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The spring cereals traits of soil cover, disease resistance and yielding essential for organic growing

A. Leistrumaitė, Ž. Liatukas and K. Razbadauskienė

Lithuanian Institute of Agriculture, Instituto al. 1, Akademija, Kėdainiai distr., LT-58344, Lithuania; e-mail: alge@lzi.lt

Abstract. Investigation on 12 spring barley and 7 oat genotypes under organic growing system during 2007–2008 revealed that mean yield of oats was 3.3 t ha^{-1}, whereas barley yielded on average 2.3 t ha^{-1}. Also, oats were found to be more resistant to leaf diseases. Oats were severely infected by leaf rust in 2007, but the disease did not correlate (r = –0.17) with yield. The majority of barley genotypes were infected with powdery mildew in both years and with leaf spotting diseases in 2007. Leaf spotting diseases negatively influenced (r = –0.53*) yield. Oats possessing higher vegetative growth rate, higher plant height, large and prostrate leaves, and larger stems were superior to barley by canopy traits during the growing season.

Key words: barley, oats, cultivars, breeding lines, organic farming

INTRODUCTION

In Europe, varieties of arable crops are tested in multiple environments to assess their value for cultivation and use for a certain cropping system or region both before and after inscription in a National or the European Common Catalogue of varieties. Over the last decade the acreage dedicated to organic cropping system has shown a continuous growth in a number of European countries. With this increased attention for organic farming, also the issue of how to identify varieties that are better adapted to organic farming conditions surged (Przystalski et al., 2008).

Selection of cereal varieties suited to organic agriculture requires a different approach to that used when developing cereals for conventional high input systems. This is because there are fewer opportunities to compensate for limitations to yield imposed by diseases, low nutrients and weeds in organic agriculture, as well as need to adapt to highly variable environmental conditions across a diversity of organic agriculture systems (Wolfe et al., 2008).

During the last decades breeding for disease resistance was very effective in the case of spring barley powdery mildew but less progressive in respect of other diseases of barley as well as oats. The majority of present barley and oat cultivars range by resistance to leaf spot diseases from medium susceptible to medium resistant. Selection of disease resistant barley genotypes for organic system is limited from the viewpoint of leaf spot diseases. Oat genotypes are rather susceptible to leaf spot diseases, however much smaller acreage of oats than barley enables growers to make rotations that prevent the occurrence of these diseases (BSA, 2008).

Poor weed control is one of the main constraints in organic system and results in yield loss and the build-up of weed seed bank in the soil. This complication is mainly the consequence of low priority given to cereal competition with weeds in conventional plant breeding (Lamberts Van Beuren et al., 2002). Direct selection can be based on identifying genotypes with good weed suppression across a large number of trials. However, rank order in competitive ability may not be adequate in selection of the most robust or stable genotypes. Selection for weed suppression can be carried out directly in the presence of weeds (Lemerle et al., 2006) or indirectly by selecting for traits associated with competitive ability (Olesen et al., 2004).

Considering scientific papers tendencies for organic breeding and selection of the most promising lines should involve more complex traits than for conventional breeding. It's are higher abilities to compete with weeds, to extract soil for nutrient and water in combination with adequate disease resistance and satisfactorily yielding capacity. These traits are unique for all environments. However, particular areas have it's own specificities.

The aim of the experiment was to evaluate the essential traits of spring barley and oats for organic breeding.

MATERIALS AND METHODS

Field studies were carried out at the Lithuanian Institute of Agriculture during 2007–2008. The registered cultivars and advanced breeding lines of spring barley and oats, 12 and 7, respectively, were involved in the test.

