DIALLEL AND PARTIAL DIALLEL ANALYSIS OF SOME YIELD FACTORS IN *LINUM USITATISSIMUM* *

B. R. MURTY, V. ARUNACHALAM and I. J. ANAND

Division of Botany, Indian Agricultural Research Institute, New Delhi—12 (India)

1. INTRODUCTION

DIALLEL analysis has been widely used in studies on the nature of gene action both in cross-pollinated crops like maize (Matzinger, 1958; Moll *et al.*, 1962) and self-pollinated ones like *Nicotiana* (Jinks, 1954) where a sufficient number of pollinations can be made with ease. However, a full diallel set becomes unmanageable with an increase in the number of parents, particularly in crops like wheat and linseed where the number of seeds per reproductive unit is very low. The reports on partial diallel analysis (Kempthorne and Curnow, 1961; Hinkelmann and Kempthorne, 1963; Curnow, 1963; Fyfe and Gilbert, 1963) have shown that selection can be made among crosses from a wider range of parents and the general combining abilities of a larger number of parents can be estimated although with a certain loss of precision which is compensated by the greater intensity of selection that can be applied to the parents. Kearsey (1965), in comparing different experimental designs, has found that " the partial diallel appears to yield no more information that the two North Carolina designs ". It is desirable, therefore, to find out the changes in the estimates of the components of genetic variation which occur with a change in the size of the partial diallel as compared to the full diallel. Such an analysis on six characters related to yield in a full diallel set without reciprocals in some varieties of linseed representative of the cultivated types, whose genetic divergence as assessed by the multivariate D^2-statistic is already known, is presented in this paper.

2. MATERIALS AND METHODS

Ten highly inbred varieties of linseed, namely, N.P.12, N.55, M.10, Mayurbhung, Afghanistan-2, F.Wada, A17-1-1, N.P.(RR)9, N.P.(RR)45 and Mohaba local representing Peninsular (from the Deccan peninsula), Indo-Gangetic (from the Indo-Gangetic plains), and exotic (non-Indian in origin) groups with varying degrees of genetic diversity formed the parental material. The full diallel set of crosses among them, excluding reciprocals, was grown here during 1963-64 and 1964-65 in a randomised complete block design with three replications.

Observations were taken on six characters related to fitness, namely, flowering time, height, height at branching, number of fruit-bearing branches, number of capsules per plant and number of seeds per five capsules on random samples of five plants.

Following the circulant sampling design outlined by Kempthorne and Curnow

---

(1961), partial diallel sets corresponding to $s = 7, 5, 3$ were formed from the full diallel set of F_1's. The data on the six characters for both the years were analysed for the full and each of the partial diallel set using an I.B.M. 1620 electronic computer.

3. RESULTS

The analyses of variance for 1963-64 for all the six characters are presented for the cases $s = 9, 7, 5$ and 3 in table 1.

TABLE 1

Analysis of means for six characters from partial diallel crosses in Linum usitatissimum L. *(1963-64)*

Character	Source	G.C.A.	S.C.A.	Error
	d.f.	9	$5^s — 10$	$10^s — 2$
	s	Mean sum of squares		
Flowering time (days)	9	605·85	410·27	58·55
	7	501·78	452·46	54·73
	5	350·36	522·83	54·59
	3	242·16	1050·15	45·83
Height (cm.)	9	684·82	495·27	60·46
	7	439·38	500·12	62·84
	5	295·46	485·32	26·80
	3	217·74	927·89	12·27
Height at branching (cm.)	9	288·37	186·66	26·24
	7	170·57	168·08	26·58
	5	116·97	196·29	15·34
	3	67·42	354·67	14·42
No. of fruit-bearing branches	9	* 2211·10	6969·16	2215·02
	7	* 1652·68	7556·45	2350·09
	5	* 1715·83	10,802·83	1922·66
	3	* 2065·82	19,060·95	2173·90
No. of capsules per plant	9	* 24,197·14	68,177·36	17,995·90
	7	* 18,695·11	71,457·04	19,497·29
	5	* 20,708·05	104,685·77	15,232·52
	3	* 21,667·10	18,005·42	15,918·96
No. of seed per capsule	9	22·53	27·49	5·50
	7	19·26	29·90	4·69
	5	16·07	35·64	5·29
	3	* 7·58	40·06	4·95

* N.S.—Not significant.   Others significant at 1 per cent. level.

