STUDIES OF MILK PRODUCTION IN CROSSBRED
DAIRY CATTLE

by

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ABSTRACT

The main objectives of this investigation were to determine class averages for crossbreds and for backcrosses, to study heterosis, results of polyallel analysis, sire combining ability and age of maximum milk production in crosses.

Production records (60,931) of dairy cattle under test by the Dairy Herd Improvement Association in British Columbia for the years 1958-1961 inclusive were used. Out of these records, 56,765 were of purebreeds (including high grades), 3113 of cross bred and 1053 of backcrosses.

To decide class averages for crossbreds, a t-test and F-test (using the average of milk and fat indexes for t-test and fat-corrected-milk values for F-test) were carried out. There were no significant differences between production records of various groups of crossbreds at 5 % level of probability in both the tests. Therefore, these data indicate that a single set of class averages may be recommended for all crossbred dairy cows.

Fat-corrected-milk values for purebreeds, crossbreds and backcrosses were compared. Nine out of 12 comparisons made indicated that backcrosses were closer in production to the parental breed used in backcrossing than to the crossbreds of the breeds concerned. Therefore, for the purposes of establishing base averages and of calculating indexes, it is

considered that backcrosses should be classified with the parental breed used in backcrossing.

Fat-corrected-milk values were also used for a comparison of purebreeds and their corresponding crossbreds to detect the presence or absence of heterosis. Hybrid vigour was demonstrated in all crossbreds except Holstein-Ayrshire.

A polyallel analysis was applied to the data using the average of milk and fat indexes for the two-year-old and three-year-old production records of the crossbreds. It was found that the general combining ability and reciprocal effect were highly significant. Specific combining ability was significant only at the 5 % level. Heritability was calculated for fat-corrected-milk values and found to be 0.47.

Purebreed and crossbreed daughter indexes were used from 10 artificial insemination sires for a within-breed-of-sire comparison. The analyses indicated that the best sire for purebreeding is not necessarily recommended for crossbreeding.

The average production of crossbreds, grouped according to age, showed a sharp increase from 2 years to 4 years, followed by a relatively small increase from 4 years to 7 years. There was a gradual drop in production after the seventh year. Crossbreds reached their maximum milk production at 7 years of age.

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CHAPTER I

INTRODUCTION

Crossbreeding has been practised in cattle for a long time, but experimental work in crossing dairy cattle started only about 60 years ago. In British Columbia, crossing of dairy cattle is being carried out by a number of farmers mainly by using Holstein sires on females of the other 3 dairy breeds. Recording of milk and milk fat production of crossbred cows by the Dairy Herd Improvement Association began in 1954. Now over ten percent of the cows on Dairy Herd Improvement Association tests are crossbreds.

Occasionally a dairyman owning one type of breed wishes to change over to another breed, but he has the fear of unknown risks that might be involved. Some of the dairymen would like to know whether there is a possibility of obtaining advantages parallel to those realized in hybrid corn, and in crossbreds of poultry, swine and sheep. More information about the results of crosses between breeds of dairy cattle is needed in order to provide adequate guidance for dairymen.

This investigation, was undertaken in order to determine class averages for crossbreds and for backcrosses. In addition, a study of heterotic effects, the results of a polyallel analysis, estimate of sire combining ability and

determination of the age of maximum milk production in cross-breds are an integral portion of this thesis. The data used for the studies were recorded under natural field conditions all over the Province of British Columbia. The results should, therefore, be of practical application and extreme interest to the dairy farmers in this province who may want to start crossbreeding dairy cattle.

CHAPTER II

REVIEW OF LITERATURE

To a practical dairyman, meaningful aims of crossbreeding are two. First, crossbreeding is a source of new genetic variation. Due to this, it is possible to introduce into the gene pool of a breed hereditary factors which were not there before and which may be important in milk and fat production. It is because of increased genetic variation that crossbreeding is used in order to develop a new breed. The second aim of crossbreeding is to utilize the effects of heterosis.

Heterosis has been defined in two different ways by genetisists. Falconer (13), Lush (29) and Touchberry (40), all agree on a more or less similar definition. Falconer defines it as the difference of cross-bred progeny from the mean of the two parent populations. But Bogart (7) and Robertson (35), have a different definition of hybrid vigour. According to them, heterosis is a condition in which the crossbred population shows more vigour than either of the parental stocks used in making the crosses. In terms of milk production, the last definition implies that the crossbred cows must be superior to the higher producing parent breed if hybrid vigour is to be demonstrated.

Touchberry (40), in an experiment with crossbreds of Holstein and Guernsey, reported that crossbreeding resulted

in a 4.5 % increase in milk yield and 14.6 % increase in butter-fat yield over the average of the parental breeds.

Steves (23), using average index values of crossbred milk and fat production found an increase above the mean of the two parental breeds concerned as shown below.

<u>Cross and Reciprical</u>	<u>% Increase</u>
Ayrshire x Guernsey	9.9
Ayrshire x Jersey	6.6
Holstein x Jersey	3.4
Guernsey x Jersey	3.2
Holstein x Guernsey	2.2
Holstein x Ayrshire	- 5.6

Steves' data comprised one year (1958) of Dairy Herd Improvement Association records in British Columbia.

Fohrman (14) reported the results of an experiment on crossing of dairy cattle at Beltsville. The experiment was started in 1939 and the breeds involved were: Holstein, Gurnsey, Jersey and Danish Red. The production of all the crosses showed presence of hybrid vigour. It was found that crossbreds had a high degree of persistency which accounted for their heavy yields.

It is not only because crossbred cows average more milk per lactation that they prove superior to their parental population. They also live and produce longer. In Agricultural Research (1), it has been shown that crossbred dairy cattle, because of their superior hardiness, live and produce

longer, on the average, than comparable pure breeds. It is reported in a U.S.D.A. - Illinois experiment that 44 of 63 crossbred cows (Holstein-Guernsey) survived 6 lactations. But only 31 of 65 purebreds performed that well.¹ Crossbreeding, because of hybrid vigour phenomenon it was stated, appears to be a practical genetic way of appreciably increasing the length of productive life in dairy cattle. According to the scientists, efforts to breed for longer life in purebreds fail mainly because heritability of longevity is practically zero. Genetically it is said, that similar animals do not pass on their long living traits to offspring.

Toucberry and Dickinson (40) believe that due to the favourable results realized in crossbreeding, the owners of average dairy herds might well consider using crossbred animals to improve herd longevity.

Branton et al (9), in an experiment conducted at 3 different research stations with Holstein, Brown Swiss, and Red Sindhi-crosses, reported on F1 and backcrosses. Their crossbreeding experiments were concurrently being carried out at Baton Rouge, Beltsville and Homer. The data recorded below were used for comparisons between backcrosses versus purebreds and backcrosses versus crossbreds.

1 Animals that died from accidental causes were not included in the research data. But those removed because of sterility, disease or deformity were. Also included were still-born calves that survived at least 7 months of pregnancy.

<u>Breed Group</u>	<u>No. Animals</u>	<u>Ave. Milk</u>	<u>Ave. Fat</u>	<u>Fat-corrected Milk</u> ²
H x Red Sindhi	33	4,710	175	4,509
3/4 H 1/4 Red Sindhi	21	6,765	276	6,846
Pure Holstein	-	9,713	362	9,315
Brown Swiss x Red Sindhi	30	3,286	161	3,729
3/4 Brown Swiss 1/4 Red Sindhi	25	5,047	225	5,394
Pure Brown Swiss	-	5,603	228	5,661

The comparisons between backcrosses with the purebreeds and backcrosses with first generation crosses using fat corrected milk values, indicate that backcrosses in case of Holstein-Red Sindhi, made records nearer to F_1 than to those of the parental breed (Holstein) used in backcrossing. The second comparisons where Brown Swiss and Red Sindhi are involved show that backcrosses made average production nearer to that of the parental breed (Brown Swiss) used in backcrossing than to the average production of the F_1 .

In order to compare the production of crossbreds, records were weighted by the factor $\frac{n}{n+1}$. The above workers followed this procedure rather than attempting to adjust the crossbred records to a mature equivalent (M.E.) basis because no reliable correction age factors were available for use on the crossbred records. This shows the necessity of developing

2 Fat-corrected-milk values were calculated by the writer.

a method by which crossbred and backcross records can be adjusted satisfactorily.

One of the factors causing variation in both milk and fat production among dairy cattle is age of the animal. The adjustment of production records in order to make reasonable comparisons between the cows and in order to appraise the breeding worth of dairy bulls has become an essential requirement for dairy cattle improvement. There are two methods used in adjusting records of purebreeds. The first one is - use of correction factors to adjust production to a common class. This method was devised earlier than the second one. The second is - the Breed Class Average (B.C.A.) system explained in detail by Gyles (21) in 1949.

Berry (5) says that B.C.A. eliminates the drawbacks of correction factors. He reports that the drawbacks of the correction factor method are: (a) it brings some confusion, because of the one performance being measured by both actual and corrected pounds of milk, (b) there is an implied prediction that corrected pounds represent what the animal would have done under other circumstances. This prediction does not prove to be correct very often.

The B.C.A. system was first put into practice by the Canadian Ayrshire Association in co-operation with R.O.P. on May 1, 1953, and the other dairy breeds soon followed. So far this system is being used only in Canada. It is worth mentioning here that neither of the two methods has ever been applied to crossbreds in Canada.

Under B.C.A. system, the production of a cow is reported by calculating indexes. There are two different methods followed in calculating indexes. The first one is the average of milk and fat index method which is the one already established for comparing purebreeds within a given breed. The second method is that of fat corrected milk index.

Rice (34) states that Gains and Davison had suggested a method for converting milk of any test to a given standard percent of fat corrected milk. He reported the factors for this as, 0.4 times total mil + 15 times total butterfat. He said that it would be impossible to determine superiority between a cow which made 20,000 lbs. of 3% milk and 600 lbs. of butterfat and one which made 14,000 lbs. of 5% milk and 700 lbs. of butterfat unless correction is made for differences in fat %. Applying the above factors, however, gives us

$$(20,000 \times 0.4) 8,000 + (600 \times 15) 9,000 = 17,000 \text{ lbs. of } 4\%$$

F.C.M. for the first animal and

$$(14,000 \times 0.4) 5,600 + (700 \times 15) 10,500 = 16,100 \text{ lbs. of } 4\% \text{ F.C.M. for the second.}$$

According to Rice, the first cow transformed more feed energy into milk energy than did the second without regard to the efficiency of the transformation. The figure 17,000 lbs. of 4% F.C.M. for the first cow means that in making 20,000 lbs. of 3% milk she transformed as much feed energy into milk energy as she would have done if she had made 17,000 lbs. of 4% milk. He said that the breeder in any breed will have cows which vary quite a bit in butterfat test. A method is available for converting milk of any test to any standard.

