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New Optimal Series for Complete Diallel Cross Design

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ABSTRACT

Developing of experimental designs has an important role to setting down the experiment in agriculture sciences. In this paper examine the special kind of incomplete block design known as nested balanced incomplete block design which is established via series. Construction of optimal diallel cross designs using the proposed approach which is demonstrated. A simple method to construct the series of optimal block design for complete diallel cross matting design has been presented by nested balanced incomplete block design. Optimal complete diallel crosses are distinguish, and such matching plans are derived using optimal diallel series. Optimality of complete diallel series in incomplete block is investigated.

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1. Introduction

In plant breeding research, parallel crosses are employed as mating designs to examine the genetic characteristics of inbred lines. If the lines are p, then cross between lines represented by the symbols (i, j) for i , j = 1, 2,..., p. This is Griffing (1956) type IV mating design after investigated in-depth the examination of such mating design presented in balanced incomplete block design (BIBD) design. Gupta and Kageyama (1994) introduced a revolutionary technique for creating diallel cross designs, and the majority of subsequent advances in optimal design have been largely inspired by their ideas. They paying close attention to crossing lines as treatments in an incomplete block design. The lines in each block are paired to create diallel crosses. If BIB design is irreducible with block size 2 is nested within nested in the sense of Preece (1967), the pairing of the lines within the blocks of incomplete block will result in a complete diallel cross design. The variability in experimental material's occur by adapting RCB designs crossing as treatments would provide a significant error variance with significant number of parental lines. In order to take the inaccuracy into account, one would prefer IBD design. Examples of people who have used this strategy are (Ceranka & Mejza, 1988). However, if one is interested in the statistical characteristics of these designs, such as their optimality, then this technique is best. The specific procedures are needed to create effective designs for diallel cross experiments since the analysis of a diallel cross experiment in IB depends on the incidence of a lines in blocks rather than the treatments or crosses in blocks.Gupta and Kageyama (1994) have addressed the issue of locating the best incomplete block designs for the particular sort of matting design.

For this, they made use of Preece (1967) nested balanced incomplete block design (NBIBD). In this research, we derive new series for optimal designs by Gupta and Kageyama (1994). According Gupta and Kageyama (1994), the crosses of series are orthogonally blocked, and this will be further examined in the context of PDCs. In this new study, we provide a straightforward procedure to construct ten series of optimal diallel cross designs, which were designed for 'p' parental lines and treated as invariant. Instead of beginning with $(n)_c$, complete number of different crosses in experiment and 'i' number of lines. This method produce complete diallel cross designs that is for multiple replications. Ghulam Hassan et.al (2017) worked for analysis of important morphological traits by using diallel techniques on wheat.

Iqbal, Parveen and Mahmood (2018) constructed new complete diallel cross designs through resolvable balance incomplete block design by using the method of cyclic shifts. Also compute MS-optimal criterion by shah (1960), Eccleston and Hedayat (1974). The purpose of the current paper is construct complete diallel cross matting designs series with initial blocks. In the present context we estimate all pairwise differences.

2. Method of Construction

In literature, assumes nested design for diallel cross series have block size *k* and it shows that the total number of crosses *b k* (*k*-1)/2. This implies the each cross replicate *r* times and it denotes replication of design. It construct complete block designs with crosses in each block and became optimal design. The *p* parental lines investigated in diallel cross design. Therefore, the treatments shown as crosses in the optimal diallel cross design. We can discuss incomplete block design in *p* treatments, block *b*, replications and block size is constant and presented by *b*, *r*. After satisfying these conditions the pairs of parents are presented in each block further these pairs results in *k* crosses of block. Finally, these pairing, result in a complete diallel cross. These techniques of crosses and treatments occurs within block "*b*" outcome become as complete diallel cross if the design reduce to incomplete block design, say E_n with block size 2 within *E* according to Preece (1967). For obtaining optimality, design *E* should take as nested balanced incomplete block design. The construction is illustrated below.

