AGRONOMIC AND QUALITY CHARACTERIZATION OF OATS GENOTYPES SELECTED FOR WINTER TOLERANCE

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ABSTRACT

Although oats have recently become more and more important as human food due to its high nutritive value, oat production has not increased, even decreased in Turkey because oats are much less winter hardy than other fall-sown cereals. Therefore, improving winter tolerant oats genotypes is necessary to increase oats production. This study was undertaken to evaluate the agronomic and quality traits of twenty-three oat lines selected from a Quaker Nursery for cold tolerance in comparison to a local check. The material was grown on-farm in Kızılkaya in 2003 and in Ürkütlü in 2004 in the Burdur Province of the West Mediterranean Region of Turkey using a Randomized Complete Blocks Design with three replicates. Grain yield, biomass, harvest index, 1000-grain weight, days to heading, plant height, test weight and protein contents were studied. Results showed that there were statistically significant differences among genotypes for most of the traits studied. The genotype, 95Ab1222, was superior for protein content compared to the remaining entries; 95Ab1-4 was superior for grain yield and biomass and finally 95Ab1216 had the highest test weight. Considering the winter tolerant background of the genetic material studied, these superior lines should be suitable for fall sowing, and thus contribute to increase oat production and quality directly or indirectly.

Key words: *Avena sativa* L., protein content, winter survival

INTRODUCTION

Oats (*Avena sativa* L.) have value as feed for livestock and food for humans (Helland and Holland 2001). Oats have recently become more and more important as a human food because of their high nutritive value. This trend has increased the amount of research on oats due to their emerging importance. Improving the quality of oats for human consumption has been an important objective for breeders. Many factors have played important roles in improving the quality of oats, *e.g.* crop management and management practices (May *et al. 2004;* Zhou *et. al.* 1998), swathing time (May *et al.* 2005), nitrogen supply (Zhou *et al.* 1998; Doehlert 2002; Givens *et al.* 2004) and application time (Frey 1959; Welch and Yong 1980).

Oats need more water to produce a unit of dry matter compared to other small-grain cereals except rice (Coffman and Frey 1961). However, oats are generally sown in early spring in the period of low rainfall due to the lack of reliable winter cultivars. Therefore, cold tolerance of oats is an important breeding objective to take advantage of winter rainfall. Oats require a cool climate for optimum production as a winter cereal; however, they are the most sensitive to winter damage among all the cereals requiring improved cold tolerance. Furthermore, available cold tolerant germplasm should also be improved for other economic characters (Veisz *et al.* 1996). The aim of the study was therefore to screen oat lines for winter-tolerance in a Mediterranean upland and to evaluate the agronomic and quality characters of oat genotypes selected for winter tolerance.

MATERIALS AND METHODS

Three hundred segregating and advanced lines from the Quaker Oat Nursery of 1996 were preliminarily screened in the field at the campus of Akdeniz University in Antalya, Turkey during the 1997-1998 growing season, for general agronomic traits and growth habits. One hundred and thirty five oat lines selected from this nursery for agronomic and morphological traits were sown for winter tolerance observation at Ürkütlü Cereal & Legumes Experiment Station in the Burdur province (37^o 19' N, 30^o 17' E and 850 m above sea level) during the last week of October 1999 and 2001. Twenty three genotypes were determined as winter tolerant in these experiments and these genotypes were evaluated for agronomic and quality traits. The selected material was grown in a Randomized Complete Blocks Design with three replications on farmers' fields at Kızılkaya and Ürkütlü villages in 2003 and 2004, respectively. Both locations represent semi-arid conditions; however, the Kızılkaya location has more productive soil and receives more rainfall than the Ürkütlü location. Plots arranged in four rows of 3m length with inter-row spacing of 20 cm. N and P were applied at a rate of 60 kg per ha prior to planting in the form of composed 20-20-0 % (NPK) granular fertilizer. Grain yield (t/ha), biomass (t/ha), harvest index (%), 1000-grain weight (g), days to heading and plant height (cm) traits were measured during both years, test weight (kg/hl) and protein content (%) were measured in 2004. Days to heading were recorded daily from 1 May up to the day on which at least 50% of the plants in the plot showed their panicles. At physiological maturity, the plants in plots were cut at *ca* 5 cm above ground, air dried and threshed. The harvest index was calculated according to the equation [(grain yield/biomass) x 100] and expressed as a percentage (%). Test weight was measured as the weight of the grain using a 25 cc cylindrical container and expressed as kg/hl. Protein content was determined by the Kjeldahl method using a 6.25 factor. Data obtained were subjected to variance analysis using MSTAT-C statistical program. Genotype means were compared by Duncan's multiple range test using the same software (Freed *et al.* 1989).

