TWO-SIDED NEIGHBOURS FOR BLOCK DESIGNS WITH NEIGHBOURING EFFECTS

LAXMI, R.R.*
Professor, Department of Statistics,
M.D.University, Rohtak, Haryana, India
drrrlaxmi@gmail.com,

PARMITA*
Department of Statistics, M.D.University, Rohtak
Haryana, India
parmita23sangwan@gmail.com

RANI, S.*
Department of Statistics, M.D.University, Rohtak
Haryana, India
maliksarita332@gmail.com

Abstract:

A method for finding left-neighbours and right-neighbours of a treatment in a Balanced Incomplete Block Design incompletely balanced for neighbour competition effects has been suggested in this paper. It is found that these left-neighbours and right-neighbours form common series for a treatment and has circular property.

Keywords: OS2 Series, Border Plots, Neighbour Design, Common Left-Neighbour Series, Common Right-Neighbour Series, Neighbouring effects.

1. Introduction:

In agriculture and other fields, the treatment applied to the experimental plot may affect the response of the plot to which it is applied and the response of neighbouring plots. The tall varieties may affect the other crops grown in neighbouring plots by their shades. These effects are known as neighbour effects or competition effects. The concept of neighbour designs was introduced by Rees(1967) in serology and defined it as a collection of circular blocks in which any two distinct treatments appear as neighbours equally often. Freeman (1967, 1969) gave polycross designs (on forest trees) using the concept of neighbour effect for directional and non-directional situations. Das & Saha (1976) provided some methods of construction for neighbour balanced designs. In 1979, Freeman defined two dimensional designs balanced for nearest neighbours. Mead(1979) had studied the effect of varying number of neighbouring plants on an individual plant to understand plant competition. Kiefer & Wynn(1981), Cheng(1983) investigated neighbour balanced designs for incomplete blocks. Misra et al.(1991) gave several methods of construction of neighbour designs of equal and unequal block sizes. Azais et al.(1993) obtained designs that are balanced and have also given a series of partially neighbour balanced designs. Meitei(1996) gave a method of construction of incomplete block neighbour designs in which number of blocks is not a multiple of number of treatments. Bailey(2003) considered study of one-sided neighbour effects only including its merits & demerits. Tomar et al. (2005) had obtained a series of totally balanced block designs for competition effects. Jaggi, Gupta & Ashraf(2006) suggested general method of construction of complete and incomplete block designs partially balanced for neighbour effects. Pateria, Jaggi, & Varghese(2007) considered a series of block designs by putting $N-1$ MOLS with N treatments and had obtained designs for N=5 and N=7 with necessary analytical methods. Kedia and Misra (2008) constructed some series of neighbour designs which are obtained by developing the initial blocks. Laxmi & Rani(2009) studied the pattern of first-order neighbour treatments in incomplete block design for two-sided (right & left) neighbour effects for OS1 series. Laxmi and Parmita (2010) studied left neighbours in incomplete block design for OS2 series ($v= s^2+s+1= b$, $r= s+1= k$ and $\lambda=1$). In 2011, Laxmi and Parmita studied right neighbours in incomplete block design for OS2 series ($v= s^2+s+1= b$, $r= s+1= k$ and $\lambda=1$). The purpose of this paper is to study two-sided i.e. left and right neighbours simultaneously in incomplete block design for OS2 series without constructing the actual design.

2. Construction of Neighbour Designs:

With the help of complete sets of MOLS it is very easy to construct the BIBD for OS2 series. Then neighbour design may be constructed by using the border plots, that is, one plot is added at each end of each block. The neighbour designs are constructed in such a way that interior treatments at one end of the block are the neighbour at the other end of the block. Therefore, the border treatments at either end of the block are the same as the treatments on the interior plot at the other end of block of neighbour design, hence all the blocks are circular. This shows that, for a design d, d(i, j) denotes the treatment applied to plot j of block i. Particularly, d(i, 0) and d(i, k+1) are the two treatments applied to the border plots of block i and the circularity condition implies that d(i, 0)= d(i, k) and d(i, k+1)= d(i, 1) ; where $1 \leq i \leq b$ & $1 \leq j \leq k$. Arrangement of treatments at border plots is not used for measuring the response variable. Plots other than border plots are described as internal plots for neighbour designs. When s=3 the resulting design is the neighbour design with parameters $v=b=3^2+3+1= 13$, $r=k=3+1= 4$ & $\lambda= 1$:

