A set of crosses produced by involving 'n' lines in all possible combinations is designated as diallel cross and the analysis of such crosses is known as diallel analysis. Such an analysis provides information on (i) the nature and amount of genetic parameters and (ii) general and specific combining ability of parents and their crosses, respectively. The two main approaches being followed for diallel analysis are

(i) Hayman's approach  (ii) Griffing's approach

Griffing Approach
In this approach, using a suitable statistical model the component variances due to general and specific combining ability are estimated which, in turn, may be translated into genetical components such as under certain assumptions. In diallel analysis, three sets of materials are involved namely, parents, F1 crosses and reciprocals. Griffing (1956) has given 4 methods of diallel depending on the material involved in the analysis, (i) parents (n), n(n-1)/2 F1's and reciprocals, (ii) parents and F1's only. The worked examples for all these four methods, have been given here.

Griffing (1956) has described the method of analysis for combining ability considering Eisenhari's model I (fixed effect) and model II (random effect). It may be noted that the procedure for the analysis of variance remains the same in both the models, but the expectations of mean sum of squares due to various items are different. Accordingly the interpretations of the results also differ. In this chapter, the same set of data will be analysed to illustrate the procedure for calculation in both these models. However, in actual experiments, the scientist himself has to decide which of the two models is appropriate in his case.

In each method two steps are involved in the analysis of data. The first step consists of analysis of data for testing the null hypothesis that there are no genotypic differences among the F1's, parents and the reciprocals. Only when the significant differences among these are established, there is need to proceed for second step of analysis, i.e., the combining ability analysis.

Test of Significant: The expectations of mean squares, and hence the 'F' test, differ with the models. In model I, both the gca and sca mean squares are tested against error mean square. Contrarily, in model II, the gca mean square is tested against the sca mean squares, which in turn, is tested against the error mean squares. In case the sca mean square is non-significant, the mean squares due to sac and error are pooled together for testing the mean squares for gad. To obtain the pooled mean squares, the sums of squares due to sca and error are pooled mean squares, the sums of squares due to sca and error are pooled and are divided by sum of the degrees of freedom for sca and error. Note that the degrees of freedom change according to the various methods. There are four SAS macro for diallel analysis for four Griffing’s methods are available in literature and are given by Zhang and Kang (1997). These are reproduced in the sequel.
SAS listing for a diallel analysis with $p = 5$ (Griffing's Method 3)

```
OPTIONS PS = 56 LS=78;
DATA METHOD3;
INPUT I J REP HYBRID YIELD ENV;
DROP N NI NJ P;
P=5:*NUMBER OF PARENTAL LINES; /* If number of parental
lines = $p$, the GCA effects in ARRAY statements = $p-1$ */
ARRAY GCA N) G1 G2, G3 G4;
DO N=1 TO (P-1);
GCA= (( 1=N) - (1=P)) + ((J=N) – (J=P));
END;
ARRAY SCA N) S12 S13 S14 S23 S24; /*
The number of estimable SCA effects in this ARRAY = $p(p-3)/2$*
N=0;
DO NI = 1 TO (P-3);
DO NJ = N + 1 TO (P-1):
    SCA = (I=NI)* (J =NJ) – ((I=NI) + (I =NJ))*(J=P) +
    (J=N)*(I=NI) – (I=P)*(J=NI) + (J=NI);
    IF ((I >= (P-2)) & (J>= (P-1)))/ ((I>= (P-1)) &
    (J>= (P-2))) THEN DO;
    SCA= - (1= (P-2))*(J= (P-1)) + (I>= (P-2))*
    (J=P)*(I NE NJ) – (J= (P-2))*(I= (P-1)) +
    (J>= (P-2))*(I=P)*(J NE NJ);
    END;
END;
END;
    *The number of estimable reciprocal effects in this ARRAY= p*p 1,2*/
N=0
DO NI = 1 TO (P-1);
DO NJ = (NI+1) TO P;
N+1;
REC= =NI)*(J=NJ) – (J=NI)*I=NI)
END;
END;
ARRAY MAT N) M1 M2 M3 M4; /* The number of estimable maternal
effects in this ARRAY = $p -1$ */
DO N=1 TO (P-1);
MAT = (I=N) + (J=P) – (J=N) – (I=P);
END;
ARRAY NONM/ (N) N12 N13 N14 N23 N24 N34; * The number of estimable nonmaternal
effects in this ARRAY = (p-1)(p-2)/2*/
```
Diallel Analysis using SAS

