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Inheritance of Grain Yield in a Half-Diallel Maize Population

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Abstract: Inheritance of grain yield, heterosis and combining ability were investigated in maize populations obtained from half-diallel crossing among 9 inbred parental lines. General and specific combining ability effects were significantly different among parental lines. The grain yield was under the dominance gene effect. The parents W 552 and DNB were considered suitable according to their yield capacities and general combining ability effects. The midparent heterosis values ranged from 46.10% (H.96 x DNB) to 573.12% (ALKD 222 x A 632) whereas the useful heterosis values varied between –46.47% (A 619 x A 632) and 10.78% (N 7A x ALKD 90-1), and only 9 crosses had higher grain yields than that of the check variety. Of these crosses, N 7A x ALKD 90-1, N 7A x DNB and N 7A x IDRN Cornell, were considered promising hybrids.

Key Words: Maize, diallel analysis, combining ability, heterotic effect

Yarım Diallel Mısır Populasyonunda Tane Veriminin Kalıtımı

Özet: Dokuz kendilenmiş mısır hattı ve bunların yarım diallel melezlenmesi sonucu oluşturulan populasyonda dane verimine ilişkin kalıtım parametreleri, heterosis ve uyuşma yetenekleri incelenmiştir. Genel ve özel uyuşma yeteneği etkileri yönünden genotipler arasındaki farklılığın istatistiki olarak önemli olduğu saptanmıştır. Mısırda dane veriminin dominant genlerin etkisi altında olduğu bulunmuştur. Verim ortalaması ve genel uyuşma yeteneği etkileri dikkate alındığında; W 552ve DNB hatlarının melez mısır ıslahı için uygun anaçlar olduğu belirlenmiştir. Heterosis değerlerinin %46.10 (H.96 x DNB) ve %573.12 (ALKD 222 x A 632) arasında değiştiği, buna karşın kullanılabilir heterosisin % –46.47 (A 619 x A 632), ve %10.78 (N 7A x ALKD 90-1) arasında değiştiği ve buna bağlı olarak sadece 9 melezin kontrol çeşitten daha verimli olduğu saptanmıştır. Bu melez kombinasyonlar içerisinde N 7A x ALKD 90-1, N 7A x DNB ve N 7A x IDRN Cornell melezlerinin mısır ıslahında kullanılabileceği kanısına varılmıştır.

Anahtar Sözcükler: Mısır, diallel analiz, uyuşma yetenekleri, heterotik etkiler

Introduction

Providing raw material for the food industry and animal feed, maize (*Zea mays* L.) is one of the major cereal crops. The production area of maize is gradually increasing in Turkey. New maize hybrids thus need to be improved with high yield capacity to meet the demands of maize producers.

Several breeding procedures have been established to increase the grain yields of the maize populations and their hybrids. In order to choose the best hybrid combinations a large number of subjectively chosen inbred lines are crossed. It would be a considerable advantage to be able to estimate the combining ability of parents, gene effects and heterotic effects of crosses before making crosses among inbreed lines. Diallel crossing programs have been applied to achieve this goal by providing a systematic approach for the detection of suitable parents and crosses for the investigated characters. In addition, diallel analysis gives plant breeders the opportunity to choose the most efficient selection method by allowing them to estimate several genetic parameters (Verhalen and Murray, 1967).

Combining ability describes the breeding values of parental lines to produce hybrids. Sprague and Tatum (1942) used the term general combining ability (GCA) to designate the average performance of a line in hybrid combinations, and used the term specific combining ability (SCA) to define those cases in which certain combinations do relatively better or worse than would be expected on the basis of the average performance of the lines involved. In many studies, GCA effects for parents and SCA effects for crosses were estimated in maize

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(Dehghanpour et al., 1996; San-Vicente et al., 1998; Konak et al., 1999; Chaudhary et al, 2000: Araujo et al., 2001; Kalla et al., 2001). Non-additive gene effects for grain yield were found to be significant in maize (Dehghanpour et al., 1996; San-Vicente et al., 1998; Kalla et al., 2001). In addition, heritability degrees varied from low to moderate for grain yield (Dehghanpour et al., 1996; Singh et al., 1998; Kalla et al., 2001; Muhammad and Muhammad, 2002).

