BIOLOGIJA. 2008. Vol. 54. No. 2. P. 89–92
DOI: 10.2478/v10054-008-0017-5

Genetic resources of spring barley: influence of organic and conventional growing systems on spring barley varietal characteristics

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Developing organic agriculture requires cultivars with a complex of special traits. Organic farmers still largely depend on varieties produced for conventional farming systems. In order to test the utilisation of such crop varieties in organic agriculture, we evaluated how organic farming methods affected the grain yield, plant length, 1000 kernel weight, hectolitre weight, protein and starch content of spring barley (*Hordeum vulgare* L.) breeding lines basically bred for the conventional farming system. The study was conducted at the Lithuanian Institute of Agriculture during 2006–2007 in conventional and organic crop rotations. The spring barley breeding lines LIA 8264, LIA 8056-2, LIA 8056-6, LIA 8611 and the variety 'Luokė' were involved in the test.

Having assessed breeding lines of spring barley under different farming conditions, some lines were discriminated as possessing important and valuable traits for practical use in organic farming: LIA 8611 was noted for resistance to lodging and diseases and a high malting grain quality, LIA 8264 for resistance to powdery mildew, a high number of productive tillers and protein content.

Key words: spring barley, breeding lines, conventional farming, organic farming

INTRODUCTION

Sustainable and organic agriculture involves production management systems based on some fundamental principles such as minimal use of off-farm inputs. Crop production in low-input agricultures requires cultivated varieties showing resilience to adverse or varying environmental effects in farmers' fields. The assessment of the genotype × environment interaction pattern for parental breeding lines has an important bearing on their choice for crossing to cultivated varieties to derive new resilient varieties [1].

Recently, interest has increased in plant varieties specifically adapted to organic farming conditions. Plant breeding is a time-consuming activity and may take 10 to 15 years before a new variety is available on the market. Most European breeding companies are conventional, but some of them are interested in producing varieties for low-input and organic conditions [2].

Despite an intensive growth of the organically managed area, farmers still largely depend on cereal varieties produced for conventional farming systems. Usually such varieties ensure a stable and acceptable yield of good quality when grown under high-input conditions. Therefore, an important question is whether varieties bred for conventional farming systems may be appropriate for organic farming system too. It is well known that varieties often perform and yield differently in various environments due to genotype–environment–management interactions. Thus, there is a need to evaluate the characteristics of varieties in organic as well as in conventional farming systems simultaneously.

The majority of requirements for varieties in an organic production system are distinctive from those in conventional farming. The main requirements are related to improved nutrient uptake and use efficiency due to limited nutrient availability in soil, competitive ability with weeds and resistance to diseases, especially seed-born diseases. But many selection criteria, e. g., resistance to many pests and diseases and abiotic stress factors, have a similar importance in both organic and conventional breeding systems [3].

Several studies have shown that spring barley varieties bred for conventional farming systems might be grown in organic farming systems rather well. On the other hand, the results suggest that there is a need for breeding programmes that prefer varieties better adapted to organic farming systems [4]. Higher yields in organic conditions were obtained for extensive type varieties with a good stress tolerance, but in conventional conditions intensive short-strawed varieties were the highest yielding ones [5].

The other complex of mandatory traits for organic varieties is resistance to fungal diseases. It is apparent that a low-herbicide cereal cropping system may have quite different effects on disease development compared to a conventional cropping system, largely as a result of the modified environmental and physical parameters of the cereal crop [6].

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The aim of the experiment was to evaluate the yield and trait expression of various spring barley genotypes from the genetic resources collection in organic and conventional growing conditions, to identify essential traits for organic breeding and to find parental genotypes for breeding in organic farming.

MATERIALS AND METHODS

Field studies were carried out in conventional and organic crop rotations at the Lithuanian Institute of Agriculture during 2006–2007. The Lithuanian origin spring barley breeding lines from the genetic resources collection stored at the Lithuanian Plant Gene Bank – LIA 8264 (LIA7383/Baronesse), LIA 8056-2 (LIA 7385/LIA 7355), LIA 8056-6 (LIA 7385/LIA 7355), LIA 8611 (Jacinta / Vortex) and the variety 'Luokė' were involved in the test.