He gave the procedure as being based on the figures for converting to 4 % F.C.M., namely, 0.4 of the milk plus 15 times the total butterfat. He stated that one pound of 5.3 % milk is equal to $1 \times 0.4 = 0.4$ plus $0.053 \times 15 = 0.795$ or 1.195 lb. F.C.M. and the figures for converting milk of any test to a standard 5.3 % F.C.M. are obtained by dividing $(0.4 M + 15 F)$ by 1.195, which gives us milk times 0.3347 and total fat times 12.55.

Joubert (27) gave the meaning of Mature Equivalent (M.E.) as the way to express the result of all calculations necessary to put production of a cow on a common basis with the production of all the cows of the breed. He realized the confusion in application of M.E. which he explained was due to the fact that results were being expressed in lbs. of milk. The lbs. which were not actually produced were according to him a source of error. To avoid this, he suggested that results be expressed in percentages of breed averages. For example, instead of saying that cow x gave say 8,982 lbs. in 305 days at 5 years (actual) and 9,182 lbs. (M.E.), he suggested they say - cow x gave 8,982 lbs. (103.8 %) at 5 years.

McKinnon (32) states that by using the mature equivalent any one record or any average of records could be compared with another average of records.

Gyles (21) states that although the total amount of milk produced tends to increase until the cow is about 8 years

of age, the increase after the 5th year is relatively unimportant. He says that after the age of maximum flow is passed (8 years), the flow diminishes with advancing age. He further states that the rate of decrease after the maximum is much slower than the rate of increase preceding the maximum.

CHAPTER III

MATERIAL STUDIED

Production records (60,931) of dairy cattle under test by Dairy Herd Improvement Association (D.H.I.A.) in British Columbia for the years 1958 - 1961 inclusive were used. Out of these, 56,765 records were of purebreeds (including high grades), 3113 of crossbreds and 1053 of backcrosses. Records of crossbreds and of backcrosses were those from 240 days to 305 days inclusive all considered as full 305 days records. Those of purebreeds were from 182 to 305 days. The crossbred and backcross records had advantage over the purebred records which amounted to approximately 2 % of F.C.M. values. (It is reported in Canadian R.O.P. for purebred dairy cattle (10), that in 1957 the requirements for lactation length were changed and accordingly B.C.A. calculations are applied to records of 240 days and over instead of 182. This means that records made in the past 6 years have an advantage in being compared to the old standard. The advantage, it was reported, amounts to approximately 2 B.C.A. points.) Therefore prior to comparing the crossbred and backcross records to those of purebreeds it was necessary to reduce the F.C.M. values for crossbreds and backcrosses by 2 %. The resultant values would bring those records to the same minimum days (182) as applied to records of purebreeds. See Appendix Vb and VIb. The dairy

cattle studied were: Holstein-Friesian (H), Ayrshire (A), Guernsey (G), Jersey (J) and their crosses and recipricals.

Arrangements and Calculations

1. The Purebreeds

The purebreed records for the four years were used to find weighted averages for each breed regardless of age. From these averages, fat-corrected-milk (F.C.M.) values were calculated for each breed. Taking breeds two at a time for all possible combinations, between-breed means were calculated. From these F.C.M. values were calculated as shown in appendices I and II.

2. Crossbreeds or F_1 's

a. All records were sorted by age, cross and reciprocals. In sorting by age, months were omitted because in some cases they were not available while in others there was uncertainty as to how reliably they had been recorded. When sorting the records had been done, milk and fat averages were then calculated for each age-group cross and its reciprocal. From these averages milk index (M.I.) fat index (F.I.) and the average of milk and fat indexes (A.I.) for 2 year old and 3 year old cross groups were worked out. (To calculate the indexes, the over-all weighted averages (Wtd.Av.) for each age group was used as a base). Appendix III presents the figures.

b. Records were grouped according to age for all the crossbreds combined. Then weighted averages and F.C.M. values were calculated resulting in the figures shown in Appendix IV.

c. The production records were also sorted by crosses and recipricals regardless of age. Here, again the weighted averages and F.C.M. values were calculated. See Appendix V.

d. Artificial Insemination: Sires. Many artificial insemination sires were used in crossing. Only sires with at least 5 recorded daughters were selected for study. The daughters' records were sorted by age and cross. A.I. values were then calculated for each individual record - Appendix VII.

3. Backcrosses

Sorting of the records was done by age and by backcrosses. Then milk average (M.A.), fat average (F.A.) and F.C.M. values were worked out - Appendix VI.

CHAPTER IV

ANALYSES AND RESULTS

Crossbred Class Averages

Two tests (t and F) were carried out to find whether the various groups of crossbreds belong to different populations as far as milk production is concerned. (i) t-test. Six samples each of size 30 were randomly selected from the six groups of crossbred records. These selected records were then sorted by ages. MI, FI and AI values were calculated for each record. These AI values were used for analysis. Arranged in descending order, the means from the 6 samples turned out as follows: $\overleftrightarrow{HJ}^3$ highest, followed by $\overleftrightarrow{HG}$, $\overleftrightarrow{JG}$, $\overleftrightarrow{AG}$, $\overleftrightarrow{AJ}$ and lowest was $\overleftrightarrow{HA}$ as can be seen in Appendix IX. t-test was then used to compare the highest and the lowest means - See table 1. Prior to comparing the two means, variance for each sample was calculated. Comparing the variances, it was found that they were homogeneous.

Table 1

Comparing the Highest and Lowest Sample Means
of Records from Crossbred Groups

df	Calculated t	Table t at 5 %
58	1.64 ns.	2.01
ns - not significant $P < 0.05$		

3 $\leftrightarrow$ Indicates cross and reciprocal.

These results indicate that there is no significant difference in production among the 6 crossbred groups. Crossbreds, therefore, belong to the same population. (ii) F-test. In this analysis, F.C.M. values from averages were used. The 6 different crossbred groups were considered as treatments and their ages as replications.* There were in all 6 treatments and 8 replications. All the 3113 crossbred records were used in the analysis. To simplify the calculations it was essential to code the data. Coding was done by subtracting 8,300 lbs. from F.C.M. values. See Appendix IV and X. The analysis carried out was that of the completely random design. The results are in Table 2.

Table 2
Analysis of Variance of Milk Yield by
Different Crossbred Groups

SV	df	SS	Calculated F	Table F at 5 %
Cross	5	8,981,245 ^{ns}	2.22	2.41
Error	42	33,969,294		
Total	47	42,950,539		

ns - not significant $P < 0.05$

The F-test in Table 2 like the t-test in Table 1 shows no significant differences among the production records of the various crossbred groups at the 5 % level of probability. Thus both tests indicate that crossbreds belong to the

*See glossary of symbols, page 53.

same population.

Backcrosses

The number of backcross records was not large enough to establish reliable class averages for backcrosses. Therefore, an analysis was carried out to decide whether the average production of each backcross group was closer to that of the appropriate crossbred group or whether it was closer to that of the parental breed used in backcrossing. To solve this problem, F.C.M. values from all the 60,931 production records of purebreeds, crossbreeds and backcrosses were utilized as shown in Table 3. See also Figure 2.

Of the 12 comparisons, 9 were closer to the parental breed. The average deviation of the parental breed from the backcrosses was 568 lbs. of F.C.M. = 6.4 percent deviation. The comparable figures for crossbreeds were 902 lbs. and 10.2 percent.

The other 3 comparisons show an average deviation from the backcrosses of 812 pounds and 8.5 percent and 417 pounds and 4.6 percent for the pure breeds and the crossbreeds respectively. It is concluded, therefore, that backcrosses should be classified with the parental breed.

Heterosis

There are two different definitions of hybrid vigour as has been explained under review of literature. To satisfy both the definitions, calculations were directed accordingly.

Table 3

Twelve (12) Comparisons between Backcrosses v.s. Purebreeds
Backcrosses v.s. Crossbreds

Back-cross	No Records	F.C.M.	Com- pared with	No Records	F.C.M.	Devi- ation	% Devi- ation
HHA	56	10,315	H	37,416	11,209	-894	-8.7
HHA	56	10,315	↔ HA	264	10,208	107	1.0
HHG	296	11,108	H	37,416	11,209	-101	-0.9
HHG	296	11,108	↔ HG	828	10,866	242	2.2
HHJ	368	10,792	H	37,416	11,209	-417	-3.9
HHJ	368	10,792	↔ HJ	1,254	10,673	119	1.1
AAH	16	9,354	A	1,969	9,551	-197	-2.1
AAH	16	9,354	↔ HA	264	10,208	-854	-9.1
AAG	18	9,975	A	1,969	9,551	424	4.3
AAG	18	9,975	↔ AG	128	10,596	-621	-6.2
AAJ	19	9,536	A	1,969	9,551	-15	-0.2
AAJ	19	9,536	↔ AJ	188	9,965	-429	-4.5
GGH	31	8,027	G	8,240	9,920	-1893	-23.6
GGH	31	8,027	↔ HG	828	10,866	-2839	-35.4
GGA	21	9,080	G	8,240	9,920	-840	-9.3
GGA	21	9,080	↔ AG	128	10,596	-1516	-16.7
GGJ	103	8,796	G	8,240	9,920	-1124	-12.8
GGJ	103	8,796	↔ GJ	451	9,821	-1025	-11.7
JJH	74	9,363	J	9,140	9,262	101	1.1
JJH	74	9,363	↔ HJ	1,254	10,673	-1310	-14.0
JJA	22	9,418	J	9,140	9,262	156	1.7
JJA	22	9,418	↔ AJ	188	9,965	-547	-5.8
JJG	29	8,611	J	9,140	9,262	-651	-7.6
JJG	29	8,611	↔ GJ	451	9,821	-1210	-14.1

F.C.M. values from all the records of purebreeds and of crossbreds were used in hybrid vigour estimations. The average production of each group of crosses was compared with the mean production of the two parent breeds concerned and also compared with the records of the higher producing parents. The results of the comparisons are shown in Table 4 and for further clarification see Figure 2.

