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Some Aspects of Dairy Sire Selection

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INTRODUCTION.

Importance of the Sire:

None will dispute the great importance of bull selection in dairy herd improvement. Although some genetic gain may be expected from an enlightened culling and dam selection programme, it is to the sire that the dairy farmer must look for major progress. Regarding all the cows in the country as a single herd, if the true breeding value of every bull born were known and if each bull retained was mated to 25 cows for each of two years (so that only the top 5% need be kept) we could expect a genetic improvement under natural mating of some 36lb. butterfat per sire-generation or about 10lb. per year through sire selection alone, an exciting prospect indeed.

Selection and Use:

Two major problems immediately arise. In the first place, the true genetic merit of an animal is never known; it can at best be inferred from records on itself and its relatives. Relevant available records must then be combined as best to predict a bull's breeding value. Equally important is the question of the optimal use of available bulls once they have been so appraised. It is assumed, of course, that the objectives of selection are properly defined.

Prediction of Breeding Value from Observed Records:

Differences between the observed records of two animals reflect differences not only in their inheritance but also in the effects of the environments to which they are and have been subject. Some of these effects are common to groups of animals or of records, others are random, specific to individuals. The latter, but not the former, will be reduced when records are averaged within the groups. The three major non-random environmental factors affecting butterfat yield are herds, ages and seasons.

Also the sampling nature of inheritance makes it impossible to predict exactly what a parent will transmit to its offspring, even if the genetic make-up of the former were in fact known. This introduces further errors in appraising an animal from the performance of its relatives. These errors will be reduced, but never completely eliminated, as the number of relatives is increased.

Appraising a Sire on its Pedigree:

Initial selection of which male calves shall be kept must be based on the production performance of their ancestors (dam, paternal grand-dam) and possibly collateral relatives (full and half-sisters). In comparing records or combinations of records made at different ages or seasons, allowance is necessary for the effects of these factors; and when the number of records per animal varies, knowledge of the repeatability of successive records may be used to standardise to a uniform basis. Statistical techniques may then be employed to ascertain the optimum combination of relatives' records in predicting an individual's breeding value, hence providing a valid basis for selecting the "best bet" among the bull calves available. Due cognizance would, of course, be taken of any other relevant information, concerning the calf itself or its relatives.

Where the records to be compared are made in different herds—as in selecting young sires for an A.B. unit—it will clearly be desirable to make allowance for differences in the herd environments concerned.

Importance of Progeny Tests:

A progeny test can provide more accurate information on the breeding value of a sire than can any possible information on his female ancestors and collateral relatives. Since, however, the bull will be at least five years old at this stage, having probably been used over four successive seasons, it is evident that, under natural mating, little direct benefit on a population basis can accrue from progeny testing. What then is the importance of sire surveys? In the first place, although the subsequent use (under natural mating) of proved sires is limited, the information on their breeding values will be a valuable guide in selecting their sons for the next generation of bulls to be tested, in other words, providing a "sib-test" of bull calves. Secondly, the greatest initial progress in an expanding artificial breeding set-up may be expected to come from the widespread use of the best naturally-proved sires.

Scope of this Paper:

The scope of the subject is clearly very wide and in fact many gaps exist in our knowledge both of the underlying genetic processes and of the relevant descriptive constants of the population. I will consider only three aspects (1) the problem of herd differences in sire appraisal, (2) the accuracy of sire surveys as influenced by the number of daughter records, and (3) some implications of an expanding A.B. scheme. Butterfat yield only is considered as the basis of selection and the emphasis is on the population rather than the individual. It is hardly necessary to stress, however, that any specific case must be judged in the light of its own circumstances, regard being had to all relevant information such as the physical appearance of a bull, his breeding performance, the selection of his mates, the lifetime treatment of his daughters, and their milking ability.

HERD DIFFERENCES AND SIRE SELECTION.

Significance of Herd Differences:

To illustrate the effects of herd differences in interpreting sire surveys consider the hypothetical example in Table 1.

