Grain Yield and Some Quality Traits of Different Oat (*Avena sativa L.*) Genotypes

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Abstract**—** *Oat cultivars should have both high yield potential and some quality criteria in accordance with using targets. Hence, grain yield and some quality traits of 25 oat genotypes grown in two consecutive years were studied. This study was carried out during the 2012–2013 and 2013–2014 growing seasons in Yozgat, Turkey. Grain yield, plant height, hectolitre weight, thousand grain weight, great percentage and grain composition (protein, fat, ash, acid detergent fiber (ADF), neutral detergent fiber (NDF), β-glucan and starch) were evaluated. Analysis of the combined data for two years showed significant genotypic differences for all traits. According to the average of two years, among the genotypes, grain yield varied from 2432.3 (2 numbered genotype) to 5650.2 (19 numbered genotype) kg ha^{-1}, plant height from 76.3 to 128.3 cm, hectoliter weight from 41.5 to 52.3 kg, thousand grain weight from 24.5 to 41.3 g, groat percentage from 70.4 to 76.6 %, protein content from 11.1to 14.3 %, fat content from 5.86 to 8.47 %, ash ratio from 2.52 to 3.43 %, ADF content from 11.0 to 16.4 %, NDF content from 29.5 to 37.3 %, β-glucan content from 1.33 to 2.58 % and starch content ranged from 34.9 to 47.7 %. Grain yield was significantly and positively correlated with thousand grain weight (r = 0.253**) and neutral detergent fibre (r = 0.160**). However, correlations between grain yield with crude protein (r = -0.216**) and hectolitre weight (r = 0.246) were significantly and negative.*

Keywords**— *Oat, Genotype, Yield, Quality traits.***

I. INTRODUCTION

Oat (*Avena sativa* L.) is an important cereal crop that is grown all over the world for human food and animal feed. In proportion to other cereal crops, oat is considered to be better suitable for production under marginal environments, including cool-wet region and soils with low fertility (Hoffmann, 1995; Buerstmayr et al., 2007). For human consumption, oat grains are highly noticeable as a functional food rich in protein and fiber. Traits most generally used to describe oat quality include test weight, thousand kernel weight, groat percentage and grain chemical composition. The important grain compositional traits relating to quality include the protein, fat, and β-glucan concentrations (Douhlert et al., 2001).

For human food oat groat is required, that high in protein, β-glucan and low in fat, whereas high fat and low β-glucan with the high protein is required for animal feeding to maximize the energy (Peterson et al., 2005).

The oat trade is very dynamic with new cultivars releasing every year. Grain features of these varieties may have effect in animal performance as well as human health. Then, once oat grain is harvested, its chemical attributes are the main interest according to intended consumption (Martinez et al., 2010).

The objective of this study was to evaluate different oat genotypes in order to compare grain yield and some important quality traits during two consecutive years in the Central Anatolia Region in Turkey.

II. MATERIALS AND METHODS

Field experiments were carried out consecutively for two years (2012 to 2014) in the experimental field at the Department of Field Crops, Faculty of Agriculture, Bozok University in Turkey (39° 39´ N, 34° 15´ E and 775 m a.s.l.). 25 oat genotypes were used as the experimental material of this study. 5, 6, 7, 8, 9, 10, 11, 13, 14, 15, 16 and 18 numbered genotypes collected from the West and Middle Black Sea Region of Turkey are local varieties. 17, 19, 20 and 22 numbered genotypes are pure line obtained from "Quaker International Oat Nursery". 1, 4, 12 and 21 numbered genotypes are registered in Turkey. Mascani cultivar was obtained from England, and Winter Turf, Hairy Culberson and Wintok obtained from USA (Table 1). The genotypes were grown in randomized block design with three replications. The sowing rates were