Weather conditions: The precipitation, average moisture, extreme and average minimum and maximum temperatures taken from Korkuteli meteorology station (Appr. 40 km west of Ürkütlü) during 1999-2000 and 2001-2002 for the periods of winter screenings was presented in Table 1.

Table 1. Weather conditions during 1999-2000 and 2001-2002 in Korkuteli

Months	Temperature (°C)											
	Extreme minimum		Extreme maximum		Average minimum		Average maximum		Moisture (%)		Rainfall (mm)	
	1999-2000	2001-2002	1999-2000	2001-2002	1999-2000	2001-2002	1999-2000	2001-2002	1999-2000	2001-2002	1999-2000	2001-2002
October	3,2	0,6	30,2	29,2	7,8	6,7	23,8	23,4	56,3	52,6	3,0	13,8
November	-6,8	-5,0	22,3	20,5	1,8	3,1	16,9	13,1	56,2	67,4	4,5	165,5
December	-5,2	-6,6	17,7	13,3	-0,1	0,2	13,6	7,8	64,3	69,0	12,3	240,8
January	-11,0	-11,8	12,8	18,0	-5,2	-4,0	6,1	7,8	59,8	58,5	23,7	23,1
February	-7,7	-3,6	15,4	18,0	-2,9	-0,4	9,0	14,1	62,4	57,7	13,3	30,6
March	-7,0	-1,9	23,6	22,8	-1,5	2,8	12,8	15,3	59,1	57,6	37,9	33,4
April	-0,8	0,2	24,4	23,5	5,8	5,2	17,6	16,4	64,9	61,5	43,1	141,7
May	4,4	4,6	26,6	26,2	9,2	8,3	22,2	23,0	61,4	53,6	70,8	13,8
June	6,8	8,4	34,0	34	12,3	13	28,8	28,3	44,4	50	23,4	46

RESULTS AND DISCUSSION

Agronomically acceptable one hundred and thirty five oat genotypes were sown in late-October of 1999 and 2001 in Ürkütlü to screen for winter tolerance. The average minimum temperatures were below zero in January and February during the growing seasons. The average minimum temperatures were below zero values from December to March in the first year of trials carried out for winter observations. The extreme minimum temperatures were -11°C and -11.8°C in January 1999-2000 and 2001-2002 growing seasons, respectively. Twenty-three genotypes were selected for their survivals rates and general agronomic performance (data not shown). These entries were used to evaluate further their agronomic performance and quality characters. Significant ($p<0.01$) genotypic differences were found for the grain yield and biomass in Kızılkaya in 2003 while there was no difference ($p<0.05$) in Ürkütlü in 2004 (Table 2).

The mean values of genotypes for grain yield ranged from 1.02 to 3.20 t/ha at Kızılkaya. The best grain yields at Kızılkaya were obtained from the genotypes, 95Ab1-4, followed by 95Ab351-355, 95Ab1227 and 95Ab129-132 with 2.36, 2.34 and 2.23 t/ha, respectively. These genotypes showed higher grain yields than the local variety. Grain yields ranged from 0.40 to 1.53 t/ha in Ürkütlü. The pure line, 95SA15, had the highest grain yield and was followed by the genotypes, 95Ab81-85, 95Ab119-123 and 95SA262 with 1.44, 1.40 and 1.37 t/ha, respectively. While the mean values for biomass ranged from 3.24 to 8.71 t/ha at Kızılkaya, biomass ranged from 2.10 to 4.02 t/ha in Ürkütlü. Only the genotype, 95Ab1-4, from Quaker nursery has shown greater biomass over the local variety in Kızılkaya. The 95Ab129-132 had the highest biomass, followed by the genotypes, 95SA263 and 95SA15, in Ürkütlü. Genotypes grown on farmer's field at Kızılkaya showed generally higher performances for both grain yield and biomass than at Ürkütlü because Kızılkaya receives much rainfall and is a better environment than Ürkütlü. Additionally, while the most of the oat genotypes in Ürkütlü where received less rainfall showed a better performance than the local variety, only five oat genotypes had a higher yield than the local variety at Kızılkaya. Whereas 95Ab1-4 only had a higher yield than the local variety in Kızılkaya, once again most of the oat genotypes showed a higher biomass than the local variety in Ürkütlü. This implies that oat genotypes looks better adapted to drier conditions considering their selection history.