Table 1. Comparison of Sires Surveyed at Different Herd Levels

Sire	Herd level (lbs. fat)	Superiority of daughters	Sire's — herd av. breeding value	Superiority of herd		Sire's breeding value
				Total	Genetic*	
A	400	+10	+20	100	10 (30)	30 (50)
B	300	+20	+40	—	—	40
C	200	+30	+60	-100	-10 (-30)	50 (30)

*Assuming inter-herd heritability of 10% (30%)

It will be assumed that the three basic requirements of a sire survey have been met, i.e. (1) the mates are an unselected sample of the cows available for mating, (2) there is no selection of daughter records and (3) the daughters are subject to the same overall environment as other cows in their respective herds. It is assumed further in this example that the herd and daughter averages are based on large numbers of records, properly age-corrected.

The "absolute" daughter averages ($400 + 10$ i.e. 410, 320, and 230 lb. respectively) reflect the wide differences between the three herds

and, by themselves, are clearly poor guides to the relative genetic merit of the sires. The genetic merit of sire A is estimated to be $2 \times 10 = 20$ lb. (the factor 2 entering because only half a daughter's inheritance comes from her sire) above the average genetic merit of the cows in the herd. His true genetic merit (relative to the breed mean) is therefore equal to this quantity plus the difference between the herd and the breed mean genetic merit. The latter is estimated by multiplying the observed difference, herd average—breed average, by the proportion of the total variation among herd means which is due to genetic differences, i.e. by the inter-herd heritability. Thus if the latter amounts to 10 per cent, A's breeding value is estimated to be $20 + 10 = 30$ lb. Likewise the value for sire B, tested in the "average" herd is $40 + 0 = 40$ lb. and for Sire C, $60 - 10 = 50$ lb. If, however, the between-herd heritability is as high as 30 per cent, the respective breeding values will be 50, 40, and 30, and the ranking of the bulls will be completely reversed.

Knowledge of inter-herd heritability is thus of great importance in comparing sires on the basis of surveys made at different herd levels. It is equally important in the appraisal of dams, and hence of young bulls, in different herds.

Nature of Herd Differences.

It is obvious that existing wide differences in feeding levels, management, topography and climate will induce considerable variation in production between herds; in fact, experimental evidence suggests that environmental factors could explain all the observed variation. Genetic differences between herds could, however, arise in two ways. Firstly, a herd may be considered as a family, in that animals in it tend to be more closely related than are animals in different herds. If the average coefficient of relationship within herds is 0.1, heritability (within herds) is 25 per cent, and herd differences account for 35 per cent of the total variance, this factor will contribute approximately 5 per cent to inter-herd heritability. Secondly, the effective adoption of different breeding aims in distinct sections of the population (essentially assortive mating) will in time engender genetic differences between the groups, over and above those due to relationship. The extent of this factor is hard to determine, but low heritability of most selective characters together with the "pyramid-like" breeding structure of the population (1) would not appear to permit great differentiation.

The Magnitude of Inter-herd Heritability.

A.B. results to date show little evidence of sires effecting greater improvement in low producing herds, which would be expected if these were, in fact, genetically inferior. A preliminary analysis of production records of half-sibs (from natural mating—N.Z. Dairy Board data) yields an estimate of between-herd heritability of around 5 per cent, though this estimate is subject to large sampling errors. Nor is there any clear evidence of differences between originating studs in respect of the performance of progeny of proven bulls. Finally, overseas studies (2) (3) (4) in Britain, America, and Sweden, indicate that rather less than 10 per cent of the variation between herd mean butterfat yields can be ascribed to genetic differences.

It is hoped to publish elsewhere the results of investigations into the direct estimation, from analysis of relevant field data and from planned experiments, of inter-herd heritability.

Expectancy Values.

The question naturally arises as to whether the "expectancy line" as used by the New Zealand Dairy Board does make allowance for possible genetic differences between herds. The expectancy value is

simply the regression estimate, based on analysis of previous survey data, of the average (age-corrected) daughter yields corresponding to a given herd level. In theory, therefore, the index "difference from expectancy" measures one half the superiority in merit of a particular bull relative to the average bull previously surveyed in herds of similar productive level.

The analogy with the direct comparison of daughter average and herd level is apparent. In both the overall effects of different herd environments are eliminated; but the bias due to genetic differences among the sire's mates i.e. among herds is now replaced by one due to possible genetic variation among the "average sires" surveyed at different herd levels. Insofar as the sires used in the industry tend to be drawn from a restricted group of parent herds, it is likely that the latter variation is less (resulting in an overall tendency for herd averages to regress towards the population mean). On the other hand is the increased difficulty of assessing the amount of the resulting bias and hence the appropriate correction in predicting a sire's true breeding value.

