Levels of Inbreeding in New Zealand Pedigree Jersey Cattle

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THE herd books of the three specialised dairy breeds of importance in New Zealand have long been closed to all except imported animals and consequently, some inbreeding is probably taking place. As far as is known, however, the extent and the role of inbreeding in the development of the pure breeds of dairy cattle in the Dominion has not been studied.

Pedigree breeders generally view inbreeding with distaste but it should be born in mind that they usually confine their use of the term "Inbreeding" to the mating of close relatives such as parents and offspring, full or half-sibs. Inbreeding, however, includes not only the mating together of such closely related animals but also the mating together of animals more closely related to each other than the average relationship within the breed concerned. (Lush, 1945).

These two definitions of inbreeding—the restricted definition of breeders and the broader scientific definition—permit a division of total inbreeding into two main categories. The first of these consists of inbreeding as defined by the breeders which for convenience may be called Current Inbreeding. The second category, known as Non-current Inbreeding, includes the remaining inbreeding due to the repetition of more remote ancestors in both top and bottom halves of individual pedigrees. The line joining an animal's seperate appearances in the two halves of a pedigree is defined as a "tie." Current Inbreeding refers to ties which lie completely within the parental or grandparental generations, Non-current Inbreeding to ties, part or all of which, lie beyond the grandparental generation.

It is appropriate at this stage to mention the confusion which usually surrounds the use of the two terms "inbreeding" and "line-breeding." The difference in the minds of most breeders is one of degree—when the mates are closely related the offspring are inbred, when less closely related the offspring are line-bred. The real difference, however, is one of intent. When the primary aim is to build up relationship to an admired ancestor then the term "line-breeding" should be employed. When the primary aim is to build up prepotency or homozygosity then the term "inbreeding" is correct. Insofar as breeders' intentions are seldom clearly defined and frequently subject to change, classification of mating according to intent is not at all satisfactory. Consequently, in classifying matings it is generally convenient to use the distinction made by breeders between line—and inbreeding—that is differentiation based on closeness of relationship between mates rather than the hoped-for results of the mating. Thus the inbreeding which invariably accompanies line-breeding as it is defined by breeders is included in the Non-current Inbreeding.

In order to estimate the degree of Current Inbreeding in the pedigree section of the Jersey breed in New Zealand, samples varying in size according to the number of heifers registered annually were taken from herd books published at five-yearly intervals and pedigrees reconstructed for each animal back to the four grandparents. For each sample, the total number of "close" matings, the proportion of each type of mating, and the estimate of the average inbreeding (F) is shown in Table I.

TABLE I: Current Inbreeding in the N.Z. Pedigree Jersey Breed, 1905-1950.

Herd Book Years	Sample (No.)	"Close" Matings (No.)	Percentage of all matings which were:— Sire-Dtr. (%)	Dam-Son (%)	Full Sib (%)	Pat.½-Sib (%)	Mat.½-Sib (%)	Average Inbreeding (F%)
1903–5	193	16	3.11		0.52	4.66		1.49
1908–10	356	24	3.09	0.28	0.56	2.53	0.28	1.33
1915	300	21	2.00			4.67	0.33	1.12
1920	300	20	1.00	0.33		5.33		1.00
1925	300	29	3.33	0.67		5.33	0.33	1.71
1930	300	23	1.33	0.33		5.67	0.33	1.17
1935	500	41	2.40			5.60	0.20	1.32
1940	500	31	1.00	0.20	0.20	4.60	0.20	0.95
1945	500	39	1.60	0.20		5.40	0.60	1.20
1950	500	20	0.80	0.20		3.00		0.62

Whether or not one considers the proportion of "close" matings high depends on one's prior opinions. In the 1925 sample almost one in every ten effective matings was "close" although the average figure for the ten samples studied was approximately one in every fourteen. With the exception of the sample taken from the 1950 herd book the proportion of "close" mating has been remarkably uniform.

The reason for the decline in "close" matings in the 1950 sample is not clear. It may reflect the individually diverse origins of the many new herds founded since 1945. In view of the general antipathy to inbreeding these new breeders would be unlikely to purchase sires and dams which were half-sibs. Further, as will be mentioned later, financial considerations probably play a part in the amount in inbreeding practised and, since the dairy industry has enjoyed prosperity and the breeders greater opportunities for visiting sales and buying bulls since 1945 than hitherto, the decline in the proportion of close matings is not altogether unexpected.

