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COMPARISON OF ADVANCED OAT BREEDING LINES IN LITHUANIA

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Advanced oat breeding lines were investigated in 2009–2011 at the Institute of Agriculture of Lithuanian Research Centre for Agriculture and Forestry. The highest grain yield (4.10 t ha^{-1}) and fat content (4.41%) was in 2009 and the highest protein and starch content (12.54% and 51.4%) was in 2011. Every year the yield of oat line LIA 1526-9 was higher or similar to the standard variety yield. The breeding line LIA 1526-9 also gave good results for fat, protein and starch yield. Every year fat, protein and starch content of naked line 1579-1 was higher in comparison with standard variety Mina DS: respectively, 7.39%, 12.6%, and 61.7% (standard variety 6.49%, 12.3%, and 55.7%) in 2009, 6.27%, 15.1%, and 60.7% (standard variety 5.06%, 11.5%, and 52.8%) in 2010 and 6.24%, 15.1%, and 63.6% (standard variety 5.66%, 14.0%, and 58.4%) in 2011. Significantly higher yields of fat, protein and starch per hectare were obtained in 2009 and reached 176, 454, and 1910 kg ha^{-1}. Fat, protein and starch yields per ha of naked oat breeding lines were not higher than those of hulled oat breeding lines because of their low grain yield.

Key words: Avena sativa*, yield, fat, protein.*

INTRODUCTION

Oats (*Avena sativa* L.) is an important crop worldwide (Butt *et al.*, 2008; Rivera-Reyes *et al.*, 2008). Despite declining production areas, oat still attracts attention because of its high nutritive value as animal feed and human food (Tiwari and Cummins, 2009; Zhao *et al.,* 2009). The area of oats grown in Lithuania is on average 60 000 ha (Kulikauskas and Statkevičiūtė 2008).

Different varieties of cereals respond differently to agro climatic conditions of a particular area due to differences in their genetic make up and physical life processes. Selection of improved and high yield genotypes having a wide range of adaptation to agro climatic conditions is essential to increase grain yield (Shah *et al.,* 2002). Oat breeding in Lithuania was started in 1922. During the first ten-year period, the chief breeding method was individual selection. Later the initial material in most cases was developed by intervarietal hybridization. Oat varieties Stipruolės, Dotnuvos baltosios, Gyrūnės, Skaistūnės, Sdabrės, Šušvė, Jaugila, Migla DS and hulles Mina DS were developed within the period of the last 90 years (Kulikauskas and Sprainaitienė, 1998).

Oats can be broadly classified as hulled and naked. The naked oats are nutritionally superior compared to conventional hulled oats. Naked oats have a thin non-lignified husk on the outside of the grain, which falls off during harvesting, resulting in a grain of energy, protein and lipid and lower fibre content compared with hulled oats (Givens and Brunnen, 1987; Bhatty, 1995; Tiwari and Cummins, 2009).

The amount of oats used for human consumption has increased because of the dietary benefits (Tiwari and Cummins, 2009).

Oat groats have the highest lipid concentration among cereal grains. Thus, the lipids and lipid-associated components in the groat are important to the functionality of oat products. The high lipid content of oats provides a benefit in animal feed, as it has high energy value and good fatty acid composition (Zhou *et al.,* 1998).

Amino acid analysis and comparative feeding studies show that oat is equal or superior in nutritional quality to other commonly used cereal grains. Reports by various workers indicated that varietal and environmental conditions influence the amino acid composition of oat protein (Hischke *et al.* 1968).

The aim of this investigation was to evaluate the agronomic traits and chemical composition of advanced Lithuanian spring oat (*Avena sativa* L.) breeding lines, which later can be used for development of new hulled and hull-less oat varieties with better nutrition value.