I would contend in fact that, given the existing sort of sire survey data, a bull would be best appraised by comparison of his daughters' average with that of the other cows in the herd (all records being standardised to a common age, preferably two years), in conjunction with an allowance, entailing an estimate of inter-herd heritability, for the difference between the herd average and the breed average.

STANDARDIZATION OF PROGENY TESTS FOR NUMBER OF DAUGHTER RECORDS.

Effect of Number of Records.

As indicated earlier the effects of random environmental factors and genetic sampling are reduced in averages over a number of animals and, to a lesser extent, of records per animal. It follows that a daughter average becomes a more reliable guide to the breeding value of a sire as the number of records in it is increased. For a fair comparison of bulls it is necessary therefore to allow for differences in the number of records in their surveys. For example, is a bull whose ten daughters (one lactation each) show a superiority (over the other cows in the herd) of 30lb. butterfat in fact better than a second, surveyed in a similar herd, with 60 lactations on 30 daughters averaging 20lb. above the herd average?

Adjustment Factor.

The problem is essentially that of making the best prediction from existing data of what future daughters will produce. We consider here the prediction only in relation to the particular herd, or herd level, at which the daughters' records were made; the problem of extrapolation to other herds has already been discussed. The required value (expected superiority of future daughters) is obtained by applying a regression factor, K, to the difference, D, averaged over all seasons, between the daughter average and an independent measure of the herd level. The latter may be the average, assumed based on a large number of records, of all other cows (corrected for age) or of mature cows; or it may be the derived expectancy value.

The factor K, in effect the heritability of a progeny test, is found to depend on heritability (h^2) and repeatability (R) within herds, on the average genetic relationship between the sire and his mates (r) and among the latter (r'), on the number of records (N) and on the sum of squares of the number of records for each daughter divided by N (P). The formula is

$$K = \frac{Nh^2(1+r)}{(N-p)h^2(1+r') + 2Nh^2R + (P-1)R + 4}$$

A very satisfactory empirical relationship has been established (using published N.Z. Sire Survey data) between P and p , the mean number of records per daughter, namely

$$P = 1.32p - 0.32 \quad (+ \text{ or } - 0.13)$$

With this approximation, assuming that heritability is 25 per cent, repeatability is 45 per cent, the average coefficient of relationship among a sire's mates is 0.1 and the sire is unrelated to his mates, we find

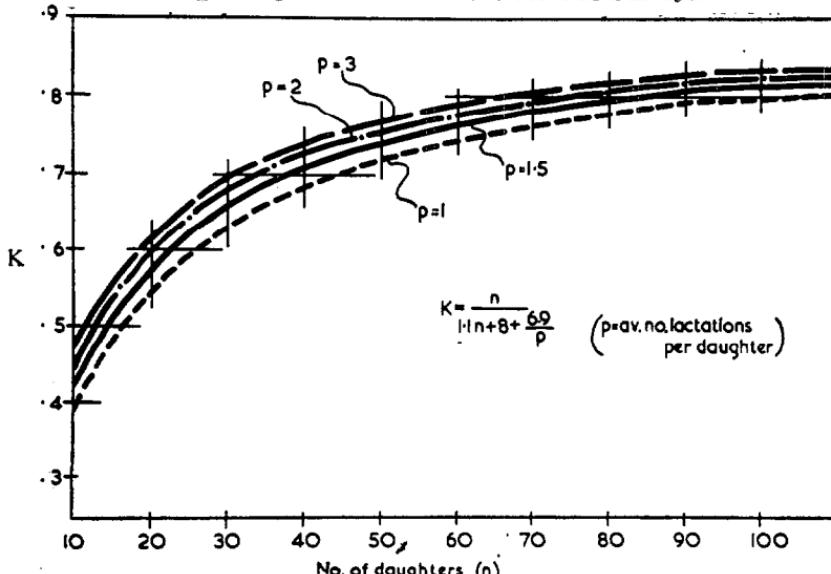
$$K = \frac{n}{1.1n + 8 + \frac{6.9}{p}}$$

where n is the number of daughters. The relationship between K and n is shown graphically in Figure 1 for $p = 1, 1.5, 2$ and 3 .

Accuracy of Progeny Tests.