N=0;
DO NI=1 TO (P-2);
DO NJ = (NI+1) TO (P-1);
N+1;
NONM= ((I=NI)*(J=NJ)) - (I=NJ)*(J=N) +
    (((I=NJ)-(I=NI))*(J=P)) + ((I=P)*
    ((J=NI) - (J=NJ)));
END;
END;
CARDS; *After this statement enter your data */
PROC SORT; BY ENV REP I J;
*ANOVA of the data */ TITLE 'ANOVA';
PROC SORT; BY REP ENV I J HYBRID;
PROC GLM; CLASS REP ENV HYBRID; MODEL YIELD=ENV
    REP (ENV) HYBRID ENV*HYBRID; TEST H=HYBRID
    E=ENV*HYBRID; TEST H=ENV E=REP (ENV);
    LSMEANS HYBRID; RUN;
*SAS program based on Kang’s */TITLE DIALLEL-SAS 1;
PROC GLM; CLASS REP HYBRID ENV;
MODEL YIELD=ENV REP (ENV) G1 G2 G3 G4 S12 S13 S14 S23
    S24 R12 /* change model if number of parental lines changes */
R13 R14 R15 R23 R24 R25 R34 R35 R45 G1 *ENV G2 *ENV G3 *ENV
    G4 *ENV
S12 *ENV S13 *ENV S14 *ENV S23 *ENV S24 *ENV R12 *ENV
    R13 *ENV R14 *ENV
R25*ENV R23 *ENV R24 *ENV R25 *ENV R34 *ENV R35 *ENV
    R45 *ENV;
SMACRO GCASCA;
CONTRAST 'GCA' G1 1, G2 1, G3 1, G4 1; /* Contrast statement changes
    according to the GCA ARRAY statement */
CONTRAST 'SCA' S12 1, S13 1, S14 1, S23 1, S24 1; /* Contrast statement changes
    according to the SCA ARRAY statement */
ESTIMATE 'G1' G1 1; ESTIMATE 'G2' G2 1; ESTIMATE 'G3' G3 1; /*Change estimate
    statements based on PROC GLM */
ESTIMATE 'G4' G4 1; /* model and descriptions in the text */
ESTIMATE 'G5' G1-1 G2-1 G3-1 G4-1;
ESTIMATE 'S12' S12 1; ESTIMATE 'S13' S13 1: ESTIMATE
    'S14' S14 1;
ESTIMATE 'S23' S23 1; ESTIMATE 'S24' S24 1;
ESTIMATE 'S15' S12-1 S13-1 S14-1; ESTIMATE 'S25'
    S12-1 S23-1 S24-1;
ESTIMATE 'S34' S12-1 S13-1 S14-1 S23-1 S24-1;
ESTIMATE 'S35' S12 1 S14 1 S24 1; ESTIMATE 'S45'
    S12 1 S13 1 S23 1;
%MEND GCASCA;
%GCASCA
CONTRAST 'REC' R12 1; R13 1; R14 1; R15 1; R23 1; R24 1;
Diallel Analysis using SAS

