GENETIC STUDIES IN VARIETIES OF MAIZE¹⁾

II. Genetic Analysis of Certain Ear and Tassel Characters

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Synopsis. Diallel experiment was carried out with six varieties and 15 F_1 crosses to study the inheritance of ear and tassel characters. Dominance controlled the expression of ear diameter, length of peduncle number of primary branches and length of branching space. Ear length was controlled by overdominance. Epistasis of the complementary type also controlled the expression of a number of characters.

In an earlier paper (MUKHERJEE and DHAWAN, 1970), the genetic analysis of yield and other quantitative traits in varieties of maize have been reported. While considerable investigations have been carried out on the relationship between certain plant and ear characters of inbred lines to the yield of hybrid progenies, relatively little information is available on the genetic make up of these characters with particular reference to varietal materials. Additive genetic variance was found to make a major contribution in the expression of ear length, ear diameter, and kernel row number by ROBINSON *et al.* (1949), GARDNER and LONQUIST (1959), ROBINSON and COMSTOCK (1955), LINDSEY *et al.* (1962), and WILLIAMS (1961). Indications of epistasis associated in the expression of these characters have been reported by SENTZ *et al.* (1954), GORSLINE (1961), GAMBLE (1962), BAUMAN (1959), and SHARMA (1963). Reports on the genetic make up of tassel characters are relatively few. SHARMA (1963) reported the presence of overdominance in the expression of number of primary branches in inbred lines of maize. He did not find presence of inter-allelic interaction. ANDERSON and BROWN (1948) postulated that

tassel condensation was apparently due to one or two recessive genes with a large number of modifiers. SHARMA (1963) reported partial dominance in the expression of this character. There is no report in literature regarding the genetic make up of the tassel characters, length of peduncle, number of secondary branches and length of branching space. ANDERSON (1944), ANDERSON and BROWN (1948) and WELLHAUSEN *et al.* (1954) have emphasized the importance of certain ear and tassel characters. It is their contention that if a maize breeder could size up the potentialities of the ear by examining the tassels, he could bring about many shortcuts in his breeding programme. Moreover, a knowledge of nature of gene action involved in these characters would determine the efficiency of the breeding procedure adopted. The present investigation provides information on the genetic architecture of certain ear and tassel characters.

The materials and methods used in this study were the same as in the 1964 experiment reported in the earlier paper (MUKHERJEE and DHAWAN, 1970).

Results

A. Graphic Analysis

1. Ear characters

(i) **Ear length:** The W_r , V_r graph is presented in Figure 1.

The regression coefficient 'b' did not deviate significantly from unity. The observed regression line shifted to the right of the origin and fell below the theoretical line $h=2d$, thereby indicating the presence of high degree of overdominance in the expression of this

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Fig. 1. W_r , V_r Graph for Ear Length

ARRAY POINTS	PARENTS
1	COL.-2.
2	F.F.
3	CO.
4	BA.
5	DOR
6	EA.

character. The position of the observed regression line beyond the theoretical regression line $h=2d$ and also the fall of the array points below this indicated the presence of non-allelic interaction of the complementary type. The scatter of the array points was not much thereby indicating absence of much genetic diversity among the parents for this character. Nevertheless, it was observed that parents Basi and Eto Amarillo possessed maximum number of dominant alleles while Dorado de Tequisate, Francisco flint and Colorado possessed the maximum number of recessive alleles. Colombia 2 was intermediate. Basi, Eto Amarillo, Colombia 2 and Francisco flint appeared to be more homozygous than Dorado de Tequisate. The nature of heterozygosity in the parent Colorado was masked by epistasis.

(ii) **Ear diameter**: The W_r , V_r graph is presented in Figure 2.

The regression coefficient 'b' did not deviate significantly from unity. The observed regression line shifted to the left of the line of unit slope and fell between the theoretical regression lines $h=1/2d$ and $h=d$. This indicated that dominance was involved in the expression of the character. There was no indication of non-allelic interaction. The position of the array points on or very near the observed

Fig. 2. W_r , V_r Graph for Ear Diameter.

ARRAY POINTS	PARENTS
1	COL.-2.
2	F.F.
3	CO.
4	BA.
5	DOR
6	EA.

regression line indicated that the parents were homozygous for the genes controlling this character. Five out of six parents formed a group towards the point of origin while Eto Amarillo occupied the position of far away from the origin. This indicated that Eto Amarillo was genetically diverse from the other group. Moreover, it possessed the maximum number of recessive alleles while the remaining five possessed the maximum number or dominant alleles. Dominant alleles governed the maximum expression of this character.

2. Tassel characters

(i) **Length of peduncle**: The W_r , V_r graph is presented in Figure 3.

The regression coefficient 'b' deviated significantly from unity. The observed regression line shifted to the right of the line of unit slope and slightly below the origin. Overdominance and to a greater extent complementary epistasis was controlling this character. Due to the presence of high degree of non-allelic interaction, no conclusion could be drawn regarding the level of heterozygosity in the parents. Array points fell into two groups. First group consisting of parents

Fig. 3. W_r , V_r Graph for Length of Peduncle.