The accuracy of a progeny test in appraising a sire is measured by the correlation between his estimated and his true breeding value. In the absence of any relationship between the sire and his mates this is equal to the square root of the corresponding regression, i.e. to \sqrt{K} . It is apparent from Figure 1, for example, that, other things being equal, a survey based on 15 daughters with one lactation each is rather more accurate than one having 30 records on only ten daughters. In general, increasing the number of daughters raises the accuracy of a progeny test much more than does a proportionate increase in the number of records per daughter.

Fig 1. Adjustment Factor (K) for Sire Surveys.



NOTE:

- (1) The formula for K may require modification as better estimates become available of h^2 , R , r and r' .
- (2) It may prove desirable to include some allowance for the number of records contributing to the measure of herd level, particularly in comparing surveys covering a varying number of seasons.
- (3) With only one record per cow, $K = \frac{n}{1.1n + 14.9}$ which may be compared with the factors $\frac{n}{n + 12}$ (5) and $\frac{n}{n + 15}$ (6) used by overseas workers.

(4) Instead of being averaged over all lactations, D, the overall mean difference between daughters and herd level, could alternatively be computed as the unweighted mean of individual daughter mean differences — involving a different adjustment factor K'. Theoretical considerations indicate the latter to be rather more accurate when $p > 1.4$. In a number of cases examined, however, the differences in accuracy were negligibly small.

Some Examples:

The practical effects of variation in numbers of daughters and of records are illustrated in Table 2, showing successive survey results on three bulls.

Table 2. Effect of Numbers of Records on Sire "Expectancy" Indexes.

Sire	Maori Golden Glow				Cranford Sam Brown				Gainesville Theodore		
Sire Survey Edition (9)	8	9	10	11	7	8	9	10	7	8	9
No. of daughters	10	18	22	30	10	17	21	27	11	16	16
No. of records	13	30	50	74	12	27	45	68	11	24	34
Diff. from expectancy	45	41	32	29	32	26	18	14	-35	-22	-19
Adjustment factor, K	.41	.56	.62	.69	.40	.55	.61	.67	.41	.53	.56
Adjusted Value	19	23	20	20	13	14	11	9	-14	-12	-11

In accord with theoretical expectation the unadjusted indexes (differences from expectancy) tend to decline, in absolute amount, as the number of records increases, for both positive and negative values (bulls improving and lowering production respectively). It is instructive to compare the first bull on the basis of his final survey with the initial survey of the second. Superficially, the latter appears the better, but reference to the adjusted indexes indicates the reverse is the case.

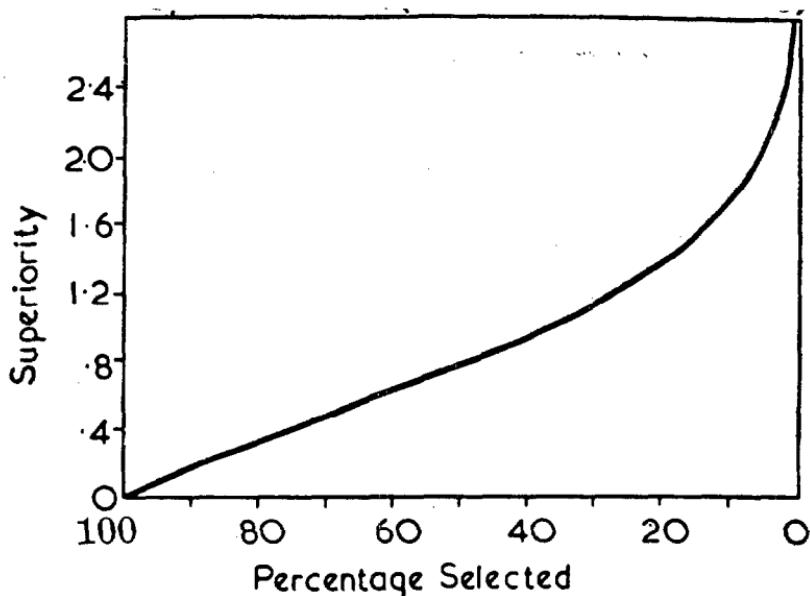
SIRE SELECTION IN ARTIFICIAL BREEDING.

Factors Affecting Selection Progress.

Improvement per generation through selection (of a single trait) is equal to the genetic superiority — "selection advantage" — of the animals kept for breeding over the mean of their generation. This is a function of the intensity of selection (the proportion saved for breeding), the observed (phenotypic) variability in the population and the heritability of the trait (conditioning the accuracy of selection). The effect of selection intensity is shown in Figure 2, though it must be emphasised this presupposes a normal distribution.