MATERIALS AND METHODS

Advanced oat lines of hulled and naked oats (*Avena sativa* L.) were investigated in 2009–2011 at the Institute of Agriculture of Lithuanian Research Centre for Agriculture and Forestry (Table 1). The experiment was carried out as crop rotation by the Cereal Breeding Department. The previous crop was pea. Oat was sown at a rate of 5 million seed ha^{-1} with 12-cm row spacing, in 15 m^2 plots in four replicates. The soil type was light loamy Gleyic Cambisoil with content of available phosphorus (P_2O_5) 200 mg kg^{-1} in 2009, 156 mg kg^{-1} in 2010 and 163 mg kg^{-1} in 2011, available potassium (K_2O) 188, 168, 190 mg kg^{-1}, respectively, pH_{KCl} 6,5, 6,0 and 5,1 respectively.

Oat breeding lines were selected according to many characteristics, such as yield, lodging, resistance to fungal diseases (loose smut, leaf blotch, crown rust), chemical composition. New breeding lines with good traits were added every year and some breeding lines, which had not shown good traits, were removed. The variety Ivory was grown as a standard variety in 2009 and 2010 and Lithuanian variety Migla DS and German varieties Carron and Typhon were grown in 2011. Lituanian variety Mina DS was grown as a standard naked oat variety.

Climatic diagrams (Figs. 1, 2, 3, 4) show the course of rainfall and temperature in 2009–2011. Periods of drought occured when red line showing temperature rose above the blue line (precipitation) in the diagrams. Spring of 2009 was dry, but there was enough moisture for normal oat germination. Precipitation in June was extremely high. 2010 was without drought periods. Precipitation in July was high and harvesting conditions were complicated. Two drought periods occurred in 2011, but they did not strongly influence oat growth and development.

The data were processed by means of ANOVA statistical analysis using the Statgrafics Plus software package.

RESULTS

Spring oat yield, plant height and some quality characteristics had normal or very close to normal distributions (Table 2). Therefore, average values were used with standard deviation as a measure of data dispersion.

Weather conditions had significant influence on oat grain yield and chemical composition of grain (Table 3). The highest grain yield and fat content in grain was in 2009 and

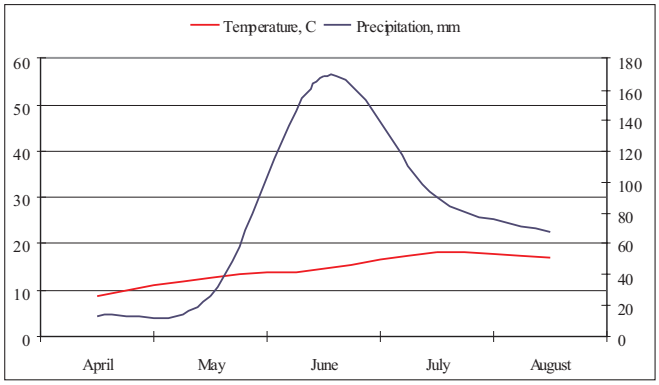

Fig. 1. Climatic diagram, 2009, Lithuania (temperature – upper curve).

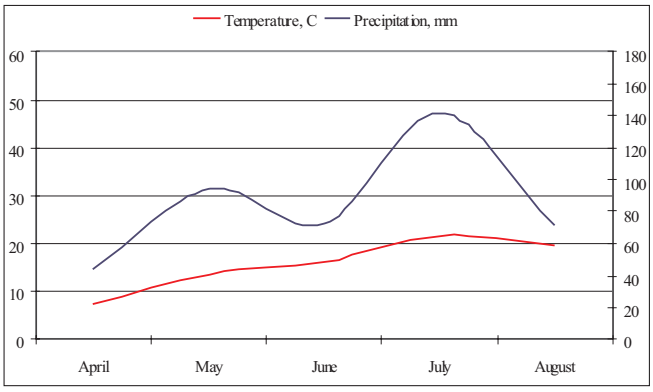

Fig. 2. Climatic diagram, 2010, Lithuania (temperature – upper curve).

