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# Estimation of Genetic Parameters in Barley (*Hordeum vulgare* L.)
## II. Partial Diallel Analysis

B.D. Chaudhary, S.N. Kakar and R.K. Singh
Haryana Agricultural University, Hissar (India)

Summary. Four different sets of partial diallels were analysed for their relative efficiencies for estimating the genetic parameters in barley: (1) partial diallel with 12 parents, each involved in only 5 crosses; (2) partial diallel with 12 parents, each involved in only 3 crosses; (3) partial diallel with 8 parents, each involved in only 5 crosses; and (4) partial diallel with 8 parents, each involved in only 3 crosses. In partial diallel experiments, the estimates of gca effects were higher than in those of full diallel. Ranking pattern of the parents on the basis of gca effects in partial diallels deviated considerably from the ranking in full diallel. With decreasing 's' per parent, the deviation in ranking was also more. This clearly suggests the unsuitability of partial diallel analysis for screening high general combiners. Selection of best cross combinations is also not possible because only a sample of crosses (s out of n) is analysed under partial diallel so that there is every possibility of the best cross being excluded from the sample. In general, overdominance was exhibited, indicating that there is ample scope for heterosis breeding in barley.

Diallel cross analysis involving all possible combinations in a set of $n$ inbreds becomes unmanageable as the number of lines (n) increases. On the other hand, if only a small number of inbreds is tested, the estimates of combining ability tend to have a large sampling error. These difficulties have led to the development of the concept of sampling of crosses produced by a larger number of inbreds without affecting the efficiency of diallel technique. To achieve this goal different approaches have been followed by various workers (Kempthorne and Curnow 1961; Hinkelmann and Stern 1960; Fyfe and Gilbert 1963; Hinkelmann 1968). In the present investigation the model proposed by Kempthorne and Curnow (1961) for partial diallel was used. Its relative efficiency in contrast to full-diallel was tested in estimating the genetic parameters in barley, considering (i) two sets of parents, the one with 12 and the other with 8 parents, and (ii) the two sizes of the sampled crosses per line. The information collected on the nature and magnitude of genetic parameters would help in formulating a suitable breeding policy in barley.

### Material and Method

Six exotic (AB-12/59, Eb-1556, PTS-57, A-59, Numer and EC-24882) and six indigenous (BG-1, K-572/10, IB-226, C-164, RD-42 and BP-3) varieties of barley were selected, keeping in view their diversity, and the following four sets of partial diallel crosses (PD) were produced:

1. PD I : 12 parents, each involved in 5 crosses
2. PD II : 12 parents, each involved in 3 crosses
3. PD III : 8 parents, each involved in 5 crosses
4. PD IV : 8 parents, each involved in 3 crosses.

The Kempthorne and Curnow (1961) sampling process was adopted. The crosses, together with their parents, were tested in a randomised block design with four replications. In each case, five plants per plot were selected randomly and observations were recorded on (i) plant height, (ii) number of effective tillers, (iii) ear length, (iv) number of grains per ear, (v) 100-seed weight and (vi) grain yield per plant. The following statistical model was used for the analysis of partial diallel:

$$Y_{ijl} = m + r_l + g_i + s_{ij} + e_{ijl}$$

where,

$Y_{ijl}$ = the phenotypic value of ijth cross in lth replication
$m$ = general mean
$r_l$ = effect of lth replication
$g_i$ = general combining ability (gca) effect of ith parent
$s_{ij}$ = specific combining ability (sca) effect of the i × jth cross
$e_{ijl}$ = error effect.

The general and specific combining ability effects and variances were estimated; these variances were translated into components of genetic variances (i.e. $\sigma_A^2$ and $\sigma_D^2$) following the model of Griffing (1956). The additive genetic variance ($\sigma_A^2$) and the variances due to dominance deviations ($\sigma_D^2$) were used to estimate the average degree of dominance.

Table 1. Combining ability analysis in full and partial diallel experiments with the degree of dominance

