VALIDITY OF PREDICTION METHODS UNDER POPULATION STRESS IN COMPOSITE AND VARIETAL HYBRIDS IN MAIZE (ZEA MAYS L.)

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ABSTRACT

Studies on validity of prediction methods under population stress in composite and varietal hybrids were carried out in six synthesized, genetically broad based populations, namely, KS14C, JML305, J236, JML24, DMR1 and DMR5, under three plant densities. The correlations between the predicted and actual values for different kind of progenies ($F_{1,jk}$, $F^r_{1,jk}$ and $F^s_{1,jk}$) were found to be significant to highly significant in all the densities for majority of the characters. In general, there was good correspondence between actual and predicted estimates under all densities in all kinds of progenies. Predictions were fairly efficient under additive as well as nonadditive genetic situations in all the three densities. The prediction estimates in case of advance generations of selfed and random mated progenies under all densities compared so well with their actual performance that it offers an efficient method to predict the performance of advanced generations of three-way and four-way multiple varietal hybrids without actually making them. It could also be inferred that the prediction method was applicable even in the presence of considerable epistasis in different density stresses.

Key words: *Zea mays*, maize, density composite, epistasis.

Prediction studies are extremely valuable part of maize breeding research programme. Considerable literature on the subject is available and methods are known which enable the maize breeders to predict the performance of the better hybrid combinations without making and testing literally thousands of undesirable crosses. Theories about prediction methods were first developed for self-pollinated crops but were later extended to cross-pollinated crops wherein homozygous inbred lines were used as parental materials [1, 2]. However, very little work is reported on the prediction of performance of hybrids involving heterozygous parents like races and varieties [3, 4].

Varying plant populations are expected to affect prediction studies considerably. Are evaluations of hybrids at one density appropriate for predicting performances at different densities? Duncan [5] found linear relationship between plant density

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and the logarithm of yield per plant, and suggested that only two densities are necessary to predict yield at other densities, one below and one above the optimum. However, Cornelius and Byars [6] concluded that the inclusion of one density near the optimum would be desirable. The present study has been, therefore; undertaken keeping in view the above objectives and to find the answer whether the prediction of hybrids in one density holds good for the other densities as well.

MATERIALS AND METHODS

The material consisted of six genetically broad based populations, namely, KS14C, DMR1, DMR5, JML24, JML305 and J236. Various types of progenies derived from them were: six selfed progenies (V^s_j), 15 F_1 crosses ($F_{1.jk}$), 15 F_1 selfs ($F^s_{1.jk}$) and 15 random mated progenies of the F_1 crosses ($F^r_{1.jk}$). These progenies along with six original populations were studied in a split plot design with 3 replications and 3 plant densities in the kharif seasons of 1979 and 1980. The densities formed main plots and the genotypes subplot. Buffer rows of appropriate material were planted as borders. Each plot was represented by one row of 5 m length, the rows being 75 cm apart. Plant spacings were 50 cm, 25 cm, and 12.5 cm with one seed per hill, thus giving 29,333 plants/ha, i.e. below normal density (BN), 56,000 plants/ha i.e. normal density (N), and 1,00,333 plants/ha, i.e. above normal density (AN). Observations were recorded on all the plants in a row for yield and all yield components. The number of rows for each genotype under different densities were kept constant to avoid differential environmental interaction. Statistical analysis was carried out following Gardner and Eberhart [7] and Castro et al. [8] on the basis of average of two years.

Table 1. R^2 value in per cent between observed and predicted performance of parents and other progenies under different densities

Parameter	Density	Grain yield	Ear length	Ear diameter	Kernel rows per ear	Kernels per row	100-kernel weight
V_j	BN	76*	83*	80*	85**	60	86**
	N	72*	84**	64	90**	73*	66*
	AN	77*	63	31	84*	64	74*
V^s_j	BN	37	80*	41	74*	31	37
	N	45	64	74*	85**	27	67*
	AN	48	77*	59	85**	59	48
$F_{1.jk}$	BN	75**	40**	51**	70**	47**	76**
	N	63**	61**	52**	64**	47**	65**
	AN	41*	45**	58**	71**	41**	73**
$F^r_{1.jk}$	BN	41**	33*	30*	33*	37*	64**
	N	34*	44**	33*	44**	41**	53**
	AN	32*	16	48**	51**	27*	36*
$F^s_{1.jk}$	BN	18	46**	31*	47**	49**	42**
	N	35*	56**	44**	54**	44**	43**
	AN	70**	51**	45**	56**	54**	57**

*, **Significant at 5% and 1% levels, respectively.

RESULTS

Table 1 presents the coefficient of determination (R^2) between observed and predicted performance of parents and other progenies in different densities over two years. The R^2 values were significant to highly significant for grain yield, kernel rows per ear, and 100-kernel weight in all the three densities. The coefficients were also highly significant for ear length and significant for kernels per row in normal density and significant for ear length and ear diameter in below normal density. On the other hand, selfed progenies of parents showed significant to highly significant coefficients for kernel rows per ear in all three densities. Significant R^2 values were also observed for ear diameter and 100-kernel weight in normal density and for ear length in both BN and AN densities for selfed progenies. However, the coefficients for grain yield and kernels/row were non-significant in all the three densities. In $F_{1.jk}$, $F^r_{1.jk}$ and $F^s_{1.jk}$ progenies, significant to highly significant coefficients were observed for all the characters in all three densities except for ear length in AN density and grain yield in BN density with respect to $F^r_{1.jk}$ and $F^s_{1.jk}$ progenies, respectively.

