MATERIALS AND METHODS

A. MATERIALS:

A set of fifteen barley varieties both hulled and hull-less in six-rowed and two-rowed types of diverse geographic origin, were used as parents for partial diallel crosses. Characteristics and origin of these parental lines are given below:

<table>
<thead>
<tr>
<th>Group</th>
<th>Variety</th>
<th>Origin</th>
<th>Special features</th>
</tr>
</thead>
<tbody>
<tr>
<td>(1) Six-rowed and hulled:</td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>2.</td>
<td>K 1596</td>
<td>India (Kanpur)</td>
<td>Good yielder under late-sown conditions, kernel golden, medium tall, early in maturity.</td>
</tr>
<tr>
<td>3.</td>
<td>Numar</td>
<td>California</td>
<td>Medium yielder, kernel light blue, semi-dwarf, late in maturity, stiff straw.</td>
</tr>
<tr>
<td>4.</td>
<td>Conquest</td>
<td>Canada</td>
<td>Medium yielder, kernel light blue, tall, medium in maturity, quality barley.</td>
</tr>
<tr>
<td>5.</td>
<td>Mex.22</td>
<td>Mexico</td>
<td>Medium yielder, kernel golden, tall, medium in maturity, stiff straw.</td>
</tr>
<tr>
<td>6.</td>
<td>Glacier</td>
<td>U.S.A.</td>
<td>Poor yielder, kernel golden, medium tall, late in maturity.</td>
</tr>
</tbody>
</table>
7. **DG 2**  
**India**  
(I.A.R.I.)  
Poor yielder, kernel light blue, dwarf, medium late in maturity.

(ii) **Six-rowed and hull-less:**

8. **Majwah**  
**China**  
Medium yielder, kernel greenish grey, medium tall, medium in maturity.

9. **IB 65**  
**India**  
(I.A.R.I.)  
Good yielder, kernel golden, tall, late in maturity, stiff straw.

(iii) **Two-rowed and hulled:**

10. **EB 921**  
**Taiwan**  
Good yielder, kernel golden, tall, medium in maturity, stiff straw.

11. **Clipper**  
**Australia**  
Good yielder, kernel golden, medium tall, late in maturity, quality barley.

12. **AQ 769**  
**Australia**  
Good yielder, kernel light blue, semi-dwarf, medium late in maturity.

(iv) **Two-rowed and hull-less:**

13. **EB 1626**  
**Ethiopia**  
Poor yielder, kernel black, tall, medium in maturity.

14. **REB 614**  
**Ethiopia**  
Poor yielder, kernel golden, tall, medium in maturity.

15. **EB 2342**  
**Anatolia**  
Poor yielder, kernel golden, medium tall, medium in maturity.
Sampling of Partial Diallel crosses:

These Partial Diallel crosses were made during 1971-72 at U.P. Institute of Agricultural Sciences, Kanpur and F2 was developed in the summer season of the same year by raising F1 crosses at Wellington (Tamilnadu).

The crosses in Partial Diallel set involving 15 parents were sampled according to the method given by Kempthorne and Curnow (1961). Accordingly, the crosses were sampled from parents 1 to n as follows:

\[
\begin{align*}
\text{line 1} & : \text{line } k+1, \ k+2 \ldots \ (k+s) \\
\text{line 2} & : \text{line } k+2, \ k+3 \ldots \ (k+1+s) \\
& \ldots \ \ldots \ \ldots \ \ldots \ \\
\text{line } i & : \text{line } k+i, \ k+i+1 \ldots \ (k+(i-1)+s) \\
& \ldots \ \ldots \ \ldots \ \ldots \ \\
\text{line } n & : \text{line } k+n, \ k+n+1 \ldots \ (k+(n-1)+s) \\
\end{align*}
\]