| Type of diallel experiment | Source | D.F. | Mean sum of squares* | | | | | |
|---|---|---|---|---|---|---|---|---|
| | | | Plant height (cm) | Ear length (cm) | Number of effective tillers | Grain yield (gm) | 100-grain weight (gm) | Number of grains per ear |
| F.D | gca | 7 | 151.50 | 2.05 | 58.07 | 543.64 | 0.33 | 206.89 |
| | sca | 28 | 82.68 | 1.78 | 140.95 | 787.87 | 0.15 | 108.66 |
| | error | 189 | 11.12 | 0.98 | 8.72 | 21.35 | 0.11 | 3.97 |
| | $\sigma^2_D/\sigma^2_A$ | | 4.59 | 12.58 | 7.37 | 14.92 | 1.16 | 4.70 |
| PD-I | gca | 11 | 185.07 | 6.56 | 558.47 | 4025.57 | 0.68 | 213.06 |
| | sca | 18 | 140.85 | 3.19 | 355.58 | 1750.00 | 0.51 | 275.15 |
| | error | 87 | 19.76 | 0.25 | 21.63 | 124.38 | 0.01 | 2.74 |
| | $\sigma^2_D/\sigma^2_A$ | | 6.22 | 1.98 | 3.74 | 1.62 | 7.11 | 9.98 |
| PD-II | gca | 11 | 82.41 | 5.74 | 385.25 | 3865.49 | 0.58 | 130.00 |
| | sca | 6 | 43.09 | 2.54 | 358.73 | 1623.74 | 0.70 | 275.21 |
| | error | 51 | 20.08 | 0.25 | 18.26 | 106.93 | 0.01 | 2.15 |
| | $\sigma^2_D/\sigma^2_A$ | | 0.79 | 0.98 | 17.51 | 0.92 | 7.96 | 2.56 |
| PD-III | gca | 7 | 449.83 | 5.10 | 341.28 | 1702.63 | 0.28 | 173.62 |
| | sca | 12 | 111.53 | 6.19 | 314.14 | 1770.16 | 0.31 | 232.10 |
| | error | 57 | 19.33 | 0.27 | 17.10 | 104.32 | 0.01 | 3.59 |
| | $\sigma^2_D/\sigma^2_A$ | | 0.58 | 11.48 | 23.83 | 52.86 | 5.50 | 8.30 |
| PD-IV | gca | 7 | 311.86 | 4.98 | 478.11 | 3029.85 | 0.37 | 215.62 |
| | sca | 4 | 164.53 | 11.02 | 227.90 | 944.23 | 0.52 | 340.21 |
| | error | 33 | 21.43 | 0.32 | 16.90 | 100.65 | 0.01 | 4.05 |
| | $\sigma^2_D/\sigma^2_A$ | | 1.25 | 1.99 | 1.09 | 0.52 | 4.30 | 3.47 |

* All mean sum of squares were significant at 5 % level

## Results

Combining ability analysis showed that variances due to general and specific combining ability were significant for all the characters under each of the four sets of partial diallel (Table 1). The significance of both these components indicated the occurrence of both additive and non-additive types of gene effect in the present material. The relative magnitude of additive to non-additive type of gene action was measured as a ratio of $\sigma^2_D/\sigma^2_A$, i.e. average degree of dominance. In general, the dominance type of gene action seemed to predominate. For number of effective tillers and number of grains per ear, over-dominance was exhibited under all the four sets of partial diallel. For ear length, the values under the three partial diallels, i.e. PD-I, PD-III and PD-IV, were in the range of overdominance, but in PD-II complete dominance was shown. Overdominance was also evident under PD-I, II and III for grain yield and 100 grain weight. For plant height, however, the over-dominance values were obtained only under PD-I and IV, whereas the other two designs gave an indication of partial dominance. Another observation was that the value for average degree of dominance was lower in P.D.-II than in P.D.I, except for effective tillers. Similarly, these estimates were lower in PD IV than in PD III, except for plant height. The full diallel which was comparable with PD III and IV provided an estimate of degree of dominance which was less than that of PD III, but more than PD IV, except in the case of plant height. The mean sums of squares due to gca and sca were generally greater in partial diallels than in full diallel.

An analysis of the gca effects (Table 2) obtained under four different partial diallels indicated that the ranking pattern of the parents with regard to gca effect under PD-I was similar to that under PD-II; also, ran-

Table 2. General combining ability effects in full and partial diallel experiments

