Specific Combining Ability between Six Different Types of Maize (*Zea mays* L.) Obtained from a Diallel Set of Eleven Open-pollinated Varieties¹⁾

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In practical hybrid maize breeding, it is necessary to select combinations with a high degree of specific combining ability as well as to improve general combining ability. It is well-known that more genetically distant combinations induce higher specific combining ability and result in more yielding hybrids. Although SUTŌ *et al.* (1956) classified the flint types present in Asia into five types, namely, *North American*, *Caribbean*, *European*, *Aegean*, and *Persian*, there have been no reports on the specific combining ability between the six types which are composed of the above five flint types in addition to a dent type, *American dent*. The purpose of this study was to investigate the relationship between the modes of varietal combinations and specific combining ability effects estimated from the analysis of a diallel set of eleven open-pollinated varieties belonging to the six types, and to identify a general trend of specific combining ability between the six types. The results obtained here were as follows: 1) Combinations between different types, especially between flint and dent types, were superior to those within same types in specific combining ability effect and F₁ yield. 2) High specific combining ability was observed in crosses between *Caribbean* and *American dent*, and between *Persian* and other types except for *European* and *Aegean*. 3) Specific combining ability effects were closely related to genetic divergence estimated from the previous classification results, in which the values of specific combining ability effects increased with increasing genetic divergence.

KEYWORD : *Zea mays*, genetic divergence, diallel cross, specific combining ability.

Introduction

Maize hybrids which make the best use of heterosis have been widely adopted in Japan. One of the important points in breeding superior hybrids is to identify combinations expressing a high degree of heterosis, in other words, to breed parental materials with high combining ability. Combining ability has been generally divided into general and specific combining abilities (SPRAGUE and TATUM 1942). In Practical breeding, it is necessary to select combinations which have a high degree of specific combining ability between materials as well as to improve each material for general combining ability. Regarding the evaluation of general combining ability, various kinds of efficient testcross methods have been developed (JENKINS and BRUNSON 1932, KELLER 1949, and MATZINGER 1953).

On the other hand, several aspects relating to specific combining ability remain to be elucidated and no reliable method to predict it has been developed thus far. It is a well-known fact that more genetically distant combinations induce higher specific combining ability and result in more yielding hybrids, as reported by WU (1939), JOHNSON and HAYES (1940), MOLL *et al.* (1962), GOMEZ (1966), and INOUE and KANEKO (1974).

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Therefore, the most efficient method to predict specific combining ability, at present, is to identify hybrid combinations based on previous classification results relating to geographical distribution and morphological characteristics, such as ear shape and kernel property, and also based on genetic relationships estimated from pedigrees in the process of breeding. In this report, such differences between materials are generally referred to as "genetic divergence".

SUTŌ *et al.* (1956) classified the flint types distributed in Asia into five different types, namely, *North American*, *Caribbean*, *European*, *Aegean*, and *Persian* on the basis of botanical characteristics. With regard to specific combining ability, although some authors have studied the relationship between different types, there are no reports on the specific combining ability between the six types which consist of the five flint types and a dent type, *American dent*. For instance, YAMASAKI (1954) and NAKAMURA *et al.* (1978) investigated grain yields of various combinations among open-pollinated varieties belonging to *Caribbean*, *North American*, and *American dent*, and reported that varietal crosses between the different types, especially between *Caribbean* and *American dent*, outyielded those within the same types. INOUE and KANEKO (1974), who compared grain yields of diallel crosses among the inbred lines belonging to *North American* and *European*, and also, among those belonging to *North American* and *American dent*, reported that combinations between different types showed higher specific combining ability. Furthermore, they demonstrated that effects of specific combining ability based on diallel analysis were closely related to genetic divergence, and indicated that when inbred lines with identical general combining ability were crossed, genetic divergence determined the yielding ability of the hybrids. In these reports, however, *Aegean* and *Persian* were not included and the relative intensity of specific combining ability between a large number of different types could not be compared at the same time.