The experimental genotypes were grown in three replications with a plot size of 5.0×1.5 m^2. The crop was sown with a Hege 80 in a well prepared seedbed 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 150–180 mg kg^{-1} and K 100–150 mg kg^{-1}. The nursery was sown after black fallow. The field was certified for organic agriculture. No agrochemicals and fertilizers were used. The plots were harvested with a Wintersteiger harvester. Combine-harvested grains from each plot were dried and sampled for analyses. The diseases were assessed from tillering to the late milk growth stage (BBCH21-77). The disease resistance was measured in scores using a 1–9 scale: score 1 – no visible symptoms of diseases, score 9 – heavily infected plants (infection ≥80%). The highest severity of diseases was used for characterization of tested material. Spring barley and oat development was assessed using the scale: 1 – soil covered up to 20 %, plants are very thin; 2 – up to 30 %, plants are thin; 3 – up to 40 %, plants are medium thin; 4 – up to 50 %, plants are medium; 5 – up to 60 %, plants are medium lush; 6 – up to 70 %, plants are lush; 7 – up to 80 %, plants are lush; 8 – up to 80 %, plants are very lush; 9 – up to 100 %, plants are exclusively lush. Genotypes were evaluated at stem elongation - flowering stages (BBCH32-33; 59-63). Plant height and number of productive tillers were measured at early-medium milk stage (BBCH73-75).

The period 2007–2008 was rather favourable for versatile evaluation of spring cereals because of the variable weather conditions (2007 – wet, 2008 – dry at the beginning of the season and later wet).

The data were statistically analyzed using ANOVA from package SELEKCIJA (Tarakanovas & Raudonius, 2003) for calculation of the least significant difference from mean and correlation coefficients at the 0.05 and 0.01 probability levels to compare the differences among the treatment means.

RESULTS AND DISCUSSION

Barley genotypes weakly covered soil at stem elongation stage (SC1) (Table 1). Lines 8080-4 and 8234 among 12 genotypes covered soil only in 2.0 scores. The most thriving were 7939-1 and 'Luokė', 3.5 and 3.3 scores, respectively. Soil cover at flowering stage was much higher, the tested barley genotypes were evaluated from 4.0 to 5.5 scores. Generally, cultivars with more intensive growth rate at the stem elongation stage possessed higher capability of covering soil at flowering stage, too.

Table 1. Differences of traits among spring barley genotypes.

No.	Genotype	SC1	SC2	PT	PH	PM	LS	Y	HW	TGW
1	Simba	2.3*	5.5*	486*	51.0*	1.0*	4.5	2.7*	644	50.7*
2	8650	2.5	5.0	412	46.5*	3.5*	5.9*	1.6*	580*	40.7*
3	7661-1	2.5	4.4*	472*	63.0*	4.0*	5.0*	2.7*	688	45.2
4	7939-1	3.5*	5.5*	398	56.0	4.9*	4.8	2.6*	668	43.4
5	8080-4	2.0*	5.0	484*	58.5	5.8*	4.0*	2.7*	680	47.6
6	8264	2.0*	5.0	384*	48.5*	1.1*	5.3*	1.9*	679	40.1*
7	8056-2	2.5	4.5	446	57.0	3.0*	4.3*	2.2	674	45.4
8	8056-6	2.7	5.3	436	55.0	4.0*	4.4	2.3	651	44.5
9	8147-7	2.7	4.8	352*	60.5*	4.0*	5.4*	2.0	634	44.4
10	8151-7	2.5	4.0*	404	56.0	6.0*	5.3*	2.2	634	46.5
11	8611	3.0*	5.3	358*	58.0	4.0*	4.0*	2.2	648	43.4
12	Luokė	3.3*	5.0	394	60.0*	6.3*	3.0*	2.4	673	49.7*
	Mean	2.6	4.9	419	55.8	3.8	4.6	2.3	654	45.1
	LSD_{05}	0.19	0.40	28.3	3.7	0.12	0.25	0.34	59.2	3.6

SC1- BBCH32-33; SC2-BBCH59-63; PM – Powdery mildew; LS – Leaf spot; Y- Yield; HW – Hectolitre weight; TGW – 1000 grain weight; PT – Number of productive tillers; PH – Plant height; * Least significant difference from mean at $P < 0.05$ probability level.