Table 4
Percent Hybrid Vigour in Crossbreds

Cross	No. Records	F.C.M.	Compared with	F.C.M.	Devia- tion	% Devia- tion
HA	246	10,208	$\frac{H + A}{2}$	10,436	-228	-2.2
HA	246	10,208	H	11,209	-1001	-9.8
HG	828	10,866	$\frac{H + G}{2}$	10,647	219	2.0
HG	828	10,866	H	11,209	-343	-3.2
HJ	1254	10,673	$\frac{H + J}{2}$	10,318	355	3.3
HJ	1254	10,673	H	11,209	-536	-5.0
AG	128	10,596	$\frac{A + G}{2}$	9,710	886	8.5
AG	128	10,596	G	9,920	676	6.4
AJ	188	9,965	$\frac{A + J}{2}$	9,381	584	5.9
AJ	188	9,965	A	9,551	414	4.2
GJ	451	9,821	$\frac{G + J}{2}$	9,591	230	2.3
GJ	451	9,821	G	9,920	-99	-1.0

As can be seen in the table (column of % deviation), all the crossbreds except HA crosses, showed the presence of hybrid vigour in their F.C.M. values when average production of each group of crosses was compared with the mean production

of the two parental breeds concerned.

When crossbred records were compared with those of the higher producing parent, however, both positive and negative heterosis were demonstrated. In all cases where H was used, it was the higher producing parent and heterosis was negative. In all other cases, except GJ, positive heterosis was indicated.

Polyallel Analysis⁴

In order to test the combining ability of a group of breeds and to estimate the parameters of the populations from which the data for this study came, polyallel analysis was used. The different crosses and their recipricals were blocked according to genotypes of breeds. F.C.M. and AI values for all the 3113 crossbred records were used separately for preliminary calculations. It was found that F.C.M. values and AI values gave similar results. The records of animals aged 4 years and above showed irregularity in the rough preliminary estimates. Therefore, it was decided to use only 2 year old and 3 year old production records. It was decided also to use AI values of those records because compared to F.C.M. values, they are usually smaller figures and are

4 C.E. Gates, personal communication 1963, on split-plot diallel analysis when the F_1 's are blocked according to the female or the male parents, selfs not included.

equally useful as established in the preliminary work.

There were then 2 replications, 2 year olds considered as first replication and 3 year old production records as the second one. The analysis was necessarily split-plot in nature and it was considered only under Eisenhart's model II.

$$X_{gij} = u + P_g + a_i + a_j + \delta_{gi} + \delta_{gj} + Y_{ij} + \pi_{ij} + e_{gij}$$

where $g = 1, 2 \dots r$

$i \neq j = 1, 2 \dots n$

u = over all mean

P_g = replication effect (R)

a_i = general combining ability effect of the parental breed. (Gca)

δ_{gi} = replication x general combining ability interaction

Y_{ij} = specific combining ability effect. (Sca)

e_{gij} = residual effect.

Table 5 a, b, and c give figures used, expectations of mean squares and the results of analysis of variance table respectively.

Table 5(a) reveals that H sires did better in crosses than H dams and J sires also proved better than J dams. H sires on G dams combined better than the remaining pairs. Second to these were H sires on J dams. G dams on the average, give the best combining ability.

Table 5(c) shows that in these particular crosses, Gca and reciprocal effects in general, were highly significant. Sca ability was significant. Calculations from some

of the results of Table 5(c) gave the following answers:

Gca = 9.8

Sca = 12.0

Reciprical effect = 8.7

Additive genetic variance = 19.6

Heritability (h^2) = 0.47

Table 5(a)

Split-plot Polyallel Analysis when the F₁'s are Blocked

According to Female and Male Parents

- Selfs not Included

(The figures are in AI values)

	H	A	G	J	Total	Average
H		85.0 ⁽¹⁾ 90.2 ⁽²⁾	99.1 99.1	99.9 102.7	576.0	192.0
A	99.40 99.2		93.5 98.0	96.7 88.6	575.4	191.8
G	106.0 106.1	94.2 89.7		93.4 95.4	584.8	194.9
J	101.2 102.4	84.3 88.8	91.5 84.8		552.7	184.2
Total	610.0	532.2	566.0	576.7	2,288.9	
Average	204.7	177.4	188.7	192.2	190.7	190.7

(1) Replicate one*

(2) Replicate two*

* See glossary of symbols, page 53.

Table 5(b)
Expectations of Mean Squares

SV	df	E.M.S.					
		σ_e^2	σ_π^2	σ_γ^2	σ_δ^2	σ_a^2	σ_p^2
Replication	r-1	1	0	0	4(n-1)	0	n(n-1)
Gca	n-1	1	0	2r	2(n-2)	2r(n-2)	
R x Gca	(r-1)(n-1)	1	0	0	2(n-2)		
Sca	$\frac{n(n-3)}{2}$	1	0	2r			
Recipricals	$\frac{n(n-1)}{2}$	1	2r				
Residue	n(n-2)(r-1)	1					
Total	rn(n-1)-1	1					

Table 5(c)
Analysis of Variance

SV	df	SS	Calculated F	Table F at	
Replications	1	0.01		5 %	1 %
Gca	3	462.4**	13.64	3.3	4.76
R x Gca	3	15.3			
Sca	2	118.6*	5.25	3.42	5.66
Recipricals	6	276.0**	4.07	2.53	3.71
Residue	8	90.2			
Total	23	962.5			

** Highly significant $P < 0.01$

* Significant $P < 0.05$

Sire Combining Ability in Crosses Compared with Pure Breeds

There were 10 artificial insemination sires selected for comparisons. These were sires used in crossbreeding. Out of 10,4 were H, 2 A, 2 G and 2 J sires. Production records of their daughters were among the 3113 crossbred records for which AI values had been worked out as mentioned under material studied (d). The average of milk and fat indexes of the crossbred and the purebred daughters of each sire were sorted out. The sires' performance was, therefore, evaluated in purebreeds as well as in the crossbreds. A comparison among sires was carried out based on how a sire performed in his breed and on crosses. The results are shown in Table 6.

Table 6⁵

Comparison of Artificial Insemination Sires
Used in Both Crosses and Pure Breeding

Table 6(a) 4 Holstein Sires Compared									
Type	No. Blueboy Records	AI	No. Peter Ormsby Records	AI	No. Valiant Records	AI	No. Blazer Records	AI	
J-Daughters	22	114.6	9	111.9	5	122.4	15	110.8	
G-Daughters	12	117.5	12	123.2	15	105.3	6	105.2	
Wtd AI	34	115.6	21	118.4	20	109.6	21	109.2	
H-Daughters	352	123.7	780	116.5	245	119.3	131	113.3	

5 This table is not to be used for comparing productivity of purebreeds and crossbreds because of reasons explained on page 38.

Table 6(b) 2 Ayrshire Sires Compared

Type	No. Records	White Cockade AI	No. Records	Spitfire AI
J-Daughters	15	110.0	5	99.2
G-Daughters	11	86.8	9	98.3
Wtd AI	26	100.2	14	98.6
A-Daughters	84	116.8	61	116.0

Table 6(c) 2 Guernsey Sires Compared

Type	No. Records	Romlus Lad AI	No. Records	Spring Ike AI
J-Daughters	20	89.2	8	86.1
G-Daughters	148	104.6	125	109.9

Table 6(d) 2 Jersey Sires Compared

Type	No. Records	Sound Radar AI	No. Records	Glomousboy AI
H-Daughters	8	104.5	13	89.9
G-Daughters	3	117.3	15	102.1
Wtd. AI	11	108.0	28	96.4
J-Daughters	72	119.9	80	100.5

Table 6(e)

The Differences in AI of the Daughters of Sires in
Crosses and in Purebreeds

Sires		On Crossbreds	On Purebreeds
H	Peter Ormsby - Blueboy	2.8	-7.2
	Peter Ormsby - Valiant	8.8	-2.8
	Peter Ormsby - Blazer	9.2	3.2
	Blueboy - Valiant	6.0	4.4
	Blueboy - Blazer	6.4	10.4
	Valiant - Blazer	0.4	6.0
A	White Cockade - Spitfire	1.6	0.8
G	Romlus Lad - Spring Ike	3.1	-5.3
J	Sound Radar - Glomousboy	11.6	9.4

Table 6(a) shows that Peter Ormsby did better in crosses than the rest. But in purebreeds, Blueboy led, followed by Valiant and then Ormsby. Blazer remained last in both the cases.

In Table 6(b) White Cockade did better than Spit Fire both in the crossbreds and in the purebreeds.

In Table 6(c) Romlus Lad leads Spring Ike in crosses while in the purebreeds it is the opposite picture.

In Table 6(d) Sound Radar leads over Glomousboy in crossbreds as well as in purebreeds.

These results indicate that the best sire for purebreeding is not necessarily best also for crossing.

A limitation on the reliability and validity of Table 6 is the absence of daughter-dam or contemporary comparisons in evaluating sires.

Age of Maximum Milk Production by Crossbreds

All the crossbred production records were classified into 8 different age groups - 2 year olds, 3 year olds etc., up to 8 year olds. Animals of more than 8 years were grouped together as over 8-, because attempting to divide them into different age groups would result in unreliable averages because of too small numbers. F.C.M. values, total milk and total fat were used. Sorting of the records was done by age regardless of the type of cross. See Appendix IV and Figure 1(a)-(i). These reveal that the total amount of milk

Age in Years and No. of records per Age Group

Figure 1(a) The Influence of Age on Milk Yield of Crossbreds (All Crosses Grouped Agewise)

Age in Years and No. of Records per Age Group

Figure 1(b) The Influence of Age on Butterfat

Yield of Crossbreeds

(All Crossbreeds Grouped Agewise)

Age in Years and No. of Records per Age Group

Figure 1(c) The Influence of Age on the Production
of Crossbred Cows

(All Crossbreds Grouped Agewise)

Age in Years and No. of Records per Age Group

Figure 1(d) The Influence of Age on the
Production of $\overleftarrow{H}$ A Crosses

Age in Years and No. of Records per Age Group

Figure 1(e) The Influence of Age on the
Production of H $\leftrightarrow$ G Crosses

Age in Years and No. of Records per Age Group

Figure 1(f) The Influence of Age on the
Production of H J Crosses

Age in Years and No. of Records per Age Group

Figure 1(g) The Influence of Age on the
Production of A G Crosses

Figure 1(h) The Influence of Age on the
Production of A J Crosses

Figure 1(i) The Influence of Age on the
Production of J & G Crosses

produced tends to increase until the crossbred cow is about 7 years of age. The increase after the fourth year is relatively small. It is, therefore, seen that in crossbreds of this study the maximum production of milk is at the age of 7 years. After this age is passed, the production diminishes with advancing age. The rate of decrease after the maximum is slower than the rate of increase preceding the maximum.