Let *E* be nested BIB design with treatments *p*=5, and blocks *b*=5 of size *k*=2*k*=4, number of replication *r*=4 of every treatment and number of concurrence *λ*=2 means each treatment in the design occurs twice t of any six treatments having, blocks (Chai, 1999,4), {1,2,3,4,0}, {2,3,4,0,1}, {4,0,1,2,3}. These blocks are further divided into sub blocks (0×1), (1×2), (2×3), (3×4), (0×4), (0×2), (1×3), (2×4), (0×3), (1×4), (0×4), (0×1), (1×2), (2×3), (3×4), (1×2), (2×3), (3×4), (0×4), (0×1), (1×4), (0×2), (1×3), (2×4), (0×3), (2×4), (0×3), (1×4). There is total 30 crosses in the experiment and since each treatment replicate thrice.

Gupta and Kageyama (1994) constructed an orthogonally block optimal series for Partial diallel crosses (PDCs) these series are more complicated and limited for some initial blocks for the Construction of Partial diallel crosses (PDCs). Optimal designs are a class of experimental designs that are optimal concerning some statistical criterion these assumptions are for the diallel cross design. The number of crosses per block must be equal to *k* (*k*-1)/2. Calculate the total number of crosses by *b k* (*k*-1)/2 and number of plots should measure by *k* (*k*-1)/2.The number of block must equal to number of treatments and represent by i,j so, i is always less than j. Where n_c is used for total number of crosses obtained from the new series and parameter C represent the all crosses occurs from the series. Treatment i,j = 1,2,…, p and *P* used for parental lines. Provides variance balanced CDC design when treatments i,j replaced by i×j.

Take E_n as irreducible balanced incomplete block design with block size 4 which is nested under *E* and developing initial blocks {1× 3*n*}, 2× {3*n*-1}, . . ., {n× 3*n*-*n*+1}, mod(3*n*+1). Then series for designs can obtained. The layout is developed through the newly proposed techniques to form such designs for different values of "*p*, *b*=*k*", *k*=*n*, *n*>3**,** and they were constructed for the initial block, modulo (3*n*+1) and mod (3*n*+1) constructed as follows.

2.1. New Series

$$\{1\times\ (3n), 2\times\ (3n-1)\ldots n\times\ (3n-n+1)\}$$

Cyclically developing the initial block with mod (3n+1) results an optimal design for *p*=3*n* lines into *b*=*k* blocks, there are *n* crosses in each block.

Example 2.1: For the above Series the number of treatments or parental lines *P*=3*n*, *n*=4 block size *b*=*k* where *k*=*n*. Now construct the initial block of optimal diallel cross design:

$$\{(1\times\ 12), (2\times 11), (3\times 10), (4\times 9)\}$$

Where *k*=4, *P*=12, *n*= 4 and *b*=4. There are four crosses in each block and mod (13). Have different yields of the optimal design D (*P*=12, *b*=4, *k*=4). Next four series are developed on the same patterns according to Gupta and Kageyama (1994) these series are optimal by nature.

2.2. New Series

$$\{1\times(3n), 2\times(3n-1)\ldots 3n/2\times(3n/2+1)\}$$

Example 2.2: The initial block of newly proposed series and number of treatments or parental lines P=3*n*+1, *n*=4 block size *b*=*k*, *n*≥3 where *k*=*n*+2, the initial block by using the above series we evolve optimal diallel cross design as follows:

$$\{(1\times 12), (2\times 11), (3\times 10), (4\times 9), (5\times 8), (6\times 7)\}$$

Where *k*=6, *P*=13, *n*= 4, and *b*=6 there are six crosses in each block and mod (13), keeping the symbol 6 yields optimal design D (*P*=13, *b*=6, *k*=6).

2.3. New Series

$$\{1\times(4n), 2\times(4n-1)\ldots n\times(4n-n+1)\}$$

Example 2.3: For the above Series the number of treatments or parental lines *P*=4*n*+1, *n=5* block size *b*=*k* where *k*=n. Now construct the initial block of optimal diallel cross design.

$$\{(1\times 20), (2\times 19), (3\times 18), (4\times 17), (5\times 16)\}$$

Where *k*=5, *P*=21, *n*=5 and *b*=5. There are twenty-four crosses in each block and mod (21). Have different yields of the optimal design D (*P*=21, *b*=5, *k*=5, *n*= 5).