450 seeds m^2 for experiment conditions. Sowing dates were 10^{th} October 2012 and 16^{th} October 2013, respectively. The seeds were planted using an experimental drill in 1.2 × 6 m plots consisting of six rows with 20 cm row space. At the maturity stage, four rows in the middle of plots were harvested. Fertilizers were applied as 60 kg ha^1 N and 60 kg ha^1 P_2 O_5 at planting. In addition, top-dressing was applied as 4 kg ha^1 N at tillering stage. Herbicide was used for weed control. The soil taken from 30 cm depth is classified as clay loam with pH: 8.20, $CaCO_3$: 7.93 %, P_2O_5: 86.2 kg ha^{-1} and K_2O: 484.7 kg ha^{-1}. Organic matter is low in experimental fields. Throughout the vegetation period (from October to July) of 2012-13 and 2013-14 total rainfall were 535.2 and 513.6 mm, mean temperature were 9.3 and 8.3 ^{0}C, average relative humidity were 63.8 and 60.7 %, respectively.

TABLE 1
THE NAMES AND PEDIGREES OF OAT LANDRACES AND CULTIVARS USED IN THIS STUDY

Genotype No	Genotype	Genotype No	Genotype
1	Seydişehir[1]	14	Amasya-Taşova[2]
2	Mascani[1]	15	Amasya-Merzifon[2]
3	Checota[1]	16	Samsun-Bafra[2]
4	Yeşilköy-330[1]	17	Trophy(LA9810)/TX98AB2732[3]
5	Bolu-Center[2]	18	Samsun-Center[2]
6	Bolu-Yeniçağa[2]	19	Trophy/Horizon 474[3]
7	Zonguldak-Center[2]	20	TAMO386ERB/TX93Ab693(833'S')[3]
8	Zonguldak-Ereğli[2]	21	Faikbey[1]
9	Zonguldak-Gökçebey[2]	22	FL99175-H5/Horizon 474[3]
10	Sinop-Center[2]	23	Winter Turf Select[1]
11	Samsun-Asarcık[2]	24	Hairy Culberson[1]
12	Yeşilköy-1779[1]	25	Wintok[1]
13	Tokat-Reşadiye[2]		

[1] -cultivar, [2] –landraces, [3] –pure line

Grain yield (GY), plant height (PH), thousand grain weight (TGW), hectolitre weight (HW) and groat percentage (GP) were determined as previously described (Buerstmayr et al., 2007).

Crude protein (CP), crude fat (CF), ash and starch (STA) by standard analytical methods (AOAC, 2006). Neutral detergent fibre (NDF) and acid detergent fibre (ADF) were determined, as described by Van Soest and Wine (1967). β-glucan (BG) was measured by the enzymatic method 'Mixed-linkage beta-glucan assay procedure' from Megazyme International Ireland (McCleary and Codd, 1991).

2.1 Statistical analysis

Data were analyzed using SAS, (SAS / STAT User's Guide, 1990). Significant differences between means were determined using Duncan's multiple range tests at the 5% level. Pearson correlation coefficients between traits were calculated using genotypes means.

III. RESULTS AND DISCUSSION

Analysis of variance combined over two years (Tables 2 and 3) revealed significant differences among genotypes and between years (Except for ash and starch) for grain yield and investigated traits. The influences of genotype and climate conditions are significant parameters affecting yield and quality of oat (Burstmayer et al 2007).