Where, \( k = \frac{(n+1-s)}{2} \) and is a whole number. All the numbers greater than n were reduced to multiples of n so that the number thus arrived at is \( \frac{1}{2} n \). For \( k \) to be a whole number, \( n \) is chosen odd and \( s \) even or vice versa. The value of \( s \) is constant for each line, which is greater than 2, for estimating specific combining ability variances. By adopting such a plan where \( n = 15, \ s = 8 \) and \( k = \frac{(15+1-8)}{2} = 4 \), excluding reciprocals, the number of crosses made were 60. Details of strains and sampled crosses are presented below:
<table>
<thead>
<tr>
<th>Parents ($P_1$)</th>
<th>The eight parents with which $P_1$ was crossed</th>
</tr>
</thead>
<tbody>
<tr>
<td>$P_1$ Ratna</td>
<td>$P_5$ $P_6$ $P_7$ $P_8$ $P_9$ $P_{10}$ $P_{11}$ $P_{12}$</td>
</tr>
<tr>
<td>$P_2$ K 1596</td>
<td>$P_6$ $P_7$ $P_8$ $P_9$ $P_{10}$ $P_{11}$ $P_{12}$ $P_{13}$</td>
</tr>
<tr>
<td>$P_3$ Numar</td>
<td>$P_7$ $P_8$ $P_9$ $P_{10}$ $P_{11}$ $P_{12}$ $P_{13}$ $P_{14}$</td>
</tr>
<tr>
<td>$P_4$ Conquest</td>
<td>$P_8$ $P_9$ $P_{10}$ $P_{11}$ $P_{12}$ $P_{13}$ $P_{14}$ $P_{15}$</td>
</tr>
<tr>
<td>$P_5$ Mex-22</td>
<td>$P_9$ $P_{10}$ $P_{11}$ $P_{12}$ $P_{13}$ $P_{14}$ $P_{15}$</td>
</tr>
<tr>
<td>$P_6$ Glacier</td>
<td>$P_{10}$ $P_{11}$ $P_{12}$ $P_{13}$ $P_{14}$ $P_{15}$</td>
</tr>
<tr>
<td>$P_7$ IB 65</td>
<td>$P_{11}$ $P_{12}$ $P_{13}$ $P_{14}$ $P_{15}$</td>
</tr>
<tr>
<td>$P_8$ Majawah</td>
<td>$P_{12}$ $P_{13}$ $P_{14}$ $P_{15}$</td>
</tr>
<tr>
<td>$P_9$ EB 1626</td>
<td>$P_{13}$ $P_{14}$ $P_{15}$</td>
</tr>
<tr>
<td>$P_{10}$ REB 614</td>
<td>$P_{14}$ $P_{15}$</td>
</tr>
<tr>
<td>$P_{11}$ EB 2342</td>
<td>$P_{15}$</td>
</tr>
<tr>
<td>$P_{12}$ EB 921</td>
<td>$-$</td>
</tr>
<tr>
<td>$P_{13}$ Clipper</td>
<td>$-$</td>
</tr>
<tr>
<td>$P_{14}$ AQ 679</td>
<td>$-$</td>
</tr>
<tr>
<td>$P_{15}$ DG 2</td>
<td>$-$</td>
</tr>
</tbody>
</table>

(-) Reciprocals not attempted.

Lay out of the experiment:

An experiment with fifteen parents, 60 $F_1$'s and 60 $F_2$'s of the sampled crosses was laid out on 21.11.1972 under irrigated
conditions in randomised complete block design with three replications at U.P. Institute of Agricultural Sciences, Kanpur.

There were two rows for each of the F$_2$ populations and one row for each of the F$_1$ and parental lines. Distance between plant to plant was maintained at 15 cm and row to row 30 cm for the convenience of handling individual plant. Border effect was removed by growing hooded barley around the plot in each replication. 40 kg N, 20 kg P$_2$O$_5$ and 20 kg K$_2$O per hectare was applied. Other agronomic practices recommended for the cultivation of barley were followed.

Observations:

Twelve plants from each F$_2$ population and five plants from each parent and F$_1$ were selected randomly from each replication for recording observations on following sixteen characters:

1. **Days to flowering**: Number of days taken from sowing to the full emergence of the ear in main shoot, was calculated.

2. **Grain development period**: Number of days was calculated from the date of flowering to the full-ripening of the ear.

3. **Height of the plant**: It was measured in cm from the base of the plant to the tip of the ear, excluding awns, in the main shoot.

4. **Length of the peduncle**: Length of the last internode in the main shoot from the node to the neck of the ear was measured in cm.