2.4. New Series

$$\{1\times(4n), 2\times(4n-1), \ldots, (\frac{4n}{2})\times(\frac{4n}{2}+1)\}$$

Example 2.4: For the above Series the number of treatments or parental lines *P*=4*n*+1, *n*=5 block size *b*=*k* where *k*=2*n*. Now construct the initial block of optimal diallel cross design.

$$\{(1\times 20), (2\times 19), (3\times 18), (4\times 17), (5\times 16), (6\times 15), (7\times 14), (8\times 13), (9\times 12), (10\times 11)\}$$

Where *k*=10, *P*=21, *n*=5 and *b*=10. There are ten crosses in each block and mod (21). Have different yields of the optimal design D (*P*=21, *b*=10, *k*=10, *n*= 5).

2.5. New Series

$$\{1\times(3n), 2\times(3n-1)\ldots(3n-1)/2\times(3n-1)/2+2)\}$$

Example 2.5: The initial block of above series total number of treatment or parental lines *P*=3*n*+1, *n*=5 block size *b*=*k*, *n*>4 where *k*=*n*+2, the initial block by using the above series we construct the optimal diallel cross design as follows.

$$\{(1\times 15), (2\times 14), (3\times 13), (4\times 12), (5\times 11), (6\times 10), (7\times 9)\}$$

Where *k*=7, P=16, *n*= 5, and *b*=7 there are seven crosses in each block and mod (16), keeping the symbol 7 leads to optimal diallel design D (*P*=16, *b*=7, *k*=7). Now we can discussed the optimality of above designs, developing through new series.

3. Model and Optimality

Consider a diallel cross design having *p* lines in a block design with *b* block and block size can be represent by *k* and block have *k* crosses. The model can be expressed as follows:

$$Y_{ij} = \mu + G_i + G_j + S_{ij} + e_{ij} \qquad (1)$$

The following model involving the gca effect of the model where Y_{ijk} is the observation for the *k* th replication of the ith female crossed with the *jth* male, *μ* is the overall mean or general mean, Gi and Gj are the main effects of the parents, Si*j* is the SCA effect, and *E ijk* is the error term of independent vector with constant variance and zero expectations. It can be verify that (u,v) the elements of G_{ij} and S_{ij} should be equals to (i) in uth experimental unit the parent is single "v" (b) otherwise "0". Where u=1, 2, and n, v=1,2, . . . , p. Let n $_{ij}$ are number of repetitions of the cross (i,j), in experiment T= Gi Gj = T_{ij}, $T_{ij} = \sum_{j(\neq i)}^{p} nij$ (1) same as it can also verify that, n_{il} shows how many times parent i appears in j and the information matrix C for j is as follows:

$$C = T - {}^{1}/_{K} = (Cij) \tag{2}$$

i = 1, 2, … , p with, C_{rp}=0 (a)

The main criteria of optimality for general combining ability is consistency of variances for all pairwise comparisons with minimum variance. Here we show the universal optimal and show matrix is feasible if (a) trace tr[1] maximum, (b) it is of the form

$$C = \theta\left(rp\frac{1}{p}1p1'p\right) \tag{3}$$

So, the design is universal optimal , p and Q constant and r_p is identity matrix. Preliminary, T_{ij}=0 and it comply with (1) and (2).

$$\text{Tr (c)} = \sum_{i=j=1}^{p} Tij - k^{-1} \sum_{l=i=1}^{lp} ril \qquad \text{(b)}$$

Since

$$\sum_{i=l}^{p} ril = 2k$$

In diallel cross design tr (c) = 2(T−b) and T = ${}^{bk(k-1)}/_{2}$ shows the whole crosses in experiment. This shows the experimental design with given values of b and k is equivalent as the trace is maximal with given values of k and b, that design of any type satisfying equation (3) is optimal and from equation (2).

