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Estimates of Genotype x Environment Interactions and Heritability of Black Point in Durum Wheat

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Abstract

Experiments were carried out in four different locations with 14 durum wheat genotypes in two successful seasons of 1999- 2000 and 2000-2001. Black point disease of genotypes was evaluated by interactions of genotypes and environment as well as heritability (h^2). It was found that black point disease affected differently in different locations and growing seasons. This indicates that the genotypes have different adaptation ability for traits studied in different locations. Heritability rate that variance analyzes accepted means squares calculated was found as phenotypic variance rate of genotypic variance was found as 49%. Variance of genotype x location x year was bigger than other variance components. Genotype x year variance was bigger than genotype x location variance too. The heritability of black point disease was founded moderate. In addition to one of factors on the black point disease genotype also environment x genotype interactions were found effective. According to evaluation of black point disease, the highest value was obtained from 'Sorgül' (2.7%), 'Dicle-74' (2.56%) and 'Gidara-II' (2.32%) varieties; the least value was obtained from 'Balcali-2000' variety (0.64%). *Alternaria* spp., *Phoma* sp, *Fusarium* spp., *Helminthosporium* spp., and *Stemphylium* spp., fungi were isolated from the grain affected by black point diseases.

Keywords: wheat varieties, black point, environment x genotype interaction, heritability.

Introduction

Wheat is one of the world's three most important cereal crops (the other two are maize and rice) and it has the widest distribution of any cereal. The crop is primarily grown for its grain, which is consumed as human food. *Durum wheat* is a minor crop, grown in only 8 to 10% all the wheat cultivated area.

Combine analyses done over the multi location are used for determination of genotype x environment interaction and theirs variance components. This method occupies important place to estimate the heritability and selection of characters (Crossa, 1990). Information about phenotypic stability is useful for the selection of crop varieties as well as for breeding programs (Akçura *et al.*, 2005). The phenotypic performance of a genotype is not necessarily the same under diverse agro-ecological conditions (Ali *et al.*, 2003). Some genotypes may perform well in certain environments, but, fail in several others. Genotype-environment (GE) interactions are extremely important in the development and evaluation of plant varieties because they reduce the genotypic stability values under diverse environments (Hebert *et al.*, 1995).

Black point disease is characterized by a brown black discoloration of the embryos of the wheat (*Triticum durum* L.) kernels. Genetic factors are important in durum susceptibility to black point. Empirical multi location registration trials have long since show durum cultivars differ considerably in black point susceptibility (Geves, 1994). The disease can be a problem in wheat areas receiving heavy rainfall during the early stages of kernel development (Greaney and Wallace, 1943; Kilpatrick, 1968). The disease can reduce the commercial grade of wheat causing economic losses to wheat producers. Besides, TMO (Turkish Grain Council) assesses the grain as called black point over the 10% injury. Black pointed kernels have also an adverse effect on the quality of the flour (Rees *et al.*, 1984; Lorenz, 1986). This disease is resistance under different genetic control in certain cultivars (Conner and Davidson, 1988).

Alternaria sp., Cladosporium sp., Drechslera sp., Epicoccum sp., Fusarium sp., and *Phoma sp.*, were isolated from black pointed kernels of wheat cultivars grown in Central Anatolia, Southern Anatolia and Çukurova regions in Turkey (Biçici and Çınar, 1988; Tunalı and Aktaş, 1999; Sağır and Akıncı, 2001). In all these studies fungi were determined by plating the intact kernels on agar medium or on moistened filter paper. The presence of fungal mycelium in different parts of black pointed kernels has been determined by microscopically observations (Bhowmink, 1969; Lorenz, 1986; Agrawal *et al.*, 1987).

In addition, recent studies have determined some markers for identifing for black point disease. Markers have been identified on chromosomes 2 H and 5H (Fox *et. al.*, 2004). Sulman *et al.* (2003) also reported levels of

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heritability from 39 to 70+% in a number of populations suggesting that development of resistance to this grain defect was readily achievable through selection.

This present study was undertaken to describe the fungi relation with genotype x environment interactions as well as heritability (h^2). In this study 14 durum wheat cultivars planted in four different locations in south-eastern Anatolia in Turkey.

