EFFICIENCY OF CHANGE OVER DESIGN IN ANIMAL EXPERIMENTATIONS

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The role of Statistical planning in ensuring the validity and enhancing the efficiency of the experimentation is beginning to be recognised in the field of animal science as in that of agricultural research. Designs such as completely randomised design, randomised block design and latin square design are being increasingly applied in animal experiments. The cross-over or switch over design is found to be specially suited to short term animal experiments.

The largest source of experimental error variation in animal experiments is the variation among animals due to their genetic and physiological dissimilarities. The variation due to the differential yielding ability of animal is removed to an extent by the conventional procedure of suitable grouping of the animals as in randomised block design or latin square design. The residual error variation is, however, still substantial. This variation is sought to be eliminated altogether by applying to each animal all the treatments in sequence. In other words an experimental unit receives different treatments in different periods. The design which incorporates this concept is known as change over or switch over design. The period variation is prevented through rendering periods and treatments orthogonal by having all the treatments occur in the design equally frequently in each period.

These designs are most suitable for short term experiments. In the present work, a study has been made of the relative efficiency of the switch-over design in its various forms with the conventional designs, *viz.*, the completely randomised design, randomised block design utilising milk yield data. The change in efficiency with different types of blocking has been investigated. The utility of allowing a part of each period under uniform treatment and taking the yield in the pre-treatment period as concomitant variable has been examined. The efficiency of extra period switch over design has also been studied.

Review of Literature

In the study of efficiency of designs, uniformity trials play an important role. Cochran (1937) has listed the uniformity trials conducted in the agricultural field. Uniformity trial data can be utilised in studying the relative efficiency of different designs by superimposing the design. Yates (1936) collected the data on orange trees and showed that pseudofactorial arrangements enable the block size to be kept within limits without the use of repeated controls and is 26 to 57% more efficient than randomised block design. Cochran (1941) utilised the results of uniformity trials on wheat and corn to study the relative efficiency of Lattice square design and found it to vary from 104 to 136 per cent.

A comprehensive study on the shape and size of the plot was made in agricultural field by Fairfieldsmith (1938) who derived the relation between the variance per plot and the size of the plot. Yates (1938) conducted an experiment on school children in the nutrition field.

Some work on the study of designs suited to animal experiments has been carried out. Brandt (1938) discussed what he called double reversal trials with two treatments tried on each animal in twins. Cochran et al. (1941) have discussed the use of switch over design in dairy cattle feeding experiments to secure accurate comparisons of the effects of the ration. Taylor and Armstrong (1953) described the efficiency of the design such as double reversal trials involving two treatments and periods in incomplete Latin square. Lucas (1960) discussed some critical features of good dairy feeding experiments and the usefulness and efficiency of the rotation type, and switch back designs.

Subrahmaniam (1961) worked out the relative efficiency of randomised block design against the total variation in the data with no-classification. The efficiency was also seen due to the factors, *viz.*, season of calving and order of lactation with and without the use of an auxiliary variable. He did some preliminary work on the switch over design and found that switch over design was more efficient than conventional designs such as completely randomised design and randomised block design.

The present study investigates the use of change over design in a more detailed and comprehensive manner.

Data on the following herds have been taken for the present investigation :—

1. Konkrej herd at Agricultural College, Anand (Gujarat).
2. Murrah buffalo herd at Military Farm, Ambala Cantt. (Punjab)

The data were recorded in the form of history sheets for each animal having the relevant information such as brand number, name of the bull, date of service, date of calving, lactation order and its yield, lactation length and dry period, etc. Daily milk yield records were also maintained in a separate register. The animals in each herd were maintained under a common management with uniform treatment of feeding at the same place.

Data pertaining to the daily milk yield of 40 Konkrej cows at Anand recorded in the period May, 1962 to March, 1965 and 24 Murrah buffaloes at Ambala Cantt. recorded in the period from December, 1954 to October, 1955 were considered for the invctigation. Normally it is advisable to select those animals for the investigation whose date of calving falls during a short interval of time, so that the lactation period more or less starts at the same time, but in case of Konkrej herd at Anand due to smaller number of animals this was not possible. The animals belonged to different orders of lactation. Records pertaining to abnormal lactations *viz.* abortion, still birth and mastitis were left out from the analysis.

PROCEDURE OF ANALYSIS

The most common measure of efficiency that has received the miximum usage is due to Fisher. He defined the reciprocal of the population variance σ^2 per unit as the "amount of information". If σ^2 is known, the information would be $1/\sigma^2$; otherwise the information would be as

$$\frac{n+1}{n+3}\,\frac{1}{S^2}$$

where S^2 is the error mean square corresponding to the design and n is the number of degrees of freedom. The relative efficiency of the first design to second is thus estimated by

$$\frac{(n_1+1)\ (n_2+3)\ S_2^2}{(n_2+1)\ (n_1+3)\ S_1^2}$$

If n_1 and n_2 are large, the efficiency would approach $\frac{S_2^2}{S_1^2}$.