$$C_{ij} = n_{ij} - \text{Tr (c)} = \sum_{l=1}^{b} -k^{-1}\ Til.Tlj \tag{4}$$

For checking optimality we have the consistency of c_{ij} and for measuring consistency, nested balanced incomplete block design E is used and equation (5) as follows

$$n_{ij} = \lambda_n$$

$$\frac{\lambda}{k} = \sum_{l=1}^{b} -k^{-1}\ Til.Tlj$$

So,

$$C_{ij} = \lambda\ n - \frac{\lambda}{k} \tag{5}$$

Number of concurrences for any two treatments in the balanced incomplete block design denoted by λ_n. So, nested balanced incomplete block design E with E_n yields an optimal designs in block b and crosses k in every treatment. The five series provides optimal designs for different replications and initial blocks of complete diallel crosses.

$$C = K - M\,[U - V]$$

$$C^{-} = K\,\{U(M)\}^{-} \tag{6}$$

Through these formulae we can find differences between combining abilities and estimate the variance. Now the mating designs constructed by the above five series and all are optimal designs for different values of p and k are listed below.

Some initial blocks for different values of P, K, N.

Table 1: Over-all Optimality for above series 2.1

No	*P*	*K*	*n*	Initial 1st Block Crosses	Optimal design
1	12	4	4	{(1×12), (2×11), (3×10), (4×9)}	D (12,4,4,4)
2	15	5	5	{(1×15), (2×14), (3×13), (4×12), (5×11)}	D (15,5,5,5)
3	18	6	6	{(1×18), (2×17), (3×16), (4×15), (5×14), (6×13)}	D (18,6,6,6)

4	21	7	7	{(1×21), (2×20), (3×19), (4×18), (5×17), (6×16), (7×15)}	D (21,7,7,7)
5	24	8	8	{(1×24), (2×23), (3×22), (4×21), (5×20), (6×19), (7×18), (8×17)}	D (24,8,8,8)
6	27	9	9	{(1×27), (2×26), (3×25), (4×24), (5×23), (6×22),(7×21), (8×20), (9×19)}	D (27,9,9,9)
7	30	10	10	{(1×30), (2×29), (3×28), (4×27), (5×26), (6×25), (7×24), (8×23), (9×22), (10×21)}	D (30,10,10,10)
8	33	11	11	{(1×33), (2×32), (3×31), (4×30), (5×29), (6×28), (7×27), (8×26), (9×25), (10×24), (11×23)}	D (31,11,11,11)
9	36	12	12	{(1×36), (2×35), (3×34), (4×33), (5×32), (6×31), (7×30), (8×29), (9×28), (10×27), (11×26), (12×25)}	D (36,12,12,12)
10	39	13	13	{(1×39), (2×38), (3×37), (4×36), (5×35), (6×34), (7×33), (8×32), (9×31), (10×30), (11×29), (12×28), (13×27)}	D (39,13,13,13)
11	42	14	14	{(1×42), (2×41), (3×40), (4×39), (5×38), (6×37), (7×36), (8×35), (9×34), (10×33), (11×32), (12×31), (13×30), (14×29)}	D (42,14,14,14)
12	45	15	15	{(1×45), (2×44), (3×43), (4×42), (5×41), (6×40), (7×39), (8×38), (9×37), (10×36), (11×35), (12×34), (13×33), (14×32), (15×31)}	D (45,15,15,15)
13	48	16	16	{(1×48), (2×47), (3×46), (4×45), (5×44), (6×43), (7×42), (8×41), (9×40), (10×39), (11×38), (12×37), (13×36), (14×35), (15×34), (16×33)}	D (48,16,16,16)

Some initial blocks for different values of *P*, *K*, *N*.