It is found that the variation due to general combining ability (*g.c.a.*) among the parents and specific combining ability (*s.c.a.*) among

the crosses are significant in both the years for flowering time, height and height at branching while in the cases of other characters only *s.c.a.* is significant excepting that the *g.c.a.* in the case of number of seeds per five capsules is significant for $s = 9$, 7 and 5 in 1963-64 only. About half the total variation is accounted for by the differences due to *s.c.a.* for all the values of *s* and for all the characters in both the years. The sum of squares due to *s.c.a.* is about two to three times more than the sum of squares due to *g.c.a.* for all the characters except in the cases of number of fruit-bearing branches and number of capsules per plant where this proportion is much larger. Thus, predominant non-additive gene action is indicated for the characters under study. However, the *g.c.a.* component is also substantial and significant for most of the characters which indicates that progress under selection is possible to a considerable degree. Whether material effects are also operating is being examined in a separate experiment.

The *g.c.a.* effects estimated by the method of least squares along with the average standard error of the difference between any two *g.c.a.* effects (taken over all the crosses) for four of the characters are presented in table 2.

For example, in the case of flowering time, Afghanistan-2, A-17-1-1, N.P.12 have positive *g.c.a.* effects in that order while Mayurbhung, M.10, F.Wada, Mohaba local and N.55 have negative *g.c.a.* effects indicating that the latter are desirable parents for this character. However, when *s* is reduced from (*n*-1) gradually (where *n* is the number of parents), the *g.c.a.* effects of different parents tend to be overestimated in the case of each character. The magnitudes of the effects have varied with years for all characters, probably due to the unfavourable environmental conditions in 1964-65.

From the mean sum of squares of the various components, σ_s^2 ($=\sigma_{s.c.a.}^2$) and σ_e^2 have been estimated for different characters in both the years. The values of *s* plotted against $\log_e \sigma_s^2/\sigma_e^2$ and average S.E. (g_i-g_j) are presented in fig. 1.

As expected, the average S.E. (g_i-g_j) increases as *s* decreases. For example, in the case of flowering time, the average S.E. for $s=5$ is about 1·7 times that of $s=9$, but when $s=3$, it is increased to about four times that of $s=9$. Thus there is a steep rise in the slopes for *s* less than $n/2$ for all the characters indicating thereby that it is not desirable to reduce the fraction of diallel with *s* less than $n/2$ in this material. It is to be seen if the fraction can further be reduced with larger values of *n*.

4. DISCUSSION

The present study, which was undertaken to compare the precision of the estimates of *g.c.a.* with a decrease in the size of the partial diallel as compared to the full diallel, has indicated that, in a crop like linseed, it is possible to reduce the crossing programme substantially with a

C 2

TABLE 2

General combining ability effects of the ten parents used in partial diallel crosses for six characters in Linum usitatissimum *L.* (1963-64)

Character	s	Parents										Av. S.E. $(g_i - g_j)$
		1	2	3	4	5	6	7	8	9	10	
A	9	3·81	—4·97	—6·51	—6·80	19·81	—6·48	8·99	—3·30	0·64	—5·19	5·85
	5	8·04	0·69	—3·30	—5·74	18·43	—11·26	4·73	—7·97	—0·55	—3·07	9·85
	3	12·17	2·66	—1·26	—8·50	14·27	—15·75	0·68	—6·81	1·49	1·05	24·13
B	9	—7·32	—6·90	—8·52	—2·88	13·82	19·03	2·13	—3·73	—3·54	—2·09	6·42
	5	—4·73	—5·83	—8·12	—6·35	15·91	15·93	4·00	—6·96	—2·78	—1·07	9·49
	3	—5·01	—3·85	—9·89	—5·53	15·52	14·58	2·87	—9·17	0·79	—0·31	22·74
C	9	—3·43	—5·61	—5·05	—4·22	9·80	10·12	4·86	1·23	—3·04	—2·20	3·94
	5	—3·90	—5·74	—4·35	—4·64	11·98	9·01	4·74	1·68	—3·19	—2·23	6·03
	3	—3·01	—2·22	—4·46	—4·56	11·16	5·74	4·53	3·67	—2·95	—0·56	14·06
D	9	—19·95	18·66	4·79	—17·52	21·36	—22·76	7·06	17·88	—1·46	—8·06	24·08
	5	—8·90	11·02	21·99	—17·85	26·47	—38·34	5·74	4·68	—8·00	3·29	44·76
	3	—25·26	15·75	54·24	—3·18	74·48	—22·96	—21·01	—14·53	—45·15	—12·38	103·05
E	9	—76·53	36·16	29·22	—40·46	68·69	—85·03	30·80	60·69	7·07	—30·61	75·36
	5	—15·60	39·14	80·62	—60·14	70·22	—143·83	37·04	26·48	—19·15	—14·79	139·30
	3	—50·01	75·11	196·74	—10·67	210·05	—106·69	—69·24	—46·74	—134·42	—64·13	316·69
F	9	—0·57	—1·17	0·42	1·14	0·86	2·86	—2·31	1·72	—2·05	—0·90	1·51
	5	—0·02	—0·78	1·38	0·25	1·00	1·94	—3·69	2·27	—2·17	0·32	2·56
	3	—0·47	2·12	3·90	2·21	1·70	0·46	—4·54	—1·87	—4·09	0·68	4·73