Table 2 presents the observed (Y) and predicted (Ŷ) yield of a few selected F_1 crosses and their selfed and random mated progenies. Only six crosses in each density, representing high, intermediate and low specific heterotic effects were selected on the basis of average of two years. It could be seen from the table that in almost

Table 2. Mean observed (Y) and predicted (Ŷ) yield (g/plant) of $F_{1.jk}$, $F^r_{1.jk}$ and $F^s_{1.jk}$ progenies selected on the basis of high, intermediate and low specific heterotic effects (average of two years)

Den-sity	Pedigree	$F_{1.jk}$			$F^r_{1.jk}$			$F^s_{1.jk}$		
		Y	Ŷ	differ-ence	Y	Ŷ	differ-ence	Y	Ŷ	differ-ence
BN	DMR1 × DMR5	108.4	101.6	6.8	86.7	84.3	2.4	45.2	61.2	16.0
	JML305 × J236	96.4	100.7	4.3	96.9	95.7	1.2	63.9	56.4	7.5
	KS14C × DMR1	98.7	91.0	7.7	73.7	78.9	5.2	39.2	49.4	10.2
	J236 × JML24	98.5	91.5	7.0	81.5	83.0	1.5	44.7	57.3	12.6
	JML305 × DMR5	80.9	86.5	5.6	88.5	86.1	2.4	58.4	49.5	8.9
	JML24 × DMR1	85.7	89.5	3.8	60.5	75.9	15.4	80.7	57.8	22.9
N	JML305 × DMR1	72.2	71.8	0.4	59.4	62.2	2.8	47.9	45.7	2.2
	J236 × JML24	75.5	68.0	7.5	58.5	62.5	4.0	32.9	44.0	11.1
	KS14C × JML305	77.2	84.1	6.9	69.4	74.8	5.4	43.7	44.8	1.1
	JML24 × DMR1	56.2	61.9	5.7	58.4	57.2	1.2	50.9	40.5	10.4
	J236 × DMR5	52.2	52.2	0.0	54.4	54.1	0.3	37.5	37.7	0.2
	JML305 × JML24	67.5	65.5	2.0	57.2	63.1	5.9	44.5	42.7	1.8
AN	JML305 × J236	33.5	36.8	3.3	38.7	33.5	5.2	26.0	24.8	1.2
	J236 × JML24	37.0	35.1	1.9	29.5	32.1	2.6	21.7	22.9	1.2
	KS14C × J236	37.7	32.5	5.2	18.2	30.1	11.9	22.4	20.2	2.2
	DMR1 × DMR5	31.7	34.2	3.0	38.0	32.0	6.0	21.7	21.7	0.0
	J236 × DMR5	31.7	28.4	3.3	25.9	29.6	3.7	17.9	20.7	2.8
	JML305 × JML24	29.8	30.2	0.4	30.5	29.3	1.2	19.7	20.2	0.5
	CD at 5%	19.2								

all the crosses in all the three densities, there was fairly good agreement in the observed and predicted values of $F_{1.jk}$, $F^r_{1.jk}$ and $F^s_{1.jk}$ progenies. There was, however, only one exceptional cross (JML24 × DMR1) which gave substantial difference in the actual and predicted values in $F^s_{1.jk}$ progenies in BN density.

The percentage of contribution to different genetic components averaged over two years with respect to the three densities (Table 3) shows that, except for number of kernel rows per ear, in all other characters the magnitude of dominance component far exceeded the respective additive components in all the three densities. The deviation caused by epistasis and linkage disequilibrium made a contribution ranging from 24.9% (BN) to 30.70% (AN) in case of grain yield. For all other components of yield also there was substantial contribution from such deviation in all three densities.

Table 3. Mean percentage contribution of genetic components to the total genetic variation over the two years

Parameter	Density	Grain yield	Ear length	Ear diameter	Kernel rows per ear	Kernels per row	100-kernel weight
a_j	BN	6.3	13.0	7.4	22.4	10.5	21.1
	N	7.8	12.3	10.1	29.2	7.5	27.6
	AN	3.7	14.7	10.2	25.9	14.8	27.3
d_j	BN	53.3	41.1	45.4	18.9	48.7	22.7
	N	46.7	42.8	35.8	13.9	49.9	16.5
	AN	50.5	32.9	32.0	23.9	34.0	17.9
Intervarietal dominance	BN	15.4	16.0	16.2	12.3	13.3	22.2
	N	15.9	15.2	16.9	20.0	11.2	16.4
	AN	15.1	12.3	17.1	18.4	12.2	17.7
Deviations	BN	25.0	29.9	31.0	46.4	27.4	34.0
	N	29.0	29.7	37.2	36.9	31.4	39.4
	AN	30.7	40.1	40.7	31.8	39.0	37.0

a_j—additive effects due to j^{th} variety; d_j—dominance effects due to j^{th} variety.