Table – 2.1

10	1	2	3	10	1
10	4	5	6	10	4
10	7	8	9	10	7
11	1	4	7	11	1
11	2	5	8	11	2
11	3	6	9	11	3
12	1	6	8	12	1
12	2	4	9	12	2
12	3	5	7	12	3
13	1	5	9	13	1
13	3	4	8	13	3
13	2	6	7	13	2
13	10	11	12	13	10

In the design obtained here, no treatment is (i) immediate to itself and (ii) immediate to any other treatment more than once. Similarly neighbour design can be constructed when s is a prime power e.g. $s=4(=2^2)$, with the parameters $v=b=4^2+ 4+1=21$, $r=k=4+1=5$ & $\lambda=1$. The resulting neighbour design is:

Table – 2.2

17	1	2	3	4	17	1
17	5	6	7	8	17	5
17	9	10	11	12	17	9
17	13	14	15	16	17	13
18	1	5	9	13	18	1
18	2	6	10	14	18	2
18	3	7	11	15	18	3
18	4	8	12	16	18	4
19	1	6	11	16	19	1
19	2	5	12	15	19	2
19	3	8	9	14	19	3
19	4	7	10	13	19	4
20	1	8	10	15	20	1
20	4	5	11	14	20	4
20	2	7	9	16	20	2
20	3	6	12	13	20	3
21	1	7	12	14	21	1
21	3	5	10	16	21	3
21	4	6	9	15	21	4
21	2	8	11	13	21	2
21	17	18	19	20	21	17

In the above design obtained again no treatment is (i) immediate to itself and (ii) immediate to any other treatment more than once and all the blocks are circular in the sense that the border treatments at either end of the block is the same as the treatment on the interior plot at the other end of block. Similarly the neighbour designs for s =5, 7, $2^3=8$, $3^2=9$, 11 can be obtained.

3. Two-Sided Neighbours For OS2 Series:

Laxmi and Parmita(2010) found the left neighbours of a treatment for OS2 series in incomplete block designs, can be summarized in the following table:

Table-3.1

Other Left Neighbour	Common Left Neighbour Series	Treatment Number (i)	Series In Which Treatment Number 'i' Lies
s^2+1	$s^2+2,\ldots, s^2+s+1$	1	
i-1	$s^2+2,\ldots, s^2+s+1$	2	
.	.	.	
.	.	.	$1 \leq i \leq s$
.	.	.	
i-1	$s^2+2 ,\ldots, s^2+s+1$	s	
s^2+1	1,…,s	s+1	
i-1	1,…,s	s+2	
.	.	.	
.	.	.	$s+1 \leq i \leq 2s$
.	.	.	
i-1	1,…,s	2s	
.	.	.	
.	.	.	
.	.	.	
s^2+1	(s-2)s+1,…,(s-2)s+s	(s-1)s+1	
i-1	(s-2)s+1,…,(s-2)s+s	(s-1)s+2	
.	.	.	
.	.	.	$(s-1)s+1 \leq i \leq s^2$
.	.	.	
i-1	(s-2)s+1,…,(s-2)s+s	$(s-1)s+s = s^2$	
$i-1 = s^2$	**$s,2s,\ldots,(s-1)s$& s^2+s+1**	**s^2+1**	**$i = s^2+1$**
s^2+1	$(s-1)s+1,\ldots, s^2$	s^2+2	
i-1	$(s-1)s+1,\ldots, s^2$	s^2+3	
.	.	.	
.	.	.	$s^2+2 \leq i \leq s^2+s+1$
.	.	.	
i-1	$(s-1)s+1,\ldots, s^2$	s^2+s+1	

Laxmi and Parmita(2011) also found the right neighbours for the same series and obtained pattern, is summarized in the following table:

Table-3.2

Series In Which Treatment Number 'i' Lies	Treatment Number (i)	Common Right Neighbour Series	Other Right Neighbour
$1 \leq i \leq s$	1 2 . . . s	s+1,…,2s s+1,…,2s . . . s+1,…,2s	i+1 i+1 . . . s^2+1
$s+1 \leq i \leq 2s$	s+1 s+2 . . . 2s	2s+1,…,3s 2s+1,…,3s . . . 2s+1,…,3s	i+1 i+1 . . . s^2+1
	. . .	. . .	. . .
$(s-1)s+1 \leq i \leq s^2$	(s-1)s+1 (s-1)s+2 . . . $(s-1)s+s = s^2$	s^2+2 ,…, s^2+s+1 s^2+2 ,…, s^2+s+1 . . . s^2+2 ,…, s^2+s+1	i+1 i+1 . . . $i+1= s^2+1$
$i = s^2+1$	**s^2+1**	**1,s+1,2s+1,…,(s-1)s+1**	**$i+1=s^2+2$**
$s^2+2 \leq i \leq s^2+s+1$	s^2+2 s^2+3 . . . s^2+s+1	1,…,s 1,…,s . . . 1,…,s	i+1 i+1 . . . s^2+1

Laxmi and Parmita found that there shall be s+1 left neighbours and s+1 right neighbours for each treatment of OS2 series and neither of these two sided neighbours is common. Therefore, there must be 2s+2 neighbours in total when considering both sided neighbours simultaneously. A design is said to be completely balanced for neighbours if every experimental treatment has every other treatment once as a left neighbour and once as a right neighbour whereas a design is said to be partially balanced for neighbours if every treatment has every other treatment as neighbour, on either side, at most once. For the analyses purposes one needs both sided neighbours which can be easily obtained in the manner given in the following table:

Table-3.3

Other Left Neigh- bour	Common Left Neighbour Series	Treatment Number (i)	Common Right Neighbour Series	Other Right Neigh- bour	Series In Which Treatment Number 'i' Lies
s^2+1	$s^2+2,\ldots, s^2+s+1$	1	$s+1,\ldots,2s$	i+1	
i-1	$s^2+2,\ldots, s^2+s+1$	2	$s+1,\ldots,2s$	i+1	
.	.	.	.	.	$1 \le i \le s$
.	.	.	.	.	
.	.	.	.	.	
i-1	$s^2+2 ,\ldots, s^2+s+1$	s	$s+1,\ldots,2s$	s^2+1	
s^2+1	$1,\ldots,s$	s+1	$2s+1,\ldots,3s$	i+1	
i-1	$1,\ldots,s$	s+2	$2s+1,\ldots,3s$	i+1	
.	.	.	.	.	$s+1 \le i \le 2s$
.	.	.	.	.	
.	.	.	.	.	
i-1	$1,\ldots,s$	2s	$2s+1,\ldots,3s$	s^2+1	
.	.	.	.	.	
.	.	.	.	.	
.	.	.	.	.	
s^2+1	$(s-2)s+1,\ldots,(s-2)s+s$	(s-1)s+1	$s^2+2 ,\ldots, s^2+s+1$	i+1	
i-1	$(s-2)s+1,\ldots,(s-2)s+s$	(s-1)s+2	$s^2+2 ,\ldots, s^2+s+1$	i+1	
.	.	.	.	.	
.	.	.	.	.	$(s-1)s+1 \le i \le s^2$
.	.	.	.	.	
i-1	$(s-2)s+1,\ldots,(s-2)s+s$	$(s-1)s+s = s^2$	$s^2+2 ,\ldots, s^2+s+1$	$i+1= s^2+1$	
$i-1 = s^2$	**$s,2s,\ldots,(s-1)s$ & s^2+s+1**	**s^2+1**	**$1,s+1,2s+1,\ldots, (s-1)s+1$**	**$i+1= s^2+2$**	**$i = s^2+1$**
s^2+1	$(s-1)s+1,\ldots, s^2$	s^2+2	$1,\ldots,s$	i+1	
i-1	$(s-1)s+1,\ldots, s^2$	s^2+3	$1,\ldots,s$	i+1	
.	.	.	.	.	$s^2+2 \le i \le s^2+s+1$
.	.	.	.	.	
.	.	.	.	.	
i-1	$(s-1)s+1,\ldots, s^2$	s^2+s+1	$1,\ldots,s$	s^2+1	

