strikingly similar to that of sh-bz-x_2. McClintock stated that crossing over within the affected segment of some mutant heterozygotes was reduced in varying degrees or completely absent. However, crossover reduction in the fourth mutant was not specifically mentioned.

If sh-bz-x_2 represents suppression of the two alleles by a controlling element, the mechanism by which this element inhibits crossing over may be similar to that of recombination genes.

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1. Observed and "expected" heterosis in interracial crosses of maize.

When epistasis is negligible, heterosis of an interpopulational hybrid can be expressed as a function of gene frequencies and dominance effects.

An attempt is made to compare actual heterosis values for yield in 9 interracial crosses of corn with calculated heterosis parameters. Observed heterosis ($\hat{h}_{ij}$) was measured as the excess in yield of a hybrid over the midpoint between its parents. Experiments conducted in three locations with three rep./location provided the yield averages. Based on knob frequencies obtained by Kato (1964) and Blumenschein (1968) and on hypothetical dominance values, "expected" heterosis parameters were computed as follows:

$$h^*_{ij} = \sum_k \left[(p_{ik} - p_{jk})^2 + 2 \cdot \bar{\Delta}_{ijk} \right] \cdot \delta_k$$

p_{ik} being the knob frequency [of any type of knob (large, medium or small)] at chromosome position k for population i; $\bar{\Delta}_{ijk}$ is the average Hardy-Weinberg disequilibrium parameter for populations i and j and chromosome position k, i.e., $\bar{\Delta}_{ijk} = (1/2)(\Delta_{ik} + \Delta_{jk})$, and Δ_{ik} = the observed frequency of homozygous knobbed plants minus the corresponding expected frequency under Hardy-Weinberg equilibrium, for position k.

Table 1

Observed heterosis and calculated h_{ij}^* values

Cross				Observed heterosis (kg/10 m^2)	Calculated h_{ij}^* values
12	Chapalote	x	Caingang	0.696	5.142
13	Chapalote	x	Canario de ocho	1.575	3.132
14	Chapalote	x	Cristal	0.434	4.936
15	Chapalote	x	Cateto	1.396	4.206
23	Caingang	x	Canario de ocho	0.632	0.295
24	Caingang	x	Cristal	-0.123	1.054
25	Caingang	x	Cateto	0.686	1.282
34	Canario de ocho	x	Cristal	1.133	0.153
35	Canario de ocho	x	Cateto	-----	-----
45	Cristal	x	Cateto	0.874	0.857

Table 2

Average yield (kg/10 m^2) of parental varieties and F_1's

	CAINGANG	CRISTAL PARAGUAI	CATETO	CHAPALOTE	CANARIO DE OCHO
CAINGANG	3.903	3.656	4.304	3.573	3.590
CRISTAL PARAGUAI		3.654	4.368	3.186	3.867
CATETO			3.334	3.988	-----
CHAPALOTE				1.850	3.407
CANARIO DE OCHO					1.813

δ_k is the dominance value (as defined by Gardner and Eberhart, 1966) for the knob-knobless condition at position k. For comparison with observed heterosis, δ_k values were assumed to be equal to one for all 21 knob positions.

Knob frequencies were obtained by pachytene chromosome examination. The presence or absence of knobs at each knob forming position was recorded. If present, the size (small, medium or large) of each knob was determined and it was noted whether such knobs were present in the homozygous or the heterozygous condition.

To simplify the determination of the heterosis parameters, we considered only the presence or absence of knobs, independent of their sizes, although it is known that knob size is important for characterizing germplasms.

In a certain way, the presence or absence of knobs in these races reflects the absence of a particular knob complex, the Andean Complex. This Complex is basic for South American races of maize and is characterized by the presence of small knobs in the 6 L_3 and 7 L positions and by the absence of knobs in all other knob forming positions.

Thus, the presence of knobs in positions other than 6 L_3 and 7 L can be taken as meaning introgression of other complexes into the Andean Complex.

The results are shown in Tables 1, 2 and 3 and Figure 1. The hybrid Cateto x Canario de Ocho was not included because no data on the yield of this hybrid were available.

The results must be viewed with caution as the samples utilized for knob frequency estimation were not completely comparable to the samples utilized for yield data. In addition, the sizes of some samples were relatively small.

It seems clear, however, that the relationship between observed heterosis and population diversity, as measured by differences in knob frequencies, is not linear. The highest observed heterosis values are associated with intermediate h^*_{ij} values. These results seem to agree with the conclusion reached by Moll et al. (1965): the maximum heterotic expression is observed at an intermediate degree of diversity, and heterosis decreases with very high levels of diversity.

