GRAIN YIELD STABILITY OF WINTER OAT (AVENA SATIVA L.) CULTIVARS IN THE CENTRAL ANATOLIAN REGION OF TURKEY

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ABSTRACT

The objectives of this research were to assess genotype environment interaction and determine stable oat (Avena sativa L.) cultivars for grain yield in Central Anatolian Region of Turkey. Stability analysis [9] were to performed on results for grain yield of 5 oat cultivars (Chekota, Yesilkoy-1779, Yesilkoy-330, Faikbey-2004, Seydisehir-2004) from 24 trials (6 irrigated, 18 rain fed) was conducted over 6 years in the Central Anatolian Region, Turkey. There was considerable variation in grain yield within and across environments. Year by location and location variability were dominant sources of interactions. The cultivar, "Seydisehir-2004" with respective regression coefficient value of 1.03, the smallest deviations from regressions (S^2_{di}) value and the highest grain yield could be considered the most widely adapted cultivar. The other test cultivars were sensitive to production-limiting factors, their wider adaptability, stability and general performance to the fluctuating growing conditions within and across environments being lowered.

KEY WORDS: Avena sativa L., Grain Yield, Genotype Environment Interactions, Oat, Stability

INTRODUCTION

The development of cultivars or varieties, which can be adapted to a wide range of diversified environments, is the ultimate goal of plant breeders in crop improvement program. The adaptability of a variety over diverse environments is usually tested by the degree of its interaction with different environments under which it is planted. A variety or genotype is considered to be more adaptive or stable one if it has a high mean yield but low degree of fluctuations in yielding ability when grown over diverse environments [5].

Several methods have been proposed to analyze genotype environment interactions and phenotypic stability [6,14 and 17]. These methods can be divided in two major groups, univariate and multivariate stability statistics [14]. Joint regression is the most popular among the univariate methods because of its simplicity of calculation and application [6]. Joint regression provides a conceptual model for genotypic stability [6].The regression of the yield genotype on environment mean yields is determined. The genotype environment interaction from analysis of variance is portioned into heterogeneity of regression coefficients (b_i) and the sum of deviations from regressions. Finally Wilkinson [10] defined a genotype with regression coefficient equal to zero (b_i =0) as stable, while Eberhart and Russell [9] defined a genotype with (b_i=1) to be stable. According to the joint regression model, a stable genotype is one with a high mean yield, b_i=1 and S^2_{di}=0 [9].

Some stability studies have been carried out on different crops in Turkey; [2] in Triticale, [22, and 23] in potato, [21] in winter barley, [1, 8, 11, and 13] in bread wheat, [15] in chickpea, [6] in dry bean. But, only one study has been carried out with winter oat in the Central Anatolian Region of Turkey [12]

The objectives of this study are to: (i) evaluate the grain yield of winter oat genotypes under different environments; (ii) examine the magnitude of genotype environment interaction in 24 environments in oat cultivars, (iii) determine the adaptation of winter oat cultivars, using stability parameter.

MATERIALS AND METHODS

Genotypes and growth conditions

Five oat cultivars; including two new registered oat cultivars (Seydisehir-2004, Faikbey-2004) and three old oat cultivars (Chekota, Yesilkoy-330 and Yesilkoy-1779) from Bahri Dagdas International Agricultural Research Institute were used in this study (Table 1).

During the 1996-2001 growing seasons, a total of 24 trials (6 irrigated, 18 rain fed) were conducted in 4 representative environments of Turkey, which are the Konya, Cumra and Obruk in the Central Anatolian Region of Turkey. Irrigation experiments were carried out in Konya, rain-fed experiments were carried out in Konya, Cumra and Obruk conditions. Amounts of rainfall in growing season, mean temperatures and growing seasons are given in Table 2.

