THE STABILITY OF GENE EFFECTS OF PARENTAL INBRED LINES USED TO PRODUCE A SYNTHETIC VARIETY OF HIGH YIELD IN MAIZE, *ZEA MAYS* L.

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Introduction

Generally, those inbred lines or homozygous varieties which have high general combining ability can provide any intercrosses of high yield. The concept has been recognized early and introduced into the improvement of synthetic varieties of maize by maize breeders, i. e., they selected the parents of synthetic varieties based on the level of general combining ability.

However, there was no paper reporting that one can raise the production up or over the standard of the other hybrid breeding methods. The main cause may be well known as the absence of specific effects of gene actions in synthetic varieties. Therefore, to reconsider gene effects, the stability of additive and non-additive effects, in the first step of selecting parental lines must be important in order to find out the more effective method of breeding a synthetic variety of high yield, such as how to choose the suitable source of materials or wether we can take advantage of specific gene effects favorably in selecting parents and so on.

Materials and Method

The materials used in this experiment, were kindly supplied by Corn Breeding Laboratory of HOKKAIDO NATIONAL EXPERIMENT STATION in 1969, which consisted of 20 inbred lines ; 10 line of them were selected from the offspring of the hybrid IWANAI ZAIRAI A×N 85 on the basis of the combining ability in yield, and other 10 lines were originated diversely (N 28, N 56, N 146, N 203, N 206, T 6, T 23, T 24, T 113, T 117).

For the experiment, thes lines were crossed within source in diallel sets without reciprocals. In 1970, all 20 parental lines and their 90 crosses were planted in 5×5 cm (440 plants per acre) at the above said station.

Based on the test for G.C.A. in ear weight, shelled corn, and ear weight, only 5 inbred lines within each source were evaluated as those having high general combining ability, and F_1 were planted at the field of HOKKAIDO UNIVERSITY in 1971 (460 plants per acre). The purpose of changing planting conditions as well as density was dealed with to minimize the interferences of environment in analyzing the data.

Analysis were based upon hypothesis as follows:

—No selection per generation.

—Linkage absent.

—Normal diploid segregation.

—No plasma effect, i.e., no difference between reciprocals.

The method of computing herafter, was applied by ANALYSIS III of the genetic models presented by GARDNER and EBERHART (2).

Results

Analysis of genetic ariances of parental lines and their crosses were computed for the significance of mean squares of productive characters, at statistical probability level under the assumption that all effects were random variables. The results in two years (1970 and 1971) were given on TABLE 1, 2, and 3.

It was clearly showed that the average mean of F_1 population was quite greater than the average mean of parental population, in both sources of origins, by the values of mean squares of the "*lines vs crosses*" item to be of highly significance for all characters. The "*lines vs. crosses*" is considered corresponding to average heterosis between hybrid and parents, and from TABLE 1 and 2, we also knew that the mean square values of the said heterosis of the later were always greater than the first. MOLL et al. (10) reported that heterosis in yield of maize appears to increase with increased genetic divergence of the parent population over a rather wide range of diversity. In the experiment, the 10 inbred lines originated from diverse origins (D.O.), actually were largely different in genotype, and therefore, there brought a great value of heterosis in yield by assembling many favorable genes. It was illustrated that productive characters such as seed yield, and so on were controlled not only by one major gene but by a mass of genes or polygene.

Examing the heterosis effect in the F_1 population, additive effects or general combining ability were detected as highly significant at 1% for all

TABLE 1. Analysis of variances of 10 inbred lines from same origin and their 45 crosses in a diallel set (1970).

Source	d.f.	M.S ear w.	shelled c.	grain w.	100 kernel w.
repl.	1				
entries	54	**	**	**	**
lines	9	106.483*	92.095*	91.012**	17.983**
lines vs crosses	1	1619.430**	1314.318**	1294.076**	77.390**
crosses	44	174.848**	133.302**	133.208**	23.987**
G. C. A. (g_j)	9	575.480**	431.108**	430.817**	109.209**
S. C. A. ($s_{jj'}$)	35	71.859	56.723	56.680	2.073
entries × repl.	54	45.319	36.916	33.064	1.055

** significant at 1%
* significant at 5%

TABLE 2. Analysis of variances of 10 inbred lines from diverse origins and their 45 crosses in a diallel set (1970).