The effect of Current Inbreeding in increasing the homozygosity of the breed has, however, not been large. When measured in terms of Wright's Coefficient of Inbreeding (F) it may be seen from Table I that in the last fifty years it has been responsible for the breed being approximately only 1% more homozygous than if no "close" breeding had occurred.

The relative importance of the various types of "close" breeding which comprise Current Inbreeding is of interest. Sire-daughter matings appear to have become less popular in recent years while dam-son, full-sib and maternal half-sib matings have not been frequent at any stage of the breed's recorded history. Numerically, paternal half-sib matings have been by far the most important. Approximately 5% of all matings resulting in the birth of registered offspring have been between animals with a common sire.

TABLE II: Distribution of Paternal ½-sib Matings.

Matings according to ages of mates.

Age of Sire at mating	Age of Dam at Mating 1yr.	2yr.	3yr.	4yr.	5 & over	%age Dist. Close mtgs.	All mtgs.
1 year	29	9	1	2	2	46.2	25.5
2 years	4	7	1	3	2	18.3	23.4
3 years	1	2	5	1	5	15.1	13.0
4 years	1		1	5	1	8.6	12.3
5 & over			1	2	8	11.8	25.8
Dist. "Close" Matings (%)	37.6	19.4	9.7	14.0	19.4	100.0	
Dist. All Matings (%)	22.4	18.8	13.3	7.2	38.3		100.0

The relative importance of these paternal half-sib matings justified closer examination of the data and the ninety-three matings of this type recorded in the 1935-50 samples were distributed according to the age at mating of both sire and dam. The findings are shown in Table II together with the distribution according to age at mating of sires and dams of a random sample of registered heifers (Stewart 1951). 46.2% of the sires and 37.6% of the dams involved in the "close" breeding were "yearlings" when mated. The comparable percentages in the breed sample were 25.5% and 22.4% respectively. The preponderance of young animals in these "close" matings may represent breeders' efforts to line-breed to a particular sire since the progeny would bear approximately the same relationship as either parent to this sire. On the other hand, since in twenty-nine of the ninety-three matings considered both mates were yearlings it is possible that home-bred

"yearling" bulls and "yearling" heifers by the same sire have been run together for reasons of convenience or economy with the primary aim of getting the heifers in calf rather than inbreeding as such. It may well have been the original intention of the breeders concerned not to register the resulting inbred progeny but, with both parents registered and the offspring apparently normal, the latter would fulfil the requirements for registration. These speculations, however, should not be permitted to draw attention from the high incidence of "close" matings. Inbreeding, as defined by the majority of breeders and reputedly held in disfavour by them, is commonly practised.

In addition to the Current Inbreeding due to an animal appearing twice in the parental and/or grandparental generations there is the Non-current Inbreeding due to the repetition of more remote ancestors in individual pedigrees. To determine the Non-current Inbreeding a method of sampling herd books and pedigrees described at this Conference two years ago in a paper dealing with the importance of importations in the New Zealand Jersey breed was used. (Stewart 1952). These data consisting of ten samples of 100 registered heifers drawn from herd books separated by five-year intervals permitted estimates of Non-current Inbreeding relative to the N.Z. pedigree Jersey population in 1895 to be made. Because complete pedigree information for all imported animals was not available, it was not possible to continue lines tracing to imported animals back to 1894. For this reason it was necessary to assume that all imported animals were neither inbred nor related to each other.

The estimate of Non-current Inbreeding relative to 1895 was obtained comparatively simply. If, in an eight-line pedigree an animal appeared in one of the top four lines and also in one of the bottom four a "tie" was said to exist between the two lines. These "ties" indicated that some inbreeding had taken place and were all that were needed to be counted regardless of the number of generations separating the inbred individual from the ancestor responsible for the inbreeding. With four lines in each half of a pedigree there were sixteen possible ties in each pedigree. By a modification of Wright's formula (Robertson and Asker 1951) it was possible to estimate the Non-current Inbreeding by dividing the actual ties by twice the possible ties. Thus with one tie in every pedigree the average Non-current Inbreeding Coefficient would be one half of one sixteenth or 3.125%.