The experimental varieties were grown in three replications and with a plot size of 5.0 × 1.5 m^2. The crop was sown in a well-prepared seedbed with Hege 80 at a rate of 5 million seed ha^{-1}. The soil of the experimental site is Endocalcari-Epihypogleyic Cambisol (CMg-p-w-can)) (55°24'N, 23°50'E), with pH 7.3, the percentage of organic matter 2.1, available P_2O_5 150–180 mg kg^{-1} and K_2O 100–150 mg kg^{-1}.

In a conventional farming system spring barley varieties succeeded grain legumes. At sowing, 90 kg of N, 60 kg of P_2O_5 and 60 kg of K_2O were broadcast-applied, weeds and insects were controlled chemically.

In an organic farming system, spring barley varieties were sown after black fallow. The field was certified for organic agriculture. No agrochemicals and fertilizers were used. The soil was checked for the content of mineral nitrogen in spring before resumption of vegetation. A low amount of available mineral nitrogen (20–30 kg ha^{-1}) was determined.

The plots were harvested with a Wintersteiger harvester. Combine-harvested grains from each plot were dried and sampled for analyses. One thousand grain weight (TGW) (ISO 580), total grain protein (total nitrogen by Kjeldahl multiplied by 6.25, ICC 105/2), total starch content (by hydrochloric acid dissolution, ICC 123/1) were determined. Yield data were adjusted to a 15% moisture content, and grain quality characters were determined in dry grain.

A sample of sheaf was taken from each plot shortly before harvesting for length measurement of individual plants

The diseases were assessed at the medium milk development stage (BBCH 75). The resistance to diseases was measured in scores using a 1–9 scale: score 1 – no visible symptoms of diseases, score 9 – heavily infected plants (infection ≥80%).

The period 2006–2007 was rather favourable for spring barley versatile evaluation because of the variable weather conditions (2006 – hot and dry, 2007 – wet).

The data were analysed statistically using Fisher's analysis of variance technique, and the least significant difference test at the 0.05 probability level was employed to compare the differences among the treatment means.

RESULTS AND DISCUSSION

Five spring barley genotypes of various types of intensity and plant morphology were grown in organic and conventional growing conditions in 2006–2007. The main difference between the locations was the fertilization system, crop rotation and minor differences in soil.

During both years of variety testing, all varieties produced a higher grain yield in the conventional farming system than in the organic farming system (Table 1). But in 2007 the differences were more considerable. During the two growing seasons, the yield of organically grown plants decreased, and for breeding lines the grain yield was by 25.4–32.8% lower than that for conventionally grown plants. The grain yield of the variety 'Luokė' was least influenced by organic growing conditions. The decrease in its grain yield was as low as 8%.

On the average for all barley varieties and testing years, organically grown plants were by 14.0% shorter than conventionally grown plants (Table 1). Lodging resistance ranged from 8 to 9 points (on 1–9 scale, where 9 – very resistant) in conventional growing conditions. In organic growing conditions all varieties were not lodged (9 points).

The 1000 kernel weight (TKW) and hectoliter weight (HLW) varied among the varieties (Table 2). However, there was no significant difference for the following traits regardless the growing system. On average, for all testing years and varieties for conventional and organic growing conditions the 1000 kernel weight was 42.9 and 43.2 g and the hectoliter weight 642.1 and 651.1 g l^{-1}, respectively. All tested varieties produced more productive tillers in a conventional than in organic farming system.

Table 1. **Mean grain yield, plant height and resistance to lodging of spring barley genotypes tested under conventional and organic farming conditions, 2006–2007**

Variety	Grain yield t ha^{-1}			Plant height, cm			Resistance to lodging		
	CONV	ORG	%*	CONV	ORG	%	CONV	ORG	%
Luokė	3.63	3.34	–8.0	73.0	63.5	–13.0	9.0	9	0
LIA 8264	4.81	3.23	–32.8	62.0	52.5	–15.3	8.5	9	5.9
LIA 8056-2	4.74	3.40	–28.3	70.0	59.5	–15.0	8.5	9	5.9
LIA 8056-6	4.52	3.37	–25.4	69.0	57.0	–17.4	8.3	9	8.4
LIA 8611	4.64	3.40	–26.7	69.0	62.5	–9.4	9.0	9	0
Mean	4.47	3.35	–25.1	68.6	59.0	–14.0	8.7	9	3.4
LSD_{05}	0.783	0.647		4.24	8.00		1.21	0.07	

* Difference from conventional farming conditions.

