence	severity	incidence	severity
‘Milda’	0.00	0.00	41.00	5.86	12.22	0.21	45.00	2.92
‘Alma’	3.30	0.12	51.00	3.30	16.66	0.61	41.00	6.31
’Ada‘	0.00	0.00	63.00	5.82	22.22	0.44	43.00	2.09
‚Širvinta I‘	6.66	0.24	64.00	4.76	34.44	3.45	26.60	0.52
‘Residence’	0.00	0.00	18.00	5.20	7.77	0.16	5.00	0.50
‘Baltimor’	16.30	0.64	20.00	4.30	11.11	0.73	16.00	0.24

The winter wheat varieties tested responded differently to ecological growing conditions. The greatest grain yield (5.52 t ha $^{-1}$) was produced by the winter wheat variety 'Residence' and the lowest yield (3.59 t ha $^{-1}$) by variety 'Širvinta I' (Table 4), which was not treated with biojodis. The variety 'Alma' was distinguished for grain protein content and grain quality. It had the highest protein content, high sedimentation and gluten values (Table 5). Winter wheat variety 'Residence' had the greatest yield, but lagged behind the other varieties in grain quality. The use of biojodis improved the quality of wheat varieties and agreat and significant increase was observed in flour sedimentation value: for some varieties it was as high as 39.8% (Table 5).

Wheat grain quality is determined mostly by weather conditions during the post-flowering period. When weather conditions are unfavorable or, when there is a shortage of nutrients, the varieties are incapable of actualizing their genetic potential. Unfavourable weather conditions during grain ripening period result in a low protein content. Our experimental findings obtained in 2004 (Table 5) corroborate this fact. Disease incidence is also highly dependent not only on the genotype but also on the weather conditions during the growing year. In 2004 the wheat varieties 'Milda', 'Ada', and 'Residence' were not infected with *Septoria tritici*, but were heavily affected in 2005 (Table 5). However, the differences in disease incidence between varieties were determined. The disease incidence in the variety 'Residence' amounted to 18 %, and that of the variety 'Ada' - 63% (Table 5). All the varieties tested were affected by net blotch *Drechslera* spp., the incidence of which is also highly dependent on weather conditions in the growing year(Table 5).

The winter rye diploid variety 'Joniai' was distinguished by the grain yield, which was on average 4.19 t ha $^{-1}$ (Table 7). It is noteworthy that rye grain yield in separate years was relatively stable (Table 7). Winter triticale was more productive than rye, producing a grain yield of 5.44 t ha $^{-1}$ (Table 7).'Vitalis' was identified as a greater yielding triticale variety, although significant differences in grain yieldwere observed for separate experimental years. The grain yield differences of winter barley varieties tested were insignificant (Table 7).

Table 7. Grain yield of different varieties of winter rye, triticale and barley.

LUA, Agroecology Centre, 2004–2005

Species and variety	Yield t ha $^{-1}$		
	2004	2005	Average 2004–2005
Rye 'Rūkai'	3.46	3.12	3.29
Rye 'Duoniai'	4.00	3.23	3.61
Rye 'Joniai'	4.54	3.85	4.19
LSD_{05}	0.36	0.28	0.32
Triticale 'Vitalis'	5.24	4.51	4.87
Triticale 'Fidelo'	7.30	3.58	5.44
LSD_{05}	0.61	0.54	0.57
Barley 'Catania'	4.53	4.55	4.54
Barley 'Madu'	5.08	3.56	4.32
LSD_{05}	0.57	0.42	0.50

All varieties of winter rye tested were affected by diseases, however, the severity was determined more by the environmental conditions than by the genotype (Table 8). The barley variety 'Catania' was more affected by *Drechslera teres* than variety 'Madu' (Table 9). There were significant differences between years for *Puccinia* *hordei* incidence on barley (Table 9), and for the incidence of *Septoria tritici* and *Puccinia graminis* on triticale (Table 10).

Experimental results confirmed that individual varieties exhibit a different response to ecological cultivation conditions, therefore it is necessary to select the best-performing varieties or develop new ones, well suited for ecological management.

Table 8. *Septoria secalis* and *Puccinia recondite* on winter rye varieties (%).
LUA, Agroecology Centre, 2004-2005.

Disease incidence and severity %	Variety					
	'Duoniai'		'Rūkai'		'Joniai'	
	2004	2005	2004	2005	2004	2005
Septoria secalis incidence	22.23	100.00	38.80	100.00	23.30	100.00
Severity	1.08	11.87	1.28	16.61	1.50	28.70
Puccinia recondita incidence	11.10	100.00	5.50	100.00	20.10	100.00
Severity	0.20	7.70	0.58	13.87	0.38	11.54

Table 9. *Drechslera spp.* and *Puccinia hordei* on winter barley varieties.
LUA, Agroecology Centre, 2004–2005.

Disease incidence and severity %	Variety			
	'Madu'		'Catania'	
	2004	2005	2004	2005
Drechslera spp. incidence	75.55	55.00	87.70	62.00
Severity	4.82	3.14	6.83	7.60
Puccinia hordei incidence	13.30	66.00	18.80	57.00
Severity	1.38	5.50	1.96	8.20

Table 10. *Septoria tritici* and *Puccinia graminis* on winter triticale varieties.
LUA, Agroecology Centre, 2004-2005.

