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Evaluation of oat (*Avena sativa* L.) genotypes for grain yield and physiological traits

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Abstract

The aim of this research was i) to evaluate the oat genotypes for grain yield and physiological traits, ii) to investigate the oat genotypes having the highest grain yield in the conditions of research region and the relationships between grain yield and traits, iii) to investigate the genetic improvements of registered oat cultivars for grain yield and traits by the year of release. This research was carried out using 8 oat landraces and 9 registered oat cultivars, sown in a randomized complete block design with four replications, between 2006 and 2008 in Kahramanmaras city conditions. In the research, leaf area index (LAI), chlorophyll content (CC), canopy temperature (CT), leaf area duration (LAD), stomatal conductance (g_s), net photosynthetic rate (A), 1000-grain weight (1000-GW), biomass at maturity (BM), grain yield (GY) and harvest index (HI) were investigated.

According to the average of two years, genotypes were significantly different for all investigated traits except for CT, g_s, A, 1000-GW. The highest grain yield 4246.5 kg ha^{-1} in the conditions of the region was produced by the 'Checota' cultivar.

In this research, we found significant and positive relationships between GY and LAI, CC, LAD, HI by the Pearson correlation coefficients. The result of linear regression analysis according to GY and the year of release of registered cultivars showed significant improvements (51.1 kg^{-1} ha^{-1} year) in the oat grain yield by the year 1986. There was not any improvement for GY of the cultivars registered after 1986.

Key words: oat genotypes, physiological traits and yield.

Introduction

Oat is cultivated over limited areas both world-wide and in Turkey. It was produced in 10,212 million ha area with an annual production of 23,3 million tons in the world, while it had a cultivation area of 92,684 ha in Turkey with an annual production of 218,286 tons (Anonymous, 2009).

Oat is highly sensitive to drought and cold (Frey, Colville, 1986). Therefore, oat is significantly affected by cold conditions in the regions where winter sowing is practiced. Insufficient and irregular precipitation in spring also negatively affects the oat yield (Barut, 2003). Oat plant is not selective with regard to soil conditions and can be cultivated over a wide range of soils from the lightest to the heaviest ones just with sufficient moisture. Beside the sensitivity to drought and cold, oat has limited production due to grain shattering, lodging and long ripening period both in Turkey and over the world (Buerstmayr et al., 2007). The origin centre of white oats (*Avena sativa* L.) and red oats (*Avena byzantina* Koch.) is Anatolia (Kun, 1988). Local oat cultivars of Turkey were collected and put under protection within the scope of researches for preservation of genetic resources. Although the local oat materials were collected, there were not sufficient researches carried out for adaptation of these cultivars to various conditions and determination of genetic variations for grain yield, morphological, biological, agricultural and physiological characteristics of these cultivars. Genetic materials with unknown characteristics are not able to be used either in practical agriculture or in plant breeding programmers. Determination and detailed evaluation of characteristics of local cultivars will definitely provide significant knowledge for oat cultivation and breeding.

High grain yield is the most desired characteristic of oat cultivars. Therefore, grain yield potential of oat cultivars should be genetically increased. In past practices, grain yield potential was mostly increased by grain yield-based selection studies. World-wide wheat breeding programs have provided significant genetic improvements in grain yield potential without new selection techniques. Physiological mechanisms of genetic improvements in grain yield potential are not fully understood. However, it is known that together with grain yield, some changes were also observed in physiological characteristics controlling the yield during the yield increase process. Physiological characteristics had significant impacts on growth and development of plants grown in production systems. Therefore, the work was aimed to determine the physiological characteristics limiting or increasing grain yield by using these characteristics in breeding researches (Frederick, Bauer, 2000). They will definitely speed up the genetic improvements (Satorre, Slafer, 1999). Local cultivars in Turkey, oat gene centre create a significant potential to be used in genetic work. Genetic work was carried out mostly with wheat, and the researches investigating physiological characteristics of oat were very limited. Therefore, there is a need for physiological methods to reach higher yield potentials and genetic improvements for oat (Peltonen-Sainio et al., 2009).

