THE INHERITANCE OF MILK YIELD IN THE COW.

by

Mohammed Tawfick Ragab

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Institute of Animal Genetics
University of Edinburgh

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INTRODUCTION:

The ultimate aim of dairy cattle breeding is to raise the efficiency of economical milk production; in this the most important factor, though not the only one, is the increase in milk yield. This can be achieved either by improving the system of management or by selecting for the highest possible milking capacity. As neither a good environment and bad genes, nor good genes and a bad environment will give the maximum improvement in milk production, it is of profound importance to secure both good genes and a good environment.

The environment cannot be controlled completely on the dairy farm. There are many factors which are beyond the breeder's control. Even after control of the known causes of environmental variations, there still remains a good amount of variation due to unknown environmental causes.

Environment sometimes has such a large effect that dairy cows of one genotype may appear phenotypically like those of a class superior or a class inferior in their milk production. Such effects will result in the overlapping of phenotypes, and consequently the right type of animal may be rejected by the breeder and an inferior one selected instead.

As the effects of environment are liable to exist in varying degrees, any scheme of selection carried out with the purpose/

purpose of improving the herd genetically depends on the extent to which hereditary differences account for the differences between individuals, because the success of selection depends upon how much of the variation found between individuals is transmitted from parents to offspring.

Milk yield is a quantitative character controlled by genes which can be shown to act largely in an additive manner; its phenotypic expression is greatly affected and modified by the environment, hence the breeder is unable to discriminate in any individual case between the pure genetical effects on the one hand and those which are due to the action of environment on the other. His task is to find methods which will enable him to detect the genetic fraction and put it to the best possible use.

If the part played by the environment in causing variations in milk yield is wholly ignored, lack of appreciation of the differences between genotype and phenotype will follow. The genetic improvement expected from selection and grading up in a population of dairy cattle is often far higher than can be achieved, owing to the failure of the breeder to realise that superiority shown by one animal or herd over others is at least in part not genetic and therefore not transmissible. As Lush (1936) said "the improvement from phenotypic selection is proportional to the additively genetic (heritable) fraction of the observed variance and this varies for the different traits."

Since/

Since absolute control of environment in farm animals is impracticable, the observed variance in milk yield is always bound to be the result of the interaction between the environment and heredity. The environmental fraction may vary in degree, but it cannot be dismissed. Thus a practical tool is needed to discriminate between those two types of variation.

In this work it is our aim to measure the relative importance of the genetic and all other factors which interact to bring about differences in milk yield by estimating the heritable fraction of the variance, i.e. heritability.

There are varying opinions about the best measure for estimating the milking capacity of the cow. One of the measures most generally used is the lactation yield (i.e. total milk yield). This may be taken either as it is, or with corrections for the age of the cow, the dry period &c.

In order to avoid the need for correcting for lengths of lactations and calving intervals, the milk yield of the first 305 days after calving is usually taken as an estimate of the milking capacity of a cow. This period of 305 days is chosen because if a normal lactation extends for such a time, and a dry period of 60 days follows, it will give a standard calving interval of one year.

Although this fixed period of lactation is adopted by the National Milk Record, the Milk Marketing Board, and a good number of breed societies, yet there are still some societies which, considering that their cows are usually in milk for a longer period than 305 days, adhere to 365 days records. This made it of more interest to study both the 305 days/

days record and the total milk yield, and to compare the two.

In this investigation the main object has been to study hereditary causes of variation in milk yield. The relation between the month of calving, the age and the milk yield, has been studied as a preliminary to the fundamental analysis. The effect of the age at first calving on both the 305 days milk yield and the total milk yield has been studied also.

The following table shows the parameters which have been calculated in order to investigate the inheritance of milk yield.

A. The "repeatability" of both 305 days milk yield and the total milk yield.

B. The "heritability" of :
   (1) The first lactation of 305 days milk yield.
   (2) " " " of the total milk yield (in the biggest herd.)
   (3) The second lactation of 305 days milk yield.
   (4) " " " of the total milk yield (in the biggest herd.)
   (5) The third lactation of 305 days milk yield.
   (6) The average of the first three 305 days milk yield lactations after correcting for age.
   (7) The cow's maturity index.

C. The phenotypic correlation between the 305 days and total milk yield in the first and the second lactations.

D. The genetic correlation between :
   (1) The first and the second 305 days milk yields.
   (2) The first 70 days milk yield and the 305 days milk yield of the first lactation.
   (3) The first 70 days milk yield and the 305 days milk yield of the second lactation.

REVIEW OF LITERATURE:

a) The Inheritance of Milk Yield.

One of the first methods of allowing for the effects of environment was evolved by the German School led by Von Patow (1930). They used what they called "The Byre Average" to correct for the effects of weather, feeding and management (i.e. year-to-year variations). This method was first introduced by Peters (as reported by Hansen 1917). Its main purpose was to eliminate, as far as possible, the effects of the environment; thus any comparison between the individuals, after correcting their production, would be according to their genetical merits.

There are two objections to this method. Firstly, the herd may be too small. Peters (1924) places the number limit as twenty cows. Consequently the method cannot be used for any herd having a smaller number of cows. Secondly the genetic composition of the herd may vary from year to year.

Lush (1936) later strengthened this criticism by saying that such a method regards the annual changes in milk yield as due entirely to environmental causes and thus ignores the genetic part of the change.

Lortscher (1937) stated that Von Patow's method makes corrections/

corrections for changes not only in the environment but also in the average genetic composition of the herd as well as for differences between herds.

Rinecker (1922) used another method based on Von Patow. He compared the yield of the individual animals with that of their stable-mates of the same age and year, if possible. This method, although it is better than the earlier methods and enables one to put animals in the same herd on a fairly comparable basis, does not tell what the comparison means in terms of genetics.

Wilson (1910), Dunne (1914), Wriedt (1930), Hills and Ballard (1913), Funkquist (1921), Hansen (1917) and Patow (1921), tried to measure the number of genes which govern the milk yield, but their factorial explanations failed to clarify accurately the causes of variation in milk yield because they assumed that they were dealing with genetic variation only.

Lachow (1921), Yapp (1925), Nachtsheim (1926) and Turner and Gifford (1927) came to a more reasonable explanation which is summarised in the following :

(i) Milk yield is influenced by many genes.
(ii) Many genes favouring high milk production are dominant.
(iii) All genes do not have the same effects.

Smith and Robison (1933, 1939) suggested that milk secretion must be dependent on a fairly large number of genes, some of which are probably of greater importance than others.

Cole (1925) doubted the possibility of a low number of genes, while Crew (1925) said that the mechanism concerned in milk yield is of the multiple factor type.

It/

It was not until Lush (1936) took up this subject that any attempt was made to find out, after correcting for systematic trends in the environment on the lines of Rinecker and others, what fraction of the remaining variation was inherited. Obviously a factoriall analysis is not possible if the fraction is small and the number of genes many. Lush (1936 &c) estimated the genetic part of variance in milk yield as 25-30% while Johansson and Hansson (1941,1947) reported an estimate of 30-40% for this same part of the variance for butterfat yield.

From the practical point of view as much can be done in determining the best breeding policy from analysis of this sort as could be done if the number of genes involved could be accurately stated.

b) Non-Genetic Factors affecting Milk Yield.

In addition to the sort of overall correction for environment suggested by Rinecker and Von Patow, it is possible to make corrections for systematic differences due to known environmental factors such as season of calving, age at first calf &c. Determination of these influences not only bring out more clearly any genetic effects which may be present by reducing the proportion of the apparent variation due to non-genetic factors, but also focus attention on causes of variation in milk yield which can be controlled.

I. The Effect of Season of Calving on Milk Yield.

The season of calving has two types of effect on milk yield/

yield :-

1) a direct effect, through the influence of the seasonal variations in temperature and weather;

2) an indirect effect, since the type of crops grown on the farm changes with the season of the year. This enables the cows which have a longer period of grazing to give more milk than those which enjoy a shorter one.

The farmer is more likely to be interested in the second kind of indirect effect than in the first, because it is within his control.

Hammond and Sanders (1923) found that there is a difference of 15-20% in the milk yield of animals calving in the different seasons; they attributed this to bad management.

Again Ellinger (1923) reported a difference of 16% between the milk yield of October calvers and that of March calvers. He suggested the necessity for correction for the season of the year before starting any record analysis.

Sanders (1927) emphasised that the low yield of yearly summer calvers is due to the rapid drop in yield during the summer, and if this drop could be arrested, there seems no reason why these cows should not give yields as high as autumn calvers. He gave reasons for the conclusion that the existence of this seasonal variation is evidence of bad management somewhere (during summer). He said too, that where feeding and management are on a very high plane, the seasonal variation is almost obliterated.

Wylie (1925) concluded that there is not much difference between the different months of calving; he was working/

working on R.M. Jersey records. He also put forward the explanation that amongst a group of animals which are highly fed and cared for, the season of calving plays but a limited part in milk yield variation.

Von Patow (1926-30) found a difference of 3% in the milk yield due to the season of the year.

Tuff (1931) stated that the total milk yield of Norwegian cattle is usually 10-20% greater when the cows calve in the autumn or winter, than when they calve in spring and summer. He attributed this increase to the more favourable environmental conditions in winter (cooler weather and absence of flies) and to the more digestible feeds than are available in late summer.

Cannon (1933) recorded that in Iowa State the cows which calved in November had the highest average milk yield. From November to June the group calving in each month produced less milk than the group calving in the preceding month. From June until November the group calving in each month had a larger production than the group of the preceding month.

Schubert (1934) found a slight correlation between climate and milk yield, but a stronger one between the concentrates used in different years and milk yield.

Plum (1935) states that there is a significant influence of the season of the year upon butterfat yield, but estimated/

estimated its effect in the total variance at 3% only. He found also that the butterfat yield of cows calving in November to January exceeded by 13.6% that of cows calving in May to July; this agrees with the finding of Cannon (1933).

Dickerson (1937) found that by applying correction factors for the season of calving, the differences between records of the same cow increased by nearly as much as the differences between cows, which means that the season of calving has no appreciable effect on the milk yield. Again in 1941 he found that .019 and .010 of the total variance in the 305 days and total lactation records respectively was due to the season of calving. This in turn suggests that the seasons have but little effect on milk production.

Johansson and Hansson (1941) came to the conclusion that the main factor influencing the seasonal variations in milk yield is the lack or abundance of food. They went further in suggesting that such an effect could be overcome if farmers pay special attention to the feeding of their animals during the seasons which are known to be bad as regards pasture. They found in their study that the effect of the season of calving causes only 3.3% of the total variation in butterfat yield. This estimate was obtained when the animals studied were divided into only two groups, summer and winter calvers.

This of course does not give an accurate picture of the effects of calving seasons, and more accurate results would be expected/

expected when the animals are divided into twelve groups according to their months of calving during the whole year.

Cannon and Hansen (1943) explained why the autumn and winter calvers exceed in their milk yield those which calve in the other seasons of the year. They said that cows which calve in autumn and winter are in a fairly advanced stage of lactation by the time the factors favourable to milk production (good grazing and mild weather) are most pronounced.

Woodward (1945) made it clear that the quantity of milk produced in a lactation period is not a factor of major importance for the dairy farmer to consider in determining the best season of calving for his cattle, provided he has adequate food supplies for his animals at all seasons of the year.

Frick, Mann and Johanson (1947) found that, in Connecticut, the most favourable month of calving came later in autumn, and that milk yield in the most favourable months exceeded that in the least favourable by 13.7%.

Johansson (1947) again in his study on the variation in milk yield and butterfat in the Polled Swedish cattle, stated that the influence of season of calving on the butterfat yield varies from farm to farm, but, on the average, summer calvers produced 5-10% less butterfat per lactation than did winter calvers.

Oloufa and Jones (1948) found that seasonal variations in Oregon State had no appreciable effects upon butterfat production.

Blau/

Blau (1949) examined 1827 "corrected" milk yields of cows belonging to five Red Pied Lowland pedigree herds. He indicates that performance is influenced by feeding rather than by season. Where feeding is at the same level throughout the year, time of calving has no significant effect on milk production.

The conclusion to be drawn from these varied results seems to be that the effect of the season of calving is an indirect one operating through the food supply. When grass is the main feed, the effect of season will be greater; proper feeding, to supplement grazing can largely remove the effects of season of calving. Thus the effect of season of calving is largely one of management and will vary from farm to farm according to the way the farmer manages his herd.

II. The Effect of Age at First Calving on Milk Yield.

Many studies have been carried out to find what are the effects and limits of early and late calving of heifers on their milk production.

Eckles (1915) was the first to have made a study on the effect of early and late calving of heifers on their milk yield. The early calvers, in this study, were six Jersey and two Holstein heifers; they were bred at 20-24 months of age. The late calving group consisted of four Jerseys and five Holsteins; they were bred to calve at 30-34 months of age. He reported a slight increase in the milk and fat yields of the late/

late calvers over those of the early ones. However, the number of animals in each group was very small, and the breeds were not represented in equal numbers in each group. Eckles believes that it is decidedly disadvantageous for a Jersey heifer to calve under 24 months of age, while nothing seems to be gained by allowing her to reach an age of more than 30 months. The smaller number of Holsteins gives less foundation for such a statement, but it also indicates that the best milk producers are, on the average, found among those which are well matured before coming into milk for the first time.

Beam (1918) found a difference of 10 lbs of butterfat between early and late calvers, which indicates a little advantage in late calving.

White (1917) comparing two groups of Holstein cows concluded that late calvers (average age 37 months) exceeded the early calvers (average age 25 months) by 544 gallons of milk. The results of this study are not very reliable since it comprised only ten animals (5 in each group) and there were also some exceptionally high producers among the first group of animals. Owing to the extremely small number of animals used in these studies the results are unreliable since they fail to eliminate individual variations.

Turner (1932) in his study of four breeds of cattle (Ayrshire, Friesian, Jersey and Guernsey) comprising 22,482 animals, observed an increase in the yearly milk and fat production as the age at first calving increased. He also found that the maximum was reached at the age of 30 months, while the most efficient production was obtained at the age

of/

of 20-24 months. No gain was obtained when heifers were delayed in their calving beyond the age of 30 months; 23-43% of the heifers included in this study calved after that age.