The purpose of this study is to analyse a diallel set of eleven open-pollinated varieties belonging to the above six types in order to confirm the results obtained by YAMASAKI (1954), NAKAMURA *et al.* (1978), and INOUE and KANEKO (1974), and to identify a general trend of specific combining ability between the six types. This would make a

Table 1. Name and origin of the eleven open-pollinated varieties used for the experiment

Name	Origin	Type ¹⁾
1. Longfellow	Local variety in Hokkaido, Japan, introduced from U. S. A. a century ago.	North American flint
2. Iwanai A	"	"
3. Mais Peta	Introduced from Italy about fifty years ago.	European flint
4. Granturco Marano	"	"
5. Mizuhiki 2	Local variety in Honshu, Japan.	Caribbean flint
6. Hirano	"	"
7. Nepal 55	Introduced from Nepal in 1954.	Persian flint
8. Dai Sui Hwang	Introduced from China about fifty years ago.	Aegean flint
9. Zan Kong Shun Zai Rai 227	"	"
10. Reid's Yellow Dent	Introduced from U. S. A. about fifty years ago.	American dent
11. Wisconsin 12	"	"

¹⁾ Type defined here depends on classification by SUTŌ *et al.* (1956).

significant contribution to practical breeding.

Materials and Methods

Two typical open-pollinated varieties from each of the six types (one variety from *Persian*) were selected on the basis of the results classified by SUTŌ *et al.* (1956) shown in Fig. 1. The name and origin of the eleven varieties used for the study and the types they belong to are shown in Table 1. SUTŌ *et al.* (1956) specified the main characteristics of each type and also, defined the relationships between the five flint types based on the results of their classification. Furthermore, it is considered that *American dent* originated from the hybridization between *North American* and *Southern dent* in the south-eastern part of the U. S. (ANDERSON and BROWN 1952). Consequently, although a relationship between *American dent* and the four flint types other than *North American* can not be clearly established, the following relationship between the six types is suggested.

North American—Caribbean—European—Aegean—Persian
|
American dent

In this report, the above relationship will be used as the standard to estimate the degree of genetic divergence between the types.

Eleven varieties were intercrossed in all possible combinations exclusive of reciprocal crosses. In 1974, the eleven parental varieties and their fifty-five progenies were evaluated for grain yields in Sapporo, Japan. The experimental design consisted of randomized blocks with two replications (one-row plot with thirty hills) and the planting density was 45000 plants/ha. Grain yields (15% moisture content) and additional sixteen traits of ten plants per plot were determined in the center of a row. The comparison of specific combining ability between the varieties and the different types was made by

Fig. 1 Geographical distribution of the five types of maize found in Asia (SUTŌ *et al.* 1956).

evaluating the magnitude of effects of specific combining ability obtained from diallel analysis. Experimental method 2 (Model I) of the diallel analysis generalized by GRIFFING (1956) was applied to the study, which includes the analysis of variance for general and specific combining abilities and the estimation of their effects. Although this method is usually applied to diallel crosses of fixed lines, it was postulated that Model I could be applied to open-pollinated varieties. In this case, the model is expressed by the following equation. $x_{ijk} = u + g_i + g_j + s_{ij} + b_k + e_{ijk}$ where u is the mean value in all combinations, g_i and g_j are the values for general combining ability effect for the i th and j th parents. s_{ij} is the value for specific combining ability effect for the cross between i th and j th parents, b_k is the value for block effect for the k th block, and e_{ijk} is the value for the error.

Results

The sixteen characters except for the grain yields of the eleven varieties are listed in Table 2. First, the degree of agreement with the characteristics of each type specified by SUTŌ *et al.* (1956) was analysed in order to determine whether the eleven varieties belonged to the types of the classification. Longfellow and Iwanai A showed the typical characteristics of *North American* consisting of excellent spring vigor, many tillers, few kernel rows, long cylindrical ears, and long oval-shaped flint kernels. Mais Peta and Granturco Marano classified as *European* showed early maturity and had short stalks, small conical ears, and small round flint kernels, which were very similar to the characteristics of *Aegean*. According to SUTŌ *et al.* (1956), *European* is the general name for the flint types distributed in Europe. Therefore, the main type contributing to these two varieties was estimated to be *Aegean*. Mizuhiki 2 and Hirano were charac-

