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Estimation of Genetic Trends from Cow and Sire Evaluations

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ABSTRACT

Milk production records of Ayrshire, Guernsey, Holstein, Jersey, and Brown Swiss in the Northeast were used to estimate trends in transmitting ability of sires and genetic merit of cows. Genetic trends in the transmitting ability of Artificial Insemination sires for the Ayrshire, Guernsey, Holstein, Jersey, and Brown Swiss breeds averaged 23.7, 14.6, 17.9, 18.3, and 34.7 kg per year.

Genetic trends in the AI cow populations averaged 36.1, 25.4, 26.1, 25.0 and 38.1 kg. The genetic trends of cow populations were less than twice the contribution of sires to genetic trends, indicating that estimating genetic trends in cow populations by doubling the trend in transmitting ability of sires is biased upwards.

INTRODUCTION

A goal of dairy cattle breeders is to increase genetic merit for milk production. To determine the effectiveness of breeding programs, genetic trends in dairy cattle populations must be monitored. The purpose of this study was to investigate genetic trends in milk production among Holstein, Ayrshire, Guernsey, Jersey, and Brown Swiss cows and sires in the Northeast.

MATERIALS AND METHODS

Records of Ayrshire, Guernsey, Holstein, Jersey, and Brown Swiss cows which were on Dairy Herd Improvement test in 1975 in the Northeast were used. Only cows calving first between the ages of 18 and 35 mo and between 1961 and 1974 were included. All available lactation records of a cow were used to estimate genetic merit of cows and sires. The cows were divided into two groups: artificially-sired cows (AI) and naturally-sired cows (non-AI). The AI cows were cows with an identified AI sire, but non-AI cows were cows either with an identified natural-service sire or cows without an identified sire. Numbers of cows per year of freshening are summarized in Tables 1and 2.

Unbiased predictors of the additive genetic value of cows and sires were obtained by best linear unbiased prediction (BLUP) as described by Henderson (10) and Slanger et al. (21). The model was

$$\mathbf{y} = \mathbf{X}\beta + \mathbf{Z}\mathbf{a} + \mathbf{Z}\mathbf{p} + \mathbf{e}$$

where $\mathbf{y}$ is the vector of age-adjusted milk records; β is a vector of fixed herd-year-season effects and the population mean; $\mathbf{X}$ is a known design matrix; $\mathbf{a}$ is a vector of additive genetic values of the cows and sires; $\mathbf{Z}$ is a known matrix relating elements of $\mathbf{y}$ to elements of $\mathbf{a}$; $\mathbf{p}$ is a vector with each element being the remainder of the total genetic value plus the permanent environmental effect specific to a particular cow; and $\mathbf{e}$ is a vector of temporary environmental effects. All elements of $\mathbf{a}$, $\mathbf{p}$, and $\mathbf{e}$ have zero expected values; $\text{Var}(\mathbf{a}) = \mathbf{A}h^2\sigma_y^2$ where $\mathbf{A}$ is the numerator relationship matrix of the animals in the herd, h^2 is the heritability, and σ_y^2 is the within herd-year-season variance of records in a noninbred population; $\text{Var}(\mathbf{p}) = \mathbf{I}(r-h^2)\sigma_y^2$ where r is repeatability; $\text{Var}(\mathbf{e}) = \mathbf{I}(1-r)\sigma_y^2$. Further, $\mathbf{a}$, $\mathbf{p}$, and $\mathbf{e}$ are uncorrelated. The covariance between records on different animals is due to additive genetic effects; thus, $\mathbf{A}h^2\sigma_y^2$ is the matrix of covariances between the cows and sires used in the herd.

The predictions of additive genetic value or genetic merits were used to estimate genetic trends. For estimating genetic trends, a cow's estimated genetic merit was used only in the

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TABLE 1. Number of artifically-sired cows that initiated first lactation within 1961 to 1974 in herds which were on test in 1975.

Year of freshening	Ayrshire	Guernsey	Holstein	Jersey	Brown Swiss
61	225	250	5817	338	62
62	393	557	10761	605	130
63	390	590	13677	740	152
64	513	643	16851	864	184
65	670	778	19647	1028	193
66	784	869	22748	1143	291
67	903	950	25358	1369	267
68	832	1019	28431	1382	310
69	1054	1122	32914	1699	324
70	1124	1202	35722	1830	352
71	1271	1203	39787	2016	366
72	1207	1242	44167	2239	459
73	1241	1257	46173	2397	411
74	1171	1259	49681	2714	450

year of first calving and a sire's estimated transmitting ability was used only in the year of a daughter's first calving. Transmitting ability was defined as one-half of additive genetic value.

Trends in transmitting ability of sires were obtained from the regression of the weighted average of sires' transmitting abilities for each year on year. For the pth year, the weighted average of sires' transmitting abilities was

$$\sum_i n_{ip}\hat{s}_i/n_{.p},$$

where n_{ip} is the number of daughters of sire i first freshening in the pth year, and $\hat{s}_i$ is the predicted transmitting ability of the ith sire.

