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Genetic and Environmental Changes as shown by Idaho D.H.I.A. Records

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Introduction

YEAR-TO-YEAR fluctuations of milk and butterfat yields are caused by deviations due to heredity and environment or to deviations from either of these components alone. Heritability measures the fraction of the observed, or phenotypic, differences between members of the parent generation which may reasonably be expected to be recovered in their offspring. Variations caused by environment may be large, but do not change the inheritance of an animal. This environment must be reproduced in each generation to provide the same media for the genetic worth of an animal or its offspring to express itself on an equivalent basis. Hereditary and environmental influences cannot be exactly determined and proportioned since their interaction effect confounds them in a manner that cannot be expressed in a simple additive fashion. Nevertheless, the observed changes of production may be separated into estimates of environmental and genetic components. These estimates are not fundamental constants, but are descriptions of a particular characteristic in a specific population at some given moment. These estimates may be either raised or lowered by some factor such as the breeding system or method of selection affecting the hereditary variance as well as by any factor such as feeding, management or climatic condition affecting the environmental variance.

An examination of herd or regional averages with respect to yearly changes tells nothing at all about the causes of these changes. A change in production may be the result of a change in genetic merit or a change in environmental conditions, or some combination of a changed environment and genotype. Therefore, if the hereditary component of production is to be measured, the environmental component first must be properly evaluated and adjusted. Adjusting the environmental factor facilitates the appraisal of the effectiveness of a breeding system. To obtain a high degree of efficiency in selection, production records must be corrected for yearly environmental differences when individuals make

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[1] Data presented in this bulletin are taken from a thesis by the senior author in partial fulfillment for the degree, Master of Science in Agriculture.

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records in different years. Methods of evaluating animals, such as comparing production records of daughters and dams, are often biased by environmental changes existing between the time the dams' records and the daughters' records were produced. These comparisons would be more accurate if the environmental effects were adjusted for in the daughter-dam production records.

Review of Literature

Bayley and Heizer (2) analyzed herd data information on 967 cows in 47 Holstein-Friesian herds to determine the effects of certain environmental influences on production. They obtained statistically significant regressions for milk and fat yield on selection rating, pounds total digestible nutrients (T.D.N.) fed daily per 1,000 pounds body weight, nutritive ration, condition at calving, and herd size. For an increase of 1 pound in T.D.N. daily per 1,000 pounds body weight, there was an average annual increase of 551 pounds of milk and 18 pounds of butterfat.

Erb and Shaw (5) classified herds into above average, average, and below average management groups. Classification was based on feeding practices, care of replacement stock, pasture and forage programs, and general practices. Of the 2,491 D.H.I.A. records studied, the 974 lactations of cows in above average management group produced an average of 13.8 percent more fat-corrected milk than did the average group and 17.5 percent more than did the below average group.

Plum (18) determined the relative importance of causes of variations in butterfat production of 2,316 Jersey, Holstein and Guernsey cows in 95 Iowa herds. Breed differences accounted for only 2 percent of the variance, while cow differences (mostly genetic) accounted for 26 percent of the variation. Herd differences were responsible for 33 percent of the variation, of which 12 percent was attributable to the feeding policy of the herd and 21 percent to other causes. Year-to-year variations comprised 36 percent of the total variation and were subdivided into feeding variations within the herd (6 percent), season of calving (3 percent), length of dry period (1 percent), and other factors (28 percent).

Legates (12) found that intra-herd, year-to-year differences accounted for about 8 percent of the intra-herd variance and 5 percent of the total variance in Herd Improvement Registry individual lactation records scattered throughout the United States. He further reports that Johansson and Hanson found differences among years within herds which accounted for between 5 and 6 percent of the total variance. They express the opinion that in well-managed herds yearly fluctuations about the general herd trend are a minor source of variation.

Herd differences have been estimated as causing 17, 30, 33 and 39 percent of the total variance in corrected lactation records by Dickerson (3), Lush and Straus (15), Lush and Shultz (14), and Legates (12) respectively.

Winters (24) cited the classical study by Eckles to illustrate the vast influence which environment may exert on production records. Forty-one cows of the four major dairy breeds averaged 8,393 pounds of milk and 343 pounds of butterfat under ordinary farm conditions. When placed under the environment of official test conditions, they averaged 14,331 pounds of milk and 564 pounds of butterfat.