Table 2. Characteristics of the eleven varieties

Variety	Character	Dent or Flint	Plant height at 40 days after planting	Days to mid-silking	Stalk length	Ear height	No. of ears per plant	No. of tillers per plant	Ear length	Ear diameter	Row number	No. of kernels per row	Hundred-kernel weight	Kernel length	Kernel width	Kernel thickness	Ear weight
			(cm)	(cm)	(cm)	(cm)			(cm)	(cm)			(g)	(mm)	(mm)	(mm)	(kg/a)
1. Longfellow		F	33.9	79	156	45	1.4	2.2	21.3	3.6	8.0	42.7	34.9	9.6	11.1	4.8	93.5
2. Iwanai A		F	35.5	84	167	46	1.0	1.1	21.9	4.0	8.0	47.5	38.1	9.2	12.0	4.5	111.1
3. Mais Peta		F	31.8	77	138	57	1.2	0.4	17.0	4.2	12.2	27.3	32.2	9.0	9.3	5.7	75.1
4. Granturco Marano		F	23.6	78	127	48	1.1	0.2	15.2	4.3	13.6	31.9	25.1	8.5	8.0	5.1	64.4
5. Mizuhiki 2		F	27.8	87	172	74	1.3	0.1	17.1	5.0	14.2	26.5	33.3	9.1	9.5	5.2	98.9
6. Hirano		F	30.1	90	186	92	1.2	0.0	18.2	4.3	8.6	34.6	35.4	9.1	11.4	4.6	85.6
7. Nepal 55		F	25.6	92	206	112	1.0	0.0	17.4	4.2	14.6	28.5	22.6	7.9	7.8	5.6	76.3
8. Dai Sui Hwang		F	24.1	92	185	109	1.5	0.2	18.2	5.0	15.4	31.0	26.8	8.8	8.2	5.2	101.6
9. Zan Kong Shun Zai Rai 227		D	24.1	80	124	54	1.1	0.0	13.4	4.5	12.8	26.6	26.5	9.3	8.7	4.9	69.7
10. Reid's Yellow Dent		D	31.4	90	177	77	1.1	0.3	18.5	4.8	14.4	39.5	25.6	9.7	8.6	4.6	110.9
11. Wisconsin 12		D	29.6	90	193	94	1.2	1.0	17.6	4.7	12.8	37.2	27.5	9.7	8.6	4.6	111.9

terized by medium to late maturity, medium to long stalks, large somewhat conical ears, and large oval-shaped flint kernels, which almost conformed to those of *Caribbean*. However, there were considerable differences between the two varieties in spring vigor and appearance of ear and kernel. Nepal 55 showed the typical characteristics of *Persian* consisting of late maturity, long stalk length, highly set ears, small conical ears, and small round flint kernels. Dai Sui Hwang classified as *Aegean* showed late maturity and had long stalks, which were entirely different from those of *Aegean*, but were rather similar to those of *Caribbean* or *Persian*. Zan Kong Shun Zai Rai 227 classified also as *Aegean* showed early maturity and had short stalks, small conical ears, and small round kernels, which were similar to those of *Aegean*. But, this variety differed from *Aegean* in possessing complete dent kernels. Reid's Yellow Dent and Wisconsin 12 showed the typical characteristics of *American dent* with medium to late maturity, medium to long stalks, long cylindrical ears, and large wedge-shaped dent

Table 3. Mean grain yields of the eleven varieties and one set of all possible single crosses among them

Variety	(Unit: kg/a)											Mean
	1	2	3	4	5	6	7	8	9	10	11	
1. Longfellow	57.5	60.6	56.2	61.1	67.6	62.3	65.5	61.9	58.6	71.7	56.5	61.8
2. Iwanai A		59.9	58.6	55.6	58.6	61.9	62.3	60.6	65.5	65.6	59.0	60.8
3. Mais Peta			43.8	43.7	50.0	59.3	44.8	58.8	55.7	54.7	52.0	52.5
4. Granturco Marano				40.9	53.8	57.6	49.7	61.3	52.4	62.6	55.3	54.0
5. Mizuhiki 2					48.4	59.5	56.5	62.7	58.4	61.1	60.4	57.9
6. Hirano						45.1	64.5	62.6	56.9	64.8	70.1	60.4
7. Nepal 55							37.6	64.2	47.1	65.6	61.2	56.3
8. Dai Sui Hwang								50.3	59.6	75.5	59.4	61.5
9. Zan Kong Shun Zai Rai 227									41.3	58.4	47.9	54.7
10. Reid's Yellow Dent										47.6	56.6	62.2
11. Wisconsin 12											59.0	58.0