Although it was stated by Kun (1988) that there were suitable genotypes among local varieties available for direct selection and registration, this gene source was not able to be sufficiently evaluated. Therefore in this study, physiological characteristics of local oat genotypes and registered varieties commonly cultivated in Turkey will be investigated and genetic variation with regard to these characteristics will be determined.

The objectives of this study were: i) to evaluate the oat genotypes for grain yield and physiological traits, ii) to investigate the oat genotypes having the highest grain yield in the conditions of research region and the relationships between GY and traits, iii) to investigate the genetic improvements of registered oat cultivars for grain yield and traits by the year of release.

Materials and methods

Field experiments were carried out consecutively for two years (2006 to 2008) at Kahramanmaras province (Eastern Mediterranean Region of Turkey) located between 37°32′ N, 36°55′ E, and 507 m above sea level. Typical Mediterranean climate is dominant over the region.

A total of 8 local ('Erzurum TR 32787', 'Amasya TR-37100', 'Antalya TR 40707', 'Tokat TR 44419', 'Ordu TR 44457', 'Sivas TR 45320', 'Canakkale-Ovacik Koyu', 'Samsun Ladik-IbiKoyu') and 9 registered ('Ankara-76', 'Ankara-84', 'Apak 2-3', 'Bozkir 1-5', 'Faikbey', 'Checota', 'Seydisehir', 'Yesilkoy-330', 'Yesilkoy-1779') nation-wide oat cultivars supplied from Bahri Dagdas International Agricultural Research Centre were used as the experimental material of this study. Names and registration years of the cultivars and genotypes used in this study were presented in Table 1. Registered cultivars were selected as 4 groups for linear regression analysis. For this purpose, cultivars of 'Apak 2-3', 'Bozkir 1-5' and 'Yesilkoy-1779' were selected to represent the cultivars registered in 1960s, cultivars of 'Ankara-76', 'Ankara-84' and 'Yesilkoy-330' were selected for cultivars registered in 1970s, cultivar 'Checota' was selected to represent 1980s, and cultivars 'Faikbey' and 'Seydisehir' for the years 2000s. Since the cultivars 'Faikbey' and 'Seydisehir' exhibit special adaptation to Konya region, linear regression analysis for the investigated characteristics was performed over the other registered cultivars.

Field experiments were carried out in a randomized complete block design with four replications. The sowing rates were 400 seeds m^{-2} for experiment conditions. Sowing dates were 20th November 2006–2007 and 18th November 2007–2008 respectively. The seeds were planted using an experimental drill in 1.2 × 8 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 80 kg ha^{-1} N and 80 kg ha^{-1} P_2O_5 at planting. In addition, top-dressing was applied as 100 kg ha^{-1} N at tillering. Herbicide (Tribenuron-Methyl 75%) was used for weed control.

Table 1. The names of oat landraces, cultivars and registration years used in the experiment

Genotype No.	Genotypes	Registration year of cultivar	Genotype No.	Genotypes
1	Ankara-76*	1975	10	Erzurum TR 32787**
2	Ankara-84*	1975	11	Amasya TR-37100**
3	Apak 2-3*	1963	12	Antalya TR 40707**
4	Bozkir 1-5*	1963	13	Tokat TR 44419**
5	Faikbey*	2004	14	Ordu TR 44457**
6	Checota*	1986	15	Sivas TR 45320**
7	Seydisehir*	2004	16	Canakkale-Ovacik Koyu**
8	Yesilkoy-330*	1975	17	Samsun Ladik-IbiKoyu**
9	Yesilkoy-1779*	1964		

* – cultivars, ** – landraces

Leaf area index (LAI) in each plot was measured at the beginning of anthesis. LAI was measured with a LAI-2000 Plant Canopy Analyser (Jonckheere et al., 2004). Leaf area duration (LAD) during grain filling was calculated as:

$$LAD\ (d) = (L_1 + L_2) \times (T_2 - T_1)/2,$$

where L_1 and L_2 are LAI at times T_1 (anthesis) and T_2 (physiological maturity), respectively (Araus et al., 1993).