Translating progress per generation into effective progress per year introduces the further important factor, generation interval (average age of parents when offspring are born). In the proving of sires it is necessary to strike a balance between increased accuracy of advanced surveys and corresponding increased age of the bull. In this respect, the possibility of obtaining an early proof, based on say the first two months daughters' yields—in effect, allowing a selected sire to be mated a year earlier—warrants exploration.

**Fig 2. Superiority of Selected Individuals above Population Mean
(in standard deviation units)**



Importance of the Sire in A.B.

It is immediately evident that efficient sire selection is the key-stone in dairy cow improvement through A.B. Since, even with existing techniques, one bull can sire up to 2000 daughters in a single season, the selection intensity for sires is increased many-fold. In the initial phases of an A.B. scheme, where relatively few bulls are required, maximum improvement should result from the use of the best naturally-proved sires. Although some 2000 pedigree bulls are at present under proof in any one year, the number of these which survive to be potential A.B. sires is very much less. Even with 40 per cent wastage (7), however, a very considerable reserve of proven bulls remains.

Initial Gains Under A.B.

The standard deviation of daughter averages, adjusted for differences in herd levels but not in numbers of records, is of the order of 25lb. (8). Ignoring the possible bias due to herd differences, and taking a value of K—the heritability of a progeny test—of 0.56, corresponding to 30 records on 18 daughters, the top 3 per cent of proven sires may be expected to raise their daughters' yields initially by an average of 32lb. That this goal is attainable is shown by the fact that two proven sires have already made such an improvement in A.B. (N.Z. Dairy Board 30th An. Rept., 1954). The estimate would require modification in the event of non-normality of the distribution—of herd-corrected daughter averages—or of unequal variances at different herd levels. In the latter event, it might be preferable to choose the same proportion of sires in each of several strata of herds.

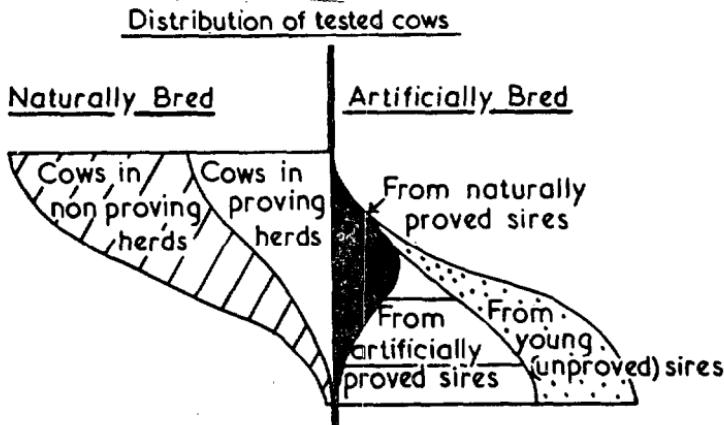
Gains in subsequent generations are likely to be less, as the population of daughters is graded up to the genetic level of the selected sires. However, the improvement, though less per cow, will be spread over an increasing number of cows. Further progress will result

from improved methods of initial selection of bulls to be tested, from increase in the number of possible inseminations per bull, and from increase in the available pool of proven sires. In this latter connexion, the publication and use of surveys of non-pedigree bulls demands close examination. Likewise, the restriction of choice to so-called "Merit Sires" (generally surveyed in high producing herds) is open to serious criticism if genetic differences between herds are, in fact, unimportant.

General Development of A.B.

In New Zealand physical factors dictate that the number of cows bred artificially will rise at an increasing rate for a period and then at a decreasing rate—see Figure 3. As A.B. expands, it may be expected that progressively fewer testing herds will be available for the natural proving of sires, whereas the number of bulls required for A.B. will increase. The sire selection advantage will, therefore, decline. To offset this it will become necessary to an increasing extent either to rely on a judicious selection of sire replacements (either from within the unit or outside) on the basis of known pedigrees, or to undertake a system of bull-proving within the A.B. scheme.

Fig. 3. Progress of Artificial Breeding.



Optimal Structure of A.B. Organisation.