SUPERIMPOSITION OF THE DESIGN

In order to study the efficiency of switch-over design, the design was superimposed on the uniformity data available. Three, four and five treatments corresponding to the periods of 80, 60 and 50 days respectively were studied since in the majority of cases, milk yields upto 250 days were available.

Reduction in error variance due to the use of concomitant variable was studied in the following way. At the start of each period, the 1st three days yield for 50 day period and 5 days yield for 60 and 80 day periods were excluded for eliminating the irregular yields during the switch over. The next seven days yield in 50 day period and 10 days yield in 60 and 80 day periods were taken as concomitant variables. The underlying assumption is that residual effect is small and is over during the short period of carry over. The first 7 or 10 days period may be called standardization period and remaining experimental period (Lucas, 1960).

The standardization period yield (X) was used as a concomitant variate and the experimental period yield (Y) as depending variable. During the standardization period each animal would be switched to the appropriate experimental treatment.

FORMATION OF BLOCKS

The efficiency of grouping of experimental animals for forming homogeneous blocks on the basis of the following three characters were examined.

1. Season of calving.
2. Previous lactation yield.
3. Persistency of the milk yield in the previous lactation.

For forming blocks according to season of calving all the brand numbers of animals were arranged in the order of their date of calving, equal in number to the treatments were taken as blocks. Similarly all animals were arranged in the ascending order of previous lactation yield and blocks were formed, and similarly in case of persistency of milk yield also (persistency being the ratio of the last period yield to the total periods yield).

Analysis of Variance Table of the Design

In case of uniformity data, the treatment S.S. will be merged with error sum of squares. The analysis was done with and without blocks.

1. *Without blocks* :—Let there be t treatments and r be the number of latin squares.

In completely randomised design one treatment is allotted to r animals randomly and in switch over design the squence of t treatments is allotted randomly to r animals. After every period, the treatment will be changed. The following is the analysis of variance table :

Analysis of variance table

Source of variation	*d.f.*	*M.S.*
Between periods	$(t-1)$	—
Between Animals	$(tr-1)$	S_2^2
Residual	$(t-1)(tr-1)$	S_1^2
Total	t^2r-1	

In the corresponding completely randomised design, the error variance for one single period will be S_2^2. Therefore, the comparison of S_1^2 and S_2^2 will give the efficiency of switch over design without blocks relative to completely randomised design, *viz.*

$$\text{Relative efficiency} = \frac{S_2^2}{S_1^2}$$

(when the adjustment factor was ignored).

2. *With blocks* :—When the blocks were formed, there will exist the interaction between periods and blocks, Following is the skeleton of analysis of variance :

Analysis of variance table

Source af variation	*d. f.*	*M.S.*
Between blocks	$(r-1)$	—
Between periods	$(t-1)$	—
Blocks × periods	$(r-1)(t-1)$	—
Between animals within blocks	$r(t-1)$	S_4^2
Error	$r(t-1)^2$	S_5^2
Total	(t^2r-1)	

The proper error variance for randomised block design will be S_4^2 *i.e.* mean square between animals within blocks, and for switch-over design with blocks is S_5^2. Therefore, the relative efficiency of switch-over design with blocks relative to randomised block design would be $\frac{S_4^2}{S_5^2}$ ignoring the adjustment factor.

Similarly the comparison between S_1^2 and S_5^2 will give the relative efficiency of blocking in switch over design.

By taking the extra period, the efficiency was compared in a similar fashion with and with out blocks and analysis of variance table is given below :

I. *Without blocks*

Analysis of variance table

Source of variation	*d. f.*	*M.S.*
Between periods	t	—
Between animals	$tr-1$	S_2^2
Between animals residual	$t(tr-1)$	S_1^2
Total	$tr(t-1)-1$	

II. *With blocks*

Analysis of variance table

Source of variation	*d.f.*	*M S.*
Between blocks	$r-1$	—
Between periods	t	—
Blocks × periods	$t(r-1)$	—
Animals within blocks	$r(t-1)$	S_4^2
Error	by subtraction	S_5^2
Total	$tr(t-1)-1$	

Lucas (1959) showed that better estimates of the residual effects can be made entirely from the results of 2nd, 3rd,...$(t+1)$th period after leaving the yield of first period. The relative efficiency of this modified switch over design was obtained as in switch over design.

The analysis of covariance was done and the relative efficiency was obtained as earlier after adjusting the proper error mean square for the design with and without blocks.