A—Flowering time (days)   B—Height (cm.)   C—Height at branching (cm.)
D—No. of fruit-bearing branches   E—No. of capsules per plant   F—No. of seeds per capsule

1—N.P.12   2—N.55   3—M.10   4—Mayurbhung   5—Afghanistan-2   6—F.Wada   7—A-17-1-1   8—N.P.(RR)9   9—N.P.(RR)45   10—Mohaba local

FLOWERING TIME

HEIGHT

No. OF CAPSULES PER PLANT

No. OF SEEDS PER CAPSULE
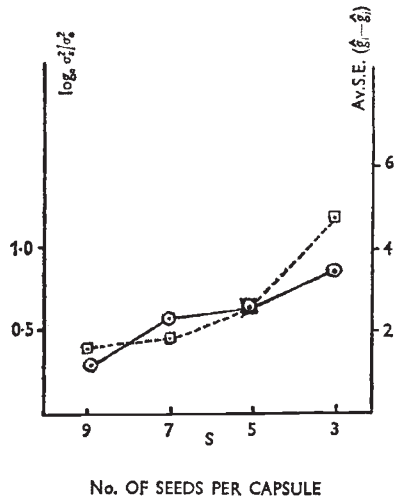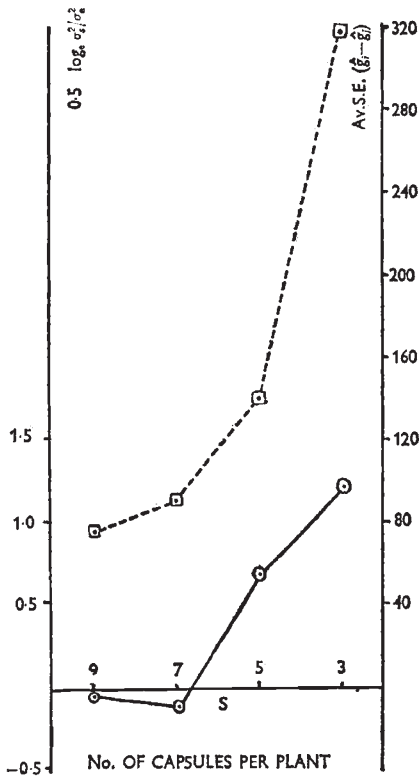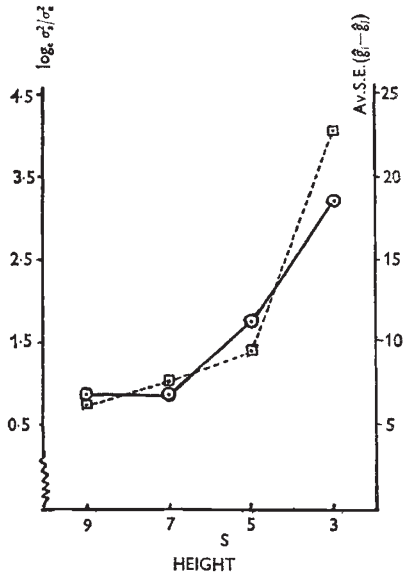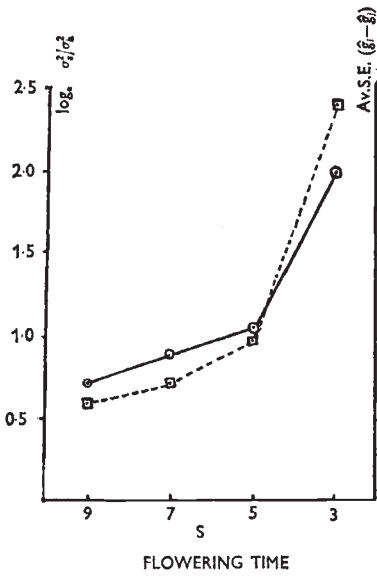
moderate decrease in precision. Moreover, there is a substantial increase in the standard error of estimates as s is reduced below $n/2$, where n is the number of parents, in the present investigation (see fig. 1). This phenomenon is consistent for all the six characters reported and four more characters, viz., number of early tillers, length of early tillers, number of late tillers and length of late tillers. The results are consistent in both the years confirming that $s=5$ is adequate for all the characters. Since the characters are known to influence yield (directly or indirectly), it appears that nearly half the number of possible crosses would be adequate for yield analysis.