This can be explained by considering the design, $v=b=3^2+3+1= 13$, $r=k=3+1= 4$ & $\lambda= 1$ (i.e. s=3) using Table -3.3, both sided neighbours so obtained can be presented in the following table:

Table-3.4

Other Left Neigh- bour	Common Left Neighbour Series	Treat- ment Number (i)	Common Right Neighbour Series	Other Right Neigh- bour	Series In Which Treatment Number 'i' Lies
10	11,12,13	1	4,5,6	2	
1	11,12,13	2	4,5,6	3	$1 \le i \le 3$
2	11,12,13	3	4,5,6	10	
10	1,2,3	4	7,8,9	5	
4	1,2,3	5	7,8,9	6	$4 \le i \le 6$
5	1,2,3	6	7,8,9	10	
10	4,5,6	7	11,12,13	8	
7	4,5,6	8	11,12,13	9	$7 \le i \le 9$
8	4,5,6	9	11,12,13	10	
9	**3,6,13**	**10**	**1,4,7**	**11**	**i = 10**
10	7,8,9	11	1,2,3	12	
11	7,8,9	12	1,2,3	13	$11 \le i \le 13$
12	7,8,9	13	1,2,3	10	

From the above table we observe that the treatment number 1 has s = 3 neighbours 11,12,13 as common left neighbours which is the series immediate left to the series in which i-th treatment ($1 \leq i \leq s$) lies. Other s = 3 neighbours are 4,5,6 as common right neighbours which is the series immediate right to the series in which i-th treatment ($1 \leq i \leq s$) lies. Here the left neighbours 11, 12, 13 can be written as s^2+2, s^2+3 (or s^2+s), s^2+4 (or s^2+s+1). Similarly 4, 5, 6 can be written as s+1, s+2, s+3 (or s+s/2s). Other two treatments of i=1 are observed as 10, 2. As the concept of neighbour means adjacent it should be i-1 and i+1, where i+1=2 is the immediate right neighbour of i and i-1 =0(mod v) = 13 has already occurred as one of the members in the left series, is replaced by the treatment number 10 which can be written as treatment number s^2+1. So it may be percepted that other two neighbours of i-th treatment are i-1 and i+1. If any of these two occur in the previously obtained 2s neighbours of the i-th treatment, it may be replaced by the treatment number s^2+1.

The treatment number 2 has s = 3 neighbours 11, 12, 13 which is again immediate common left neighbour series which can be written as s^2+2, s^2+3 (or s^2+s), s^2+4 (or s^2+s+1). Other s = 3 neighbours are 4, 5, 6 which is again the immediate common right neighbour series of i-th treatment ($1 \leq i \leq s$) which further can be written as s+1, s+2, s+3 (or 2s). As noticed earlier, there shall be 2s+2=8 neighbours for each treatment, so other two neighbours of treatment number i=2 observed are 1, 3 which may be written as i-1 and i+1.

Treatment number 3 has s = 3 neighbours 11, 12, 13 as the immediate common left neighbour series of i-th treatment ($1 \leq i \leq s$) and other s = 3 neighbours are 4, 5, 6 as the immediate common right neighbour series of i ($1 \leq i \leq s$). Here again these can be written as s^2+2, s^2+3 (or s^2+s), s^2+4 (or s^2+s+1) and s+1, s+2, s+3 or s+s, respectively. The other two neighbours observed are 2 and 10. It should have been i-1 and i+1 i.e. 2 and 4. But the treatment number 4 has already occurred as one of the members in the immediate common right neighbour series of the treatment so it may not appear again as a neighbour. Therefore it may be replaced by the treatment number s^2+1 i.e. 10 which is a true perception.