RESULTS

The results are presented under four main headings given below :—

1. Efficiency of switch over design.
2. Efficiency of extra period design and comparison with switch over design.
3. Efficiency of modified extra period design. Comparison with extra period and modified extra period design.
4. Efficiency of switch over design utilising the information on concomitant variate.

The relative efficiency has been expressed in percentage.

1. EFFICIENCY OF SWITCH OVER DESIGN

The switch over design without blocks was compared with completely randomised design and the relative efficiency was found to vary from 403 to 2757.

The results of comparison of switch over design with blocks relative to randomised block design are summarised in the table 1.

TABLE 1

Relative efficiency of switch over design with blocks compared to randomised block design (percentage)

Relative efficiency in %	*No. of treatments*		
	Three	*Four*	*Five*
			No .of sets of data
100-500	—	—	3
501-1000	7	5	—
1001-3000	10	6	2
3001-5000	—	—	1
above 5000	1	1	—
Total	18	12	6

Next the relative efficiency of grouping the experimental units into homogeneous blocks in a switch over design as against the design without blocks varied in the range of 86 and 366 and the relative efficiency was found more than 100 in 28 cases out of 36.

2. Extra Period Design

By adding an extra period to the basic switch over design, extra period design is constructed. When the design without blocks was compared with completely randomised design, the values of relative efficiency varied from 615 to 2880 which shows that extra period design is 6 to 29 times more efficient than completely randomised design. A comparison made between extra period design with blocks and randomised block design showed that extra period design was 7 to 136 times more efficient. The values are summarised in the table 2.

TABLE 2

Relative efficiency of extra period design with blocks compared to randomised block design

Relative efficiency in %	No. of treatments		
	Three	Four	Five
			No. of sets of data
501-1000	6	3	—
1001-3000	3	2	1
3001-5000	1	—	2
above 5000	2	1	—
Total	12	6	3

Next the extra period design with blocks was compared relative to without blocks. The formation of blocks resulted in decreased error variation, the relative efficiency being more than 100 in 17 cases out of 21.

3. Modified Extra Period Design

(Omitting the period)

With the same conventional method first of all, the relative efficiency of the design without blocks *vis-a-vis* the completely randomised design was obtained. It ranged from 326 to 3279 per cent.

The design with blocks was, next, compared with the randomised block design. The design was found highly efficient as the relative efficiency varied between 408 to 5789 per cent. The values are classified in the table 3.

TABLE 3

Relative efficiency of modified extra period design with blocks compared with randomised blocks

Relative effieiency in %	No. of treatments		
	Three	Four	Five
	No. of sets of data		
100-500	2	—	—
501-1000	4	3	—
1001-3000	5	1	3
3001-5000	1	1	—
above 5000	—	1	—
Total	12	6	3

Next the relative efficiency of this design with blocks against without blocks was found to range from 87 to 226. The relative efficiency was less than 100 in 5 cases out of 21.

It was observed that the efficiency of modified extra period design without blocks was inferior to that of extra period design without blocks only in one case, *viz.*, in case of Murrah herd, but on the contrary the modified extra period design with blocks was found less efficient in 9 cases out of 21 and the efficiency varied from 40 to 159 per cent.

Similarly when compared with switch over design without blocks, the modified design was less efficient only in two cases and the efficiency ranged from 40 to 297. On the other hand the design with blocks was less efficient than switch over design with blocks in 16 cases out of 39 and the efficiency varied from 30 to 371.

4. USE OF COVARIANCE TECHNIQUE
(in switch over design)

The relative efficiency of switch over design without blocks but with utilisation of concomitant variate relative to completely randomised design varied from 280 to 4643 per cent.

In the first case, the comparision was made between switch over design without blocks with covariate and without covariate, the gain in efficiency varied from 25 to 78 per cent.

In the second case, the efficiency of switch over design with blocks with concomitant variate was compared with the design without covariate. The relative efficiency ranged between 97 to 206. The efficiency was found less than 100 in 7 cases out of 36.

Next the gain in efficiency due to blocks in switch over design with utilisation of anciallary information was studied. The relative efficiency varied from 78 to 223 per cent.

The formation of blocks did not contribute to efficiency much in case of 3 and 4 numbers of treatments but in case of five treatments it resulted in increasing the gain in efficiency. When the switch over design with blocks but without concomitant variate was compared with the design without blocks with covariate, the efficiency was less than 100 in 17 cases out of 36. The formation of blocks was more efficient than the use of concomitant variate in case of five treatments while it is reverse in case of three and four treatments as the formation of blocks is less efficient in 16 cases out of 40.