TABLE 2
MEAN PERFORMANCE OF OAT GENOTYPES GROWN 2012-13 AND 2013-14 GROWING SEASONS

Genotype No	GY**		PH**		TGW**		HW**		GP**		ADF**	
1	4498.3	bc	111.1	c-f	35.2	b-f	42.9	l	72.6	e-h	14.3	bc
2	2432.4	j	76.3	jk	34.5	b-g	41.5	m	70.4	j	13.3	b-h
3	4578.9	b	97.3	g-j	35.5	b-e	49.6	c	71.0	hij	16.4	a
4	4176.6	bf	108.6	ef	41.3	a	43.5	l	74.3	bcd	12.4	fgh
5	3668.3	efg	128.3	a	32.8	d-g	49.3	cd	73.1	e-g	14.5	bc
6	3180.8	ghi	106.0	e-h	33.9	c-g	49.5	c	76.6	a	11.0	i
7	4022.2	b-f	119.4	a-d	33.5	c-g	49.4	cd	76.0	ab	13.7	b-f
8	4277.9	b-e	91.8	ijk	29.8	fgh	47.0	f-i	71.8	g-j	14.7	b
9	4249.5	b-e	106.7	efg	39.7	ab	49.1	cde	72.1	f-i	11.9	hi
10	3007.0	hij	120.8	abc	34.7	b-g	45.3	jk	74.2	cde	14.4	bc
11	2606.0	ij	125.2	ab	31.6	efg	44.1	kl	76.2	a	13.2	c-h
12	3834.1	def	127.7	a	38.7	abc	46.3	hij	73.7	c-f	11.9	hi
13	3871.5	c-f	113.2	cde	35.4	b-f	51.6	ab	76.2	a	12.8	e-h
14	3155.1	ghi	109.6	def	35.5	b-e	50.4	bc	76.6	a	13.9	b-e
15	3125.3	ghi	119.5	a-d	33.1	c-g	45.9	ij	76.4	a	12.7	e-h
16	4601.1	b	102.0	f-i	37.5	a-d	46.6	g-j	71.0	hij	12.4	f-i
17	4372.0	bcd	95.8	hij	32.7	d-g	48.1	def	73.8	c-f	14.1	b-e
18	4087.1	b-f	112.5	cde	34.8	b-g	47.3	fgh	75.2	abc	13.4	b-g
19	5650.4	a	82.9	kl	31.0	efg	47.0	f-i	73.0	e-g	14.7	b
20	3600.7	fgh	91.2	l	24.8	h	52.3	a	71.3	hij	12.8	d-h
21	4137.4	b-f	107.6	ef	34.0	b-g	46.6	g-j	70.8	ij	14.6	bc
22	2957.5	ij	87.0	jk	29.2	fgh	43.1	l	74.2	cde	14.2	bcd
23	2930.2	ij	115.1	b-e	29.8	e-h	47.5	fgh	76.2	a	13.8	b-f
24	2984.6	hij	89.0	jk	29.4	fgh	47.1	f-i	71.8	g-j	12.2	g-i
25	2894.4	ij	88.8	jk	24.5	h	47.8	efg	75.9	ab	14.0	b-e
First year**	4156.9	A	98.5	B	33.4		46.0	B	72.8	B	13.0	B
Second year	3275.0	B	112.2	A	33.2		48.3	A	74.7	A	13.9	A
Overall mean	3716.0		105.3		33.3		47.2		73.8		13.5	

The values followed by common letters at each column are not significant at 5% level of probability using the Duncan's test. GY – grain yield, PH – plant height, TGW – thousand grain weight, HW – hectolitre weight, GP – groat percentage, ADF – acid detergent fibre.

Grain yield in the first year (4156.9 kg ha^{-1}) was also higher than that of the second year (3275.0 kg ha^{-1}). The combined data over the two years (Table 2) showed that the grain yield for genotypes ranged from 5650.4 kg ha^{-1} (obtained by 19 numbered genotype) to 2432.4 kg ha^{-1} (obtained by 2 numbered genotype). Grain yields of 16, 3, 1, 17, 8, 9, 4, 21, 18, 7, 13, 12, 5 and 20 numbered genotypes were also higher than overall mean, respectively. The variation in grain yield of genotypes may be attributed to genetic characteristics and adaptability of these varieties to different environmental conditions. Peterson et al. (2005) indicated significant impacts of environment and genotype over grain yield. Plant height in the second year (112.2 cm) was also higher than that of the first year (105.3 cm). The combined data over the two years (Table 2) showed that the plant height for genotypes ranged from 76.3 cm (obtained by 2 numbered genotype) to 128.3 cm (obtained by 5 numbered genotype). Differences in plant height among genotypes are expected due to genetic make-up of the varieties. Generally, landraces had higher plant height in this study.

