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The Population Vigors of Diallel F_4 Offsprings of Six Bread Wheat Genotypes for Grain Yield under Irrigated and Rain-Fed Conditions

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ABSTRACT

Grain yield estimate from early segregating populations is an interesting feature of today's wheat breeding programs, and F_1 populations are generally recommended as the most suitable population by researchers. In the present study, we evaluated the population vigor of diallel F_4 offsprings of six bread wheat genotypes (Sultan, Bezostaya, Süzen, Harmankaya, Altay and Gerek) under irrigated (IR) and rain-fed conditions (RF). The experiment as two sets under IR and RF were established in the field of Anatolian Agricultural Research Institute, Eskişehir. The mean of grain yield (5468 kg ha^{-1}) of F_4 populations in RF and IR had been lower than the mean of genotypes (5654 kg ha^{-1}). The mean of grain yield of genotypes (7062 kg ha^{-1}) under IR was higher than F_4 populations (6703 kg ha^{-1}), while genotypes and F_4 populations were nearly similar under RF (4246 kg ha^{-1} and 4234 kg ha^{-1}, respectively). The mid-variety population vigor for grain yield varied from -6.70% (Hrm/Grk) to 8.77% (Bez/Grk) under RF, and from -22.58% (Sltn/Alty) to 10.87% (Bez/Süzen) under IR. There was not positive significance population vigor in F_4s. According to results under RF and IR, F_4 populations are observed as the most suitable populations for realistically estimation of grain yield performance of populations.

Keywords: Wheat; Population vigor; Grain yield; F_4 offspring

Altı Ekmeklik Buğday Genotipinin Diallel F_4 Melez Döllerinde Sulu ve Yağmura Dayalı Koşullar Altında Populasyon Güçleri

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ÖZET

Erken dönemde açılan populasyonlardan verim tahmini yapmak günümüz ıslah programlarında ilgi çekici bir özellik olup, genellikle F_1 populasyonlarının bu amaçla kullanımı araştırmacılar tarafından önerilir. Sunulan bu çalışmada, yağmura dayalı (RF) ve sulu şartlar altında (IR) altı ekmeklik buğdayın (Sultan, Bezostaya, Süzen Harmankaya, Altay

ve Gerek) diallel F_4 melez döllerinde populasyon güçleri değerlendirilmiştir. Deneme, IR ve RF şeklinde iki set olarak Eskişehir Anadolu Tarımsal Araştırma Enstitüsü arazisinde kurulmuştur. RF ve IR'deki F4 populasyonlarının dane verim ortalamaları (5468 kg ha^{-1}) çeşitlerin ortalamasından daha düşüktü (5654 kg ha^{-1}). IR'de çeşitlerin dane verimi ortalaması (7062 kg ha^{-1}) F_4 populasyonlarından (6703 kg ha^{-1}) yüksek çıkarken, RF altında hemen hemen yakın çıkmıştır (sırası ile 4246 kg ha^{-1} and 4234 kg ha^{-1}). Dane verimi açısından ebeveyn ortalamasına göre populasyon gücü RF altında -6.70% (Hrm/Grk) ve 8.77% (Bez/Grk) arasında değişirken, IR altında -22.58% (Sltn/Alty) ve 10.87% (Bez/Süzen) arasında değişmiştir. F_4 populasyonlarına ait populasyon güçlerinin hiç birinde pozitif önemli bir sonuç çıkmamıştır. RF ve IR altındaki sonuçlara göre, F_4 populasyonlarının gerçekçi dane verim performansı tahmini için en uygun populasyonlar olduğu gözlenmektedir.