In each trial, cultivars were grown in randomized complete-block design with three replications. The experiments were sown with an experimental drill in 1.2 m x 7 m plots, consisting of six rows with 20 cm between the rows. The seeding rate was 550 seeds m^{-2} for rain fed and 450 seeds m^{-2} for irrigated environments. The rainfall experiments plots were fertilized 27 kg N ha^{-1} and 69 kg P_2O_5 ha^{-1}at planting and 40 kg N ha^{-1} applied at the stem elongation stage. The irrigation experiments plots were fertilized 36 kg N ha^{-1} and 92 kg P_2O_5 ha^{-1}at planting and 40 kg N ha^{-1} applied at the steam elongation stage. Irrigated experiments, supplementary irrigation of about 100 mm was added in each growing seasons (Table 2). Harvesting was done in 1.2 m x 5 m plots by combine harvester and yield determined (t ha^{-1}).

Statistical analysis

A combined three-factor analysis of variance was performed on data collected for all locations and years using the statistical model

$Y_{ijkl}= \mu + g_i + p_i + t_k+ (gp)_{ij}+ (gt)_{ik} + (tp)_{ik} + (gpt)_{ijk} + e_{ijkl}$

Where, Y_{ijkl} is the i^{th} observation on the l^{th} cultivar in j^{th} location in the k^{th} year. The first four terms are the mean and main effects of cultivars, locations and years. The next three terms are the first order interaction and finally the micro environmental deviation within locations and years. It is usually assumed that cultivars and locations are fixed effects and years random effects, so that the model is a mixed effects model.

The method of Eberhart and Russell [9] was used in this study to characterize genotypic stability. The following linear regression model was used:

$Y_{ij} =\mu + b_iI_j + \delta_{ij} + \varepsilon_{ij}$

Where Yij is the mean of the genotypes i^{th} at the location j; μ is the general mean of genotype i; b_i is the regression coefficient of the i^{th} genotype at the location index which measures the response of this genotype to varying location; I_j is the environmental index which is defined as the mean deviation of all cultivars at a given location from the overall mean; δ_{ij} is the deviation from regression of the i^{th} cultivar the j^{th} location; ε_{ij} is the mean of experimental error.

Two stability parameters were calculated: (a) the regression coefficient, which is the regression of

Table 1. Cultivars, Origins, Pedigrees and Registration year

Cultivars	Origin	Pedigree (landraces collected)	Registration Year
Chekota	USA-hibridization	Arlington/Vintok	1986
Yesilkoy-1779	Turkey-selection from landraces		1964
Yesilkoy-1730	Turkey-selection from landraces		1975
Seydisehir-2004	Turkey-selection from landraces	Konya	2004
Faikbey-2004	Turkey-selection from landraces	Eskisehir	2004

Table 2. Growing seasons, meteorological data for the three sites and grain yield of environments.

Environments/ Locations		Growing Seasons	Meteorological Data (September-July) Air Temperatures (°C)		Rainfall (mm)+irrigation	Grain yield (t ha^{-1})			
			min	max		mean	max	min	range
E1	Konya	1996-1997	-10	35	378	1.57	1.75	1.37	0.38
E2	Konya	1997-1998	-12	38	317	2.25	2.47	1.99	0.49
E3	Konya	1998-1999	9	38	319	2.19	2.68	1.93	0.75
E4	Konya	1999-2000	-19	41	218	1.91	2.46	1.63	0.84
E5	Konya	2000-2001	-12	38	188	1.87	2.14	1.38	0.76
E6	Konya	2001-2002	-17	38	385	2.90	3.13	2.69	0.44
E7	Konya*	1996-1997	-10	35	378+100	4.63	5.46	4.18	1.28
E8	Konya*	1997-1998	-12	38	317+100	4.63	5.46	4.19	1.27
E9	Konya*	1998-1999	9	38	319+100	4.41	5.50	3.70	1.80
E10	Konya*	1999-2000	-19	41	218+100	3.43	3.99	2.93	1.06
E11	Konya*	2000-2001	-12	38	188+100	3.90	4.32	3.52	0.80
E12	Konya*	2001-2002	-17	38	385+100	3.96	4.80	3.33	1.47
E13	Cumra	1996-1997	-21	38	339	3.08	3.68	2.37	1.31
E14	Cumra	1997-1998	-12	38	354	2.58	2.97	2.28	0.69
E15	Cumra	1998-1999	-13	37	257	2.06	2.77	1.52	1.26
E16	Cumra	1999-2000	-20	40	347	3.15	3.70	2.27	1.43
E17	Cumra	2000-2001	-13	39	228	2.42	2.79	1.93	0.86
E18	Cumra	2001-2002	-10	39	392	2.66	2.79	2.49	0.30
E19	Obruk	1996-1997	-21	36	311	1.24	1.52	1.04	0.49
E20	Obruk	1997-1998	-15	40	300	1.01	2.00	0.63	1.37
E21	Obruk	1998-1999	-14	38	237	1.10	1.52	0.79	0.73
E22	Obruk	1999-2000	-14	38	269	1.20	1.56	0.93	0.63
E23	Obruk	2000-2001	-13	38	233	1.65	1.91	1.31	0.60
E24	Obruk	2001-2002	-13	39	327	1.03	2.00	0.69	1.31