The Non-current Inbreeding may be further subdivided. Since the present New Zealand Jersey herd is descended from comparativly few animals—approximately 279 bulls and 225 cows were imported into the Dominion between 1862 and 1950—the two parents of an animal selected at random from the breed may have one or more ancestors born since 1894 in common. Such an animal would be inbred although the breeder may be unaware of it. On the other hand, particularly if breeders have tried to preserve strains within the breed, such inbreeding may have been the result of deliberate line-breeding.

One way of determining that proportion of the Non-current Inbreeding which is deliberate and that which is incidental is to compare the level of Non-current Inbreeding in a sample of actual matings with that which would have occurred had random breeding taken place, i.e. if each sire in the sample had been mated with every dam in the sample with the exception of his actual mate. The difference between the actual Non-current Inbreeding and the incidental Non-current Inbreeding estimated from random mating gives a measure of the deliberate Non-current Inbreeding. This indicates the tendency of the breed as a whole to split up into strains or families.

Thus it is possible to subdivide the Total Inbreeding into

(1) The Current Inbreeding—due to sib or parent-offspring matings.

(2) The Non-current Inbreeding consisting of:—

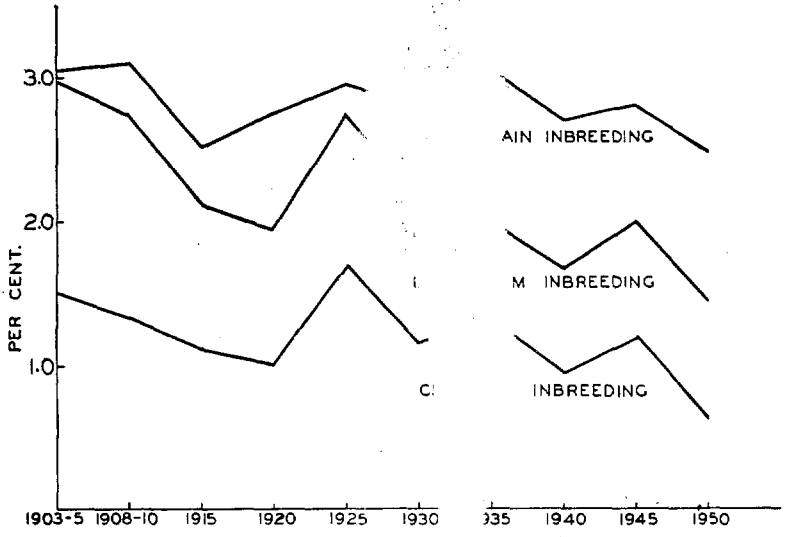
(a) The Incidental or Long-term Inbreeding—due to important animals in the breeding appearing beyond the grand-parental generation in either or both the top and bottom halves of each pedigree.

(b) The Deliberate Non-current Inbreeding—due to the separation of the breed into strai .

TABLE III: The Total Inbreeding and its Components in the N.Z. Pedigree Jersey Breed 50 relative to 1895.

Herd-Book Year(s)	Inbreeding Current %	Inbreed Long-t %	Inbreeding Strain %	Inbreeding Total %
1903–05	1.49	1.4	0.07	3.05
1908–10	1.33	1.4	0.36	3.11
1915	1.12	1.0	0.40	2.52
1920	1.00	0.9	0.82	2.76
1925	1.71	1.'	0.21	2.96
1930	1.17	0.'	0.64	2.78
1935	1.32	0	1.05	3.05
1940	0.95	0	1.02	2.70
1945	1.20	0.	0.81	2.79
1950	0.62	0	1.06	2.49

The Total Inbreeding and the itions of each of the three main components for each of the ods sampled are shown in Table III and Fig. I. Bearing in e assumption that all imported animals are neither inbre lated to each other or to animals born in New Zealand ans that the Non-current Inbreeding will have been under- some tentative conclusions may be drawn. First the level breeding relative to 1895 has remained remarkably unifor a comparatively low level



THE COMPONENTS OF TOTAL INBREE IN N.Z. REGISTERED JERSEY HEIFERS 1903 - 1950.

throughout the last fifty years. In view of the relatively high incidence of "close" matings during the period studied these findings are somewhat unexpected. This is probably due to inbred heifers seldom being mated to related sires and thus the Current Inbreeding in successive generations would not be cumulative. Further, with the assumption that each imported animal represents an outcross, the Non-current Inbreeding contributes less to the Total Inbreeding than would be the case were complete pedigree details back to 1895 available for all imported animals.