Chlorophyll content (CC) was measured in the field on flag leaves at anthesis with a portable chlorophyll photometer (Ashraf, 2000). Measurement of net photosynthesis rate (A) and stomatal conductance (g_s) were measured on the flag leaf at grain filling period using LCpro + portable photosynthesis system ("Analytical Development Company", England) (Monneveux et al., 2006).

Canopy temperature (CT) was measured by infrared thermometer and measurement angle was 30 degrees to horizontal (Fahliani, Assad, 2003). For both years, grain yield (GY), biomass at maturity (BM), harvest index (HI), and 1000-grain weight (1000-GW) at maturity were measured. Harvest index was calculated as the ratio of the dry grain mass to total above ground biomass.

Statistical analysis. Pearson correlation coefficients between traits were calculated using cultivar means. Regression analysis, correlations with yield and other traits (as reported by Giunta et al., 2008) were also determined. Data were analyzed using *SAS*, version 9.0 (SAS / STAT User's Guide, 1999). Significant differences between means were determined using Duncans multiple range test at the 5% level.

Results and discussion

Among the genotypes, the differences for investigated characteristics were significant (Table 3).

The highest grain yield (4246.5 kg ha^{-1}) was obtained from 'Checota' cultivar. Grain yields of 'Ankara-84', 'Antalya TR 40707', 'Canakkale-Ovacik Koyu', 'Sivas TR 45320', 'Tokat TR 44419', 'Yesilkoy-330' and 'Bozkir 1-5' genotypes were also higher than averages. Therefore these cultivars were placed in the same group with 'Checota' cultivar. As the average of two years, the lowest grain yield (2772.1 kg ha^{-1}) was obtained from the cultivar 'Apak 2-3' (Table 3). Oat landraces had grain yield closer to registered cultivars. Kara et al. (2007) also reported grain yield of genotypes as between 2496 and 4030 kg ha^{-1} and observed the highest yield from 'Checota' cultivar.

Peterson et al. (2005) indicated significant impacts of environment and genotype over yield. Branson, Frey (1989) observed that landraces had higher grain yields than standard cultivars. Tamm (2003) observed the significant impacts of climate factors on oat grain yield in a study carried out between the years 1998–2002 and reported that high temperature and drought decreased the grain yield. In our research, high temperatures observed during May and June of the first year decreased the grain yield during the grain setting period.

According to correlation coefficients, grain yield was significantly and positively correlated with leaf area index (r = 0.55*), chlorophyll content (r = 0.57*), leaf area duration (r = 0.60*) and harvest index (r = 0.84**) (Table 2). These traits were used as selection criteria to improve oat cultivars with higher grain yield in region conditions.

Table 2. Coefficients of correlation among investigated traits

	LAI	CC	CT	LAD	1000-GW	g_s	A	BM	GY
CC	0.437	–							
CT	0.012	0.119	–						
LAD	0.554*	0.778**	−0.007	–					
1000-GW	−0.047	−0.415	−0.170	−0.386	–				
g_s	0.119	−0.108	0.197	−0.108	0.098	–			
A	−0.048	−0.344	−0.062	−0.153	−0.104	0.761**	–		
BM	0.389	−0.304	0.061	−0.088	0.398	−0.165	−0.235	–	
GY	0.546*	0.571*	0.261	0.604**	−0.193	0.0149	−0.351	0.382	–
HI	0.334	0.703**	0.123	0.679**	−0.353	−0.014	−0.363	−0.095	0.838

* – significant at 0.05, ** – significant at 0.01. CC – chlorophyll content, CT – canopy temperature, LAD – leaf area duration, 1000-GW – 1000-grain weight, g_s – stomatal conductance, A – net photosynthetic rate, BM – biomass at maturity, GY – grain yield, HI – harvest index, LAI – leaf area index.