Johansson (1929) came to the conclusion that the butterfat production of Swedish Red and White cattle increases with age at first calving and that this increase becomes somewhat less pronounced during the 4th to 6th lactations. He accounted for this by the general correlation between age and production and suggested the setting up of experiments especially planned to test this hypothesis.

Dickerson (1936) found that age at first calving affects the butterfat yield in the first lactation; he reports a correlation coefficient of .22 between the two. He also pointed out that this effect decreases as the number of lactations per cow increases, because the length of the productive period tends to balance the effects of age on total production.

Tuff (1931) tried to estimate the effect of age at first calving upon the first 180 days milk yield in Norwegian cattle, through the application of the following equation:-

$$\hat{y} = 1096 + .447x$$

where y = mature milk yield for the first 180 days in Kgms.

x = age at first calving in months.

Johansson (1941) found that the regression of butterfat production is :

$$\hat{y} = 132.79 + 3.566x - 0.1544x^2$$

He stated the yield in kgms for 13 age groups of 2 months interval each, that is, ranging from 25-50 months. This equation/

equation gives the following value, when transformed into pounds of milk, applied to an average butterfat percentage of 4%.

$$\hat{y} = 7470 + 202.5x - 8.78x^2$$

It corresponds to an increase of 8 gallons of milk in 300 days milk yield per month of age at first calving.

Dickerson and Chapman (1940) divided the records for two large Holstein herds into two groups in which age at first calving ranged from less than 24 months to more than 36 months. Analysis of the records indicated that breeding heifers as early as 26 months was not detrimental to reproduction or growth rate and resulted in a slight but definite increase in lifetime production efficiency.

Hansson (1941) found that early calving has no effect on the size ultimately attained by the cow. He stated that the butterfat yield during the first lactation increases with increasing age at first calving, and after the cow has reached 36 months of age the rise in the yield with increasing age is very slight. He also found that the lifetime record of the cow showed a tendency to decrease with increase in age at first calving. This means that the economy of milk production is greatly influenced by the age at first calving. If the average age of cows at first calving is reduced by 6 months, the fat production per 1000 feed units increases by 3.5 kgms. butterfat. He suggested that the best and most economical age for first calving in the Swedish Red and White breed is 26-28 months.

Gaines (1943) in his work on milk records of Shorthorns/

Shorthorns in Illinois found that there is a general regression of 6 gallons a month in total milk yield in all lactations.

Luthman (1947) studied the effect of age at first calving on lifetime milk production in the German Lowland and Highland cattle. "The lifetime yield" of cows was expressed as yield per feeding day, the total milk yield of 7 lactations being divided by the number of days in the period between the first calving date and the last day of the seventh lactation. It was concluded that cows first calving at the age of 31-36 months produced more milk and fat than younger or older ones. He stated too that the feeding of the young stock has a great effect on the condition of the heifer at her first calving and also on her production in subsequent lactations.

These various studies show how the age at first calving affects the heifer's milk and butterfat yield. The different estimates of increase in production when the breeding age is delayed, previously mentioned, are all of the same magnitude. They all agree that delay in breeding causes increase in milk production in the first lactation, but that the milk yield is likely not to increase if heifers are delayed in their breeding beyond a certain age. They also clearly state that the efficiency of milk production through the lifetime of the cow increases when she is bred early. The definite ages and amount of increase in production differ from breed to breed and from farm to farm as the conditions are not the same. Moreover, the dairy farmers hold conflicting views as regards the effects of early first calving on the capacity

for/

for milk production. Some believe that it is detrimental to body development and milk yield, while other claim that the efficiency of the cow as a converter of feed energy into milk reaches a higher level when she starts her productive life at an early stage. Therefore, some of them breed their cows at a late age while the others make them calve as early as possible. But, in general, the farmer is probably inclined to breed his heifers when they reach a satisfactory size. This size is determined by the breed of his cattle, his system of management and lastly by the quantity and quality of food which he supplies to his animals. This explains why some farmers obtain disappointing results when they let their heifers calve early, while other have every success. The conditions of the farm, the growth of the animals and their degree of maturity are important factors in this connection.

This suggests the need for further investigations based on practical experiments, where the material should be freed from the effects of other factors than age at first calving. The study should cover many breeds because of their different growth rates; the feeding of the animals should be controlled and, lastly, the numbers of animals should be sufficiently large.

Until then, statistical analysis will give some idea about the effect of age at first calving on milk production.

III/

III. The Relation between Age and Milk Yield over the Successive Lactations.

The age of the dairy cow is one of the important non-genetic causes of variation in milk yield. Many investigators have measured its effect in different lactations. If the different lactations are to be compared the records need to be standardised, since the difference between first lactation and mature yield is of the order of 30%.

Langmarck (1921) studied the effect of age on milk yield and was the first to show that age correction factors drawn from single records are useless as they do not allow for the effects of selection. He confined his study to cows which had at least 10 lactations each, and found that the maximum yield was reached in their 7th lactation. This maximum record was higher than that of the first lactation by 60%. This result is somewhat misleading because during such a long period of time the environmental conditions had certainly changed. This makes his findings of little general application.

Sanders (1927) found that age rather than the number of lactations is the important factor in determining the variation in milk yield. He realised that selection within herds would affect the age conversion factors obtained by comparison between animals in the different age groups. He used what he called "the paired lactation method", which secured the elimination of such effects, but the result was still open to the error introduced by more or less continuous improvement in the environment. This method, however, excelled that of Langmarck and still better results could be obtained if the investigation were limited to a comparatively short period of time/

time (4-5 lactations). This would increase the chances of getting larger numbers of records as well as minimise the effect due to change in the environment.

Krüger (1934), Johansson and Hansson (1941) agree with Sanders, but make the reservation that the number of previous lactations of the cow also has its effect.

Subsequently, Sanders (1928 and 1930), Kay and McCandlish (1929), Schmidt (1933), Gaines and Palfrey (1931), Kendrick (1937), and Plum (1935) have all recognised the complicated effects of selection on their material. They have attempted to avoid the difficulty by studying the influence of age within individual animals. But, again this method is still subject to one source of error, i.e. the conditions of environment may have changed during the interval of time from the first to the last record. It must be also remembered that not all breeds, or perhaps herds, will be affected by age to the same extent.

Other authors have studied the way corrections for age should be applied.

Tuff (1931), from an analysis of seventy-four animals with seven consecutive lactation years, concludes that "the increase in milk yield from young to full grown age of an individual can neither be summarised by a constant addition nor by a percentage addition alone", and proceeds to state a formula of the nature $y = 1096 + 0.447x$ for conversion from two years (x) to maturity (y) for the first 180 days milk production.

Ward/

Ward and Campbell (1938) analysed the records of 702 cattle of predominantly Jersey type for at least six consecutive years. They did not find any evidence supporting the theory that increase in milk production operates as a percentage addition from early age to maturity. They suggested that the increase in milk production according to age is best represented by a regression formula of the nature $x = ay + b$, where x equals the maturity production and y is the immature production.

Dickerson and Chapman (1939) studying the effect of age and dry period on milk yield, found that correction factors for age obtained by the analysis of variance method, over-corrected the low yielding cows and under-corrected those with a high yield. They suggested confining the use of such factors to cows up to 5 years of age only.

Sanders (1928) observed too that the application of correction factors resulted in over- and under-correction of some of the records. He attributed this to nutritional causes, and to the small number of animals with which he dealt.

Lush (1947) suggested that the number of the records each cow gave and the herd's average should be considered when age conversion factors are worked out. This precaution allows for the regression towards the herd's average.

To sum up, studies on the effect of age on milk yield over the succeeding lactations should be made on herd basis, because the effects of weather, feeding and management in any one/

one herd are expected to be the same for all cows in the herd, and any comparison between age groups within herds should give a more appropriate result than when made between herds.

The best method to apply is that based on "paired lactations". In this method the first lactation yield is compared with the second for the same group of cows, then the second is compared to the third and the third to the fourth &c. Thus, the effect of selection is eliminated, as the same animal is compared in two succeeding lactations. One more advantage of this method is that large numbers of animals, i.e. all animals having two or more lactations, can be used. The only snag in this approach is that it is subject to error introduced by consistent trends in the environment.

c) Repeatability of Milk Yield.

This is a comparatively new expression used in the field of animal breeding to show how much resemblance is found between the different observations of a certain character in the same animal. In milk yield repeatability means the degree to which the cow is able to repeat its records in the different lactations.

Looking at it from the other point of view, one can say that repeatability shows to what extent the change of environment affects performance. The repeatability is the correlation between two measures of the same character on the same animal.

Gowen (1924) found an average correlation of .67 between successive 365 day milk yields of Holstein-Friesian cows, and an average correlation of .70 between similar yields of Guernsey cows.

These estimates are high compared with the more recent ones, the difference being largely due to the way the data were treated. Gowen treated all his data as one sample and so included the differences between herds in his correlation. More recently, the correlations have been calculated so as to exclude these differences, that is, all calculations are done on a herd basis. This method is essential when calculating heritable variation,

as/

as otherwise similarities due to a common herd en-:vironment are confused with similarities due to relationship.

Gaines and Palfrey (1931) in a population of Danish cows, found for fat-corrected milk yield an average correlation of .50 between the successive lactations. Each of those cows had been long enough in the herd to have ten normal lactations. Probably few really low producers among those which started on test would have escaped culling for this length of time.

Plum (1935) studied the effect of differ-:ences between cows on the butterfat yield in 92 herds of Guernsey, Holstein and Jersey cows. He obtained a correlation of .60 between records of the same cow in a population of cows kept in many herds (i.e. between herds). This is somewhat higher than that of Gaines and Palfrey, but somewhat lower than that found by Gowen. This may be due to two reasons: firstly, that all records were corrected to mature equivalent basis by using factors obtained from the same data; and secondly, that there was no major changes in the environment through the long period of time which the records covered. This last argument is supported by the fact that during the eleven years included in the study only 2.8% of the total variance was due to changes in yearly averages.

Therefore the time trend was a minor cause of variation among these records.

Lush, Harris and Schultz (1934) obtained a repeatability for milk yield varying from .30 to .40, calculated on a within-herd basis.

Berry (1945), using 6-7 records of butterfat yield for each cow, reported an average estimate of repeatability of .29 calculated on an intra-herd basis. This may be due in part to the restriction of the study to cows which had at least six records. Undoubtedly some selection against low yielders took place in these herds, especially after the first and second records. This discarding of cows with extremely low first records would reduce the standard deviations of those early records and would cause the mean of the first records to be a little higher than the mean of the later records.

Sanders (1930) obtained a higher estimate than all the previous ones, viz. .70. This may be due to his correction of the data for the season of calving, age, and calving interval. Although the correlation coeffecient was calculated on an intra-herd basis, yet such corrections must have reduced the variation originally found between the records.

The/

The different estimates of repeatability arrived at by the previous workers seem to disagree. There are low and high estimates in some cases; this may be due to the fact that some workers based their calculations on a within-herd basis (Lush et al. Berry and Sanders), while the others did not (Gowen, Gaines, Palfrey and Plum). Each herd may be a distinct group with a certain uniformity obtained either by selection or by line breeding. Such selection and culling may not have been toward the same ideal or with equal intensity in all herds.

The environment and management may be rather uniform for all cows in the same herd but distinctly different from one herd to another. If the correlation between records in the different lactations is worked out on a between herd basis, this will lead to the inclusion of the differences between herds, and consequently a higher estimate of repeatability is obtained.

Moreover, some of the workers have corrected the records for various factors such as age, season of calving, etc. before working the repeatability estimates. Such corrections result in increasing the likeness between the records of the/

the same cow. Lastly, there was no general rule as to how many lactations they should include in their studies.

However, the repeatability could be considered as a reasonable measure for the genetic worth of milk records since it includes all the genetic variance and that which is due to permanent environmental conditions. It also gives an estimate of the part played by factors other than permanent environmental factors (year to year variations) in affecting the expression of milk yield in the various lactations of the cow.

d) Heritability of Milk Yield.

In judging dairy cows there is no possibility of distinguishing between the part played by heredity in their records, and that played by environment. But in a group of cows an estimate may be made of the relative importance of heredity and environment in bringing about variation in their milk yields. Several attempts have been made to determine this measure.

S. Wright (1920) made a study of the relative effects of heredity and environment on white spotting in two inbred stocks of guinea-pigs. He was able to separate the variance into two portions, one due to heredity estimated at 2.8%, and the other of 97.2% due to environment.

Gowen (1934) analysed data from the Jersey Register of Merit. He came to the conclusion that 50-70% of the variation in milk yield is controlled by heredity. In his calculations Gowen assumed that a common environment contributed nothing to the correlation between daughter and dam. Such an assump; :tion seems too extreme in view of the differences in herd management. This may explain how he exaggerated the hereditary part of variation and underestimated the effect of environment.

Plum/

Plum (1935) working on data from Iowa State Testing Association, obtained an intra-cow correlation for butterfat yield (for the first 8 months of the lactation) of .40. The dam-daughter correlation based upon the first available lactation record of each cow was .31. When the coefficients were calculated on contemporary records for dams and daughters the total correlation obtained was .32. Plum finally arrived at the conclusion that $\frac{1}{4}$ to $\frac{1}{3}$ of the total variance in butterfat yield within a herd is determined by heredity.

Lush (1936) applied Wright's system of analysis and used it more widely in measuring the heritable fraction of variance in the different traits of livestock. He called it "heritability". He and Schultz (1936) estimated the heritability of the total butterfat production as .25.

Lush and Arnold (1937) reported that about one-fourth of the variance in total fat production could be regarded as hereditary in the simple additive manner.

Lush, Norton and Arnold (1941) reported heritability estimates for milk yield based on some earlier studies. They were in fact .41, .57 and .38 for Edwards (1932), Rice (1935) and "Brain Truster" (1936)/

(1936). They explained why these estimates differed from each other as well as from other results. They state that the data may contain more inter-herd differences in some cases than in others. Most of the previous studies were confined to bulls which had an unusually large number of tested daughters. Doubtless that increased the proportion of cases where some of the dams and daughters were kept in one herd while others were kept in another where the manage-:ment differed. This would have contributed an en-:vironmental portion to the daughter-dam correlation. Restricting the study to bulls which had very many daughters would also extend the time over which the daughter-dam comparisons had accumulated and would offer a little more opportunity for time trends in management to contribute to the observed correlation.