5. **Extrusion of peduncle**: Length of the peduncle extruding
above the flag leaf was measured in cm, from the base of
the flag leaf to the neck of the ear.

6. **Length of the awn**: It was measured in cm, from the tip
of the last grain in the main spike to the tip of the awn.

7. **Length of the ear**: It was measured in cm, from the neck
of the ear to the tip of the last grain in the main spike
(excluding awns).

8. **Area of the flag leaf**: It was calculated by the formula:
   \[ \text{Area} = (\text{Length} \times \text{Breadth}) \times 0.64 \]  
   (Lajaroo, 1965).

9. **Number of ears per plant**: Total number of ear-bearing
tillers were counted in individual plant at maturity.

10. **Number of grains in the main spike**: Number of grains in
each ear of the main shoot was counted (here to referred as
number of grains per spike).

11. **Kernel colour**: Colour of the kernels was scored,subjective-
ly, after removing the husk of the hulled types from grades
1 (golden) to 7 (black).

12. **Number of grains per plant**: Total number of grains obtained
from all the ears from individual plant was counted.

13. **1000-grain weight**: It was worked out from the number and
weight of the grains harvested from the individual plant
as follows:

   \[
   \frac{\text{Grain yield in gm/plant}}{} \times 1000
   \]

   \[ \frac{\text{No. of grains/plant}}{} \]

14. **Grain yield of the main spike**: Grains obtained from the
main spike (as in Sl.No.10) were weighed in gm (referred to
as grain yield per spike).

15. **Grain yield per plant**: Total grains obtained from individual plant (as in Sl.No.12) was weighed in gm.

16. **Protein content**: Estimation of protein in the grain samples of parents, $F_1$ and $F_2$ population was made by Biuret method (Williams, 1961).

**B. STATISTICAL METHODS:**

(i) **Analysis of variance**: The analysis of variance for experimental design was based on the model:

$$P_{ijk} = \mu + g_{ij} + b_k + e_{ijk} \quad (i, j = 1, \ldots, t; \text{and} \quad k = 1, \ldots, b)$$

Where, $P_{ijk}$ = the phenotype of $ijk$th observation

$\mu$ = the population mean

$g_{ij}$ = the progeny effect

$b_k$ = the block effect, and

$e_{ijk}$ = the error term of $ijk$th observation.

The resulting data of the experiment were analysed in the form of the ANOVA structure given below for each character separately.

<table>
<thead>
<tr>
<th>Source</th>
<th>d.f.</th>
<th>M.S.S.</th>
</tr>
</thead>
<tbody>
<tr>
<td>1. Replications</td>
<td>(b - 1)</td>
<td>Mb</td>
</tr>
<tr>
<td>2. Entries</td>
<td>(t - 1)</td>
<td>Mt</td>
</tr>
<tr>
<td>3. Parents</td>
<td>(n - 1)</td>
<td>Mn</td>
</tr>
<tr>
<td>4. $F_1$ hybrids</td>
<td>(f_1- 1)</td>
<td>$M_{f_1}$</td>
</tr>
<tr>
<td>5. $F_2$ progenies</td>
<td>(f_2- 1)</td>
<td>$M_{f_2}$</td>
</tr>
<tr>
<td>6. Parents vs. crosses</td>
<td>1</td>
<td>$M_{s_1}$</td>
</tr>
<tr>
<td>7. $F_1$ vs. $F_2$</td>
<td>1</td>
<td>$M_{s_2}$</td>
</tr>
<tr>
<td>8. Error</td>
<td>(t-1)(b-1)</td>
<td>$M_e$</td>
</tr>
<tr>
<td><strong>Total</strong></td>
<td>(b.t - 1)</td>
<td></td>
</tr>
</tbody>
</table>
The significance of blocks and progenies were tested by taking the variance ratio of corresponding m.s.s. with the error m.s.s. by F test on \((b-1), (t-1) (b-1); (t-1), (b-1) (t-1)\); respectively both at 5 percent and 1 percent level of significance.