Discussion

On the whole, change over design proved far superior to completely randomised design and randomised block design. The relative efficiency of switch over design without blocks, relative to completely randomised design, varied from 1046,to 4643 at Anand and from 2c0 to 1181 at Ambala herd, while that of switch over design with blocks *vis-a-vis* randomised block design varied from 87 to 13, 556 in case of Konkrej cows at Anand and from 339 to 2814 in case of Murrah buffaloes at Ambala. It resulted that large number of animals would be required in case of traditional design to gain the same precision as in switch over design.

One way of eliminating the variation is through local control of error. Table 4 summarises the results.

TABLE 4

Relative efficiency of change over design with blocks against without blocks

Relative efficiency in %	*Basis of Blocks* — *Persistency of milk yield*	*Season of calving*	*Previous lactation yield*
			No. of sets of data
Less than 100	3	7	14
100-500	35	31	24
Total	38	38	38

From the above table it is clear that the formation of blocks based on persistency of milk yield resulted in a gain in efficiency in almost all cases and the gain was higher than with the blocks based on the other two characters. Grouping of units based on season of calving seemed to be next best. This finding is interesting and practically important. If detailed yields of previous lactation are not available, it would seem preferable to base the formation of blocks on season of ensuing calving which could be guessed at once, as the cows are diagnosed for pregnancy.

The extra period design with three and four treatments, each of length 50 days when compared with switchover design with three or four treatments each of 60 days period was found more efficient in almost all cases. Similarly the extra period design with 4 treatments and 60 day period was better than three treatments of 80 day period in switch over design. The extra period design with and without blocks was found more efficient in all cases, The modified extra period design without blocks showed that the modified design to be slightly more efficient in general but modified design with blocks was more efficient only in 60 per cent cases.

The comparison of modified extra period design and switch over design showed very interesting results. In the first case, keeping the total period of experiment constant, modified extra period design over switch over, both without blocks, the relative efficiency ranged from 104 to 297 per cent and with varying total duration of of experiment it varied from 218 to 155. The design was less efficient only in two cases. Secondly the comparision with the blocks, the efficiency ranged from 81 to 371 for constant duration and 30 to 150 with varying period. The design was found slightly less efficient in case of constant length but in 14 cases out of 21 in case of varying length.

The covariance technique was seen to increase the efficiency in all cases except one. In the case of switch over design with blocks, the use of covariance technique was found to result in gain in 29 cases out of 36. If the covariate is used, the formation of blocks in switch over design was useful in 29 cases out of 36. It can be concluded that the change over design with blocks was found more efficient than without blocks with or without the utilisation of concomitant variate.

The nature of efficiency was also examined after increasing the number of treatments and the duration of treatment period. It was observed that the relative efficiency went down with the increase of number of treatments for constant period under each treatment and for constant treatments.

The values of the relative efficiency were found to be generally of lower order for the data of Murrah buffalo herd at Ambala as compared with those for data on Konkrej herd at Ag. College, Anand, which indicated that variation between buffaloes was of lower order than the cows.

SUMMARY

Switch over design is particularly suited to animal experimentation. In the present paper, a study has been made of the relative efficiency of change over design in its various forms including extra period design with the conventional designs. Daily record of milk

yield of a herd of cows and another of buffaloes under uniform conditions of feeding and management have been utilised for the purpose. The utility of allowing a part of each period under uniform treatment and taking the yield in pre-treatment period as a concomitant variable has also been studied.

The change over design without blocks compared with completely randomised design was found 3 to 47 times more efficient and with blocks 3 to 135 times more efficient than randomised block design.

In this investigation, three criteria were used for the formation of blocks:—

1. Season of calving
2. Previous lactation yield
3. Persistency of milk yield.

It was concluded that formation of blocks based on persistency of milk yield provided greater efficiency than other two. Surprisingly, the design with blocks based on season of calving proved to be more efficient than based on previous lactation yield. Three durations of period under each treatment of 50, 60 and 80 days were tried.

The extra period design was more efficient than the ordinary switch over design. If the total experimental period was kept constant, the relative efficiency of extra period design compared with switch over design was more than when the total duration of experiment varied keeping the treatment period constant.

The modified extra period design with blocks was slightly efficient than the extra period design without blocks and with blocks was more efficient in 60% cases. The relative efficiency of modified extra period design compared with switch over design was more when total experimental period was kept constant than when it was varied.

The adoption of covariance technique eliminated considerable error variation when the design was with or without concomitant variate and was found almost equally efficient as the design without block but with covariate.

It was observed that as the number of treatments was increased for constant duration of treatment, the relative efficiency decreased almost in all cases. It was seen that as the duration of treatment period increased for constant treatments, the efficiency showed the downward trend linearly.

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