Disease incidence and severity %	Variety			
	'Vitalis'		'Fidello'	
	2004	2005	2004	2005
Septoria tritici incidence	12.20	100.00	7.80	100.00
Severity	1.55	5.55	1.10	10.05
Puccinia graminis incidence	8.88	6.00	6.66	8.00
Severity	0.72	0.22	0.67	0.12

CONCLUSIONS

Having investigated the productivity of different varieties of winter wheat, rye, triticale, and barley under the conditions of ecological cultivation, results indicate that the most productive were winter wheat and triticale varieties. Individual varieties demonstrated a different response to ecological growing conditions; the average grain yield of the winter wheat variety 'Residence' was 5.52 t ha^{-1}, and that of the variety 'Širvinta was 1' 3.59 t ha^{-1} . The high-yielding variety 'Residence' lagged behind the other varieties in grain quality indicators. The variety 'Alma' was noted for grain quality and productivity. Grain quality and disease resistance were highly dependent on the weather conditions of the year of cultivation and genotype. Of the tested winter rye varieties, 'Joniai' was found to be the most productive. It is noteworthy that that winter rye varieties are characterized by yield stability between years, whereas triticale productivity varies more markedly. Application of the organic agent biojodis resulted in an improved chemical composition of the grain. Depending on the variety, winter wheat grain yield increased by 0.38 – 0.97 t ha^{-1}. This agent was also noted for its fungicidal properties. By using adapted winter wheat varieties and the bioagent biojodis under certain ecological conditions, it is possible to achieve a grain yield of 6.0 t ha^{-1}.

REFERENCES

Eisele, I.A. & Kapke, U. 1997. Choice of cultivars in organic farming: new criteria for winter wheat ideotypes. *Pflanzenbauwissenschaften* **1**(2), 84–87.

Gaile, Z., Bleidere, M., Skrabule, I. & Vigovskis I. 2004. The first steps in variety testing for organic agriculture in Latvia. *Proceedings of the first World Conference on organic seed Challenges and opportunities for organic Agriculture and the seed Industry,* pp. 173–174.

Kalinina, S., Jegorova, V. & Katanenko, S. 2005. Results of value for cultivation and use testing in field crops for organic farming in Latvia in 2004. *Proceedings of the seminar "Environmental friendly food production system: requirements for plant breeding and seed production",* pp. 66–70.

Knudsen, M.B., Hockenhuil, J. & Jensen, D.F. 1995. Biocontrol of seedling disease of barley and wheat caused by Fusarium culmorum and Bipolaris sorokiniana: effects of selected fungal antagonists on growth and yield components. *Plant Pathology* **44,** 467–477.

Kokare, A. & Kronberga, A. 2005. Evaluating suitability of rye varieties to organic farming. *Proceedings of the seminar "Environmental friendly food production system: requirements for plant breeding and seed production",* pp. 90–92.

Lammerts von Bueren, E.T., Striuk, B.C. & Jacobson, E. 2002. Ecological concepts in organic farming and their concequences for on organic crop ideotype. *Netherlands Journal of Agricultural Science* 50, 1–26.

Mašauskienė, A. & Cesevičius, J. 2004. Žieminių kviečių technologinių savybių kitimas priklausomai nuo tręšimo azoto trąšomis ir grūdų laikymo trukmės. *Maisto chemija ir technologija* **38**(1), 49–60.

Ostergard, H. & Jensen, I.W. 2004. Characteristics of spring barley varieties for organic farming Genetic variation for plant Breeding. *Proceedings of the 17th Eucarpia General Congress.* 8-11 September, Tulln., pp. 483.

Schmidt, H.L. 1991. Cereal grain strukture and the way in which fungi colonize kernel cels. In *Cereal grain. Mycotoxins. Fungi and quality in drying and storage*. Elsevier, Amsterdam, pp. 1–22.

Sliesaravičius, A. & Kučinskas, J. 2001. Selection of winter wheat suitable for ecological farming. Zeszyty Noukuwe Akademi Rosnizy H. Kailataja W. Krakowie, Nr. 375 scientific Paper of the Agricultural University of Crakow Sesija Naukowa Zeszyt 77, produkcija roslinna, pp. 87–93.

Strazdina, V. & Bleidere, M. 2004. Cereal varieties for the organic farming in Latvia. *Proceedings of the first World Conference on organic seed Challenges and opportunities for organic Agriculture and the seed Industry*, pp. 186–187.

Strazdina, V. & Opmane, Z. 2005. The best results of winter wheat varieties suitable for organic farming in Latvia. *Proceedings of the seminar "Environmental friendly food production system: requirements for plant breeding and seed production"*, pp. 109–110.

Tarakanovas, P. & Raudonius, S. 2003. Taikant kompiuterines programas Anova, Stat, Split – Plot is paketo Selekcija ir Irristat. Akademija, 57 p.

Žemės ūkio ligos ir jų apskaita. LŽI. 2003. 346 p.

Vigovskis, J., Svarta, A.& Jermuss A. 2005. Variety trials of cereals, oil seeds and potatoes in organic farm. *Proceedings of the seminar "Environmental friendly food production system: requirements for plant breeding and seed production"*, pp. 100–103.