Source	d.f.	M.S ear w.	shelled c.	grain w.	100 kernel w.
repl.	1				
entries	54	**	**	**	**
lines	9	139.853**	106.624**	106.478**	32.228**
lines vs crosses	1	28016.060**	22522.729**	22184.718**	1107.533**
crosses	44	191.566**	150.188**	147.965**	51.442**
G. C. A. (g_j)	9	490.550**	353.113*	347.178**	241.257**
S. C. A. ($s_{jj'}$)	35	114.684*	98.007**	96.737**	2.633**
entries × repl.	54	59.103	46.293	44.216**	0.137

** significant at 1%
* significant at 5%

characters in 1970 as given in TABLE 1 and 2, except for the colum of shelled corn in TABLE 2 was at 5%.

According to EBERHART's genetic model, the mean square of "*lines vs. crosses*" reflects average heterosis and is also attributable entirely to *non-additive* gene effects. Therofore, the overdominant effects. Therefore, the overdominant effects appeared in the F_1 population (TABLE 2) seemed to be resulted by genes acting in geometric way, and ($s_{jj'}$) s were determined as 114.684, 98.007, 96.737 and 2.633 respectively, fairly high comparing with standard errors.

Estimates of general combining ability (G.C.A.) and specific combining ability (S.C.A.) of 5 lines and single crosses were paesented in TABLE 3. All the lines involved had been tested previously and were known to have good G.C.A., the same trend of heterosis appearances could be seen in lines of same origin (S.O.) of the table with high values of M.S. in all the "*lines vs. crosses*", "*crosses*" and "G.C.A." items, respectively.

TABLE 3. Analysis of varainces of 5 inbred lines and their crosses (1971).

Source	d.f.	ear weight S.O.	ear weight D.O.	shelled corn S.O.	shelled corn D.O.	100 hernel w. S.O.	100 hernel w. D.O.
entries	14						
lines	4	**	*	**	—	**	**
lines vs. crosses	1	**	**	**	**	*	**
crosses	9	**	**	**	**	**	**
G.C.A. (g_j)	4	**	*	—	**	**	**
S.C.A. ($s_{jj'}$)	5	—	**	**	—	—	—
entr.×repl.	14	46.671	90.042	26.796	75.801	5.750	13.218

** significant at 1%
* significant at 5%

It should be emphasized that non-additive effects of gene action in ($s_{jj'}$) item appeared clearly instead of additive effect or G.C.A. to be absent in D.O. It was clarified that when parents are divergence in genetic genes act in geometric way more than arithmetic way in contributing heterosis in yield. In regard to genetic variances of 100 kernel weight, additive effect was considered as main behavior of gene; in fact, there was no great difference in size of maize kernel between parents and progenies.

FUJIMOTO (3) reported the results of diallel crosses in sugar beets showing the existence of high correlation values between mid-parent (M.P.) and *heterosis ratios* in the components of gross sugar: root weight, sugar content, and brix value. As can be be seen in TABLE 4, the estimate from our data in 1970 showed the high significant values of correlation coefficients between M.P. and heterosis ratio. As M.P. is calculated as the mean performance of two parents, it is quite dependent on the gene additive effect. And the high relationship between M.P. and heterosis ratio showed those

TABLE 4. Correlation values between M.P. and heterosis ratio in 1970 and 1970.

Source		correlation values ear w.	shelled c.	grain w.
Same origin	1970	0.586**	0.527**	0.591**
	1971	0.784**	0.690**	—
Diverse or.	1970	0.788**	0.816**	0.835**
	1971	0.029	0.096	—

** indicates significance at 5%

lines which own high performance per se. will bring high performance in their crosses by genes acting in additive way. In 1971, however, the values decreased greatly in D.O. (1971) as 0.021, and 0.096, said the unstability of additive gene effects when parent were so different in genotype.