Genetic trends in the cow population were estimated from the regression of yearly average cow merit on year. For the pth year, the average cow merit was

$$\sum_j \hat{c}_j/m_p,$$

where m_p is the number of cows first freshening in the pth year, and $\hat{c}_j$ is the predicted genetic merit of the jth cows.

TABLE 2. Number of naturally-sired cows that initiated first lactation within 1961 to 1974 in herds which were on test in 1975.

Year of freshening	Ayrshire	Guernsey	Holstein	Jersey	Brown Swiss
61	219	231	3628	368	54
62	356	484	6166	595	117
63	419	541	7331	707	122
64	396	574	8199	828	109
65	362	615	7911	922	105
66	333	666	8827	1018	144
67	388	701	10112	1107	137
68	369	741	11497	1133	143
69	441	710	14144	1310	163
70	431	742	16951	1230	203
71	369	745	21010	1244	191
72	617	725	26673	1309	219
73	659	604	32331	1165	208
74	665	698	42073	1255	243

TABLE 3. Average genetic merit of cows and transmitting ability of sires in kg: Ayrshires.

Year of freshening	Genetic value AI cows	Transmitting ability AI sires	Genetic value non-AI cows
61	-174	-132	-452
62	-229	-137	-498
63	-225	-163	-518
64	-146	-87	-471
65	-1	56	-492
66	68	122	-403
67	80	144	-366
68	142	171	-338
69	189	197	-235
70	239	220	-209
71	220	193	-118
72	165	107	-130
73	158	91	-126
74	171	85	-110

RESULTS AND DISCUSSION

The average predicted genetic merit of cows and transmitting ability of sires by year for the Ayrshire, Guernsey, Holstein, Jersey, and Brown Swiss breeds are in Tables 3 to 7. Annual genetic trends (regression of average predicted genetic merit and average predicted transmitting ability on year) are in Table 8.

Estimates of genetic gains per year among Brown Swiss and Ayrshire AI cows were not uniform, since estimates for Brown Swiss were negative from 1961 to 1964 and positive from 1964 to 1971. Estimates for Ayrshires were positive from 1962 to 1970 and negative from 1970 to 1973. Estimates of genetic gains per year for Guernsey and Jersey cows were also not uniform since estimates for both breeds fluctuated over the 14 yr. Yearly differences in the average genetic merit of AI Holstein cows were relatively uniform.

Estimates of genetic improvement per year for non-AI Brown Swiss and Ayrshire cows paralleled the gains for AI cows. Genetic gains per year among Guernsey and Holstein non-AI cows, 35.4 and 31.0 kg, were greater

TABLE 4. Average genetic merit of cows and transmitting ability of sires in kg: Guernseys.

Year of freshening	Genetic value AI cows	Transmitting ability AI sires	Genetic value non-AI cows
61	-120	-51	-273
62	-71	-21	-296
63	-24	-11	-242
64	-55	-16	-222
65	13	29	-213
66	65	70	-224
67	90	81	-215
68	89	86	-150
69	138	114	-106
70	153	109	-43
71	164	112	38
72	167	106	120
73	192	122	116
74	224	148	131

TABLE 5. Average genetic merit of cows and transmitting ability of sires in kg: Holsteins.

Year of freshening	Genetic value AI cows	Transmitting ability AI sires	Genetic value non-AI cows
61	-161	-110	-370
62	-158	-99	-375
63	-58	-51	-307
64	-42	-30	-306
65	-10	-9	-278
66	29	22	-240
67	39	34	-221
68	55	39	-167
69	53	22	-113
70	80	43	-73
71	118	69	-38
72	152	95	-20
73	171	121	-32
74	205	156	-30

than genetic gains per year among Guernsey and Holstein AI cows, 25.4 and 26.1 kg. Genetic improvement per year for Jersey AI cows, 25.0 kg, was more than for non-AI cows, 12.8 kg. Comparisons of rates of genetic improvement of AI cows and non-AI cows may not be valid, however, because the estimate of genetic improvement in the non-AI cows may include unidentified AI sires classified as natural-service sires. The fraction of unidentified sires which are actually AI sires is unknown. The percentages of non-AI cows without an identified sire were 8.9, 9.9, 44.3, 12.8, and 10.9 among Ayrshire, Guernsey, Holstein, Jersey, and Brown Swiss cows. In 1974, the AI populations had 281, 93, 235, 340, and 224 kg advantages in estimates of average genetic merit for milk production over those classified as non-AI populations.

The rate of genetic improvement for milk has been small but relatively uniform in AI and non-AI populations of Holsteins over the 14 yr. The increase in genetic value for milk for AI and non-AI cows of the other four breeds also has been small but has not been uniform.

TABLE 6. Average genetic merit of cows and transmitting ability of sires in kg: Jerseys.