CHAPTER V

DISCUSSION AND RECOMMENDATION

Crossbred Class Averages

The t-test and F-test showed that the crossbred groups did not differ significantly in their production. The main reason why two tests were applied was to check the reliability of each test.

These tests indicate that crossbreds, regardless of which two of the four dairy breeds are crossed, can be considered as belonging to the same population. Therefore, as is presently the case for each of the purebreeds, it is recommended that a single set of class averages be constituted. Such a move would meet a long-felt need as voiced by Stevès (23). He thought that it was not fair to farmers, who were venturesome enough to use crossbreeding to increase their production, when they did not have standards by which they could judge the relative production of their crossbred cows.

Those interested in crossbreeding have only one important object, i.e. to have high production from their cattle. They would not be expected to be influenced by breed bias as occurs sometimes under the purebreeding concept. Therefore, it would seem desirable to have all the various kinds of crosses compared with each other, and this of course will be the result of establishing a single set of class

averages.

The class averages calculated from the data of this study are presented in Appendix IV and are shown also in Figure 1. Appendix IV gives what could be used (as it is or by adding more comprehensive data) as a base for calculating MI and FI values for crossbreds divided into eight age categories.

Indexes of all breeds in British Columbia are now averaging about 118 to 120. National average is about 108 to 110. Thus, the national average is 10 % lower than British Columbia's average, as can be seen in the (R.O.P.) table below.

Average Performance by Province 1962-1963

Province	B.C.A.							
	1. Ayrshire		2. Holstein		3. Guernsey		4. Jersey	
	Milk	Fat	Milk	Fat	Milk	Fat	Milk	Fat
P.E.I.	114.6	118.9	99.6	105.0	100.7	103.2	106.2	111.1
N.S.	108.4	108.9	102.5	105.3	103.1	101.7	96.1	95.2
N.B.	100.5	100.6	101.8	104.4	98.3	96.8	102.6	103.8
Que.	105.8	105.8	100.4	101.1	98.4	94.2	97.7	97.4
Ont.	114.9	112.9	110.1	112.5	111.3	107.5	108.7	106.2
Man.	93.2	88.0	110.5	109.4	122.1	122.0	100.4	96.9
Sask.	96.3	97.9	113.1	113.4	114.8	108.3	94.4	95.7
Alta.	113.7	108.4	110.3	108.9	97.9	95.5	109.5	109.1
B.C.	120.5	120.0	119.0	119.4	119.9	119.1	119.2	118.8

It is not unreasonable to assume that the national averages for crossbreds may be expected to be about 10 % lower than British Columbia's crossbred averages. That is,

if national class average for crossbreds had been set up at the same time as B.C.A.'s for the purebreeds, then the figures given in Appendix IV would probably average about 20 % lower. Therefore, in order to obtain indexes for British Columbia crossbreds that are of similar magnitude to those of purebreeds in this province, the figures in Appendix IV would be reduced by 15-20 % to establish a base.

In reporting the production of crossbred cows, there are two different methods that can be followed in calculating indexes:

- (1) The average of milk and fat indexes.

Actual Milk | Actual Fat | % Fat | MI | FI | AI

- (2) Fat corrected milk index.

Actual Milk | Actual Fat | % Fat | F.C.M. | F.C.M.I.

Where MI = Individual milk record divided by average milk in that age x 100

FI = Individual fat record divided by average fat in that age x 100

$$AI = \frac{MI + FI}{2}$$

$$FCM = 0.4 \times \text{Actual Milk} + 15 \times \text{Actual Fat}$$

FCMI = FCM for individual record divided by FCM for average in that age x 100

AI gives approximately the same answer as FCMI especially for cows testing close to 4 %. Cows that test quite high will have AI values a bit lower than FCMI values and the reverse will occur for lower-test cows. Exactly the same value occurs

for cows testing 4 %. These differences do not appear to be important as shown below:

The chart shows 7 records of 3 year old HG crosses selected at random for comparison of AI and FCMI values.

Milk	Fat	MI	FI	FCM	FCMI	AI	Difference FCMI - AI
10,956	497	114.3	117.7	11,837.4	116.5	116.0	0.5
11,434	462	119.2	109.4	11,503.6	113.2	114.3	-1.1
13,737	566	143.3	134.0	13,984.8	137.7	138.6	-0.9
10,256	477	107.0	112.9	11,257.4	110.8	109.9	0.9
8,848	397	92.3	94.0	9,494.2	93.5	93.3	0.2
9,858	404	102.8	95.7	10,003.2	98.5	99.2	-0.7
7,217	346	75.3	81.9	8,076.8	79.5	78.6	0.9
							-0.2

It is recommended that the average index method be used for following reasons:

a. AI is factual while FCMI is based upon a calculated quantity of fat corrected milk. Thus, the former will be understood more easily by all concerned - especially by the farmers.

b. Showing only the actual production and the indexes for that production is now well accepted. Some averaging of milk and fat indexes to facilitate comparisons and rankings is already being done (Ayrshire Association). For all practical purposes, the average of the two indexes is a reliable indication of the productive merit of any crossbred cow in relation to the average of all crossbreds. The same would also apply for herd averages.

c. AI values reflect very closely the returns from milks of different fat % levels.

Class Averages for Backcrosses

Backcrossing in dairy cattle is followed mainly as the first step in grading up. When a farmer owning say J dairy cows wishes to change these gradually into another breed, say H, he uses only H sires on the cows generation after generation. The second generation or backcrosses have been classified together with the parental breed used in backcrossing by the D.H.I.A. office in Victoria. Since the problem of establishing class averages for first generation crosses was being considered, it was decided to find out whether the backcrosses would be classified with these F_1 's (after working out class averages for them) or with the parental breed used in backcrossing.

Calculations have proved that the people at the D.H.I.A. Victoria office are correct in classifying backcrosses with the parental breed used in backcrossing for the purposes of finding indexes. Of the 12 comparisons made 9 indicate that backcrosses make records closer to those of the parental breed used in backcrossing than to those of the crossbreds from each two breeds concerned. It is, therefore, felt that the procedure presently used at the D.H.I.A. office should be continued.

While comparing the backcrosses to purebreeds and to crossbreds, it was found that crossing back to the Guernsey

breed, resulted in a considerable drop in production as can be seen in Figure 2. This depression in production is noticed in all cases of backcrossing to G.

It is difficult to account for these drops in production. Theoretically, backcross performance should be about mid-way between that of crossbreds and the parental breed for the backcrosses. It may be that the findings here are the result of small numbers. Associated with this cause could be that the Guernsey inheritance which reached 75 % in the backcrosses was of lower quality than in Guernseys of purebreeding. Regardless of cause, the fact remains that the 155 records of Guernsey backcrosses were quite low in production which certainly poses some question about the usefulness of making this particular backcross.

Heterosis

Of the two definitions of heterosis mentioned, the writer prefers that one which states that hybrid vigour is the difference of crossbred progeny from the mean of the two parent populations.

Theoretically, crossbred performance should be about mid-way between those of the two parental populations involved. This is the effect of all genetic variance acting in an additive fashion. The effect of dominant genes would place the performance of the cross somewhere between that of the higher producing parent and the average of the two parents. It is, therefore, not expected that the performance of the

cross should be more than that of the higher parental breed.

Using the above definition, it was found that, all the crossbreds analysed showed the presence of hybrid vigour except $\leftrightarrow$ HA crosses. $\leftrightarrow$ AG and $\leftrightarrow$ AJ crossbreds revealed more heterosis than the other crosses. The occurrence of very high heterosis among $\leftrightarrow$ AG and $\leftrightarrow$ AJ crosses may be an effect of sample size, or it may be due to the frequencies of genes conditioning milk production in G&J cattle. These may be somewhat different from those in the Ayrshire breed.

The lack of heterosis in Holstein-Ayrshire crosses may be because of considerable genetic similarity between these two breeds. It is known that H, G, J and other dairy breeds contributed their genes to the development of the Ayrshire breed. How much of each breed was used in building the Ayrshire is not known. If the H breed was the greatest contributor to the gene pool of the Ayrshire breed, then this might explain why $\leftrightarrow$ HA crosses do not show hybrid vigour.

Briggs (8), stated that the principal blood used in the improvement of Ayrshire cattle was that of the Teeswater stock. This stock was derived from the Dutch or Flemish blood lines. The Flemish blood he reported, had been contributed by a strain of cattle used in forming the Holstein breed. This indicates that possibly the Holstein breed and the Ayrshire breed have many similar genes. Heterosis or hybrid vigour usually varies according to the diversities of the genotypes.

Falconer (13), says that if the populations crossed do not differ in gene frequency, there will be no heterosis, and that the heterosis will be greatest when one allele is fixed in one population and the other allele in the other population.

Despite the very high amount of heterosis shown by $\leftrightarrow$ AG and $\leftrightarrow$ AJ crossbreds, it is still evident that the highest levels of production are obtained by crossing proven H sires with females of the other three breeds. $\leftrightarrow$ HG and $\leftrightarrow$ HA prove to be better than $\leftrightarrow$ HJ crosses in production when we consider total milk. This is to be expected because of the lower milk production associated with higher butterfat test of the Jersey breed. When F.C.M. values are applied, the second and third place crosses are reversed. A probable cause of $\leftrightarrow$ HA crosses ranking third is the apparent absence of hybrid vigour in this particular cross.

Results of Polyallel Analysis

In poultry, the difference between the sire effect and the dam effect is usually ascribed to sex linkage and/or maternal effects - Lerner (28). The dam effect is usually greater than the sire effect depending upon the trait studied.

The polyallel analysis of the AI values show that the opposite effect occurred in dairy cattle. The combined maternal influence and sex linkage in poultry does not exist in dairy animals since the sire is the heterogametic sex.

The larger sire effect shown in table 5(a) (H and J), may be a reflection of sex linkage but in all likelihood, it is due to a more intense selection on the sires than on the dam lines. Caution should be taken when analysing this type of material. If all sires in the analysis are proven ones, then the sire effect may be the result of a fixed effect and the subsequent dam effect would still be random.

Heritability was calculated using AI values for production of all the crossbreds. It was found to be 0.47. This is in agreement with the results of Johansson (1950) as reported by Falconer (12) and of Robertson (36). Johansson found that in cattle the h^2 for butterfat percent was 0.6 and for milk yield 0.3. The average of the two is 0.45. Robertson (36), using data from White Fulani cattle in Nigeria, reported that the h^2 of a single record of milk yield was 0.32 while that of the average of two records was 0.47.

