Proc. 4th Int. Wheat Genetics Symp, page 569-576. 1973 Columbia, Mo.

M. Feldman

A COMPARISON OF GENETIC BEHAVIOR IN A SIX-PARENT DIALLEL CROSS OF WINTER WHEAT GROWN UNDER NORTHERN AND SOUTHERN HEMISPHERE ENVIRONMENTS[1]

PATRICIO C. PARODI AND F. L. PATTERSON

Catholic University of Chile, Santiago, and
Purdue University, Lafayette, Indiana, USA

SUMMARY

A six-parent winter wheat diallel cross was tested under northern and southern hemisphere environments (Indiana, USA, and Cautín, Chile), for stability of some genetic parameters governing yield and its components. Genotypes performed poorly in Chile, but yield heterobeltiosis was higher, an indication that hybrids tolerated the adverse environment better than their parents. Combining ability analyses showed that additive gene action controlled, at both locations, a large portion of the genetic variance. Jinks and Hayman's graphic analysis showed drastic environmental effects. Narrow-sense heritability values confirmed the preponderance of additive gene action.

One of the advantages of hybrid wheat may be its potentially wide range of adaptation. BORLAUG *et al.*,(1964) suggested that a spring wheat hybrid could be developed with a range of adaptation from Canada to Chile.

Our aim in designing this experiment was to test the stability of several genetic parameters, as expressed in yield and yield components, in six winter cultivars of *Triticum aestivum L.* and their F_1 progenies, under northern and southern hemisphere environments: Lafayette, Indiana, USA, at 40° 28' latitude North, and Temuco, Cautín, Chile, at 38°44' latitude South.

---

[1]Research financed by the Rockefeller Foundation, the Chilean Institute of Agricultural Research, and Purdue University.

Lafayette is characterized by severe, continental winters, and hot, humid summers. Winters in Temuco are Mediterranean and comparatively mild; summers are cool and fairly dry. Pathogenic conditions differ widely: *Puccinia recondita* Rob. ex Desm. f. sp. *tritici* is the primary rust disease at Lafayette; *Puccinia striiformis* West. is the main pathogen at Temuco. These differences were considered a severe challenge to the stability of the genetic mechanisms controlling yield and yield components.

MATERIALS AND METHODS

The soft red winter wheat cultivars Vermillion (Vm), Seneca (Se), Knox 62, Benhur (Bhr), Arthur (Atr), and Purdue 5215A1-5-1-8-10 (5215), were crossed in a diallel system. Parents and F_1 hybrids were planted at Lafayette in September, 1966 and 1967, and at Temuco in July, 1970, in a randomized complete-block design with 10 replications. Genotypes were seeded in hills spaced 30.5 cm in a grid design, at a rate of 14 seeds per hill. An individual hill area was the plot unit. The two-year Lafayette data and the one-year Temuco data were analyzed separately. The environmental diversity, where Lafayette was considered "normal" and Temuco "abnormal" for this germplasm, precluded a joint analysis. Characters measured were number of spikes per hill, number of kernels per spike, 100-kernel weight, and grain yield.

Hybrids were compared with the mid-parental average and with the better parent of the cross to determine percent heterosis and heterobeltiosis, respectively. Estimates of general combining ability (GCA) and specific combining ability (SCA) were obtained using GRIFFING's (1956) combining-ability analysis, method 4, model I. JINKS and HAYMAN's (1953) graphic analysis was utilized to determine degree of dominance and genic relations within the parents. The assumptions underlying the (V_r,W_r) analysis were tested conducting analyses of variance on the W_r minus V_r values (W_r-V_r; HAYMAN, 1954). The slope and the position of the regression lines were tested for deviations from unity slope and deviations from the origin, respectively. Narrow-sense heritability was estimated computing the regression of F_1 on mid-parental average, as described by FALCONER (1960), where heritability = $b \pm s_b$.

RESULTS AND DISCUSSION

Yield and yield components were consistently low at Temuco, an expression of the non-adaptation of the material to that environment, possibly reinforced by a severe attack of stripe rust, to which all genotypes were susceptible. Mean squares from mean analyses of variance were significant for most comparisons (Table 1).