Anahtar Kelimeler; Populasyon gücü; Dane verimi; F_4 melez dölü

1. Introduction

Wheat is an important crop being a staple food in Turkey (Yildirim et al 2008). In Turkey, per capita wheat consumption is 228.7 kg. Wheat production is 20.1 million tons under cultivated areas in Turkey (TSI 2012). However, its production fluctuates year to year because of the change of environment conditions and the use of sensitive genotypes to unfavorable environment. There are significant differences between the wheat genotypes for most of the traits (Awan et al 2007). There is an urgent need to study genetic diversity used germplasm in order to keep a desirable level of genetic variation of wheat in future breeding (Gulnaz et al 2012). High grain yield in wheat has been the main aim in wheat breeding studies was focused on attempts to improve the yield potential by new genotypes (Kusaksiz & Dere 2010).

Grain yield estimate from early segregating populations is an interesting feature of wheat breeding programs of today, due to the high annual variation in wheat average yield, particularly under irrigated and rain-fed conditions. Wheat breeders try to estimate high-yielding genotypes from early segregating populations (Tuhina-Khatun 2010; Josekutty 2011). In bread wheat, heterosis over mid and better parent has the key importance (Akbar et al 2010). Therefore, breeders look at grain yield performance of segregating populations. Breeders use mid-variety vigor and high-variety vigor to estimate grain yield performance from segregating populations (Yildirim 2005; Krystkowiak et al 2009). Generally, they use hybrid vigor of F_1 offspring (Lonnquist & Gardner 1961; Cress 1966; Yildirim 2005). In reality, the most suitable population for the estimation of high grain yield performance is F_4 segregating population. The selection in advanced generations might be effective for grain yield in wheat (Erkul 2010). Because, F_4 populations have higher purity compared to F_1 populations (more than 90% level). The heritability for grain yield at F_4 is also higher than F_1 (Bhullar et al 1977). So, single plant selection from F_4 can give a better result for grain yield in a breeding program (Josekutty 2011). Not only parental selection is the most important for wheat crossing program (Josekutty 2011) but also plant selection from F_4 population for high yield potential is the most important under both irrigated and rain-fed conditions. Therefore, in Turkey, single plant selection from F_4 population for irrigated and rain-fed conditions are made by Turkish breeders. In Turkish wheat breeding program, F_4 populations are usually evaluated in different environments (irrigated and rain-fed) before plant selection suitable ones.

2. Materials and Methods

2.1. Study site description

The study was carried out at the experimental field of Anatolian Agricultural Research Institute in Eskişehir (located at 39°45' N latitude, 30°33' E longitude at an altitude of 801 m above sea level) during 2005-2006 growing season. Rainfall during the 11-month growing season (from 1st September

2005 to 31st July 2006) was 280.3 mm (Figure 1). The average of long-term precipitations from 1926 to 2006 was 340.8 mm. In experimental years, the experimental field had lower rainfall about 60.5 mm than long-term. In addition to that March, April and May had lower rainfall according to long-term. The precipitation of these months is very important for wheat growing in this area. Soil analysis indicated the soil of field to be loamy, slightly alkaline and medium in terms of organic matter and calcium, poor in terms of available phosphorus and rich in terms of available potassium.

2.2. Experimental design

This study included two parts, which were irrigation and rain-fed conditions. The first condition part (IR) was irrigated three times at 3rd April, 8th May and 5th June in 2006 and the second condition part (RF) was not irrigated under rain-fed condition. The flood irrigation method was used for IR. Six winter wheat genotypes, such as Sultan (Sltn), Bezostaya (Bez), Süzen (Szn), Altay (Alty), Harmankaya (Hrm), Gerek (Grk) and their half diallel 15 F_4 offspring populations, were included in this experiment. The half diallel crosses among six genotypes for F_4 populations were made in 2002, and F_1 hybrids were grown 2002-2003 growing seasons in Eskişehir (Yildirim 2005). F_2 and F_3 populations were grown in bulked (in 2003-2004 and 2004-2005 growing seasons, respectively). The experiment was set up in a randomized complete block design with three replications. Plant material was sown on 12th October 2005. Plots in the trial consisted of four 5-m rows (20 cm between rows) sown at a rate of 500 seeds/m^2. Fertilizer was applied DAP (150 kg N ha^{-1}) before planting and AN (200 kg P_2O_5 ha^{-1}) at the shooting stage (Zadoks 1974). Given that crop plants are more susceptible to herbicide at the early growth stage (Qasem 2011), weed-control was performed by herbicide application at the main shoot stage (Zadoks 1974).