Johansson (10) states that differences in the plane of nutrition are undoubtedly the most important causes of variation between herd averages for milk yield, and they are also important sources in intra-herd variation. The plane of nutrition of heifers at their first calving was demonstrated to have a pronounced influence on the rise of yield with advancing age.

Many investigators have studied and estimated the inheritance of milk and butterfat production. The results obtained have varied rather widely, depending upon the method of analysis employed. Johansson (10) states that in statistical investigations up to 1935 only the total phenotypic relationship between relatives was calculated and no attempts were made to separate the genetic correlation from that caused by environment. On the basis of such gross correlation, heritability was overestimated.

Heritability estimates of the D.H.I.A. data used in this study by the intra-sire daughter-dam regression method were determined by Taylor (22). The total 2,025 daughter-dam pairs from 237 sires yielded heritability estimates of 0.264 for milk and 0.302 for butterfat on an intra-breed basis. Heritability estimates for the breeds studied were:

Breed	Pairs	Sires	Milk	Butterfat
Guernsey	431	57	0.362	0.320
Holstein	868	102	0.260	0.220
Jersey	726	78	0.212	0.398

Genetic Improvement

The question of whether it was worthwhile to try and improve a character which was very lowly heritable was answered as early as 1939 by Wright (25). He pointed out that if the hereditary variability is due to a large number of minor factors and the favorable allele is in most cases the uncommon one, the mean improvement possible by fixing all the favorable genes may go far beyond the current limit. The importance of estimates of the relative amount of hereditary and environmental variability is not in setting limits to possible achievement by improving either one but in indicating the method to be used. When selecting for characters with little non-genic variation, selection should be based directly on that character in the individual. Conversely, in selecting for characters which have little nonenvironmental variation more attention should be given to pedigree and progeny of an individual.

Lush and McGilliard (13) calculated genetic progress possible in sire proofs. They assumed butterfat production as 0.2 percent heritable and the standard deviation as 80 pounds, making the genic standard deviation about 35 pounds. Therefore, about 1 bull in 40 would be expected to raise by that much or more the production of his daughters out of average cows, and only 1 in 500 would raise them by more than 50 pounds. The main reason for many large sire proofs is in most cases the environment for daughters were better than their dams. Sampling errors were also given as the cause of some error in sire proofs.

The rate of genetic improvement reasonably expected for milk production from direct mass selection under optimum conditions was estimated to be 1 percent per year by Rendel and Robertson (19). This estimate was made under conditions of natural service and without using progeny tests and sib tests. By the optimum use of progeny and sib tests and artificial insemination, their estimate of increase rose to 2 percent per year. In either case, achieving this genetic improvement would require devoting all the selection methods to milk production without diverting any attention to type or other characters.

Mahadevan (16) calculated the intensity of selection practiced on 5,000 lactation records from 12 leading Ayrshire herds in Scotland. The difference between the average yield of those cows chosen as parents and the average of their own generation was multiplied by 0.25 to convert it to a genetic measure. The rate of genetic improvement per year for mass selection of females was found to be 0.13 percent.

Seath (20) cites a study of Plum in Denmark of the Kollekolle herd from 1900 to 1934. Of an 80-kilogram increase in butterfat production, 10 kilograms were attributed to the selection of females. This resulted in an average yearly improvement of 0.65 pounds of butterfat.

Nelson (17) used a least squares method of analysis in estimating year-to-year environmental changes in the Iowa State College herd. His results indicated a genetic increase of production averaging 3.86 pounds of butterfat over a 12-year period. This was based on the assumption that the environmental effects had been eliminated.

Harvey (6) analyzed records of 185 Holstein cows and 136 Jersey cows in the University of Idaho herd from 1927 through 1951 by Henderson's maximum likelihood method. Linear regression lines fitted to the data after adjusting for the environmental effects, showed an average yearly increase of 8.0 pounds of butterfat for the Holsteins and 5.3 pounds for the Jerseys during the 25-year period. These phenomenal increases in genetic merit are explained on the basis of low herd averages at the beginning and the careful selection of proven or partially proven sires for both herds.

Dillion and associates (4) applied Henderson's maximum likelihood method to the University of Illinois Holstein herd from 1901 to 1954. They found that the improved environment in the herd resulted in an increase of 2,000 pounds in F.C.M. production. The regression of average real producing ability indicated that essentially no genetic progress for F.C.M. production was made. It is thought that more genetic progress would have resulted if a breeding program more nearly like that used in a closed herd had been followed.