ARRAY POINTS	PARENTS
1	COL.-2.
2	F.F.
3	CO.
4	BA.
5	DOR
6	EA.

Colombia 2, Colorado, Francisco flint and Eto Amarillo had lower values of W_r , V_r and contained maximum number of dominant alleles. Basi and Dorado de Tequisate constituting the other group contained the maximum number of recessive alleles. The greater length of peduncle was controlled by dominant alleles.

(ii) **Number of primary branches:** The W_r , V_r graph is presented in Figure 4.

The regression coefficient 'b' did not deviate significantly from unity. The observed regression line fell between the theoretical regression lines $h=d$ and $h=1/2d$. It can, therefore, be concluded that dominance played a major role in the expression of this character. Non-allelic interaction was found to be absent. The scatter of the array points along the regression line showed that Basi was genetically diverse from the other parents and possessed maximum number of recessive alleles. Dominant alleles were predominant in the remaining parents. Dorado de Tequisate, Colombia 2 and Basi were more homozygous than Colorado and Eto Amarillo while Francisco flint was the most heterozygous. Dominant alleles appeared to control maximum expression of

Fig. 4. W_r , V_r Graph for Number of Primary Branches of Tassel.

ARRAY POINTS	PARENTS
1	COL.-2.
2	F.F.
3	CO.
4	BA.
5	DOR
6	EA.

the character.

(iii) **Length of branching space:** The W_r , V_r graph is presented in Figure 5.

The regression coefficient 'b' deviated significantly from unity. The observed regression line shifted to the left of the line of unit

Fig. 5. W_r , V_r Graph for Length of Branching Space

ARRAY POINTS	PARENTS
1	COL.-2.
2	F.F.
3	CO.
4	BA.
5	DOR
6	EA.

slope intersecting the W_r axis between the region $h=0$ and $h=1/2d$. The greater part of the observed regression line, however, fell below the line of unit slope. The distortion of the observed regression line was due to the presence of high degree of non-allelic interaction of the complementary type. This was further supported by the fact that five out of six parents fell below the line of unit slope. The scatter of the array points was very wide thereby indicating the presence of considerable genetic diversity among the parents. Dorado de Tequisate possessed the maximum number of dominant alleles while Colombia 2 on the other hand, possessed maximum number of recessive alleles. It appeared that recessive alleles controlled the maximum expression of this character.

B. Variance Component Analysis :

1. Ear characters

(i) **Ear length** : (Table 1) The additive genetic variance (D_I) was less than that due to dominance (H_I), and the ratio H_I/D_I was 1.86 thereby indicating that dominance component was making a major contribution to the expression of this character even though both were equally important. The expression $\sqrt{\frac{1/2(H_I+H_{IV})}{D_I}}$ which represented the degree of dominance (weighted estimate) was 1.46 indicating that the mean level of dominance was in the overdominance range. The values of H_I and H_{II} differed widely, thereby, suggesting the presence of unequal allelic frequency. The positive value of F_I indicated the preponderance of dominant alleles.

(ii) **Ear diameter** : (Table 1) Both additive

genetic and dominance variances were found to make equal contribution to the expression of the character. The degree of dominance was 0.93 thus indicating dominance. There were wide differences in the values of H_I and H_{II} indicating the presence of unequal allelic frequencies. The positive value of F_I indicated preponderance of dominant alleles.

2. Tassel characters

(i) **Length of peduncle** : (Table 1) The value of H_I was 3.91 times more than that of D_I indicating thereby that dominance component was making a major contribution in the expression of the character. The degree of dominance was found to be 2.30 suggesting overdominance. The values of H_I and H_{II} were different showing unequal allelic frequencies. There was preponderance of dominant alleles as indicated by the positive values of F_I .

(ii) **Number of primary branches** : (Table 1) The variances due to additive genetic and dominance components were about the same magnitude, the value of H_I/D_I being 1.06. This indicated that in the expression of this character, both additive genetic and dominance components were of equal importance. The degree of dominance was 1.37 showing dominance. Unequal allelic frequencies were noticed and there was preponderance of dominant alleles as indicated by the positive value of F_I .

(iii) **Length of branching space** : (Table 1) No appreciable difference was observed between the values of additive genetic and dominance variances. Both these components, therefore, appeared to play equal roles in the expression of this character. The degree of dominance was 1.61 indicating overdominance. Unequal allelic frequencies and preponderance of dominant alleles were observed.