(ii) **Combining ability analysis:**

The model for analysis as suggested by Kempthorne and Curnow (1961), used in the present studies, is as follows:

**Model for combining ability test:**

The following model for combining ability test was followed:

\[
Y_{ijl} = \mu + r_l + g_i + g_j + s_{ij} + e_{ijl}.
\]

\((i, j = 1, 2 \ldots n; l = 1, 2 \ldots r)\)

Where,

- \(\mu\) = the population effect
- \(r_l\) = replication effect
- \(g_i, g_j\) = gca effects or parental effects
- \(s_{ij}\) = sca effects or non-additive effects of parents, and
- \(e_{ijl}\) = plot error corresponding to \(ij^{th}\) cross in \(l^{th}\) replication.

It is assumed that \(g_i, s_{ij}\) and \(e_{ijl}\) are independently normally distributed with zero means and variances \(6^2g, 6^2s\) and \(6^2e\) respectively.

The combining ability analysis for the estimation of general combining ability effects and corresponding ANOVA giving general and specific combining ability variances were performed as per procedure recommended by Kempthorne and Curnow (1961),
on the basis of the model given above.

The ANOVA for combining ability analysis along with the expectations of m.s.s. in terms of the parameters $6^2g$ and $6^2s$ is given below:

<table>
<thead>
<tr>
<th>Source</th>
<th>d.f.</th>
<th>Expected value of m.s.s.</th>
</tr>
</thead>
<tbody>
<tr>
<td>1. Replications</td>
<td>$(r-1)$</td>
<td></td>
</tr>
<tr>
<td>2. gca</td>
<td>$(n-1)$</td>
<td>$6^2e + r 6^2s + rs(n-2)/n-1 6^2g$</td>
</tr>
<tr>
<td>3. sca</td>
<td>$n(s/2-1)$</td>
<td>$6^2e + r 6^2s$</td>
</tr>
<tr>
<td>4. Replicates x crosses</td>
<td>$(r-1)(\frac{ns}{2}-1)$</td>
<td>$6^2e$</td>
</tr>
<tr>
<td>Total</td>
<td>$\frac{rns}{2} - 1$</td>
<td></td>
</tr>
</tbody>
</table>

(iii) Estimation of heterosis:

Heterosis over the superior parent, mid-parent and the best variety for that trait was calculated using the following formula:

(i) Heterosis over the superior parent $= \frac{F_1 - (SP)}{(SP)} \times 100$

(ii) Heterosis over the mid parent $= \frac{F_1 - MP}{MP} \times 100$

(iii) Heterosis over the best variety $= \frac{F_1 - BV}{BV} \times 100$

(iv) Estimation of inbreeding depression:

The performance of $F_2$ was compared with $F_1$ for assessing the extent of inbreeding depression as follows:

$$\frac{F_2 - F_1}{F_1} \times 100$$
Where, $F_1$ and $F_2$ are the mean values of $F_1$ and $F_2$ progenies for that trait.

(v) **Estimation of heritability:**

Heritability in narrow sense, for each character, was estimated as:

\[
 h^2 = \frac{\text{Additive variance}}{\text{Total variance}} \times 100
\]

\[
 = \frac{6^2_g}{6^2_g + 6^2_s + 6^2_e} \times 100
\]

Where, $6^2_g = \text{the additive variance}$  
$6^2_s = \text{the non-additive variance}$  
$6^2_e = \text{the error variance}$.

(vi) **Estimation of genetic advance:**

Genetic advance achieved under selection intensity of 5 per cent in terms of standard deviation of phenotypic variance was estimated by the formula:

\[
 \text{Genetic advance} = \frac{V_g}{\sqrt{VP}} \times k
\]

\[
 = \frac{V_g}{VP} \times \sqrt{VP} \times k
\]

\[
 = \text{Heritability} \times \sqrt{VP} \times k
\]

Where, $V_g = \text{the additive genotypic variance}$  
$VP = \text{the phenotypic variance}$  
$k = \text{the selection differential at 5\% selection pressure} = 2.06$.

Genetic advance in percentage of mean was also calculated from the genetic potential and general mean of the respective characters:
Genetic advance in % of mean = \( \frac{GA}{\bar{X}} \times 100 \)

Where,
\( \bar{X} \) = the mean value of the trait.