Epistasis and linkage disequilibrium have accounted for 25–46%, 29–39% and 31–41% in BN, N and AN densities, respectively. The magnitude of epistatic contribution exceeded additive, dominance and intervarietal dominance in case of five characters (except grain yield) in AN density, three characters (ear diameter, kernel rows/ear, and 100-kernel weight) in N density and two characters (kernel rows/ear and 100-kernel weight) in BN density out of the total six characters studied. Under BN density, dominance component exceeded all other components in majority (4 out of 6) of the characters. The intervarietal dominance has also contributed 12 to 19% of the total variation over the three densities and this contribution exceeded the additive component at least in two characters (grain yield and ear diameter) in all three densities.

DISCUSSION

In the development of commercial types, particularly double cross hybrids and synthetics, prediction procedures form an important part of maize breeding programme.

Most of the prediction methods reported in literature in the early fifties were based on the mean performance of progenies [2, 9–12]. Such prediction methods, therefore, were based mainly on models precluding the effects of nonallelic interactions which, when present, created serious disturbances in the predicted estimates. In the prediction of double crosses and synthetics, the existence of epistatic interaction being negligible, there exists a good correlation between the actual and predicted values.

In a population improvement programme, wherein unselected broadbased heterozygous germplasms are the main source material, it is not unusual to encounter high degree of interaction from epistasis and linkage disequilibrium [3, 13]. Under such situation, predictions based on mean peformance are bound to be erroneous. It, therefore, becomes imperative to derive predicted estimates not from the mean values but from the gene effects themselves. Eberhart and Gardner [14] and Castro et al. [8] have suggested models for prediction of the performance of advanced generations of different progenies wherein cumulative gene effects have been used to derive the predicted estimates.

A major source of error in predicting performances of genotypes in varying environments is the effect of genotype × environment interactions. Therefore, in the present investigation, the two above mentioned models have been used to predict the performance of advanced generations of selfed as well as random mated progenies of F_1 crosses in three plant densities. A perusal of Table 1 indicates that, in general, the predictions have been most efficient and successful for all kinds of progenies under all densities for most of the characters studied. The deviations between the predicted and actual values for different kinds of progenies have been found to be minimal in all the densities in case of $F_{1.jk}$, $F^r_{1.jk}$ and $F^s_{1.jk}$ progenies for majority of characters. The results obtained clearly establish the efficieny of cumulative gene effect model in the prediction of advanced generations in spite of the fact that the inheritance of most of these characters is highly complicated due to high degree of nonallelic interaction from epistasis and linkage disequilibrium, especially in AN density (Table 3). The earlier work of Eberhart and Gardner [14] also indicated that the above interaction may underestimate the predicted performance, but quantitatively the values were inconsequential. Mukherjee et al. [3] and Ahuja [4] also confirmed the efficacy of this prediction method even under high magnitude of epistasis under normal plant density. That environment creates no major disturbance in the actual and predicted values is clearly established from the results of the present investigation under both half as well as double the plant population pressures. Similar conclusions were also derived by Eberhart and Gardner [14] with respect to absence of environmental influence on the validity of prediction for double and three-way crosses.

The prediction estimates computed for different kinds of progenies, when compared with corresponding actual values in case of grain yield, reveal that, in general, there is good correspondence between actual and predicted estimates under all the densities in all kinds of progenies studied (Table 2). However, a consistent discrepancy may be noticed in case of $F^s_{1.jk}$ progenies in BN density. This may have arisen from sampling error which obviously gets aggravated in case of $F^s_{1.jk}$ progenies.

The prediction studies applied to three sets of crosses, namely, having high specific heterotic effects (middle two crosses) and low specific heterotic effects (bottom two crosses) in each density, indicate the efficiency of the prediction methods under entirely different genetic situations. The crosses with high specific heterotic effects, under normal circumstances, represent preponderance of nonadditive gene effects, whereas crosses with low specific heterotic effects represent either very low degree of dominance or preponderance of additive genetic effects. Biometrical basis of prediction usually envisages greater success under additive gene action. Nevertheless, we have seen that predictions are fairly efficient under additive, nonadditive, and both additive as well as nonadditive genetic situations in all the three densities.

The prediction estimates not only in case of two-parent varietal hybrids but also in the advanced generation of their selfed and random mated progenies in all the densities compare extremely well with their actual performance. It gives us enough confidence to predict the performance of advanced generation of three-way and four-way multiple hybrids without actually making them. The present findings bear greater relevance and importance in the population improvement approach. It facilitates the selection of parental varieties not only on the per se performance alone but also on their probable performance in the advanced generation in conjuction with other genetically diverse varietal materials, irrespective of the nature of inheritance of the agronomic traits. It may also be concluded from the present findings that the prediction made for hybrid performance under one density may be applied to other density even in the presence of fairly high degree of epistasis.

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