Table 2. Mean values and Duncan multiple range test of the genotypes for grain yield and biomass at Kızılkaya and Ürkütlü

Genotypes	Grain yield (t/ha)		Biomass (t/ha)	
	Kızılkaya	Ürkütlü	Kızılkaya	Ürkütlü
Local variety	2.19 abc[1]	1.04 abc	7.06 ab	3.39 abc
95SA15	1.02 c	1.53 a	3.24 e	3.82 ab
95SA17	1.76 bc	1.37 ab	5.34 bcde	3.76 ab
95SA27	1.24 bc	1.35 ab	4.76 bcde	3.47 abc
95Ab1-4	3.20 a	1.28 ab	8.71 a	3.74 ab
95Ab28-32	1.75 bc	0.97 abc	5.04 bcde	3.01 abc
95Ab48-51	1.34 bc	1.27 ab	4.63 bcde	3.51 abc
95Ab81-85	1.10 bc	1.44 ab	4.19 cde	3.66 abc
95Ab115-118	2.13 abc	1.30 ab	7.00 abc	3.44 abc
95Ab119-123	1.54 bc	1.40 ab	5.13 bcde	3.71 abc
95Ab129-132	2.23 abc	1.26 ab	5.87 bcde	4.02 a
95Ab144-148	2.30 abc	1.25 ab	6.46 abcd	3.73 abc
95Ab351-355	2.36 ab	1.33 ab	6.12 abcd	3.51 abc
95Ab471-475	1.44 bc	0.92 abc	4.26 bcde	2.67 abc
95Ab731-734	1.37 bc	1.22 ab	5.21 bcde	3.31 abc
95SA258	1.15 bc	1.09 abc	3.88 de	2.98 abc
95SA262	1.65 bc	1.37 ab	5.59 bcde	3.66 abc
95SA263	1.55 bc	1.32 ab	5.37 bcde	3.84 ab
95Ab1210	1.75 bc	0.40 c	5.55 bcde	2.10 c
95Ab1215	2.09 abc	1.16 ab	6.25 abcd	3.60 abc
95Ab1216	1.65 bc	0.73 bc	4.57 bcde	2.77 abc
95Ab1222	1.60 bc	0.97 abc	5.36 bcde	2.29 bc
95Ab1227	2.34 ab	1.01 abc	6.58 abcd	3.03 abc
95Ab1229	1.59 bc	1.07 abc	5.09 bcde	3.30 abc
F values	1.90*	1.33^{ns}	2.06*	1.10^{ns}

*, **, ns; significant at p<0.05, p<0.01 and statistically non-significant, respectively.
[1] Values within a group followed by the same letter or letters are not significantly different at the 5% level (Duncan's multiple range)

Significant (p<0.01) genotypic differences were found for 1000-grain weight at both locations (Table 3). The mean values of 1000-grain weight ranged from 29.80 to 44.13 g in Kızılkaya and from 33.87 to 38.97 g in Ürkütlü. The 95Ab81-85 had the highest 1000-

grain weight, followed by 95SA263 and 95Ab129-132 with 38.6 and 38.0 g, respectively in Kızılkaya. The 95Ab1222 had the highest value in Ürkütlü. The 95SA258 had the lowest value in both sites. Oat genotypes in Ürkütlü showed generally higher values for 1000-grain weight. While there were no statistically significant differences for harvest index among genotypes in Kızılkaya, there were statistically significant differences ($p<0.05$) at Ürkütlü. Genetic variation in traits that contribute to high yield in all environments, such as a high harvest index, is greater in predictable environments and is therefore more likely to be selected under favorable conditions (Richards *et. al* 2002). The mean values of harvest index ranged from 26 to 38 % at Kızılkaya and from 19 to 42 % in Ürkütlü. The 95Ab1-4 which had the highest grain and biomass yield, showed the highest harvest index at Kızılkaya.

Table 3. The mean values and Duncan multiple range test of genotypes for 1000-grain weight and harvest index in Kızılkaya and Ürkütlü

Genotypes	1000-grain weight (g)		Harvest index (%)	
	Kızılkaya	Ürkütlü	Kızılkaya	Ürkütlü
Local variety	36.7 bcd	37.9 abcd	31 ab	31 abc
95SA15	35.5 bcd	36.4 ef	32 ab	42 a
95SA17	34.4 bcde	36.8 def	33 ab	37 abc
95SA27	32.9 cde	36.5 ef	26 b	39 abc
95Ab1-4	32.9 cde	38.7 ab	37 ab	34 abc
95Ab28-32	34.6 bcde	38.4 abc	34 ab	31 abc
95Ab48-51	37.9 bcd	37.9 abcd	28 ab	36 abc
95Ab81-85	44.1 a	38.0 abc	26 b	39 ab
95Ab115-118	35.8 bcd	38.4 abc	28 ab	38 abc
95Ab119-123	37.1 bcd	36.0 f	30 ab	36 abc
95Ab129-132	38.0 bc	37.3 cde	38 a	31 abc
95Ab144-148	37.1 bcd	38.7 ab	35.4 ab	32 abc
95Ab351-355	34.5 bcde	36.1 ef	38 a	37 abc
95Ab471-475	35.3 bcd	36.8 def	34 ab	34 abc
95Ab731-734	32.8 de	36.3 ef	27 b	37 abc
95SA258	29.8 e	33.9 g	30 ab	36 abc
95SA262	33.0 cde	36.4 ef	28 ab	37 abc
95SA263	38.6 b	37.7 bcd	29 ab	33 abc
95Ab1210	35.7 bcd	36.7 def	32 ab	19 d
95Ab1215	37.2 bcd	37.8 abcd	34 ab	33 abc
95Ab1216	36.9 bcd	37.8 abcd	34 ab	28 cd
95Ab1222	35.8 bcd	39.0 a	31 ab	42 a
95Ab1227	33.8 bcde	36.8 def	35 ab	34 abc
95Ab1229	36.7 bcd	38.1 abc	32 ab	30 bc
F values	3.41**	10.21**	1.30^{ns}	2.00*

*, **, ns; significant at $p<0.05$, $p<0.01$ and statistically non-significant, respectively. [1] Values within a group followed by the same letter or letters are not significantly different at the 5% level (Duncan's multiple range)

The mean values for days to heading ranged from 21 to 26 days in Kızılkaya and 20 to 31 days in Ürkütlü (Table 4). Significant (p<0.01) genotypic differences were found for days to heading in both locations. The genotypes, 95Ab1210 and 95Ab1229, were the earliest lines in both sites. Days to heading are highly associated with the regional and seasonal adaptability of cereals. Selection for early heading as an escape mechanism from drought is important in dry areas. It may be expected that genotypes with early heading show, in most cases, the better yield and quality. In our study, some lines with early heading showed good performance for biomass in Ürkütlü. The early habits trait may therefore be used for preliminary selection in oat breeding populations in dry conditions.

Table 4. Mean values and Duncan multiple range test of genotypes for heading date and plant height in Kızılkaya and Ürkütlü

Genotypes	Days to heading (days)		Plant height (cm)	
	Kızılkaya	Ürkütlü	Kızılkaya	Ürkütlü
Local variety	23 def[1]	26 b	92 f	84 d
95SA15	24 bcd	23 cdef	97 cdef	92 abcd
95SA17	25 ab	31 a	110 abcd	97 abc
95SA27	25 ab	24 bcd	96 def	87 bcd
95Ab1-4	24 bcd	24 bcd	112 ab	90 abcd
95Ab28-32	22 fg	21 efg	98 cdef	81 de
95Ab48-51	25 ab	24 bcd	104 abcdef	94 abcd
95Ab81-85	23 def	21 efg	105 abcdef	98 abc
95Ab115-118	23 cde	22 defg	100 abcdef	91 abcd
95Ab119-123	22 fg	20 fg	97 cdef	91 abcd
95Ab129-132	23 def	20 g	104 abcdef	99 ab
95Ab144-148	22 efg	20 fg	104 abcdef	101 a
95Ab351-355	22 efg	20 fg	110 abc	94 abcd
95Ab471-475	22 efg	22 cdefg	102 abcdef	90 abcd
95Ab731-734	26 a	29 a	106 abcdef	83 d
95SA258	23 def	22 defg	99 bcdef	85 cd
95SA262	25 abc	23 bcdef	106 abcde	93 abcd
95SA263	24 bcd	23 bcde	114 a	92 abcd
95Ab1210	21 g	21 efg	95 ef	72 e
95Ab1215	22 fg	21 efg	102 abcdef	92 abcd
95Ab1216	23 cde	23 bcde	105 abcdef	83 de
95Ab1222	24 bcd	24 bcd	103 abcdef	83 d
95Ab1227	26 a	25 bc	106 abcdef	84 d
95Ab1229	21 g	20 g	98 bcdef	87 bcd
F values	9.11**	11.05**	1.89*	3.28**

*, **, ns; significant at p<0.05, p<0.01 and statistically non-significant, respectively.