Table 1

INVESTIGATED BREEDING LINES

Breeding line	Cross combination	Breeding line	Cross combination
LIA 1396-44	WW17579 / 1152-192	LIA 1614-26	Condor / Perona
LIA 1416-2	Goral / 1313-100	LIA 1619-22	Mell / Vietinės (Baškirija)
LIA 1518-7	1313-100 / Michal	LIA 1621-4	Obyknovennyj / 1396-44
LIA 1526-9	Viet Ispanija / 1373-14	LIA 1629-3*	Belinda / Abel
LIA 1532-6	1373-14 / Edit	LIA 1631-9*	Mestny / Abel
LIA 1566-12*	Bueler /Abel	LIA 1632-3	VIR 1998 / Abel
LIA 1562-20	AC 805 / Rhianon	LIA 1638-9	Cwal /1491-11
LIA 1578-20	Forward / Abel	LIA 1639-8	Flamingstern / Flamingsprofi
LIA 1579-1*	Bordeweis / Abel	LIA 1639-11	Flamingstern / Flamingsprofi
LIA 1606-26	Flamingstern / Veles	LIA 1639-37	Flamingstern / Flamingsprofi
LIA 1609-3	Freddy / Neson	LIA 1644-47	Triton / LPSH 00503
LIA 1611-55	Cwal / Markus	LIA 1644-68	Triton / LPSH 00503
LIA 1614-15	Condor / Perona	LIA 1645-26	Hja 73006 / Omihi

* naked oat breeding lines

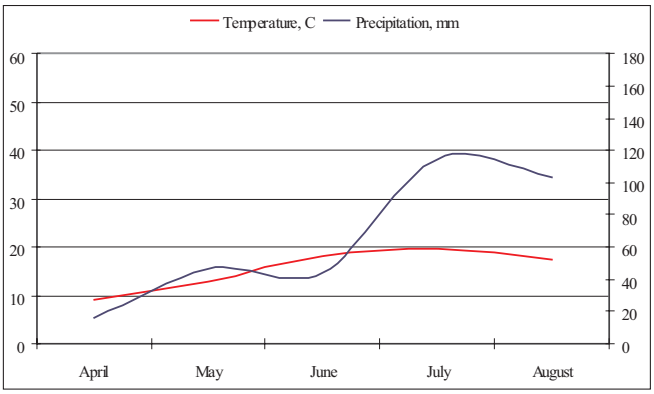

Fig. 3. Climatic diagram, 2011, Lithuania (temperature – upper curve).

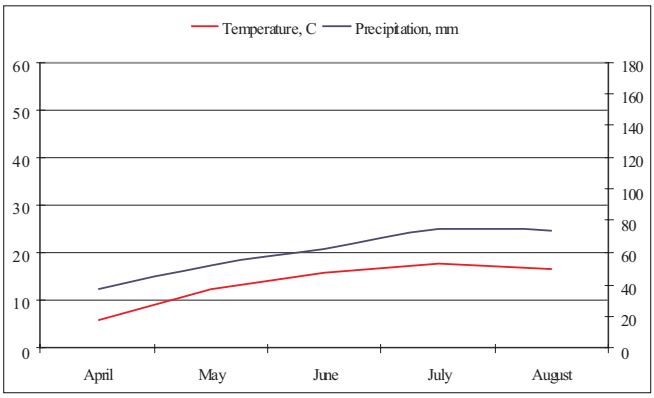

Fig. 4. Climatic diagram, 1924–2010, Lithuania (temperature – upper curve).

Table 2

STATISTICAL CHARACTERISTICS OF OAT BREEDING LINES, 2009–2011

Statistic	Yield, t ha^{-1}	Plant height, cm	Fat %	Protein %	Starch %
Average	3.38	95.5	4.21	12.01	50.10
Variance	1.14	28.9	1.48	2.48	44.12
Stand. deviation	1.07	11.35	1.22	1.57	6.64
Minimum	1.4	75.0	2.37	9.80	38.7
Maximum	5.4	131.0	7.39	16.20	63.6
Stand. skewness	0.32	3.16	2.21	1.88	1.72

Table 3

DYNAMICS OF OAT LINES CHARACTERISTICS. 2009–2011

Year	Yield, t ha^{-1}	Plant height, cm	Fat %	Protein %	Starch %
2009	4.10a	95.8b	4.41a	11.12b	47.5b
2010	3.19b	112.0a	3.91ab	12.07a	47.6b
2011	2.95c	92.4c	3.89b	12.54a	51.4a

Means with the same letter in the column do not differ significantly ($P < 0.05$)

the highest protein and starch content was in 2011. Plant height significantly differed between years.