Bonnier (1939) in his study on the Swedish Red and White cattle found that there is a low co-:efficient of correlation between dams' and daughters' milk and butterfat yield. These were .035 and .041 respectively within herds. In fact those estimates are surprisingly low, which may be due to his basing his calculations on yearly records.

Sikka (1940) studying the effect of en-:vironment on the total milk yield of Ayrshire cows reported/

reported a heritability of 52%, the average of the first three lactations. This would be expected, because averaging the three records would minimize the variance due to circumstances which change at random from one lactation to another by the third. The relative value of the genetic variance would consequently also increase.

Tyler and Hyatt (1947), working on Ayrshire milk records, estimated the heritability of milk yield and butterfat production at 31% and 28% respect:ively.

The general discussion of the estimates of heritability previously mentioned shows a rather wide range of differences between them, namely from .25 to .50.

The reasons for such discrepancies could be summarized as follows:

1) The environmental circumstances, systems of management and systems of breeding, were different in different herds.

2) The number and order of records used differed from one study to another.

3) Some of the records used were corrected for some non-genetic effects (mainly age), while others were uncorrected.

4) The time trends in the management were not the same in all herds, and consequently their contributions to the observed variance would differ.

However/

However, such discrepancies do not detract from the importance of heritability, since it is only on the basis of heritability calculations that the importance of the genetic variance in milk yield can be assessed. They emphasize, however, the need for accurate and consistent methods of estimation which will enable a distinction to be made between real differences in heritability and differences in methods of handling the data.

The symbols used in this study are included below :

Item	Symbol
1. Preparatory treatment	
Correlation coefficient	r
Regression "	b
Age in months	A
Age at first calving	A_1
Expected milk yield in terms of gallons at a given age in months	$\hat{y}$
A given age in months for the regression equation	x
The deviations of the age from the mean age	sx
" " " " yield " " " yield	sy
The co-variance of age and 305 days milk yield deviations	sxy
Significant	Sig.
Not significant	N.Sig.
Degrees of Freedom	D.F.
2. Heritability	
Dam-daughter pairs	D.D.pairs
Deviations of daughters from the mean	sy
Square " " " " "	sy^2
Deviations of dams from the mean	sx
Square " " " " "	sx^2
Co-variance of dam-daughter deviations	sxy
Heritability	h^2
Regression of daughters over dams	$b_{D.Dams}$

Item	Symbol
3. <u>Genetic Correlation</u>	
Genetic Correlation between the 1st-2nd 305 days milk yield	rGL_1L_2
Regression of daughter's 1st 305 days yield on dam's second 305 days yield	bL_1L_2
Regression of daughter's 2nd 305 days yield on dam's 1st 305 days yield	bL_2L_1
Regression of daughter's 1st 305 days yield on dam's 1st 305 days yield	bL_1L_1
Regression of daughter's 2nd 305 days yield on dam's 2nd 305 days yield	bL_2L_2
Genetic Correlation between 1st 70 days yield and the 1st 305 days yield	rGI_1L_1
Regression of daughter's 1st 70 days yield on dam's 1st 305 days yield	bI_1L_1
Regression of daughter's 1st 305 days yield on dam's 1st 70 days yield	bL_1I_1
Regression of daughter's 1st 70 days yield on dam's 1st 70 days yield	bI_1I_1
Genetic Correlation between 2nd 70 days yield and the 2nd 305 days yield	rGI_2L_2
Regression of daughter's 2nd 70 days yield on dam's 2nd 305 days yield	bI_2L_2
Regression of daughters 2nd 305 days yield on dam's 2nd 70 days yield	bL_2I_2
Regression of daughter's 2nd 70 days yield on dam's 2nd 70 days yield	bI_2I_2

MATERIAL AND METHOD.

A. Source of Data.

This study comprises ten herds from the highest 2% in milk yield in England. The breeds dealt with are: British Friesian, Shorthorn, Jersey, Guernsey and Kerry. The Kerry herd was included only in our study of the heritability and genetic correlations.

These herds comprised 1126 cows with over 3000 lactations ranging from the first to the fourth. Although the numbers of the cows and records dealt with is large, yet it should be borne in mind that it is a selected sample. The animals involved in the study are among the best 2% of all the herds in England. As the aim of this investigation is limited to certain points and aspects which have been mentioned before (page .4.) the relative size of the data and the standard of production of the animals have been taken into consideration when the results are discussed later on.

The information necessary for the analysis was extracted from the milk record books of the/

the farmers and put into a standard form as shown below:

Breed: Herd: Pedigree: Dam No.: Sire No.: Cow No.: Birth: Age at 1st calving : No.: and date of lactation: Sex of calf: Services required for calving: Diseases: Calving interval: Length of lactation: Dry period: Previous calving interval: Previous dry period: B.F.: Intensity: Yield: 305 days yield: Persistency:
Monthly yield (note if incomplete)
___/___/___/___/___/___/___/___/___/___/___/

Only the pedigree animals of each breed were included. The records affected by diseases were excluded. These diseases were mainly abortion, mastitis, tuberculosis and udder troubles.

The data are dealt with on the basis of units of ten gallons. Age is measured in months with approximation to the nearest month. The first four days of the lactation have not been included. The three times milking records were corrected to a twice milking basis, when that was necessary, by using the correction factor of .83 approved by the U.S. Dairy Department. In no other circumstances were correction factors used, except for the biggest Friesian /

Friesian herd, which was corrected for the month of calving to study its effect on the repeatability.

Age correction factors were calculated on a herd basis and used when the study needed such application.

B. METHOD OF ANALYSIS

I. Preparatory Treatment.

Prior to the main analysis, a preliminary study was made of the effects of some environmental factors upon milk yield . Those most important were (1) the effect of age, (2) the effect of the season of calving, (3) the effect of age at first calving upon the milk yield in the first lactation.

The effect of month of calving upon the 305 days and total milk yields has been studied by the analysis of variance method. This method was applied to every herd to measure the significance of differences in the season of calving and to calculate the necessary correction factors for such effects. Tables Nos. 1 and 2 show the relation between the months of calving and both 305 days and total milk yield respectively.

The corrections for the different calving seasons were obtained by comparing the over-all average 305 days yield (or the total milk yield) with the average for groups of cows which calved in the different months. The fourth lactation was grouped with the subsequent lactations. Finally, an average correction factor for each herd was calculated from the average of each monthly ratio in the four lactation groups/

TABLE 1.

Relative Total Milk Yield for Cows calving in different months of the Year.

Breed	Herd No.	Jan.	Feb.	Mar.	Apr.	May	June	July	Aug.	Sep.	Oct.	Nov.	Dec.
Shorthorn	8	1.08	.90	1.09	1.15	1.05	.98	.87	.94	.96	1.07	1.05	.99
	9	.98	.96	.94	.91	.96	1.02	1.01	.98	1.05	1.09	1.06	1.06
Friesian	1	1.09	.98	1.05	.95	1.00	.89	.88	.92	.96	1.01	1.07	.96
	2	.92	1.00	.96	.97	1.06	.92	1.09	1.07	1.06	1.01	.97	1.01
	3	1.04	1.01	1.05	1.01	1.01	.96	.93	.89	.97	1.06	1.07	1.02
Jerseys and Guernseys	J. 6	1.08	1.07	1.04	.93	.80	.88	.87	.93	1.07	1.01	1.13	1.20
	J.10	.94	.98	1.12	1.03	1.06	1.07	.86	.91	.98	1.08	1.05	1.03
	G 4	1.03	1.08	1.12	1.17	.97	1.02	.96	.98	.92	.98	.90	1.12
	G.12	.96	1.06	.95	1.10	1.08	1.13	1.03	.91	.90	.95	1.15	1.00
Average of All Breeds		1.03	1.07	1.04	1.02	1.04	1.02	.92	.93	.99	1.04	1.04	1.02

TABLE 2.

Relative 305 Days Milk Yield for Cows calving in the different months of the Year.

Breed	Herd No.	Jan.	Feb.	Mar.	Apr.	May	June	July	Aug.	Sep.	Oct.	Nov.	Dec.
Shorthorn	8	1.10	.86	1.10	1.00	1.07	.95	.89	.90	.96	1.07	1.06	.99
	9	1.00	.97	.96	.91	.94	1.00	.98	.98	1.03	1.08	1.07	1.08
Friesian	1	1.09	1.09	1.01	.94	1.02	.85	.96	.95	1.03	.98	1.09	.99
	2	.93	.98	.95	.91	.96	.86	1.00	1.02	1.06	1.02	.99	1.03
	3	.99	.96	1.01	1.04	.99	.93	.92	.96	.95	1.05	1.06	1.04
Jersey and Guernsey	G.6	1.10	1.10	1.05	.94	.93	.88	.85	.90	1.04	1.00	1.13	1.21
	G.10	1.04	1.03	1.02	1.04	1.00	.93	.87	.90	.99	1.04	1.10	1.02
	J.4	1.02	1.10	1.13	1.02	.96	.95	.94	.98	.88	.98	.95	1.15
	J.12	.97	1.04	.99	1.13	1.04	1.15	1.05	.92	.90	.98	1.19	1.02
Average of All Breeds		1.01	.98	1.03	.99	1.01	.93	.92	.93	.99	1.04	1.05	1.04

groups, as shown in tables 1 and 2. This is well illustrated in fig. 1 where the curves for both 305 days and total milk yield based on the data are given.

These tables show that both 305 days and total milk yield are affected by seasonal variations in the same way. The favourable months are the same in the two items, being October to March. The differences between herds in the favourable season of calving - confirmed by various workers in this field - suggest that such differences are due to management or nutrition, rather than seasonal factors in the narrow sense, i.e. the types of crops and pasture grown on the farm changes with the seasons of the year, and consequently the cows which calve during the favourable period of the year give more milk because they enjoy better food and a longer period of grazing.

When comparing the averages for all herds from different breeds with averages for individual herds in the different months, we found that the latter do not follow the general trend of change and that each herd deviates from the general mean in a different way. These differences between herds in their reaction to seasonal variations suggest that the management was different in these herds and indicate/

indicate that it can to a certain extent neutralize the effect of seasonal factors. It is always very difficult to find what are the conditions of feeding and management in different herds, hence when analysing data, it is necessary that correction factors, if used, should be based on an intra-herd basis. This allows for the local influences.

General correction factors derived from many herds could be used only if strong evidence exists that the herds have been kept under very similar systems of feeding and management.

The effects of the different seasons of the year show that the variation in the 305 days yield due to seasonal variations in all lactations is 1.6% compared with 3.7% for the total yield (tables 3 and 4). This agrees with Dickerson's results (1941) for the 305 days yield, but not with those for the 365 days. His results are 1.9% and 1% respectively. He also says that longer lactations are bound to show smaller relative influence of the season of calving due to the greater total variance for longer records. This is not the case here; the amount of variance caused by the calving season upon the total milk yield is approximately double that of the 305 days yield. This may be due to variations between calving intervals in the different seasons. These variations/

TABLE 3.

The Relation between the month of calving and the 305 days milk yield (Level of Significance 5%)

Breed	Herd No.	1st Lactation			2nd Lactation			3rd Lactation			4th Lactation		
		Total Mean Square	Mn. Sq. within months	Nature of Variance Ratio	1	2	3	1	2	3	1	2	3
Shorthorn	9	206	193	N.S.	218	230	N.S.	261	262	N.S.	434	457	N.S.
	8	176	187	Sig.	251	228	Sig.	280	258	N.S.	499	401	Sig.
Friesian	1	560	491	Sig.	827	853	N.S.	1185	1369	Sig.	1234	1194	N.S.
	2	416	418	N.S.	917	847	Sig.	1114	1028	N.S.	1209	1096	N.S.
	3	301	290	Sig.	343	360	Sig.	413	408	N.S.	467	456	Sig.
Jersey and Guernsey	1	194	196	N.S.	278	254	N.S.	288	345	N.S.	762	790	N.S.
	2	236	208	N.S.	305	265	N.S.	345	396	N.S.	325	249	Sig.
	3	247	246	N.S.	301	311	N.S.	458	401	N.S.	583	565	N.S.
	4	162	78	Sig.	312	527	Sig.	570	533	N.S.	391	407	N.S.
All Breeds		2498	2307		3752	3875		4914	5000		5904	5615	

Total Mean Square = 17068
Total Squares within months = 16797
Average difference between
months = 271
Percent. = 1.6

Variance between months of Calving (in Percent.)

Lact. 1st	7.6
2nd	-
3rd	-
4th onwards	4.9

TABLE 4.

The Relation between the month of calving and the total milk yield (Level of Significance 5%)

Breed	Herd	1st Lactation			2nd Lactation			3rd Lactation			4th Lactation		
		1	2	3	1	2	3	1	2	3	1	2	3
Shorthorn	9	282	265	N.S.	282	301	N.S.	331	339	N.S.	501	524	N.S.
	8	323	289	Sig.	280	259	N.S.	506	281	Sig.	586	496	Sig.
Friesian	1	939	883	N.S.	1199	1003	N.S.	1773	1882	N.S.	1570	1430	Sig.
	2	586	602	N.S.	1186	1122	N.S.	1652	1726	N.S.	1615	1571	N.S.
	3	435	424	N.S.	489	462	Sig.	496	479	N.S.	685	680	N.S.
Jersey and Guernsey	1	340	400	N.S.	342	302	N.S.	426	657	N.S.	1588	1209	Sig.
	2	271	311	N.S.	328	440	Sig.	450	615	N.S.	384	284	Sig.
	3	383	420	Sig.	550	560	N.S.	611	607	N.S.	1378	1346	N.S.
	4	324	295	N.S.	797	622	Sig.	684	468	Sig.	780	865	N.S.
All Breeds		3883	3889		5453	5071		6929	7054		9087	8405	

Total Mean Square = 25352
Mean Sq. within months = 24419
Difference due to between months = 933
Percent. = 3.7

Variance due to month of calving (in percent)

Lact.	1st	-
	2nd	7.00
	3rd	-
	4th onwards	7.5

variations would be expected to affect the total yield more than the 305 days yield (see fig. 1). The variance due to the month of calving when computed for each lactation separately showed that the variation ranges from 7.6 to 4.9% with the 305 days yield, while it is from 7.0 to 7.5% with the total milk yield (tables 3 and 4). The nature of the effect is not the same in the 305 days and total milk yields. The first lactation in the 305 days was affected to a greater extent by the season of calving than was that of the total milk yield (7.6 and .00 respectively). While the second lactation in the total milk yield showed a variation of 7%, that of the 305 days did not show any significant effect. The third lactation was not affected in either case, but the fourth lactation showed more pronounced effect in the total milk yield than the 305 days yield (7.5% and 4.9% respect-:ively).