One can only speculate on the levels to which the average degree of inbreeding in New Zealand pedigree Jerseys could be increased without general deterioration in the breed. There is some evidence which indicates that if careful selection is practised, levels of inbreeding may be considerably higher than those obtaining within the breed as a whole at present without prejudicing productive capacity. The fifty-two registered heifers born in 1949 in a pedigree Jersey herd which, with the exception of two imported bulls, had been closed for approximately twenty years had an average inbreeding coefficient of 7%, approximately three times as high as the average. This high producing herd has an outstanding record as a source of sires for the industry.

Secondly, with the exception of the 1925 sample, the conservative estimates of Non-current Inbreeding consisting of the "long-term" or incidental inbreeding and the "strain" or deliberate inbreeding has been more important than the Current Inbreeding—that due to close matings—in increasing the homozygosity of the breed relative to 1895. In other words, though the proportion of close matings has been uniformly high, it is the animals well back in pedigrees which make the major contributions to increases in homozygosity. Since the New Zealand Jersey herd books have long been closed and since the breed in the Dominion is descended from relatively few animals some degree of Non-current Inbreeding is unavoidable. Should it be considered desirable to avoid further increases in the average level of inbreeding, opening the herd books should be advocated.

Thirdly, the contribution of "strain" inbreeding, though relatively more important in recent years than formerly, suggests that the breed as a whole has not been and is not now, split into strains. There may be some breeders who have endeavoured to confine their matings to descendants of a reputedly outstanding individual but their efforts, if successful, have been obliterated by those of the majority of breeders who have either ignored relationship considerations in their herd breeding policies or indulged in frequent outcrosses. One herd with the reputation of being "one of the most intensely bred Majesty herds in the country" was studied and it was estimated that of the genes in the registered heifers born in 1949 the probable contributions made by Soumise Majesty and Soumise Lily were 4.5% and 6.2% respectively. One "Majesty" gene in every ten scarcely entitles a herd to particular distinction.

It is clear that in the breed as a whole uninterrupted line-breeding programmes have featured rarely among the mating systems practised. This is not surprising in view of the short duration of the majority of pedigree herds (Stewart 1952) and the mixed origins of the large number of new pedigree herds established each year. Among herds of longer duration, mild line-breeding may be practised for two or three generations but at this stage the breeder almost invariably senses the need for an outcross. Assuming that the need is a real one, in view of the mild form of line-breeding usually practised the need to outcross is likely to be due as much to poor selection as to the deleterious effects of the low levels of inbreeding which accompany mild line-breeding.

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Discussion

Professor RAE: Some of the implications of this paper are of interest. Bearing in mind the assumptions made by Dr. Stewart, it appears that the level of inbreeding attained after approximately fifty years is about the same that would have occurred had random mating been practised and only thirty bulls used at any one time. I understand that the number of bulls already being used at the local artificial breeding centre is in excess of thirty and on this score breeders should not be unduly concerned about the general level of inbreeding in the Jersey breed.

Dr. CARTER: Was there any difference between the level of inbreeding between bull and heifer registrations?

Dr. STEWART: This information was not extracted. It is possible that bull calves were more inbred than heifers but heifer registrations were chosen because they are less selected than bull registrations and more likely to give a picture of the inbreeding taking place in the breed as a whole.

Col. DURRANT: How long do you consider it would take to reach the danger level of inbreeding in a closed herd?

Dr. STEWART: It would depend on many factors. Firstly, the danger level may vary from herd to herd according to the genetic material being used. Secondly, the speed with which the danger level would be reached would depend on the mating system practised, the size of the herd, and luck. I have quoted the example of a 100-cow herd which has been closed for twenty years. The average inbreeding is now about 7% and there is no sign that the danger level has been reached as yet. One might anticipate it at 10-15% but the deterioration due to this level of inbreeding might well be concealed by the improvements due to the accurate selection possible.