[1] Values within a group followed by the same letter or letters are not significantly different at the 5% level (Duncan's multiple range)

There were statistically significant differences for plant height at both Kızılkaya and Ürkütlü. Oat genotypes had a large variation for plant height at both sites. The mean values for plant height ranged from 92 to 114 cm in Kızılkaya and 81 to 101 cm in Ürkütlü. The plant height of all genotypes in the first year was greater than the second year and also the local variety had the shortest plant height in the better location.

Table 5. Mean values and Duncan multiple range test of the genotypes for test weight and crude protein in Ürkütlü

Genotypes	Test weight (kg/hl)	Protein content (%)
Local variety	44.93 g[1]	13.27 ab
95SA15	48.53 def	11.00 hij
95SA17	40.27 h	11.90 cdefghi
95SA27	48.13 ef	12.73 bcd
95Ab1-4	49.20 cdef	11.20 ghij
95Ab28-32	49.47 cdef	11.67 defghi
95Ab48-51	44.40 g	11.70 defghi
95Ab81-85	43.07 g	11.73 defghi
95Ab115-118	48.53 def	11.43 efghij
95Ab119-123	49.47 cdef	10.37 jk
95Ab129-132	48.00 ef	12.50 bcde
95Ab144-148	50.13 bcde	9.86 kl
95Ab351-355	48.53 def	11.33 fghij
95Ab471-475	51.07 abc	12.13 cdefg
95Ab731-734	43.60 g	12.37 bcdef
95SA258	51.73 ab	11.43 efghij
95SA262	44.13 g	9.10 l
95SA263	47.73 f	12.90 abc
95Ab1210	50.67 abcd	12.33 bcdef
95Ab1215	48.00 ef	11.97 cdefgh
95Ab1216	52.67 a	10.83 ijk
95Ab1222	48.53 def	13.80 a
95Ab1227	47.87 ef	12.00 cdefgh
95Ab1229	48.40 ef	11.83 cdefghi
F values	19.89**	10.03**

*,**, ns; significant at p<0.05, p<0.01 and statistically non-significant, respectively
[1] Values within a group followed by the same letter or letters are not significantly different at the 5% level (Duncan's multiple range)

There were statistically significant differences among genotypes (p<0.01) for test weight and protein content (Table 5). The mean values for test weight ranged from 36.67 to 52.67 kg/hl. Among the genotypes, 95Ab1216 had the highest test weight with 52.67 kg/hl followed by 95SA258 and 95Ab471-475 with 51.73 kg/hl and 51.07 kg/hl, respectively. The 95SA17 had the lowest test weight with 40.27 kg/hl. Test weight of the

95Ab1216 was 1.3 times greater than 95SA17. Precipitation has an impact on test weight and high precipitation decreases test weight. N fertilization rate is the main factor for test weight and increased N supply has a tendency to decrease test weight (Doehlert 2002). Pixley and Frey (1991) indicated that test weight and grain yield were typical positively correlated and breeding high yield oats with improved test weight should be possible. The mean values for protein content ranged from 9.10 to 13.81 %. The 95Ab1222 had only a higher protein ratio than the local variety. Furthermore, the 95Ab1222, which had the highest protein content value, also had the highest harvest index and 1000-grain weight.

In concluson, the study showed that there was a large genetic variation indicated by statistically significant differences for most of the traits in the Quaker germplasm. Despite the close distance between Ürkütlü and Kızılkaya locations, they were quite different environments with soil and rainfall characteristics which make genotype testing effective. More severe drought conditions at Ürkütlü led to a decrease in grain and biomass yield of oat genotypes; consequently, the average grain and biomass yield of oat genotypes was high at Kızılkaya. While only 5 oat lines showed a higher grain yield than the local check in Kızılkaya, most of the oat lines (almost 70%) had a higher grain and biomass yield than the local check in the drier condition of Ürkütlü. It may be therefore stated that oat germplasm under study is better adapted to drought conditions than the local cultivar. The genotype, 95Ab1222 with the highest protein content, also had the highest harvest index and 1000-grain weight; thus, the 1000-grain weight may be used as a indirect selection criteria to predict the genotypes with high protein content and this entry should be useful in the improvement of agronomic traits and grain quality. We finally expect that these novel germplasm of oats which is suitable to winter growing and tolerant to drought stress should be useful for cultivar release directly and to develop new germplasm for the new cycles of selection.

ACKNOWLEDGEMENTS

This research was funded by the Akdeniz University Scientific Research Project Unit and by International Atomic Energy Agency, IAEA-TUR-RC-10964 and publication costs were gifted by the IAEA-RC-13001. We are also thankful to the people of Ürkütlü and Kızılkaya who supported the project with their infrastructure.

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