However, the general effect on both items is not very appreciable since it does not exceed 3.4% of the total variance in the total milk yield and 1.6% in the 305 days milk yield in all lactations.

Although this was evidently proved, yet the results could not be generalized without reservation. The/

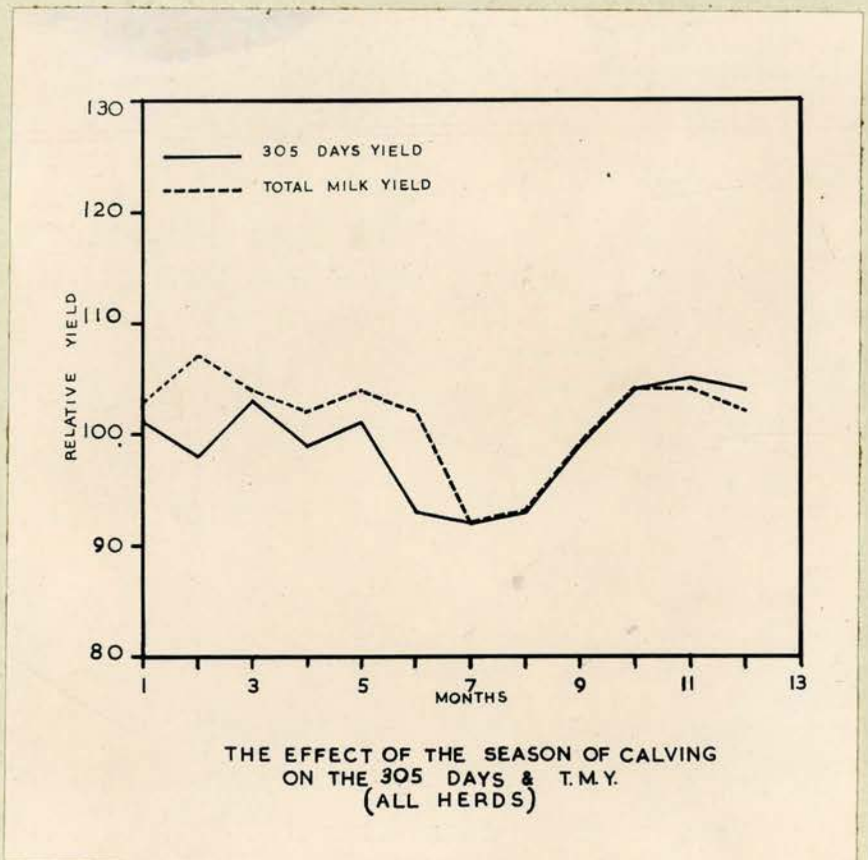
130
120
110
100
90
80
RELATIVE YIELD
305 DAYS YIELD
TOTAL MILK YIELD
1
3
5
7
9
11
13
MONTHS
THE EFFECT OF THE SEASON OF CALVING
ON THE 305 DAYS & T.M.Y.
(ALL HERDS)

Fig. 1.

TABLE 5.

Repeatability of Friesian Herd No. 3.

Lactation	Uncorrected						Lactation	Corrected					
	2nd	N	3rd	N	4th	N		2nd	N	3rd	N	4th	N
1st	+.50	163	+.39	126	+.43	97	1st	+.26	161	+.36	123	+.39	93
2nd			+.55	130	+.53	102	2nd			+.54	127	+.51	100
3rd					+.79	106	3rd					+.59	106

TABLE 6.

The Effect of Age on the 305 days yield in the Successive Lactations.

Breed	Herd No.	1st Lact.	2nd Lact.	3rd Lact.	4th Lact.
Shorthorn	8	1.00	1.17	1.30	1.40
	9	1.00	1.07	1.23	1.32
Friesian	3	1.00	1.15	1.35	1.47
	2	1.00	1.14	1.37	1.47
	1	1.00	1.12	1.31	1.30
Jersey	6	1.00	1.14	1.25	1.28
	10	1.00	1.03	1.16	1.22
Guernsey	12	1.00	.90	1.15	1.15
	4	1.00	1.18	1.27	1.48

TABLE 7.

The Effect of Age on the Total Milk Yield in the Successive Lactations

Breed	Herd No	1st Lact.	2nd Lact.	3rd Lact.	4th Lact.
Shorthorn	8	1.00	1.15	1.25	1.38
	9	1.00	1.02	1.18	1.27
Friesian	3	1.00	1.14	1.31	1.44
	2	1.00	1.12	1.32	1.45
	1	1.00	1.11	1.20	1.25
Jersey)	6	1.00	1.12	1.24	1.33
)	10	1.00	.98	1.10	1.11
Guernsey)	12	1.00	1.22	1.13	1.14
)	4	1.00	1.09	1.22	1.50

The data which we dealt with were large enough; they comprised 2994 305 days milk records and 3581 total milk records. They came from among the top 2% of all herds in England, and such herds are supposed to be among the best managed and cared for. This comparatively good standard of feeding and management is expected to neutralize the effects of seasonal variations in milk yield and consequently their contribution to the total variance is expected to be rather small. This seems to be the reasonable explanation to our results.

The general (over-all herds) correction factors obtained here would be expected to be correct only on the average for the whole population and in all lactations. If they are applied to individual herds they should not be expected to give the same accuracy because of the differences which exist between herds. Each herd is an independent unit in itself either in management or constitution, and so it shows a distinct characteristic feature in its response to the season of calving. This implies the necessity of using special correction factors for each herd in order to make as small as possible the errors of correction which are bound to occur if those general factors are used.

The/

The correction factors for the month of calving were applied to the biggest Friesian herd (No. 3). The repeatability before and after correc-:tion was estimated, and no effective difference was found between the corrected and the uncorrected repeatabilities. It was therefore decided that the data should not be corrected. (Table 5).

The other set of correction factors was that for the effect of age on the successive lac-:tations. Tables 6 & 7 show the age correction factors for both 305 days and total milk yield respect-:ively. These factors were computed by the paired lactation method.

THE EFFECT OF AGE AT FIRST CALVING ON THE FIRST LACTATION MILK YIELD.

The effects of the two tangible causes of variation in milk yield, i.e. month of calving and age in lactations, have been discussed briefly before. But, owing to the fact that the third cause of the non-heritable variation in milk yield (age at first calving) has a pronounced influence upon the cow's milk production, especially that of the first lactation, the problem was investigated thoroughly in this work.

The method used was that of the regression of milk yield upon age, in order to find out the relation between milk production and the increase in age at first calving. The following tables (8 and 9) give the results for the Shorthorn herds for both 305 days and total milk yield respectively. They show that the gain in milk yield obtained per month in the total milk yield is half that of the 305 days yield.

In the Friesians the gain obtained per month of age is the same in both 305 days and total milk yield (Tables 10 and 11). The Channel Island breeds differ from the other breeds in that the gain obtained in the total milk yield is very high when compared with that of the 305 days (Tables 12 and 13).

Comparing/

TABLE 8.

The Effect of Age at First Calving on the First Lactation 305 Days Milk Yield (Shorthorns).

Herd	No. of Cows	Regression Equation	Mean Average of age in mths.	Sy^2	Sx^2	Sxy	$Sy^2-\frac{(sxy)^2}{sx^2}$	$b_{y_1A_1}$	Range of Age in Months.
8	143	10 + 1.4x	34.3	42693	3570	4999	35694	1.4	29 - 43
9	135	4.8 + 2.0x	32.05	27357	996	1963	23689	1.9	28 - 43
	278	13.5 + 1.5x	33.2	70250	4566	6962	59383	1.5	28 - 43

		D.F.
Total Deviation within groups	70250	276
Removed by regression	10615	1
Deviations from regressions	59635	275

Significance of differences between regression:

	Sum of Squares	D.F.	M.Square.
Difference between slopes	252	1	252
Residual difference	59383	274	217
Total "	59635	275	

F. for greater mean square = $\frac{252}{215}$ = 1.2 N.Sig.

TABLE 9.

The Effect of Age at First Calving on the First Lactation Total Milk Yield in the Shorthorn.

Herd	No. of Cows	Regression Equation	Mean Average of age in mths.	Sy^2	Sx^2	Sxy	$Sy^2 - \frac{(sxy)^2}{sx^2}$	$b_{T_1 A_1}$	Range of Age in Months.
8	147	56.8 + .12x	34.9	47172	823	103	47159	.12	29 - 43
9	138	31.3 + 1.3x	32.1	38672	996	1271	37050	1.27	28 - 43
	285	38.6 + .76x	37.05	85844	1819	1374	84209	.76	28 - 43

		D.F.
Total Deviation within groups	85844	283
Removed by regression	1037	1
Deviations from regressions	84807	282

Significance of difference between regression:

	Sum of Squares	D.F.	M.Square
Difference between slopes	598	1	598
Residual difference	84209	281	300
Total "	84807	282	

F. for greater mean square = $\frac{598}{300}$ = 2.00 N.Sig.

TABLE 10.

The Effect of Age at First Calving on the First Lactation 305 Days Yield (Friesians).

Herd	No. of Cows	Regression Equation	Mean Average of age in mths.	Sy^2	Sx^2	Sxy	$Sy^2 - \frac{(sxy)^2}{sx^2}$	$b_{Y_1 A_1}$	Range of Age in Months.
1	101	48.7 + 1.2x	33.6	56318	1904	2342	53438	1.2	20 - 48
2	202	78.6 + .6x	25.6	83872	1966	1214	83123	.62	21 - 39
3	231	54.1 + .4x	34.8	65382	6433	2388	64506	.37	22 - 58
	534	63.8 + .59x	31.1	205572	10303	5944	201067	.58	20 - 58

		D.F.
Total Deviation within groups	205572	531
Removed by regression	3429	2
Deviations from regressions	202143	529

Significance of differences between regressions:

	Sum of Squares	D.F.	M.Square
Difference between slopes	1076	2	538
Residual difference	201067	527	382
Total "	202143	529	

F. for greater mean square = $\frac{538}{382}$ = 1.4 N.Sig.

Comparing the three breeds together we find that the Shorthorn gain is 15 gallons of milk in their 305 days milk yield for every month increase in their age at first calving, while the Friesians gain is about 5.8 gallons. The Channel Island breeds came last as they do not gain more than 1.9 gallons of milk. This suggests that the Channel Island breeds, being the smallest in size, mature earlier than any of the other breeds investigated.

The gain in the three groups of breeds in total milk yield is nearly the same, being 7.6, 6.9 and 8.4 gallons for the Shorthorns, Friesians and Channel Island breeds respectively. The discrepancy between these results and those for the 305 days in milk yield could be explained by the fact that the 305 days record is a standardised one. The exceedingly long lactation period in the latter case may also be responsible for a part of this difference.

Turner (1932) found an increase in average milk yield of 40 gallons for the Jersey breed between 24 and 30 months of age at first calving. This corresponds to 6.6. gallons increase per month. He found double this value for the Guernseys.

Beam/

Beam (1918) obtained an increase of 9 gallons in his Shorthorn cattle for every month's increase in their age at first calving.

Gains (1934) obtained an increase of 6 gallons in his Friesians, while Johansson (1941) estimated the increase in milk yield per month in his Swedish Red and White Cattle at 6-8 gallons with each month of increase in their age at first calving.

One would expect that the different estimates would not be exactly the same in the various studies. What really matters is the existence of the influence of age itself rather than its degree. The differences in the various environments under which the herds were raised, the management, and the plane of nutrition would undoubtedly affect the response of the animals to the influence of age at first calving on their milk yield.

The average ages for breed groups were 27.4, 31.4, 33.2 and 37.05 months in the Jerseys, Guernseys, Shorthorns and Friesians respectively. With the exception of the Jerseys, the age averages for the other breeds seem to be somewhat higher than these reported by Turner (1932) which are 27.3, 28.5, 28.8 months for Jerseys, Guernseys and Friesians /

Friesians respectively. This may be due to the fact that the herds investigated by Turner were under better management and in a better environment than the animals with which we dealt. Good management and environmental conditions would naturally encourage their growth and enable them to calve at an earlier age.

The fact that not much gain would be expected by delaying breeding in any of the above breeds beyond a certain age is well illustrated here. The increases in milk production in different breeds may seem different in amount if they are taken at their face value, but they are not very far removed from each other when they are compared with the average milk yields of their respective breeds. How:ever, this increase has a limit. As was reported previously by other workers, no gain in milk yield can be expected if Shorthorns or Friesians are delayed in their breeding beyond 30 months of age.

Some farmers, because of their keenness to secure the maximum milk production from their cows, prefer to delay their first calving as long as poss:ible. When considering this from the economic point of view, they should realize that maximum milk production is not the only factor which ensures their maximum profit. It is the efficiency of milk production/

production rather than its quantity which should be their main concern.

Undoubtedly, the age of the heifer at first calving have a direct bearing upon the economical production of milk. The period from birth to the time of first calving is a non-productive period in the life of the dairy cow. Anything which can be done to minimize the cost of raising of the heifer to a productive age will affect her efficiency of milk production and increase the profits of the farmer.

Therefore, such farmers should breed their heifers at an earlier age. But the problem of defining the most satisfactory age is not an easy one.