Tillering ability was not as different as soil cover ability among the tested genotypes. The tallest (7661-4) and the shortest (8650) lines differed by about 30%.The height of most lines was 55–60 cm. Evaluation of powdery mildew resistance showed that genotypes ranged from very resistant ('Simba', 8264) to susceptible (8151-7, 'Luokė'), 1, 1.1 and 6.0, 6.3 scores, respectively. Primary data analysis shows that resistance to leaf spot was moderate, too. However, a detailed explanation reveals a little different situation. Only genotypes resistant and medium resistant to powdery mildew can be adequately characterized by leaf spot resistance as the true resistance of the rest of the genotypes was masked by powdery mildew. It was determined in our previous research that powdery mildew under natural infection pressure out - competed leaf spot diseases on susceptible to powdery mildew barley cultivars (Liatukas & Leistrumaitė).

Yield of the tested genotypes ranged from 1.6 to 2.7 t ha^{-1}. High yielding genotypes exhibited a better soil cover, formed more tillers and were more disease resistant than the rest ones. However, the tested material was very similar by hectolitre weight, except for one line 8650, which was the most susceptible to leaf spot, too. Genotypes differed more by 1000 grain weight. Cultivars 'Simba' and 'Luokė' formed larger and lines 8650 and 8264 produced smaller grains.

The investigated oat material was less divergent than barley material (Table 2). However, genotypes of oats were characterized as possessing higher values of some essential traits than barley. Oats covered soil better (mean 4.2 scores) than barley (mean 2.6 scores) especially during the first assessment. It was mainly influenced by taller, more massive and denser plants of oats. The mean height of all oat material was 90.7 cm, whereas that of barley material was only 55.8 cm. Oats were severely infected only with leaf rust, but only in one testing year. The mean yield of oats (3.3 t ha^{-1}) was much higher (by 43%) than that of barley (2.3 t ha^{-1}).

Table 2. Differences of traits among spring oat genotypes.

No.	Genotype	SC1†	SC2	LR	LS	Y	HW	TGW	PT	PH
1	Migla	4.0	5.9*	7.0*	3.0*	3.0*	508	38.2*	410	98.0
2	1396-44	4.3	6.5	6.5*	1.6*	3.0*	496	30.4*	422	85.0
3	1416-2	4.0	6.0	8.0*	2.0*	2.9*	492	35.8	428	94.0
4	1514-44	4.3	6.5	8.5*	2.0*	2.8*	515	42.7*	376*	94.5
5	1532-6	4.3	6.5	7.5	2.1*	3.7*	535	34.8	480*	85.5
6	1533-63	4.3	6.5	7.0*	1.6*	3.6*	530	29.8*	474*	86.0
7	1533-66	4.5	6.3	7.5	3.0*	4.1	531	31.7*	428	92.0
	Mean	4.2	6.3	7.4	2.2	3.3	515	34.7	431	90.7
	LSD_{05}	0.31	0.40	0.24	0.07	0.18	39.4	2.3	31.5	7.4

† See Table 1, LR – Leaf rust, * Least significant difference from mean at $P < 0.05$ probability level.

Table 3. The correlations among spring barley traits.

Trait	SC2†	PT	PH	PM	LS	Y	HW	TGW
SC1	0.15	-0.46*	0.34*	0.58*	-0.34*	0.11	-0.02	0.05
SC2	1.00	-0.12	0.07	-0.68*	-0.55*	0.11	0.62*	-0.22
PT		1.00	0.00	0.03	-0.15	0.63**	0.27	0.49*
PH			1.00	0.45*	-0.46*	0.53*	0.53*	0.41*
PM				1.00	-0.04	0.43*	0.03	0.69**
LS					1.00	-0.53*	-0.15	-0.46
Y						1.00	0.63*	0.71**
HW							1.00	0.27
TGW								1.00

† See Table 1, *, ** Least significant difference at $P < 0.05$ and $P < 0.01$ probability levels.