Table 4. Ten best combinations for grain yield adjusted by the date of mid-silking

Combination		$F_1 - \hat{F}_1^{(2)}$
		(kg/a)
1. Dai Sui Hwang × Reid's Yellow Dent	(F × D) ¹⁾	15.1
2. Longfellow × Reid's Yellow Dent	(F × D)	12.9
3. Longfellow × Mizuhiki 2	(F × F)	10.3
4. Hirano × Wisconsin 12	(F × D)	9.2
5. Iwanai A × Zan Kong Shun Zai Rai 227	(F × D)	8.8
6. Iwanai A × Reid's Yellow Dent	(F × D)	6.3
7. Longfellow × Nepal 55	(F × F)	5.7
8. Granturco Marano × Reid's Yellow Dent	(F × D)	5.3
9. Longfellow × Granturco Marano	(F × F)	4.9
10. Longfellow × Hirano	(F × F)	3.5

¹⁾ F and D stand for flint and dent, respectively.

²⁾ F_1 is actual grain yield and $\hat{F}_1$ is the value estimated from the regression equation; $\hat{F}_1 = 0.52M + 15.79$, where M indicates the days from planting to mid-silking.

kernels.

Table 3 shows the mean grain yields of the eleven varieties and one set of all possible single crosses among them, and Table 4 shows the ten best combinations for grain yield sampled from Table 3. Since a positive correlation was observed between grain yield and the duration of the growth period, Table 4 was arranged on the basis of relative intensities of deviation from the regression line obtained from the grain yields and the data of mid-silking of the fifty-five crosses. Table 4 shows that all of the ten best combinations were those between varieties from different types and that five of the six best combinations were those between flint and dent varieties.

Table 5 shows the results of analysis of variance for general and specific combining abilities, in which both values were significant at 1% level and the variance for general

Table 5. Analysis of variance for general and specific combining abilities according to Griffing (1956)

Source	DF	MS
General combining ability	10	140.53**
Specific combining ability	55	42.47**
Error	65	13.20

** --- Significant at 1% level.

al combining ability was three times or more larger than that for specific combining ability.

Table 6 shows general and specific combining ability effects estimated from the diallel table for grain yield. Values for general combining ability effect of the eleven varieties ranged from 3.75 to -5.15, and were high in Longfellow and Reid's Yellow Dent, and low in Mais Peta, Granturco Marano, and Zan Kong Shun Zai Rai 227. However, as shown in Fig. 2, there was a significant correlation between general combining ability effects and the data of mid-silking in the eleven varieties. Therefore, general combining ability in consideration of the above relation was high in Longfellow and Iwanai A, Hokkaido local varieties belonging to *North American* and Reid's Yellow Dent belonging to *American dent* and low in Nepal 55 belonging to *Persian*.

Values for specific combining ability effect, on the other hand, ranged from 11.81 to

Table 6. General combining ability (G. C. A.) effects of the eleven varieties and specific combining ability (S. C. A.) effects between them

(Unit: kg/a)

Variety	S. C. A. effect										G. C. A. effect
	2	3	4	5	6	7	8	9	10	11	
1. Longfellow	-3.56	0.25	4.11	6.72	-0.44	6.84	-2.19	0.98	7.26	-5.22	3.75
2. Iwanai A		3.33	-0.71	-1.59	-0.16	4.32	-2.81	8.56	1.84	-2.04	3.06
3. Mais Peta			-4.40	-1.98	5.45	-4.97	3.60	6.97	-0.85	-0.83	-5.15
4. Granturco Marano				0.78	2.71	-1.11	5.06	2.63	6.01	1.43	-4.11
5. Mizuhiki 2					0.72	1.18	2.58	4.75	0.62	2.65	-0.22
6. Hirano						7.94	0.61	1.38	2.46	10.48	1.64
7. Nepal 55							6.29	-4.34	7.34	5.66	-2.44
8. Dai Sui Hwang								2.73	11.81	-1.57	2.99
9. Zan Kong Shun Zai Rai 227									1.18	-6.60	-3.48
10. Reid's Yellow Dent										-4.72	3.34
11. Wisconsin 12											0.62