The age effect is bound up with the growth and maturity of the animals, and the local conditions of feeding etc. in the different farms are not the same. The abundance and richness of pasture play their part in encouraging the growth of the heifers and allow them to approach their mature size at an early age. The farmer must not breed his heifers until they reach a satisfactory stage of development, which may be taken as "maturity". The correct age at which to breed heifers will then be/

TABLE 11.

The Effect of Age at First Calving on the First Lactation Total Yield (Friesians)

Herd	No. of Cows	Regression Equation	Mean Average of age in mths.	Sy^2	Sx^2	Sxy	$Sy^2 - \frac{(sxy)^2}{sx^2}$	$b_{T_1A_1}$	Range of Age in Months.
1	122	43 + 1.6x	33.6	114798	2407	3945	108333	1.6	20 - 48
2	204	90.3 + .3x	25.6	130016	2028	630	129821	.31	21 - 39
3	233	55.1 + .4x	34.7	107303	6500	2949	105966	.45	22 - 58
	559	42.3 +.69x	31.1	352117	10935	7524	344120	.69	20 - 58

		D.F.
Total Deviation within groups	352117	557
Removed by regression	5177	2
Deviations from regressions	346940	555

Significance of differencesbetween regressions:

	Sum of Squares	D.F.	M.Square
Difference between slopes	2820	2	1410
Residual difference	344120	553	622
Total "	346940	555	

F. for greater mean square = $\frac{1410}{622}$ = 2.3 N.Sig.

TABLE 12.

The Effect of Age at First Calving on the First Lactation 305 days yield (Jerseys and Guernseys)

Herd	No. of Cows	Regression Equation	Mean Average of age in mths.	Sy^2	sx^2	Sxy	$Sy^2 - \frac{(sxy)^2}{sx^2}$	$b_{Y_1A_1}$	Range of Age in Months.
12 J.	24	106.15 - .19x	28.5	2856	292	- 55	2846	- .19	24 - 40
10 G.	89	59.7 + .01x	31.3	21706	2540	31	21705.6	+ .01	25 - 66
6 G.	41	54.3 + .33x	29.3	9355	676	223	9279	+ .33	21 - 40
4 J.	52	41.8 +.9x	26.9	9344	689	602	8818	+ .87	17 - 39
	206	57.0 + .19x	29.9	43261	4197	801	42648.6	+ .19	17 - 66

		D.F.
Total Deviation within groups	43261	203
Removed by regression	152	3
Deviations from regressions	43109	200

Significance of differences between regressions:

	Sum of Squares	D.F.	M.Square
Difference between slopes	460.4	3	153.4
Residual difference	42648.6	197	216
Total "	43109	200	

F. for greater mean square $= \frac{216}{153.4} = 1.4$ N.Sig.

TABLE 13.

The Effect of Age at First Calving on the First Lactation Total Yield (Jerseys and Guernseys)

Herd	No. of Cows	Regression Equation	Mean Average of age in mths.	Sy^2	Sx^2	Sxy	$Sy^2 - \frac{(sxy)^2}{sx^2}$	$b_{T_1 A_1}$	Range of Age in Months.
6 G.	41	61.7 + .18x	29.3	13502	676	534	13161	.79	21 - 40.
10 G.	89	33.6 + 1.1x	31.3	34297	2540	2813	31182	1.10	25 - 66
12 J.	24	4.7 + 1.8x	28.5	6263	292	52	6253	1.78	24 - 40
4 J.	52	71.7 + .16x	26.9	17334	689	110	17317	.16	17 - 39
	206	46.6 + .84x	29.5	71476	4197	3509	67913	+.84	17 - 66

		D.F.
Total Deviation within groups	71476	203
Removed by regression	2933	3
Deviations from regressions	68543	200

Significance of differences between regressions:

	Sum of Squares	D.F.	M.Square.
Difference between slopes	630	3	210
Residual difference	67913	197	345
Total "	68543	200	

F. for greater mean square $= \frac{345}{210} = 1.6$ N.Sig.

be different in different herds according to the standards of management and feeding.

The differences in the planes of feeding in different farms make it necessary that the problem should be re-investigated on the basis of practical experiments specially planned for that purpose. In such experiments the feeding and management of animals could be adjusted in such a way that the real effect of age on milk production could be measured.

In addition, the age at first calving is rather important from the standpoint of improvement. If the heifers are bred to calve early, the generation length is shortened and consequently the amount of improvement per year tends to be greater. Thus the standard of improvement aimed at could be reached in less time, at lower expense, and with less labour.

2. THE REPEATABILITY OF THE 305 DAYS AND TOTAL MILK YIELDS.

The repeatability of milk records may be defined as the fraction of variance in these records which is due to permanent individual differ:ences (mostly genetical and some environmental). This can be estimated by the correlation coefficient between the successive as well as the non-successive records of the same cow. Such an estimate measures the amount of variation due to all genetic causes and to those environmental causes which accompany the cow all through her life.

In estimating the milking ability of dairy animals, one is confronted with two problems:

1) Different cows do not give the same number of lactations during their lives;

2) Records made by any cow through the different lactations are liable to different environmental effects.

Lush (1941), taking into consideration the factors mentioned previously, developed a formula for calculating as accurately as possible a cow's potential milking ability on more than one record for/

for each cow as follows:

$$= \frac{nr \quad (\text{her average record})}{1 - r + nr}$$
$$\overline{1 - r \quad (\text{herd average record})}$$

or, $$= \text{Herd average} + \frac{nr}{1 + (n-1)r} (\text{cow's average} - \text{herd average.})$$

where r = the correlation between the successive records (repeatability)

and n = the number of records given by the cow.

The estimation of the repeatability of milk records gives an approximate picture of their genetic worth. Wright (1921) stated that "all the genetic variability contributes to the repeatability, which is the correlation between the recurrent ex:pressions of a characteristic by the same animals." In other words, the repeatability is the upper limit to the heritability.

Lush and Arnold (1937) have reported that heritability comprises about two-thirds of the re:peatability for butterfat production records.

In estimating the repeatability of milk yield, both 305 days and total milk yields were examined. The correlation coefficients between successive lactaions were calculated for all the possible combinations of 1st, 2nd, 3rd and 4th lac:tations. The correlations between non-consecutive as/

TABLE 14.

The Repeatability Estimates for the Shorthorn Breed (305 days milk yield)

Herd No.	Bivariates Correlated													Average
	No.	1st,2nd	No.	2nd,3rd	No.	3rd,4th	No.	1st,3rd	No.	2nd,4th	No.	1st,4th	T.No.	
8	102	+.59	68	+.68	52	+.76	63	+.53	53	+.63	49	+.63	387	+.65
9	84	+.59	39	+.50	20	+.43	31	+.14	12	+.54	12	+.11	198	+.48
14	38	+.68	18	+.55	15	+.18	11	+.23	6	-	4	-	92	+.53
	226	+.60	125	+.62	87	+.64	105	+.41	71	+.59	65	+.56	677	Total Average +.59 ±.039

TABLE 15

The Repeatability Estimates for the Friesian Breed (305 days milk yield)

Herd No.	Bivariates Correlated													Average
	No.	1st,2nd	No.	2nd,3rd	No.	3rd,4th	No.	1st,3rd	No.	2nd,4th	No.	1st,4th	T.No.	
3	163	+.50	130	+.55	106	+.79	126	+.39	102	+.53	97	+.43	724	+.54
2	154	+.54	92	+.61	41	+.57	85	+.35	38	+.52	37	+.38	447	+.51
1	88	+.47	74	+.54	55	+.63	63	+.59	50	+.43	39	+.79	369	+.49
	405	+.51	296	+.56	202	+.71	274	+.43	190	+.51	173	+.52	1540	Total Average +.52 ±.026

TABLE 16.

The Repeatability Estimates of the Guernsey and Jersey Breeds (305 days milk yield).

Herd No.	Bivariates Correlated													Average
	No.	1st,2nd	No.	2nd,3rd	No.	3rd,4th	No.	1st,3rd	No.	2nd,4th	No.	1st,4th	T. No.	
6 G.	37	+.58	29	+.49	17	+.77	26	+.35	18	+.64	16	+.42	143	+.55
10 G.	75	+.59	44	+.51	24	+.66	40	+.39	18	+.64	16	+.49	217	+.55
	112	+.59	73	+.50	41	+.70	66	+.36	36	+.64	32	+.46	360	Total Av. +.55
4 J.	27	+.66	17	+.09	11	+.62	15	+.19	7	+.28	9	+.57	86	+.46
12 J.	21	+.21	21	+.10	21	+.40	19	-.07	12	-.09	10	-.08	104	+.12
	48	+.49	38	+.10	32	+.47	34	+.04	19	+.02	19	+.25	190	Total Av. +.28
	160	+.56	111	+.38	73	+.62	100	+.27	55	+.48	51	+.40	550	Total Av. +.46 ±.043

TABLE 17.

The Repeatability Estimates for the Shorthorn Breed (Total Milk Yield)

Herd No.	Bivariates Correlated												Total Number	Total Average
	No.	1st,2nd	No.	2nd,3rd	No.	3rd,4th	No.	1st,3rd	No.	2nd,4th	No.	1st,4th		
8	103	+.63	68	+.62	52	+.53	63	+.63	53	+.63	49	+.49	388	+.60
9	89	+.65	40	+.43	19	+.58	33	+.10	15	+.57	14	+.27	210	+.51
14	37	+.65	25	+.65	15	+.26	12	-.11	6	-	4	-	99	+.51
	229	+.64	133	+.57	86	+.50	108	+.39	74	+.60	67	+.45	697	+.53 ±.038

TABLE 18.

The Repeatability Estimates for the Friesian Breed (Total Milk Yield)

Herd No.	Bivariates Correlated												Total Number	Total Average
	No.	1st, 2nd	No.	2nd, 3rd	No.	3rd, 4th	No.	1st, 3rd	No.	2nd, 4th	No.	1st, 4th		
3	163	+.46	129	+.51	108	+.59	125	+.26	105	+.46	100	+.34	730	+.45
1	92	+.50	73	+.47	56	+.56	61	+.50	50	+.66	39	+.54	371	+.51
2	158	+.66	91	+.60	41	+.64	85	+.38	35	+.53	38	+.38	448	+.57
	413	+.55	293	+.53	205	+.59	271	+.36	190	+.54	177	+.39	1549	+.51 ±.026

TABLE 19.

The Repeatability Estimates of the Guernsey and Jersey Breeds (Total Milk Yield)

Herd No.	Bivariates Correlated No.	1st,2nd	No.	2nd,3rd	No.	3rd,4th	No.	1st,3rd	No.	2nd,4th	No.	1st,4th	Total Number	Total Average
6 G.	37	+.52	29	+.89	17	+.82	22	+.39	19	+.38	17	+.29	141	+.61
10 G.	75	+.24	44	+.51	23	-.53	41	+.22	18	+.20	16	+.32	217	+.22
	112	+.34	73	+.71	40	+.13	63	+.27	37	+.29	33	+.30	358	+.38
4 J.	27	+.18	17	+.20	11	+.48	14	-.14	7	-.09	9	+.06	85	+.14
12 J.	22	+.36	21	+.04	20	+.49	20	+.02	12	-.09	10	-.01	105	+.18
	49	+.26	38	+.11	31	+.48	34	-.04	19	-.08	19	+.03	190	+.15
G & J	161	+.31	111	+.56	71	+.29	97	+.20	56	+.19	52	+.22	548	+.32 ±.047

as well as consecutive lactations were studied to see whether changes in environment and the lapse of a longer period of time between records would affect their degree of similarity.

The repeatabilities for the different herds and breeds for the 305 days, in our study, are given in tables 14, 15 and 16 and in tables 17, 18 and 19 for the total milk yield.

We used in averaging the correlations the method suggested by Lush (1931) and set out in Snedecor (1948) "Statistical methods" (p. 151). The repeat:abilities were calculated on a within-herd basis.

The investigation dealt first with the herds independently, and, secondly, with the herds of each breed grouped together. This was to find out whether there is a breed difference or not. The same steps were taken for both 305 days and total milk yield.

Herd, breed and all-over repeatabilities for the 305 days yield were compared with those of the total milk yield to see if there is any difference between the two estimates.

Only one Friesian herd (No.3) was treated in both the corrected and uncorrected way, as mentioned previously/

TABLE 20.

The Repeatability for All the Breeds (305 days milk yield)

Herd No.	Breed	No.	1st,2nd	No.	2nd,3rd	No.	3rd,4th	No.	1st,3rd	No.	2nd,4th	No.	1st,4th	Total No.	Total Average	S.E.
		Bivariates Correlated														
8	Shorthorn	102	+.59	68	+.68	52	+.76	63	+.53	53	+.63	49	+.63	387	+.65	±.051
9	"	84	+.59	39	+.50	20	+.43	31	+.14	12	+.54	12	+.11	198	+.48	±.072
14	"	38	+.68	18	+.55	15	+.18	11	+.23	6	-	4	-	92	+.53	±.106
6	Guernsey	37	+.58	29	+.49	17	+.77	26	+.35	18	+.64	16	+.42	143	+.55	±.085
10	"	75	+.59	44	+.51	24	+.66	40	+.39	18	+.64	16	+.49	217	+.55	±.068
4	Jersey	27	+.66	17	+.09	11	+.62	15	+.19	7	+.28	9	+.57	86	+.46	±.110
12	"	21	+.21	21	+.10	21	+.40	19	-.07	12	-.09	10	-.08	104	+.12	±.099
3	Friesian	163	+.50	130	+.55	106	+.79	126	+.39	102	+.53	97	+.43	724	+.54	±.037
1	"	88	+.47	74	+.54	55	+.63	63	+.59	50	+.43	39	+.79	369	+.49	±.052
2	"	154	+.54	92	+.61	41	+.57	85	+.35	38	+.52	37	+.38	447	+.51	±.047
		791	+.54	532	+.54	362	+.68	479	+.40	316	+.52	289	+.52	2767	+.53	±.019

TABLE 21.