Table 2: Over- all Summary for above series 2.2

No	P	k	N	Initial 1st Block Crosses	Optimal design
1	13	6	4	{(1×12), (2×11), (3×10), (4×9), (5×8), (6×7)}	D (13,6,6,4)
2	19	8	6	{(1×18), (2×17), (3×16), (4×15), (5×14), (6×13), (7×12), (8×11)}	D (19,8,8,6)
3	25	10	8	{(1×24), (2×23), (3×22), (4×21), (5×20), (6×19), (7×18), (8×17), (9×16), (10×15)}	D (25,10,10,8)
4	31	12	10	{(1×30), (2×29), (3×28), (4×27), (5×26), (6×25), (7×24), (8×23), (9×22), (10×21), (11×20), (12×19)}	D (31,12,12,10)
5	37	14	12	{(1×36), (2×35), (3×34), (4×33), (5×32), (6×31), (7×30), (8×29), (9×28), (10×27), (11×26), (12×25), (13×24), (14×23)}	D (37,14,14,12)
6	43	16	14	{(1×42), (2×41), (3×40), (4×39), (5×38), (6×37), (7×36), (8×35), (9×34), (10×33), (11×32), (12×31), (13×30), (14×29), (15×28), (16×27)}	D (43,16,16,14)
7	49	18	16	{(1×48), (2×47), (3×46), (4×45), (5×44), (6×43), (7×42), (8×41), (9×40), (10×39), (11×38), (12×37), (13×36), (14×35), (15×34), (16×33), (17×32), (18×31)}	D (49,18,18,16)
8	55	20	18	{(1×54), (2×53), (3×52), (4×51), (5×50), (6×49), (7×48), (8×47), (9×46), (10×45), (11×44), (12×43), (13×42), (14×41), (15×40), (16×39), (17×38), (18×37), (19×36), (20×35)}	D (55,20,20,18)
9	61	22	20	{(1×60), (2×59), (3×58), (4×57), (5×56), (6×55), (7×54), (8×53), (9×52), (10×51), (11×50), (12×49), (13×48), (14×47), (15×46), (16×45), (17×44), (18×43), (19×42), (20×41), (21×40), (22×39)}	D (61,22,22,20,)

Some initial blocks for different values of *P*, *K*, *N*.

Table 3: Over- all Summary for above series 2.3

No	P	B	K	n	Initial Block Crosses	Optimal design
1	21	5	5	5	{(1×20), (2×19), (3×18), (4×17), (5×16)}	D (21,5,5,5)
2	25	6	6	6	{(1×24), (2×23), (3×22), (4×21), (5×20), (6×19)}	D (25,6,6,6)
3	29	7	7	7	{(1×28), (2×27), (3×26), (4×25), (5×24), (6×23), (7×22)}	D (29,7,7,7)
4	33	8	8	8	{(1×32), (2×31), (3×30), (4×29), (5×28), (6×27), (7×26), (8×25)}	D (33,8,8,8)
5	37	9	9	9	{(1×36), (2×35), (3×34), (4×33), (5×32), (6×31), (7×30), (8×29), (9×28)}	D (37,9,9,9)

6	41	10	10	10	{(1×40), (2×39), (3×38), (4×37), (5×36), (6×35), (7×34), (8×33), (9×32), (10×31)}	D (41,10,10,10)
7	45	11	11	11	{(1×44), (2×43), (3×42), (4×41), (5×40), (6×39), (7×38), (8×37), (9×36), (10×35), (11×34)}	D (45,11,11,11)

Some initial blocks for different values of *P*, *K*, *N*.

Table 4: Over-all Summary for above series 2.4

No	P	B	k	N	Initial 1st Block Crosses	Optimal design
1	21	10	10	5	{(1×20), (2×19), (3×18), (4×17), (5×16), (6×15), (7×14), (8×13), (9×12), (10×11)}	D (21,10,10,5)
2	25	12	12	6	{(1×25), (2×14), (3×23), (4×22), (5×21), (6×20), (7×19), (8×18), (9×17), (10×16), (11×15), (12×14)}	D (25,12,12,6)
3	29	14	14	7	{(1×28), (2×27), (3×26), (4×25), (5×24), (6×23), (7×22), (8×21), (9×20), (10×19), (11×18), (12×17), (13×16), (14×15)}	D (29,14,14,7)
4	33	16	16	8	{(1×32), (2×31), (3×30), (4×29), (5×28), (6×27), (7×26), (8×25), (9×24), (10×23), (11×22), (12×21), (13×20), (14×19), (15×18), (16×17)}	D (33,14,14,7)
5	37	18	18	9	{(1×36), (2×35), (3×34), (4×33), (5×32), (6×31), (7×30), (8×29), (9×28), (10×27), (11×26), (12×25), (13×24), (14×23), (15×22), (16×21), (17×20), (18×19)}	D (37,18,18,9)
6	41	20	20	10	{(1×40), (2×39), (3×38), (4×37), (5×36), (6×35), (7×34), (8×33), (9×32), (10×31), (11×30), (12×29), (13×28), (14×27), (15×26), (16×25), (17×24), (18×23), (19×22), (20×21)}	D (41,18,18,9)

Some initial blocks for different values of *P*, *K*, *N*.