Experimental Procedure

All the reported complete lactation records for milk and butterfat production in Idaho D.H.I.A. herds from January, 1940 to August, 1952 were obtained from the Extension Dairyman. Only the Jersey and Holstein breeds contained sufficient data to be analyzed on a regional basis, so the other breeds were not used. The data consisted of 4,449 lactation records from 2,459 Jerseys and 6,112 lactation records from 3,401 Holsteins. All records were adjusted to a twice-a-day milking, mature equivalent 305-day basis. If the actual record was more than 305 days, only the first 305 days were used. No record of less than 270 days duration was used in the study. An attempt has been made to separate the genetic and environmental portions of the changes in milk and butterfat production in these data by the use of Henderson's maximum likelihood method.

Methods of Statistical Analysis

The maximum likelihood method presented by Henderson (9) is a computational procedure which enables one to properly weigh the yearly environmental influences in comparing any two individual lactation records, regardless of their time of production. Previous methods presented (17) for estimating and eliminating the environmental portion of a record have yielded biased results.

The Maximum Likelihood Analysis

Henderson follows basically the same procedure as used for the least squares method to set up his model for the maximum likelihood method (9).

$$y_{ijk} = \mu + a_i + b_j + c_{jk} + e_{ijk}$$

The only new element in this model as compared to the least squares is the b_j symbol. In this study this symbol denotes the average real producing ability of cows born in the same year, which should, therefore, have shared a somewhat common permanent environment and in many cases a closer relationship than the mean of the population.

The following assumptions are made before setting up the normal equations (9):

1. The real producing abilities of the individual cows are normally and independently distributed with mean zero and vary as do the cows.

2. The random environmental effects peculiar to the individual record are normally and independently distributed with the mean of zero and vary as does the environment.

3. The variance of the real producing ability and the environmental variance are uncorrelated.

The values of the population mean, environmental effects, average real producing ability of the birth-year groups and the real producing ability of the individual cows may now be computed. This will maximize the probability of obtaining the sample of records actually at hand.

Henderson (9) set the estimated population mean, times the total number of records, plus the summation of the products of the number of records produced in each year multiplied by its environmental effect, plus the summation of the products of the number of records produced by each birth-year group multiplied by its average real producing ability, plus the summation of the products of each individual record times the real producing ability of the cow which made it, equal to the summation of all the production records.

$$n_{...}\,\hat{\mu} + \sum_{i} n_{i..}\,\hat{a}_i + \sum_{j} n_{.j.}\,\hat{b}_j + \sum_{j}\sum_{k} n_{.jk}\,\hat{c}_{jk} = \sum_{i}\sum_{j}\sum_{k} y_{ijk}$$

The population mean and the real producing ability of each birth-year group are combined in a single parameter and the equations for the environmental effects of specific years, the permanent producing abilities of the sub-populations and the permanent producing abilities of individual cows are derived as in the least squares method.

The equations for the individual years may be expressed as the number of records produced in the ith year multiplied by the environmental effect of that year, plus the summation of the number of records produced by each birth-year group in the ith year multiplied by the permanent producing ability of each birth-year group, plus the summation of the number of individual cows producing records in the ith year multiplied by their real producing ability, which taken together equals the summation of the production records produced in the ith year:

$$n_{i..}\,a_i + \sum_{j} n_{ij.}\,(\mu + b_j) + \sum_{j}\sum_{k} n_{ijk}\,c_{jk} = \sum_{j}\sum_{k} y_{ijk}$$

In like manner the summation of the product of the number of records produced in each year by the jth birth-year group, multiplied by the environmental effect of each year, plus the number of records produced by the jth birth-year group times the permanent producing ability of that birth-year group, plus the summation of the products of the number of records produced by the individual cow multiplied by her real producing ability, equals the sum of the production records produced by the jth cow group.

$$\sum_{i} n_{ij.}\,a_i + n_{.j.}\,(\mu + b_j) + \sum_{k} n_{.jk}\,c_{jk} + \sum_{i}\sum_{k} y_{ijk}$$