-6.60 and the ten best combinations are shown in Table 7. According to Table 7, as in the case of F_1 yield shown in Table 4, all of the ten best combinations with regard to specific combining ability effect involved different types and six of the seven best combinations were those between flint and dent types. Six of the ten best combinations for F_1 grain yield also showed high values for specific combining ability effect. As shown in Table 7, Dai Sui Hwang and Zan Kong Shun Zai Rai 227 belonging to the Chinese varieties, and Nepal 55, the variety with the lowest general combining ability, were included in four of the ten best combinations, suggesting that there is no relationship between general and specific combining abilities.

Fig. 2. Relationship between days from planting to mid-silking and general combining ability effects of the eleven varieties.

* --- Correlation coefficient calculated exclusive of three varieties, Longfellow, Iwanai A, and Nepal 55.

Table 7. Ten best combinations for specific combining ability (S. C. A.) effect

combination			S. C. A. effect
			(kg/a)
1. Dai Sui Hwang×Reid's Yellow Dent	(F×D) ¹⁾		11.8
2. Hirano×Wisconsin 12	(F×D)		10.5
3. Iwanai A×Zan Kong Shun Zai Rai 227	(F×D)		8.6
4. Hirano×Nepal 55	(F×F)		7.9
5. Nepal 55×Reid's Yellow Dent	(F×D)		7.3
6. Longfellow×Reid's Yellow Dent	(F×D)		7.3
7. Mais Peta×Zan Kong Shun Zai Rai 227	(F×D)		7.0
8. Longfellow×Nepal 55	(F×F)		6.8
9. Longfellow×Mizuhiki 2	(F×F)		6.7
10. Nepal 55×Dai Sui Hwang	(F×F)		6.3

¹⁾ F and D stand for Flint and Dent, respectively.

Discussion

According to SPRAGUE and TATUM (1942), combining ability is divided into general and specific combining abilities. The term "general combining ability" is used to designate the average performance of a line in hybrid combinations. INOUE and KANEKO (1974) indicated that the difference in general combining ability arises mostly from differences in the accumulation of superior additive genes which are largely dependent on the adaptability to specific locations and history of breeding. This point of view was also supported by the results of this study showing that general combining ability was high in Longfellow and Iwanai A which are well-adapted in Hokkaido, and Reid's Yellow Dent

introduced from the U.S. where maize breeding is highly developed, while low in Nepal 55. Moreover, numerous effective methods to evaluate general combining ability, such as topcross method, have already been developed (JENKINS and BRUNSON 1932, KELLER 1949, and MATZINGER 1953).

On the other hand, the term "specific combining ability" is used to designate those cases in which certain combinations do relatively better or worse than would be expected on the basis of the average performance of the line involved (SPRAGUE and TATUM 1942). Therefore, it is considered that specific combining ability could be most efficiently evaluated by the values of specific combining ability effects based on diallel analysis. Specific combining ability usually plays a minor role in F_1 grain yield compared with general combining ability. However, specific combining ability actually determines the yielding ability of hybrids after general combining ability has been improved or when materials with identical general combining ability are crossed. The importance of specific combining ability was also evident in this study in which six of the ten best combinations for grain yield also showed high values for specific combining ability effect. Specific combining ability, however, is considered to be appreciably influenced by non-additive gene effects. Many problems remain to be solved and no reliable methods to predict specific combining ability have been developed thus far.