Year of freshening	Genetic value AI cows	Transmitting ability AI sires	Genetic value non-AI cows
61	-79	-47	-257
62	-89	-51	-278
63	-71	-55	-232
64	-31	-12	-242
65	-13	1	-237
66	-13	1	-239
67	40	47	-249
68	72	69	-215
69	74	58	-187
70	103	73	-166
71	151	113	-124
72	180	133	-141
73	203	164	-97
74	209	171	-131

TABLE 7. Average genetic merit of cows and transmitting ability of sires in kg: Brown Swiss.

Year of freshening	Genetic value AI cows	Transmitting ability AI sires	Genetic value non-AI cows
61	-419	-367	-796
62	-523	-379	-816
63	-556	-406	-744
64	-600	-499	-704
65	-555	-429	-632
66	-489	-372	-608
67	-443	-330	-490
68	-379	-276	-478
69	-320	-197	-531
70	-224	-110	-394
71	-184	-96	-520
72	-185	-79	-378
73	-91	-55	-413
74	-105	-36	-329

Estimates of annual genetic improvement from other studies are listed in Table 9. There are no reported genetic trends for non-AI populations, except for Holsteins, to compare with the genetic trends of non-AI cows that were estimated in this study. For Holsteins, the estimate of 31.0 kg/yr is higher than the only previous report of 23.0 kg/yr.

Trends in the average transmitting ability of AI sires for the Ayrshire, Guernsey, Holstein, Jersey, and Brown Swiss breeds were 23.7, 14.6, 17.9, 18.3, and 34.7 kg, which agree with the range of previous reports of 17 to 28, 16 to 17, 16 to 25, 11 to 17, and 23 to 41 kg. However, annual genetic trends in the AI cow populations for the five breeds were 36.1, 25.4, 26.1, 25.0, and 38.1 kg, consistently less than previously reported estimates of 34 to 55, 32 to 92, −3 to 166, 22 to 83, and 46 to 81 kg. In doubling the trends calculated from average transmitting abilities of sires to estimate genetic trends of cow populations, it is assumed that genetic improvement is constant each generation. This assumption implies that the genetic change due to sires is the same for each generation, which may not be appropriate (20).

CONCLUSIONS

Genetic progress in dairy cattle has been considerable, although much slower than theoretically possible (Rendel and Robertson, [18]; Van Vleck, [23]). Trends in the genetic contribution of sires of the five breeds were less than previous reports, suggesting that estimating genetic trends of cow populations by doubling the trends in estimated transmitting abilities of sires is biased upwards.

TABLE 8. Regression of average genetic merit and average transmitting ability in kg on year.

Breed	Genetic value AI cows		Transmitting ability AI sires		Genetic value non-AI cows	
	$\bar{X}$	SE	$\bar{X}$	SE	$\bar{X}$	SE
Ayrshire	36.1	5.4	23.7	6.3	36.1	3.4
Guernsey	25.4	1.5	14.6	1.3	35.4	3.2
Holstein	26.1	1.6	17.9	1.2	31.0	1.7
Jersey	25.0	1.0	18.3	1.0	12.8	1.5
Brown Swiss	38.1	5.3	34.7	4.4	36.4	3.5

TABLE 9. Reported estimates of genetic trends in kg.

Reference	Year	Breed	Location	AI or non-AI[a]	Method 1[b]	Method 2[c]
5	1959	Hol	New York	AI	...	33
25	1961	Hol	New York	AI	29	...
		Hol		Non-AI	23	...
7	1961	Hol	One herd	Both	3	...
18	1963	Hol	Texas	Both	-3, 81	...
		Jer			62, 83	...
1	1964	Jer	California	Both	34	...
11	1966	Unknown	California	Both	14	...
9	1967	Hol	New York	AI	47	...
2	1967	Hol	One herd	Both	51	...
3	1967	Hol	Unknown	Both	45, 55	...
4	1968	Hol	One herd	Both	0	...
		Ayr	One herd		1	...
14	1969	Unknown	Unknown	AI	48, 18	...
16	1971	Jer	One herd	Both	38	...
8	1971	Hol	SE US	Both	53	...
		Jer			25	...
27	1972	Guer	Florida	Both	92	...
		Hol			33	...
		Jer			22	...
12	1974	Hol	Unknown	Both	9, 166	...
17	1974	Hol	Mid-west, US	Both	66-133	50
20	1975	Hol	Ontario	AI	...	42
13	1975	Hol	Quebec	AI	...	46
15	1976	Hol	Wisconsin	Both	79	43
6	1976	Ayr	NE US	AI	...	34
		Guer			...	14
		Hol			...	46
		Jer			...	22
		BS			...	46
23	1977	Ayr	NE US	AI	...	55
		Guer			...	32
		Hol			...	39
		Jer			...	34
		BS			...	81

[a]If AI or non-AI was not indicated, it was assumed that both AI and non-AI were in the study.

[b]Weighted regression (Smith, 1962) or a modification of the method.

[c]Twice the linear regression of average sire merit on year.

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