Similarly the summation of the products of the number of records of the individual cow in the ith year, multiplied by the environmental effect of the ith year, plus the number of records of the individual cow multiplied by the permanent producing ability of her cow group, plus the sum of her total number of records and the value of $\sigma^2 e/\sigma^2 c$ multiplied by her real producing ability, equals the sum of the production records of each individual cow.

$$\sum_{i} n_{ijk}\,a_i + n_{.jk}\,(\mu + b_j) + (n_{.jk} + \sigma^2 e/\sigma^2 c)\,c_{jk} = \sum_{i} y_{ijk}$$

Each standardized record can be considered as equal to the real producing ability of the cow under standard conditions plus or minus some error for incomplete or inaccurate correction for unstandard conditions. The coefficient of correlation, or repeatability between records made by the same cow on an intra-herd basis has been taken as 0.4 (9). Since repeatability (r) is the fraction of the total variance among the corrected records due to permanent differences between cows and 1—r is the fraction of the variance caused by temporary circumstances which vary between records of the same cow, $\frac{\sigma^2 e}{\sigma^2 c}$ may be written as l—r, or with $r = 0.4$, $\frac{1-0.4}{0.4}$, or 1.5. Solving for c_{jk} results in:

$$c_{jk} = \frac{\sigma^2 c}{n_{.jk}\,\sigma^2 c + \sigma^2 e}\left(\overset{\Sigma}{i} y_{ijk} - n_{.jk}\,\mu - n_{.jk} b_j - \overset{\Sigma}{i} n_{ijk}\, a_i\right)$$

This equation states that the real producing ability of each cow equals the fraction of the variance of her real producing ability, divided by her total number of records, multiplied by the expression of the number of records produced by the individual cow, minus the mean, multiplied by her total number of records, minus her real producing ability, multiplied by her total number of records, minus the sum of the product of the environmental effects of each year she produced a record. Therefore, the c_{jk} expressions may be substituted for by these expressions and will thereby be eliminated. A set of equations then exists in which the $\mu + b_j$ can be expressed in terms of the a_i and certain observed effects. Finally by proper substitution, the equations can be reduced to one involving only the a_i.

Table 1.—Definition of the symbols used in the maximum likelihood analysis.

Symbol	Definition
y_{ijk}	The individual lactation record; the record made in the ith year by the kth cow of the jth cow group
a_i	the environmental effect of the ith year
b_j	the average real producing ability of the jth group of cows (grouped as to year of birth)
c_{jk}	the real producing ability of the kth cow of the jth group of cows
e_{ijk}	a random environmental effect peculiar to the individual record
$n_{...}$	the total number of records
$n_{i..}$	the number of records in the ith year
$n_{.j.}$	the number of records made by the cows of the jth group
$n_{.jk}$	the number of records made by the kth cow of the jth group
$n_{ij.}$	the number of records made by the jth group in the ith year
$\sigma^2 e/\sigma^2 c$	the random environmental variance divided by the variance of the real producing ability of the cow

Results

The D.H.I.A. regions analyzed in this study were Regions 1, 2, 3, and 4, all of which are in the irrigated regions of southern Idaho. Region 1 included Ada and Canyon Counties. Region 2 covered Gem, Payette, and the southern part of Washington County, Region 3 included Bear Lake, Franklin and the southern part of Caribou County. Region 4 included the Magic Valley Counties of Twin Falls, Jerome, Minidoka, Cassia and Gooding; Region 5, which included the north Idaho District, and Region 6, comprising the upper Snake River District, lacked sufficient cow numbers for analysis.

Regression values for butterfat and milk are presented in Tables 3 and 4 respectively. Fiducial limits and the "T" test of significance were calculated for the linear regression of production after Snedecor (21).

Butterfat Production

No significant genetic change in butterfat production existed for either the Jerseys of the combined regions or those of Region 2. A highly significant genetic regression of −1.81 pounds per year was found for the Jerseys in Region 1.

A significant genetic regression of butterfat on year of +2.75 pounds for the Holsteins of Region 1 resulted. No significant genetic change was found for Holsteins in the combined regions, or Regions 3 and 4.

Discussion

The results indicate that little or no improved genetic merit has occurred in the average cow on D.H.I.A. test, and that practically all the increase in milk production is due to an improved environment. The Holsteins have made a small genetic gain in butterfat production while the Jerseys have made no genetic gain. However, the sampling error inherent in the Idaho D.H.I.A. has biased the data as an estimate

Table 2.—Genetic and environmental estimates of butterfat production.