Discussion

In a breeding programme for the improve ment of maize, selection is usually exercised for plant and ear characters and yield. ANDERSON (1944), ANDERSON and BROWN (1948), and

Table 1. Estimates of components of genetic variation of ear and tassel characters

Parameters	EAR CHARACTERS		TASSEL CHARACTERS		
	Ear length	Ear diameter	Length of peduncle	No. of primary branches	Length of branching space
D_I	14.2248	8.8532	11.3250	179.1272	37.8890
H_I	26.4016	12.5320	44.3132	191.2670	38.7428
H_{II}	12.4464	2.0624	4.9440	34.4448	13.7184
H_{IV}	31.4864	2.9624	76.0648	481.8744	159.1232
F_I	50.6944	27.8912	21.3256	535.8288	131.7144
H_I/D_I	1.86	1.42	3.91	1.06	1.02
$\sqrt{\frac{1/2(H_I+H_{IV})}{D_I}}$	1.46	0.93	2.30	1.37	1.61

WELLHAUSEN *et al.* (1954) have pointed out the importance of certain ear and tassel characters. The existence of high positive correlations of certain tassel and ear characters with yield (SHARMA, 1963) has led to the possibility of simplifying the selection procedures which could ultimately accelerate the development of superiormaize types. It is, therefore, imperative that genetic analysis of such characters be carried out to obtain maximum gains from a particular breeding procedure adopted. In the present investigation two procedures, namely, graphic analysis and variance component analysis were used.

Genetic analysis of ear length revealed that though non-allelic interaction of the complementary type was playing a major role and that the degree of dominance was in the overdominance range, yet the additive genetic variance was of considerable magnitude. Working with heterozygous materials, WILLIAMS (1961), ROBINSON and COMSTOCK (1955), ROBINSON *et al.* (1955) and LINDSEY *et al.* (1962) reported that additive component was of greater importance. It, therefore, appears that in the population under study, considerable progress can be made in ear length by first exploiting the additive genetic variance and then the complementary type of epistasis. The data on ear diameter indicated that additive genetic variance made the major contribution. There was absence of non-allelic interaction and presence of complete dominance. These results are similar to those found by the workers mentioned earlier.

Considering the tassel characters, it was found that additive genetic variance was about the same magnitude as dominance variance for the number of primary branches and length of branching space. On the other hand for the length of peduncle, the dominance variance was nearly four times larger than the additive genetic variance. However, the weighted estimate of mean level of dominance for each of these characters indicated that the degree of dominance was in the overdominance range, the maximum value being for the length of peduncle. The overdominance observed was due to non-allelic interaction of the complementary type in case of characters length of peduncle and length of branching space.

For number of primary branches, the W_r , V_r graphic analysis and variance component analysis did not present the same genetic picture. The graphic analysis indicated the presence of dominance without any indication of non-allelic interaction while the variance component analysis indicated presence of overdominance. Since the value of mean level of dominance is not of a higher magnitude, this could result from experimental bias. The interesting point noticed in the present investigation was that the dominant alleles controlled the expression of ear length, ear diameter, length of peduncle, and number of primary branches while for length of branching space the maximum expression was under the influence of recessive alleles. The efficiency of a male parent to be used as a donor of pollen in a top cross block or in a three way hybrid depends on the size of tassel and number of spikelets. The size of tassel affects the pollen producing potential of a plant by increasing the distance between the recemes on the primary stalk through increased branching space. One of the positive contributors of branching space is bigger size of the peduncle. In general, it was found that for all the characters studied, the parents were relatively homozygous. As pointed out in the earlier paper (MUKHERJEE and DHAWAN, 1970), sib-mating used for the maintenance of varieties brings about considerable homozygosity hence the varieties should be maintained in large plots in the form of germ plasm complexes.

Summary

The genetic analysis of ear and tassel characters of maize was carried out by graphic and variance component analyses. Six varieties derived from five different races and their all possible F_1 crosses were used. Dominance controlled the expression of characters; ear diameter, length of peduncle, number of primary branches and length of branching space. Ear length was controlled by overdominance. Non-allelic interaction of the complementary type was found to control the expression of all of the characters tested except ear diameter and number of primary branches.

Unequal allelic frequencies and preponderance of dominance alleles were found for all

the characters studied. Dominant alleles governed the maximum expression of all the characters except length of branching space whose greater expression was influenced by recessive alleles. The W_r , V_r graphic analysis revealed that relative parental homozygosity was attributed to the system of maintaining these varieties by sib-mating in limited population.

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トウモロコシ品種における遺伝的研究

II. 雌穂および雄穂形質の遺伝的解析

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トウモロコシの雌穂および雄穂形質の遺伝的解析がグラフ法および分散成分法によつて行なわれた。5つの異なるレースからみちびかれた6品種と、それらの間の可能なすべての F_1 交配とが用いられた。雌穂径、雌穂柄長、一次側枝数および側枝を出している部分の長さなどの形質では優性効果がみとめられた。雌穂長は超優性の支配をうけていた。補足因子型の非対立遺伝子交互作用が雌穂長、一次側枝数をのぞくすべての形質の表現を支配していることがわかった。すべての調査形質で対立遺伝子の頻度が等しくなく、優

性因子の方が頻度が高いことがわかった。1形質をのぞくすべての形質で優性因子は大きい（又は長い）ほうの表現を支配していたが、例外の形質、側枝を出している部分の長さでは長いほうの表現を劣性因子が支配していた。 W_r , V_a グラフによる解析の結果、親はほとんどの形質を支配する遺伝子についてかなり同型接合的であることが明らかとなつた。これらの品種は限られた集団内での兄妹交配によつて維持されて来たので、その期間内にかんがりの程度まで同型接合性を得るに至つたと解釈された。