Registered cultivars ('Apak 2-3', 'Bozkir 1-5', 'Yesilkoy-1779', 'Ankara-76', 'Ankara-84', 'Yesilkoy-330', 'Checota', 'Faikbey' and 'Seydisehir') were classified into four groups with regard to date of registration as 1960s, 1970s, 1980s and 2000s. Linear regression analysis carried out to determine the relationships between the registration years and grain yields revealed that a linear regression equation of $y = 7.884x - 12221$ (Fig. 1). R^2 value is over 7.8%. Although the R^2 value of 7.8% for this linear relationship indicates that this relationship was able to explain only 7.8% of variation in grain yield, it was possible to see significant increase in grain yield of varieties registered between 1960 and 1986 (Fig. 1).

Analysis showed significant yield increases with regard to 1980s. However, the cultivars 'Seydisehir' and 'Faikbey' registered for Central Anatolia, in 2004 were not able to sustain their yield increase trend and it was thought that these two cultivars had special adaptations to Central Anatolian Region. There were not any genetic improvements for grain yield of these two cultivars registered after 1986 (Fig. 1).

Calculations made by using group averages of cultivars from 1963 to 1986 revealed that there was an average yield increase of 51.1 kg^{-1} ha^{-1} year until 1986. Acreche et al. (2008) also found yield increases from 1940 to 1970 with registration dates and specified lower increases after 1970s.

According to the results of this research, there was not any improved oat cultivar having higher grain yield after the year 1986. This situation occurred due to limited scientific researches related to oat plant. Therefore, oat researches should focus on developing new cultivars with higher grain yields.

The highest chlorophyll content during the flowering periods was observed in 'Antalya TR 40707' genotype with 54.00 mg m^{-2}. Except for 'Yesilkoy-1779', 'Erzurum TR 32787' and 'Faikbey', the other genotypes were placed in the same group with 'Antalya TR 40707' genotype with regard to chlorophyll content. The lowest chlorophyll content was observed in 'Faikbey' registered cultivar with 45.021 mg m^{-2} (Table 3). Giunta et al. (2008) also indicated large variations among cultivars with regard to chlorophyll content and Ashraf (2000) observed that genotypes with high chlorophyll content had higher photosynthetic impacts and there was a relationship between chlorophyll content and net photosynthesis rate. In another study, Zhao et al. (2008) observed chlorophyll contents between 27.4 and 47.4 mg m^{-2}, obtained an average value