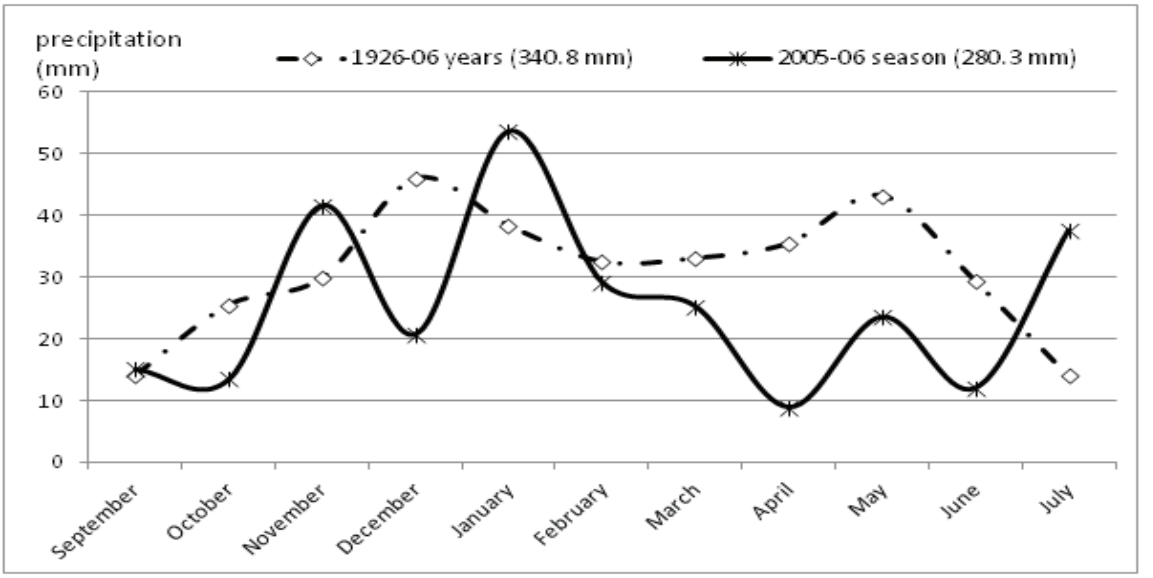

Figure 1- The averages of monthly rainfall (mm) of experimental year and over the long-term in Eskişehir (Anatolian Agricultural Research Institute Meteorology Station)

Şekil 1- Eskişehir'de deneme sezonuna ve uzun yıllar ortalamasına ait aylık ortalama yağışlar (Anadolu Tarımsal Araştırma Enstitüsü Meteoroloji İstasyonu)

2.3. Measurements and statistical analysis

The harvesting was made on 14th July 2006 using combine harvester machine. Grain yield (g) was weighed per plot and converted to kg ha^{-1}. In this study, grain yields of fifteen F_4 offspring populations with their six parents were only evaluated and irrigated, and rain-fed were compared to each other.

The Data from irrigated rain-fed conditions was analyzed using the MSTAT-C Statistical Program (1986). Differences between means were determined by LSD (Kalayci 2005) and were considered significant at $P \leq 0.05$ (Mohammed 2009). Mid-variety population vigor (PvM) and high-variety population vigor (PvH) were calculated in comparison to genotypes using the following formulas (Ozgen 1989; Budak & Yildirim 1996; Dagustu & Bolek 2002; Dagustu 2008; Beche et al 2013) separately for irrigated and rain-fed conditions.

$$PvM = \frac{F_x - M_v}{M_v} 100 \quad (1)$$

$$PvH = \frac{F_x - H_v}{H_v} 100 \quad (2)$$

Where; F_x, mean performance of F_4; Mv, mean of mid parental value (= (Parent1 + Parent2) / 2); Hv, mean of high parental value; PvM , mid-variety population vigor; PvH, high-variety population vigor.

