Selection of winter wheat for organic growing

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Abstract. The study was conducted at the Lithuanian Institute of Agriculture during 2006–2008. Sixteen registered winter wheat varieties and advanced breeding lines were tested. Correlation analysis of traits of winter wheat genotypes grown under conventional and organic systems showed stronger correlations between the traits that had been found to be environmentally more stable. Overwintering, plant height, heading, maturity, lodging and hectolitre weight strongly correlated (r = 0.74**–0.98**) between the growing systems in both years. Soil coverage, which is a very important trait for organic system showed weak or medium correlations (r = 0.43*–0.64**) between the systems tested. Yield and 1000 grain weight mostly correlated with the traits of plant vegetative development, whereas hectolitre weight showed random correlations with the other traits. The yield was found to positively correlate with soil coverage at development stages BBCH41-42, 60-65 and number of productive tillers (r = 0.31*–0.54*).

Key words: winter wheat, cultivars, breeding lines, organic farming

INTRODUCTION

Separate organic fields for all breeding nurseries are hardly available due to the peculiarities of plant stands in breeding nurseries. Weeds without chemical control usually cause many problems as plants in most of the nurseries do not shade soil satisfactorily. Crop harrowing is problematic in early stages of crop developments, especially in pre-germinating/post-germinating period when seedlings can be easily moved to the next plot or row. Such contamination of lines is completely unacceptable at the existing system of standards for wheat cultivars. Therefore, it is more practical to develop selection technique which enables selection of genotypes grown under conventional system by traits that are most desirable for organic conditions (Löschenberger et al., 2008; Przystalski et al., 2008). The modern European winter wheats are quite similar. However, introduction of some Ukrainian and Russian material and crossing of parental material from less geographically related countries enable developing of the adequate breeding material for different purposes for growing under Lithuanian conditions (Ruzgas, 2001). Considering economics, organic breeding system can hardly take more than 10% from the total breeding system in private breeding companies. Possibly, bigger share of organic breeding could be in the national breeding institutions if adequate subsidizing is provided.

Some of the cultivar traits are highly desirable in both growing systems: disease resistance and yield stability. However, resistance to some diseases can be lower in cultivars designed for organic growing. These are high input diseases, e.g. powdery mildew, and diseases linked to unfavourable crop rotation, e.g. eyespot, root rots. Higher differences are in cultivars' ability to compete with weeds. Modern wheat cultivars possess erect or semi erect leaves and short straw, whereas cultivars grown under organic system should be taller, with wide prostrate leaves (Liatukas & Leistrumaitė, 2007). The new methods must permit a rapid, easy, accurate and cheap determination of the parameters in order to allow the screening of a multitude of breeding lines. For instance, rating of plant growth habit, leaf habit and inclination, visual scoring of ground cover (Richardson et al., 2001) is more feasible for a practical breeder than light interception measurements or the determination of weed biomass per unit area (Hoad et al., 2005; 2008).

The present study was designed to evaluate genotypes of winter cereals for correlation between traits in conventional and organic growing systems.

MATERIALS AND METHODS

The study was conducted at the Lithuanian Institute of Agriculture during 2006–2008. Sixteen registered winter wheat varieties and advanced breeding lines were tested. The soil of the experimental site is *Endocalcari-Epihypogleyic Cambisol* (CMg-p-w-can) (55°24'N, 23°50'E), with a pH_{KCl} 7.0, amount of organic matter 21 g kg^{-1}, available P 65-80 mg kg^{-1} and K 83–125 mg kg^{-1}. The experimental varieties were grown in three replications and with a plot size of 5.0 x 1.5 m^2. The crop was sown in the middle of September on a well-prepared seedbed with a Hege 80 using a rate of 5 million seed ha^{-1}. Seeds used for sowing in 2006 were prepared from 2005 conventionally grown cereal yield. The next year the seeds were organic.

The cereals were preceded by a black fallow. The field was certified for organic agriculture. No agrochemicals and fertilizers were used. The soil was checked for the amount of mineral nitrogen in spring before resumption of vegetation. Low amount of available mineral nitrogen (sum of nitrate and ammonium nitrogen) (20–30 kg ha^{-1}) was determined.

In conventional farming system winter wheat varieties succeeded a black fallow too. At sowing, 20 kg of N, 60 kg of P_2O_5 and 60 kg of K_2O were broadcast-applied and additionally 90 kg of N in spring, weeds and insects were controlled chemically.

Overwintering was evaluated using the scale: 1– all plants alive; 9 – died more than 80%. Evaluation of autumn and spring growth was done using the following scale: 1 – soil covered up to 20%, very slow growth rate; 5 – up to 100%, very fast growth rate. Genotypes were evaluated in autumn at the end of intensive vegetation and in spring when intensive growth started (BBCH29-30). Later, wheat development was assessed using the scale: 1 – soil covered up to 20%, plants are very thin; 9 – up to 100%, plants are exclusively lush. Genotypes were evaluated at stem elongation - flowering stages (BBCH 32-34; 41-42; 60-65).