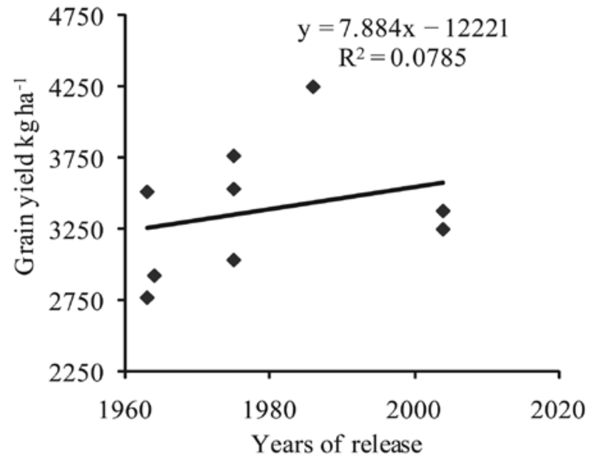

Figure 1. Relationship between grain yield and years of release

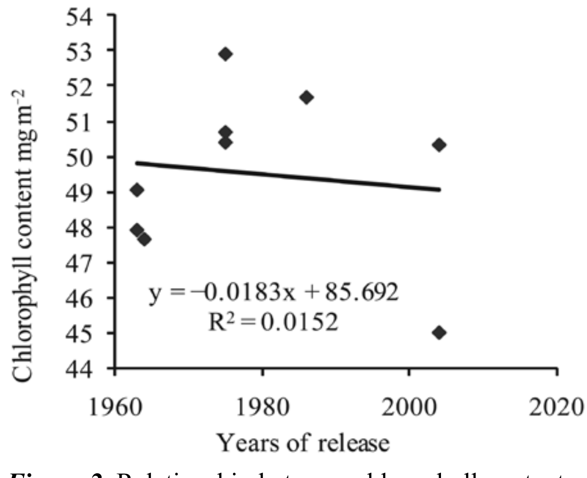

Figure 2. Relationship between chlorophyll content and years of release

for varieties as 36.1 mg m^{-2} and did not observe a relationship between chlorophyll content and net photosynthesis rate. That supports the findings of our experiments (Table 2). Significant and positive relationship was observed between grain yield and chlorophyll content (r = 0.57*) in our research. Similar relationship was also observed in a previously carried out study (Reynolds et al., 1994).

Linear regression analysis carried out for chlorophyll contents of oat cultivars with regard to registration years revealed a linear regression equation of y = −0.0183x + 85.692 (Fig. 2). The R^2 value of 1.5% for this linear relationship indicates that this relationship was able to explain only 1.5% of variation. Significant increases were not observed in chlorophyll contents of cultivars registered after. 'Faikbey' and 'Seydisehir' cultivars registered in 2004 were not able to provide sufficient increase in their chlorophyll contents under experiment conditions (Fig. 2). However, there was significant increase for chlorophyll content of oat cultivars registered between 1960 and 1986 (Fig. 2).

While the highest leaf area index (6.28) was observed in 'Antalya TR 40707'genotype, 'Ankara-84', 'Bozkir 1-5', 'Checota', 'Seydisehir', 'Yesilkoy-330', 'Ordu TR 44457', 'Sivas TR 45320', 'Canakkale-Ovacik Koyu' and 'Samsun Ladik-IbiKoyu' genotypes also had high leaf area index values and placed in the same group with 'Antalya TR 40707' genotype. The lowest leaf area index (4.86) was obtained from the registered cultivar of 'Ankara-76' (Table 3). A positive relationship was observed between leaf area index and grain yield (r = 0.55*) (Table 2). Borojevic, Williams (1982) also indicated positive relationships (r = 0.45*) between leaf area index and grain yield.

Canopy temperatures of oat genotypes were observed between 25.36ºC and 21.51ºC. Evaporation from plant surface provides lower plant temperatures than atmospheric temperature and lower plant temperatures indicate higher stoma efficiency and higher adaptation capability (Reynolds et al., 2000). Positive but insignificant relationship was observed in this study between plant cover temperature and stoma efficiency. Increasing plant cover temperatures with increasing atmospheric temperatures and higher plant cover temperatures under stress conditions than non-stressed conditions were reported by Araghi and Assad (1998).