Barley material showed no correlation between soil cover scores (Table 3). Also, soil cover weakly correlated with the number of productive tillers (r = –0.46*) and plant height (r = 0.34*). It complicates selection of adequate lines possessing high soil cover abilities. Higher soil cover at stem elongation stage increased (r = 0.58*) powdery mildew severity, whereas at flowering stage a converse relationship was observed (*r* = –0.68*).

The first relation is clear as more intensive barley growth rate was characteristic of the majority of older type genotypes which had much lower powdery mildew resistance than newly developed ones. One of the explanations for converse second relation is that less powdery mildew affected genotypes grew more intensively than severely infected ones. Leaf spots severity negatively influenced all soil cover traits which agree with other research evidence (Deadman & Cooke, 1986; Lazauskas et al., 2005). The yield did not correlate with soil cover at both scorings, but it correlated with the number of productive tillers (*r* = 0.63**), plant height (0.53*) and powdery mildew severity (0.43*). Positive correlation of yield with powdery mildew could be related to more favourable conditions for powdery mildew development in higher canopy density but not with positive direct influence of this disease.

The yield was negatively influenced (*r* =–0.53*) by leaf spots as productive leaf area decreased. Considering yield relations with the other traits, selection of tall lines resistant to leaf disease and possessing high number of productive tillers is the most promising under our conditions. However, 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. Since weed population re-established later, visual scoring should be more related to yield (Seavers & Wright, 1999).

Oat material showed medium correlation (*r* = 0.61**) between soil cover scorings (Table 4). The ability of oats to cover soil at stem elongation stage strongly correlated (*r* = 0.75**) with yield. This relation should help select oat lines for organic growing at early growth stages without detailed screening of canopy traits during all vegetation season as yield showed considerable but weaker correlation (*r* = 0.62*) with the number of productive tillers. Highly positive effect of early vigour was determined in the study of Bertholdsson (2005) and our early studies (Deveikytė et al, 2008).

Table 4. The correlations among spring oat traits.

Trait	SC2†	PT	PH	LR	LS	Y	HW	TGW
SC1	0.61**	0.14	-0.43*	-0.03	0.07	0.75**	0.64**	-0.39*
SC2	1.00	0.27	0.47*	-0.04	-0.66*	0.26	0.44*	-0.25
PT		1.00	-0.69**	-0.40*	-0.28	0.62*	0.52*	-0.67*
PH			1.00	0.47*	0.69*	-0.40*	-0.31*	0.71**
LR				1.00	0.11	-0.17	0.05	0.72**
LS					1.00	0.27	0.18	0.27
Y						1.00	0.84**	-0.57*
HW							1.00	-0.18
TGW								1.00

† See Table 1, *, ** Least significant difference at $P < 0.05$ and $P < 0.01$ probability levels.

However, counting of productive tillers is much more time and labour intensive compared to visual scoring of soil covering. Rough calculation of inputs shows that counting of tillers takes at least 20–30 times longer than simple visual scoring of soil cover.

Comparison of barley and oats shows that barley has much more disadvantages than oats. The comparison of yield showed much lower ability of barley to utilize limited soil nutrients. Barley usually forms higher yield under conventional growing system with intensive application of fertilizers with high doses of nitrogen and intensive chemical weed control. Our organic field was infested by weeds only slightly, but weaker barley genotypes could have been more negatively influenced by allelopathic weed competition than oats (Bertholdsson, 2004; Hoad et al., 2008). Therefore, oat is 'wilder' than barley and is better adapted to growing under low nutrition and higher weed competition conditions.

CONCLUSIONS

The tested barley genotypes could be grown only in the fields characterized by fertile soils and low weed infestation as all of them were relatively much shorter, weaker covering soil and low yielding compared with oats. Barley grains were rather small, average 1000 seed weight for all genotypes was 45.1 g. Hectolitre weight was low, too. Therefore, usage of organic barley grains for food industry was limited due to substandard quality. Higher barley susceptibility to foliar diseases, especially seed-borne leaf spots, impose more constrains for efficient barley cultivation under organic conditions. Growing of oats seems to be less risky in terms of yield and soil cover abilities.

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