Hybrid Vigor

Our discussion will be limited to the heterobeltiosis values. Spikes per hill at Temuco showed no negative values and a higher average than at Lafayette; all genotypes were significantly superior to

Table 1. Analyses of means of yield components and yield for parental and F_1 generations

Source of variation	d.f.	Mean squares: Spikes/ hill	Kernels/ spike	Kernel weight	Grain yield
		Lafayette, Ind. (2 years)			
Years (Y)	1	**	**	**	**
Genotypes (G)	20	*	**	**	**
Parents vs F_1's	1	**	NS	**	**
Parents (P)	5	*	*	**	**
F_1's	14	NS	*	**	**
Y x G	20	**	**	**	NS
Y x (P vs F_1's)	1	**	**	NS	*
Y x P	5	*	*	**	NS
Y x F_1's	14	NS	**	**	NS
Error	360				
		Temuco, Chile			
G	20	**	**	**	**
P vs F_1's	1	**	NS	**	**
P	5	**	**	**	**
F_1's	14	**	**	**	**
Error	180				

*, ** Significant at the .05 and .01 levels, respectively.

their better parent (Table 1). The adverse Temuco environment appeared to exert a more drastic negative effect on the parental genotypes than on the F_1 hybrids. At both locations, but more so at Temuco, this component contributed positively to higher yield. Significant positive heterobeltiosis did not occur for kernels per spike at either location. Thirteen progenies presented negative values at Lafayette, all of which coincided with Temuco's negative values. A genetic and/or physiologic barrier may exist within this germ plasm that precludes this component from contributing positively to higher yields. Heterobeltiosis values for kernel weight were lower at Temuco, as shown by a -8% average, versus 0.8% at Lafayette. Heterobeltiosis values for kernel weight of hybrid Se x Atr was positive and significant at both locations. The information suggests that kernel weight, although not the most important yield component at Lafayette, was less important in the Temuco environment.

Grain yield, a result of the compensations, oscillations and interactions of the primary yield components, showed a heterobeltiosis range from -22 to 23%, and an average of 4% in the "normal" Lafayette environment. At Temuco, the range went from -67 to 179%, with an average of 16%. Heterobeltiosis values for grain yield of hybrid Knox 62 x Bhr was positive and significant at both locations; Vm x Bhr, Vm x Atr and Bhr x Atr were negative at both sites. Hybrid Se x Bhr, which produced 4% heterobeltiosis at Lafayette, had an outstanding 179% at Temuco, and the highest yield of the experiment. Vm x Se, the best yielder at Lafayette, ranked 9th at Temuco, in spite of a 45% nonsignificant heterobeltiosis. The high heterobeltiosis values observed at Temuco are thus not the reflection of high yields but, rather, an expression of the ability of the hybrids to withstand better than their parents the effects of an adverse environment. PARODI (1972) has postulated that certain F_1 wheat hybrids may possess, in addition to their potential to produce higher yield, a mechanism associated with their heterozygous nature that allows them to tolerate adverse environmental conditions that severely hurt their homozygous parents. The data presented here may be an example of this feature, which might represent an advantage as large, or larger, than higher productivity under normal conditions.

Combining Ability

GCA mean squares were highly significant for all characters at both locations, an indication that additive gene action was responsible for an important portion of the genetic variance associated with yield and yield components (Table 2). The statistical significance and the magnitude of SCA mean squares shows that nonadditive gene action controlled a lesser portion of the genetic variance associated with kernels per spike, kernel weight and grain yield at Lafayette, and kernel weight and grain yield at Temuco. With one exception, SCA for kernels per spike, the stability of the additive and nonadditive portion of the genetic variance was good. No consistency was found between locations for GCA effects (Table 3).

Gene Action

Genotype mean squares from analyses of variance on (W_r-V_r) values were nonsignificant for all characters at both locations, indicating that the materials met the assumptions underlying the Jinks and Hayman analysis.

Features of the (V_r, W_r) graphs, and inferences derived from them are presented in Table 4. The regression line deviated from unity slope for spikes per hill and kernels per spike at Lafayette, and for

Table 2. General combining ability (GCA) and specific combining ability (SCA) mean squares for yield components and grain yield

Source of variation	d.f.	Mean squares: Spikes/hill	Kernels/spike	Kernel weight	Grain yield
		Lafayette, USA (2 years)			
GCA	5	59.74**	17.66**	0.314**	135.27**
SCA	9	7.54	4.15**	0.006*	8.23**
Residual	252	5.45	0.90	0.003	3.24
		Temuco, Chile			
GCA	5	12.75**	62.40**	1.03**	111.19**
SCA	9	2.06	2.92	0.309**	16.10**
Residual	180	2.18	2.32	0.014	1.24

*, ** Significant at the .05 and .01 levels, respectively.

