# SAS MACRO for Generation of Partial Triallel Cross Design using Triangular Association Scheme

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Triallel crosses, often referred as three-way crosses, are those type of mating designs in which each cross is obtained by crossing three inbred lines. A triallel cross can be obtained by crossing the resultant of a diallel cross with an unrelated inbred line. A common triallel cross involving three inbred lines A, B and C can be symbolically represented as (A×B)×C or (A, B, C) or simply (A B C). Unlike diallel cross, the three lines involved in the triallel cross do not contribute equally and thus, it is important to differentiate amongst them. The two lines A and B which are used first to produce a diallel cross contribute half as much as that of the third line C used to obtain the triallel cross. Hence, lines A and B are also referred as half parents whereas line C as full parent. Triallel crosses can be broadly categorized as complete triallel cross (CTC) and partial triallel crosses (PTC).

Rawlings and Cockerham (1962) defined CTC as the set of all possible three-way matings between several genotypes (individuals, clones, homozygous lines, *etc*). If there are $N$ number of inbred lines involved in a CTC, the total number of crosses is $T = \frac{N(N-1)(N-2)}{2}$.

When the number of lines increases, the total number of crosses in CTC also increases. It is almost impossible for the investigator to handle it with limited available resources. This situation lies in taking a fraction of CTC with certain underlying properties, known as PTC. In 1965, Hinkelmann defined PTC as a set of triallel matings in which every line occurs $r_H$ and $r_F$ times as half-parent and full-parent, respectively and each cross of the type $(i \times j) \times k$ {alongwith $(i \times k) \times j$ and $(j \times k) \times i$, to maintain the Structural Symmetry Property (SSP) } occurs either once or not at all. Here, a SAS macro has been developed to generate a series of PTC designs using triangular association scheme (Harun *et al*., 2019).

Let there be $N = \frac{n(n-1)}{2}$ lines, where $n > 4$. Arrange these $N$ lines in a two-associate triangular association scheme, *i.e.*, allot $N$ lines to the off diagonal positions above the principal diagonal in a natural order and repeat the same below the diagonal such that the final arrangement is symmetrical about the diagonal. Diagonal positions are left empty. Consider all possible pair of lines that can be made from each row of the array. Add a third line to each of these pairs to form triplets. Line that appears at the intersection of the second row containing the first line in the pair and column containing the second line in the pair is considered, and added to each pair to form triplets. Make three-way crosses from these triplets considering lines in the pairs as half parents and third added line in the triplet as full parent. This will result in a partial three-way cross design with parameters $N = \frac{n(n-1)}{2}$, $T = \frac{n(n-1)(n-2)}{2}$, $b = n$, $k = \frac{(n-1)(n-2)}{2}$, $r_H = 2(n-2)$ and $r_F = (n-2)$.

The layout of the design can be obtained as generated using the developed SAS macro by just entering the number of lines.

**SAS Output**

The SAS System

Partial Triallel Cross Design using Triangular Association Scheme

PTC_Design

| | Block1 | Block2 | Block3 | Block4 | Block5 | Block6 |
|---|---|---|---|---|---|---|
| ROW1 | ( 1x 2)x 6 | ( 1x 6)x 2 | ( 2x 6)x 1 | ( 3x 7)x 1 | ( 4x 8)x 1 | ( 5x 9)x 1 |
| ROW2 | ( 1x 3)x 7 | ( 1x 7)x 3 | ( 2x 10)x 3 | ( 3x 10)x 2 | ( 4x 11)x 2 | ( 5x 12)x 2 |
| ROW3 | ( 1x 4)x 8 | ( 1x 8)x 4 | ( 2x 11)x 4 | ( 3x 13)x 4 | ( 4x 13)x 3 | ( 5x 14)x 3 |
| ROW4 | ( 1x 5)x 9 | ( 1x 9)x 5 | ( 2x 12)x 5 | ( 3x 14)x 5 | ( 4x 15)x 5 | ( 5x 15)x 4 |
| ROW5 | ( 2x 3)x 10 | ( 6x 7)x 10 | ( 6x 10)x 7 | ( 7x 10)x 6 | ( 8x 11)x 6 | ( 9x 12)x 6 |
| ROW6 | ( 2x 4)x 11 | ( 6x 8)x 11 | ( 6x 11)x 8 | ( 7x 13)x 8 | ( 8x 13)x 7 | ( 9x 14)x 7 |
| ROW7 | ( 2x 5)x 12 | ( 6x 9)x 12 | ( 6x 12)x 9 | ( 7x 14)x 9 | ( 8x 15)x 9 | ( 9x 15)x 8 |
| ROW8 | ( 3x 4)x 13 | ( 7x 8)x 13 | ( 10x 11)x 13 | ( 10x 13)x 11 | ( 11x 13)x 10 | ( 12x 14)x 10 |
| ROW9 | ( 3x 5)x 14 | ( 7x 9)x 14 | ( 10x 12)x 14 | ( 10x 14)x 12 | ( 11x 15)x 12 | ( 12x 15)x 11 |
| ROW10 | ( 4x 5)x 15 | ( 8x 9)x 15 | ( 11x 12)x 15 | ( 13x 14)x 15 | ( 13x 15)x 14 | ( 14x 15)x 13 |