The yield of oat lines LIA 1609-3 and LIA 1611-55 was significantly higher compared with that of the standard variety in 2009 (Table 4). Thirteen lines including naked oat had higher fat content, and eight lines had protein and nine had higher starch content compared with those of the standard variety. Breeding lines LIA 1578-20 and LIA 1518-7 had higher fat, protein and starch content compared with those of the standard variety, but the yield of line LIA 1518-7 was lower and of line LIA 1578-20 was significantly lower. LIA 1562-9 had the shortest straw, but for other parameters it had poorer results than did the standard variety. The naked oat line LIA 1579-1 yield was higher and it had higher fat, protein and starch content compared with those of the standard naked oat variety Mina DS.

Table 4

BREEDING LINES CHARACTERISTICS, 2009

Breeding line	Yield, t ha^{-1}	Plant height, cm	Fat, %	Protein, %	Starch, %
LIA 1578-20	3.15a	100.0bcdefg	4.81	12.7	51.2
LIA 1396-44	4.06b	89.2ab	3.23	10.0	47.6
LIA 1614-15	4.10bc	103.3cdefg	4.33	11.8	43.7
LIA 1614-26	4.23bc	91.7abc	4.14	10.9	43.1
LIA 1532-6	4.25bc	93.3abcd	3.47	10.1	48.7
LIA 1518-7	4.27bc	106.7efg	3.74	11.1	44.6
LIA 1416-2	4.48bcd	108.3efg	4.28	9.8	38.7
LIA 1526-9	4.48bcd	93.3abcd	3.72	10.1	45.7
LIA 1562-20	4.62bcde	81.7a	3.15	9.8	41.5
St. variety	4.67cd	91.7ab	3.28	11.1	47.5
LIA 1606-26	5.18de	96.7bcde	4.35	10.6	43.0
LIA 1609-3	5.35e	98.3bcdef	4.15	10.1	44.8
LIA 1611-55	5.35e	100.0bcdefg	4.93	11.1	45.0
		Naked oat			
LIA 1566-12	2.55a	111.7fg	6.36	14.0	56.0
Stand. variety	2.55a	100.0bcdefg	6.49	12.3	55.7
LIA 1579-1	2.75a	106.7defg	7.39	12.6	61.7

Means with the same letter in the column do not differ significantly ($P < 0.05$)

The yield of oat line LIA 1526-9 was significantly higher compared with the average standard variety yield in 2010 (Table 5). The standard variety had the highest fat, protein

Table 5

BREEDING LINES CHARACTERISTICS, 2010

Breeding line	Yield, t ha^{-1}	Plant height	Fat, %	Protein, %	Starch, %
LIA 1632-3	3.08c	109.0ab	3.81	11.1	40.9
LIA 1562-20	3.15c	97.0a	2.37	10.5	41.2
LIA 1532-6	3.43cd	110.0b	3.17	9.9	45.9
LIA 1619-22	3.58cd	109.0ab	3.05	10.9	43.8
St. variety	3.62d	108.4b	5.12	11.8	52.0
LIA 1526-9	4.32e	110.0b	3.15	11.6	47.1
		Naked oat			
LIA 1566-12	1.43a	131.0d	5.76	14.9	61.6
LIA 1579-1	1.50a	125.0cd	6.27	15.1	60.7
LIA 1629-3	1.75ab	105.0ab	6.06	14.6	57.9
LIA 1631-9	2.12b	107.0ab	5.02	16.2	52.6
Stand. variety	2.22b	115.0bc	5.06	11.5	52.8

Means with the same letter in the column do not differ significantly ($P < 0.05$)

and starch content. The yield of all naked oat lines were lower compared with the standard variety Mina DS, but fat, protein and starch content almost in all cases was the lower than for the standard variety.

Yield of nine varieties was higher compared with the average yield of standard varieties, but only the yield of line LIA 1532-6 was significantly higher in 2011 (Table 6). Naked oat variety LIA 1579-1 had the highest fat, protein and starch content and non-significantly higher grain yield, compared with naked oat standard variety Mina DS.