The t-test was used to determine whether PvM and PvH were statistically different at $P \leq 0.01$ and $P \leq 0.05$ from mid-variety and high-variety means, following formulas given by Panse and Sukhatme (1961).

$$PvM - t = \left(\frac{3E_r}{2R_p}\right)^{1/2} \quad (3)$$

$$PvH - t = \left(\frac{E_r}{R_p}\right)^{1/2} \quad (4)$$

Where; Er, error sum of squares for analysis of variance; Rp, number of replications; t, 't' test from table value at error degrees of freedom corresponding to 5% or 1% level of significance; PvM-t, difference for mid-variety population vigor ; PvH-t, difference for high-variety population vigor.

3. Results and Discussion

3.1. Grain yield

The effect of genotypes (G), conditions (C) and their interactions (G x C) on grain yield were highly significant ($P \leq 0.01$) according to combined analysis of variance. The effect of G on grain yield was also statistically highly significant ($P \leq 0.01$) in separately for irrigated and rain-fed conditions, too. Average grain yield of six genotypes and their 15 F_4 offspring populations are shown in Table 1. Average grain yield at the two combined conditions in this study ranged from 6388 kg ha^{-1} at Harmankaya to 4764 kg ha^{-1} at Bezostaya. The difference between genotype mean and F_4 populations mean (5654 kg ha^{-1} and 5468 kg ha^{-1}, respectively) at the two combined conditions was 186 kg ha^{-1}.

Average grain yield of the IR was higher (60.6%) than the RF. The mean of genotypes at the IR was higher (66.3%) than the mean of the RF and the mean of F_4 populations at the IR was also higher (58.3%) than the mean of the RF. In the RF, Gerek was the highest yielding genotype with 4851 kg ha^{-1}, and Sultan was the lowest with 3430 kg ha^{-1}. This result is an expected situation because Gerek is a rain-fed genotype, and Sultan is an irrigated genotype in Turkey. Grain yield of the F_4 populations ranged from 3708 kg ha^{-1} for Sltn/Bez to 4590 kg ha^{-1} for Bez/Grk. In the IR, Harmankaya was the highest yielding genotype with 8245 kg ha^{-1}, and Bezostaya was the lowest with 5939 kg ha^{-1}. Grain yield of the F_4 populations ranged from 5743 kg ha^{-1} for Sltn/Alty to 7936 kg ha^{-1} for Alty/Hrm. The differences between IR and RF of six genotypes and their 15 F_4 offspring populations ranged 31.9% at Gerek to 121.7% at Sultan. Sltn/Bez had the highest difference with 87.8% between IR and RF.

3.2. Population vigors

Among parents, the lowest series mean of mid-variety population vigor (PvM) for grain yield was recorded by Harmankaya (-2.72%) and the highest by Bezostaya (2.39%). As shown in Table 2 below, The PvM for grain yield over mid-variety varied from -6.70% (Hrm/Grk) to 8.77% (Bez/Grk) under

Table 1- The average grain yield performances (kg ha^{-1}) of six bread wheat genotypes and their 15 F_4 offspring populations under irrigated (IR) and rain-fed (RF) testing conditions and in Eskişehir experimental field

Çizelge 1- Eskişehir deneme tarlasındaki sulu (IR) ve yağmura dayalı (RF) test şartlarında altı ekmeklik buğday ve bunların 15 F_4 melez döllerinin ortalama dane verim performansları (kg ha^{-1})