The relationship between the M.P. and heterosis ratio in S.O. were quite high in two years, therefore the additive effects of gene action seemed to be stable to various enviroments, in responsible for the depression of the reduction of yield per generations. Moreover, those lines in S.O. which do have the high average in yield per se. and per crosses, must be selected as lines having good general combining ability (3, 6, 9, 12).

The stability of the additive effect variances for 5 parents were performed on 3 productive characters in 1970 and 1971; the results were shown in TABLE 5.

TABLE 5. Analysis of variances of additive effects for the 5 parental lines from S.O. and D.O. in 1970 and 1971

Source	d.f.	ear weight S.O.	ear weight D.O.	shelled corn S.O.	shelled corn D.O.	100 kernel w. S.O.	100 kernel w. D.O.
Years	1	**	**	**	**	**	**
Parents	4	**	**	**	**	**	**
Parents×Years	4	**	**	**	**	**	**
Errors	42	55.833	103.403	30.540	70.395	3.353	12.335

** to be significant at 1%

According to ALLARD (1) this way of tesŧ is based on the assumption that heritability differences between homozygous parents, in the absence of epistasis, are determined by the additive effects of gene actions. The item of years was significant, in fact, in the average performances of ear weight, shelled corn were different for each of the two years. It can be, therefore, concluded that the absolute values of additive effects of the interactions between homozygous loci have been altered with environmental changes. The PARENT × YEARS item was significant at high level of statistical probability (1%), and this provided the evidence that additive effects may be also unstable in response to environments.

Discussion

In relation to the selection of parental lines which should be used to developthe synthetic varieties of maize, the most of maize breeders have seemed to have the premise that the additive gene effects are stable in response to changeable environments acted mainly in retaining heterosis of vigour per generations. Since, it can be assembled in a synthetic variety of maize, a large number of such desirable genes acting in the arithmetic way. The formula of predicting yield performance of Syn 2 reported by WRIGHT (12), which has been used extensively, was also based on the assumption of arithmetic gene action. The concept of taking advantage of additive gene effects can be seen in the other papers reported by KIESSEBACH (8), HULL (7), KINMAN and SPRAGUE (9), and recently by FUJIMOTO (3).

Really, the estimates of genetic variances from our data proved the importance of additive effects or G.C.A. contributing heterosis in progeny population (TABLE 1 and S.O. in TABLE 3). The stability of additive effects for two years perhaps promised the stability of yield in SYN 2 and subsequent generations. There was no problem if parental lines of synthetic varieties were selected according to the level of G.C.A.

HO, KANEKO and HOSOKAWA (6) reported that in improving a high productive synthetic variety of maize, parents of diverse origins which beared unrelated genotypes were more desirable than parents of same origin. It was in agreement with the discussions of MOLL (10) that the degree of heterosis in F_1 increased with the more diversity of parents in genotypes. The *non-additive effects* ($s_{jj'}$) of gene actions also took on the important role in bringing overdominance in yield of F_1 population (TABLE 2 and 3).

From the studied results, it is possible to be concluded that, specific gene effects or S.C.A. can not be negligible in selecting the effective parental lines of synthetic varieties of maize aimed at raising the seed production up to the maximum level as other series of hybid breeding methods ; and actually, in testing for specific combining ability of inbred lines, we should repeat the yield-test experiment in various conditions of planting in 2 years or more in order to maximize the stability of this specific effect of lines selected.

Résumé

The estimates of genetic variances clarified that additive gene effects took on the important role of introducing heterosis of many characters concerning productivity, such as ear weight, shelled corn, and 100 kernel weight, etc., in the F_1 population of same origin. On the contrary, when parents derived from diverse origins were intercrossed, there appeared the *non-additive effects* in two years 1970 and 1971, determined by $(s_{jj'})$, values in the analysis results. Therefore, *non-additive effects* of gene actions should be considered as a main factor which attributed to overdominance in yield, and the *non-additive effects* can not be negligible in selecting preantal lines of synthetic varieties in maize if we want to improve the seed production to maximum.

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