Area		Genetic changes		Environmental changes	
	Mean	Regression	Fiducial limits	Regression	Fiducial limits
Total Jerseys	425.5	+0.01	−1.46 to +1.48	+ 2.42†	+0.92 to + 3.92
Total Holsteins	458.0	−0.25	−1.77 to +2.27	+ 5.97†	+3.37 to + 8.57
Region 1 Jerseys	423.4	−1.81†	−0.76 to −2.85	+ 3.14†	+1.59 to + 4.59
Region 2 Jerseys	445.7	+0.55	−2.80 to +3.91	+ 4.01*	+0.46 to + 7.56
Region 1 Holsteins	474.7	+2.75*	+0.40 to +5.45	+ 4.36*	+0.09 to + 8.63
Region 3 Holsteins	470.5	−0.47	−8.24 to +7.30	+10.03†	+5.20 to +14.89
Region 4 Holsteins	455.9	+0.45	−3.87 to +4.77	+ 6.37*	+0.73 to +12.02

†Highly significant at 1% level.
*Significant at 5% level.

Table 3.—Genetic and environmental estimates of milk production.

Area	Mean	Genetic changes		Environmental changes	
		Regression	Fiducial limits	Regression	Fiducial limits
Total Jerseys	8,038	− 27	− 57 to + 4	+ 72†	+ 48 to + 96
Total Holsteins	13,195	− 76*	− 16 to −136	+192†	+ 97 to +287
Region 1 Jerseys	7,939	− 73†	− 35 to −111	+104†	+ 80 to +127
Region 2 Jerseys	8,362	− 1	− 74 to + 75	+ 83†	+ 23 to +144
Region 1 Holsteins	13,203	− 37	−120 to + 46	+195†	+102 to +287
Region 3 Holsteins	13,728	−233	−468 to + 1	+332†	+216 to +450
Region 4 Holsteins	13,112	− 91	−211 to + 30	+270†	+139 to +402

†Highly significant at the 1% level.
*Significant at the 5% level.

Table 4.—Number of herds and cows in Idaho D.H.I.A.

Year	No. of DHIA herds	No. of DHIA cows	% of Total cows on DHIA	Completed lactation records	
				Jersey	Holstein
1940	292	4,562	2.20	197	389
1941	365	5,815	2.60	164	315
1942	282	4,382	1.83	78	217
1943	173	2,500	1.01	49	80
1944	222	3,622	1.45	183	193
1945	262	4,224	1.78	259	219
1946	302	4,798	1.97	305	366
1947	474	7,423	3.11	435	577
1948	562	8,838	3.86	560	720
1949	548	9,277	4.06	625	833
1950	574	9,691	4.37	569	809
1951	549	9,798	4.45	634	837
1952	744	11,562	5.21	391	557

Table 5.—Average production per cow in Idaho, U.S., and D.H.I.A.

Year	No. of cows 2 yrs. and older (Idaho)	No. of Idaho DHIA cows	Ave. lbs. milk (Idaho)	Average pounds of fat per cow			
				Idaho	Idaho DHIA	U.S.	U.S. DHIA
1930	174,000	......	5,750	227	332	177	303
1935	196,000	......	5,320	210	347	165	322
1940	207,000	4,562	5,930	234	351	183	331
1941	224,000	5,815	5,910	233	357	188	335
1942	240,000	4,382	5,700	225	348	188	339
1943	248,000	2,500	5,520	218	360	183	338
1944	250,000	3,622	5,620	222	...	182	336
1945	237,000	4,224	5,690	225	355	191	346
1946	244,000	4,798	5,870	233	359	203	349
1947	239,000	7,432	6,110	241	359	205	348
1948	229,000	8,838	6,150	240	365	201	350
1949	227,000	9,227	5,890	230	371	209	359
1950	222,000	9,691	6,300	243	367	210	370
1951	220,000	9,798	6,240	245	377	212	370
1952	222,000	11,562	6,210	243	367	212	366

of improvement for the original cows which were in the D.H.I.A. program in 1940. This bias is strikingly illustrated by Table 4. The number of cows on D.H.I.A. test has more than doubled from 1940 when 2.20 percent of the Idaho cow population were on test to 1952 when 5.21 percent were on test. Table 5 illustrates the level of production of the population from which the increased D.H.I.A. cow numbers were drawn. The average yearly D.H.I.A. production has been over 110 pounds of butterfat, more than the average total Idaho production for any corresponding year of this study.