The leaf diseases were assessed from stem elongation (BBCH 30-31) to late milk development (BBCH 77). The resistance to diseases was measured in scores, using 1-9 scale. Score – 1 no visible symptoms of diseases, 9 – ≥80%. The area under the disease progress curve (AUDPC) was calculated.

Correlation analysis was applied to calculate the relationships between different traits at probability levels 0.05 and 0.01.

RESULTS AND DISCUSSION

Correlation analysis of traits of winter wheat genotypes grown under conventional and organic systems showed stronger correlations between the traits that had been found to be environmentally more stable (Table 1). Overwintering, plant height, heading, maturity, lodging and hectolitre weight strongly correlated (*r* = 0.74**-0.98**) between the growing systems in both years. Meteorological conditions differed considerably between years; however the correlation analysis revealed that the above mentioned traits were stable. Spring regrowth showed strong correlation (*r* = 0.83**) in 2007 and medium (*r* = 0.61**) in 2008 when wheat developed much slower in organic system. Leaf spot resistance correlated strongly (*r* = 0.78**–0.84**) in 2007 with high disease severity. Whereas, it showed only a trend of correlation (*r* = 0.23–0.30) in 2008, when the severity of leaf spot diseases was very low. The correlation of the autumn growth type between the systems and year was medium (*r* = 0.55*–0.68**). It was mainly influenced by a slower growth rate in organic field due to less available nitrogen in the soil. Soil coverage at different growth stages correlated weakly or medium (*r* = 0.43*–0.64**) between the systems and years. Powdery mildew mainly correlated weakly, as its severity was much lower in the organic system. However, resistance to powdery mildew in winter wheat is adequate for selecting of parental cultivars for development of organic cultivars (Liatukas & Ruzgas, 2008). Soil coverage, which is a very important trait for organic system showed weak or medium correlations (*r* = 0.43*–0.64**) between the systems tested. Considering this relation, lines characterized by the most luxurious growth should be selected when they are grown under conventional system. The main problem is decrease of soil coverage ability in organic system when available nitrogen is limited. Therefore, the lines with the best soil coverage should be selected (Causens et al., 2003; Carr et al., 2006). Lines for organic growing can be tested for their allelopathic ability under laboratory or greenhouse conditions (Belz, 2006; Cosser et al., 2008). Also, attention should be paid to the ability of selected lines for nitrogen use efficiency (Le Gouis et al., 2000; Baresel et al., 2008). Of course, under conventional system such lines especially taller ones will be discarded as they are characterized by lower grain/straw ratio (Ruzgas, 2002).

Table 1. The correlation of traits of winter wheat grown under conventional and organic conditions in 2007–2008.

Trait	Year		Trait	Year	
	2007	2008		2007	2008
Autumn growth type	0.55*	0.68**	Maturity	0.80**	0.78**
Overwintering	0.86**	0.95**	Lodging	0.74**	0.98**
Spring re-growth	0.83**	0.61	Powdery mildew, scores	0.58*	0.31
Soil coverage, BBCH32-34	0.64**	0.57*	Powdery mildew, AUDPC	0.43*	0.24
Soil coverage, BBCH41-42	0.51*	0.43*	Leaf spots, scores	0.78*	0.30
Soil coverage, BBCH60-65	0.47*	0.60*	Leaf spots, AUDPC	0.84*	0.23
Productive tillers	0.15	0.38*	Yield	0.21	0.65*
Plant height	0.97**	0.92**	1000 grain weight	0.53**	0.67**
Heading	0.90**	0.87**	Hectolitre weight	0.80**	0.84**

*-significant at $P < 0.05$, ** $P < 0.01$ probability level

Table 2. The correlation of winter wheat traits with yield under organic conditions in 2007–2008.

Trait	Yield		1000 grain weight		Hectolitre weight	
	Years					
	2007	2008	2007	2008	2007	2008
Autumn growth type	-0.67**	-0.41*	0.32*	0.41*	-0.52*	0.14
Overwintering	0.25	-0.01	-0.04	0.38*	0.08	0.17
Spring re-growth	-0.26	-0.25	0.31*	0.65**	-0.03	0.59*
Soil coverage, BBCH32-34	-0.38*	0.41*	0.35*	0.56**	0.12	0.12
Soil coverage, BBCH41-42	0.45*	0.31*	-0.44*	0.51*	0.60*	0.28
Soil coverage, BBCH60-65	0.54**	0.26	-0.36*	0.42*	0.52*	0.34*
Productive tillers	0.45*	0.50*	-0.37*	-0.28	-0.26	0.43*
Plant height	-0.22	-0.11	0.54**	0.25	0.34*	0.48*
Heading	-0.34*	0.23	-0.32*	-0.56*	0.11	-0.28
Maturity	0.31*	0.28	-0.26	-0.50*	0.09	-0.39*
Lodging	0.58*	0.02	-0.57*	0.01	0.45*	0.02
Powdery mildew, scores	-0.25	0.81**	0.09	-0.12	0.31	-0.62*
Powdery mildew, AUDPC	-0.04	0.52*	0.05	-0.09	0.29	-0.43*
Leaf spots, scores	0.06	-0.02	-0.09	0.13	-0.64*	0.21
Leaf spots, AUDPC	-0.06	-0.10	-0.02	0.10	-0.54*	0.16
Yield	1.00	1.00	-0.09	-0.10	-0.53*	-0.31*
1000 grain weight	-0.53*	-0.10	-0.20	1.00	1.00	-0.03
Hectolitre weight	-0.09	-0.31	1.00	-0.03	-0.20	1.00