Materials and methods

According to plant materials and field conditions fourteen durum wheat genotypes were designed by a randomized complete block design with 4 replications. The names and code numbers of genotypes/cultivars of durum wheat genotypes are given in Tab. 1. The experiment was performed under rainfed and supplemented irrigation conditions in the 1999-2000 and 2000-2001 growing seasons in 4 different locations in South-eastern Anatolia: Diyarbakır-1, Diyarbakır-2, Akçakale and Ceylanpınar. The seeds were sown using an experimental drill in 1.2 m x 7 m plots consisting of 6 rows with a 20 cm row space. The seeding rates were about 450 seeds per m^2 for all locations. The plots were fertilized with 60 kg N ha^{-1} and 60 kg P_2O_5 ha^{-1} at the planting and 40 kg N ha-1 in spring at stem elongation for Diyarbakır rainfed condition, 50 kg P_2O_5 ha^{-1} and 50 kg N ha^{-1} at planting and 50 kg N ha^{-1} in spring at stem elongation for Ceylanpınar and Akçakale rainfed conditions. However, plots were fertilized with 80 kg N ha^{-1} and 80 kg P_2O_5 ha^{-1} at planting and 60 kg N ha^{-1} in spring at stem elongation for Diyarbakır irrigation condition. For Plots 1.2 m x 5 m size were harvested by a combined harvester All field conditions such as growing seasons, environments, soil properties, fertilization treatments, and the rainfall at each location during the growing period and sowing date and harvesting date are summarized in Tab. 2.

Tab 1. Pedigrees and other information related to genotypes used in 8 environments.

Code	Cultivars	Pedigrees
1	'Altintoprak-98'	Altar84/AOS "S"–CD67124.1Y-503M-OY
2	'Aydin-93'	OMRABİA "S"
3	'Ceylan-95'	Stk "S"/Rabi "S"
4	'Dicle-74'	Cocorit 71=RA_E-TC^4 x stw63// AA "S" D.27617-18M-6Y-OM
5	'Diyarbakır-81'	LD.393 x Belle-Tc^2Cit71. SE:0.364-1S-4S-OS
6	'D.5456'	(hybridization) 100 D X Semolina
7	'Ege–88'	JO/AA//FG CM9799-126M-1M-4Y-0M
8	'Fırat-93'	AA "S" /Vol "S" //Fg "S" /3/Shwa "s" CM:2798-6-1M-2Y-1Y-OM
9	'Gidara-II'	Gidara
10	'Ozberk'	Fg"s"/Gr"s"//CandealI/4/Grebe/3/Ctfn/ Fg"s"//Ptl"s"/5/Akb.073.44/Yerli/6/Car"s"
11	'Harran-95'	Korifla (D.S.15 Gieger) =Korifla CD523-3Y-1Y-2M.OY
12	'Sarıçanak-98'	Daki "S"
13	'Sorgul'	Local population
14	'Balcali 2000'	MAGH72/FG*s*//CR"S"/USA2299/3/ YAV*S*/4/DACK/RABI*S*//WIN*S*

Percentage of Black point (%), is determined by counting the number of infected kernels in given sample and dividing by the total of number of seeds in the sample. All the experiments were arranged in a completely randomized design. Data on the incidence of fungi and, the percentage of black point disease of grain were subjected to an angle (arc sin) transformation prior to analysis of variance (ANOVA) procedures of JMP-5.0.1 (SAS Institute Inc. 2002). Means were compared with the level of 5 % for Tukey Range Test.

Five fungal isolates were obtained from contaminated seeds of 14 wheat cultivars. Contaminated seeds have a black point; this characteristics symptom of the disease caused by Alternaria spp., Phoma sp, Fusarium spp., Helminthosporium spp. and Stemphylium spp. Spores of all varieties from this isolate were put into Petri dishes with PDA (potato-dextrose-agar) culture medium. After seven days at a temperature of 24 ± 2°C and a photoperiod of 12 h, small blocks of the culture medium with fungus mycelia were transferred to 250 ml Erlenmeyer flasks with 25 ml of