The graphs in figure 2 a, b and c, represent the average effect of the reduction in the percentage of genotype by the introduction of a second genotype. The reverse effect is also represented. Each line has been reduced from 100 % pure to 75 % pure and 50 % pure by a second line. The second line has the same genetic reduction.

The graphs show that H breed acts in a dominant fashion to the other three breeds. In crossbreds as well as in backcrosses, it is seen that H breed is not unduly influenced by the other breeds which agrees with the fact that proven H sires are expected to be better than the proven sires

Figure 2(a) Average Milk Production of Individuals whose Genotypes are of Different Percentages of H, G, and A

Figure 2(b) Average Milk Production of Individuals Whose Genotypes are of Different Percentages of H, G, and J

Figure 2(c) Average Milk Production of Individual Whose Genotypes are of Different Percentages of A, G, and J

of the other three breeds. In addition the progenies of top H bulls on selected H dams have been shown to give highest level of milk production.

All the graphs in figure 2 a, b and c show that recipricals failed to coincide. Roberts (37), testing on series of nutritional environments in poultry, reported that (based on similar graphic evidence) the failure of the reciprical crosses to coincide at the 50 % level was suggestive of maternal effects. The depression in milk production when backcrossed to G has been explained under discussion on class averages for the backcrosses.

Sire Combining Ability in Crosses Compared with Purebreeds

The results of Table 6 show that the best sire for purebreeding may not be the best one for crossing. Only limited confidence, however, can be placed on this finding because of the small amount of data used. In theory, it is reasonable to expect that a sire's combining ability may well vary in different breed crosses. While more conclusive evidence is needed to resolve this matter, it would appear to be desirable to establish a sire's usefulness in crossing by crossbreeding evidence.

Age of Maximum Milk Production by Crosses

In figure 1, the average amount of milk and butter-fat produced increases until the crossbred cow is about

7 years of age. The increase after the fourth year is, however, quite modest. If a straight line is drawn joining the two points (4-7 years), there is a very slight deviation, from the straight line of the fifth and the sixth years records. This deviation may be due to modest record numbers.

The results of figure 1, are in agreement with those of other authors. Anderson and Kiser (3), while discussing age as one of the factors which influence milk yields and composition, reported that a cow will attain maximum production at about 7 years of age under normal conditions. They said that at 10 years, production begins to decline.

Gyles (21), states that purebreed cows reach the age of maximum production at about 8 years.

Therefore, it appears that both crossbreds and purebreeds produce maximum milk at the same age.

CHAPTER VI

SUMMARY

The objectives of the investigation were to determine class averages for crossbreds and for backcrosses, to study heterosis, the results of polyallel analysis, sire combining ability and age of maximum milk production in crossbreds.

Out of 60,931 production records used, 56,765 were of purebreeds (including high grades), 3113 of crossbreds (F₁'s) and 1053 of backcrosses.

Analysis showed that there was no difference in the crossbred cows. The results of the tests revealed that the various crossbred groups studied did not belong to different populations. On this basis, a single set of class averages is recommended for crossbreds.

Records of purebreeds, crossbreds and backcrosses were compared. Nine out of 12 comparisons made indicated that backcrosses were closer in production to the parental breed used in backcrossing. It is, therefore, recommended to classify backcrosses with the parental breed used in backcrossing for the purposes of finding indexes.

F.C.M. values for pure breeds and for their corresponding crossbreds were compared. There was evidence of hybrid vigour in all crossbreds except those of HA. This exception may be due to the similarity of origin of these two breeds.

A polyallel analysis was applied to the data using AI values for the two year old and the three year old production records of crossbreds. It was found that general combining ability and reciprical effects were highly significant. Specific combining ability was significant at the 5 % level.

The heritability of milk production, using AI values, was found to be 0.47.

The performances of the daughters of artificial insemination sires were compared both in purebreeds and in crossbreds. The results indicate that the best sire for purebreeding is not necessarily best for crossing, and that combining ability may depend upon the dam's breed. The modest records of the crossbred data may have affected the reliability of the results. However, the final proof can only be ascertained when a substantial set of data has been subjected to a comprehensive analysis.

The average production of crossbreds, grouped according to age, showed a sharp increase from 2 years to 4 years. This was followed by a relatively small increase from 4 years to 7 years. There was a gradual drop in production after the seventh year. Crossbreds reached their maximum milk production at 7 years of age.

GLOSSARY OF SYMBOLS

B.C.A.	Breed Class Average (s)
D.H.I.A.	Dairy Herd Improvement Association
A	Ayrshire breed
H	Holstein - Friesian
G	Guernsey
J	Jersey
HA	Progeny of Holstein sire used on Ayrshire dam
AH	Progeny of Ayrshire sire used on Holstein dam
$\overleftrightarrow{HA}$	Holstein-Ayrshire reciprocal crosses, etc.
F ₁	First generation cross or crossbred
HHA	Holstein-Ayrshire cross backcrossed to Holstein (The double H may be both sires or sire and dam)
$3/4 H \frac{1}{4} A$ HHA or 75 H 25 A etc.	
AM	Average Milk
AF	Average Fat
MI	Milk Index
FI	Fat Index
AI	Average Index (Average of milk and fat index)
FCM	Fat Corrected Milk
FCMI	Fat Corrected Milk Index
MA	Mature Age
ME	Mature Equivalent
Wtd.	Weighted

St.	Total Sum of Squares
SR	Replication Sum of Squares
Ss	Specific Sum of Squares
Se	Residual Sum of Squares
Gca	General Combining Ability
Sca	Specific Combining Ability
R.O.P.	Record of Performance

Replication - The actual stratification of ages when tested via the analysis of variance table 5(c) did not indicate any significant difference. Therefore, it was assumed that these two age groups (2 year olds and 3 year olds) could be considered as replications. Consequently it was further assumed that age and the variance of the production traits were uncorrelated throughout the study.

APPENDIX I

Purebreed Records 1958-1961 inc.

Breed	No. Records	Total Milk	Total Fat	Wfd.A.M.	Wtd.A.F.	F.C.M.
H	37,416	440,839,236	16,611,460	11,782.1	444.0	11,209.1
A	1,969	18,453,279	754,859	9,371.9	383.4	9,550.9
G	8,240	72,970.081	3,504.071	8,855.6	425.2	9,920.2
J	9,140	71,906.726	3,726,642	7,867.2	407.7	9,262.4
Total	56,765	604,169.322	24,597.032	10,643.3	433.3	10,756.8

APPENDIX II

Means of Purebreeds

Breed	No. of Records			F.C.M. Means
H + A	37,416	+	1969	10,436.3
H + G	37,416	+	8240	10,646.5
H + J	37,416	+	9140	10,317.6
A + G	1,969	+	8240	9,710.0
A + J	1,969	+	9140	9,381.1
J + G	9,140	+	8240	9,591.3

APPENDIX III

Grouping According to Crosses and Ages

Cross	Age	Size	Total Milk	Total Fat	Wtd.A.M.	Wtd. A.F.	MI	FI	AI
HJ	2	157	1,389,580	61,354	8,850.8	390.8	101.1	101.3	101.2
JH	2	<u>83</u>	714,776	32,447	8,611.7	390.9	98.4	101.3	99.9
		240	2,104,356	93,801	8,768.1	390.8	100.2	101.3	100.8
HJ	3	119	1,156,434	51,685	9,717.9	434.3	101.3	102.8	102.1
JH	3	<u>50</u>	487,069	21,927	9,741.4	438.5	101.6	103.8	102.7
		169	1,643,503	73,612	9,724.9	435.6	101.4	103.1	102.3
HJ	4	109	1,165,906	52,400	10,696.4	480.7			
JH	4	<u>50</u>	504,067	22,759	10,081.3	455.2			
		159	1,669,973	75,159	10,503.0	472.7			
HJ	5	95	1,012,035	43,960	10,653.0	462.7			
JH	5	<u>62</u>	646,367	28,099	10,425.3	453.2			
		157	1,658,402	72,059	10,563.1	459.0			
HJ	6	111	1,229,170	52,821	11,073.6	475.9			
JH	6	<u>52</u>	548,476	24,437	10,547.6	469.9			
		163	1,777,646	77,258	10,905.8	474.0			
HJ	7	89	1,044,765	44,278	11,738.9	497.5			
JH	7	<u>53</u>	543,689	24,098	10,258.3	454.7			
		142	1,588,454	68,376	11,186.3	481.5			
HJ	8	61	703,757	29,958	11,537.0	491.0			
JH	8	<u>45</u>	473,267	20,950	10,517.0	465.6			
		106	1,177,023	50,903	11,104.0	480.2			
HJ	OV8	66	747,734	31,708	11,329.2	480.4			
JH	OV8	<u>52</u>	556,375	24,128	10,699.5	464.0			
		118	1,304,109	55,836	11,051.8	473.2			
1254									
HG	2	137	1,291,554	55,119	9,427.4	402.3	107.7	104.3	106.0
GH	2	<u>37</u>	319,867	14,186	8,645.0	383.4	98.8	99.4	99.1
		174	1,611,421	69,305	9,261.0	398.3	105.8	103.2	104.5
HG	3	115	1,183,795	50,831	10,293.9	442.0	107.4	104.7	106.1
GH	3	<u>19</u>	181,442	7,912	9,549.6	416.4	99.6	98.6	99.1
		134	1,365,237	58,743	10,188.3	438.4	106.3	103.8	105.1
HG	4	103	1,166,344	49,888	11,323.7	484.1			
GH	4	<u>21</u>	212,104	9,355	10,100.1	445.5			
		124	1,378,448	59,243	11,116.5	477.8			
HG	5	89	1,030,154	44,378	11,574.8	498.6			
GH	5	<u>24</u>	248,641	10,583	10,360.0	440.9			
		113	1,278,795	54,961	11,316.8	486.4			