Heterosis is defined as the percentage of F_1 over the parental mean, and generally high heterosis values are desirable for grain yield in maize. While Dehghanpour et al. (1996) estimated 152% midparent heterosis for grain yield, Larish and Brewbaker (1999) reported an average of 55% midparent heterosis for variety crosses and 105% heterosis for inbred crosses in maize.

The objectives of this study were to estimate the genetic parameters and heterotic effects and to determine suitable parents and promising crosses for grain yield in a 9 x 9 half-diallel maize population.

Materials and Methods

Nine inbred lines, H 96, A 619, N 7A, W 552, IDRN Cornell, ALKD 222, ALKD 90-1, A 632 and DNB, obtained from the Mediterranean Agricultural Research Institute were crossed in a 9 x 9 half-diallel mating scheme in the 2000 growing season. The parents, their 36 F_1 populations and a commercial hybrid (Tieter), 46 entries in total, were grown at the Agriculture Faculty Experimental Station, Adnan Menderes University Aydın, in the 2001 growing season. The plots were represented by 4 rows, 5 m long and spaced 0.7 m apart with 25 plants per row after thinning. The experiment design was a randomized complete block design with 4 replications. Cultural practices were consistent with the production of maize at this location. Grain yields of each genotype were obtained from the middle 2 rows of the plots and were corrected according to 15% of kernel moisture.

Data obtained from the 36 F_1 progeny and 9 parents were analyzed by Jinks-Hayman type diallel analysis for genetic parameters (Jinks and Hayman, 1953). Griffing's Method 2 Model 1 was then used to analyze combining abilities (Griffing, 1956). The analyses were performed using the TARPOPGEN program (Özcan and Açıkgöz, 1999). Midparent (MP) heterosis (Halluer and Miranda, 1981) and useful heterosis (Davis, 1978) values were calculated by using the mean of the parents, F_1-MP/MP, and the mean of the check variety (MCV; Tieter), F_1-MCV/MCV, respectively. The narrow and broad sense heritability degrees were calculated according to the methods of Crumpacker and Allard (1962) and Mather and Jinks (1971).

Results and Discussion

Preliminary analysis of variance and combining ability of variance indicated that genotypes were significantly different for grain yields (Table 1). The general combining ability (GCA) and specific combining ability (SCA) effects of genotypes were also significantly different for grain yields.

The genetic parameters for grain yield estimated from the 9 x 9 half-diallel cross population are given in Table 2. While a negative F value indicates an excess of recessive alleles in the parents, a positive value shows more dominant alleles than recessive alleles in parents. If the dominant and recessive alleles of each gene are distributed equally among the parents, the F value will be equal to zero (Crumpacker and Allard, 1962).

As an indicator of the relative frequency of dominant and recessive alleles in the parents, the F value was found to be positive but non-significant for grain yield, which means either that no alleles exhibit dominance or else that the dominant and recessive alleles are distributed equally among the parents (Verhalen and Murray, 1967). In our experience, the latter alternative may apply since the variances for H_1 and H_2 were significantly different from zero. It may thus be concluded that the dominant and

Table 1. Mean squares obtained from preliminary analysis and combining abilities in 9 x 9 diallel maize crosses at F_1.

Source of variation	d.f.	Mean Squares
Replication	3	17,501.87
Genotype	44	612,732.12**
Error (Preliminary)	132	18,917.41
G.C.A.	8	106,875.87**
S.C.A.	35	163,473.51**
Error (Combining ability)	132	4,729.35

* and ** indicate significant differences at the 0.05 and 0.01 levels, respectively.

recessive alleles of the related genes are distributed equally among the parents. Since the mean dominance effect of the heterozygote locus (h^2) was significant, high heterotic effect values would be expected for grain yield among crosses.

The parameters, E, an estimate of the genotypic environmental variation and D, the additive genetic variance, were not different from zero (Table 2). The parameter D, which may also include a portion of the additive x additive epistatic variances as well as additive genetic variance itself, was non-significant for grain yield. Dominance variance (H_1) and corrected dominance variance (H_2) were significantly different from zero. It may thus be concluded that grain yield is under the dominance gene effect. This result was also supported by the GCA/SCA ratio (0.65). Similarly, Dehghanpour et al. (1996), San-Vicente et al. (1998), and Kalla et al. (2001) estimated that a non-additive gene effect was involved in maize grain yield.

The estimated heritability degree of yield (narrow sense; 0.236) is consistent with other researchers' results (Dehghanpour et al., 1996; Singh et al., 1998; Kalla et al., 2001; Muhammad and Muhammad, 2002). Since the K value was 3.929, approximately 4 genes will control grain yield. The negative and significant r-value (-0.915) indicates that the parents with high grain yield may carry dominant genes.