Tab. 2. Site description and agronomic details

Code	Growing season	Environments	Soil properties	Fertilization kg h^{-1}		Rain fall mm	Irrigation mm	Sowing date	Emergency date
				N	P2O5				
E1	2000-2001	Diyarbakır -1	pH= 7.4 clay-silt	60+60	60	245	-	01.11.99	16.01.00
E2	1999-2000	Diyarbakır -2	pH= 7.4 clay-silt	80a+60b	80a	245	150	01.11.99	16.01.00
E3	2000-2001	Diyarbakır -1	pH= 7.4 clay-silt	60-60	60	537	-	09.11.00	27.11.00
E4	1999-2000	Diyarbakır -2	pH= 7.4 clay-silt	80+60	80	537	100	09.11.00	27.11.00
E5	1999-2000	Akçakale	Ph=7.8 clay-silt	50+50	50	212	-	28.10.99	25.12.99
E6	2000-2001	Akçakale	Ph=7.8 clay-silt	50+50	50	319	-	27.11.00	16.12.00
E7	1999-2000	Ceylanpınar	Ph=7.8 clay-silt	50+50	50	156	-	11.11.99	14.12.00
E8	2000-2001	Ceylanpınar	Ph=7.8 clay-silt	50+50	50	295	-	24.11.00	18.12.00

a Seed-bed; b Stem elongation Source: Anonim (2001)

Tab. 3. Total rain and irrigation (mm) and average maximum and minimum temperatures (°C) for Diyarbakır, Ceylanpınar and Akçakale, (May) 2000 to 2001.

			Irrigation	Temperature (°C) w	
Location, year	Period	Rain (mm)x	Amount (mm)y	Min.	Max.
Diyarbakır -1					
2000	1-31 May	6.1	50 (1)	10.8	28.4
2001	1-31 May	86.9	50 (1)	9.8	23.5
Diyarbakır -2					
2000	1-31 May	6.1	NA	10.8	28.4
2001	1-31 May	86.9	NA	9.8	23.5
Ceylanpınar					
2000	1-31 May	7.2	NA	10.0	37.4
2001	1-31 May	47.2	NA	9.0	38.0
Akçakale					
2000	1-31 May	10.6	NA	12.5	30.5
2001	1-31 May	52.1	NA	11.3	27.9

w Minimum and maximum mean temperatures during grain filling period.
x Amount of rain during grain filling period .
y Amount of irrigation during grain filling period (number of applications).
z NA = not applicable
Source: Anonim (2001)

modified liquid Fries medium (Luke and Wheeler, 1955) or 1000 ml Erlenmeyer flasks with 200 ml of modified Fries medium and small balls of glass. *Fungus* culture was incubated for 21 days in an orbital incubator at a temperature of 24 ± 2°C. After incubation, the fungus mycelium was separated from the liquid phase by filtering through Whatman No. 1 filter paper. The filtrate was concentrated at 45°C in a steam bath in a vertical flux chamber to 10% of its original volume (Barbieri *et al.*, 1997).

Statistical analyses. A combined analysis of variance was first undertaken across the test environments. Then broad-sense heritability was determined by means of variance components calculated from expected means squares from the ANOVA as proposed by Sabancı (1992), Demir and Turgut (1999) by using the following formula;

$H = Q^2_g / Q2\ ph = Q^2_g / (Q2_g + Q^2_{gl} / l + Q^2_{gy} / y + Q^2_{gyl} / ly + Q^2_e / _{rly})$ where Q^2_g is the genotypic variance; Q^2ph is the phenotypic variance; Q^2_{gl} is the variance for interaction of genotypes with locations; Q^2_{gy} is the variance for genotypes with years; Q^2_{gy}l is the variance for genotypes, locations and years; and Q^2_e is the variance for error. All statistical analyses were performed by using SAS (Statistical Analyses Systems) program (SAS Institute, 2002).

Results and discussion

In this study, black pointed kernels appeared to have high frequency of Alternaria spp.(Tab. 4), Sağır and Akıncı (2001) and Sönmez *et al.* (2005) reported that they found *Alternaria spp.* (84.3%), Fusarium spp (9.3%) and *Helminithosporium sp.* (6.2%) from isolated black pointed kernels in south-eastern Anatolia. The occurrence of *Alternaria alternata* as a dominant species on black pointed kernels and other fungi, except for *Stemphylium botryosum* and *Fusarium culmorum*, agrees with other reports (Greaney and Wallace, 1943; Rana and Gupta, 1982; Khanum *et al.*, 1987; Conner and Kuzyk, 1988; Fakir *et al.*, 1989; Zhang *et al.*, 1990; Fernandez *et al.*, 1994).