The Repeatability Estimates for All Breeds (Total Milk Yield)

Herd No.	Breed	Bivariates Correlated No.	1st,2nd	No.	2nd,3rd	No.	3rd,4th	No.	1st,3rd	No.	2nd,4th	No.	1st,4th	Total No.	Total Average	S.E.
8	Shorthorn	103	+.63	68	+.62	52	+.53	63	+.63	53	+.63	49	+.49	388	+.60	±.051
9	"	89	+.65	40	+.43	19	+.59	33	+.10	15	+.57	14	+.27	210	+.51	±.069
14	"	37	+.65	25	+.65	18	+.26	12	-.11	6	-	4	-	82	+.48	±.110
6	Guernsey	37	+.52	29	+.89	17	+.82	22	+.39	19	+.38	17	+.29	141	+.61	±.085
10	"	75	+.24	44	+.51	23	-.53	41	+.22	18	+.20	16	+.32	217	+.22	±.068
4	Jersey	27	+.18	17	+.20	11	+.48	14	-.14	7	-.09	9	+.06	85	+.14	±.110
12	"	22	+.36	21	+.04	20	+.49	20	+.02	12	-.07	10	-.01	105	+.18	±.099
3	Friesian	163	+.46	129	+.51	108	+.59	125	+.26	105	+.46	100	+.34	730	+.45	±.037
1	"	92	+.50	73	+.47	56	+.56	61	+.50	50	+.66	39	+.54	371	+.51	±.052
2	"	158	+.66	91	+.60	41	+.64	85	+.38	35	+.53	38	+.38	448	+.57	±.047
		803	+.54	537	+.60	362	+.53	476	+.35	320	+.50	296	+.39	2794	+.49	±.019

previously (p. 50) the other records were used with-:out any correction.

The result of the overall repeatabilities are shown in tables 20 and 21 for both items.

Results and Discussion:

The results mentioned before show that the average repeatability for the 305 days milk yield in the different breeds is .46 ± .043 in the case of the Channel Island breeds, .59 ± .039 for the Shorthorns and .52 ± .026 for the Friesians; while it is .53 ± .019 for all the breeds over all lac-:tations. In the total milk yield it is .32 ± .047 for the Channel Island breeds, .53 ± .038 for the Shorthorns and .51 ± .026 for the Friesians; while it is .49 ± .019 for all the breeds over all lactations.

The differences between the repeatabilities are not very striking. This may suggest that there is no breed difference as regards repeatability, although it is very difficult to draw a definite conclusion owing to the limitation of the data, which consisted of only a small number of herds.

The results obtained for within-herd repeatability show that this is higher between the successive lactations than between the non-successive ones. This suggests the possibility that the longer the/

the period of time the greater is the change in management conditions, diseases etc. These may influence the milk production in such a way that the repeatability between the non-successive lactations is lowered.

Discussing the results of the different breeds one by one, we find that the Shorthorn (table 14) comprised three herds consisting of 679 records. The average repeatability of this breed is .59, which is rather high, suggesting that the three herds were under stabilised environmental conditions. The re:peatabilities of the consecutive lactations are much higher than those of the non-consecutive lactations. The lowest repeatability obtained in this breed was that between the first and third lactations, being .41. This is still within reasonable limits of estimation.

Our study of the Friesians (Table 15) was based on three herds with 1540 lactations. The average repeatability for over-all lactations was .52. The lowest repeatability obtained was that of .43, again between the first and third lactations.

When the Jerseys and Guernseys were grouped together (Table 16) the average repeatability for all lactations was found to be .46, but when each breed was/

was worked out by itself we obtained an estimate of .55 and .28 for Guernseys and Jerseys respectively. However, the lower repeatability of the Jerseys could not be as dependable as that of the Guernseys, since the numbers of Jersey records were comparatively smaller - 190 compared to 360 for Guernseys. In both breeds the lowest correlation was that between the 1st and 3rd lactations. This may add to our previous suggestions that the relation between the later re:cords is very close because they are near to maturity. But, as the difference in maturity of both the 1st and 3rd lactations is very marked, the degree of likeness is expected to be considerably lower.

The repeatability of the 1st and 4th lactations of .52 is comparatively weaker than any of the other repeatabilities with the exception of that of the 1st and 3rd lactations. This again could be due to the increased difference in time between the two lactations concerned.

The repeatability of the total milk yield in different breeds is shown in tables 17, 18, 19 and 21.

By/

TABLE 22

The Correlation between the 305 days yield and total milk yield in the various lactations

Lactations	n	r
1st Lactation	220	+ .94
2nd "	163	+ .95
3rd "	96	+ .95
4th "	48	+ .95
All Lactations	527	Av r + .95

By comparing the total milk repeatabilities with those of the 305 days yield we found that they are very similar and that they both follow the same trend. There is no significant difference between the two. It may, then, be concluded that the 305 day records tend to repeat themselves in succeeding years about as closely as the total milk yield. Therefore the 305 days record can be considered as reliable as the total milk yield for estimating the cow's milking ability. This has been confirmed by working out the correlation between the two estimates in the different lactations in one of the biggest herds (Friesian No. 2) which contained 527 observa-:tions in the first four lactations. The coefficients of correlations are .94, .95 and .96 for the 1st, 2nd, 3rd and 4th lactations respectively, and these are shown in table 22.

Moreover, the 305 days milk record excels that of the total milk yield for the following reasons:-

1) /

1) The 305 days is a standard lactation, which is free from the effects of non-pregnancy and of an unduly lengthened lactation period, which are often reflected in the total milk yield record.
2) The length of this lactation is a commercial one which encourages regular annual calvings.
3) The shorter the lactation the less is the need of correction factors for environmental in-:fluences.
4) Since it is in wide international use in dairying countries, comparison between records obtained here and abroad could be made with less error than at present.

In conclusion, we can state that the estimates of repeatability for our data, which are highly selected (10 herds of the top 2% in England) - nominally .53 ± .019 for the 305 days milk yield and .49 ± .019 for the total milk yield - are well justi-:fied, because we expect that such herds must have been under better than average management. This will help in standardizing and correcting the cows' records for the known environmental conditions, and the year-to-year variations are then expected to be very small, leading to higher estimates of repeatability.

In/

In general, we can summarize our results as follows:

1) Although the large numbers of records dealt with (2767 305-day records and 2794 total milk yield records) make the overall repeatability estimate mentioned before a fairly reasonable result, yet the small numbers of herds, especially in the case of the Channel Island breeds, made it difficult to make a conclusive decision regarding breed differences.

The results for the different breeds are summarized in the following table:-

Breed.	No. of Herds	No. of Records.	305 days Repeatability.	T.M.Y. Repeatability.
Friesians	3	1549	.52 ± .026	.51 ± .026
Shorthorns	2	697	.59 ± .038	.53 ± .038
Jerseys	2	190	.28 ± .023	.15 ± .023
Guernseys	2	385	.55 ± .017	.38 ± .017

2) The milk records (either 305 days or total milk yield) tend to repeat themselves most closely when they are from close lactations; the nearer the lactations, the higher is the correlation between them.

3) The later records, or the records nearer to maturity, show higher repeatability than the other records.

4) /

4) The repeatability of the 305 days and total milk yield is approximately the same.

As one would expect, there is a high correlation between the 305 days and total milk yield.

3. THE HERITABILITY OF MILK YIELD.

Many arguments have been used in the past concerning whether environment or heredity plays a more important part in determining the milk yield of cows; this debate and its like were solved by the fact that both are important, every character being both hereditary and environmental, since it is the result of the interaction of the two factors.

As milk yield is commonly accepted as a character which is highly responsive to changes in environment, only a fraction of the total observed variance in a population is actually accounted for by genetic action. The estimate of this fraction is known as the "heritability". This fraction is a statistic describing a particular population. It can be larger or smaller if the numerator (genotypic variation) or the denominator (causes of phenotypic variations) is altered. Thus it may vary from one population to another for the same character, as well as from one characteristic to another within the same population.

The heritability of milk yield has been measured in the usual way by taking twice the re-:gression of daughters on dams; all daughters being by the same sire. Environmental correlations between daughters/

TABLE 23.

The heritability estimate of first lactation 305 days yield. (Kerry Breed)

No. of Bulls	Dam-Daughter pairs	Sxy Covariance	Sx^2 Mean Sq. of dams	b Dam-Daughter regression	h^2 Heritability
40	279	4095.7	25489.6	+ .161 ± .0678	.322 ± .1256

Table 24.

The heritability estimate of first lactation 305 days yield. (Friesian Breed) *

No. of Bulls	D. D. pairs	Sxy	Sx^2	b	h^2
5	78	3298.0	36081.8	+ .091 ± .104	.182 ± .208
5	25	226.8	7794.3	+ .029 ± .181	.058 ± .362
14	117	1606.7	18899.6	+ .085 ± .100	.170 ± .200
Av.	220	5131.5	62775.7	+ .082 ± .092	.164 ± .194

* 3 herds

TABLE 25.

The heritability estimate of first lactation 305 days yield.
(Guernsey and Jersey Breeds) *

No.of Bulls	D.D. Pairs	sxy	sx^2	b	h^2
J. 1	4	481.5	574.8	+ .837 ± .223	1.674 ± .446
J. 5	26	531.4	2767.3	+.1920 ± .137	.384 ± .274
G. 2	10	-328.1	1556.1	- .211 ± .398	.422 ± .796
G. 6	34	3773.0	8162.0	+ .462 ± .525	.524 ± 1.050
Av.	74	4457.8	13060.2	+ .34 ± .113	+.68 ± .226

* 4 herds

TABLE 26.

The heritability estimate of first lactation 305 days yield.
(Shorthorn Breed) *

No.of Bulls	D.D. Pairs	sxy	sx^2	b	h^2
2	10	543.2	364.8	+ 1.489 ± .101	
3	13	-60.7	270.9	- .224 ± .169	
Av.	23	482.5	635.7	+ .76 ± .104	

* 2 herds

TABLE 27.

Heritability estimate of first lactation 305 days yield (All Breeds)

Breed *	No. of Bulls	D. D. Pairs	sxy	sx^2	b	h^2
Kerry	40	279	+ 4095.7	25489.6	+.161 ± .068	.322 ± .126
Friesian	24	220	+ 5131.5	62775.7	+.082 ± .092	.164 ± .194
Jersey & Guernsey	14	74	+ 4457.8	13060.2	+.34 ± .113	+.68 ± .226
Shorthorn	5	23	+ 482.5	635.7	+.76 ± .104	
All Breeds	83	596	14167.5	101961.2	+.168 ± .036	.336 ± .072

* 10 herds

daughters and dams are excluded as far as possible by doing all the regressions within single herds. The regression so calculated contains no contribution from dominance and only a fraction of the variation due to interaction between different loci and is the best estimate of heritability, being less susceptible to errors from environmental correlations.

The values given here, of course, only apply to the populations actually measured. When results are generalized it must be remembered that our figures apply to the level of genetic and environmental variation found in the leading pedigree herds of England and Wales.

A. <u>Heritability of the first 305 days milk yield</u>.

Tables 23, 24, 25, 26 and 27 contain the heritability estimates for the different breeds and for the total sum overall breeds.

Since the mean and variance in Friesians and Shorthorns are higher than in the other breeds, the average for all breeds would be more biased because of the extra weight given to higher yielding breeds (i.e., Friesians and Shorthorns).

Therefore Lush's (1931) method of averaging the correlations was applied, with the assumption that a regression value is equal to its corresponding correlation value.

The/

The heritability of .322 - .0678 obtained for the Kerry herd agrees with Plum's (1935) finding of .20 - .40.

Sikka (1940) reported a heritability for total milk yield based on intra-sire correlation of about .52, which appears rather high. He based his calculations on the average of three lactation records for milk yield. Lush (1936) found that the heritability of total fat production is .25; he and Arnold (1937) reported another estimate of .28 and later on in 1940 he found that the heritability of a single lactation butterfat production record was from .20 to .25. Bonnier (1939) got a somewhat low figure of .070. Johansson and Hansson (1940) found that the dam-daughter correlation of the first lac:tation records uncorrected was .183, which corres:ponds to a heritability estimate of .366. Ward (1941) found that for 3076 daughter-dam pairs whose lifetime fat yield averages were used in proving 104 sires, the intra-sire regression of daughter on dam was .15. This was equivalent to a heritability of about .25 when the number of records per dam and the repeatability of records were taken into account.

The general overall herd heritability of .336 ± .072 seems to be not far from the values reported/

reported previously. When it does differ seriously from other estimates, it is in those cases where environmental correlations have been included with the genetic ones i.e. Gowen (.50 - .70), or in other cases where many lactations were averaged (Sikka .52). This would evidently minimize the variance due to circumstances which change at random from one lac:tation to another by the third. The relative value of the genetic variance would consequently also increase.

B. Heritability of the second 305 days milk yield.

Since the first lactation has been suggested by other workers to be more stable than any of the successive lactations, it becomes a matter of interest to estimate the heritability in the second and third lactations respectively; and to compare the different estimates with each other.

The second lactation has been found to be very sensitive to environmental changes. Johansson and Hansson (1941) found that the first lactation is lower in its variance than the third. This in turn is higher than that of the second lactation by 18%.

From a comparison between the overall breed heritability estimates in the first lactation and those of the second, it seems that the herit:ability for the second is considerably lower than that of the first. The heritabilities are .336 ± .072 and .208 ± .092 respectively, thus giving a reduction of 2/5ths.

On/

TABLE 28.

The heritability estimate of second lactation 305 days yield.

(Kerry Breed)

No. of bulls	D. D. pairs	Sxy	Sx^2	b	h^2
37	192	2752.4	21630.2	+.127 ± .069	.254 ± .138

TABLE 29

The heritability estimate of second lactation 305 days yield.

(Friesian Breed) ✱

No. of bulls	D. D. pairs	Sxy	Sx^2	b	h^2
3	42	-1388.0	32259.3	-.0430	
3	12	+ 291.0	4374.4	+.067	.134
13	91	+1886.0	34753.9	+.054	.108
Av.	145	789.0	71387.6	+.050 ± .090	.100 ± .180

✱ 3 herds

TABLE 30

The heritability estimate of second lactation 305 days yield.