One of the purposes of this study was to confirm the results of the previous reports and to generalize them. Although the data referred to only two varieties for each type (one for *Persian*) and were restricted to one year and location, the results obtained were in good agreement with those of the previous reports, namely, combinations between different types, especially those between flint and dent types, showed a higher specific combining ability and resulted in more yielding crosses. Moreover, on the basis of Table 8 which shows the values for average grain yield and specific combining ability effect of

Table 8. Comparison of F_1 yields and specific combining ability (S. C. A.) effects in the various combinations among flint and dent types

Combination	No. of combinations	F_1 yield (kg/a)		S. C. A. effect
		Mean	Maximum	
Flint $\times$ Flint	28	58.6	67.6	1.21
Dent $\times$ Dent	3	54.3	58.4	-3.38
Flint $\times$ Dent	24	60.4	75.5	2.95

various combinations differing in kernel property, that is, flint and dent types, it is evident that the hybrid combinations between different kernel types were superior to those within the same kernel types, indicating that this trend can be expanded as a general relationship in hybrid combinations between flint and dent types.

The second purpose of this study was to identify the general trend of specific combining ability between the six different types. Table 9 shows the average values of specific combining ability effects between the six types. In the Table 9, however, Dai Sui Hwang and Zan Kong Shun Zai Rai 227 which fell into the group of *Aegean* defined by SUTO *et al.* (1956) were dealt as varieties which did not belong to any type, because some of their characteristics did not correspond to those of *Aegean*. Consequently, Table 9

Table 9. Average values of specific combining ability effects between the different types classified by SUTŌ *et al.* (1956)

Type	North American	European	Caribbean	Persian	American dent †	Dai Sui ¹⁾ Hwang	Zan Kong Shun ¹⁾ Zai Rai 227
North American	−3.56	1.75	1.13	5.58	0.46	−2.50	4.77
European		−4.40	1.74	−3.04	1.44	4.33	4.80
Caribbean			0.72	4.88	4.05	1.60	3.07
Persian				—	6.50	6.29	−4.34
American dent					−4.72	5.12	−2.71
Dai Sui Hwang						—	2.73
Zan Kong Shun Zai Rai 227							—

¹⁾ As regards Dai Sui Hwang and Zan Kong Shun Zai Rai 227, the types to which they belong were not clearly established.

actually shows the relationship between the five types except for *Aegean*. It can be seen that combinations within the same types were low in specific combining ability, as already stated based on the results shown in Table 7.

Although *North American*, one of the most important breeding materials in northern Japan, has been best utilized in the combinations with *American dent*, its specific combining ability was not so particularly high as that of the combinations with other types. This could be explained by the fact that the present *American dent* was derived from the hybridization between *North American* and *Southern dent* as mentioned by ANDERSON and BROWN (1952).

Another important material in Japan is *Caribbean* which is distributed in various areas of the country except for Hokkaido. YAMASAKI (1954) and NAKAMURA *et al.* (1978) reported that the combinations of *Caribbean* with *American dent* resulted in more yielding hybrids. From the results of this study it was also shown that the combinations between these types induced high specific combining ability. *European*, in any of the combinations with other types, showed small values of specific combining ability effects. This may be ascribed to the fact that *European* consists of varieties derived from various degrees of hybridization among *Aegean*, *North American*, and *Caribbean*. The characteristics of Mais Peta and Granturco Marano classified as *European* showed that they mainly corresponded to those of *Aegean*. Therefore, the very small value of specific combining ability effect in the combination of *European* with *Persian* is in agreement with data of SUTŌ *et al.* (1956) who inferred that *Aegean* was a subtype of *Persian*.

It would be noteworthy in hybrid breeding that, *Persian*, of which only one variety was studied, had remarkably high values of specific combining ability effects in the combinations with *North American*, *Caribbean* and *American dent*. Some of the characters of Dai Sui Hwang classified as *Aegean*, such as maturity and stalk length, were entirely different from those of *Aegean*. This finding was also supported by the values of specific combining ability effects which were large when Dai Sui Hwang was combined with *European* and *Persian* which are considered to be closely related with *Aegean*, and which were small when it was combined with *North American* and *Caribbean*. Zan Kong Shun Zai Rai 227, based on the observed characteristics, was estimated to be derived from the

hybridization between *American dent* and *Aegean*. This was also confirmed by the fact that values of specific combining ability effects were small in the combinations with *American dent* and with *Persian* which is presumably closely related to *Aegean*.