Table 3. Mean performance of genotypes across growing seasons

Genotypes	LAI	CC mg m^{-2}	LAD day	BM kg ha^{-1}	GY kg ha^{-1}	HI %
'Ankara-76'	4.86 d	50.71 abcd	129.3 cdef	13049 c	3035.0 bcd	23.22 abc
'Ankara-84'	6.07 ab	52.93 ab	154.4 ab	14683 bc	3763.0 ab	24.71 ab
'Apak 2-3'	5.20 bcd	49.07 abcd	126.5 cdef	14958 abc	2772.1 d	18.60 c
'Bozkir 1-5'	5.78 abc	47.93 abcd	123.9 def	17208 a	3512.0 abcd	21.02 bc
'Faikbey'	5.06 cd	45.02 d	107.6 f	15951 ab	3250.8 bcd	20.36 bc
'Checota'	5.47 abcd	51.70 abc	146.3 abcd	15654 ab	4246.5 a	27.13 a
'Seydisehir'	5.85 abc	50.35 abcd	136.6 abcde	14087 bc	3378.1 bcd	23.07 abc
'Yesilkoy-330'	5.40 abcd	50.42 abcd	157.9 a	15383 abc	3532.3 abcd	24.25 ab
'Yesilkoy-1779'	5.35 bcd	47.67 bcd	129.3 cdef	14358 bc	2926.9 cd	20.43 bc
'Erzurum TR 32787'	5.12 cd	45.87 cd	118.9 ef	14618 bc	2902.1 cd	20.57 bc
'Amasya TR-37100'	4.99 cd	50.84 abcd	114.9 ef	14020 bc	3186.3 bcd	22.42 abc
'Antalya TR 40707'	6.28 a	54.00 a	152.4 ab	15567 ab	3710.6 abc	23.71 ab
'Tokat TR 44419'	5.24 bcd	53.53 ab	148.2 abc	14132 bc	3551.3 abcd	23.19 abc
'Ordu TR 44457'	5.42 abcd	49.35 abcd	124.0 def	15199 abc	3365.4 bcd	23.40 abc
'Sivas TR 45320'	5.45 abcd	52.21 ab	154.9 ab	14456 bc	3614.6 abc	24.36 ab
'Canakkale-Ovacik Koyu'	5.46 abcd	49.56 abcd	128.8 cdef	15882 ab	3711.6 abc	22.78 abc
'Samsun Ladik-IbiKoyu'	5.53 abcd	48.23 abcd	135.1 bcde	15632 ab	3344.5 bcd	21.49 bc
Mean	5.44	49.96	134.7	14990	3400.17	22.63
$LSD_{0.01}$	0.258	1.784	6.596	696.36	232.33	1.438
Prb	*	*	**	*	**	*

ns – not significant, explanations of abbreviations under Table 2

Stomatal conductance values ranged between 0.261 mol H_2O m^{-2} s^{-1} and 0.172 mol H_2O m^{-2} s^{-1}. Jiang et al. (2000) found stomatal conductance values for durum wheat cultivars as 0.800–0.330 mmol H_2O m^{-2} s^{-1} during milk stage, as 210–570 mmol H_2O m^{-2} s^{-1} during dough period and stated that stoma conductivity was not related to grain yield at any growth stages. Zhao et al. (2008) observed significant differences among 8 F_1 strains with regard to stomatal conductance and stated high photosynthesis rates with high stomatal conductance. They observed stomatal conductance of less than 0.2 in F_2 strains.

Net photosynthesis rates of 17 genotypes were found between 10.27−13.09 µmol CO_2 m^{-2} s^{-1} and average of genotypes was 11.15 µmol CO_2 m^{-2} s^{-1}. A negative but non-significant relationship was observed between chlorophyll content and net photosynthesis rate (r = −0.34) (Table 2). As stated by Zhao et al. (2008) dark and large leaves have high chlorophyll content but chlorophyll content cannot be selection criteria for photosynthesis rate. Reynolds et al. (2000) observed net photosynthesis rate of 16.0 µmol CO_2 m^{-2} s^{-1} during dough period of wheat and they indicated that net photosynthesis rate was closely related to chlorophyll loss; besides leaf aging, changes in rate of photosynthesis during the growth stages were also effective for yield potential of wheat. A positive and significant relationship was observed in this study between net photosynthesis rate and stoma conductivity (r= 0.76**). Jiang et al. (2000) also observed positive and significant relationships between net photosynthesis rate and stomatal conductance during the flowering period. Zhao et al. (2008) did not observe any relationship between rate of photosynthesis and chlorophyll content but noted low level of correlations (r = 0.38*) between stoma conductivity and rate of photosynthesis.

A 1000-grain weight of genotypes varied between 22.03 and 30.71 g and the average was determined as 26.32 g. Sharma (1994) specified higher 1000-grain weights for genotypes with longer dough periods than the genotypes with shorter dough periods.

While the registered cultivar of 'Bozkir 1-5' had the highest biomass (17208 kg ha^{-1}), the registered cultivar 'Ankara-76' had the lowest biomass (13049 kg ha^{-1}) (Table 3). Branson, Frey (1989) also reported higher biomass values for oat strains than standard cultivars.