The environmental factors, especially high rainfall at anthesis or milk development stages were probably responsible for black point as previously reported (Kilpatrick, 1968; Adlaka and Joshi, 1974; Conner *et al.*, 1990).

Estimates for pertinent variance components were given in Tab. 5. While genotype x location interactions, year x location interactions, locations, years and genotypes were highly significant ($P < 0.01$), the genotype x location x year interactions was important ($P<0.05$). The presence of genotype x location interactions indicates that particular genotypes tended to rank differently in black point rate at different locations; Moreover, the genotype x year interaction indicates that genotypes tended to rank differently in black point rate at different years (Tab. 5).

The result of combined analysis over the years and locations indicated that there were significant ($P<0.005$ level) differences between varieties. While the highest percentage of black point was obtained from 'Sorgül' cultivar (16.85%) in Diyarbakır-1 location in 2000/2001 growing season, the lowest percentage black rate were obtained from 'Balcali-2000' cultivar (0.05%) in Diyarbakır-2 and Akçakale locations in 1999/2000 growing season (Tab. 6).

The local 'Sorgül' and 'Dicle-74' were the most susceptible and the 'Balcali-2000' cultivar was the most resistant to black point. These results were also reported by Southwell at all (1980). They reported that resistance of durum

Tab. 4. The incidence of fungi detected by black pointed kernels of four locations in 2000 and 2001

Locations	Percentage of wheat kernels contaminated with						
	Alternaria spp.	*Fusarium spp*	*Phoma sp*	*Stemphylium spp.*	*Helminthosporium spp*	Others	Total
Diyarbakır-1	80.0	-	-	-		20	100
Diyarbakır-2	69.0	4.8.0	11.9	7.1	4.8	2.4	100
Akçakale	69.0	8.0	15.4"	-	-	7.7	100
Ceylanpınar	69.2	6.2	-	-	24	-	100
Means	70.4	4.93	8.64	3.70	7.40	4.93	

Tab. 5. Analysis of variance and variance components for black point percentage of 14 durum wheat genotypes

Source of variation	df	Sum of Square	Means Square	F
Model	135	11698.325	86.6543	Prob > F
Replications (LxY)	24	122.9099	5.12124	783.0523
Genotypes (G)	13	451.2995	34.7153 **	398.9437
Years (Y)	1	2813.5177	2813.51 **	307.5568
Locations (L)	3	4300.2306	1433.41 **	1.4253
GxY	13	131.4421	10.1109 **	9.6619
GxL	39	333.4326	8.54955 **	2.8141
YxL	3	3315.1671	1105.05 **	2.3795
GxYxL	39	230.3256	5.90578 *	1.6437
Pooled Error	312	1121.020	3.5930	Prob > F
Corrected Total	447	12819.345		

**significant at 0.01 probability level. *significant at 0.05 probability level.

wheat cultivars to black point caused by *Alternaria alternata* was evaluated in the field in northern New South Wales. The cultivars tested showed a range of infection levels. The most susceptible cultivars were 'Duramba' and 'Gaza', while those showing the greatest resistance were 'Wandell', 'Wascana' and 'Aus 15350'.

Heritability: To determine proportional effect of environment factors on black point dividend variance resources were given in Tab. 7.

G x L x Y effects were fairly large (2.32) relative to genotype main effects, and G x L (0.165) and G x Y (0.525) effects were smaller, as estimated by components of variance. These findings are in accordance with those of as Barbieri *et al.* (1997), Sulman *et al.* (2003) and Fox *et al.* (2004). Just as Barbieri at al (1997) reported that the heritability values for the genotypes along the generations analyzed showed that the environment is responsible for 50%. In addition, more recent studies have identified markers for black point. Markers have been identified on chromosomes 2H and 5H (Fox *et al.*, 2004). Sulman *et al.* (2003) also reported levels of heritability from 39 to 70+% in a number of populations suggesting that development of resistance to this grain defect was readily achievable through selection.