Table 5: Over-all Optimality for above series 2.5

No	P	B	n	Initial 1st Block Crosses	Optimal design
1	16	7	5	{(1×15), (2×14), (3×13), (4×12), (5×11), (6×10), (7×9)}	D (16,7,7,5)
2	22	9	7	{(1×21), (2×20), (3×19), (4×18), (5×17), (6×16), (7×15), (8×14), (9×13)}	D (22,9,9,7)
3	28	11	9	{(1×27), (2×26), (3×25), (4×24), (5×23), (6×22), (7×21), (8×20), (9×19), (10×18), (11×17)}	D (28,11,11,9)
4	34	13	11	{(1×33), (2×32), (3×31), (4×30), (5×29), (6×28), (7×27), (8×26), (9×25), (10×24), (11×23), (12×22), (13×21)}	D (34,13,13,11)
5	40	15	13	{(1×39), (2×38), (3×37), (4×36), (5×35), (6×34), (7×33), (8×32), (9×31), (10×30), (11×29), (12×28), (13×27), (14×26), (15×25)}	D (40,15,15,13)
6	46	17	15	{(1×45), (2×44), (3×43), (4×42), (5×41), (6×40), (7×39), (8×38), (9×37), (10×36), (11×35), (12×34), (13×33), (14×32), (15×31), (16×30), (17×29)}	D (46,17,17,17)
7	52	19	17	{(1×51), (2×50), (3×49), (4×48), (5×47), (6×46), (7×45), (8×44), (9×43), (10×42), (11×41), (12×40), (13×39), (14×38), (15×37), (16×36), (17×35), (18×34), (19×33)}	D (52,19,19,19)
8	58	21	19	{(1×57), (2×56), (3×55), (4×54), (5×53), (6×52), (7×51), (8×50), (9×49), (10×48), (11×47), (12×46), (13×45), (14×44), (15×43), (16×42), (17×41), (18×40), (19×39), (20×38), (21×37)}	D (58,21,21,19)

optimal plans for diallel crosses from the above model (1), the normal equation for estimating the gca effects of design *E* is as follows

$$Gd = \theta\left(Iv - \frac{I}{v}Evv\right) \quad (7)$$

And θ is the value of Gd matrix and θ is given below

$$\theta = (k(v-2) - 1/k)$$

Now the generalized inverse of Gd is given as

$$Gd' = \theta^{-1} Iv \quad (8)$$

So the ith line of the gca effect is given by

$$\hat{g}_i = \frac{1}{\theta} Qi$$

and hence

$$\hat{g} = \frac{K}{[\lambda v(k-2)-1]} Qi \quad (9)$$

The line contrast of variance can be obtained as

$$V = (\hat{g}_i - \hat{g}_j) = \frac{2K}{[\lambda v(k-2)]} \sigma^2$$
(10)

Where $\hat{g}_I$ and $\hat{g}_j$ are the effects of ith and jth line using the above equation we have calculate the gca and variances and general combining ability for the above crosses is calculated as

$\hat{g} = \frac{4}{[8]} Qi$ From 2.1 series
$\hat{g} = \frac{6}{[16]} Qi$ From 2.2 series
$\hat{g} = \frac{5}{[15]} Qi$ From 2.3 series
$\hat{g} = \frac{10}{[80]} Qi$ From 2.4 series
$\hat{g} = \frac{7}{[35]} Qi$ From 2.5 series

4. Discussion

In this study, optimal diallel series have been generated through nested balanced incomplete block design and thoroughly discussed the procedure of to develop the newly proposed series. These types of designs generated from newly proposed series frequently used in genetic studies to determine the mode of inheritance of the examined traits. Optimal diallel cross designs have been used in animal and plant breeding to study the genetic properties of inbred lines. These series presents the initial block of the design. Further we can discussed the optimality criteria and assumption of optimal designs are fulfill. The over-all optimality of newly designed serieslisted down in the tables.

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