Under the A.B. organisation considered there are three groups of cows, mated respectively (1) to naturally proved, (2) to artificially proved, and (3) to young bulls. Within each group improvement from sire selection is compounded of the appropriate selection advantage and the generation interval. The selection advantage of sires used in group (2) is influenced both by the number of bulls and by the number of cows per bull in group (3)—for a given number of "bull-proving" cows, the greater the number of bulls proved the greater is the resulting selection intensity but the less is its accuracy. A measure of the accuracy (or heritability) of A.B. proofs is required here. It must be remembered that the effective selection advantage for group (2) includes that for group (3).

Overall progress is estimated as the average improvement over the three groups, weighted according to the number of cows in each. The problem then arises of determining that distribution of total cows among groups which will maximise this progress — with due

allowance, of course, for economic considerations. Purchase, rearing and maintenance costs are obviously relevant in deciding on the number of young bulls to be proved. Some allowance is necessary also for the fact that not all cows in the unit will be tested. In particular, the effective number of cows per bull entering into the accuracy of an A.B. proof will be the number which are in tested herds. Finally, attention must be given to the avoidance of inbreeding high enough to adversely affect production—a potential danger with the use of a few proven bulls and continued son-halfsister matings.

Appraisal and Accuracy of A.B. Progeny Tests.

The main difference between natural and A.B. proofs is that in the latter the daughters are scattered through a number of herds. Statistically, the bias, in a daughter average as an index of a sire's breeding value, due to the herd environment under natural proof becomes a (more or less) random error under A.B. proof. Two criteria of appraising a bull in the latter case may, therefore, be considered:

- (1) The difference between daughter average and "herd level" (or expectancy value), averaged over all herds. The necessary adjustment factor for number of daughter records will then be substantially as for natural surveys. In fact, it, and hence the accuracy of the proof for a given number of daughters, will be slightly greater since the average relationship among the sire's mates which appears in the denominator will be less under A.B. The possibility of greatly increasing the number of daughters will, of course, make the accuracy much greater than for a natural proof in practice.
- (2) The daughter average alone. In this event the error due to herd differences will inflate the denominator of the adjustment factor so that, for a given number of daughters, the accuracy will be less than before. For the particular case of one record only per daughter and one daughter per herd the factor is approximately $\frac{n}{n + 23}$

With either method it is supposed, as for natural proof, that a sire's mates are chosen at random—which may be questionable in some cases. It is assumed also that the herds in which the daughters' records are made are unselected. When the number of daughters is large the difference in accuracy of the two methods is small and the second method may be preferable on the grounds of simplicity.

The possibility of obtaining a satisfactory A.B. proof at an earlier age is distinctly advantageous from the point of view of reduced generation turnover. On the other hand, this incurs the possible danger of selecting for early maturity rather than lifetime yield. Also, it accentuates the need for adequate age correction factors.

CONCLUSION.

Improvements to Date.

The production levels of present-day dairy cows bear tribute to the selection endeavours of our forebears. Recent improvement in general, however, has been disappointingly small and can mostly be ascribed to improved feeding and management. Progress under A.B. has likewise, in most countries, been small or negligible. Production increases have indeed been achieved in New Zealand, but only on a very small fraction of the population and even here gains have fallen far short of what could be expected.

Requirements for Future Progress.

Future progress in a selection programme will depend on the validity of the underlying assumptions, on the accuracy of the estimates of the population parameters involved, and on the thoroughness with which the programme is applied. Solution of the many problems arising calls for co-operation among geneticists, statisticians, field workers and administrators.

In my opinion, the most urgent needs in New Zealand at this stage are for:

1. Improved methods of age correction;
2. Better estimates of the major components of total variance (herds and cows, both genetic and environmental; seasons; and their interactions) which determine heritabilities and and repeatability;
3. Knowledge of the relationships among cows within herds;
4. A selection index for young bulls based on all relevant production data in their pedigrees;
5. Study of the mode of inheritance of butterfat yield, particularly in respect of non-additive genetic effects (dominance, epistasis and heterosis) and genotype-environment interaction;
6. A procedure for assessing the genetic gains made.

These are by no means easy problems. Nevertheless it is my belief that the science of population genetics, even in its present youthful state, can provide answers, albeit imperfect, application of which will operate to the material advantage of New Zealand's dairy industry.