Significant ($P < 0.01$) genotypic differences were found for thousand grain weight (TGW) and hectolitre weight (HW) (Table 2). TGW in the first and second years was found 33.4 and 33.2 g, respectively. According to the average of years, the mean of TGW ranged from 24.5 to 41.3 g. While 4 numbered genotype had the highest TGW, 25 numbered genotype had the lowest TGW (Table 2). The combined data over the two years (Table 2) showed that the HW for genotypes ranged from 41.5 kg (2 numbered genotype) to 52.3 kg (20 numbered genotype). The results obtained in this study were in agreement with those acquired in previous studies on the quality of oat grain, which also showed that the quality of oat grain depended on the genetic factors and environmental conditions throughout the growing season (Doehlert and McMullen, 2000; Peterson et al., 2005; Rhymer et al., 2005; Buerstmayr et al., 2007).

Oat genotypes ‘Bolu-Yeniçağa and Amasya-Taşova’ had maximum value of groat percentage. Groat percentage of oat genotypes varied from 70.4 to 76.6 % (Table 2). Low hull content is particularly important for the achievement of high milling yield, which is an important criteria for hulled food oat (Cowan and Valentine, 2004). Early maturing oats are considered to be superior regarding groat percentage (Doehlert, 2002). Peltonen-Sainio et al. (2004) found that, high hull rate limited oat (*Avena sativa* L.) using as an animal feed.

TABLE 3
MEAN PERFORMANCE OF OAT GENOTYPES GROWN 2012-13 AND 2013-14 GROWING SEASONS

Genotype No	NDF**		CP**		ASH**		FAT**		STA**		βGLU**	
1	35.1	a-d	12.9	f-i	2.63	jkl	6.67	e-i	46.72	ab	2.10	cde
2	30.1	ijk	11.7	jk	2.78	g-k	5.88	mn	44.33	a-g	1.91	e-h
3	35.4	abc	11.1	k	3.11	bcd	7.11	cd	38.27	kl	1.33	l
4	32.7	e-h	13.8	a-e	2.59	kl	6.51	f-k	46.70	ab	1.93	efg
5	33.4	c-f	12.7	f-i	2.93	e-g	6.46	g-k	43.20	b-h	1.67	hij
6	29.5	k	13.1	c-g	2.82	g-i	6.49	f-k	45.20	a-e	2.08	c-f
7	32.6	fgh	13.2	c-g	2.97	c-g	6.13	k-n	42.63	e-j	2.19	bcd
8	33.6	b-f	12.7	f-i	3.04	b-e	6.88	c-f	41.48	f-k	1.92	e-h
9	31.5	f-k	13.4	a-f	2.71	h-l	6.84	c-g	46.58	abc	1.63	ijk
10	33.4	b-f	13.9	a-d	2.86	f-i	5.86	n	42.98	e-i	2.12	cde
11	32.0	f-i	14.0	abc	2.91	e-h	6.15	k-n	43.80	b-h	1.93	d-g
12	30.9	g-k	13.0	d-h	2.52	l	6.72	d-h	47.72	a	1.91	e-h
13	31.9	f-j	12.0	ijk	2.69	i-l	6.04	lmn	43.45	b-h	1.93	d-g
14	32.7	e-h	12.2	hij	2.89	e-i	6.20	j-n	41.07	g-k	1.42	jkl
15	30.6	h-k	13.0	d-h	2.90	e-h	6.52	f-k	44.88	a-f	1.40	kl
16	32.8	efg	14.3	ab	2.72	h-l	6.04	lmn	45.97	a-d	2.38	ab
17	33.1	e-g	13.7	a-e	3.15	bc	6.96	cde	39.52	jk	1.62	ijk
18	34.8	b-e	12.4	h-j	2.81	g-i	6.27	i-n	43.42	b-h	2.22	bc
19	35.6	ab	13.0	d-h	3.07	b-e	6.28	i-m	39.68	ijk	2.25	bc
20	31.7	f-j	13.6	a-e	3.02	c-f	6.57	e-j	41.32	g-k	2.03	c-f
21	37.3	a	13.4	b-f	2.88	e-i	6.40	h-l	43.15	b-h	2.57	a
22	32.1	f-i	12.4	h-j	3.43	a	8.47	a	34.85	l	1.70	ghi
23	30.9	g-k	13.1	c-g	3.05	b-f	7.72	b	40.35	h-k	2.58	a
24	29.8	jk	12.9	e-i	2.94	e-g	7.23	c	43.00	e-i	1.84	f-i
25	32.7	e-h	14.3	a	3.22	b	8.12	ab	41.80	e-j	2.12	cde
First year**	31.8	B	12.6	B	2.92		6.77	A	42.5		1.79	B
Second year	33.5	A	13.5	A	2.89		6.55	B	43.3		2.11	A
overall mean	32.6		13.0		2.90		6.66		42.88		1.95	