Among 17 genotypes, the highest leaf area duration was observed in 'Yesilkoy-330' registered cultivar with 157.9 days. The registered cultivars of 'Ankara-84' and 'Checota' and genotypes of 'Seydisehir', 'Antalya TR

40707', 'Tokat TR 44419' were placed in the same group with 'Yesilkoy-330' with regard to lead area duration. The lowest leaf area duration was obtained from 'Faikbey' registered cultivar with 107.6 days (Table 3). In this study, significant and positive relationships were observed between grain yield and leaf area duration (*r* = 0.60**), between leaf area duration and leaf area index (*r* = 0.55 *) and chlorophyll content (*r* = 0.78**) (Table 2). Similarly, Tiryakioglu (2004) observed significant differences among cultivars with regard to leaf area duration and others indicated higher grain yields, with longer leaf area durations (Borojevic, Willams, 1982; Tiryakioglu, 2004).

Linear regression analysis carried out for leaf area duration (LAD) with regard to registration dates revealed a linear regression equation of y = −0.1523x + 435.94 (Fig. 3). The R^2 value of 2.3% for this linear relationship indicates that this relationship was able to explain only 2.3% of variation for LAD. It also indicates significant increases in leaf area durations of cultivars with regard to date of registration until the year 1986. This brings the conclusion that 'Faikbey' and 'Seydisehir' cultivars registered in 2004 were not in increasing trend for LAD in experiment region. There were not any significant improvements for LAD with cultivars registered in 2004.

While the highest harvest index was obtained from the cultivar 'Checota' with 27.13%, the cultivar 'Apak 2-3' had the lowest harvest index (18.60%) (Table 3). Differences among cultivars with regard to harvest index were due to differences in plant heights. Other researchers observed significant differences among cultivars with regard to harvest index due to variations in total dry matter and assimilate distribution (Dreccer et al., 2009). Branson, Frey (1989) stated that there were not significant differences between genotypes and standard cultivars. In this study, positive and significant relationships were observed between harvest index and chlorophyll content (*r* = 0.70**) and leaf area duration (*r* = 0.68**) (Table 2).

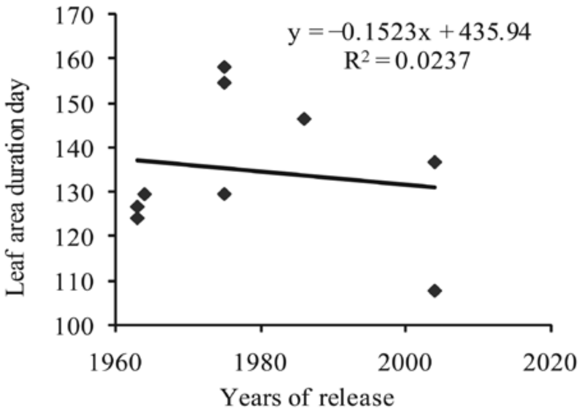

Figure 3. Relationship between leaf area duration and years of release

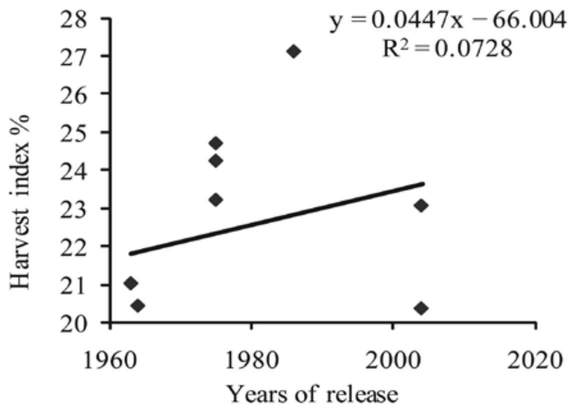

Figure 4. Relationship between harvest index and years of release

Linear regression analysis carried out to determine the relationship between harvest index and registration dates revealed a linear regression equation of y = 0.0447x − 66.004 (Fig. 4). The R^2 value of 7.2% for this linear relationship indicates that this relationship was able to explain only 7.2% of variation. The cultivars of 'Faikbey' and 'Seydisehir' registered in 2004 were not able to provide sufficient increases with regard to harvest index in Kahramanmaras (Fig. 4). Significant increases were observed in harvest index of registered cultivars from 1963 to 1986. It indicates that large part of increase in grain yield came from increase in harvest index. High correlation values between grain yield and harvest index also support this finding (Table 2).