*, Irrigation environments

Soil Properties:

Konya: pH= 8.2 clayey, alluvial;

Cumra: pH= 7.8 clayey loam, hydro-morfic alluvial;

Obruk: pH= 7.6 clayey. brown

performance of each cultivar under different locations on the environment, means over all the genotypes. This is estimated according to Sing and Chaudhary [19] as follows:

$$b_i = \sum_j Y_{ij} I_j \Big/ \sum_j I^2{}_j$$

Where

$$\sum_j Y_{ij} I_j$$

is the sum of products and

$$\sum_j I^2{}_j$$

is the sum of squares

(b) Mean square deviations (S2di) from linear regression,

$$\left[\sum_j \delta_{ij}{}^2 \Big/ (s-2)\right] - S^2{}_{di} / \mathrm{r}$$

Where

$$\sum_j \delta_{ij}^2 = \left[\sum \mathrm{Y}_{ij}^2 - \frac{\mathrm{Y}_i^2}{t}\right] - \frac{\left(\sum_j \mathrm{Y}_{ij} \iota_j\right)^2}{\sum_j \iota_j^2}$$

and

S^2e =

the estimate of pooled error.

The significance of the regression coefficients was determined using the t test, and coefficients of determination (R^2_i) were computed from individual linear regression analysis [16].

Linear regression coefficients (b_i) of the relationship between cultivars yield at each location and the mean location yield is measure of the linear responses to environmental change. The mean square for deviation from the regression (S^2_{di}) measures the consistency of this response: in other words, it is a measure of heterogeneity.

The relations between regression coefficients and the mean grain yields of cultivars were figured. The confidence limits of the regression coefficients and mean grain yields on figure were estimated follows formula [4]:

Confidence limit= $\overline{\mathrm{X}} \pm$ t value.Sx

All statistical analyses were carried out using the SAS Statistical Packet Program [3].

RESULTS AND DISCUSSION

Mean grain yield varied among environments and ranged from 1.01 tha^{-1} for environment-20 to 4.63 t ha^{-1} for environment-7 and 8 (Table 2).

The results and combined analysis of grain yield across locations and years are given in Table 3. Effects of years, locations, cultivars and their interactions for grain yield were highly significant (P<0.01). Pham and Kang [16] indicated that genotype x environment interactions minimize the usefulness of genotypes by confounding their yield performance. Backer and Leon [6] also indicated that assessment of stability across many locations and years could increase both repeatability and heritability of important traits.

The partitioning of variance components revealed that environment factors both predictable (locations) and unpredictable (year) were important source of variation (Table 3.) When genotype x environment is due to variation in predictable environment factors, Oat breeders have the alternatives of either developing specific varieties for different environments (location, soil types, winter type, spring type etc.) or broadly adapted cultivars that can perform well under variable conditions. However, when genotype x environment interaction results from variation in unpredictable environmental factors, such as year to year variation in rainfall distribution, as in the case the study, the breeders needs to develop stable genotypes that can performs reasonably well under a range of conditions.