Table 3

Estimates of knob frequencies (p) and Hardy-Weinberg disequilibrium parameters

Races / Knobs	Chapalote		Caingang		Canario de ocho		Cristal		Cateto	
	P	△	P	△	P	△	P	△	P	△
1S	0.8333	0.0556	0.1466	0.0647	0.0000	0.0000	0.2647	-0.0700	0.0455	0.0206
1L	0.0417	-0.0017	0.0000	0.0000	0.0000	0.0000	0.0000	0.0000	0.0000	0.0000
2S	0.2917	-0.0018	0.0000	0.0000	0.0000	0.0000	0.0000	0.0000	0.0227	-0.0005
2L	0.8750	0.0156	0.0517	0.0318	0.0000	0.0000	0.2059	0.1341	0.0909	0.0144
3S	0.0417	-0.0017	0.0000	0.0000	0.0000	0.0000	0.0000	0.0000	0.0000	0.0000
3L	0.7083	0.0816	0.1552	0.0449	0.2000	-0.0400	0.1471	0.0372	0.4773	0.0449
4S	0.0833	0.0764	0.0000	0.0000	0.0000	0.0000	0.0000	0.0000	0.0000	0.0000
4L	0.9583	-0.0016	0.3017	0.1504	0.5000	-0.2500	0.0588	-0.0035	0.2046	0.0945
5S	0.2083	0.0399	0.0000	0.0000	0.0000	0.0000	0.0000	0.0000	0.0000	0.0000
5L	0.8750	-0.0156	0.2155	0.0053	0.5000	-0.2500	0.0294	-0.0009	0.1932	0.0763
6L1	0.0000	0.0000	0.0000	0.0000	0.0000	0.0000	0.0000	0.0000	0.0000	0.0000
6L2	0.7083	0.0816	0.2586	0.1228	0.0000	0.0000	0.2353	0.1211	0.3977	-0.0218
6L3	0.6667	-0.0278	0.7500	0.0065	0.7000	-0.0900	0.6471	-0.0658	0.6023	-0.1128
7S	0.2500	0.1042	0.0000	0.0000	0.0000	0.0000	0.0000	0.0000	0.0000	0.0000
7L	0.9583	-0.0016	0.7931	-0.0083	0.7000	-0.4900	0.6765	-0.1048	0.8509	-0.0195
8L1	0.9583	-0.0016	0.2586	0.1572	0.0000	0.0000	0.3235	0.1307	0.2159	0.0670
8L2	0.4583	-0.0433	0.1466	0.0992	0.0000	0.0000	0.0588	-0.0035	0.1932	0.0763
9S	0.8750	-0.0156	0.0172	-0.0003	0.7000	-0.0900	0.0000	0.0000	0.2500	0.0966
9L	0.0833	-0.0069	0.0517	0.0490	0.0000	0.0000	0.1471	-0.0216	0.0796	0.0063
10L1	0.0000	0.0000	0.0000	0.0000	0.0000	0.0000	0.0000	0.0000	0.0000	0.0000
10L2	0.0417	-0.0017	0.0000	0.0000	0.0000	0.0000	0.0000	0.0000	0.0000	0.0000