Acreche et al. (2008) observed increased grain yields with regard to registration dates from 1940 to 1970; the increase was not high after 1970 and concluded that increase in harvest index was mainly due to increases observed in grain yield.

Conclusion

In this study, 'Checota' cultivar had the highest grain yield (4246.5 kg ha^{-1}) and the highest harvest index (27.13%), and the highest biomass yield (17208 kg ha^{-1}) was observed in 'Bozkir 1-5' variety. Based on these findings, the cultivar 'Checota' can be recommended for higher grain yield and harvest index, the cultivar 'Bozkir 1-5' for higher biomass yield and higher 1000-grain weight, 'Seydisehir' cultivar for stomatal conductance and photosynthesis, 'Antalya TR 40707' genotype for leaf area index and chlorophyll content under regional conditions.

According to the correlation coefficients, grain yield was positively and significantly correlated with leaf area index, (*r* = 0.55*), chlorophyll content (*r* = 0.57*), leaf area duration (*r* = 0.60**) and harvest index (*r* = 0.84**).

Regression analysis carried out with 9 registered cultivars with regard to registration dates revealed that there were not significant increases in grain yield. However, the result of linear regression analysis according to grain yield and the registration years of cultivars showed that there was a yield increase of 51.1 kg^{-1} ha^{-1} year in the oat grain yield by the year of 1986. There were not any improvements for grain yield of cultivars registered after 1986. The cultivar 'Checota' registered in 1986 had significant impacts on these increases.

It was also concluded that oat cultivars registered between 1960 and 1986 had similar increasing grain yields and therefore other physiological yield-related parameters like leaf area index, chlorophyll content, leaf area duration and harvest index should be taken into consideration to develop high-yield oat genotypes.

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Paprastosios avižos (*Avena sativa* L.) genotipų vertinimas pagal grūdų derlių ir fiziologines savybes

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Santrauka

Tyrimų metu siekta įvertinti avižos genotipų grūdų derlių bei fiziologines savybes, ištirti avižos genotipus, pasižyminčius didžiausiu grūdų derliumi (GY) tyrimų regione, ir santykius tarp GY bei požymių ir avižos registruotų veislių grūdų derliaus bei požymių atžvilgiu genetinį pagerinimą pagal veislių registravimo metus. Tirtos 8 vietinės ir 9 registruotos avižos veislės, 2006–2008 m. Kahramanmaro regiono sąlygomis pasėtos pagal išskaidytų laukelių schemą keturiais pakartojimais. Tirtas lapų ploto indeksas (LAI), chlorofilo kiekis (CC), lapijos temperatūra (CT), fotosintezės potencialas (LAD), žiotelių laidumas (g_s), fotosintezės grynasis rodiklis (A), 1000-čio grūdų masė (1000-GW), brandos tarpsnio biomasė (BM), grūdų derlius (GY) ir derliaus indeksas (HI).
Pagal dvejų metų vidurkį, genotipai labai skyrėsi pagal visus tirtus požymius, išskyrus CT, g_s, A ir 1000-čio grūdų masę. Regiono sąlygomis didžiausias grūdų derlius (4246,5 kg ha^{-1}) gautas veislės 'Checota' avižų. Taikant Pearsono koreliacijos koeficientus, esminiai ir teigiami ryšiai nustatyti tarp GY ir LAI, CC, LAD bei HI. Linijinės regresijos analizė pagal GY ir veislės registracijos metus parodė, kad avižų grūdų derlius gerokai padidėjo (51,1 kg^{-1} ha^{-1} per metus) laikotarpiu iki 1986 m. Auginant po 1986 m. registruotų veislių avižas, GY nepadidėjo.

Reikšminiai žodžiai: avižos genotipai, fiziologinės savybės ir derlius.