The stability analysis conducted for 6 year at 4 locations grain yield of the study is presented in Table 4 and revealed that the cultivars differ significantly for grain yield. The cultivar x location interaction component was further partitioned into linear (location and cultivars x locations) and non-linear (pooled deviations) components. Mean squares for both of these components were tested against pooled error mean square. The linear component was highly significant, indicating that the predictable-components shared with cultivar-location interactions. Preponderance of linear cultivar-location interaction is of great practical importance, implying that there are differences among linear regression coefficients for each cultivar.

Table 3. Analysis of variance of grain yield for five oat cultivars tested at four locations in six years in the Central Anatolian Region of Turkey.

Source of variation	DF	SS	MS
Model	167	536.658	3.210**
Replications(YxL)	36	0.086	0.002**
Cultivar (C)	4	2.592	0.648**
Year (Y)	5	45.771	9.154**
Locations (L)	3	250.407	83.470**
C x Y	20	7.773	0.389**
C x L	12	3.087	0.257**
Y x L	15	198.620	13.241**
G x L x Y	60	28.312	0.472**
Residual	192	0.192	0.001

** significant at 0.01 probability level; DF: Degrees of freedom; SS: Sum of Square; MS: Mean Square

Table 4. Analysis of variance for stability parameter for five oats cultivars grown at 24 environments in the Central Anatolian Region of Turkey.

Source	DF	SS	MS
Cultivar	4	2.592	0.648**
Locations (cultivar x location)	115	528.74	4.597**
Locations (linear)	1	490.838	490.838
Cultivar x locations(linear)	4	27.009	6.75**
Pooled deviations	110	10.907	0.991
Chekota	22	4.121	0.187*
Yesilkoy-330	22	1.908	0.087
Yesilkoy-1779	22	2.685	0.122*
Faikbey-2004	22	1.074	0.046
Seydisehir-2004	22	1.175	0.053
Pooled error	192	0.192	

** significant at 0.01 probability level; *significant at 0.05 probability level; DF: Degrees of freedom; SS: Sum of Square; MS: Mean Square

Table 5. Estimates of stability and adaptability parameters of grain yield for five oats cultivars grown at 24 environments in the Central Anatolian Region of Turkey.

Cultivars	$\overline{Y}$	bi	S^2_{di}	R_i^2
Chekota	2.48	1.01	0.187*	0.879
Yesilkoy-330	2.39	0.84*	0.087	0.880
Yesilkoy-1779	2.51	1.02	0.122*	0.962
Faikbey-2004	2.52	1.09*	0.046	0.953
Seydisehir-2004	2.77	1.03	0.053	0.947
Mean	2.52±0.124	1.00±0.073		

$\overline{Y}$: Mean grain yield (t ha^{-1}) b_i: Regression coefficient, S^2_{di}: deviation from regression (Eberhart and Russell,1966). , R_i^2: Coefficient of determination (Phinthus, 1973). *significant at 0.05 probability level

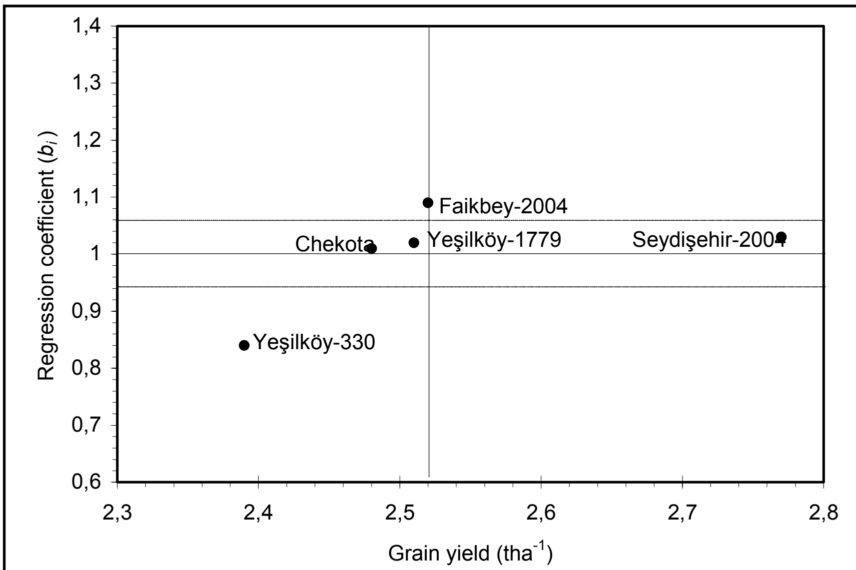
The stability parameters for all cultivars are given in Table 5. Eberhart and Russell [9] emphasized the need of considering both linear (b_i) and non-linear (S^2_{di}) components of genotype-environment interactions in judging the stability of a genotype. A wide adaptability genotype was defined as one with b_i =1 and high stability as one with S^2_{di}=0. In this study values for the regression coefficient (b_i) ranged from 0.84 (Yesilkoy-330) to 1.08 (Faikbey-2004) for grain yield.