R25 1; R34 1; R35 1; R45 1;
ESTIMATE 'R12' R12 1; ESTIMATE 'R13' R13 1; ESTIMATE 'R14' R14 1;
ESTIMATE 'R15' R15 1; ESTIMATE 'R23' R23 1; ESTIMATE 'R24' R24 1;
ESTIMATE 'R25' R25 1; ESTIMATE 'R34' R34 1; ESTIMATE 'R35' R35 1;
ESTIMATE 'R45' R45 1;
CONTRAST 'MAT SS' R12 1 R13 1 R14 1 R15 1 R12-1 R23 1 R24 1 R25 1 R34 1 R35 1 R45 1;
ESTIMATE 'MAT1' R12 1 R13 1 R14 1 R15 1 /DIVISOR=5;
ESTIMATE 'MAT2' R12 -1 R23 1 R24 1 R25 1 /DIVISOR=5;
ESTIMATE 'MAT3' R13 – 1 R23-1 R34 1 R35 1 /DIVISOR=5;
ESTIMATE 'MAT4' R14 – 1 R24-1 R34-1 R45 1 /DIVISOR=5;
ESTIMATE 'MAT5' R15 – 1 R25-1 R35-1 R45-1 /DIVISOR=5;
SMACRO INTERACT;
CONTRAST 'GCA*ENV' G1 *ENV 1-1, G2*ENV 1-1, G3*ENV 1-1, G4*ENV 1-1;
CONTRAST 'SCA*ENV' S12*ENV 1-1, S13*ENV 1-1, S14*ENV 1-1, S23*ENV 1-1, S24*ENV 1-1;
%MEND INTERACT;
%INTERACT
CONTRAST 'REC*ENV' R12*ENV 1-1, R13*ENV 1-1; R14*ENV 1-1, R15*ENV 1-1, R23*ENV 1-1, R24*ENV 1-1, R25*ENV 1-1, R34*ENV 1-1, R35*ENV 1-1, R35*ENV 1-1 R45*ENV 1-1;
RUN;
/* SAS program based on Nyquist's*/ TITLE 'DIALLEL – SAS 2';
PROC GLM; CLASS REP HYBRID ENV;
%GCASCA
%INTERACT
CONTRAST 'MAT' M1 1, M2 1, M3 1, M4 1;
CONTRAST 'NONM' N12 1, N13 1, N14 1, N23 1, N24 1, N34 1;
ESTIMATE 'M1' M1 1; ESTIMATE 'M2' M2 1; ESTIMATE 'M3' M3 1;
ESTIMATE 'M4' M4 1; ESTIMATE 'M5' M1-1 M2-1 M3-1 M4-1
ESTIMATE 'N12' N12 1; ESTIMATE 'N13' N13 1; ESTIMATE 'N14' N14 1;
ESTIMATE 'N23' N23 1; ESTIMATE 'N24' N24 1; ESTIMATE 'N34' N34 1;
ESTIMATE 'N15' N12-1 N13-1 N14-1;
ESTIMATE 'N25' N12 1 N23-1 N24-1;
ESTIMATE 'N35' N13 1 N23 1 N34-1;
ESTIMATE 'N45' N14 1 N24 1 N34 1;
CONTRAST 'MAT*ENV'M1*ENV 1-1, M2*ENV 1-1, M3*ENV 1-1, M4*ENV 1-1;
CONTRAST 'NONM*ENV' N12*ENV 1-1, N13*ENV 1-1, N14*ENV 1-1, N23*ENV 1-1, N24*ENV 1-1, N34*ENV 1-1;
RUN; /* NOTE: In the Program listing, H denotes hypothesis, not F, hybrids

SAS listing for generating matrix of estimable effects of a diallel analysis with \( p = 5 \) (Griffing's Method 1)