*-significant at $P < 0.05$, ** $P < 0.01$ probability level

The number of tiller did not correlate between the systems. More adequate and efficient selection is feasible when all traits responsible for soil coverage are considered (Wolfe et al., 2008). The yield moderately correlated (r = 0.67**) only in 2008, the year characterized by a record yield. The correlation of 1000 grain weight was medium (r =0.53**–0.67**) between the systems and similar between years. One of the desirable traits of organic wheat cultivars is large and well filled grains as these traits decrease under low nitrogen conditions (Mašauskienė et al., 2004). Winter wheat yield, 1000 grain and hectolitre weight weakly and moderately correlated with other traits (Table 2). The correlation coefficients showed positive or negative trends of traits' relationships under organic system in about half of the pairs. Yield and 1000 grain weight mostly correlated with the traits of plant vegetative development, whereas hectolitre weight showed random correlations The yield was found to positively correlate with soil coverage at development stages BBCH41-42, 60-65 and number of productive tillers (r = 0.31*–0.54*). Lodging correlated positively (r = 0.58*) as higher yielding lines were prone to lodging. The similar trend (r =0.52*, 0.81**) was calculated between powdery mildew development and yield in 2008. The main reason was higher powdery mildew severity in lines possessing higher number of tillers and canopy density. Autumn growth type negatively correlated with yield (r =–0.41*- –0.67**) due to lower yielding capacity of lines characterized by faster autumn growth. Autumn growth type itself was related with lower overwintering. Hectolitre and 1000 grain weight negatively correlated with yield as higher yielding lines produced smaller grains. Considering these correlations among traits, lines possessing higher canopy density and soil coverage should be selected for organic growing. Autumn growth type and soil coverage at spring regrowth and BBCH32-34 stage positively correlated with 1000 grain weight. It was related with higher grain filling of lines characterized by shorter vegetation. Correlations at later stages BBCH42-42 and 60-65 were contradictory (*r* =–0.36*–0.51*) between years. It showed negative trend (*r* =–0.36*- –0.44*) in 2007 with lower average yield over nursery than in 2008. Whereas, positive trend (*r* = 0.42*–0.51*) was found in 2008. Later heading and maturity time influenced (*r* =–0.26- –0.56*) 1000 grain weight negatively. Hectolitre weight was influenced negatively, too. Therefore, early heading and maturing cultivars have advanced in production of higher flour yield than later ripening ones. Also, early maturing cultivars have some advantages due to longer period for weed control after harvesting. Our organic field was cultivated under organic conditions only for several years. This field had been cultivated conventionally for several decades before the trial. Weeds were controlled intensively; therefore conversion of field to organic conditions did not cause considerable weed competition for cereals. The similar trends in reestablishment of weeds population in organic fields conversed from conventional were observed and in other European countries (Löschenberger et al., 2008). Hectolitre weight more stably correlated with soil coverage at BBCH41-42, 60-65 (*r* = 0.28–0.60*) and plant height (*r* = 0.34*–0.48*). It shows that cultivars with higher canopy density produce more filled grains and consequently higher flour yield. Powdery mildew negatively affected (*r* =–0.43*- –0.62*) hectolitre weight in 2008 when this disease was not out competed by leaf spots. High leaf spot severity decreased (*r* = –0.54*- –0.64*) hectolitre weight in 2007. Negative correlation of hectolitre weight with yield shows the necessity of lines' selection for several purposes. Genotypes with lower yield but higher flour yield could be selected for processing of white bread or similar products, whereas cultivars with higher grain yield could be used for darker bread sorts that contain more bran (Baresel et al., 2008; Wolfe et al., 2008).

CONCLUSIONS

The investigated traits differed by their stability between the organic and conventional growing system. Overwintering, plant height, heading, maturity, lodging and hectolitre weight strongly correlated (*r* = 0.74**–0.98**) between the growing systems in both years Soil coverage, which is a very important trait for organic system showed weak or medium correlations (*r* = 0.43*–0.64**) between the systems tested. Considering this relation, lines characterized by the most luxurious growth should be selected when they are grown under conventional system. Yield and 1000 grain weight mostly correlated with the traits of plant vegetative development, whereas hectolitre weight showed random correlations with the other traits. The yield was found to positively correlate with soil coverage at development stages BBCH41-42, 60-65 and number of productive tillers (*r* = 0.31*–0.54*). Early heading and maturing cultivars have advanced in production of higher flour yield than later ripening ones. Considering these relationships, lines designed for organic growing should possess high to very high soil coverage ability during all vegetation, good overwintering and disease resistance in combination with early to medium maturity. However, only detailed analysis of individual lines enables selection of stable yielding lines possessing the above mentioned traits.

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