Appendix III continued

Cross	Age	Size	Total Milk	Total Fat	Wtd.	A.M.Wtd. A.F.	MI	FI	AI
HG	6	69	809,116	34,479	11,726.3	499.7			
GH	6	<u>23</u>	247,939	10,449	10,780.0	454.3			
		92	1,057,055	44,928	11,489.7	488.3			
HG	7	50	593,974	24,956	11,879.4	499.1			
GH	7	<u>21</u>	234,466	9,810	11,165.0	467.1			
		71	828,440	34,766	11,668.2	489.7			
HG	8	36	392,520	16,793	10,903.3	466.5			
GH	8	<u>14</u>	152,978	6,347	10,927.0	453.4			
		50	545,498	23,140	10,910.0	462.8			
HG	OV 8	49	506,832	21,844	10,343.5	545.8			
GH	OV 8	<u>21</u>	244,187	10,030	11,627.9	477.6			
		70	751,019	31,874	10,728.8	455.3			
828									
HA	2	45	414,980	16,211	9,221.8	360.2	105.4	93.4	99.4
AH	2	<u>10</u>	76,905	3,168	7,690.5	316.8	87.9	82.1	85.0
		55	491,885	19,379	8,943.4	352.3	102.2	91.3	96.8
HA	3	39	392,733	15,391	10,070.0	394.6	105.0	93.4	99.2
AH	3	<u>8</u>	70,904	2,971	8,863.0	371.4	92.4	87.9	90.2
		47	463,637	18,362	9,864.6	390.7	102.9	92.5	97.7
HA	4	32	363,026	13,926	11,344.6	435.2			
AH	4	<u>15</u>	146,145	5,594	9,743.0	372.9			
		47	509,171	19,520	10,833.4	415.3			
HA	5	20	227,043	8,935	11,352.1	446.7			
AH	5	<u>13</u>	141,661	5,652	10,897.0	434.7			
		33	368,704	14,587	11,172.8	442.0			
HA	6	23	274,245	10,658	11,923.7	463.4			
AH	6	<u>11</u>	125,939	4,828	11,449.0	438.9			
		33	400,184	15,486	11,770.1	455.5			
HA	7	14	168,427	6,590	12,030.5	470.7			
AH	7	<u>9</u>	105,456	4,211	11,717.3	467.9			
		23	273,883	10,801	11,907.9	469.6			
HA	8	6	67,345	2,666	11,224.2	444.3			
AH	8	<u>6</u>	74,901	2,813	12,483.5	468.9			
		12	142,246	5,479	11,853.8	456.6			
HA	OV 8	5	54,736	1,817	10,947.2	363.4			
AH	OV 8	<u>8</u>	86,327	3,462	10,790.9	432.8			
		13	141,063	5,279	10,851.0	406.1			
264									

Appendix III continued

Cross	Age	Size	Total Milk	Total Fat	Wtd.A.M.	Wtd. A.F.	MI	FI	AI
AJ	2	13	94,937	4,269	7,302.8	328.4	83.4	85.1	84.3
JA	2	<u>10</u>	83,772	3,765	8,377.2	376.5	95.7	97.6	96.7
		23	178,709	8,034	7,770.0	349.3	88.8	90.5	89.7
AJ	3	13	110,062	4,901	8,466.3	377.0	88.3	89.3	88.8
JA	3	<u>15</u>	126,683	5,635	8,445.5	375.7	88.1	89.0	88.6
		28	236,745	10,536	8,455.2	376.3	88.2	89.1	88.7
AJ	4	15	142,375	6,253	9,491.7	416.9			
JA	4	<u>10</u>	107,709	4,626	10,770.9	462.6			
		25	250,084	10,879	10,000.3	435.2			
AJ	5	20	199,626	8,980	9,981.3	449.0			
JA	5	<u>10</u>	101,697	4,156	10,169.7	415.6			
		30	301,323	13,136	10,044.1	437.9			
AJ	6	15	146,416	6,597	9,761.1	439.8			
JA	6	<u>12</u>	129,832	5,558	10,819.4	463.2			
		27	276,248	12,155	10,231.4	450.2			
AJ	7	12	116,536	5,418	9,711.4	451.5			
JA	7	<u>12</u>	125,037	5,588	10,418.1	465.7			
		24	241,573	11,006	10,065.5	458.6			
AJ	8	7	70,376	3,035	10,053.7	433.6			
JA	8	<u>6</u>	61,349	2,747	10,224.8	457.8			
		13	131,725	5,782	10,132.7	444.8			
AJ	OV 8	6	57,420	2,415	9,540.0	402.5			
JA	OV 8	<u>12</u>	126,556	5,498	10,546.3	458.2			
		18	183,796	7,913	10,210.9	439.6			
		188							
AG	2	5	41,825	1,788	8,365.0	357.6	95.6	92.7	94.2
GA	2	<u>7</u>	57,241	2,526	8,177.3	360.9	93.4	93.5	93.5
		12	99,066	4,314	8,255.5	359.5	94.3	93.2	93.8
AG	3	8	71,190	2,926	8,898.8	365.8	92.8	86.6	89.7
GA	3	<u>5</u>	46,528	2,090	9,305.6	418.0	97.0	99.0	98.0
		13	117,718	5,016	9,055.2	385.8	94.4	91.4	92.9
AG	4	9	89,597	3,827	9,955.2	425.2			
GA	4	<u>8</u>	84,544	3,725	10,568.0	465.6			
		17	174,141	7,552	10,243.6	444.2			
AG	5	15	166,162	7,292	11,077.5	486.1			
GA	5	<u>6</u>	64,115	2,819	10,685.9	469.9			
		21	230,277	10,111	10,965.6	481.5			
AG	6	13	140,787	6,147	10,829.8	472.8			
GA	6	<u>4</u>	44,604	1,959	11,151.0	489.8			
		17	185,391	8,106	10,905.3	476.8			

Appendix III continued

Cross	Age	Size	Total Milk	Total Fat	Wtd.A.M.	Wtd. A.F.	MI	FI	AI
AG	7	15	162,921	7,392	10,861.4	492.7			
GA	7	4	39,816	1,622	9,954.0	405.5			
		19	202,737	9,014	10,670.4	474.4			
AG	8	7	70,786	3,201	10,112.3	457.4			
GA	8	4	45,336	1,882	11,334.0	470.5			
		11	116,122	5,083	10,556.5	462.1			
AG	OV 8	5	55,898	2,383	11,179.6	476.6			
GA	OV 8	13	131,884	5,666	10,144.9	435.8			
		18	187,782	8,049	10,432.3	447.2			
128									
JG	2	24	180,437	9,331	7,518.2	388.9	85.9	100.8	93.4
GJ	2	37	278,648	13,841	7,531.0	374.1	86.0	97.0	91.5
		61	459,085	23,172	7,526.0	379.8	86.0	98.4	92.2
JG	3	18	153,219	7,746	8,512.2	430.3	88.8	101.9	95.4
GJ	3	30	229,252	11,377	7,641.7	379.2	79.7	89.8	84.8
		48	382,471	19,123	7,968.1	398.4	83.1	94.3	88.7
JG	4	13	122,528	6,276	8,752.0	448.3			
GJ	4	37	316,005	15,841	8,540.7	428.1			
		50	438,533	22,117	8,770.7	442.3			
JG	5	28	251,750	12,547	8,991.0	448.1			
GJ	5	29	260,058	12,598	8,967.5	434.4			
		57	511,808	25,145	8,979.1	441.1			
JG	6	28	261,554	13,061	9,341.2	466.5			
GJ	6	32	293,463	14,556	9,170.7	454.9			
		60	555,017	27,617	9,250.3	460.3			
JG	7	19	183,485	9,052	9,657.1	476.5			
GJ	7	23	213,383	10,126	9,277.5	440.3			
		42	396,868	19,178	9,449.2	456.6			
JG	8	21	203,983	9,795	9,713.4	466.5			
GJ	8	17	163,145	7,411	9,595.8	435.9			
		38	367,128	17,206	9,661.3	452.8			
JG	OV 8	51	465,511	22,071	9,127.7	432.8			
GJ	OV 8	44	416,020	19,226	9,455.0	436.9			
		95	881,531	41,297	9,279.3	434.7			
451									

APPENDIX IV

Grouping According to Age

Cross	Age	Size	TotalMilk	Total Fat	Wtd.A.M.	Wtd.A.F.	F.C.M.
HJ	2	240	2,104,356	93,801	8,761.1	390.8	9,369
HG	2	174	1,611,421	69,305	9,261.0	398.3	9,679
HA	2	55	491,885	19,379	8,943.4	352.3	8,862
AJ	2	23	178,709	8,034	7,770.0	349.3	8,347
AG	2	12	99,066	4,314	8,255.5	359.5	8,695
JG	2	61	459,085	23,172	7,526.0	379.8	8,707
		<u>565</u>	4,944,522	218,005	8,751.4	385.8	9,288
HJ	3	169	1,643,503	73,612	9,724.9	435.6	10,424
HG	3	134	1,365,237	58,743	10,188.3	434.4	10,651
HA	3	47	463,637	18,362	9,864.6	390.7	9,806
AJ	3	28	236,745	10,536	8,455.2	376.3	9,026
AG	3	13	117,718	5,016	9,055.2	385.8	9,409
JG	3	48	382,471	19,123	7,968.1	398.4	9,163
		<u>439</u>	4,209,311	185,392	9,588.4	422.3	10,170
HJ	4	159	1,669,973	75,159	10,503.0	472.7	11,292
HG	4	124	1,378,448	59,243	11,116.5	477.8	11,614
HA	4	47	509,171	19,520	10,833.4	415.3	10,563
AJ	4	25	250,084	10,879	10,000.3	435.2	10,528
AG	4	17	174,171	7,552	10,243.6	444.2	10,760
JG	4	50	438,533	22,117	8,770.7	442.3	10,143
		<u>422</u>	4,420,350	194,470	10,474.8	460.8	11,102
HJ	5	157	1,658,402	72,059	10,563.1	459.0	11,110
HG	5	113	1,278,795	54,961	11,316.8	486.4	11,823
HA	5	33	368,704	14,587	11,172.8	442.0	11,099
AJ	5	30	301,323	13,136	10,044.1	437.9	10,586
AG	5	21	230,277	10,111	10,965.6	481.5	11,609
JG	5	57	511,808	25,145	8,979.1	441.1	10,208
		<u>411</u>	4,349,309	189,999	10,582.3	462.3	11,167
HJ	6	163	1,777,646	77,258	10,905.8	474.0	11,472
HG	6	92	1,057,055	44,928	11,489.7	488.3	11,920
HA	6	34	400,184	15,486	11,770.1	455.5	11,540
AJ	6	27	276,248	12,155	10,231.4	450.2	10,846
AG	6	17	185,391	8,106	10,905.3	476.8	11,514
JG	6	60	555,017	27,617	9,250.3	460.3	10,605
		<u>393</u>	4,251,541	185,550	10,818.2	472.1	11,409
HJ	7	142	1,588,454	68,376	11,186.3	481.5	11,697
HG	7	71	828,440	34,766	11,668.2	489.7	12,013
HA	7	23	273,883	10,801	11,907.9	469.6	11,807
AJ	7	24	241,573	11,006	10,065.5	458.6	10,905
AG	7	19	202,737	9,014	10,670.4	474.4	11,384
JG	7	42	396,868	19,178	9,449.2	456.6	10,629
		<u>321</u>	3,531,955	153,141	11,003.0	477.1	11,558