The treatment number 4 or i=s+1 has s = 3 neighbours 1, 2, 3 which is immediate common left neighbour series of the i-th treatment ($s+1 \leq i \leq 2s$). Other s=3 neighbours are 7, 8, 9 which is immediate common right neighbour series of the i-th treatment ($s+1 \leq i \leq 2s$). Now the left neighbours 1, 2, 3 can be written as 1, … , s. Similarly 7, 8, 9 can be written as 2s+1, 2s+2, 2s+s=3s (In this case $3s=s^2$). Other two treatments of i=4 observed are 10 and 5. According to the perception these should be i-1 and i+1 i.e. 3 and 5. But treatment number 3 has already occurred as one of the members in the left series. So it should be replaced by the treatment number 10 i.e. s^2+1 which again shows that our perception is true.

Now consider treatment number 5 or i= s+2 has s = 3 neighbours 1, 2, 3 again as immediate common left neighbour series of the i-th treatment ($s+1 \leq i \leq 2s$). Other s = 3 neighbours are 7, 8, 9 again as immediate common right neighbour series of the i-th treatment ($s+1 \leq i \leq 2s$). Other two treatments of i=5 are 4 and 6 which can be written as i-1 and i+1.

Let us consider treatment number 6 or i=2s has s = 3 neighbours 1, 2, 3 again as the immediate common left neighbour series of the i-th treatment ($s+1 \leq i \leq 2s$). Other s = 3 neighbours are 7, 8, 9 again as the immediate common right neighbour series of the i-th treatment ($s+1 \leq i \leq 2s$). Other two treatments of i=6 are 5 and 10. According to the perception it should be i-1 and i+1 i.e. 5 and 7. As treatment number 7 has already occurred as one of the members in the right series. So it is replaced by the treatment number $s^2+1=10$.

The treatment number 7 or i=2s+1 has s = 3 neighbours 4, 5, 6 as the immediate common left neighbour series of the i-th treatment ($2s+1 \leq i \leq 3s/s^2$). Other s = 3 neighbours are 11, 12, 13 as the immediate common right neighbour series of the i-th treatment ($2s+1 \leq i \leq 3s/s^2$). Now the left neighbours 4, 5, 6 can be written as s+1, s+2, s+s(=2s). Similarly 11, 12, 13 can be written as s^2+2, s^2+3 (or s^2+s), s^2+4 (or s^2+s+1). The other two neighbours of treatment number i=7 are 10 and 8. It should be according to the perception i-1 and i+1 i.e. 6 and 8. But treatment number 6 has already occurred as one of the members in the left series. So it is replaced by the treatment number 10 i.e. s^2+1. It is noted here that the immediate common right neighbour series of the treatment number i ($7 \leq i \leq 9$) is s^2+2, s^2+3, s^2+4 instead of s^2+1, s^2+2, s^2+3. It may be due to the reason that whenever an immediate neighbour of i i.e. either i-1 or i+1 occurs in immediate common left neighbour series or immediate common right neighbour series, it may be replaced by s^2+1.

Consider the treatment number 8 or i=2s+2 has s = 3 neighbours 4, 5, 6 which is immediate common left neighbour series of the i-th treatment ($2s+1 \leq i \leq 3s/s^2$). Other s = 3 neighbours are 11, 12, 13 which is immediate common right neighbour series of the i-th treatment ($2s+1 \leq i \leq 3s/s^2$). Other two neighbours of treatment number i=8 observed are 7 and 9. These two neighbour treatments can be further written as i-1 and i+1.

Now the treatment number 9 or $i=s^2$ has s = 3 neighbours 4, 5, 6 which is immediate common left neighbour series of the i-th treatment ($2s+1 \leq i \leq 3s/s^2$). Other s=3 neighbours are 11, 12, 13 which is immediate common right neighbour series of the i-th treatment ($2s+1 \leq i \leq 3s/s^2$). The other two neighbours of treatment number i=9 are 8 and 10 which is written as i-1 and i+1.

We observed that treatment 10 i.e. s^2+1 has neighbours which are entirely different from the series and the conception, so we will discuss it later.