| Characters | Types of diallel experiment | AB-12/59 | EB-1556 | BG-1 | PTS-57 | A-59 | K-572/10 | IB-226 | C-164 |
|---|---|---|---|---|---|---|---|---|---|
| Plant height (cm) | FD | -1.81 | 3.77 | -3.60 | -2.91 | -0.71 | 1.85 | -1.26 | 4.67 |
| | PD-I | -1.66 | 6.28 | 3.22 | -4.92 | 2.42 | -0.76 | -3.46 | 1.40 |
| | PD-II | -3.55 | 3.84 | 5.41 | 0.76 | 7.30 | 2.63 | 3.61 | 1.33 |
| | PD-III | 3.82 | 9.38 | -1.44 | -7.47 | -5.00 | -0.71 | 4.16 | 5.58 |
| | PD-IV | 4.94 | 10.73 | 0.76 | -9.46 | -6.55 | -1.63 | -7.04 | 8.25 |
| Ear length (cm) | FD | 0.16 | 0.13 | -0.49 | -0.32 | 0.06 | -0.21 | 0.69 | -0.02 |
| | PD-I | 0.02 | -0.07 | -0.48 | -0.20 | 0.97 | 0.60 | 1.56 | -0.17 |
| | PD-II | 0.48 | 0.01 | -0.75 | 0.27 | 1.69 | 0.79 | 1.38 | -0.67 |
| | PD-III | 0.74 | 0.65 | -0.50 | -0.85 | 0.06 | -0.37 | 0.44 | -0.18 |
| | PD-IV | 0.35 | 0.02 | -1.39 | -1.40 | 0.50 | 0.08 | 1.39 | 0.44 |
| Effective tillers | FD | -0.59 | -1.32 | 3.24 | -1.41 | -1.00 | 0.64 | 2.38 | -1.95 |
| | PD-I | -5.09 | -7.56 | 7.88 | 1.06 | 5.50 | -6.06 | 4.62 | -5.67 |
| | PD-II | -11.37 | -9.53 | 5.28 | 3.80 | 4.21 | -5.52 | 8.68 | -0.54 |
| | PD-III | 2.74 | 2.79 | 9.64 | 0.01 | -1.21 | -6.30 | -2.94 | -4.71 |
| | PD-IV | 4.58 | 5.07 | 21.32 | 2.05 | 1.73 | -13.37 | -9.83 | -11.55 |
| Grain yield (gm) | FD | -0.06 | 0.47 | 9.03 | -3.44 | -2.33 | -1.94 | 7.24 | -9.10 |
| | PD-I | -15.74 | -18.53 | 19.90 | 1.20 | 23.72 | -7.00 | 20.45 | -16.68 |
| | PD-II | -30.24 | -21.94 | 32.77 | 21.18 | 26.98 | -2.47 | 26.84 | -9.88 |
| | PD-III | 9.75 | 3.67 | 15.09 | -3.58 | 5.03 | -12.91 | -4.25 | -12.63 |
| | PD-IV | 24.60 | 13.16 | 40.03 | -15.34 | 5.21 | -37.61 | -13.98 | -16.07 |
| 100-grain weight (gm) | FD | -0.16 | -0.28 | -0.04 | 0.04 | 0.06 | 0.09 | 0.09 | 0.12 |
| | PD-I | -0.30 | -0.41 | 0.17 | -0.07 | 0.41 | 0.21 | 0.18 | 0.34 |
| | PD-II | -0.29 | -0.02 | 0.50 | 0.13 | 0.88 | 0.47 | 0.10 | -0.03 |
| | PD-III | -0.17 | -0.23 | -0.03 | -0.02 | 0.09 | 0.07 | 0.11 | 0.19 |
| | PD-IV | -0.01 | -0.40 | -0.22 | -0.19 | 0.09 | 0.05 | 0.45 | 0.21 |
| Number of grains per ear | FD | 2.08 | 6.93 | 1.39 | -1.52 | -1.14 | -2.10 | -0.33 | -5.30 |
| | PD-I | 0.15 | 5.52 | -0.47 | 0.42 | 1.09 | 1.05 | 3.03 | -7.81 |
| | PD-II | -1.53 | -0.68 | 2.51 | 6.30 | -1.44 | -0.79 | 4.84 | -5.05 |
| | PD-III | 3.69 | 2.53 | -2.69 | -3.12 | 3.45 | 0.83 | -0.20 | -4.48 |
| | PD-IV | 7.30 | 7.10 | -0.02 | -0.02 | 0.31 | -4.23 | -2.39 | 0.95 |

king under PD-III was similar to PD-IV. These two groups, however, differed considerably from each other. On the basis of the data on gca effects under these four diallels, EB-1556 and C-164 proved to be the best general combiners for plant height. For ear length, the parents showing consistently high combining ability were IB-226, A-59 and AB-15/59. A-59 was also a good combiner for grain yield per plant and 100-grain weight. For number of effective tillers and grain yield per plant, BG-1 exhibited exceptionally high general combining ability.

For a better comparison, the parents were ranked on the basis of their gca effects under full diallel and this ranking was compared with the ranking done on the basis of gca effects under partial diallels separately (Table 3). Again, it was evident that the ranking pattern under PD I was more or less the same as under PD II. Similarly, the rankings for PD III and PD IV were alike. However, in none of these cases was the ranking similar to that of full diallel. With the help of

Table 3. Ranking of parents based on their gca effects in full and partial diallel

| Parents | Full diallel | PD-I | PD-II | PD-III | PD-IV | Pooled PD |
|---|---|---|---|---|---|---|
| AB-12/59 | 4 | 8 | 8 | 1.5 | 1 | 4 |
| EB-1556 | 3 | 6 | 6 | 1.5 | 2 | 5 |
| BG-1 | 2 | 3 | 3 | 4 | 3 | 7 |
| PTS-57 | 8 | 5 | 4 | 8 | 7.5 | 1 |
| A-59 | 6 | 1 | 1 | 3 | 5 | 8 |
| K-572/10 | 5 | 4 | 5 | 7 | 7.5 | 3 |
| IB-226 | 1 | 2 | 2 | 5 | 6 | 6 |
| C-164 | 7 | 7 | 7 | 6 | 4 | 2 |