The values followed by common letters at each column are not significant at 5% level of probability using the Duncan's test. NDF – neutral detergent fibre, CP – crude protein, ASH – ash content, FAT – crude fat, STA – starch, βGLU – β-glucan.

According to the average of years, the mean of ADF and NDF ranged from 10.98 to 16.35 % and 29.47 to 37.32 %, respectively. ADF and NDF values in the second year were higher than that of the first year. Both ADF and NDF values of 2, 6, 9, 11, 15, 20 and 24 numbered genotypes were lower than overall means (Table 2). The neutral detergent fibre (NDF) content of oat may be in excess of 30 % of dry matter (National Research Council, 2001). Similarly, acid detergent fibre (ADF) comprises 10 to 15% of oat grain.

Protein content of the grain is one of the basic parts which report the usage of grain. Grain crude protein content was significantly affected by genotypes and years (Table 3). According to the average of years, in this study the CP ranged from 11.1 to 14.3%. 25, 16, 11, 10, 4, 17, 20, 9 and 21 numbered genotypes had significantly higher CP than other cultivars. The protein content of the grain reported seems to be influenced by genetics. Australian genotypes of husked oats varied from 10.0 to 18.0 % of CP (Farrell et al., 1991). Peterson et al. (2005) and Yanming et al. (2006) showed that genetic variation was important for protein content.

According to the average of years, ash ration ranged from 2.52 (12 numbered genotype) to 3.43 % (22 numbered genotype).

There is a high nutritional potential of oat because of the valuable fatty acid composition of the fat. Oat genotypes usually include more fat than other cereal grains (Zhou et al., 1999). In this study, fat content in the first and second years was found 6.77 and 6.55 %, respectively. According to the average of years, the mean of fat content of genotypes ranged from 5.86 (10 numbered genotype) to 8.47 % (22 numbered genotype). Fat contents of 1, 3, 8, 9, 12, 17, 22, 23, 24 and 25 numbered genotypes were also higher than that of the other genotypes. The combined data over the two years (Table 3) showed that the starch content for genotypes ranged from 34.85 kg to 47.72 %. Givens et al. (2004) reported that starch ranged from 40.0 to 42.9 % in two cultivars of the UK. Rhymer et al. (2005) indicated that starch content differences were influenced by genotype in five Canadian oat genotypes.