(Shorthorn Breed)+

No. of bulls	D. D. pairs	Sxy	Sx^2	b	h^2
2	7	139.2	425.7	+.327	.634
2	7	298.9	1415.5	+.211	.422
Av.	14	438.1	1841.2	.238 ± .281	.476 ± .562

+ 2 herds

TABLE 31.

The heritability estimate of second lactation 305 days yield.

(Jersey and Guernsey Breeds)+

No. of bulls	D. D. pairs	Sxy	Sx^2	b	h^2
J.1	3	- 34.2	44.7	-.765	
G.2	9	+376.0	1525.7	+.246	.492
G.2	22	+1673.5	10714.3	+.156	.312
Av.	34	+2015.3	12284.7	+.164 ± .206	.328 ± .412

+ 3 herds

TABLE 32.

The heritability estimates of the second lactation 305 days records - All Breeds.

Breed *	No. of Bulls	D. D. Pairs	sxy	sx^2	b	h^2
Kerry	37	192	2742.4	21630.2	+ .127 ± .069	.254 ± .138
Friesian	19	145	789.0	71387.6	+ .050 ± .090	.100 ± .180
Shorthorn	4	14	438.1	1841.2	+ .238 ± .281	.476 ± .562
Jersey & Guernsey	5	34	2015.3	12284.7	+ .164 ± .206	.328 ± .412
	65	385	5984.8	107143.7	+ .104 ± .046	.208 ± .092

* 9 herds

On considering the breed heritabilities in both lactations we found that the same trend appears in each breed, giving reductions ranging from 1/3 to 1/5 (tables 28, 29, 30, 31, 32).

It seems that the sensitivity of the second lactation to environmental changes is respons-:ible for this difference, since our data were select-:ed at random from the same level of production, and the selection practised in all herds can reasonably be expected to be of the same intensity.

C. Heritability of the third 305 days milk yield.

This study was carried on (i) to test the reliability of the third lactation as an estimate for the cow's milking ability, (ii) to determine the relation between age and heritability, and (iii) to compare the average of the first three lactations after age correction with the same records treated separately.

The results are given in table 33. The allover herd and breed estimate of .198 ± .214 is lower than that of the first lactation (.336 ± .072), but it is not far from that of the second (.208 ± .092).

It could be concluded that age does not seem to affect heritability to any great extent after the/

TABLE 33.

The heritability estimates of the third lactation 305 days records.
(All Breeds)*

Breed	No. of bulls	D. D. Pairs	sxy	sx^2	b	h^2
Kerry	19	78	- 20.2	11715.8	- .002	
Friesian	12	52	2862.9	16576.2	+ .173	.246
Shorthorn	1	3	- 9	84	- .107	
Jersey	1	2	+ 3	18	+ .167	.234
All Breeds	33	135	2836.7	28394.0	.099 ± .107	.198 ± .214

*5 herds

TABLE 34.

The heritability estimate of the average of the first three lactations corrected for age. +

Breed	No. of bulls	D. D. pairs	Sxy	Sx^2	b	h^2
Kerry	19	78	1148.2	4980	.230	.460
Friesian	12	52	3196.4	5691.9	.56	
Shorthorn	1	3	3.0	54	.055	.110
Jersey	1	2	2.0	8	.25	.50
All Breeds	33	135	4349.6	10733.9	.39 ± .080	.781 ± .160

+ 5 herds

the second lactation, as the two heritability esti-:mates of the second and third lactations are not very different from each other. However, our results are not necessarily conclusive because of the small numbers dealt with (138 dam-daughter comparisons in the third lactation.

Moreover, the comparison between the three estimates of heritability shows clearly that the first lactation record gives more reliable information on the breeding worth of the cow than either the second or third lactation records.

D. Heritability of the average of the first three lactations after correction for age.

This study comprised only 135 dam-daughter comparisons, as those animals which completed at least three records are a selected group. The age correction factors applied were in a number of previous lactations. The average of the three age-corrected 305 day yields was then used as the unit of this analysis.

The results are given in table 34. The overall heritability for all breeds is .78 ± .160. This, compared with those of the first, second and third uncorrected records, seems to be very high; again the small number of dam-daughter pairs and the sampling error may be responsible for the high estimate/

estimate.

Johansson and Hansson (1941) obtained a heritability of .374 for the average of the first three lactations corrected for age and calving in-:terval; when compared with the estimates of herit-:ability for the first lactation record as well as with the average of the first three lactations un-:corrected, it was found to be lower than the former (.442) and slightly higher than the latter (.328).

However, the differences between our results and those of Johansson and Hansson cannot be taken very seriously considering the small numbers on which ours are based (especially in the case of the third lactation and the average of the three lactations). One might expect the heritability of the second lactation to be lower than that of the first owing to the selection which takes place between the first and second lactations. Thus, only daughters which have a high first lactation will get through to the second, so that the environmental factors operating in the first lactation will tend to even out differences between daughters' mean yields for first and second lactations.

E. <u>Heritability of the cow's maturity index</u>.

The cow's maturity index is the ratio between/

between the second lactation 305 days yield and the first lactation 305 days yield. It measures the degree to which the first lactation approaches the second. Therefore it shows to what extent the first lactation record is mature, considering the second lactation as our standard. The second lac-:tation was chosen as the standard mature record of the cow for two main reasons: (a) the rate of in-:crease in milk production from the first to the second lactation is higher than any rate of increase between the second and the third or between the third and the fourth: (b) the number of cows which have first and second lactation records is far larger than those having second and third or third and fourth lactation periods.

Evidently this index does not give a full indication of the ultimate maturity of the first lactation record, because the second lactation is not the highest of all lactations; but it does give a reasonable idea about the maturity of the first lactation records.

As it was also reported by Johansson and Hansson (1941) that the second lactation is more susceptible to environmental variations than any of the other lactations it became of interest to know to/

TABLE 35.

The heritability of the cow's maturity index (Kerry)

No. of bulls	D. D. pairs	Sxy	Sx^2	b	h^2
36	152	+4224.3	87769.7	+.049 ± .068	.096 ± .136

TABLE 36.

The heritability of the cow's maturity index (Friesian)*

No. of bulls	D. D. pairs	Sxy	Sx^2	b	h^2
3	40	+ 257.0	47140.5	+.005	.010
1	4	-307.0	456.8	-.672	
13	82	+12487.0	32201.2	+.387	.776
Av.	126	12437.0	79798.5	+.155 ± .087	.310 ± .174

* 3 herds

TABLE 37.

The heritability of the cow's maturity index (Shorthorn)*

No. of bulls	D. D. pairs	Sxy	Sx^2	b	h^2
2	7	230	850	+.271	.542
2	7	-1212	1343.3	-.902	
Av.	14	-982	2193.3	-.448 ±.148	

* 2 herds

TABLE 38.

The Heritability of the cow's maturity index. (Guernsey & Jersey). *

No. of bulls	D. D. pairs	Sxy	Sx^2	b	h^2
J.1	2	+ 330.0	72.0		
J.4	17	+4210.5	9495.8	+.443	.886
G.2	8	+ 101.5	1619.4	+.063	.126
Av.	27	4642.0	11187.2	+.415 ±.184	+.830 ±.368

* 3 herds

TABLE 39.

The heritability estimate of the cow's maturity index.
All Breeds. +

Breed	No. of bulls	D. D. pairs	Sxy	Sx^2	b	h^2
Kerry	36	152	+ 4224.3	87769.7	+.048 $\pm$ .068	.096 $\pm$ .136
Friesian	17	126	+12437.0	79798.5	+.155 $\pm$ .087	.310 $\pm$ .174
Shorthorn	4	14	- 982	2193.3	-.448 $\pm$ .148	
Jersey & Guernsey	7	27	+ 4642.0	11187.2	+.415 $\pm$ .184	.830 $\pm$ .368
All Breeds	64	319	20321.3	180948.7	+.100 $\pm$ .055	.200 $\pm$ .110

+ 9 herds

to what extent the relation between the first and second lactations is governed by heredity.

The following Tables (Nos. 35, 36, 37, 38 and 39) give the heritability estimates for this character.

The results show that the cow's maturity index is moderately heritable (.200 - .100 overall herds). In fact, it is as heritable as that of the second lactation. This suggests that the maturity of the first lactation record could be fixed in herds through constructive breeding.

F. Heritability of the total milk yield (first and second lactations).

This study was made on the Kerry herd, the largest in number, to see whether the total milk yield differs in its heritability from the 305 days yield. Both the first and the second lactations were investigated. The results are shown in Tables 40 and 41.

These results are .34 ± .106 and .215 ±.120 for both first and second lactations (total yield) compared with .322 ± .126 and .254 ± .138 for the corresponding 305 days yield. This suggests that both items are heritable to the same degree. Therefore it can be concluded that the 305 days record is/

TABLE 40.

Heritability estimate for first lactation total milk yield.
(Kerry Breed)

No. of Bulls	D. D. Pairs	sxy	sx^2	b	h^2
44	363	9361.2	54990.9	+ .170 ± .053	.34 ± .106

TABLE 41.

Heritability estimate for second lactation total milk yield.
(Kerry Breed)

No. of Bulls	D. D. Pairs	sxy	sx^2	b	h^2
40	241	3793.7	35372.0	+ .107 ± .060	.215 ± .120

TABLE 42.

Summary of heritability of the first three lactation 305 days yield, the average of the first three lactations age corrected, the cow maturity index of all herds, and the 1st, 2nd and total lactation yields of the Kerry herd.

Lactation	D. D. pairs	b D.Dam	h^2	h^2%
1st	596	+ .168 ± .036	.336 ± .072	33.6 ± 7%
2nd	385	+ .104 ± .046	.208 ± .092	20.8 ± 9%
3rd	135	+ .099 ± .107	.198 ± .214	19.8 ± 21%
Av. 1-3 corrected	135	+ .39 ± .080	.780 ± .160	78.0 ± 16%
Cow maturity index	319	+ .100 ± .055	.200 ± .110	20.0 ± 11%
1st T.M.Y. Kerry	363	+ .170 ± .053	.340 ± .106	34.0 ± 11%
2nd T.M.Y. Kerry	241	+ .107 ± .060	.215 ± .120	21.5 ± 12%
	2174			

is probably the most satisfactory for selection purposes since it becomes available sooner and is free from the effects of non-pregnancy and unduly long lactations.

Summary of heritability estimates.

Table 42 shows all the heritability estimates obtained throughout this study for both 305 days milk yield and total lactation yield. The following conclusions may be drawn:

1) The first lactation record appears to show higher heritability than do the records of other lactations. It shows that 33.6% of the variation in cows' milk yield is genetic. It appears that the first lactation record is more dependable than any other records or average of records (second and third in this study).

It is also more convenient to base selection on first lactation records as it saves time in wait- :ing for other records and increases the number of data available.

2) The 305 days record is suitable for measuring the cow's milking ability as it shows the same heritability as does the total milk yield. It excels the latter measure in that it takes a shorter time and is less variable, being more standardized and free/

free from the effects of non-pregnancy. There is, therefore, no justification for adherence to longer periods since the 305 days can be depended upon for all practical purposes.

5) Early maturity yield, represented by the ratio of the first lactation 305 days record to that of the second lactation, showed a heritability of approximately 20%.

4. THE GENETIC CORRELATION BETWEEN THE FIRST AND THE SECOND 305 DAYS YIELD.

An animal's phenotype for a particular trait (x) is known to be the sum of the following effects :

1) The average effects of the genes, "G" (Strictly additive).

2) The combined effects of environment, dominance and epistasis, "E".

Thus : $x = G + E$.

The observed variance is then : $\sigma^2 x = \sigma^2 G + \sigma^2 E$

If two traits are correlated with each other, the observed correlation may be due (1) wholly to environmental factors; (2) to genes which affect both characters; (3) to a combination of the two causes in any proportion.

What interests the breeder is the extent to which genetical variation in one character is affected by the other; or in other words, how much is contributed by the genes in the observed correlation between the two traits. Such information has an important bearing on the actual heritable amount of improvement which can be gained by choosing a certain plan of selection. This consideration depends on the fact that genes have a manifold effect, so that selection for one character will modify another. Many cases ofpleiotrpoic genes have been reported in laboratory animals, but they have received little or no attention in domestic animals; whether such genes exist in the genotype of the dairy cow has not previously been investigated. Linkage and non-random mating systems may also cause correlated variations; however their effects would be less permanent and consequently less important in selection. An additional and usually much more important cause of correlated variation/

variation within an interbreeding population (herd) lies in the environmental circumstances peculiar to each animal, particularly for traits which develop during the same or in adjacent periods of time - for example, milk yield, butterfat percentage and persistency in the dairy cow. Thus the correlation between two characters may be due to pleiotropic action of the genotype or to changes in the environment affecting both characters.

The same principle holds true of the relation between different observations of one character in a certain population of animals. If these observations (whether successive or not) are correlated, the observed correlation reveals only an approximate picture of their genetic relation. The genes governing such a character may have different pleiotropic effects, hence each observation could be only a different expression of the same genes; or the stability of the environment throughout the period when two observations were being recorded, rather than any genetic relation, could be responsible for any observed correlation between the two characters.

How much can we depend upon one observation of a certain character to indicate the others? In particular, to what extent do the different measures of milking ability measure the same genotype? Such a question must be answered before we proceed with our selection.

In this investigation the milk yield has been

studied/

studied to find out :-

1) Whether the same genes control the milk yield in both the first and the second lactations.

2) If the same set of genes does govern milk yield in both lactations, is their relative importance the same in both cases?

3) Do all the genes responsible for milk yield manifest their effects throughout the whole lactation?

To answer these questions, the genetic correlation is estimated for :-

(a) the 1st and 2nd 305 days milk yield;

(b) the first 70 days record and the 305 days milk yield in the 1st lactation;

(c) the first 70 days record and the 305 days milk yield in the 2nd lactation.