In the above discussion which is based on the relationship between the six types shown by SUTŌ *et al.* (1956) and ANDERSON and BROWN (1952), it is inferred that the higher the genetic divergence, the larger the values of specific combining ability effects are. The

Fig. 3. Illustration of genetic divergence among the five different types estimated from specific combining ability effects.

* Figures in () show values of specific combining ability effects.

results of this study, in most cases, supported the above-mentioned assumption. Furthermore, this suggested that it is possible to estimate the genetic divergence between breeding materials from the values of specific combining ability effects. Fig. 3 shows the relative position in genetic divergence between the five types exclusive of *Aegean*, estimated from the values of specific combining ability effects obtained in this study, where *Aegean* is supposed to be located between *European* and *Persian*.

There have been numerous reports indicating that higher genetic divergence resulted in more yielding hybrids. However, most of the authors did not consider genetic divergence in relation to specific combining ability effects. INOUE and KANEKO (1974) showed that the contribution of specific combining ability effects to F_1 yield in relation to genetic divergence was more significant than that of general combining ability effects. On the other hand, MOLL *et al.* (1965) reported that the degree of heterosis increased with increasing divergence within a restricted range of divergence and that extremely divergent crosses, however, led to a decrease in the degree of heterosis and F_1 yield. Since MOLL's results were not discussed in relation to specific combining ability effects, they do not conflict with the interpretation of our results. In conclusion, it appears that there is a close relationship between genetic divergence and specific combining ability effects, in which the values of specific combining ability effects increase with genetic divergence.

The information obtained from this study about specific combining ability between the different types could contribute to practical hybrid breeding, provided the classification of the types to which the breeding materials belong is improved. However, with the promotion of worldwide exchange of breeding materials and the accumulation of superior genes from different types within a population, intermediate types, such as *European* and the Chinese varieties used in this study, have been produced with higher frequency. Consequently, it becomes extremely difficult to classify these types on the basis of distinct characteristics, such as ear shape and kernel property. Therefore, it will be essential to develop a more objective classification method which would enable to predict specific combining ability between breeding materials. MOCHIZUKI (1968), who applied the principal component analysis to ten characters of seventy-two maize strains, observed a

high correlation between the scores for each strain in the first principal component and their general combining ability for grain yield estimated from topcross performance. In the future, it will become important to consider the relationship between specific combining ability and classifications based on multivariate statistical analysis and biochemical methods.

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トウモロコシの 11 自然受粉品種のダイアレル交雑から得られた
6 つの異なる型の間の特定組合せ能力

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トウモロコシの一代雑種育種では、一般組合せ能力に対する改良と並行して、特定組合せ能力 (SCA) の高い組合せの選定が必要となる。しかし、両親の SCA を適確に予知する方法は現在のところ十分に確立されていない。経験的に、遠縁の組合せ程 SCA が高い傾向にあることが知られるため、地理的分布や形態的特性の違いによる分類結果や、育種の系譜を参考にして近縁関係を推定し両親組合せを決定している。Sutō ら (1956) は、アジアに分布するフリント種を 5 つの型に分類した。これにアメリカデント種を加えた 6 つの型が日本における主な育種材料である。本研究の目的は、これら 6 つの型の間の SCA についての関係を明らかにし、一代雑種育成における両親決定上の一助にしようとした。

6 つの型に属する 11 の自然受粉品種を選び、それらの間のダイアレル交雑の子実収量を検定した。さらに、ダイアレル分析から得られた SCA 効果によって、異なる型の間の SCA についてその相対的大きさを比較した。

その結果、(1) 異なる型に属する品種組合せ、特にフリント種とデント種との組合せにおいて収量および SCA 効果が高い傾向にあり、多収一代雑種が得られることが推測された。(2) カリビア型とアメリカデント種との組合せおよびペルシア型と他の型との組合せにおいて高い SCA が認められた。(3) 本研究で得られた SCA 効果と、従来の分類結果から推定される型の間の近縁関係との間に密接な関係が認められた。そのため、SCA 効果に基づいた型の間の近縁関係の推定を試みた。