SUMMARY:

1. Since available evidence suggests that but little of the observed variation between herds is genetic, allowance for herd differences is necessary in comparing animals on the basis of records made in different herds.
2. In appraising a bull his daughters' average, or its difference from the herd level, must be scaled down by a factor depending on the number of daughters and of records per daughter.
3. Considerable initial improvement—about 30lb. increase in butterfat yield per cow—may be expected under A.B. Subsequent gains will be dependent on the efficiency of appraising bull calves from their production pedigrees, and on the balance between the numbers of naturally-proved, of artificially-proved and of young bulls used.
4. An indication is given of the most important current investigational needs.

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Discussion

MR. BRUMBY: Dr. Carter made reference to age regression. A study of the English results shows that there is no relationship at all between age correction and herd production level whereas the New Zealand data shows there is a relationship. Would Dr. Carter care to comment?

DR. CARTER: Differences undoubtedly exist between herds in respect of both real (due to environmental and genetic differences) and apparent (due to differences in selection and culling procedures) rate of approach to maturity. Correction factors for individual herds are clearly impracticable. Since yield increments with age do appear to some extent correlated with herd production level under New Zealand conditions, a regression correction is suggested (making allowance perhaps for geographical or other groups of herds). Although necessarily only an approximation such a method will be more accurate than use of a simple additive or proportionate adjustment.

MISS CASTLE: While I agree that there is room for improvement in age correction factors, I cannot see that this is going to affect our breeding progress. There is a vast difference in the rate of maturity between herds and whatever correction we use, it will have to be applied to all herds generally. I cannot see that improved correction will help us to select sires for artificial breeding.

DR. CARTER: If the true age corrections were dependent on herd level then use of a simple additive factor would bias the comparison of sires on the basis of surveys at different herd levels. Likewise in appraising artificial breeding proofs, use of an additive correction would introduce a bias if the bulls compared had their offspring in herds of different average productive levels. In either case, the bias would adversely affect the selection of the top sires for use in artificial breeding and hence the resultant genetic progress.

MR. STITCHBURY: Isn't there a danger in putting an index on any particular bull which attempts to compare one bull directly with another? Regardless of how accurate an age correction factor may be there are many other factors for which no allowance could be made.

DR. CARTER: Yes, any production index in itself is necessarily an incomplete measure of an animal's breeding worth, since many factors not susceptible to measurements are also involved. As was emphasised in the paper, all relevant information must be considered in selecting a sire. The "production index" may, in fact, be regarded as a "screen" for sifting out a reasonable number of likely bulls, selection among which may then be based on other considerations. With this qualification, however, an index is of very definite value.

MR. SEARLE: Dr. Carter appears to have taken no account of herd size into his method for weighting the difference from expectancy.

DR. CARTER: Errors in the mature cow average considered as a measure of herd level will be negligible provided the average is based on about fifty or more cows. Hence, adjustment for herd size would be an unnecessary refinement except perhaps for preliminary surveys (single season's records) in small herds.

MR. McQUEEN: Dr. Carter mentioned that it might be better to correct to the two-year stage rather than to maturity. Could he tell us what advantage there is in that system?

DR. CARTER: Although, owing to the effects of differential culling, it is not possible to predict reliably a cow's subsequent performance from, say, the first lactation records, comprehensive existing herd record data may be used to estimate the average yields of two-year-olds at any herd level. Allowance could be made in the derived prediction formulae for such factors as district, season, herd size, replacement rate, which were found to be important. By standardizing all records to two years, one would in effect compare the daughters of a sire with the normal replacements at the corresponding herd level—rather than with the (M.E.) productions of the daughters of the average surveyed sire, as in the "expectancy" method. With this procedure all other cows in the herd (and not merely the mature cows) would enter into the comparison and, for early surveys at least, where most of the daughters will have only one record, age complications in the daughter average will be reduced to a minimum.

MR. LAMBOURNE: Dr. Henderson has indicated the importance of the various factors affecting variation in butterfat yields in the United States. How does this compare with the situation in New Zealand?

DR. CARTER: I would like to refer this question to the Dairy Board, who have admirable data pertaining to New Zealand conditions. Its analysis, along the lines indicated by Dr. Henderson, should yield valuable information. In an extensive study of relevant published estimates from various sources and of available New Zealand data I have found a fair measure of agreement on the magnitude of the variation in butterfat yields between and within herds, and would guess that Dr. Henderson's subdivision of the total variance would be approximately valid here also. However, confirmation of this is definitely needed.