OPTIONS PS=56 LS=78;
DATA METHOD1; TITLE 'GRIFFING METHOD 1';
INPUT I J REP HYBRID YIELD ENV;
DROP N NI NJ P;
P=5, *NUMBER OF PARENTAL LINES;
ARRAY GCA (N) G1 G2 G3 G4;
DO N = 1 TO (P-1);
  GCA= ((I=N) - (I=P)) + ((J=N) - (J=P));
END;
ARRAY SCA (N) S11 S12 S13 S14 S22 S23 S24 S33 S34 S44
N=0;
DO NI=1 TO (P-1);
  DO NJ=NI TO (P-1);
  N + 1;
  IF NI=NJ THEN DO;
    SCA= (I=NI)*((J=NJ) – (J=NI)) + (I=NI)*
      ((J=P) – (J=NI))
  END;
  ELSE DO;
    SCA= (I=NI)*((J=NJ) – (J=NI)) + (I=NI)*
      (I=P)*2 + (I=NI)*((J=NI) – (J=NI)) + (J=NJ));
  END;
END;
ARRAY REC (N) R12 R13 R14 R23 R24 R25 R34 R35 R45
N=0;
DO NI=1 TO (P-1);
  DO NJ = (NI+1) TO P;
    N+1;
    REC= I=NI)*((J=NJ) – (J=NI))
  END;
END;
ARRAY MAT (N) M1 M2 M3 M4;
DO N=1 TO (P-1);
  MAT= (I=N) + (J=P) – (J=N) – (I=P);
END;
ARRAY NONM (N) N12 N13 N14 N23 N24 N34;
Diallel Analysis using SAS

N=0;
DO NI= 1 TO (P-2);
DO NJ= (NI+1) TO (P-1);
N+1;
NONM= ((I=NI)*(J=NJ) – (I=NJ)*(J=NI) –
    ((I=NI)*(J=P) + (I=NJ)*(J=P) + ((I=P)*
    (J=NI) – (J=NJ)));
END;
END;
CARDS; /* After this statement, enter your data */

SAS listing for generating matrix of estimable effects of a diallel analysis with \( p = 5 \)
(Griffing's Method 2)

OPTIONS PS=56 LS=78
DATA METHOD2; TITLE 'GRIFFING METHOD2';
INPUT I J REP HYBRID YIELD ENV;
DROP N NI NJ P;
P=5; *NUMBER OF PARENTAL LINES;
ARRAY GCA (N) G1 G2 G3 G4;
DO N=1 TO (P-1);
GCA= ((I=N) – (I=P)) + ((J=N) – (J=P));
END;
ARRAY SCA (N) S11 S12 S13 S14 S22 S23 S24 S33 S34 S44;
N=0;
DO NI=1 TO (P-1);
DO NJ=NI TO (P-1);
N + 1;
IF NI=NJ
THEN DO;
SCA= (I=NI)*((J=NJ) – (J=P)*2) + (I=P)*((J=P));
END;
ELSE DO;
SCA= (I=NI)*((J=NJ) – (J=P))*((I=NI) + (I=NJ) – (I=P));
END;
END;
END;
CARDS; /* After this statement, enter your data */

SAS listing for generating matrix of estimable effects of a diallel analysis with \( p = 5 \)
(Griffing’s Method 4)

OPTIONS PS=56 LS=78;
DATA METHOD4; TITLE 'GRIFFING METHOD 4';
INPUT I J REP HYBRID YIELD ENV;
DROP N NI NJ P;
P=5; *NUMBER OF PARENTAL LINES;
ARRAY GCA (N) G1 G2 G3 G4;
DO N=1 TO (P-1);
   GCA= ((I=N) – (I=P)) + ((J=N) – (J=P));
END;
ARRAY SCA (N) S12 S13 S14 S23 S24;
N=0;
DO NI= 1 TO (P-3);
   DO NJ=NI + 1 TO (P-1);
      N+1;
      SCA= (I=NI)*(J=NJ) – ((I=NI) + (I=NJ))*(J=P);
      IF ((I>= (P-2)) & (J>= (P-1)))/ ((I>= (P-1)) & (J>= (P-2)))
         THEN DO;
            SCA= - (I= (P-2))*(J= (P-1)) + (I>=(P-2))*(J=P)*(I NE NJ);
            END;
      END;
END;
CARDS; /* After this statement, enter your data */

Reference:
Diallel Analysis. *Agron. J.* **89:**176-182