A comparison of changes in $\log_e \sigma_s^2/\sigma_e^2$ (fig. 1) has confirmed that there is an abrupt change in the slope for values of s less than $n/2$ for practically all the characters. There is also a tendency of overestimating the g.c.a. effects with a decrease in s. The degree of departure from the corresponding estimates of a complete diallel was also in line with the changes in the average S.E. $(g_i - g_j)$. Since the order of magnitude of the parents in their g.c.a. effects is not altered for values of s ranging from $(n-1)$ to $n/2$, it is possible to screen several parents for their combining ability within these limits of s.

Assuming that the cost of making a cross is one unit and that of assessing it is k units, the saving in the cost of a partial diallel for $s = n/2$ as compared to the full diallel $(s = n-1)$ is nearly 45 per cent. when $n = 10$ and 47·5 per cent. when $n = 20$. In general, the saving expressed as the proportion of the cost of a full diallel is equal to $(n-2)/2(n-1)$ and the rate of change of saving as n, the number of parents, increases is equal to $1/2(n-1)^2$ and is independent of k.

It is recognised that the value of $s = n/2$ is adequate only for the size and nature of the material of this investigation. It is likely that the value of s may be considerably less than $n/2$ as n increases.

A breeder who is interested in ordering a large number of varieties for their g.c.a. effects can undertake a complete diallel programme with a limited number of parents selected on the results of the partial diallel.

The present investigation has shown that a partial diallel even with a limited number of parents is useful in crops like linseed where the seeds obtained per pollination are only three or four.

An investigation is under way to determine the optimum s with $n = 40$, which may be useful for generalised conclusions.

5. SUMMARY

1. A comparison of the estimates of combining ability obtained from a full diallel and from partial diallel sets for all possible values of s involving various lines of linseed is described.

2. The parents represent different degrees of divergence as measured by D^2 statistics.

3. Six characters which contribute to yield and fitness under cultivation have been examined in 1963-64 and 1964-65.

4. The magnitudes of the variation due to general and specific combining ability are significant for all characters and all values of s in both the years. The predominant role of non-additive gene action was reflected in the full and in all partial diallel sets for all the characters.

5. The general combining ability effects tend to be overestimated with the decrease in s particularly when s is less than $n/2$ for all the characters although the order of the parents remained essentially the same in their g.c.a. effects for different values of s.

6. The average S.E. $(g_i - g_j)$ increased with the decrease in s with a steep rise in the slope for s less than $n/2$ for all the characters. This was also confirmed by the changes in σ_s^2/σ_e^2 with changes in s.

7. Even with limited samples, a partial diallel with $s = n/2$ may be adequate for screening the parents for their general combining ability effects.

6. REFERENCES

CURNOW, R. N. 1963. Sampling the diallel cross. *Biometrics, 19*, 287-306.

FYFE, J. L., AND GILBERT, N. 1963. Partial diallel crosses. *Biometrics, 19*, 278-286.

HINKELMANN, K., AND KEMPTHORNE, O. 1963. Two classes of group divisible partial diallel crosses. *Biometrika, 50*, 281-291.

JINKS, J. L. 1954. The analysis of continuous variation in a diallel cross of *Nicotiana rustica* varieties. *Genetics, 39*, 767-788.

KEARSEY, M. J. 1965. Biometrical analysis of a random mating population: A comparison of five experimental designs. *Heredity, 20*, 205-235.

KEMPTHORNE, O, AND CURNOW, R. N. 1961. The partial diallel cross. *Biometrics, 17*, 229-250.

MATZINGER, D. F. 1958. Components of variance of diallel crosses of maize in experiments repeated over locations and years. *Iowa St. College J. Sci., 81*, 469.

MOLL, R. H., SALHAUANA, W. S., AND ROBINSON, H. F. 1962. Heterosis and genetic diversity in variety crosses of maise. *Crop Science, 2*, 197-198.

MURTY, B. R., AND ANAND, I. J. 1965. Combining ability and genetic diversity in some varieties of *Linum usitatissimum* L. *Ind. J. Genet., 26* (under publication).