Table 6

BREEDING LINES CHARACTERISTICS, 2011

Breeding line	Yield, t ha^{-1}	Plant height, cm	Fat, %	Protein, %	Starch, %
LIA 1619-22	2.63cd	92.5cd	3.29	12.4	48.2
LIA 1632-3	2.79de	90.0abcd	3.89	11.4	46.9
LIA 1638-9	2.90def	85.0abc	3.80	11.9	49.5
LIA 1621-4	2.90def	83.8ab	3.98	12.6	47.4
St. varieties	3.02def	88.3abc	3.21	12.4	50.5
LIA 1639-8	3.06defg	85.0abc	3.09	11.5	49.6
LIA 1644-68	3.10defg	82.5a	3.18	11.7	52.4
LIA 1645-26	3.10defg	103.8f	3.55	13.0	46.4
LIA 1562-20	3.12defg	82.5a	2.89	12.2	48.1
LIA 1526-9	3.20defg	91.25bcd	3.43	11.7	52.4
LIA 1639-37	3.28efg	86.2abc	3.04	11.3	62.3
LIA 1644-47	3.42fg	82.5a	3.75	12.8	49.2
LIA 1639-11	3.48fg	87.5abcd	3.55	12.6	51.3
LIA 1532-6	3.64g	91.2bcd	2.83	11.8	47.9
		Naked oat			
LIA 1566-12	1.44a	101.2ef	5.88	13.1	62.3
LIA 1631-9	1.64ab	90.0abcd	5.82	14.4	61.1
St. variety	2.14bc	94.4de	5.66	14.0	58.4
LIA 1579-1	2.17bc	103.8f	6.24	15.1	63.6
LIA 1629-3	2.61cd	91.2bcd	5.84	13.7	60.5

Means with the same letter in the column do not differ significantly ($P < 0.05$)

Significantly higher yields of fat, protein and starch per hectare were obtained in 2009 (Table 7).

Breeding lines LIA 1606-26, LIA 1609-3 and LIA 1611-55 gave the highest yield of fat, protein and starch per ha in 2009 (Table 8). The reason was high yield and high fat content of these lines.

All investigated oat breeding lines had lower yield of fat kg per ha compared with the standard variety in 2010, which

Table 7

DYNAMICS OF FAT, PROTEIN AND STARCH AMOUNT PER HA, 2009–2011

Year	Fat, kg ha^{-1}	Protein, kg ha^{-1}	Starch, kg ha^{-1}
2009	176a	451a	1910a
2010	112b	329b	1337b
2011	108b	352b	1476b

Means with the same letter in the column do not differ significantly ($P < 0.05$)

Table 8

FAT, PROTEIN AND STARCH YIELD, 2009–2011

Breeding line	Fat, kg ha^{-1}			Protein, kg ha^{-1}			Starch, kg ha^{-1}		
	2009	2010	2011	2009	2010	2011	2009	2010	2011
LIA 1578-20	152	-	-	400	-	-	1613	-	-
LIA 1396-44	131	-	-	406	-	-	1935	-	-
LIA 1614-15	178	-	-	484	-	-	1792	-	-
LIA 1614-26	175	-	-	461	-	-	1823	-	-
LIA 1532-6	148	109	103	429	338	429	2070	1574	1744
LIA 1518-7	160	-	-	475	-	-	1904	-	-
LIA 1416-2	192	-	-	439	-	-	1734	-	-
LIA 1526-9	167	136	110	452	501	374	2047	2035	1677
LIA 1562-20	146	75	90	453	331	381	1917	1298	1501
Stand. varieties	153	185	97	518	427	374	2218	1882	1525
LIA 1606-26	225	-	-	549	-	-	2227	-	-
LIA 1609-3	222	-	-	540	-	-	2397	-	-
LIA 1611-55	264	-	-	594	-	-	2407	-	-
LIA 1632-3	-	117	108	-	342	318	-	1260	1308
LIA 1619-22	-	109	86	-	390	326	-	1568	1268
LIA 1638-9	-	-	110	-	-	345	-	-	1435
LIA 1621-4	-	-	115	-	-	365	-	-	1383
LIA 1639-8	-	-	94	-	-	352	-	-	1518
LIA 1644-68	-	-	99	-	-	363	-	-	1624
LIA 1645-26	-	-	110	-	-	403	-	-	1438
LIA 1639-37	-	-	100	-	-	371	-	-	2043
LIA 1644-47	-	-	128	-	-	438	-	-	1682
LIA 1639-11	-	-	123	-	-	438	-	-	1785
			Naked oat						
LIA 1566-12	162	82	85	357	213	188	1428	881	897
Stand. variety	166	112	121	314	255	300	1420	1172	1250
LIA 1579-1	203	94	135	346	226	328	1697	910	1380
LIA 1629-3	-	106	152	-	255	358	-	1013	1579
LIA 1631-9	-	106	95	-	343	236	-	1115	1002
Average	176	112	108	454	329	352	1910	1337	1461