Any increase in number of D.H.I.A. cows drawn from a population with such a low level of production would lower the average genetic merit. The purpose of D.H.I.A. is to give the dairyman some standard upon which to base his culling. Before sufficient information can be obtained upon which to base a culling program for these new herds on D.H.I.A., the low producing cows would have completed a production record which would therefore lower the average production of both their respective birth-year groups and years of production. More cows of below-average merit entered the birth-year groups in the latter part of the period considered in this study. This would bias the genetic estimate downward more than the environmental estimate. The reason for this is because the residual effect of the earlier unselected D.H.I.A. birth-year would still be shown in the production of later years.

The length of the study of only three cow generations may be cited as another reason for a small increase of genetic value When only such a few generations are considered, any period of environmental change greatly influences the genetic value. The highest rate of genetic improvement (2.75 pounds butterfat per year for Holsteins in Region 1) is in line with Rendel and Robertson's estimate of genetic improvement through mass selection (19).

The need for replacements, especially during World War II, kept selection at a low level for this period. The Federal Milk Subsidy created a better price relationship between feed and milk. This made it profitable to continue milking "boarders" which would otherwise have been culled. These factors would greatly contribute to keeping the genetic gain at a minimum. However, profits in increased production from improved feeding probably illustrated the need for continued better feeding practices to the average dairyman. This influenced the creation of a better environment through better nutrition and management.

The difficulty of separating heredity and environment in selecting breeding stock also lowers genetic progress (7). Regardless of the skill of the herdsman making the selection, the better managed herds will be able to show genetically comparable stock to much better advantage than will poorly managed herds. Even within the herd, cows of preferred lines of breeding will sometimes receive special care that results in an environment above the herd average which may be confused with genetic merit. Another factor lowering genetic progress in production is selection for multiple factors. Selection for more than one characteristic has been shown to lower the selection pressure for one character alone (7), (23), (11).

Artificial insemination had no influence on these data, since the first cows were bred artificially in Idaho in 1948, and only 7.9 percent of the cow population was serviced during the last birth-year used in these data (1).

The improved level of environmental conditions may be seen in the annual reports of the Extension Dairyman (1). Dairy building facilities have been greatly improved since 1940 when they were described as inadequate. More milking machines, mechanical manure loaders and hay harvesting equipment have all aided the dairyman to create a better environment with less work. The development of antibiotics to treat mastitis and other diseases has had a pronounced effect on increased production. However, the greatest environmental improvement lies in nutrition. World War II awakened the dairyman to follow better feeding policies. Quality feed has always existed in Idaho, but is being utilized more efficiently now than in the past. All these better methods and improved developments have had a tremendous effect on Idaho D.H.I.A. production, as is shown in the environmental portion.

The effect that sampling error may have had on these data is shown in Table 6. All regions showed considerable variation in the yearly number of D.H.I.A. lactation records. This may be used to explain much of the genetic variation in the data.

Holsteins of the combined regions have apparently been selected intensely for butterfat production, as shown in Tables 3 and 4 by the significant genetic decrease for milk on year and a slight, though not significant, genetic increase for butterfat production. This is illustrated by the increased Holstein yearly average butterfat test in Table 7.

The increased numbers of new D.H.I.A. herds have either lowered the average of the Jerseys of the combined regions, or sufficient time has not elapsed to show any genetic increase in either milk or fat production. Perhaps the effect of increased numbers from a population with a low level of production was shown most clearly by the Jerseys of Region 1. Dairying has been established in this region for a considerable time. The increased influence of the Extension Service and Veteran's training probably interested more small farmers with herds of

Table 6.—Number of D.H.I.A. records by region within breed.

