# Variation of Performance in Dairy Cattle*

BY

P. MAHADEVAN

IT is widely known that the variation of performance in dairy cattle is caused partly by environmental factors and partly by individual differences in genetic potentialities for production. It is equally well recognized that only a selection based on genetically caused differences between individuals in a population, will be of any lasting value through an improvement in the heritable qualities of the following generation. Just how big a part is played by each of these two causes of variation and the practical importance of such knowledge are the problems that we wish to discuss in the present paper. These questions can only be answered with certain reservations depending on whether we are dealing with variation within one herd or between different herds or between districts.

We, in Ceylon, know least about the variation between districts. No evidence has hitherto been collected to determine with any degree of accuracy whether the Sinhala cows in the wet zone, for example, yield more milk than their counterparts in the dry zone. Further, even if such differences exist, no evidence is available to determine whether they are due to the genetic superiority of the Sinhala cattle in the wet zone or whether they are attributable to differences in environment. In England and Wales, however, where the milk-recording and herd-book movements have gained wide acceptance among private dairy farmers, it has been possible to gather sufficient data which shows that within breeds, there is, in general, an east-west trend consisting mainly of high milk yields and poor fat percentages in the lowlands of the east, and low milk yields and high fat percentages in the hilly regions of the west, particularly in Devon and Cornwall and Cumberland and Wales. Now, it would appear possible that these differences may be due either to genetic differentiation of local types within breeds, or to variation in feeding and management between the east and west. Two investigators, Robertson and Asker (1949), working in collaboration, traced the ancestry of the cows in the different regions, and found that there was much too much exchange between areas for any genetic differences to build up, and in particular that certain areas become common sources of breeding stock for the whole country. Their results show, in fact, that no county gets less than 7 per. cent of its Shorthorn bulls from Cumberland, while Scotland and Essex are great sources of Friesian bulls. The general conclusion to be drawn from this study

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is that the variation in milk yield and butterfat percentage between districts in England and Wales is largely environmental.

While there is no evidence regarding variation between districts in Ceylon, a little information is however coming along as regards variation between herds. On *a priori* grounds alone there are several reasons for expecting differences in yield between herds through differences in management. But the little data that has just been gathered is not sufficient to measure conclusively just how much of the differences are genetic and how much environmental. The best method by which the causes of variation in yield between herds could be partitioned, is by using the same bulls in herds with widely different average yields. If the herd averages differ due to genetic reasons, a bull from a high-yielding herd could raise the average level of production of a low-yielding herd. On the other hand, if the differences in herd averages are environmental in origin the same bull would have no effect on the average level of production of the low-yielding herd. In fact, the preliminary results obtained from artificial insemination work in the U. K., indicate that the latter is much nearer what happens than the former, and that on the average, what distinguishes a high-yielding herd from a low-yielding one of the same breed, is probably, for the most part, the skill of the farmer. The few figures that are gradually accumulating in Ceylon show much the same trend, but more convincing evidence will be available when the results of the artificial insemination scheme that has recently been started in connection with progeny testing, become available.

One practical consequence of the environmental variation in yield between herds comes in when a breeder, sooner or later, in order to avoid inbreeding, must go outside his own herd to buy a bull. What should a breeder look for in purchasing a bull? In the first place, he must determine whether the herd from which he hopes to purchase the bull, is genetically above the mean level of his own herd. This is important, because even though the other herd may be a high-yielding one it does not necessarily follow that it is genetically superior to his own herd. The superiority may be almost entirely due, as is generally the case, to skilled management. If this be so, purchasing a bull from a high-yielding herd purely on the grounds that the herd average is high, is one of the greatest mistakes that a breeder can make. After all, a bull has no power of transmitting skilled methods from one herd to another. In other words, when you buy a bull, do not hope to buy his herd average with him.

The second point that a breeder should look for when purchasing a bull is whether the bull is genetically above the mean of the herd in which he was bred. No bull should be purchased unless his dam's yield is considerably higher than the mean of the herd to which he belongs. It can be shown that if we consider a herd whose average yield is 900 gallons, the dams of prospective bulls that may be purchased from that herd, should average at least 1260 gallons.

Finally, let us consider the question of variation within herds. A fair amount of evidence has now been gathered together by analytical work on dairy cattle data both in this country and abroad, which shows that even

after allowance has been made for known environmental factors such as age, month of calving and length of calving interval, there is still a large amount of variation within herds due to intangible differences in environment. Actual tests obtained by comparing the production of a large number of daughters and dams on an intra-sire basis, and by comparing the production of half-sisters or other close relatives, have shown that only a small part of the variation in milk yield within herds is due to genetic causes. They account for about one quarter of all the differences in milk yield between single records found in any one herd. This fraction, one quarter, represents the proportion of the total variability in corrected performance that is due to genetic causes, and is called the " heritability " of the character in question.