Table 2. **Mean HLW, TKW and number of productive tillers of spring barley genotypes tested under conventional and organic farming conditions, 2006–2007**

Variety	HLW, g l^{-1}			TKW, g			Productive tillers, unit/m²		
	CONV	ORG	%	CONV	ORG	%	CONV	ORG	%
Luokė	619.5	635.0	2.5	43.4	44.7	3.0	668.5	592.0	–11.4
LIA 8264	640.0	665.5	4.0	41.8	40.5	–3.1	633.5	652.0	2.9
LIA 8056-2	649.5	658.5	1.4	42.7	44.1	3.3	706.0	602.5	–14.7
LIA 8056-6	653.5	647.0	–1.0	43.1	43.7	1.4	695.0	641.5	–7.7
LIA 8611	648.0	649.5	0.2	43.8	42.9	–2.1	618.5	561.5	–9.2
Mean	642.1	651.1	1.4	42.9	43.2	0.7	664.3	609.9	–8.2
LSD_{05}	51.33	39.10		6.15	6.52		183.63	108.25	

* Difference from conventional farming conditions.

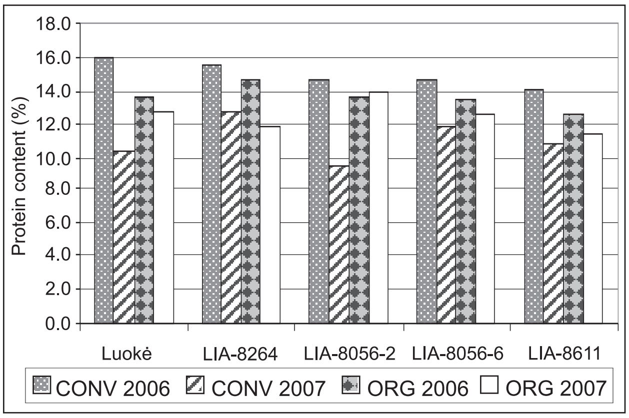

Fig. 1. Mean protein content in spring barley breeding lines grown under conventional and organic farming conditions, 2006–2007

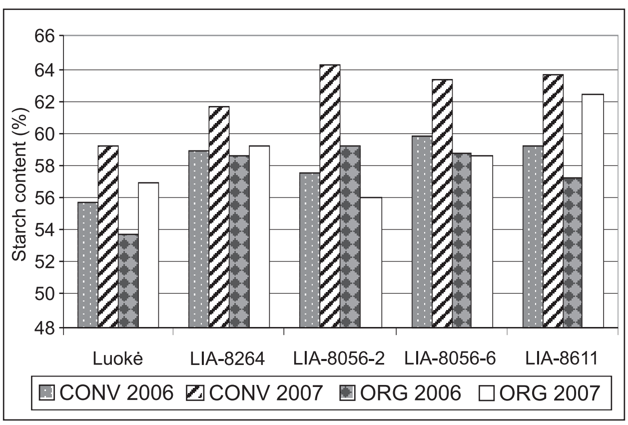

Fig. 2. Mean starch content in spring barley breeding lines grown under conventional and organic farming conditions, 2006–2007

Protein content in organically grown grains was lower than that in grains grown in a conventional system, the average by 9.2% in the dry year 2006, but in the wet 2007 it surpassed conventionally grown grain on average by 13.2% (Fig. 1). Starch content in organically grown grain was lower than in grain in a conventional system for both test years on average by 3.5% (Fig. 2). The spring barley line LIA 8611 exhibited good grain quality traits under different growing systems throughout the test period.

Many foliar fungal diseases (powdery mildew in cereals, many soil borne diseases) are of minor importance in organic farming systems, because disease-preventive agronomic measures (use of resistant cultivars, adequate rotations and nutrition balance management) prevent disease development. However, some foliar and post-harvest diseases can cause significant economic losses in organic farming systems. In general, yields in organic agriculture are 20% lower due to a lower nitrogen input (up to 50% less nitrogen) and in some cases due to pests and diseases [7].