Appendix IV continued

Cross	Age	Size	Total Milk	Total Fat	Wtd.A.M.	Wtd.A.F.	F.C.M.
HJ	8	106	1,177,023	50,903	11,104.0	480.2	11,645
HG	8	50	545,498	23,140	10,910.0	462.8	11,306
HA	8	12	142,246	5,479	11,853.8	456.6	11,590
AJ	8	13	131,725	5,782	10,132.7	444.8	10,725
AG	8	11	116,122	5,083	10,556.5	462.1	11,154
JG	8	38	367,128	17,206	9,661.3	452.8	10,656
		<u>230</u>	2,479,742	107,593	10,781.5	467.8	11,330
HJ	OV 8	118	1,304,109	55,836	11,051.8	473.2	11,519
HG	OV 8	70	751,019	31,874	10,728.8	455.3	11,121
HA	OV 8	13	141,063	5,279	10,851.0	406.1	10,432
AJ	OV 8	18	183,796	7,913	10,210.9	439.6	10,678
AG	OV 8	18	187,782	8,049	10,432.3	447.2	10,881
JG	OV 8	95	881,531	41,297	9,279.3	434.7	10,232
		<u>332</u>	3,449,300	150,248	10,389.4	452.5	10,943

APPENDIX V (a)

Grouping According to Crosses and Recipricals

Cross	No. Records	Total Milk	Total Fat	Wtd. A.M.	Wtd. A.F.	F.C.M.
HJ	807	8,409,380	368,159	10,420.5	456.2	11,011.0
JH	<u>447</u>	4,474,086	198,845	10,009.1	444.8	10,676.0
	<u>1254</u>	12,883,466	567,004	10,273.9	452.1	10,891.0
HG	648	6,974,289	298,288	10,762.8	460.3	11,210.0
GH	<u>180</u>	1,841,624	78,672	10,231.2	437.1	10,649.0
	<u>828</u>	8,815,913	376,960	10,647.2	455.3	11,088.0
HA	184	1,962,535	76,194	10,665.9	414.1	10,478.0
AH	<u>80</u>	828,238	32,699	10,353.0	408.7	10,272.0
	<u>264</u>	2,790,773	108,893	10,571.1	412.5	10,416.0
AJ	101	937,568	41,868	9,282.8	415.5	9,931.0
JA	<u>87</u>	862,635	37,573	9,915.3	431.9	10,445.0
	<u>188</u>	1,800,203	79,441	9,575.5	422.5	10,168.0
AG	77	799,166	34,956	10,378.8	454.0	10,961.0
GA	<u>51</u>	514,068	22,289	10,079.8	437.0	10,587.0
	<u>128</u>	1,313,234	57,245	10,259.6	447.2	10,812.0
JG	202	1,822,467	89,879	9,022.1	444.9	10,282.0
GJ	<u>249</u>	2,169,974	104,976	8,714.7	421.6	9,810.0
	<u>451</u>	3,992,441	194,855	8,852.4	432.0	10,021.0
	<u>3113</u>	31,596,030	1,384,398	10,149.7	444.7	10,730.0
						<u>10,515.4</u>

APPENDIX V (b)

Grouping According to Crosses and Recipricals

F.C.M. Values Reduced by 2%

Cross	Records	F.C.M.
HJ	807	10,791
JH	<u>447</u>	10,462
	1254	10,673
HG	648	10,986
GH	<u>180</u>	10,436
	828	10,866
HA	184	10,268
AH	<u>80</u>	10,066
	264	10,208
AJ	101	9,732
JA	<u>87</u>	10,236
	188	9,965
AG	77	10,742
GA	<u>51</u>	10,375
	128	10,596
JG	202	10,076
GJ	<u>249</u>	9,614
	451	9,821

APPENDIX VI (a)

Backcross Records

Back Cross	No. Records	Total Milk	Total Fat	Wtd.A.M.	Wtd.A.F.	F.C.M.
75H 25J	368	4,016,094	163,061	10,913.3	443.1	11,011.8
75H 25G	296	3,348,441	134,384	11,312.3	454.0	11,334.9
75H 25A	<u>56</u>	601,574	23,251	10,742.4	415.2	10,525.0
	720			11,064.1	445.5	
75J 25H	74	606,393	30,962	8,194.5	418.4	9,553.8
75J 25G	29	214,838	11,258	7,408.2	388.2	8,786.3
75J 25A	<u>22</u>	190,320	9,020	8,650.9	410.0	9,610.4
	125			8,092.4	409.9	

Appendix VI (a) continued

Back Cross	No. Records	Total Milk	Total Fat	Wtd.A.M.	Wtd.A.F.	F.C.M.
75G 25H	31	226,877	10,878	7,318.6	350.9	8,190.9
75G 25J	103	809,704	40,036	7,861.2	388.7	8,974.0
75G 25A	<u>21</u>	177,005	8,251	8,428.8	392.9	9,265.0
	155			7,829.6	381.7	
75A 25H	16	146,155	6,283	9,134.7	392.7	9,544.5
75A 25G	18	175,624	7,531	9,756.9	418.4	10,178.8
75A 25J	<u>19</u>	186,086	7,363	9,794.0	387.5	9,730.1
	53			9,582.4	399.6	
	1053					

APPENDIX VI (b)

Backcross Records Reduced by 2%

Back Cross	No. Records	F.C.M.
75H 25J	368	10,791.6
75H 25G	296	11,108.2
75H 25A	<u>56</u>	10,314.5
	720	
75J 25H	74	9,362.7
75J 25G	29	8,610.6
75J 25A	<u>22</u>	9,418.2
	125	
75G 25H	31	8,027.1
75G 25J	103	8,795.5
75G 25A	<u>21</u>	9,079.7
	155	
75A 25H	16	9,353.6
75A 25G	18	9,975.2
75A 25J	<u>19</u>	9,535.5
	53	

APPENDIX VII

Records of Crossbred Daughters of
10 Artificial Insemination Sires

H. Sires

1. Gilmore Magic Blueboy

Cross	Age	Milk	Fat	MI	FI	AI
1 HJ	2	9,532	406	108.9	105.2	107
2		12,711	596	145.2	154.5	150
3		11,909	526	136.1	136.3	136
4		11,136	450	127.2	116.6	122
5		7,729	303	88.3	78.5	83
6		8,789	464	100.4	120.3	110
7		7,755	343	88.6	88.9	89
8		12,619	606	144.2	157.1	151
9		10,830	487	123.7	126.2	125
10	3	9,749	521	101.7	123.4	112
11		8,190	373	85.4	88.3	87
12		10,325	505	107.7	119.6	114
13		9,845	483	102.7	114.4	108
14	4	9,849	542	94.0	117.6	106
15		10,096	497	96.4	107.8	102
16		14,063	732	134.2	158.8	146
17		9,575	461	91.4	100.0	96
18	5	11,426	599	108.0	129.6	119
19		12,758	609	120.6	131.7	126
20		14,951	731	141.3	158.1	150
21		9,340	432	88.3	93.4	91
22	M	9,520	453	88.0	95.9	92
						<u>2522</u>
						22 115
1 HG	2	11,560	428	132.1	110.9	121
2		9,525	362	108.8	93.8	101
3		11,397	472	130.2	122.3	126
4	3	10,956	497	114.3	117.7	116
5		11,434	462	119.2	109.4	114
6		13,737	566	143.3	134.0	139
7	4	13,936	621	133.0	134.8	134
8		12,922	551	123.4	119.6	121
9		13,914	568	132.8	123.2	128
10	5	13,919	537	116.4	116.2	116
11		12,071	470	114.1	101.7	108
12		9,303	393	87.9	85.0	86
						<u>1410</u>
						12 117

Appendix VII continued

2. Gilmore Peter Ormsby

Cross	Age	Milk	Fat	MI	FI	AI
1 HJ	2	9,050	477	103.4	123.6	113
2		8,627	369	98.6	95.6	97
3		10,175	528	116.3	136.9	127
4		10,008	451	114.4	116.9	116
5		9,989	419	114.1	108.6	111
6		6,832	305	78.1	79.1	79
7	3	10,815	537	112.8	127.2	120
8		12,210	490	127.3	116.0	122
9	4	13,128	550	125.3	119.4	122
						$\frac{1007}{9}$ 112
1 HG	2	8,276	318	94.6	82.4	88
2		15,777	673	180.3	174.4	177
3		11,525	498	131.7	129.1	130
4		11,508	436	131.5	113.0	122
5	3	10,256	477	107.0	112.9	110
6		8,848	397	92.3	94.0	93
7		15,346	706	160.0	167.2	164
8		10,307	452	107.5	107.0	107
9	4	9,564	391	91.3	84.8	88
10	5	10,984	433	103.8	93.7	99
11		16,037	697	151.5	150.8	151
12	M	16,337	707	151.0	149.8	150
						$\frac{1479}{12}$ 123

3. Gilmore Valiant

1 HJ	2	11,131	494	127.2	128.0	128
2	3	13,032	524	135.9	124.1	130
3	4	13,354	537	127.5	116.5	122
4	5	13,455	576	127.1	124.6	126
5	M	11,909	483	110.1	102.3	106
						$\frac{612}{5}$ 122
1 HG	2	9,939	428	113.6	110.9	112
2		10,008	432	114.4	112.0	113
3		8,298	426	94.8	110.4	102
4		8,740	410	99.9	106.3	103
5	3	9,858	404	102.8	95.7	99

Appendix VII continued

3. Gilmore Valiant

Cross	Age	Milk	Fat	MI	FI	AI
6		7,217	346	75.3	81.9	79
7		9,025	398	94.1	94.2	94
8	4	11,604	439	110.8	95.3	103
9		8,904	425	85.0	92.2	89
10		10,409	480	99.4	104.2	102
11	5	10,540	436	99.6	94.3	97
12		12,782	536	120.8	115.9	118
13		11,921	597	112.6	129.1	121
14	M	12,503	570	115.6	120.7	118
15		14,773	583	136.6	123.5	130
						<u>1580</u>
						15 105