The inheritance of grain yield is shown in a Wr–Vr graph in Figure 1. Over-dominance may be inferred from this graph since the regression line cut the Wr axis under the origin. With regard to grain yield, the parents W 552 (4) and H 96 (1) had more dominant genes whereas DNB (9), IDRN Cornell (5), ALKD 90-1 (7), A 619 (2), N 7A (3), ALKD 222 (6) and A 632 (8) carried more recessive genes.

Grain yield and GCA effects of parents are given in Table 3. Significant differences were found for grain yield among parents. While W 552, DNB and H 96 can be considered high yielding parents, N 7A, IDRN Cornell, A 619 and ALKD 90-1 had medium yield capacity. Two parents, W 552 and DNB, had high yield and statistically significant and positive GCA effects.

Grain yield, SCA effects, and midparent and useful heterosis values of the crosses are given in Table 4. Ten

Table 2. Some genetic parameters and ratios estimated from the 9 x 9 diallel cross population in maize.

Genetic parameters and ratios	Grain yield	
F	167,148.7 ± 250,215.4	
h^2	1,889,047.3 ± 136,333.8**	
E	4,721.5 ± 33,918.4	
D	122,088.9 ± 107,259.5	
H_1	542,648.7 ± 226,740.1*	
H_2	480,794.4 ± 193,510.5*	
$(H1/D)^{1/2}$	2.180	
KD/KR	1.962	
$K(h^2/H2)$	3.929	
Heritability Degree (Narrow Sense)	0.236	
Heritability Degree (Broad Sense)	0.965	
r (Yr (Wr + Vr)	-0.915**	
** P < 0.01	$t_{0.01} = 3.499$	$t_{0.05} = 2.365$
* P < 0.05	$r_{0.01} = 0.797$	$r_{0.05} = 0.666$

* and ** indicate significant differences at the 0.05 and 0.01 levels, respectively.

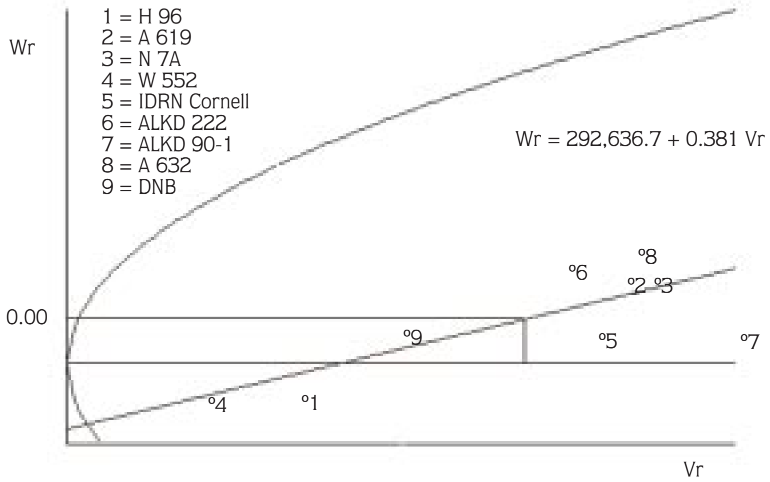

Figure 1. Covariance-variance graph for grain yield in maize.

Table 3. Mean of parents and general combining ability (GCA) effects for yield.

Parents	Yield (t ha^{-1})	GCA effect
H. 96	6.94	-25.21
A619	3.07	-39.89
N 7A	4.09	82.24**
W 552	7.53	163.85**
IDRN Cornell	3.13	23.93
ALKD 222	1.64	-174.03**
ALKD 90-1	2.44	-6.53
A 632	2.08	-85.30**
DNB	7.47	60.95*
LSD 5%	1.77	
S.E. (gi)		19.55

* and ** indicate significant differences at the 0.05 and 0.01 levels, respectively.

crosses, that had grain yields above 14 t ha^{-1} were N 7A x ALKD 90-1 (15.83), N 7A x DNB (15.78), N7A x IDRN Cornell (15.40), IDRN Cornell x ALKD 90-1 (14.93), W 552 x DNB (14.78), A 619 x N 7A (14.72), ALKD 90-1 x A 632 (14.41), H 96 x N 7A (14.39), A 619 x IDRN Cornell (14.33) and A 619 x ALKD 90-1 (14.18). These crosses also had high and positive SCA effects. Significantly, the better performing crosses usually had at least one parent with high GCA effects (Chaudhary et al., 2000). The midparent heterosis ranged from 46.11% to 573.12%. Generally high heterosis values showed parallelism with the h^2 parameter, indicating the mean dominance effect of the heterozygote locus.