kernel weight and grain yield at Temuco, weakening the interpretation of these analyses. Dominance effects were all in the partial dominance range except for overdominance at Temuco for spikes per hill,

Table 3. Estimates of general combining ability (GCA) effects for yield components and yield. Two-year data from Lafayette and one-year from Temuco

Variety	Spikes/hill		Kernels/spike		Kernel weight		Grain yield	
	Lafayette	Temuco	Lafayette	Temuco	Lafayette	Temuco	Lafayette	Temuco
Vm	-0.42	-2.58	3.33	-1.54	-0.24	-0.41	0.77	-4.49
Se	5.66	-1.06	-0.49	-0.48	0.47	0.61	10.68	1.65
Knox 62	2.43	0.94	-0.85	1.07	-0.10	-0.33	-0.01	-0.29
Bhr	-5.59	0.07	0.48	3.36	-0.14	0.17	-5.69	3.71
Atr	-2.29	-0.06	-3.07	-6.68	0.20	-0.58	-4.53	-7.43
5215	0.21	2.69	0.60	4.27	-0.19	0.53	-1.21	6.86
SE[1]	1.65	0.14	0.67	0.74	0.04	0.12	1.27	4.17

[1]SE = standard error of the difference between two effects.

and overdominance at Lafayette for grain yield. The variance of the parents was consistent for kernels per spike; it was lower at Temuco for spikes per hill and grain yield, and higher for kernel weight.

Environmental differences modified the behavior of recessive genes controlling spikes per hill, while the behavior of dominant genes remained constant. Environment affected the expression of both dominant and recessive genes governing kernels per spike. The behavior of dominant genes was most affected by environmental differences for kernel weight, while recessive genes remained constant. Grain yield, the most complex character, showed severe alterations in the behavior of both dominant and recessive genes. The position of certain parents, below the regression line, suggests that complementary types of interaction may be responsible for some of the effects described.

Table 4. (V_r, W_r) regression coefficients, parental variance, and parental dominance at Lafayette and Temuco

Character	$b \pm s_b$		Variance of parents		Most dominant parent		Most recessive parent	
	Lafayette	Temuco	Lafay.	Temuco	Lafay.	Temuco	Lafay.	Temuco
Spikes/hill	0.39±0.06[1]	0.59±0.43	37.35	10.43	5215	5215	Bhr	Se
Kern./spike	0.68±0.26[1]	0.67±0.51	19.10	17.62	Vm	Atr	Se	Vm
Kern. wt.	0.72±0.34	0.13±0.03[1]	0.10	0.68	Se	5215	Bhr, Atr	Atr, Bhr
Grain yield	1.00 0.24	0.08 0.01[1]	48.07	29.06	Se	5215, Atr	Vm	Se, Bhr

[1]Regression line deviated significantly from 1.0.

Heritability

Narrow-sense heritability values ranged from .36 to .91 (Table 5). All estimates were higher at Temuco, an indication that, according

Table 5. Narrow-sense heritability estimates for yield components and yield

Character	Lafayette	Temuco
Spikes/hill	.36 ± .17	.91 ± .26
Kernels/spike	.46 ± .20	.63 ± .21
Kernel weight	.54 ± .04	.78 ± .10
Grain yield	.47 ± .08	.59 ± .12

to this test, the additive portion of the genetic variance made a larger contribution to total variance at that location. This result is in agreement with the information derived from the combining-ability analyses.

LITERATURE CITED

BORLAUG, N.E., J. ORTEGA, I. NARVÁEZ, A. GARCÍA, and R. RODRÍGUEZ 1964. Hybrid wheat in perspective. *In* Hybrid Wheat Seminar Report, (Crop Quality Council, Minneapolis, Minn.): 1-19.

FALCONER, D.S. 1960. Introduction to Quantitative Genetics. Ronald Press, New York N.Y. 365 pp.

GRIFFING, B. 1956. Concept of general and specific combining ability in relation to diallel crossing systems. Aust. J. Biol. Sci. 9: 463-493.

HAYMAN, B.I. 1954. The theory and analysis of diallel crosses. Genetics 39: 789-809.

JINKS, J.L., and B.I. HAYMAN. 1953. The analysis of diallel crosses. Maize Genet. Coop. Newsletter 27: 48-54.

PARODI, P.C. 1972. Trigo híbrido. Resultados de los investigadores nacionales. Proc. 23rd. Ann. Meet., Chilean Soc. Agron. (in press).