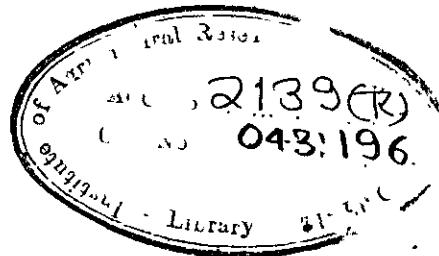


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EFFICIENCY OF CHANGE OVER DESIGN
IN
ANIMAL EXPERIMENTATION

By

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CHAPTER I

INTRODUCTION

The role of statistical planning in ensuring the validity and enhancing the efficiency of 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 Design 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 and Latin square design. The residual error variation is, however, still substantial. This variation is meant 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. By this means the error variation is sought to be reduced. A design which incorporates this concept is known as Change Over or Switch Over Design. Many of the characters studied such as milk production, growth etc., show a change with advance in period. The period to period variation is prevented from affecting the study of the treatment

differences through rendering periods and treatments orthogonal by having all the treatments occur in the design equally frequently in each period.

The design can be used with any number of treatments subject to the restriction that the number of animals must be a multiple of number of treatments. These designs are most suitable for short term experiments, because if the experiment is conducted in successive lactations, the duration of the time in the completion of the whole experiment would be too long and there is the risk of animal loss during the course of experiment.

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 and the 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 a concomitant variable has been examined. The efficiency of Extra Period Switch Over Design has also been studied.

CHAPTER II

REVIEW OF LITERATURE

In the study of efficiency of designs, uniformity trials play an important role and a large number of trials have been carried out in the field of agriculture. Cochran (1937) has given a list of 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) conducted an investigation on uniformity trial data on orange trees and showed that pseudo-factorial arrangements enable the block size to be kept within limits without the use of repeated controls, and is more efficient than the randomised block design containing all varieties in a block when there is a considerable soil heterogeneity. He found the gain in efficiency to vary from 26 to 57 percent. Cochran (1941) utilised the results of uniformity trial data on wheat and corn to study the relative efficiency of lattice square design and found it to vary from 104 to 136 percent.

A comprehensive study of uniformity trial data on the shape and size of the plot was made in the field of agriculture by Fairfield Smith, H. (1938) who derived an empirical relation of wide applicability between the variance per plot and the size of the plot. This empirical relation has been of extensive use to the agricultural statisticians. Yates (1938) conducted an experiment on school children in the field of nutrition. He

described three types of design with four treatments (4 rations) and showed one method of allotting the treatment in the design over other two designs was 80 percent more efficient.

Some work on the study of designs suited to animal experimentation has been carried out. Brandt (1938) discussed what he called double-reversal trials with two treatments tried on each animal in twin. Cochran et al (1941) have discussed the use of switch over design in dairy cattle feeding experiment to secure accurate comparisions of the effects of the rations and unbiased estimate of the experimental error. Taylor and Armstrong (1953) described the efficiency of the designs such as double-reversal trials involving two treatments and p periods and incomplete latin square. They reported that after omitting a row or column of a latin square, it is reasonably efficient. For short term experiments such as experiment of one lactation duration, other designs like round robin having small number of treatments are not highly efficient. Lucas (1960) discussed some critical features of good dairy feeding experiments and the usefulness and efficiency of the designs such as rotational type design, switch back or change over designs.

Subrahmaniam (1961) worked out the relative efficiency of a domino block design against the total variation present in the data when there was no classification made. The efficiency was also seen after eliminating the variation

due to the factors viz. season of calving and order of lactation with and without the use of an auxiliary variable. He showed that the design using season of calving for forming blocks was more efficient than designs with blocks based on the order of lactation. The randomized block design and latin square design were also superimposed and found more efficient than other designs. He did some preliminary work on the switch over design and showed that switch over design is more efficient than randomized block design.

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

CHAPTER III

EXPERIMENTAL MATERIAL

When an investigation is carried out by subjecting a typical experimental material to uniform treatment and collecting the data on the smallest feasible experimental units, such a trial is called "Uniformity trial". In agricultural experimentation, the available area under experiment is sown with a particular variety and is maintained under uniform treatment with regard to manurial and cultural operations. The experimental area is divided into a number of small units and the produce of each plot is recorded separately at harvest. In case of silvicultural and horticultural experiments, the lot may consist of a single tree or a group of trees. Similarly in the field animal science a single animal or a group of animals can be a unit of work, constitutes an experimental unit and a test on a number of such units maintained under uniform conditions of feeding and management can be regarded as a uniformity trial.

Two of the following words have been taken for the investigation:-

1. Cow of herd at Agricultural College, Ahmedabad (Gujarat).
2. Mr. A. M. Buffalo herd at Military Dairy Farm, Sabarkantha Distt. (Gujarat).

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 Konkraj cows at Ambud recorded in the period May, 1962 to March, 1965 and 24 Murrah buffaloes at Ambala Cantt. recorded in the period from October, 1954 to October, 1955 were considered for the investigation. 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 Konkraj it was not so due to smaller number of animals this was not possible. The animals belonged to different orders of lactation. Records pertaining to abnormal lactations were left out of analysis. The causes of abnormality were abortion, still birth and culling. More details about the nature and extent of culling are given in the Appendix.

CHAPTER IV

PROCEDURE OF ANALYSIS

The Concept of Efficiency: As stated earlier the principal aim of this work is to examine the relative efficiency of change over design which is of particular use in the field of animal science. A note on the concept of efficiency would not be out of place.

The most common measure of efficiency that has received the maximum usage is due to Fisher. He defined the reciprocal of the population variance σ^2 as the "amount of information", where σ^2 is the variance per experimental unit in the population. If σ^2 were known exactly, the information would be $\frac{1}{\sigma^2}$ otherwise the information is estimated as

$$\frac{n+1}{n+3} \cdot \frac{1}{s^2}$$

where s^2 is the estimated error sum of squares corresponding to the design and n is the number of degrees of freedom on which s^2 is based. Comparison of two designs in respect of efficiency consists in comparing the relative amounts of information obtained by the designs. The relative efficiency of the first design to second is thus calculated as

$$\frac{(n_1 + 1)}{(n_2 + 1)} \cdot \frac{(n_2 + 3)}{(n_1 + 3)} \cdot \frac{s_2^2}{s_1^2}$$

The adjustment factor $\frac{(n_1 + 1)}{(n_2 + 1)} \cdot \frac{(n_2 + 3)}{(n_1 + 3)}$

is of importance only if n_1 and n_2 are small, otherwise the efficiency could be measured by the simpler expression:-

$$\frac{s_2^2}{s_1^2}$$

Patterson and Lucas (1959) have defined the efficiency of the design X compared with the design Y as the ratio of the product of the number of observations and the variance of a contrast in design Y to the corresponding quantity in design X i.e.

$$\frac{n_y V_y}{n_x V_x}$$

where V_y and V_x are the variances of the designs Y and X, and n_y and n_x are the number of observations in the design Y and X respectively.

Switch Over Design: In a switch over design, each animal is to be run on a sequence of all the treatments. Designs involving such cyclical arrangements of treatment sequences, carried over several periods in order to reduce the error variance due to the variation between animals are known as "cyclo over design" or "switch over design".

In the ordinary group trial, where each animal receives only a single treatment, the average milk yield varies apart from the result of the treatment with inherent yielding ability of the animal receiving the treatment.

Since animals are highly variable in this respect, the experimental error from this source is often large, which may only be partly reduced by skilful grouping of the animals. The switch over trial eliminates this source of variation by giving every animal all the treatments in sequence. It is not however desirable to give the same sequence to all the animals. Milk production rate usually increases for a time after the calving. After attaining, the peak production rate, a relatively slow decline exists towards the end of lactation period, then the decline mostly accelerates. The initial rise and later decline in production rate vary from animal to animal in respect of both amount and duration. Thus if an animal receives treatments A, B, C in succession B, will be tested under the most productive period and C during the least. This difficulty is to be overcome by designing the experiment so that in any experimental period, an equal number of animals are receiving each treatment. In other words period to period variation is removed by making the treatments orthogonal to periods. For instance, one third of the animals will receive the sequence ABC, one third sequence BCA and one third the sequence CAB. With this arrangement, three experimental periods are equally represented in the average milk yield for any treatment. Thus an application of the Latin square type of arrangement between periods and sets of animals resulted in the switch over design as shown in the

following :

	<u>Sets of animals</u>		
	a_1	a_2	a_3
Periods I	A	B	C
II	B	C	A
III	C	A	B

The number of animals would be a multiple of number of treatments and number of periods would be the same as the number of treatments.

However, the effects of the lactation curve are not eliminated from the experimental error, unless the natural rate of fall in the yield from period to period is same for three groups of animals. Thus the groups may not be made simply at random, the object should be to obtain groups which are as similar as possible in the rates of fall of their lactation curves. Thus there could be switch over designs with or without blocks.

A complication which often arises in the case of a switch over design is that since one treatment follows another, the observed yield is the resultant of direct effect of the treatment given during the period and the residual effects, if any, of the preceding treatments. If such residual effects are present, simple averages do not give unbiased estimates of the effects of the treatments.

This problem of carry over effects can be dealt with in two ways. One way is to omit from the results these parts of the

experimental periods which appear to show carry over effects. This method is at best somewhat arbitrary, and would be unsatisfactory if carry over effects persisted through most of the succeeding periods. Alternatively the direct and residual effects can be estimated by using a design in which all the cycles of the orthogonal latin square are used. Estimation of carry over effects and direct effect is possible in such a case under specific assumptions. For example, for 3 treatments, we would have the following design.

		<u>Bots of animals.</u>					
		1	2	3	4	5	6
Period	I	A	B	C	A	-	C
	II	B	C	A	C	A	B
	III	C	A	B	B	C	A

For estimating the carry over effects the following assumptions are made:

1. Each treatment effect lasts for that period and only one subsequent period.
2. There is no interaction between the direct and residual effect. i.e. the direct effect of any treatment is the same, no matter what the previous treatment was and the residual effect of a treatment is same, no matter what the next treatment is.

The analysis of the design is based on the following linear model.

Case I: Switch over Design without block:

$$y_{ijkh} = \bar{m} + a_i + p_j + d_k + r_h + \epsilon_{ijkh}$$

where y_{ijkh} is the milk yield in the j th period of the i th animal given k th treatment in that period and h th treatment in the previous period.

\bar{m} is the general mean yield.

a_i is i th animal effect ($i = 1, 2 \dots t$)

p_j is the j th period effect ($j = 1, 2 \dots t$)

d_k is the direct effect of k th treatment ($k = 1, 2 \dots t$)

r_h is the residual effect of h th treatment on the k th treatment ($h = 1, 2 \dots (t - 1)$)

and ϵ_{ijkh} is a random variable which is distributed normally with mean zero and variance σ^2 .

Without loss of generality we can assume that the total effects of the periods, treatments, animals and residuals to be zero. In other words these effects are measured as deviations from a common mean i.e.

$$\sum_j a_j = 0, \sum_k d_k = 0, \sum_i a_i = 0, \sum_h r_h = 0$$

The $(j+1)$ th observation which were made under the i th effect of the k th treatment may be denoted by \bar{Y}_{ik} and the $(j+1)$ th of the observations following the periods when k th treatment was used, or in other words those under the residual effect after k th treatment may be denoted by R_{ik} . A_i is the sum of the i th sequence of the treatments allotted to the i th animal.

From the model we can estimate the direct, residual, animal and period effects through the least square technique. The normal equations for direct, residual and animal effect are as follows:

$$r_k = t(t-1)m + t(t-1)d_k - (t-1)r_k \dots\dots\dots(1)$$

$$R_k = (t-1)^2m + (t-1)^2r_k - (t-1)d_k - \sum_{i=g}^t a_i \dots\dots\dots(2)$$

where g = those number of sequences or those animals where the k th treatment lasts.

$$A_i = tm + ta_i - r(i)$$

where $r(i)$ is the residual effect of the treatment applied in the last period of the i th sequence.

Adding all those sequences where k th treatment lasts, it becomes as

$$\sum_{i=g}^t A_i = t(t-1)m + t \sum_{i=g}^t a_i - (t-1)r_k$$

$$\text{or } -t \sum_{i=g}^t a_i = t(t-1)m - (t-1)r_k - \sum_{i=g}^t A_i \dots\dots\dots(3)$$

Multiplying by t to the equation (2) and substituting there the value of $-t \sum_{i=g}^t a_i$ from the equation (3), we get

$$t R_k + \sum_{i=g}^t A_i = t^2(t-1)m + (t-1)[t(t-1)-1]r_k \\ - t(t-1)d_k \dots\dots\dots(4)$$

Adding equation (1) and (4)

$$R_k^t = t R_k + \sum_{i=3}^t A_i + r_k = t(t^2 - 1) n \\ + (t-1) \left[t(t-1) - 2 \right] r_k \dots\dots\dots (8)$$

Hence S.S. due to residuals eliminating direct effect-

$$= \frac{1}{t(t-1) \left[t(t-1) - 2 \right]} \left[\sum R_k^t - \left(\sum R_k^t \right)^2 \right] \dots\dots (8)$$

Similarly for solving the direct effects, multiply the equation (1) by $\left[t(t-1) - 1 \right]$

$$\left[t(t-1) - 1 \right] r_k = t(t-1) n \left[t(t-1) - 1 \right] + t(t-1) \left[t(t-1) - 1 \right] d_k \\ - (t-1) \left[t(t-1) - 1 \right] r_k \dots\dots\dots (9)$$

Adding equation (4) and (9)

$$T'_k = t R_k + \sum_{i=3}^t A_i + \left[t(t-1) - 1 \right] r_k \\ = t(t+1)(t-1)^2 n + t(t-1) \left[t(t-1) - 2 \right] d_k \dots\dots (8)$$

Therefore the S.S. due to direct effects eliminating the residual effect is equal to

$$\frac{1}{t(t-1) \left[t(t-1) - 1 \right] \left[t(t-1) - 2 \right]} \left[\sum T'_k - \left(\sum T'_k \right)^2 \right]. \dots\dots (9)$$

$$V(r_k) = t(t-1) \left[t(t-1) - 2 \right] \sigma^2$$

$$V(d_k) = t(t-1) \left[t(t-1) - 1 \right] \left[t(t-1) - 2 \right] \sigma^2$$

-: 18 :-

Rule for the variance of r_k' and d_k'

For r_k' :- multiply the coefficients of r_k and R_k from equation (9)
and σ^2

for d_k' :- multiply the coefficients of d_k and D_k from equation (8)
and σ^2 .

Similarly the variance of the difference of the residual and
direct effects are as

$$V(r_k - r_k') = \frac{2t \sigma^2}{(t-1) [t(t-1) - 2]}$$

$$V(d_k - d_k') = \frac{2 \sqrt{t(t-1) - 1} \sigma^2}{t(t-1) [t(t-1) - 2]}$$

Rule for the variance of the differences

For r_k and r_k' :- ratio of the coefficients of r_k and R_k and
multiply by $2\sigma^2$

For d_k and d_k' :- ratio of the coefficients of d_k and D_k and
multiply by $2\sigma^2$

The normal equation for common effect m , period and
animal effects becomes

$$\sum Y_{....} = \sum_{ijkh} y_{ijkh} = t^2 (t-1) m \dots \dots \text{for } m$$

$$\sum Y_{..j..} = \frac{\sum Y_{....}}{t} + t(t-1) p_j \dots \dots \text{for periods}$$

$$A_1 = \frac{t Y_{...}}{t^2 (t-1)} + t a_1 \dots \dots \dots \text{ for animal}$$

The S.S. due to period and animal effects ignoring the residual e effect are

$$\sum Y_{..j.} p_j = \frac{\sum Y_{..j.}^2}{t(t-1)} - \frac{Y_{...}^2}{t^2(t-1)} \dots \dots \dots (10)$$

and

$$\sum A_1 a_1 = \frac{\sum A_1^2}{8} - \frac{Y_{...}^2}{t^2(t-1)} \dots \dots \dots (11)$$

$$\text{Total Sum of Squares} = \sum y_{ijk}^2 - \frac{Y_{...}^2}{t^2(t-1)} \dots \dots \dots (12)$$

Case II: Switch over design with blocks: Suppose the animals are grouped into the $(t-1)$ homogeneous blocks based on some character, the total degrees of freedom $\lceil t(t-1)-1 \rceil$ for animals are divided into two groups, $(t-1)$ d.f. for blocks and $(t-1)^2$ d.f. between animals within blocks, and there will be some interaction between period and block. For the analysis of the design the linear model is taken but for convenience the model is

$$y_{ijk} = \mu + a_{ik} + p_j + b_k + I_{jk} + e_{ijk}$$

where a_{ik} is the i th animal effect in the k th block

$\lceil i = 1 \text{ to } t \rceil$

I_{jk} is the effect of interaction between j th period and k th block,

b_k is the effect of the k th block ($k = 1 \text{ to } t-1$)

and e_{ijk} is the random variable.

Let B_k and T_{jk} be the block total and j th period in the k th block respectively. The normal equations are

$$I_{ijk} = t_m + t I_{jk} + t b_k + t p_j \quad \dots \dots \dots \quad (18)$$

The 3.S. due to block is

$$\sum_k B_k b_k = \frac{\sum b_k^2}{t^2} - \frac{y_{...}^2}{t^2(t-1)} \quad \dots \dots \text{eq 1}$$

and so S. due to interaction is $\sum_{ijk} I_{ijk}$

$$\text{or } \sum \frac{Y_{jk}^2}{t} - \frac{Y_{...}^2}{t^2(t-1)} = S.S. \text{ due to blocks} - S.S. \text{ due to periods(13)}$$

The S.S. between animals within blocks may be found out by subtracting the S.S. due to blocks from the S.S. due to the animals. From the total sum of squares all these S.S. are subtracted for the error sum of squares.

and III: If this cov is repeated q times, there solutions remain the same. The coefficients of r_k and d_k are multiplied by q in case of residual and direct effect and the L.H.S. of the equations (5) and (8) does not alter. Other terms may be added q times and the divisor for sum of squares is multiplied by q . The variances of the differences between direct and residual effect are divided by q .

Analysis of Extra period Design: Lucas (1959) proposed a modification of the switch over design by adding an extra period to the basic latin square design. The treatments of the last period of the basic design are repeated in the extra period. Here the direct and residual effects are orthogonal and the information per observation can be increased. The following is an example of extra period design for 3 treatments.

		<u>Sets of animals</u>					
		1	2	3	4	5	6
Periods	I	a	B	C	A	B	C
	II	B	C	A	C	A	B
	III	C		B	B	C	A
	IV	C	A	B	B	C	A

The double period with the same treatment is considered as two separate periods in the analysis. The same model is taken. Consists are to be fitted for direct, residual, animal, period, block and interaction between block and period. The estimates of animal, period, block and interaction effects will be the same except for the divisor of p. For estimating the direct and residual effect, let

$$r_k = \sum y_k \quad \text{and} \quad R_k = \sum z_k$$

where y_k is the yield of units in the periods in which it receives the k th treatment and z_k is total of the immediately previous yield. Assumptions are same as in switch over design. The normal equations for direct and animal effects are as

$$T_k = (t^2 - 1) \pi + (t^2 - 1) d_k + \sum_{i=6}^k a_i \quad \dots \dots \dots (1)$$

where g is sequences where the treatment k lasted in the $(p+1) = p'$ th period.

...ing over the σ sequences

$$\sum_{j=1}^r a_j = (t-1) p^r n + p^r \sum_{j \in S} a_j + (t-1) d_k \quad \dots \dots (3)$$

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$$- p' \sum_{k=g}^r a_k = (t-1) p' m + (-1) a_k - \sum_{k=g}^r A_k$$

multiply equation (1) by p' and substitute the value of $-p' \sum a_i$ from (3), we get

$$x_k = p^t T_k - \sum_{j=0}^{t-1} = t(t-1)p^t n + (t-1)(p^{t-2}-1) d_k \dots \dots (4)$$

...ence L.S. due to direct effect of bac's eliminating the animal
as host is

$$\frac{\sum_{k=1}^{t^2} x_k^2}{t^2} \quad \text{where } x = \frac{t(t-1) (p^e+1) (p^e - 2)}{p^e (t-1)}$$

Similarly after eliminating period effect and ignoring
inconsistency, the residual effect is

$$k = \frac{p^t}{p^t - 1} (D_k - p_{1k})$$

where P_{1k} = total yield in period 1 of all blocks receiving the k th treatment.

= total yield of the same block over all periods.

and S.E. due to residual will be $\frac{\sum R_k'^2}{C p'^2}$

where $C = \frac{(t-1) (p'-1) (t p' - t-1)}{p' (t-1)}$

$$V(d_k - d_{k'}) = \frac{2 s^2}{A} \quad \text{and } V(r_k - r_{k'}) = \frac{2 s^2}{C}$$

where s^2 is error mean square of the design.

A better estimate of error may be obtained by omitting the first period yield. The estimates of residual effects are obtained entirely from the 2nd, 3rd ... p' th period yields, and S.E. due to the direct effect is recalculated. For purpose of convenience it will be referred to as the modified extra period switch over design.

Evaluation of the Designs: In order to study the efficiency of designs over designs, the designs were superimposed on the uniformity available. Three, four, and five treatments and correspondingly three periods of 80, 60 and 50 days each were considered. Data in the majority of cases, milk yields upto 250 days were available.

Reduction in error variance due to the use of concomitant variables is shown in the following way. At the start of each period, the first three days yield for 50 day period and 3 days yield for 60 and 80 day periods were excluded for eliminating the "run in" 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 and that the recording of the concomitant yield under a standard uniform treatment would reflect the variation in persistence among the animals. The first period of 7 or 10 days period may called standardisation period and remaining 40, 43 and 63 days experimental period (Lucas, 1960). The following table shows the distribution of days for different periods.

Total period	Carry over period	Standardisation period (X)	Experimental period (Y)
50	3	7	40
60	5	10	45
70	5	10	65

The standardisation period yield (X), was used as a concomitant variate and experiment 1 period (Y) days yield as a main variable. During the standardisation period, all the animals to be used for experiment would be maintained in a similar and common management. At the end of standardisation period, each animal would be switched to the appropriate experimental treatment.

1. 10:10, 10:5, 5:10, 5:5: The efficiency of grouping of experimental animals for forming homogeneous blocks on the basis of the following characters were examined.

1. Union of a living
2. Previous lactation yield
3. Consistency of the milk yield in the previous lactation.

For forming blocks according to season of calving all the brand number of animals were arranged in the order of their date of calving and sets of animals with close dates of calving equal in number to the treatments were taken as blocks. Similarly all animals were arranged on the basis of ascending order of previous lactation yield and blocks were formed. Similarly the persistency of milk yield was calculated of each type of period for each animal and blocks were formed. (The persistency is 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 d.f. will be merged with the error sum of squares. The analysis was done without and with blocks.

1. Without blocks: Let there be t treatments and $t \times r$ is the number of animals where r is the number of latin squares.

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

Analysis of variance table.

<u>Source of variation</u>	<u>d.f.</u>	<u>M.S.</u>
between periods	$(t-1)$	
between animals	$(t \times r - 1)$	$\frac{s^2}{2}$
residual	$(t-1)(t-r+1)$	$\frac{s^2}{1}$
Total	$t^2 \times r - 1$	

In the corresponding completely randomised design, the error variance for one single period will be s_e^2 . Therefore, the comparison of s_1^2 against s_e^2 will give the relative efficiency of switch over design without blocks over completely randomised design via

$$\text{Relative efficiency} = \frac{s_1^2}{s_e^2}$$

(when the adjustment factor was ignored).

2. 2. Analysis of switch over design with blocks: When the blocks are formed, there will exist the interaction between periods and blocks. Following is the skeleton of analysis of variance.

Analysis of variance table.

<u>Source of variation</u>	<u>d.f.</u>	<u>M.S.</u>
Between blocks	(r-1)	
Between periods	(t-1)	
Blocks x periods	(r-1) (t-1)	
Between animals within blocks	r (t-1)	s_4^2
Error	$r (t-1)^2$	s_e^2
Total	$(t^2 r - 1)$	

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_e^2 . Therefore the relative efficiency of switch over design with blocks relative to randomised block

design would be $\frac{s^2}{\frac{4}{3}}$ ignoring the adjustment factor.

Similarly the comparison between s_1^2 and s_3^2 will give the relative efficiency of switch over design with blocks relative to without blocks subject to ignoring the factor $\frac{(n+1)(n'3)}{(n+3)(n'+1)}$

where n and n' are the d.f. of switch over design with and without blocks.

By taking the extra period, the efficiency was compared in a similar fashion with and without blocks. The analysis of variance table is given below:

(i) Without blocks:

Analysis of variance table.

<u>Source of variation</u>	<u>d.f.</u>	<u>M.S.</u>
Between periods	t	
Between animals	t r -1	s^2_2
Residual	t (t r -1)	s^2_1
Total	$t r (t + 1) - 1$	

(ii) With blocks:

Analysis of variance table.

<u>Source of variation</u>	<u>d.f.</u>	<u>M.S.</u>
Between blocks	(r-1)	
Between periods	t	
Blocks x Periods	t (r -1)	
Animals within blocks	r (t -1)	s^2_3
Error	By subtraction	s^2_5
Total	$t r (t + 1) - 1$	

Lucas (1959) showed that better estimates of the residual effects can be made entirely from the results of 2nd, 3rd ($t+1$) th periods after leaving the yield of 1st period. The relative efficiency was obtained as earlier. The analysis of variance table of this type of design resembles with the switch over design.

The efficiency of Extra period design over the switch over design with and without blocks and the efficiency of extra period design after leaving the 1st period relative to the extra period design with ($t + 1$) periods and switch over design with and without blocks was also compared, with the proper error mean squares.

In the analysis of covariance the following sum of squares and sum of products were calculated.

<u>Source of variation</u>	<u>S_{yy}</u>	<u>S_{xy}</u>	<u>S_{xx}</u>
between blocks	S_{yy}	S_{xy}	S_{xx}
between periods	P_{yy}	P_{xy}	P_{xx}
blocks \times periods	$(I)_{yy}$	$(I)_{xy}$	$(I)_{xx}$
units within blocks	A_{yy}	A_{xy}	A_{xx}
error	E_{yy}	E_{xy}	E_{xx}

$\omega^4 1$	T_{yy}	T_{xy}	T_{xx}

After adjusting the proper error mean square for completely mixed design and switch over design with and without blocks, efficiency was compared in the same way. The efficiency of two techniques in the design with and without blocks for treatment effects was obtained by comparing the proper error sum of squares via. Relative efficiency = $\frac{\text{Error mean square (Unadj.)}}{\text{Error mean square (Adj.)}}$

CHAPTER V

Results.

The efficiencies of different designs for the various sets of data are presented in the Appendix in Statements 1 to 5. For summa rising, the values are here classified into the following groups:

1. 11 values less than 100
2. Values between 100 to 500
3. Values between 501 to 1000
4. Values between 1001 to 3000
5. Values between 3001 to 6000
6. Values above 6000.

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 (after omitting the first period yield in the analysis). Comparison with extra period and switch over design.
4. Efficiency of switch over design utilising the information on concomitant variate.

Under each head, first of all, the switch over design without blocks was compared with the completely randomised design. Secondly, the design with blocks was compared relative to the randomised block design, and in the last place, comparison was made between the design with blocks and without blocks. The

relative efficiency has been expressed in percentage in the tables.

1. Efficiency of Switch over Design.

The switch over design without blocks was compared with the completely randomised design in which only one treatment was allotted to one animal through out the experiment. The relative efficiency of the switch over design was found to vary from 403 to 2757. The detailed results are presented in Statement I(a).

The results of comparison of the efficiency of switch over design with blocks relative to randomised block design are presented in Statement I(b) and summarised in Table 1. The relative efficiency ranged between 839 and 9010.

Table 1: Relative efficiency of switch over design with blocks compared to randomised block design (Percentage)

Relative efficiency in %	<u>No. of treatments.</u>		
	<u>Three</u>	<u>Four</u>	<u>Five</u>
<u>No. of sets of data.</u>			
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 was examined. The relative efficiency varied in the range of 86 and 866. The results are presented in details in Statement I(c) and summarised in Table 2.

Table 2: Relative efficiency of switch over design with blocks relative to without blocks.

Relative efficiency in %	<u>No. of treatments</u>		
	<u>Three</u>	<u>Four</u>	<u>Five</u>
No. of sets of data			
Less than 100	4	2	2
100 - 300	14	10	4
Total	18	12	6

In most of the cases the switch over design with blocks was found more efficient than the design without blocks, the relative efficiency with blocks being more than 100 in 28 cases out of 36.

2. Extra Period Design.

The extra period design is constructed by adding an extra period to the basic switch over design. As a result, the direct and residual effects can be estimated by means of orthogonal contrasts. Here also the extra period design was compared with completely randomised design and randomised block design. When the design without blocks was compared with completely randomised design, the values of the relative efficiency varied from 615 to 2330 which shows that extra period design is 6 to 29 times efficient than

completely randomized design. The results are given in Statement II (a).

A comparison made between extra period design with blocks and the randomized block design showed that extra period design was highly efficient as the range of relative efficiency varied from 716 to 13,556. The values of the relative efficiency are presented in Statement II (b) in Appendix and summary of efficiencies is given in table 3.

Table 3: Relative efficiency of extra period design with blocks compared to randomized block design (Percentage)

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

The extra period design with blocks was also compared relative to the design without blocks. The distribution of the values of relative efficiency is presented in Table 4, the detailed values being given in Statement II(c). The formation of blocks resulted in decreased error variation, the relative efficiency being more than 100 in 17 cases out of 21.

Table 4: Relative efficiency of extra period design
with blocks vis-a-vis without blocks (Percentage)

Relative efficiency in %	<u>No. of treatments.</u>		
	<u>Three</u>	<u>Four</u>	<u>Five</u>
<u>No. of cases of data.</u>			
Less than 100	2	2	-
100 - 500	9	4	3
501 - 1000	1	-	-
Total	12	6	8

3. Modified Extra Period Design.
(Omitting the 1st period)

In Statement III, the comparisons are made in the similar fashion as in the case of the extra period design. The main difference was that in this design, the first period observations were left out from the analysis. With the same conventional method, first of all, in Statement III(a) the relative efficiency of the design without blocks vis-a-vis the completely randomised design was obtained. It ranged from 826 to 8279%. The order of efficiency was observed more than 500 in all cases except for the single case of three treatments at Ambala.

The design with blocks was, next, compared with the randomised block design. The values of the relative efficiency are given in Statement III(b). The design was found highly efficient and the range of relative efficiency varied between 409 to 5799 percent. All the values were found more than 500 except in 2 cases for three treatments at Ambala. The values are classified in Table 5.

Table 5: Relative efficiency of modified extra period design with blocks compared with randomised block design (Percentage).

Relative efficiency 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 modified extra period design with blocks was compared with the design without blocks in Statement III(c) and the relative efficiency was found in the range from 87 to 226. The relative efficiency was less than 100 in 5 cases out of 21.

It was also considered useful to compare the modified extra period design with the extra period design and basic switch over design. The comparison was made when the designs were taken with and without blocks. It was observed from Statement IV(a) that the efficiency of modified extra period design without blocks was inferior to that of extra period with out blocks only in single case at Ambala, but on the contrary, the modified extra period design with blocks was found less efficient in 9 cases out of 21. The range of efficiency varied from 40 to 159 percent Statement IV(b).

Similarly in Statement IV(c) when compared with switch over design without blocks, the relative efficiency ranged from 40 to 297 and only in 2 cases, the modified extra period design

value was less efficient. On the other hand in Statement IV(d) when modified extra period with blocks was compared with switch over design with blocks, the relative efficiency ranged between 30 and 371 and the modified design was less efficient than switch over design with blocks, in 16 cases out of 39.

4. Use of Covariance Technique. (in switch over design)

The efficiency of utilising a preliminary uniform period of first seven and ten days as ancillary information was studied. Statement V(a) gives the value of efficiency of switch over design without blocks but with utilisation of concomitant variate relative to completely randomised design. The range of relative efficiency varied from 230 to 4643 percent.

Next, the gain in efficiency due to utilisation of ancillary information in switch over design was studied. The relevant comparisons were made in two ways:

i) In the first case, the comparison was made between switch over design without blocks but with utilisation of concomitant variate and switch over design without blocks and no covariate (Statement V(b)). The covariance technique generally resulted in gains which were substantial for three and four treatments in the case of data on Koakraj cows at Anand, the gain ranging from 25 to 73 percent. There was very small gain in the case of data of Ambala buffaloes.

ii) In the second case, the efficiency of switch over design with blocks with concomitant variante was compared with switch over

design with blocks without use of concomitant variate. The results are presented in Statement V(c) and are summarised in Table 6. The relative efficiency ranged between 97 and 208 percent.

Table 6: Relative efficiency of switch over design with blocks with concomitant variate relative to switch over design with blocks but no covariate.

Relative efficiency in %	<u>No. of treatments</u>		
	<u>Three</u>	<u>Four</u>	<u>Five</u>
	No. of sets of data		
Less than 100	5	2	-
100- 500	13	10	6
Total	18	12	6

Next the gain in efficiency due to blocks in switch over design with the utilisation of ancillary information was studied (Statement V(d)). The values are summarised in Table 7. The range of relative efficiency varied from 73 to 223 percent. The formation of blocks did not contribute to efficiency when the information on concomitant variate was already used in 7 cases out of 30 in the case of three and four treatments. In the case of five treatments the formation of blocks resulted in increasing the efficiency in all the cases studied.

Table 7: Relative efficiency of switch over design with blocks relative to without blocks using concomitant variate in both designs (Percentage)

Relative efficiency in %	<u>No. of treatments</u>		
	Three	Four	Five
<u>No. of cases</u>			
Less than 100	5	2	-
100 - 500	13	10	0
Total	18	12	6

In Table 8, the values of the efficiency are summarised when the switch over design with blocks but without the use of concomitant variate was compared with the design without blocks but using the concomitant variate. The detailed values are given in Statement V(c).

Table 8: Relative efficiency of switch over design with blocks but no covariate relative to without blocks using covariate (Percentage).

Relative efficiency in %	<u>No. of treatments.</u>		
	Three	Four	Five
<u>No. of sets of data.</u>			
Less than 100	10	7	-
100 - 500	9	5	6
Total	18	12	6

The relative efficiency ranged from 57 to 227 percent. The formation of blocks was more efficient than the use of the information of concomitant variate in case of five treatments while reverse is found in case of three and four treatment as the formation of blocks is less efficient in 19 cases out of 50.

Chapter VI.

DISCUSSION

On the whole, change over design proved far superior in comparison to completely randomised design and randomised block design. The relative efficiency of switch over design without blocks relative to completely randomised design varied from 1043 to 4043 at Anand and from 280 to 1181 at Ambala while that of switch over design with blocks vis-a-vis randomised block design varied from 876 to 18,556 in the case of Kankrej cows at Anand and from 939 to 2814 in the case of Murrrah buffaloes at Ambala. The values showed that a very much large number of animals would be required in the case of traditional designs to gain the same precision as in the switch over design.

One way of eliminating the variation is through local control of error. The efficiency of three different types of local control for grouping the animals into homogeneous blocks was studied. Local control was based on the characters, season of calving, previous lactation yield and persistency of milk yield. Table 9 summarises the results.

Table 9: Relative efficiency of change over design with blocks relative to that without block (Percentage)

Relative efficiency in %	Season of blocks			No. of sets of data
	Season of calving	Previous lactation yield	Persistency of milk yield	
Less than 100	7	14	8	
100 - 300	31	24	35	
Total	38	38	38	38

From the table it is clear that the formation of blocks based on the 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 character. Grouping of units based on season of calving seemed to be the next best (vide Table 9). 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, the cows are diagnosed for pregnancy.

The extra period design could be studied for three and four treatments with both the sets of data, the duration of treatment period being 50 and 60 days. Although it is not usual to consider more than five periods, with the data for cows at Anand, the design could be tried for five treatments and 6 periods of 50 days each. The extra period design with three and four treatments each of length 50 days when compared with switch over design with three and 4 treatments each of 60 days period was found more efficient in almost all cases. Similarly the extra period design with four treatments and 60 days period with switch over design with three treatments of 60 days. The extra period design was found in all cases more efficient whether the design was with blocks or without blocks.

Next the modified extra period design was compared with extra period design with and without blocks. The comparison with extra period design without blocks showed the modified design to be slightly more efficient in general. But when the comparison

was made with blocks, the modified extra period design with blocks was more efficient only in 60 percent cases.

The comparison between modified extra period design and switch over design both with and without blocks was also made. In first case when the efficiency of modified extra period design without blocks measured with switch over design without blocks keeping the total period of experiment constant, the relative efficiency ranged from 104 to 297. With varying length of total duration of experiment it varied from 49 to 138. The design was less efficient only in two cases. Secondly the comparison with the blocks between modified extra period and switch over design showed the efficiency ranging from 81 to 391 for constant period and 39 to 150 for the case with varying length of total duration of experiment. The design was found slightly less efficient in case of constant length of experimental duration but in 16 cases out 21 in case of varying length.

The utilisation of concomitant variate in switch over design also improved the results and increased the efficiency of the designs generally. 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 the efficiency in 29 cases out of 86. The results of the relative efficiency of switch over design using concomitant variate with blocks vic-o-vic without blocks showed that even when covariance technique is used, formation of blocks in switch over design was useful in 29 cases out of 86. It can be concluded that switch over, extra

extra period and modified extra period design with blocks was found more efficient than the design without blocks, whether the concomitant variate was used or not. Lastly, the relative efficiency of switch over design with blocks was also examined relative to without blocks but with concomitant variate. The formation of blocks was observed to result in greater efficiency when the duration of each treatment was taken to be 50 days. In other cases of 60 and 80 days period, the case of concomitant variable was generally more efficient.

The nature of the efficiency was examined after increasing the number of treatments and the duration of treatment period. It was observed that the relative efficiency went down with increase in number of treatments, keeping the duration of treatment period constant. On the other hand for constant number of treatments, the relative efficiency showed the linear downward trend all most in all cases with increase in length of the period under each treatment.

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

SUMMARY

The role of statistical planning in ensuring the validity and enhancing the efficiency of experimentation is beginning to be recognised in dairy cattle experiments switch over design is a design particularly suited to animal experimentation. In the present work, a study has been made of the relative efficiency of the change over design in its various forms including extra period design with the conventional designs viz., the completely randomised design and randomised block design in the case of dairy experiments. Daily records 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 12 times more efficient as judged with the data on Kurrab buffaloes herd at Ambala military dairy farm and 11 to 47 times from the data on Konkraj herd at Anand. The switch over design with blocks was found to be 9 to 135 times as efficient as randomized block design with Anand data and 9 to 28 times as efficient with Ambala data.

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

1. Season of calving.

2. Previous lactation yield.

3. Persistence of milk yield based on the previous lactation yield.

It was concluded that formation of blocks based on persistence of milk yield provided greater efficiency than other two. Surprisingly the design with blocks based on season of calving based on season of calving proved to be more efficient than the one 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 treatment period was kept constant and the total duration of experiment varied.

The modified extra period design without blocks obtained by omitting the first period was found slightly more efficient than the extra period design without blocks. The modified design with blocks was more efficient than the corresponding extra period design in 60% cases. The relative efficiency of modified extra period design vis-a-vis the ordinary switch over design was more when the total experimental period was kept constant than when it was varied.

The adoption of covariance technique eliminated considerable error variation whether the design was with or without blocks.

The use of blocks in switch over design but without utilisation of concomitant variate was found almost equally efficient as the design without blocks but with the utilisation of concomitant variate.

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

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A_P_P_E_U_D_I_X

Statement I.

(a) Efficiency of switch over design without blocks relative to completely randomised design (Percentage).

Length of the treatment period (Days)	No. of treatments					
	Three		Four		Five	
	Anand	Ambala	Anand	Ambala	Anand	Ambala
50	1825	678	2383	700	2757	403
60	1046	1181	1573	615		
80	1277	527				

(b) Efficiency of switch over design with blocks compared with randomised block design (Percentage).

Length of treatment period (Days)	Blocks based on:	No. of treatments					
		Three		Four		Five	
		Anand	Ambala	Anand	Ambala	Anand	Ambala
50	1. Season of calving 2. Previous lactation yield 3. Persistency of milk yield	2120	670	2598	813	2697	339
60	1. Season of calving 2. Previous lactation yield 3. Persistancy of milk yield	1403	596	1780	676	1607	349
80	1. Season of calving 2. Previous lactation yield 3. Persistency of milk yield	6309	891	7010	694	2393	403
50	1. Season of calving 2. Previous lactation yield 3. Persistancy of milk yield	1353	1281	2079	838		
60	1. Season of calving 2. Previous lactation yield 3. Persistancy of milk yield	638	1438	1067	628		
80	1. Season of calving 2. Previous lactation yield 3. Persistency of milk yield	2028	2814	2289	1001		
50	1. Season of calving 2. Previous lactation yield 3. Persistency of milk yield	1601	577				
60	1. Season of calving 2. Previous lactation yield 3. Persistency of milk yield	876	634				
80	1. Season of calving 2. Previous lactation yield 3. Persistency of milk yield	1291	1373				

(c) Efficiency of switch over design with blocks vis-a-vis without blocks

(Percentage)

Length of treatment period (Days)	Blocks based on:	No. of treatments					
		Three		Four		Five	
		Anand	Ambala	Anand	Ambala	Anand	Ambala
50	1. Season of calving 2. Previous lactation yield 3. Persistency of milk yield	164	102	164	93	138	160
60	1. Season of calving 2. Previous lactation yield 3. Persistency of milk yield	157	86	119	93	112	95
80	1. Season of calving 2. Previous lactation yield 3. Persistency of milk yield	366	120	301	127	168	93
50	1. Season of calving 2. Previous lactation yield 3. Persistency of milk yield	160	103	145	110		
60	1. Season of calving 2. Previous lactation yield 3. Persistency of milk yield	96	109	101	102		
80	1. Season of calving 2. Previous lactation yield 3. Persistency of milk yield	193	261	151	191		
50	1. Season of calving 2. Previous lactation yield 3. Persistency of milk yield	162	93				
60	1. Season of calving 2. Previous lactation yield 3. Persistency of milk yield	109	88				
80	1. Season of calving 2. Previous lactation yield 3. Persistency of milk yield	219	251				

Statement IX

(a) Efficiency of extra period design without blocks compared with completely randomised design (Percentage).

Length of treatment period (Days)	No. of treatments				
	Three	Four	Five		
Anand	Ambala	Anand	Ambala	Anand	
50	2249	701	2847	782	2880
60	1937	613			

(b) Efficiency of extra period design with blocks compared with randomised block design (Percentage)

Length of treatment period (Days)	Block based on	No. of treatments				
		Three	Four	Five		
Anand	Ambala	Anand	Ambala	Anand		
50	1. Season of calving 2. Previous lactation yield 3. Persistence of milk yield	8206 5989 5271	782 756 887	2868 2041 18556	876 716 783	3031 1632 3879
60	1. Season of calving 2. Previous lactation yield 3. Persistence of milk yield	1937 1169 1851	767 750 936			

(c) Efficiency of extra period design with blocks relative to extra period design without blocks (Percentage).

Length of treatment period (Days)	Blocks based on	No. of treatments				
		Three	Four	Five		
Anand	Ambala	Anand	Ambala	Anand		
50	1. Season of calving 2. Previous lactation yield 3. Persistence of milk yield	152 329 263	93 94 104	140 118 500	95 97 123	162 110 132
60	1. Season of calving 2. Previous lactation yield 3. Persistence of milk yield	140 103 103	110 105 156			

Statement III.

(a) Efficiency of modified extra period design without blocks
 (leaving 1st period) compared to completely randomised design
 (Percentage)

Length of treatment period (days)	No. of treatments					
	Three		Four		Five	
Anand	Ambala	Anand	Ambala	Anand	Ambala	Anand
50	2874	630	3279	485	2948	
60	2723	328				

(b) Efficiency of modified extra period design (leaving 1st period)
 with blocks relative to randomized block design (Percentage)

Length of treatment period (Days)	Blocks based on	No. of treatments					
		Three		Four		Five	
		Anand	Ambala	Anand	Ambala	Anand	Ambala
50	1. Season of calving	2664	633	3004	793	2937	
	2. Previous lactation yield	1797	770	2431	866	1563	
	3. Persistency of milk yield	4538	612	3759	645	2605	
60	1. Season of calving	2250	429				
	2. Previous lactation yield	1609	408				
	3. Persistency of milk yield	1218	838				

(c) Efficiency of modified extra period design with blocks compared
 with modified extra period design without block (Percentage).

Length of treatment period (days)	Blocks based on	No. of treatments					
		Three		Four		Five	
		Anand	Ambala	Anand	Ambala	Anand	Ambala
50	1. Season of calving	150	93	136	91	144	
	2. Previous lactation yield	159	103	127	87	103	
	3. Persistency of milk yield	226	92	198	104	130	
60	1. Season of calving	114	114				
	2. Previous lactation yield	92	108				
	3. Persistency of milk yield.	114	162				

Statement IV

(a) Efficiency of modified extra period design (leaving 1st period without blocks relative to extra period design (Percentage).

Length of treatment period (Days)	No. of treatments		
	Anand	Ambala	Anand
50	133	109	133
60	159	81	103
			112

(b) Efficiency of modified extra period design with blocks relative to extra period design with blocks (Percentage)

Length of treatment period (Days)	Blocks based on:	No. of treatments		
		Anand	Ambala	Anand
50	1. Season of calving	131	102	116
	2. Previous lactation yield	60	119	137
	3. Persistency of milk yield	114	93	51
60	1. Season of calving	180	84	
	2. Previous lactation yield	142	83	
	3. Persistency of milk yield	100	64	

Statement IV (Contd.)

(c) Efficiency of modified extra period design without blocks compared with switch over design without blocks (Percentage).

Length of treatment period (Days)	No. of treatments				
	Three	Four	Five		
Anand	Ambala	Anand	Ambala	Anand	
P=50 vs P=50	113	123	119	93	101
P=60 vs P=60	136	48			
P=60 vs P=80	297	129			
P=50 vs P=60	224	104	141	130	

(d) Efficiency of modified extra period design with blocks compared with switch over design with blocks (Percentage)

Length of treatment period (Days)	Blocks based on	No. of treatments				
		Three	Four	Five	Anand	Ambala
Anand	Ambala	Anand	Ambala	Anand	Ambala	Anand
P=50 vs P=50	1. Season of calving 2. Previous lactation yield 3. Persistence of milk yield	104 115 71	111 149 95	93 127 78	89 83 76	91 92 78
P=50 vs P=60	1. Season of calving 2. Previous lactation yield 3. Persistence of milk yield	209 271 260	93 103 140	202 270 282	123 128 81	
P=60 vs P=80	1. Season of calving 2. Previous lactation yield 3. Persistence of milk yield	209 251 194	146 133 181			
P=60 vs P=60	1. Season of calving 2. Previous lactation yield 3. Persistence of milk yield	111 150 90	83 30 30			

Statement V

(a) Efficiency of switch over design with out block with concomitant variate relative to the completely randomised design and no concomitant variate (Percentage)

Length of treatment period (Days)	No. of treatments					
	Anand		Ambala		Anand	
	Anand	Ambala	Anand	Ambala	Anand	Ambala
50	9203	907	4643	356	8342	280
60	2079	714	4083	748		
80	2951	635				

(b) Efficiency of switch over design without blocks with covariate vis-a-vis switch over design without blocks but no covariate (Percentage)

Length of treatment period (Days)	No. of treatments					
	Three		Four		Five	
	Anand	Ambala	Anand	Ambala	Anand	Ambala
50	123	101	123	104	100	97
60	167	100	141	105		
80	169	107				

(c) Efficiency of switch over design with blocks with covariate relative to switch over design with blocks but no covariants (Percentage)

Length of treatment period (Days)	Block based on	No. of treatments					
		Three		Four		Five	
		Anand	Ambala	Anand	Ambala	Anand	Ambala
50	1. Season of calving	103	105	196	104	154	103
	2. Previous lactation yield	103	100	206	99	104	101
	3. Persistency of milk yield	98	97	137	104	140	100
60	1. Season of calving	198	99	117	103		
	2. Previous lactation yield	154	100	126	101		
	3. Persistency of milk yield	109	99	100	99		
80	1. Season of calving	133	103				
	2. Previous lactation yield	153	100				
	3. Persistency of milk yield	107	99				

Statement V (Contd.)

(d) Efficiency of switch over design with blocks with covariate compared to switch over design without blocks with covariate (Percentage)

Length of treatment period (Days)	Blocks based on	No. of treatments					
		Three		Four		Five	
		Anand	Ambala	Anand	Ambala	Anand	Ambala
50	1. Season of calving	119	119	126	98	214	115
	2. Previous lactation yield	129	86	125	91	114	109
	3. Persistency of milk yield	223	104	188	156	215	134
60	1. Season of calving	129	106	132	110		
	2. Previous lactation yield	93	102	127	101		
	3. Persistency of milk yield	87	203	115	148		
80	1. Season of calving	119	100				
	2. Previous lactation yield	89	78				
	3. Persistency of milk yield	100	220				

(e) Efficiency of switch over design with blocks but no covariate relative to switch over design without blocks using concomitant variate (Percentage)

Length of treatment period (Days)		No. of treatments					
		Three		Four		Five	
		Anand	Ambala	Anand	Ambala	Anand	Ambala
50	1. Season of calving	112	110	106	96	130	112
	2. Previous lactation yield	122	86	80	93	110	109
	3. Persistency of milk yield	227	102	186	132	154	132
60	1. Season of calving	93	107	67	103		
	2. Previous lactation yield	63	102	62	93		
	3. Persistency of milk yield	87	203	77	159		
80	1. Season of calving	83	93				
	2. Previous lactation yield	57	78				
	3. Persistency of milk yield	92	222				

List of the cows at Agricultural College Anand.

<u>Sl. No.</u>	<u>Lactation Order</u>	<u>Date of calving</u>	<u>Previous lactation yield in Kg.</u>
1.	VII	14.8.62	2821
2.	VI	2.6.62	3322
3.	V	13.6.62	2743
4.	V	14.7.62	2229
5.	III	23.8.62	2373
6.	IV	8.9.62	2197
7.	III	9.9.62	9997
8.	III	13.9.62	2063
9.	II	26.9.62	1897
10.	II	29.10.62	3745
11.	III	10.11.62	2381
12.	II	18.11.62	2603
13.	III	18.11.62	3386
14.	IV	22.11.62	1662
15.	X	7.12.62	2456
16.	V	19.1.63	3463
17.	IV	22.1.63	2082
18.	IX	24.1.63	1939
19.	II	4.2.63	3334
20.	III	22.2.63	1772
21.	III	15.4.63	2691
22.	VII	20.4.63	3243
23.	II	24.4.63	2468
24.	III	30.4.63	1794
25.	IV	21.5.63	1895
26.	IV	7.6.63	1922
27.	II	14.6.63	1899
28.	IV	18.6.63	1884
29.	III	24.6.63	3101
30.	IV	26.6.63	3295
31.	VI	30.6.63	1855
32.	II	1.1.64	2016
33.	III	7.1.64	1067
34.	II	12.1.64	1964
35.	II	30.1.64	2334
36.	II	21.3.64	2616
37.	III	29.4.64	1651
38.	II	30.5.64	1120
39.	II	2.6.64	1994
40.	II	6.7.64	2279

List of buffaloes at military dairy farm Ambala.

<u>S.l. No.</u>	<u>Lactation order</u>	<u>Date of calving</u>	<u>Previous lactation yield in lbs</u>
1.	II	26.12.54	3728
2.	II	28.12.54	4232
3.	VI	28.12.54	4364
4.	II	2.1.55	2781
5.	III	2.1.55	3292
6.	V	3.1.55	4358
7.	II	6.1.55	4232
8.	VI	7.1.55	4267
9.	III	7.1.55	3326
10.	VII	19.1.55	3244
11.	XII	23.1.55	3663
12.	IV	26.1.55	3843
13.	VI	27.1.55	4303
14.	VIII	2.2.55	5463
15.	VII	2.2.55	4616
16.	VI	2.2.55	2871
17.	II	9.2.55	3357
18.	II	14.2.55	3723
19.	II	26.2.55	3182
20.	II	4.3.55	5218
21.	II	11.3.55	4202
22.	V	12.3.55	3963
23.	III	12.3.55	2374
24.	II	14.3.55	4203