	Year of production												
	1940	1941	1942	1943	1944	1945	1946	1947	1948	1949	1950	1951	1952
Region 1 Holstein	123	97	88	6	48	118	175	171	231	241	297	318	186
Region 2 Holstein	12	9	8	10	37	11	11	11	3	2	3	7	...
Region 3 Holstein	105	85	78	63	106	50	85	142	148	152	83	101	63
Region 4 Holstein	120	116	26	1	...	26	59	147	193	249	265	277	200
Region 5 Holstein	...	...	...	...	...	14	24	46	47	43	40	30	25
Region 6 Holstein	29	8	17	...	2	...	12	60	98	146	121	104	83
Total Holstein	389	315	217	80	193	219	366	577	720	833	809	837	557
Region 1 Jersey	128	88	40	29	131	133	128	149	267	345	342	397	251
Region 2 Jersey	18	17	22	16	50	94	123	165	146	140	136	157	31
Region 3 Jersey	...	...	...	...	...	...	...	...	...	...	...	...	...
Region 4 Jersey	47	50	9	...	...	31	38	79	76	69	37	44	33
Region 5 Jersey	...	...	...	...	...	...	1	...	3	9	10	2	...
Region 6 Jersey	4	9	7	2	2	1	15	32	68	61	44	34	26
Total Jersey	197	164	78	49	183	259	305	435	560	625	569	634	391

Table 7.—Average yearly production by breed in Idaho.

Year	Jerseys			Holsteins		
	Average butterfat	Average milk	Average test	Average butterfat	Average milk	Average test
1940	413	7,779	5.31	423	12,550	3.37
1941	404	7,738	5.22	411	12,137	3.38
1942	425	7,998	5.32	430	12,817	3.35
1943	446	8,291	5.38	422	12,688	3.33
1944	413	7,902	5.23	447	13,023	3.43
1945	426	8,126	5.25	465	13,785	3.37
1946	431	8,150	5.29	464	13,470	3.45
1947	432	8,182	5.27	453	13,172	3.44
1948	432	8,186	5.27	451	13,157	3.43
1949	440	8,403	5.24	454	13,103	3.46
1950	446	8,428	5.29	478	13,656	3.50
1951	442	8,267	5.35	475	13,459	3.53
1952	441	8,342	5.29	468	13,313	3.51

untested merit to join the D.H.I.A. program, lowering the mean production. The increased production of Region 2 Jerseys may be explained in another fashion. Dairying was also well-established in this area, but not much interest was taken in testing associations for some time. The small number of cows on test during the first five years of the period may not have been a random sample of the population, or may have been subject to extremely low environmental conditions existing in two or three tested herds for this period. The importance of herd differences has been cited by many investigators (2), (4), (7), (20). Either of these conditions would bias the genetic influence upward.

Holsteins in Region 1 show a very pronounced selection for butterfat test. The reason for this may be explained if a premium is paid for higher testing milk in this area. This hypothesis is very plausible because a greater percentage of fluid milk is marketed in this region than in other parts of the state. Much more processing milk is sold in Regions 3 and 4, where a low butterfat test is not discriminated against.

These data indicate that Holsteins of Region 3 have a large decrease in milk production. This may be explained by sampling error. Extremely high production could have been lowered by some of the better herds dropping D.H.I.A. and continuing official testing programs.

Summary and Conclusions

The maximum likelihood method was used to analyze Idaho D.H.I.A. data on a within-breed and regional basis. These data consisted of 4,449 lactation records from 2,459 Jerseys and 6,112 lactation records from 3,401 Holsteins for the period 1940 to 1952.

Linear regression lines were plotted for genetic and environmental changes in milk and butterfat production. Holsteins in Region 1 showed significant genetic regressions of butterfat on year of +2.75 pounds. Holsteins in the combined regions and in Regions 3 and 4, and Jerseys in the combined regions and Region 2 were found to have made no significant genetic changes in butterfat production. Jerseys in Region 1 had a highly significant regression of —1.81 pounds of butterfat on year. This may be explained as the result of a sampling error in the early years.

A highly significant regression of milk on year of —73 pounds was the genetic change obtained for Jerseys in Region 1, which may again be attributed to sampling error. Holsteins in the combined regions were found to have a significant genetic regression of —76 pounds of milk on year. This may be attributed to an emphasis of selection for high butterfat production, accompanied with little selection for milk production. No significant genetic change was noted in milk production of Jerseys in the combined regions and Region 2, or Holsteins in Regions 1, 3, and 4.

Environmental changes accounted for large significant positive regressions for butterfat and milk production in all regions within breeds.

Although the maximum likelihood method has faults, it still is the best analysis yet presented to estimate genetic and environmental components of production. The importance of herd differences may be a limiting factor to its use on a regional basis. Perhaps herds under similar regimes of management would be much better adapted to this method of analysis than are those in a geographical area.

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