The regression coefficient of cultivars Chekota, Yesilkoy-1779 and Seydisehir-2004 for grain yield was non-significantly different from the unity (b_i =1). The cultivars Chekota and Yesilkoy-1779 gave below average performance besides deviation from regression was significant hence the performance of these cultivars seems to be unpredictable. Among these cultivars "Seydisehir-2004" had deviation from regression as small as possible (S^2_{di}=0). Accordingly, "Seydisehir-2004" was the most stable cultivar for grain yield, since its regression coefficient was almost equal to the unity and it had the lowest deviation from regression. Its coefficient of determination, R_i^2 [18], was as high as 94.7 % conforming its stability. In contrast, the cultivar Faikbey-2004 for grain yield, with regression coefficients greater than one, was regard as sensitive to environmental changes.

Figure 1 shows a representation of the cultivar regression coefficients plotted against the means. The locally adapted cultivars had regression coefficients close to the unity, had above average yields and may, therefore be characterized as well adapted all environments. These cultivars also had smallest deviations from regression and hence may be regarded as the most stable genotype. According these examinations, Seydisehir-2004 is the most stable cultivar for grain yield. The cultivar Faikbey-2004 (b_i =1.09) had regression coefficient for grain yield greater than unity and high yielding, so it may be characterized as suitable for specific adaptation in favorable environments. The cultivar Yesilkoy-330 that had regression coefficients of less than unity and below average grain yield, indicating that it offer a greater resistance to environmental change and a specially adapted to poor environments. The yield performance of cultivars; Chekota and Yesilkoy-330 was poor. They produced below average grain yield. Chekota had high deviations from regression indicating sensitivity to environmental changes. This cultivar cannot be recommended due to their overall poor performance. The cultivar Yesilkoy-1779 produced average grain yield. This cultivar had high deviation from regression with non-significant regression coefficient, revealing sensitivity to environmental fluctuations.

CONCLUSIONS

The cultivar "Seydisehir-2004" was the most stable cultivar for grain yield over all the locations. Hence, this cultivar may be recommended for cultivation in different environment (particularly in rain fed conditions) across the Turkey. ii) The cultivar "Faikbey-2004" had regression coefficient significantly greater than 1.0 with grain yield



Confidence limit for regression coefficient: 1.00 ± 0.073

Figure 1. Plot of deviation from regression coefficient against grain yield in a stability study of five oat cultivars.

equally the grand mean. This cultivar is sensitive to environmental changes and would be recommending for cultivation under favorable conditions only.

“Yesilkoy -330” had regression coefficient significantly less than 1.0 low grain yield, this cultivar is, therefore, insensitive to environmental changes and adapted only to poor environments.

The cultivar “Yesilkoy-1779” produced average grain yield. This cultivar had high deviation from regression with non-significant regression coefficient, revealing sensitivity to environmental fluctuations.

The grain yield performance of cultivar; “Chekota” was poor. It produced below average grain yield. This cultivar had high deviations from regression indicating sensitivity to environmental changes. This cultivar cannot be recommended due to its overall poor performance.

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