Genotypes and F_4 Populations	*RF*		*IR*		*Average of RF and IR*		
	kg ha^{-1}	*Rank*	*kg ha^{-1}*	*Rank*	*kg ha^{-1}*	*Rank*	*Differences (%)**
Sultan	3430	21	7603	3	5517	12	121.7
Bezostaya	3589	20	5939	19	4764	21	65.5
Süzen	4499	8	6956	12	5727	6	54.6
Altay	4578	3	7233	4	5906	3	58.0
Harmankaya	4531	4	8245	1	6388	1	82.0
Gerek	4851	1	6397	14	5624	7	31.9
Sltn/Bez	3708	19	6962	11	5335	16	87.8
Sltn/Szn	4238	13	6973	10	5606	8	64.6
Sltn/Alty	4070	15	5743	21	4907	20	41.1
Sltn/Hrm	3727	18	6664	13	5196	18	78.8
Sltn/Grk	4240	12	5757	20	4999	19	35.8
Bez/Szn	3967	17	7148	5	5558	10	80.2
Bez/Alty	4037	16	7025	9	5531	11	74.0
Bez/Hrm	4083	14	7040	8	5562	9	72.4
Bez/Grk	4590	2	6343	15	5467	13	38.2
Szn/Alty	4481	9	7071	6	5776	5	57.8
Szn/Hrm	4501	7	7059	7	5780	4	56.8
Szn/Grk	4527	5	6303	17	5415	14	39.2
Alty/Hrm	4520	6	7936	2	6228	2	75.6
Alty/Grk	4444	10	6189	18	5317	17	39.3
Hrm/Grk	4377	11	6328	16	5352	15	44.6
Genotypes mean	4246		7062		5654		66.3
F_4 mean	4234		6703		5468		58.3
General mean	4237		6806		5521		60.6
CV (%)	7.1		7.5		7.6		
LSD (P<0.05)	470		843		482		79.4

*, (irrigated – rain-fed) x 100 / rain-fed

Table 2- Estimation of mid-variety and high-variety population vigor for grain yield under rain-fed condition (RF)

Çizelge *2- Yağmura dayalı koşullar (RF) altında dane verimi için ebeveyn ortalaması ve yüksek ebevenyne göre populasyon güçlerinin tahminlenmesi*

Varieties	*Vigor*	*Sultan (1)*	*Bezostaya (2)*	*Suzen (3)*	*Altay (4)*	*Harmankaya (5)*	*Gerek (6)*
1	PvM		5.65	6.89	1.64	-6.38	2.40
	PvH		3.31	-5.80	-11.10 *	-17.75 **	-12.60 *
2	PvM			-1.91	-1.15	0.57	8.77
	PvH			-11.83 *	-11.83 *	-9.88	-5.38
3	PvM				-1.27	-0.31	-3.17
	PvH				-2.12	-0.66	-6.69
4	PvM					-0.76	-5.74
	PvH					-1.27	-8.39
5	PvM						-6.70
	PvH						-9.78 *
Series mean	PvM	2.04	2.39	0.05	-1.46	-2.72	-0.89
	PvH	-8.79	-7.12	-5.42	-6.95	-7.87	-8.57
General mean	PvM				-0.10		
	PvH				-7.45		

PvM, mid-variety population vigor; PvH, high-variety population vigor; *, **, significant at P <0.05 and P < 0.01probability level respectively

RF. Among fifteen F4 populations, not only there were six positive mid-variety population vigor values but also they were non-significant. All of them also were populations of Sultan and Bezostaya genotypes. However, all of fifteen F_4 populations had non-significant under RF condition not only positive but also negative. The high-variety population vigor (PvH) for grain yield over high-variety varied from -17.75% (Sltn/Hrm) to 3.31% (Sltn/Bez) under RF. Out of nine F_4 populations, six F_4 populations exhibited negatively significant at PvH. The PvM and PvH were desirable parameters for grain yield, but F_4 populations were not satisfactory in this trial.