Parameters of the design are

| N | T | b | k | rH | rF |
|---|---|---|---|---|---|
| 15 | 60 | 6 | 10 | 8 | 4 |

## References


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Hinkelmann, K. (1965). Partial triallel crosses. *Sankhya*, **27**, 173–196.

Rawlings, J.O. and Cockerham, C.C. (1962). Triallel analysis. *Crop Sciences*, **2**, 228-231.


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## SAS MACRO

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/*Developed by - Mohd. Harun, Cini Varghese, Seema Jaggi and Eldho Varghese */
/*Date: 10-01-2020                                    VERSION 1.0: 10-01-2020*/
/*Features:*/
/*It provides generation of PTC using Triangular Association scheme*/
/*****************************************/
ods html;
%let t=6; /*Enter t where n=t(t-1)/2, n is the number of lines (t should be >4)*/
proc iml;
n_no=((&t-1)*(&t-2))/2;/*number of crosses with in block (k)*/
n_lines=comb(&t,2); /*number of lines*/
d00 = j(&t, &t, 0);
r = row(d00);
c = col(d00);
*print r c;
*lowerIdx = loc(r > c);
UpperIdx= loc(c > r);
*print lowerIdx upperidx;
y=1:n_lines;
yt=t(y);
*print y;
*d00[lowerIdx] = y;
d00[UpperIdx] = y;
d00_lower=t(d00);
d00=d00+d00_lower;
*print d00;
d01=j(n_no, &t, 0);
do i=1 to ncol(d00);
kk=1;
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```
kkk=1;
do j=1 to nrow(d00)-1;
if d00[j,i]>0 then do;
do k=1 to (nrow(d00)-1)-kkk;
d01[kk,i]=d00[j,i];
kk=kk+1;
end;
kkk=kkk+1;
end;
end;
end;
*print d01; /*Array 1*/
d00_0=d00;
do i=1 to &t-1;
do j=1 to &t;
if i>=j then d00_0[i,j]=d00[i+1,j];
end;
end;
d00_1=j(&t-1, &t, 0);
do i=1 to &t-1;
do j=1 to &t;
d00_1[i,j]=d00_0[i,j];
end;
end;
*print d00_1; /*without zeroes*/
d02=j(n_no, &t, 0);
do i=1 to ncol(d00_1);
kk1=1;
do k1=1 to nrow(d00_1)-1;
do j=k1+1 to nrow(d00_1);
d02[kk1,i]=d00_1[j,i];
kk1=kk1+1;
end;
end;
end;
*print d02; /*Array 2*/
d01d02=d01//d02;
*print d01d02;
d03_t=j(&t,n_no, 0);
do i=1 to ncol(d03_t);
d03_t[i, ] = setdif(yt,d01d02[ ,i]);
end;
d03=t(d03_t);
*print d03; /*Array3 */
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```
varNames = "Block1":"Block&t";
ww=char(d01,4,0);
ww1=char(d02,4,0);
ww2=char(d03,4,0);
www1=j(nrow(ww),ncol(ww),'(');
www2=j(nrow(ww),ncol(ww),')');
www3=j(nrow(ww),ncol(ww),'x');
print "Partial Triallel Cross Design using Triangular Association Scheme";
PTC_Design=www1+ww+www3+ww1+www2+www3+ww2 ;
print PTC_Design[colname= varNames];
T=(&t*(&t-1)*(&t-2))/2;
b=&t;
k=((&t-1)*(&t-2))/2;
rH=2*(&t-2);
rF=(&t-2);
N=n_lines;
print "Parameters of the design are" ;
print N T b k rH rF;
print "Note: For each cross of the type (ixj)xk, crosses of the type (ixk)xj and (jxk)xi to be
ensured to maintain the Structural Symmetry Property
(SSP)";
ods html close;

quit;
```