The technique used was that suggested by Hazel (1943) in the following formulae :

1) $$rGL_1L_2 = \sqrt{\frac{b\ L_1L_2 \times b\ L_2L_1}{b\ L_1L_1 \times b\ L_2L_2}}$$

2) $$rG\ I_1L_1 = \sqrt{\frac{b\ I_1L_1 \times b\ L_1I_1}{b\ I_1I_1 \times b\ L_1L_1}}$$

3) $$rGI_2L_2 = \sqrt{\frac{b\ I_2L_2 \times b\ L_2I_2}{b\ I_2I_2 \times b\ L_2L_2}}$$

All these regressions are derived from daughter-dam comparisons.

The/

TABLE 43

The Genetic Correlation between the first and Second 305 days yields.

No. of D.D.Pairs	sx_1^2	sx_1y_1	bL_1L_1	sx_2^2	sx_2y_2	bL_2L_2	sx_2y_1	bL_2L_1	sx_1y_2	bL_1L_2
360	56441.7	3145.3	.101	94197.5	4582.5	.097	6879.5	.094	337.5	.107

$$rG\ L_1L_2 = \sqrt{\frac{.107 \times .094}{.101 \times .097}} = \sqrt{\frac{.010058}{.009797}} = \sqrt{1.027} = 1.01 = \text{unity}$$

The results for the genetic correlation between the first and second 305 days yields are given in Table 43.

It is obvious from the value of the genetic correlation shown before (Table 43) that the genes which govern the milk yield in the first lactation are the same as in the second.

If we assume that the variations observed in both first and second lactations are the result of the actions of genes controlling milk yield, the difference in variation between the two lactations could be attributed to the different effects of the genes in each lactation. But, since our estimate of the genetic correlation between the two lactations is unity, any such explanations are rendered invalid.

Tyler and Hyatt (1947) found the genetic correlation of milk and butterfat yields to be .85.

In Tables 44 and 45 the results obtained for the genetic correlation between the first 70 days yield and the 305 days milk yield in both the first and second lactations are given. These results suggest that either the genes affecting milk yield manifest their effects during the first 70 days yield in the same manner as they do for the 305 days; or that the same genes controlling this early lactation yield are also responsible for the 305 days yield.

From the genetic point of view, this may lead to the assumption/

TABLE 44.

The Genetic Correlation between the first 70 days record and the 305 days milk yield (1st lactation)

No. of D.D.Pairs	sx_I^2	sx_Iy_I	bI_1I_1	sx_L^2	$sx_L^2y_L$	bL_1L_1	sx_Ly_I	bL_1I_1	sx_Iy_L	bI_1L_1
587	7806.4	1456.3	.1866	101961.2	14167.5	.1389	7443.8	.9536	3456.8	.0347

$$rGI_1L_1 = \sqrt{\frac{.0347 \times .9536}{.1866 \times .1389}} = \sqrt{\frac{.03308992}{.02591874}} = \sqrt{1.2767} = 1.12$$

TABLE 45

The Genetic Correlation between the first 70 days record and the 305 days milk yield
(2nd Lactation)

No. of D.D.Pairs	sx_I^2	$sx_I y_I$	bI_2I_2	sx_L^2	$sx_L y_L$	bL_2L_2	$sx_L y_I$	bI_2I_2	$sx_I y_L$	bL_2I_2
398	608.6	8492.8	.0716	107143.7	5985.4	.0559	12137.3	.1066	5324.1	.0468

$$rG\ I_2L_2 = \sqrt{\frac{.1066 \times .0468}{.0716 \times .0559}} = \sqrt{\frac{.004989}{.004002}} = \sqrt{1.2473} = 1.11$$

assumption that if selection is to be based on such a part of the lactation, no genes will be lost in fixing the desired genetic make-up. Although shorter records which were investigated previously were abandoned because they were not sufficiently closely correlated with the average lactation production - the ideal measure of performance - yet a considerable amount of reliance could be placed on the 70 days record in determining preliminary selection in cases where complete records are not available or where a preliminary study is urgently needed.

GENERAL DISCUSSION :

In this investigation we were concerned with the relative effects of heredity and environment in the milk yield of dairy cows. A study was made of the following problems:

1) The effect of some important non-genetic factors on milk yield and the use of correction factors as a method for eliminating such effects. The factors studied were :-
   (a) The effect of the season of calving on the milk yield in different lactations.
   (b) The effect of age at first calving on the milk yield of the first lactation.
   (c) The effect of age on milk yield over successive lactations.
2) The repeatability of milk records.
3) The heritability of milk yield in the first three lactations.
4) The maturity index of the first lactation record.
5) The genetic correlation of the first and second lactation 305 days milk yield records, as well as those of the first 70 days and 305 days in both first and second lactations.

The effects of month of calving on both 305 days and total milk yield were found to be of minor importance when compared with other sources of environmental variance, since they caused only 1.6% and 3.7% of the total variance respectively. This was supported by the fact that the repeatability for one of the biggest herds was not much affected by using such correction factors for the month of calving. Had the different/

different months had any appreciable effect on the cow's milk yield in our study, the correction factors when used, should have considerably reduced the variability due to month of calving and consequently decreased the degree of likeness between the records (repeatability) since successive records of the same cow tend to be made at the same time of the year, thus having the same effects from year to year. Once those effects are lost the likeness between the records should decrease. As there was no reduction in general, correction factors for the month of calving could be considered in our case to be unnecessary for milk yield. This may be because our data came from the top 2% of herds in England and Wales. One would expect such herds to receive better than average management, and, in particular, a better standard of feeding. This would neutralise the effects of seasonal variations in milk yield. Where conditions of management and feeding are capable of counteracting the seasonal variations, correction factors seem to be of little use. One obvious way in which control of the environment may be expected to help in bringing out clearly the genetic differences between individuals is by reducing the proportion of the total variation which is due to non-genetic factors.

It follows that if the differences due to month of calving can be altered by management, they will be different in different herds, and correction factors should be computed on an intra-herd basis. This method will, incidentally, allow for any genetic differences in the reaction of cows to different months/

months of calving which may exist between cows of different herds, though we do not know of any as yet.

Delay in calving heifers for the first time in their lives caused an increase in their milk yield in the first lactation. This increase differed from herd to herd and from one breed to another. Here again we can expect differences in management and genetic differences between breeds to affect the rate at which cows reach maturity, and so the yield which they can give at a given age. The increase in milk yield per month of increase in age at first calving was computed for the different herds and breeds. This was 15.0, 5.8 and 1.9 gallons of milk per month of increase in age for Shorthorns, Friesians and Channel Island breeds (Jerseys and Guernseys) respectively. These gains do not seem to be very different from each other when they are compared with the average milk yield of their respective breeds.

The effect of increasing age at first calving was proved to have a certain limit, as milk yields do not increase if heifers are delayed in their calving to an unduly late age (Shorthorns and Friesians, 30 months; Jerseys and Guernseys 24 months).

Farmers hold conflicting views about early calving. Some prefer to delay the first calving of heifers as long as possible, in the hope of securing the maximum milk production, while others make their heifers calve early because they believe that the efficiency of milk production reaches a higher level when they start their productive life at an early stage. In general/

general, however, the farmer is inclined to breed his heifers when they reach a satisfactory stage of development, which may be taken as "maturity". Owing to the different methods of rearing used, it is not possible to lay down a correct age at which heifers should calve.

The only advice that can be given is that the farmer should judge the degree of maturity of his animals by the amount of growth they have made and should aim at bringing his heifers to calving size at an age which suits his farm management. This can be done by proper feeding and rearing.

Finally, the principle of early calving is desirable for two main reasons :

1) It minimises the non-productive period in the life of the dairy cow, and thus increases her lifetime efficiency in milk production. This in turn increases the farmer's profits and return.

2) It shortens the generation interval, and consequently increases the rate of advance in breeding programmes based on selection.

The repeatability of .49 for the total milk yield and .53 for the 305 days yield found over 3,000 lactations means that 51% and 47% of the variance is due to variations between lactations.. These figures show that there is no appreciable difference between the repeatability of the 305 days and total yield.

The first 305 days record showed a higher heritability than other lactation records, which makes it more dependable when considering any breeding plans. Averaging the first three lactations after correction for age did not lead to any better assessment of heritability, probably because of the limited number of dam-daughter comparisons which were available for the

study/

study.

Considering the comparatively high heritability of the first lactation record, selection in dairy cows can best be based upon such records. Use of the first lactation has the added advantage that it saves time in waiting for later records and increases the number of records available. Culling of low yielding cows after the first lactation is beneficial to the farmer from the economic point of view.

When the total milk yield was investigated in the Kerry herd, it was found to be as heritable as the 305 days record. This again confirmed the close relation between the two measures.

The maturity index was shown to be as heritable as the second lactation record (both are approximately 20% heritable), but although this estimate cannot be deemed high, yet it furnishes reasonable evidence that the degree of maturity of the first lactation record (compared with that of the second) is a heritable character. It indicates, too, that 80% of the variation among animals in this respect is due to non-genetic factors.

The genetic correlation between the first and second 305 days lactations was found to be unity. This suggested that the set of genes controlling milk yield in the first lactation is the same as in the second and that the genes have the same effect.

The genetic correlation between 70 days yield and 305 days yield in the first and second lactations was unity in each/

each case. This showed that the early lactation record and that of the 305 days are controlled by the same set of genes in both the first and the second lactations, and that the effect of the genes is the same throughout the two lactations.

Whether selection can be based on the first 70 days of the lactation depends upon how closely this partial record is related to the cow's average lactation record, which is the ideal measure; the 305 days record is known to be very closely related to the average lactation record. This makes it still advisable to depend upon the 305 days record as a reliable measure of the cow's potential milk production. But, as there is a strong genetic relationship between the first 70 days record and the 305 days yield, the breeder can depend to a great extent upon this partial lactation record when determining early selection or in cases where complete records are not available. The 305 days record would be more favourable for final selection.

In conclusion, the problem of milk yield inheritance is still as complex as it was. The attempt to discover to what extent heredity and environment respectively contribute to the total variance in milk yield has illustrated very clearly how this character is sensitive to the environment. In this investigation the month of calving played a minor part in the total variation, while other factors such as age, change in feeding and management contributed about 70% of the total variance in milk yield. This indicates clearly the great need for/

for the farmer to improve his management and feeding. He ought to provide his animals with an optimum environment so that their genetic make-up will have a better chance to show itself. This will allow him to carry on his selection with less error or confusion.

Once his animals enjoy this good management, he will be able to breed them at an early age and will consequently gain more through their increased efficiency in milk production. He will also be more able to increase his rate of progress in improving his animals.

Furthermore, he should bear in mind that milk yield is a character of low heritability, hence every precaution should be taken to ensure that selection is exercised on the most accurate basis. The records of animals should be kept carefully and every possible detail concerning health, food, and the environment of the animals should be recorded. He should make full use of all information available on the pedigree, collateral relatives and what can be obtained from the progeny test in deciding which animals are to be used for breeding purposes. Selection should be based on the first lactation. This would allow the farmer to cull the low yielders at an early stage, thus cutting down the keeping expenses of the cows.

In our opinion all those aspects must be taken into consideration separately and in combination as long as the ambition of the farmer in breeding for improvement lies in gaining maximum control over heredity.

SUMMARY:

A statistical study was made of the records of over 1126 cows from ten herds of five different breeds of dairy cattle. The breeds were: British Friesian, Shorthorn, Jersey, Guernsey and Kerry.

The aim of the study was to find out to what extent milk yield is heritable in the different lactations and how the genes controlling milk yield manifest themselves in a single lactation, and in different lactations (namely, the first and second lactations.)

The results obtained are summarised as follows :-

1) The month of calving has a negligible effect on both the 305 days and total milk yields; it accounts for only 1.6% and 3.7% of the total variance respectively. This study was based on 3565 observations for the 305 days milk yield and 3558 observations for total milk yield.

2) The conclusions drawn from the statistical study of the effect of age at first calving upon both 305 days and total milk yields, although covering 1018 and 1050 observations respectively, do not furnish concrete information on this point. There is an urgent need to set up practical experiments to investigate the question more fully.

3) Delaying the breeding of heifers has in general a favourable effect on their milk yield during the first lactation. The Channel Island breeds were less inclined than other breeds to show a rise in their 305 days record when breeding was delayed.

4)/

4) The repeatability of the 305 days and total milk yields accounted for about half of the total variance, while the change in environment from lactation to lactation caused the remainder. The figures were +.53 ±.019 for the 305 days milk yield (based on 2767 observations) and +.49 ±.019 for the total milk yield (based on 2794 observations).

5) The heritability of the first 305 days lactation yield, obtained from 596 dam-daughter comparisons, proved to be the highest among all heritabilities studied (.336 ±.072). This demonstrates that the first 305 days record is the most reliable measure of the cow's milking ability.

6) The heritability of the 305 days record of the second lactation is low compared to the first, being .208 ±.092. This may be due to the effects of selection and to the limitation of the data. This estimate was based on 385 dam-daughter comparisons.

7) The 305 days record of the third lactation, obtained from 132 dam-daughter comparisons, showed a heritability of .099 ±.107. This was the lowest estimate of all lactations.

8) The average of the first 305 days records corrected for age showed an unusually high estimate of heritability, namely .780 ±.160; the small numbers dealt with (132 dam-daughter comparisons) and the effect of selection may again be responsible.

9) The cow's maturity index, which measures the degree to which the first lactation approaches the second, studied on 360 dam- daughter pairs, showed a heritability of .200 ±.110.

This/

This is almost equal to that of the second lactation record (.208 ±.092). This leads to the conclusion that improvement in yield is possible through breeding for highly mature animals.

10) The heritability of the total milk yield in the first and second lactations was studied only in the Kerry herd. The results were in close agreement with those of the 305 days, being .340 ±.106 and .322 ±.126 respectively for the first lactation and .215 ±.120 and .254 ±.138 for the second lactation.

11) The genetic correlation between the 1st and the 2nd 305 days milk yields, based on 360 dam-daughter pairs, was found to be unity. This means that both lactations are controlled by the same set of genes, which also have the same effect on both lactations.

12) The genetic correlation between the first 70 days milk yield and the 305 days milk yield in both the first and the second lactations, based on data from 587 and 398 dam-daughter pairs respectively, was found to be unity in both cases. This suggests that the genes which control milk yield in the early part of lactation are in both cases the same as those which control lactation as a whole.

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