According to the combined analysis of years, 16, 21 and 23 numbered genotypes significantly higher BG content than other oat genotypes. Oat would increase the dietary fibre intake in humans (Givens et al., 2000). The potential use of oat in the production of functional foods is bound to nutritional value of the grain, in particular to the content and composition of dietary fibre, proteins and lipids, respectively (Demirbaş, 2005). Demirbaş, (2005) who is study with all cereal grain reported that the oat groat which is one of the highest β-glucan among all cereals is highly related to β-glucan concentration. β-glucan contents in oat cultivars varied between 1.33 and 2.58 % in the present study. As a reference β-glucan content ranged from 0.77 to 8.37 % in hulled and naked oat cultivars (Givens et al., 2000). β-glucan helps to control blood glucose, cholesterol and might be an anti-carcinogenic agent for humans (Demirbaş, 2005).

TABLE 4
COEFFICIENTS OF CORRELATION AMONG INVESTIGATED TRAITS

	GY	PH	TGW	ADF	NDF	CP	ASH	FAT	STA	βGLU	HW
PH	-0.072										
TGW	0.253**	0.251**									
ADF	-0.003	0.036	-0.212**								
NDF	0.160**	0.137**	-0.069	0.775**							
CP	-0.216**	0.192**	-0.087	-0.087	0.056						
ASH	-0.133	-0.290**	-0.532**	0.359**	0.162**	0.053					
FAT	-0.003	-0.164**	-0.216**	0.054	-0.163**	-0.038	0.338**				
STA	0.054	0.326**	0.421**	-0.451**	-0.257**	0.172**	-0.834**	-0.209**			
βGLU	-0.047	0.141**	-0.086	0.098	0.273**	0.374**	-0.08	-0.245**	0.081		
HW	-0.246**	0.112	0.179**	-0.055	-0.009	0.131	-0.146**	0.167**	0.130	0.039	
GP	-0.048	0.127	-0.027	-0.298**	-0.367**	0.085	0.049	0.123	0.016	-0.104	0.150**

***** – significant at 0.05, ** – significant at 0.01. GY – grain yield, PH – plant height, TGW – thousand grain weight, ADF – acid detergent fibre, NDF – neutral detergent fibre, CP – crude protein, ASH – ash, FAT – crude fat, STA – starch, βGLU – β-glucan, HW – hectolitre weight, GP – groat percentage***

Relationship among traits: According to correlation coefficients, grain yield was significantly and positively correlated with thousand grain weight (r = 0.253**) and neutral detergent fibre (r = 0.160**). However, correlations between grain yield with crude protein (r = -0.216**) and hectolitre weight (r = 0.246) were significantly and negative (Table 4). Buerstmayr et al. (2007) and Redaelli et al. (2008) stated positive correlation between grain weight and grain yield. Peterson et al. (2005)

and Martinez et al. (2010) reported negative correlations between grain yield and protein content. Hectolitre weight was positively and significantly correlated with groat percentage (r=0.150**), TKW (0.179**) and fat content (0.167). Similar or even higher correlation coefficients between hectolitre weight and groat percentage were reported by Doehlert et al., 2001 and Peterson et al. (2005) and Buerstmayr et al. (2007). But, HW was negatively correlated with ash content. Crude protein was positively correlated with PH, STA and βGLU. Correlations between FAT with PH, TGW and NDF were negative. Holland et al. (2001) and Peterson et al. (2005) stated negative correlations between fat content and kernel size. βGLU was positively and significant correlated with PH and NDF, but negatively with FAT (r = 0.245**) (Table 4).

IV. CONCLUSION

There were significant differences in grain yield, plant height, hectolitre weight, thousand grain weight, groat percentage, starch, protein content, fat concentration, β-glucan, acid detergent fiber, neutral detergent fiber among different oat genotypes used in this study. According to the average of years, mean grain yield ranged from 2432.4 kg ha^{-1} to 5650.4 kg ha^{-1}. Although 19 numbered genotype (Trophy/Horizon 474) had the highest grain yield, its quality traits was lower compared to other cultivars. According to some results of this study, cultivars might be bred for high performance with a diversity of genetic properties.

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