Let us consider the treatment number 11or i=s^2+2 has s = 3 neighbours 7, 8, 9 which is immediate common left neighbour series of the i-th treatment ($s^2+2 \leq i \leq s^2+s+1$). Other s = 3 neighbours are 1, 2, 3 which is immediate common right neighbour series of the i-th treatment ($s^2+2 \leq i \leq s^2+s+1$). The left neighbours 7, 8, 9 can be written as 2s+1, 2s+2, 2s+s or s^2. Similarly right neighbours can be written as s^2+s+2 (mod 13) =1, s^2+s+3 (mod 13) =2, s^2+2s+1 (mod 13) = 3 or s. Other two neighbours of treatment number i=11 observed are 10 and 12 which can be written as i-1 and i+1. As observed treatment number $s^2+1=10$ is a treatment which has entirely different neighbour treatments. It is also observed here that treatment number $s^2+1=10$ does not occur in the immediate common left neighbour series or right neighbour series of any treatment.

The treatment number 12 or i=s^2+s has s = 3 neighbours 7, 8, 9 which is immediate common left neighbour series of the i-th treatment ($s^2+2 \leq i \leq s^2+s+1$). Other s = 3 neighbours are 1, 2, 3 which is immediate common right neighbour series of the i-th treatment. Other two neighbours of treatment number i=12 observed are 11 and 13 which can be written as i-1 and i+1.

The treatment number 13 or i=s^2+s+1 has s = 3 neighbours 7, 8, 9 which is immediate common left neighbour series of the i-th treatment ($s^2+2 \leq i \leq s^2+s+1$). Other s = 3 neighbours are 1, 2, 3 which is immediate common right neighbour series of the i-th treatment ($s^2+2 \leq i \leq s^2+s+1$). The other two neighbours of treatment number i=13 observed are 12 and 10 which should be according to the perception (i-1 and i+1) i.e. 12 and 14(mod13) = 1. But treatment number 1 has already occurred as one of the members in the right series. So it is replaced by the treatment number 10 i.e. s^2+1.

As observed treatment number $s^2+1=10$ is a treatment which has entirely different neighbour treatments. The treatment number 10 or i=s^2+1 has the neighbours 1, 3, 4, 6, 7, 9, 11 & 13. These neighbours can be written as 1, s, s+1, s+s/(2s), 2s+1, 2s+s/(3s=$s^{2)}$ in this case), s^2+2 and s^2+s+1. This shows that the first treatment and the last treatment of all the series are the neighbours of the treatment number 10 or s^2+1.

This can further be observed from the perception such that treatment number s^2+1 will appear as neighbour treatment for any treatment i, $1 \leq i \leq s^2+s+1$wherever the immediate neighbour treatments (i-1, i+1)has already occurred in either left series or right series. So all such treatments come in the list of neighbour for s^2+1 and the rest two neighbour treatments are immediate neighbour of treatment number s^2+1 i.e. s^2 and s^2+2. This procedure of finding the neighbours is same for any value of s, whether s is a prime number or a prime power. Here it should be noted that every treatment does not have every other treatment as its neighbours, so it is incompletely balanced for neighbours for OS2 series as there shall be only 2s+2 neighbours of a treatment when considering both sides simultaneously. These neighbours can be obtained in the following steps.

4. Steps To Find Two-Sided Neighbours For OS2 Series:

(1) *Observe the treatment number 'i', where $i \neq s^2+1$.*

(2) *Then find the series in which the treatment number 'i' lies.*

The series is defined in such a way that the sequence of first 's' treatments of the design form the first series, the sequence of next 's' treatments i.e. 's+1' to '2s' form the second series and so on up to 's^2'. Thus have 's' series up to the treatment number 's^2'. The last series i.e. 's+1'–th series of 's' treatments always starts from treatment number 's^2+2' instead of the treatment number 's^2+1' and ended on treatment number 's^2+s+1' for any 's' whether it is a prime number or prime power. Now the 's+2'-th series of next 's' treatments shall be 's^2+s+2' to 's^2+2s+1', which with mod(v) reduces to '1' to 's'. So the s+2-th series is again the first series of the design. This shows that the design is circular.