If all the differences in yield in a herd were due to genetic causes, i.e., if the heritability were unity instead of one quarter, one would expect the difference in yield between any two animals to be a direct reflection of the difference between their parents. In other words, if two cows differing in milk yield by 100 gallons were mated to the same bull, one would expect the difference between their daughters to be 50 gallons. In actual fact, however, the difference has been found to be closer to $12\frac{1}{2}$ gallons than to 50 gallons. This accounts for the host of disappointments encountered by many dairy farmers who fail to recognize that these are an automatic consequence of the non-inheritance of environmentally caused variations.

From the point of view of applied breeding therefore, it may be stated that genetic differences between cows are overlaid to a very large extent by environmental ones. In consequence, it is of the utmost importance to remember that the maximum improvement attainable by any breeding method is dependent on the fullest use being made of the genetic fraction causing variation in milk yield.

Let us consider in this connection the simplest and most direct way of breeding dairy cattle, which is mass selection, and which involves the choosing of breeding stock purely on the basis of their own phenotype and mating the chosen animals at random. It is possible to show from theoretical considerations, that, given optimum conditions of selection, the expected rate of genetic improvement in milk yield is only of the order of 1 per cent. of the average yield per year. This means that among the Sinhala cattle in Ceylon, for example, the maximum genetic improvement by selection over a period of 20 years can only be about 18 to 20 gallons. This is due to the fact that the rate of genetic improvement is limited by such considerations as the intensity of selection possible and the heritability of the character being investigated. If a population is to be maintained at a constant or expanding size, there would be a natural limitation to the selection intensity possible depending on the reproductive and mortality rates prevailing. The rate of improvement possible would also be low if the heritability of the trait under consideration is low.

In one herd of Sinhala cattle that we have examined in great detail, the actual genetic improvement achieved over a period of 13 years is under 8 gallons—a change which is difficult to detect under the existing variations from year to year. Similar results have been obtained for another breed

of tropical cattle by Robertson (1951) who has analysed the milk yield data from a Fulani herd at Shika, Nigeria. On the other hand, the Pusa herd in India has often been cited by numerous observers, as an example of rapid improvement in milk yield that could be attained by selection. If a little more attention were paid by these observers to study the records and subject them to a genetical analysis, they would have seen that a very considerable part of the overall increase in yield was due to changes in management, and not to selection. In fact, the Pusa herd reached its high level of production under 4 times milking and with a ration of high quality concentrates of 1 lb. to 3 lb. of milk. Although from a practical point of view what matters is that the improvement has been achieved, yet from the point of view of general breeding policy what we require to know is how much of the improvement is genetical and how much environmental in origin. The Pusa herd data have not yet been analysed in this manner.

From the theoretical estimations made by Rendal and Robertson (1950) under optimum conditions of selection, and from the actual figures arrived at by Mahadevan (1951) and Robertson (1951), it is evident that the breeding of dairy cattle by mass selection is a very slow business, and that even for the smallest genetic increases to be attained, the most stringent selection should be applied. There has, however, not been enough time here to deal with the many related topics such as pedigree evaluation, progeny testing, and so on. But we may conclude from our present knowledge of the variation of performance in dairy cattle that there are two alternative long-term policies in livestock improvement work under tropical conditions. One consists of improving the indigenous stock by the usual methods of selection and progeny testing, while the other involves the production of a new breed by crossing the local stock with a foreign breed of superior performance and inter-breeding the progeny. As regards the first method, we now know how slow progress will be. For a more rapid rate of advancement therefore, one is compelled to resort to the second method, though the results are likely to be uncertain because the later crosses, although capable of a reasonably higher level of production than the local animals, may not have all the stamina and adaptability of the latter. However, if the foreign breed has an average production under local conditions which is very much higher than that of the indigenous cattle, that initial superiority of the foreign breed can only be equalled by the indigenous stock after many, many years of selection within the latter. On the basis of the results reported above, it will be readily seen that if we adopt selection within the local stock as the only means of livestock improvement, it would take us over 200 years to raise the average level of production of the Sinhala cattle in Ceylon to anything comparable to the yields given by Jersey cattle under local conditions. It would seem therefore that the two methods of improvement should be given about equal chance in any sensible programme of livestock improvement under tropical conditions. The crossing method would give a considerable increase at the start which could be consolidated by the usual selection methods, while the selection of local stock will be a standby if the crosses are found to be really unsuitable to the climate.

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