The useful heterosis values were calculated according to the performance of the check variety, Tieter (14.29 t ha^{-1}). Although all crosses had high and positive heterosis values, the useful heterosis values, varying from –46.47% to 10.78%, were lower than that of heterosis, and only 9 crosses had grain yields higher than that of the check variety. Of these N 7A x ALKD 90-1 (10.78%), and N 7A x DNB (10.43%) had higher and significant useful heterosis values.

Conclusions

N 7A x ALKD 90-1, N 7A x DNB and N 7A x IDRN Cornell cross combinations will be tested in yield trials for further evaluation. Taking the lines of these promising crosses into account, N 7A and DNB may be used as parents in hybrid maize programs. In addition to these parents, W 552, with dominant genes, high yield and general combining ability may be recommended as a parent.

Table 4. Mean yields, specific combining ability (SCA) effects and heterosis values of crosses.

Crosses	Yield ($t\ ha^{-1}$)	SCA effects	Midparent heterosis (%)	Useful heterosis (%)
H.96 x A 619	13.52	288.87**	170.13**	-5.39
H.96 x N 7A	14.39	281.32**	160.92**	0.70
H.96 x W 552	10.91	-148.19*	50.79*	-23.65**
H.96 x IDRN Cornell	11.53	53.36	128.99**	-19.31**
H.96 x ALKD 222	8.07	-94.26	88.11*	-43.53**
H.96 x ALKD 90-1	12.20	190.84**	160.12**	-14.63**
H.96 x A 632	12.15	224.53**	169.40**	-14.98**
H.96 x DNB	10.53	-83.65	46.10	-26.31**
A 619 x N 7A	14.72	329.08**	311.17**	3.01
A 619 x W 552	13.87	161.99*	161.69**	-2.94
A 619 x IDRN Cornell	14.33	347.72**	362.25**	0.28
A 619 x ALKD 222	10.26	139.28*	335.67**	-28.20**
A 619 x ALKD 90-1	14.18	362.99**	414.70**	-0.77
A 619 x A 632	7.65	-211.04**	197.08**	-46.47**
A 619 x DNB	11.31	9.34	114.61**	-20.85**
N 7A x W 552	13.55	8.35	133.22**	-5.18
N 7A x IDRN Cornell	15.40	332.95**	326.59**	7.77
N 7A x ALKD 222	10.36	26.71	261.60**	-27.50**
N 7A x ALKD 90-1	15.83	406.51**	384.84**	10.78*
N 7A x A 632	10.91	-6.83	253.64**	-23.65**
N 7A x DNB	15.78	334.23**	173.01**	10.43*
W 552 x IDRN Cornell	12.09	-79.73	126.83**	-15.40**
W 552 x ALKD 222	13.32	240.86**	190.51**	-6.79
W 552 x ALKD 90-1	12.92	33.66	159.18**	-9.59
W 552 x A 632	13.62	182.35**	183.45**	-4.69
W 552 x DNB	14.78	151.80**	97.07**	3.43
IDRN Cornell x ALKD 222	12.12	261.19**	408.18**	-15.19**
IDRN Cornell x ALKD 90-1	14.93	375.16**	436.09**	4.48
IDRN Cornell x A 632	12.02	162.63*	361.42**	-15.89**
IDRN Cornell x DNB	14.04	217.84**	164.91**	-1.75
ALKD 222 x ALKD 90-1	10.24	103.54	401.96**	-28.34**
ALKD 222 x A 632	12.52	410.56**	573.12**	-12.39*
ALKD 222 x DNB	10.78	90.02	136.66**	-24.56**
ALKD 90-1 x A 632	14.41	432.15**	537.61**	0.84
ALKD 90-1 x DNB	9.38	-217.37**	89.30*	-34.36**
A 632 x DNB	13.27	250.32**	177.91**	-7.14
LSD 0.05	2.00			
S.E. (s_{ij})		62.89		

* and ** indicate significant differences at the 0.05 and 0.01 levels, respectively.

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