was due to the unusually high fat content in the standard variety. Only breeding line LIA 1526-9 had higher protein yield.

Fat, protein and starch yield of breeding lines LIA 1644-47, LIA 1639-11 and LIA 1532-6 was the highest in 2011.

DISCUSSION

Various factors are considered responsible for better crop harvest, among which high potential varieties offer a tremendous scope (Shah *et al.,* 2002). The yield of oat breeding lines in our investigation fluctuated from 1.4 to 5.4 t ha^{-1}. The average yield of breeding lines significantly differed every year. The highest was obtained in 2009, it decreased next year and in 2011 it was the lowest and did not reach 3 t ha^{-1}. The difference in grain yield could have been influenced by different amount of precipitation, especially in June.

Plant breeders should pay attention to biochemical indicators of cereals when developing new oat varieties for food production (Zute *et al.,* 2011; Berga and Zute 2012). Surveys have reported a wide range (2–12%) of fat content in oats (Sahasrabudhe, 1979). Some oat lines can contain up to 18% fat (Banas *et al.,* 2007). It has also been shown that fat content is under genetic control, suggesting that the fat content can be increased (Sahasrabudhe, 1979). In our investigation the average fat content in grain was 4.21. Fat percent in grain had the same trend as grain yield — it was highest in 2009, lower in 2010 and the lowest in 2011, with a range from 2.37 to 7.39%. The lowest fat percent occurred for breeding line LIA 1562-20 in 2010. In 2009, it was also the lowest compared with that of other lines. In 2011, only one line had lower fat content than line LIA 1562-20. The highest fat content every year was obtained for naked oat breeding line LIA 1579-1. The highest fat yield (176 kg ha^{-1} in 2009) was due to high grain yield and fat content that year.

The use of oats as human and animal food has been justified by their taste and high nutritive value, when compared to other cereal grains, and a high protein content and protein value (Pedó *et al.,* 1999). Oats have good quality protein and high protein content compared with other cereal grain (Wu, 1983). Oat protein content is about 13–17% (Butt *et al.*, 2008; Adams, 2009). In our investigation protein content of oat breeding lines was lower than these values, ranging from 9.80 to 16.20 with an average of 12.01%. The lowest content occurred for breeding lines LIA 1562-20 and LIA 1416-2 in 2009. Protein content of breeding line LIA 1562-20 was not high also in 2010 and 2011 and this line can be described as having low fat and protein content. The average protein yield was from 329 kg ha^{-1} in 2010 to 454 kg ha^{-1} in 2009.

In conclusion, the yield of oat breeding line LIA 1526-9 every year was higher or similar to that of the standard variety yield. The breeding line LIA 1526-9 also gave good results for fat, protein and starch yield. Fat, protein and starch yield per ha of naked oat breeding lines was not higher compared with hulled oat breeding lines because of their low grain yield. Fat, protein and starch content of naked oat breeding line LIA 1579-1 every year was higher compared with that of standard variety Mina DS. Plants of naked oat breeding lines LIA 1579-1 and LIA 1566-12 every year were the highest.

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PERSPEKTĪVO AUZU SELEKCIJAS LĪNIJU SALĪDZINĀŠANA LIETUVĀ

Aprakstīti 3 gadu salīdzinošie pētījumi ar labākām plēkšņainām un kailgraudu auzu selekcijas līnijām.