The PvM for grain yield over mid-variety varied from 10.87% (Bez/Süzen) to -22.58% (Sltn/Alty) under IR (Table 3). There were only five positive PvM values among fifteen F_4 populations. Four F_4 populations exhibited negatively significant at PvM. Among them, three F_4 populations were highly significant (P≤0.01) which are Sltn/Hrm, Sltn/Grk and Sltn/Alty (-15.90, -17.76 and -22.58, respectively). and only Hrm/Grk was significant (-13.57) at P≤0.05 level. Out of eight F_4 populations, seven F_4 populations exhibited negatively highly significant at PvM (P≤0.01). They were Süzen/Hrm, Alty/Grk, Bez/Hrm, Sltn/Hrm, Hrm/Grk, Sltn/Grk and Sltn/Alty, (-14.38%, -14.43%, -14.61%, -19.17%, -23.25%,-24.28% and -24.46%, respectively) under IR.

There was no correlation (r=0.256) between RF and IR in PvM, and there was also no correlation (r=0.388) between them in PvH, too. The population vigors of F_4 populations under IR were observed lower than under RF. This result showed that the water is an important factor for population vigor.

4. Conclusions

To improve the grain yield of wheat under different environments need to identify selection criteria that can identify high-yielding genotypes in variable environments (Najaphy and Geravandi, 2010). In this study, grain yield of parent genotypes and F_4 populations at the IR was higher than at the RF. This result is similar to that reported by Zhou and Chen

Table 3- Estimation of mid-variety and high-variety population vigors for grain yield under irrigated condition (IR)

Çizelge 3- Sulu koşullar altında (IR) dane verimi için ebeveyn ortalaması ve yüksek ebevenyne göre populasyon güçlerinin tahminlenmesi

Varieties	*Vigor*	*Sultan (1)*	*Bezostaya (2)*	*Suzen (3)*	*Altay (4)*	*Harmankaya (5)*	*Gerek (6)*
1	PvM		2.81	-4.21	-22.58 **	-15.90 **	-17.76 **
	PvH		-8.44	-8.29	-24.46 **	-19.17 **	-24.28 **
2	PvM			10.87	6.67	-0.73	2.84
	PvH			2.77	-2.87	-14.61 **	-0.84
3	PvM				-0.33	-7.12	-5.59
	PvH				-2.24	-14.38 **	-9.38
4	PvM					2.54	-9.18
	PvH					-3.75	-14.43 **
5	PvM						-13.57 *
	PvH						-23.25 **
Series mean	PvM	-11.52 *	4.49	-1.27	-4.58	-6.95	-8.65
	PvH	-16.93 **	-4.80	-6.30	-9.55	-15.03 **	-14.44 **
General mean	PvM	-4.75					
	PvH	-11.18 *					

PvM, mid-variety population vigor; PvH; high-variety population vigor; *, **, significant at P < 0.05 and P < 0.01probability level respectively

(2011). Originally, this study is aimed to evaluate the population vigors of F_4 for breeding program under RF and IR, and indicated that PvM and PvH of F_4 populations can be used to estimate grain yield performance near to reality genotype yielding. Why? Yildirim studied (in 2002-2003 growing seasons) mid-parent vigor and high-parent vigor of diallel fifteen F_1 offsprings with same genotypes, which are used in this study (Yildirim 2005). He reported that there were eleven positive significant combinations at mid-parent vigor and seven positive significant combinations at high-parent vigor on grain yield per plant among F_1 offsprings. According to Yildirim's result, high-yielding genotypes had to be estimated. However, F_4 populations in this study with same parental genotypes have no positive significant values of population vigors. The F_4 populations have higher purity (more than 90%) compared to F_1 populations. Some parent characteristics can be identified easily by the F_4 generation. The heritability for grain yield at F_4 is higher than F_1 (Bhullar et al 1977). Therefore, selection of the best plants from these parents will be of advantage at F_4 (Josekutty 2011). Single plant selection from F_4 can give a better result for grain yield in a breeding program according to estimate at grain yield performance either F_4 under RF or F_4 under IR.

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