Full diallel: PD-I (rs) = 0.26
Full diallel: PD-II (rs) = 0.19
Full diallel: PD-III (rs) = 0.54
Full diallel: PD-IV (rs) = 0.36

Spearman's rank correlation (Snedecor 1946), the ranking pattern under each partial diallel was compared with that of full diallel. The correlations ($r_s$) were 0.26, 0.19, 0.54 and 0.36 for PD I, PD II, PD III and PD IV, respectively. All these correlations were low and non-significant, indicating that none of these modifications could predict the correct order of parents for their combining ability.

## Discussion

The general combining ability of a line is defined as the average performance of that line over n crosses, if n is the number of lines involved in the diallel. Thus, the average performance of a line when crossed only to a selected line(s) from a given set of parents (n), as in the partial diallel, may not be the same as its average performance in full diallel. The ranking pattern of the parents with respect to gca effects will, therefore, depend on the percentage of the total crosses being analysed in a particular partial diallel i.e. $(\frac{s}{n} \times 100)$. The results obtained in the present investigation have very clearly indicated that with smaller 's' in partial diallel the ranking of the parents deviates more from the ranking based on full diallel. The correlation between the rankings of parents, based on full diallel information on one hand and the partial diallel on the other, were 0.26, 0.19, 0.54 and 0.36 for PD I, PD II, PD III and PD IV, respectively. Considering the value of $(\frac{s}{n} \times 100)$ being 12 %, 25 %, 63 % and 38 % for PD I, II, III and IV, respectively, the above correlation values are well justified. High correlation, though non-significant, in the case of PD-III is due to its largest proportion in sampled crosses. Clearly the efficiency of a partial diallel will depend on the size of the sampled crosses and just any random number of crosses taken for a partial diallel will not give reliable estimates. Murty, Arunachalam and Anand (1966) have rightly suggested that bias in the estimates is more common when 's' is less than n/2. Of the four partial diallels studied in the present investigation, this situation was met only in PD-III. Similarly, the purpose of diallel analysis, to select the best cross combinations, is not fulfilled by the partial diallels because only a sample of the total crosses is analysed and the probability of the best cross being not included in the sample is always there. The purpose of partial diallel is only to give information on the overall trend of gene action involved in the inheritance of quantitative characters. The present study has indicated that both gca and sca variances were significant in all the four sets of partial diallel. However, in PD II and IV, where 's' was low (3), the magnitudes of gca and sca mean sum of squares were also low compared with those of PD I and III, where 's' was high (5). Similar observations could be made for gca effects also. Kearsey (1965) and Anand et al. (1969) have also reported that a decrease in 's' results in decreased significance of gca and sca variances. The average degree of dominance, measured as the ratio of $\sigma_D^2/\sigma_A^2$, gave an overall picture of overdominance. Thus, the gene action in the material indicates ample scope for heterosis breeding.

## Literature


Anand, I.J.; Murty, B.R.: Serial analysis of combining ability in diallel and fractional diallel crosses of linseed. Theor. Appl. Genet. 39, 88-94 (1966)

Fyfe, J.L.; Gilbert, N.: Partial diallel crosses. Biometrics 19, 278-286 (1963)

Griffing, B.: Concepts of general and specific combining ability in relation to diallel crossing systems. Aust. J. Biol. Sci. 9, 463-493 (1956)

Hinkelmann, K.: Missing values in partial diallel cross experiments. Biometrics 24, 903-913 (1968)

Hinkelmann, K.; Stern, K.: Kreuzungspläne zur Selektionszüchtung bei Waldbäumen. Silvae Genetica 9, 121-133 (1960)

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

Kempthorne, O.; Curnow, R.N.: The partial diallel cross. Biometrics 17, 229-250 (1961)

Murty, B.R.; Arunachalam, V.; Anand, I.J.: Diallel and partial diallel analysis of some yield factors in *Linum usitatissimum*. Heredity 22, 35-41 (1966)

Snedecor, G.W.: Rank correlations. In: Statistical methods 164-167. Ames, Iowa: Iowa State College Press 1946


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B.D. Chaudhary
Pool Officer,
Department of Genetics.

S.N. Kakar
Dean
College of Basic Scs. & Hum.

R.K. Singh
Professor of Genetics
Haryana Agric. University
Hissar (Haryana) 125004 (India)