Powdery mildew (*Erysiphe graminis* DC. f. sp. *Hordei* Em. Marchal) and net blotch (*Pyrenophora teres* Drech.) were predominant diseases in spring barley. Powdery mildew in conventional growing conditions infested spring barley varieties by 1.0 to 5.0 points and in organic growing conditions from 1.1 to 7.0 points (Table 3). The barley lines LIA 8264 and LIA 8611 were found to be more resistant to mildew.

In 2007, due to favourable weather conditions, the prevalent disease in barley was net blotch. The disease in conventional growing conditions infested spring barley varieties by 1.3 to 5. points and in organic growing conditions by 2.0 to 8.5 points. The line LIA-8611 was more resistant to net blotch in conventional growing conditions, but it was susceptible (4.0–6.0) in organic growing conditions.

Table 3. **Resistance to fungal diseases of genotypes tested under conventional and organic farming conditions, 2006–2007**

Variety	Powdery mildew, scores				Net blotch, scores			
	2006		2007		2006		2007	
	ORG	CONV	ORG	CONV	ORG	CONV	ORG	CONV
Luokė	7.0	3.5	7.0	5.0	2.0	1.3	4.0	3.5
LIA 8264	2.0	1.0	1.1	1.0	3.0	2.0	8.5	5.5
LIA 8056-2	3.0	1.5	3.0	1.0	2.0	2.3	6.5	5.0
LIA 8056-6	3.0	1.0	4.0	2.3	3.0	2.0	6.8	5.0
LIA 8611	1.1	1.0	4.0	1.5	4.0	1.5	6.0	4.5
LSD_{05}	0.23	0.43	0.10	0.72	0.81	0.44	2.10	0.78

CONCLUSIONS

The variety testing showed that spring barley breeding lines bred for conventional farming systems can perform rather satisfactorily in organic farming systems. On the other hand, the results suggest that there is a need for breeding programmes that prefer varieties better suited for organic farming systems. Having assessed breeding lines of spring barley under different farming conditions, some lines were discriminated as possessing important traits valuable for practical use in organic farming. The line LIA 8611 exhibited resistance to lodging and diseases and a high malting grain quality, and the LIA 8264 was noted for resistance to powdery mildew, a high number of productive tillers and which protein content.

ACKNOWLEDGEMENTS

We gratefully acknowledge the support for this study provided by the Agency for International Science and Technology Development Programmes in Lithuania (grant No. 10V-86) and the research programme "Genefund" initiated by the Lithuanian Ministry of Education and Science.

Received 14 January 2008
Accepted 25 April 2008

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VASARINIŲ MIEŽIŲ GENETINIAI IŠTEKLIAI: EKOLOGINIO IR TRADICINIO AUGINIMO SISTEMŲ ĮTAKA VASARINIŲ MIEŽIŲ VEISLIŲ SAVYBĖMS

Santrauka

Plėtojantis ekologinei žemdirbystei padidėjo poreikis veislių, pasižyminčių specifinių požymių kompleksu. Tačiau ekologine žemdirbyste besiverčiantys žemdirbiai dar labai priklauso nuo tradicinei žemdirbystei sukurtų veislių. Siekiant ištirti tradicinei žemdirbystei sukurtų veislių tinkamumą ekologinei žemdirbystei skirtingomis sąlygomis buvo tiriamos vasarinių miežių (*Hordeum vulgare* L.) selekcinės linijos bei ekologinės žemdirbystės įtaka jų pagrindinėms savybėms. Bandymas buvo atliktas 2006–2007 m. Lietuvos žemdirbystės institute ekologinės ir tradicinės žemdirbystės sąlygomis. Buvo tirtos vasarinių miežių selekcinės linijos LIA 8264, LIA 8056-2, LIA 8056-6, LIA 8611 ir veislė 'Luokė'.

Ištyrus skirtingai auginamų žieminių ir vasarinių javų veislių derliaus potencialą, buvo įvertintos veislės, turinčios svarbių ir naudingų požymių, kurie gali būti taikomi praktinėms reikmėms: LIA 8611 – atspari išgulimui ir ligoms, geros kokybės, LIA 8264 – atspari miltligei, gerai krūmijasi, baltyminga.

Raktažodžiai: vasariniai miežiai, selekcinės linijos, tradicinė žemdirbystė, ekologinė žemdirbystė