Conclusions

Fourteen durum spring wheat varieties (*Triticum durum* L.) comprising commercial cultivars were studied in the eight different environments, to determine the genotype x environment interactions and heritability. Genotype x environment interactions found significant indicated that the black point should be undertaken for several environments. It was showed that black point indicated moderate heritability (49%). While developing a breeding program for resistance to black point stem from *H. satívum* in the field, it is of fundamental importance to have an efficient environmental control through suitable plot size and large number of replications in various years and sites to allow an increase in the trait heritability (Barbieri *et al.*, 1997).

Tab. 6 Means and Tukey test of black point percentage (%) of multi location base on analysis of variance over eight locations in South-eastern Anatolia

Cultivars	1999/2000				2000/2001				Means
	E1	E2	E3	E4	E1	E2	E3	E4	
'A.Toprak-98'	0.79 g-I	0.00 l	1.54 e-l	0.24 h-l	8.48 bcd	1.02 e-l	1.57 e-k	0.44 g-l	1.76 BC
'Aydın-93'	0.21 i-l	0.00 l	0.67 g-l	0.11 jkl	9.58 bc	0.23 i-l	0.93 g-l	0.21 i-l	1.49 CD
'Ceylan-95'	0.23 h-l	0.00 l	1.45 e-l	0.18 i-l	11.93 abc	1.15 e-l	1.28 e-l	0.43 g-l	2.08 BC
'Dicle-74'	0.55 g-l	0.00 l	4.04 def	0.53 g-l	10.83 abc	1.80 e-j	2.10 e-i	0.62 g-l	2.56 A
'Dyb.-81'	0.73 g-l	0.00 l	2.26 e-h	0.29 g-l	9.90 bc	0.69 g-l	1.38 e-l	0.25 g-l	1.94 ABC
'D. 5456'	0.27 h-l	0.00 l	0.97 g-l	0.35 g-l	6.85 cd	0.75 g-l	1.53 e-l	0.68 bg-l	1.42 BC
'Ege–88'	0.65 g-l	0.00 l	0.96 g-l	0.11 jkl	9.75 abc	1.55 e-k	1.40 e-l	0.37 g-l	1.85 BC
'Fırat-93'	0.59 g-l	0.04 kl	1.45 e-l	0.05 kl	8.48 bcd	1.66 e-l	1.89 e-l	0.40 g-l	1.82 BC
'Özberk'	0.13 jkl	0.00 l	1.32 e-l	0.47 g-l	13.55 ab	1.52 e-l	1.53 e-k	0.86 g-l	2.42 AB
'Gidara-II'	0.75 g-l	0.08 kl	2.80 efg	0.48-g-l	9.65 bc	1.93 e-k	2.07 e-l	0.80 g-l	2.32 A
'Harran-95'	0.67 g-l	0.00 l	0.76 g-l	0.41 g-l	9.43 bc	0.75 g-l	1.45 e-i	0.57 g-l	1.75 BC
'S. Çanak-98'	1.40 e-l	0.00 l	1.13 f-l	0.33 g-l	11.08 abc	0.86 g-l	2.41 e-l	0.58 g-l	2.22 AB
'Sorgül'	0.91 g-l	0.09 l	0.46 g-l	0.22 h-l	16.85 a	1.00 e-l	1.41 efg	0.70 g-l	2.71 AB
'Balcali-2000'	0.24 h-l	0.05 kl	0.05 kl	0.13 i-l	4.08 de	0.40 g-l	0.12 e-l	0.06 kl	0.64 D
Means %	0.58	0.02	1.42	0.28	10.03	1.09	1.50	0.50	

*:Means followed by different letters within a column for each year in significant differences at the level of P<0.05 for Tukey Range Test.

Tab. 7. Tab II. Components of variance and broad sense heritability (h^2) of percentage of black point.

G x L variance	G x Y variance	G x L x Y variance	Genotype variance	Phenotype variance	Heritability %
0,165**	0,525**	2,32*	0,686**	1,392	0,49

**significant at 0.01 probability level. *significant at 0.05 probability

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