4. Frasea Netherland Trail Blazer

1	HJ	2	11,044	458	126.2	118.7	122	
2			8,520	373	97.4	96.7	97	
3		3	12,031	479	125.5	113.4	119	
4		4	9,208	391	87.9	84.8	86	
5			14,495	598	138.4	129.8	134	
6			10,995	406	105.0	88.1	96	
7		5	9,788	443	92.5	95.8	94	
8			14,624	582	138.2	125.9	132	
9			13,651	502	129.0	108.6	119	
10		M	12,091	552	111.8	116.9	114	
11			11,411	474	105.5	100.4	103	
12			10,839	450	100.2	95.3	98	
13			13,660	556	126.3	117.8	122	
14			12,999	510	102.2	108.0	114	
15			13,079	486	120.9	102.9	112	
							<u>1662</u>	111
							15	

1	HG	3	8,030	332	83.7	78.6	81	
2		4	10,447	437	99.7	94.8	97	
3		5	12,372	542	116.9	117.2	117	
4			12,403	538	117.2	116.4	117	
5		M	11,480	510	106.1	108.0	107	
6			12,954	495	119.7	104.8	112	
							<u>631</u>	105
							6	

Appendix VII continued

J. Sires

1. Brampton Sound Radar

Cross	Age	Milk	Fat	MI	FI	AI
1 JH	2	10,266	480	117.3	124.4	121
2		8,996	467	102.8	121.0	112
3		6,219	286	71.1	74.1	72
4		9,078	441	103.7	114.3	109
5		8,117	416	92.7	107.8	100
6	3	9,092	453	94.8	107.3	101
7		10,221	529	106.6	125.3	116
8	4	10,244	521.0	97.8	113.1	105
						$\frac{836}{8}$ 1045

2. Deertrail Glömousboy

1 JH	2	7,477	404	85.4	104.7	95
2		7,089	324	81.0	84.0	82
3		6,085	323	69.5	83.7	77
4	3	8,736	495	91.1	117.2	104
5		6,363	307	66.4	72.7	69
6	5	9,786	511	92.5	110.5	101
7		7,848	362	74.2	78.3	76
8	M	6,879	313	63.6	66.3	65
9		8,396	400	77.6	84.7	81
10		10,025	542	92.7	114.8	103
11		10,577	568	97.8	120.4	109
12		10,240	548	94.6	116.1	105
13		10,257	517	94.8	109.5	102

A Sires

1. White Cockade

1 AJ	2	11,449	448	130.8	116.1	123
2		4,146	235	47.4	60.9	54
3		12,165	655	139.0	169.8	154
4	3	15,344	605	160.0	143.3	152
5		11,645	674	121.4	159.6	140
6	4	10,326	590	98.6	128.0	113
7		9,191	379	87.7	82.2	84
8		15,321	614	146.3	133.2	140

Appendix VII continued

1. White Cockade

Cross	Age	Milk	Fat	MI	FI	AI
9	5	17,226	699	162.8	151.2	157
10		9,590	422	90.6	91.3	91
11		9,317	371	88.0	80.2	84
12	M	9,210	402	85.1	85.1	85
13		12,969	471	119.9	99.8	110
14		9,123	414	84.3	87.7	86
15		8,422	364	77.8	77.1	77
						$\frac{1650}{15}$ 110
1	AG 2	9,531	400	108.9	103.7	106
2	3	7,846	376	81.8	89.0	85
3		8,019	350	83.6	82.9	83
4	4	9,817	456	93.7	99.0	96
5		4,642	214	44.3	46.4	45
6		7,296	301	69.6	65.3	67
7		10,773	440	102.8	95.5	99
8	5	11,954	478	113.0	103.4	108
9		9,897	460	93.6	99.5	96
10		7,335	344	69.3	74.4	72
11	M	10,464	468	96.7	99.1	98
						$\frac{955}{11}$ 86.8

2. Governors Spit Fire

1	AJ 4	9,339	338	89.2	73.3	81
2	5	11,087	420	104.8	90.8	98
3		10,642	458	100.6	99.1	100
4	M	14,580	621	134.8	131.5	133
5	M	9,787	366	90.5	77.5	84
						$\frac{496}{5}$ 99.2
1	AG 3	7,368	287	76.8	68.0	72
2	4	8,735	407	83.4	88.3	86
3	5	9,657	459	91.3	99.3	95
4		8,287	489	78.3	105.8	92
5	M	10,754	521	99.4	110.4	105
6		8,925	488	82.5	103.4	93
7		9,870	551	91.2	116.7	104
8		10,801	632	99.8	133.9	117
9		9,343	520	106.8	134.8	121
						$\frac{885}{9}$ 98.3

Appendix VII continued

G Sires

1. Brooknill Rombus Lad

Cross	Age	Milk	Fat	MI	FI	AI
1 GJ	2	7,515	344	85.9	89.2	87
2		7,668	353	87.6	91.5	89
3		8,430	425	96.3	110.2	103
4	3	7,793	398	81.3	94.2	88
5		8,545	455	89.1	107.7	98
6		8,093	402	84.4	95.2	90
7		7,352	340	76.7	80.5	79
8		6,636	355	69.2	84.1	77
9	4	8,962	496	85.6	107.6	97
10		8,967	449	86.6	97.4	91
11		7,125	370	68.0	80.3	74
12		8,628	459	82.4	99.6	91
13	5	9,080	513	85.8	110.0	98
14		9,856	446	93.1	96.5	95
15		7,597	376	71.8	81.3	76
16		8,414	441	79.5	75.4	87
17	M	8,915	498	82.4	105.5	94
18		9,013	498	83.3	105.5	94
19		8,769	400	81.1	84.7	83
20		9,056	485	83.7	102.7	93
						<u>1784</u>
						20 89.2

2. Maple Springs Ike

1 GJ	2	6,011	380	68.7	98.5	84
2		8,984	484	102.7	125.4	114
3		5,095	268	58.2	69.5	64
4	3	6,723	368	70.1	87.1	79
5		6,626	428	69.1	101.3	85
6		8,370	450	87.3	106.6	97
7	4	6,796	415	64.9	90.0	77
8	5	8,157	470	77.1	101.7	89
						<u>689</u>
						8 86.1

APPENDIX VIII

Formulas⁵ Used in Analysis of Variance -
Diallel Analysis when Selfs not Included

$$\begin{aligned}
 St &= \sum \sum \sum X_{gij}^2 - \frac{X_{...}^2}{rn(n-1)} \\
 S_R &= \sum X_{g..}^2 - \frac{X_{...}^2}{rn(n-1)} \\
 S_{Rg} &= \sum_g \left[\sum_i \left(\frac{X_{g.i} + X_{gi.}}{2(n-2)} \right)^2 - \frac{X_{g..}^2}{n(n-2)} \right] - S_g \\
 S_S &= \frac{\sum_i \sum_{j \neq i} (X_{.ij} + X_{.ji})^2}{2r} - \frac{X_{...}^2}{rn(n-1)} - S_g \\
 S_r &= \frac{\sum_i \sum_{j \neq i} (X_{.ij} - X_{.ji})^2}{2r} \\
 S_e &= St - S_R - S_g - S_{Rg} - S_S - S_r \\
 X_{...} &= \sum_g \sum_{i \neq j}^n \sum_{j \neq i}^n X_{gij} \\
 X_{g..} &= \sum_{i \neq j}^n \sum_{j \neq i}^n X_{gij} \\
 X_{gi.} &= \sum_{j \neq i}^n X_{gij} \\
 X_{.i.} &= \sum_g X_{gi.} \\
 X_{g.j} &= \sum_{i \neq j}^n X_{gij} \\
 X_{..j} &= \sum_g X_{g.j}
 \end{aligned}$$

5 Formulas taken from the work of C.E. Gates.

APPENDIX IX

Sample Average Indexes of Crossbred

Production Records

	↔ HJ	↔ HG	↔ HA	↔ AJ	↔ AG	↔ JG	Deviation Squared	
							HJ	HA
1	78	89	85	79	87	128	635.04	110.25
2	132	116	110	86	97	92	829.44	210.25
3	104	102	71	129	97	117	0.64	600.25
4	88	125	119	77	114	95	231.04	552.25
5	91	120	95	108	111	88	125.44	0.25
6	100	101	143	93	95	90	10.24	2,256.25
7	128	108	80	95	88	73	615.04	240.25
8	83	106	78	100	74	113	408.04	306.25
9	97	90	93	81	86	87	38.44	6.25
10	102	78	85	121	98	92	1.44	110.25
11	124	85	60	84	98	120	432.64	1,260.25
12	106	114	115	100	92	100	7.84	380.25
13	96	117	78	104	109	109	51.84	306.25
14	113	141	75	75	89	119	96.04	420.25
15	93	103	98	108	86	96	104.04	6.25
16	81	96	97	96	83	109	449.44	2.25
17	132	97	106	116	137	102	829.44	110.25
18	112	109	73	95	102	88	77.44	506.25
19	123	92	102	94	116	88	392.04	42.25
20	96	103	101	105	90	82	51.84	30.25
21	80	122	99	94	79	79	538.24	12.25
22	103	101	111	79	73	91	0.04	240.25
23	98	137	113	101	68	104	27.04	420.25
24	95	90	75	80	104	110	67.24	306.25
25	114	108	81	97	103	100	116.64	210.25
26	84	95	124	81	82	92	368.64	812.25
27	88	87	90	101	95	79	231.04	30.25
28	147	67	109	100	127	104	1,918.44	182.25
29	116	82	105	97	102	82	163.85	90.25
30	92	80	93	94	116	75	125.44	6.25
Total	3,096	3,061	2,864	2,870	2,898	2,904	8,943.97	9,767.50
Mean	103.2	102.0	95.5	95.7	96.6	96.8		

APPENDIX X

Coded Average Fat-Corrected-Milk Values of the

6 Different Crossbred Groups

New York State Milk Experiment.

Coding done by Subtracting 8,300 lbs. from Actual F.C.M.

Ages used as replication.

Replication	↔ HJ	↔ HG	↔ HA	↔ AJ	↔ AG	↔ JG
1	1,069	1,379	562	47	395	407
2	2,124	2,351	1,506	726	1,109	863
3	2,992	3,314	2,263	2,228	2,460	1,843
4	2,810	3,523	2,799	2,286	3,309	1,908
5	3,172	3,620	3,240	2,546	3,214	2,305
6	3,397	3,713	3,507	2,605	3,084	2,329
7	3,345	3,006	3,290	2,425	2,854	2,356
8	3,219	2,821	2,132	2,378	2,581	1,932
Total	22,128	23,727	19,299	15,241	19,006	13,943
Mean	2,766	2,966	2,412	1,905	2,376	1,743

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