(3) *Then find out the immediate common left neighbour series and immediate common right neighbour series for the treatment.*

(4) *Other two neighbour treatments i.e. left neighbour and right neighbour can be find by taking left adjacent and right adjacent of the treatment respectively.*

(5) *The last and first treatments of each series are respectively the left and right neighbours of the treatment number s^2+1.*

(This pattern of finding two-sided neighbours for OS2 series of BIBD holds valid for any value of s, whether s is a prime number or a prime power. It may work for other series also).

Conclusion:

For the analysis of data experimenter needs C-matrix which is always expressed in terms of incidence matrix, N. Present paper suggests an accurate and shortcut method for finding the neighbours for each treatment without constructing the design for OS2 series and hence reduces calculation of finding neighbours. It is less time consuming as the experimenter can directly find out the neighbours of a particular treatment.

References

[1] Azais, J.M., Bailey, R.A. & Monod, H.(1993): A catalogue of efficient neighbour – designs with border plots. Biometrics, 49, 1252-1261.
[2] Bailey, R.A. (2003): Designs for one- sided neighbour effects. Journal of the Indian Society Agriculture Statistics,56(3),302- 314.
[3] Cheng, C.S.(1983): Construction of Optimal balanced incomplete block designs for correlated observations. Ann. Statist.,11,240-246.
[4] Das, A.D.& Saha, G.M. (1976): On construction of neighbour designs. Calcutta Statistical Association Bulletin, 25, 151-163.
[5] Freeman,G.H. (1967): The use of cyclic balanced incomplete block designs for directional seed orchards. Biometrics,23,761-778.
[6] Freeman,G.H. (1969): The use of cyclic balanced incomplete block designs for non- directional seed orchards. Biometrics,25,561-571.
[7] Freeman, G.H. (1979): Some two dimensional designs for nearest neighbours. Journal of the Royal Statistical Society, B 41, 88-95.
[8] Jaggi, Seema, Gupta, V.K., and Ashraf, Jawaid (2006): On block designs partially balanced for neighbouring competition effects. Journal of the Indian Statistical Association. Vol. 44, 1, 27-41.
[9] Kedia, R.G. and B.L. Misra (2008): On construction of generalized neighbor design of use in serology. Statistics and Probability Letters, 18: 254-256.
[10] Kiefer, J. and Wynn, H.P. (1981): Optimal Balanced Block and Latin Square Designs for correlated observations. Ann. Statist., 9, 737-757.
[11] Laxmi, R.R. and Parmita(2010): Pattern of Left Neighbours for Neighbour Balanced Incomplete Block Designs. Journal of Statistics Sciences, 2(2), pp. 91-104.
[12] Laxmi, R.R. and Parmita(2011): Pattern of Right Neighbours for Neighbour Balanced Incomplete Block Designs. Journal of Statistics Sciences, 3(1), pp. 67-77.
[13] Laxmi, R.R. and Rani, S. (2009): Construction of Incomplete Block Designs for Two Sided Neighbour Effects Using MOLS. J. Indian Soc. Stat. Opers. Res. Vol. 30,1-4.
[14] Mead, R. (1979): Competition experiments, Biometrics, 35, 41-54.
[15] Meitei, K.K. (1996): A series of incomplete block neighbour designs. Sankhya, Vol. 58, Series B, 145-147.
[16] Misra, B.L., Bhagwandas & Nutan (1991): Families of neighbour designs and their analysis. Communication Statistics Simulation, 20 (2&3), 427-436.
[17] Pateria, Dinesh Kumar, Jaggi, Seema, Varghese, Cini and Das, M.N.(2007): Incomplete non- circular block designs for competition effects. Journal of Statistics & Applications. Vol. 5 nos. 1&2, (New Series), 5-14.
[18] Raghavrao, D.(1971):Constructions and Combinatorial Problems in Design of Experiments. New York: Wiley.
[19] Rees, D. H. (1967): Some designs of use in serology. Biometrics, 23, 779-791.
[20] Tomar, J.S., Jaggi, Seema & Varghese, Cini (2005): On totally balanced block designs for competition effects. Journal of Applied Statistics, 32(1), 87-97.