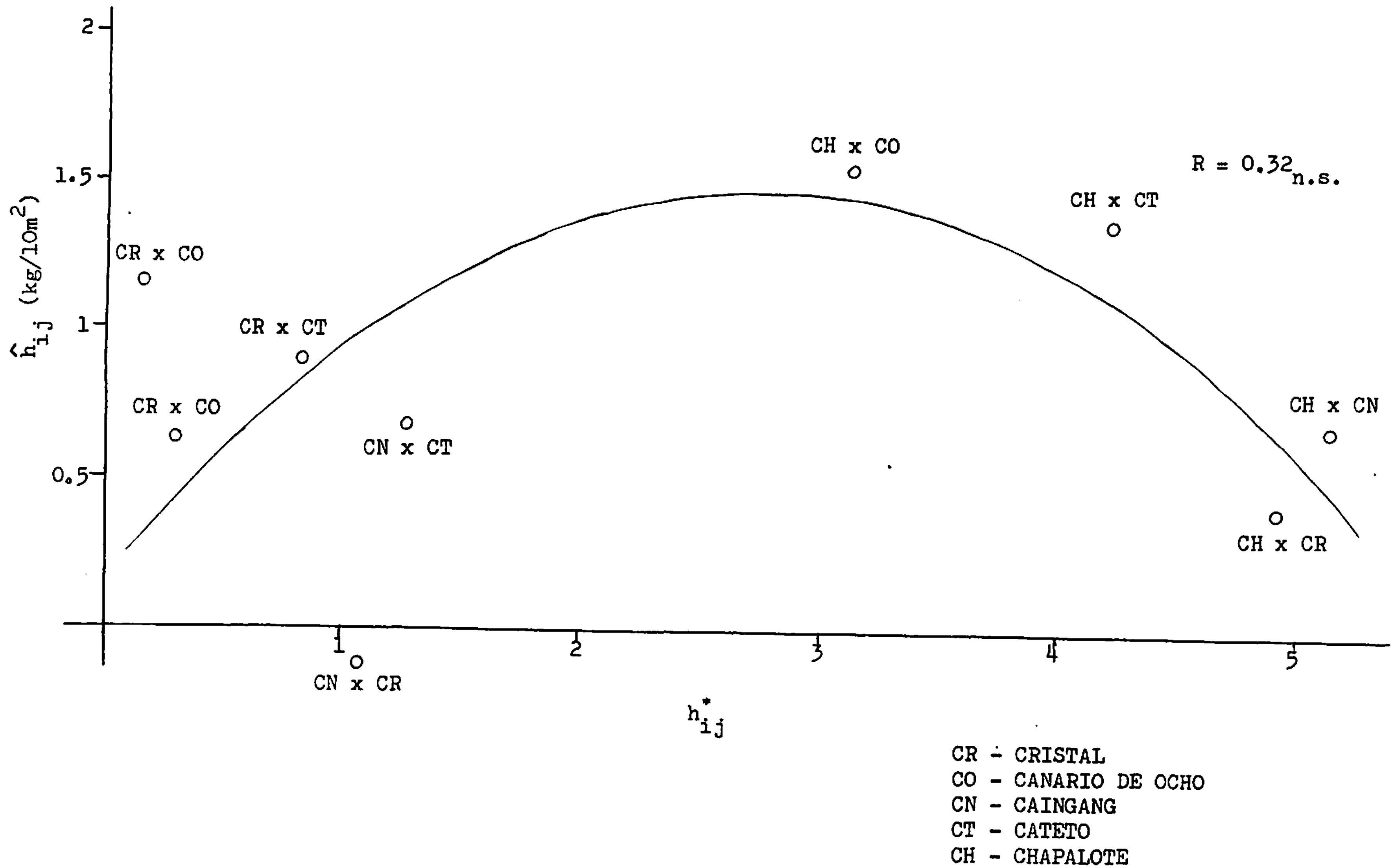

Figure 1. Observed and "expected" heterosis values in interracial crosses of maize

If similar results are obtained in more critical experiments, which we are developing, one could conclude that non-allelic interactions can be important for yield in maize.

Furthermore, it seems clear that, if epistasis exists, it will have a higher probability of expression in crosses between less related races. This is true because in interpopulational hybrids the loss of linkage equilibrium can occur alone as a consequence of differences in genic frequencies between the parental populations. Such a linkage disequilibrium can result in epistasis having a direct effect on the means of racial crosses.

Practically, if heterosis and divergence are curvilinearly related as in the figure, then the use of measures of divergence based upon knob data (or other comparable data) should be useful in the prediction of heterosis values (i.e., yield level) of maize hybrids.

REFERENCES

Blumenschein, A. 1968. Estudo das Origens e Relações de Parentesco dos Milhos do Leste da América do Sul, a partir dos Knobs Cromossômicos. (In press).

Gardner, C. O. and S. A. Eberhart. 1966. Analysis and interpretation of the variety cross diallel and related populations. Biometrics 22 (3): 439-452.

Kato, T. A. 1964. Some cytological studies on several Mexican races of maize. M.Sc. Thesis. Raleigh, N.C. USA. North Carolina State of the University of N.C.

Moll, R. H., J. H. Lonnquist, J. V. Fortuno and E. C. Johnson. 1965. The relationship of heterosis and genetic divergence in maize. Genetics 52: 139-144.

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2. Preliminary experiment in relation to the effects of gamma-rays on hybrid vigor in corn.

Seeds of two inbred lines of flint and dent corn were gamma-rayed with an approximate dose of 3,700R, and in 1967, the following crosses were carried out as well as selfing of Do, Dr, Fo and Fr: