EXPERIMENTS IN DAIRY HUSBANDRY WITH PARTICULAR REFERENCE TO YIELD OF MILK FAT

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OVER the last 30 years, R. A. Fisher and others have devised satisfactory methods of crop experimentation, but for many years no serious attempt was made to apply their work to the field of animal husbandry. In November, 1938, in an address to the Royal Statistical Society, Dr. J. Wishart sums up the position as follows:—

> ''The expense of animal experimentation is bound to limit the numbers capable of being dealt with thus keeping down the number of treatments to be tested and making an unsatisfactory experiment generally, since while there may be several thousand unit plants of wheat in a single plot of a cereal experiments, and several hundred unit roots on a plot of potatoes or sugar beet the unit with animal experimentation will often be the single animal.
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> ''For these reasons progress in the direction of laying out animal experiments which would permit of adequate statistical examination of the results has been slow and experiments have usually been of a very simple nature, comparable in fact to the duplicate plot experiments that were in vogue prior to the randomized block era, except that there was not always duplication.''

In field experiments the coefficient of variation is usually about 5% while in animal experiments it is usually more like 25%, i.e. for the simple technique of randomized blocks or what are usually known as ''Group'' experiments. In horticulture experimentation we have the same difficulty for the same reasons and the application of the methods of crop experimentation to horticulture follows a similar course to that in animal work, e.g. in fruit tree experiments, single trees or plots of usually no more than six trees form the basic unit. In recent years two important devices have been employed which may often render animal husbandry and hortcultural experiments as accurate and as efficient as crop experiments. By far the most important of these two is the technique known as analysis of covariance which like other techniques, such as the reversal trial, makes use of the fact that, for the factor we are measuring, say yield of milk, there is a high correlation between one period and the next, e.g. the correlation coefficient between the yield of the first two weeks of a dairy cow's lactation with the yield of the rest of the lactation is about 0.8 and the smaller the succeeding period the higher the correlation coefficient. Similarly in horticulture the correlation between the yield of apples for a single tree from year to year is extremely high compared with, say, the yield of small plots of sugar beets or wheat from year to year. The other method of improving the accuracy has been by assembling material inherently less variable, e.g. in fruit trees the use of clonal rootstocks reduces the variability considerably, and in dairy cattle the establishment of the identical twin herds in Sweden and particularly at Ruakura and Massey College in New Zealand marks a real advance in dairy husbandry experimentation.

Until recently most animal experiments were of the simple group type. This type of experiment is usually very crude and inaccurate or requires an inordinately large number of animals. An advance on this type is the randomized block experiment where attempts are made to group the animals first into somewhat homogenous "blocks" (the term "blocks" has been borrowed from blocks of plots in field experiments). This can be done to advantage in pig experiments where, for example, the variability between litters is much greater than that within litters. However, in dairy experiments nearly all attempts to group ordinary animals into convenient homogenous blocks have met with failure. Whether the animals are grouped according to line, date of calving, age, weight, etc., the accuracy is rarely improved; or in statistical terms the block variance is of the same order as the error variance, and we have the familiarly disappointing results when attempts at pairing are not of much avail.

While randomized block experiments are not very encouraging in dairy cattle, they are more so with other types of animals. One of the vital questions here, not usually met with in field experiments, is the use of techniques whereby the block size can be cut down to give a small number (3-5) of animals per block with any number of treatments. This question has been investigated in detail by Mr. H. R. Thompson of this laboratory, but the main application of this technique is not in the field of dairy husbandry.

Dairy experiments fall rather naturally into two main categories, short term and long term experiments, for which usually quite different techniques are used. The short term are those carried over a single lactation or a part thereof while the long term experiments are those carried over more than one complete lactation. While this division is not always clear cut, it is by no means arbitrary but due to certain inherent qualities of dairy cattle. There are two main types of short term dairy experiments. First the double-reversal or switch-back design where, as the name implies, the treatments are reversed after a given period. Secondly, the ordinary group or randomized block design where measurements of, say, yield of milk, are taken during a pre-experimental period, i.e. before the treatments are applied. In the few odd cases where neither of the above two designs are applicable, identical twins can usually be used most profitably. Neither of the above two techniques are of very much advantage for long term experiments owing to the low correlation (for, say, yield of milk) from year to year and also the losses (usually about 30% per year) impair the efficiency unduly.

We will now consider the various types of design in more detail, paying particular attention to the circumstances under which each one is most efficient and economical.

1. SHORT TERM EXPERIMENTS

(1) Double Reversal Trials with Two Treatments Only.

Here we apply two treatments, A and B, and after a certain period (usually 2-5 weeks) the treatments are reversed, and after the same period has elapsed the treatments are again reversed and so on according to the following diagram:—

Group I: A B A (B A . . .
Group II: B A B (A B . . .

This is a very efficient design giving a coefficient of variation of from 2.5 to 4.0% provided the following conditions are fulfilled:

(a) The experiment must be performed as early as possible after the sixth week after calving, and should not be extended beyond about the 25th week after calving so that we could have, say, four three-weekly periods or three five-weekly periods.

(b) The treatments must take full effect within a week or ten days, and similarly their effect should not persist for more than ten days after they have been removed since there is no way of estimating this "carry over" effect. In any experiment it is advisable to discard data for at least a week after the change-over as its inclusion may have the same effect as including "guard rows" in field experiments.

This type of design can be extended to more than two treatments. For instance, for three treatments we can have the following layout:—

Group:

1. A B A
2. B A B
3. B C B
4. C B C etc.

The analyses of these designs have been worked out fully and more details are given with respect to length of periods, number of periods, etc.

(2) Latin Square Designs.

Here were have n treatments (n is greater than 2), n groups of animals and therefore, n periods as shown in the diagram below:—

Group:

1. A B C
2. B C A
3. C A B

The coefficient of variation under optimum conditions is about 5% for three treatments and from 5·7% for four treatments, depending here on the length of the individual periods. Here the same condition (a) must be fulfilled but we can permit a certain relaxation in conditions; (b) since this design has the distinct advantage over the previous one, in that the carry-over effects, if they exist, can be estimated and allowed for. Unless the treatment effects are very persistent indeed, it is unnecessary to discard very much of the data immediately after the change-over. In the absence of strong carry-over effects, however, the previous design is up to twice as efficient. The Latin Square design is in practice restricted to either three or four periods and therefore treatments. We may, however, without impairing the efficiency, use the incomplete Latin Square design so that we may have four treatments and three periods or five treatments and four periods.

A B C	A B C D
B C D	B C D E
C D A	C D E A
D A B	D E A B
	E A B C

This type of design is fairly complicated. In all Latin Square designs it is better to have at least (n - 1) squares (for n treatments) to estimate the carry-over effects efficiently.

(3) Analyses of Covariance.

Where the effect of any particular treatment persists long after it has been removed it is obvious that the above two designs break down, and we are compelled to resort to other techniques. There is a very high correlation between any two successive portions of a single lactation, and this fact enables us to use designs which lend themselves to the analyses of covariance. These designs are usually of the ordinary group or randomized block type, except that for a short initial period all the animals are on the same treatment.

Experiments of this type are very straight forward in regard to both recording and analysis, but are 3-5 times less efficient than reversal trials over the same period, apart from twins which are certainly the best type of design in cases where the effects of treatment are very persistent. Depending on the length of the experiment and the stage of the lactation they are up to ten times as efficient as group trials.

(4) Other Short-term Experiments.

As mentioned above, in the rare cases when neither reversal nor covariance designs are applicable identical twins could almost always be used. Dairy experimentation has been improved and refined so that it can now compare with field crop trials, and we can formulate the following general principles of design:—

1. Where the effect of the treatment does not persist after they have been removed the most efficient design is that of the form A B A B . . . etc. Ideally it is more efficient to use a larger number or shorter periods, but this depends on how much data must be discarded after the change-over. The number of periods should always be three or more.
2. Where the effect of the treatments persists after the change-over to only a slight degree, but for any length of time, the most efficient design is the Latin Square type.
3. Where the effect of the treatments persists strongly after they have been removed then it is best to use analysis of covariance.

The efficiency of all the above designs is highest when the experiments are performed between the 5th and 16th week after calving, and as we extend the experimental period into the latter part of the lactation so the efficiency drops. The latter part of the lactation is more variable and erratic than the earlier part, and worse still the effect of certain treatments in the latter part of the lactation is to bring about the drying off of the animal without hope of recovery, whereas recovery from the same treatment would be normal at an earlier stage in the lactation.

II. LONG TERM EXPERIMENTS.

The correlation coefficient between one lactation and the next is fairly small and decreases with subsequent lactations, and so it is just as efficient to apply the treatments from the very start rather than wait for a year as is the usual practice with perennial crops. Were it not for identical twins the ordinary group trials would be best for experiments over more than one lactation. The efficiency of the reversal and covariance designs is not sufficient to warrant their use. The losses incurred in long term dairy experiments are considerable, being at the rate of about one-third of the herd per year, and the efficiency of the more elaborate designs is impaired very seriously by these losses. The efficiency of twin experiments is almost always very much greater, so that even these heavy losses may still make twin experiments worthwhile.

Almost all the possible experimental designs, using twins, have been worked out by Dick and Whittle of this laboratory, and again it remains only to summarize their work.

There are two main types, the quasi-factorial and the incomplete randomized block—the latter being the more efficient— but since for every twin design the basic number of animals to be used is fairly rigid, the former design was introduced to offer greater flexibility to the experimentalist, since it is only slightly less efficient.

The efficiency of twins over ordinary animals is usually between 20-25 times, depending on the number of treatments used and on the factor we are measuring (e.g. milk, fat, body weight etc.) Twins are extremely useful animals and are always more efficient than ordinary animals, and are not subject to somewhat rather rigid experimental conditions of reversal trials. For some factors, however, the efficiency of twins is disappointingly low, but never lower than ordinary animals. Twin experiments also suffer from the same faults, but to a lesser degree as in horticulture and field experiments which use clonal lines, i.e. the lack of generality. If the number of twin sets used is small, particular caution is necessary in applying the conclusion arrived at, to the whole dairy population.

Discussion on Mr. Armstrong's Paper

Mr. WRIGHT: I suggest that 5% is a minimum figure for the coefficient of variability in randomised blocks but as a rule it is nearer 10%.

Mr. FLUX: What is the interaction between environment and genotype in identical twins?

Mr. ARMSTRONG: The within set variance is different in different sets of twins, or in other words, some are more identical than others.

Mr. RANSTEAD: Twins are not necessarily a fair sample of the dairy cow population.

Dr. McMEEKAN: For long term work, that is trials involving more than two lactations, twins are hopeless. There may be four or six sets in a block and with one death, one abortion or one case of mastitis, the whole block is lost. I defy anyone to say whether a cow would go down with milk fever as a 4-year-old if she were drowned as a 2-year-old in a drain. The double reversal type of trial has limited use under New Zealand conditions where there is such a great variation in grazing from day to day. In nutrition studies which involve the early and late stage of lactation it is useless.

Mr. ARMSTRONG: These techniques can be used to detect small differences and are used mostly in short term trials. Much fewer long term trials are done but identical twins should be superior and in any case losses do occur also in ordinary animals, and these amount to about 30% per year.

Dr. FILMER: Large differences do not require statistical analysis in many instances, and with material as variable as dairy cows it is dangerous to draw conclusions from differences that are so small as to require elaborate statistical treatment to show them up.