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ABSTRACT

Records from 97,555 first daughters of 1,487 Holstein sires in artificial insemination were used to estimate components of variance and covariance of first lactation milk and fat production and stayability to 36, 48, 60, 72, and 84 mo of age. Henderson's Method 3 was used with a model including fixed herd-year-season and genetic group effects and random sire within group and residual effects. Heritabilities for milk and fat production and 36-, 48-, 60-, 72-, and 84-mo stayability were .31, .30, .02, .04, .05, .05, and .05. Genetic and phenotypic correlations between milk production and stayability ranged from .47 to .65 and from .17 to .27. Adjusting components of variance of stayability to account for the correlation with milk reduced heritability of stayability by 35%. Genetic and phenotypic correlations between stayabilities to different ages ranged from .71 to 1.00 and from .18 to .73.

INTRODUCTION

Stayability is the probability of surviving to a specific age, given the opportunity to reach that age. Overall profitability of a dairy enterprise may be influenced by stayability of daughters of sires chosen to use in the herd. Holstein cows with the opportunity to live 84 mo survived an average of 16.6 days longer for each percentage point increase in their sire's 48-mo stayability prediction (4). Bakker et al. (2) reported a correlation of .80 between stayability proofs and an economic evaluation based on predicted lifetime production of daughters and their progeny.

Calculation of the sire profitability index (2) requires predictions of stayability up to six lactations. Currently, only cows with the opportunity to survive to each age are included in prediction of sire stayability. Van Vleck's (18) multiple trait procedure for predicting stayability to any age utilizes production and survival records of all daughters regardless of survival opportunity. All multiple trait evaluation methods require estimates of variances and covariances. The objective of this study was to estimate components of variance and covariance for first lactation milk and fat production and stayability to 36, 48, 60, 72, and 84 mo in Holsteins.

DATA AND METHODS

Records from cows sired by artificial insemination (AI) in the Northeast United States were obtained from New York Dairy Records Processing Laboratory. Records of cows conceived after availability of the sire's AI summary were excluded so that estimates of components of variance would not be biased by selection of sires based on their AI summaries. Cow birth, first freshening dates, and date of first AI usage of sires were available. Records of cows born more than 5.25 yr after entry of the sire into AI service were excluded. That time limit was calculated from the average age at first freshening of 28 mo and included an extra 6 mo above the biological minimum of 4.75 yr. Records of daughters conceived prior to a sire's first AI usage also were excluded to eliminate those from natural service.

All milk and fat records were first lactation, 305-day, 2×, mature equivalent (ME) with at least 907 kg milk and 32 kg fat and less than 15,876 kg milk and 680 kg fat. Data were divided into five opportunity groups, each including only records of cows having the opportunity to survive to 36, 48, 60, 72, or 84 mo. The record of a cow in any particular opportunity group also was included in earlier opportunity groups. Stayability records were coded 1 if the cow survived to a given age and 0 otherwise. For example, a cow sold for dairy at

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68 mo of age had the opportunity to survive to 60 mo. The survival score was 1 for survival to 36, 48, and 60 mo. A cow sold for beef or otherwise disposed at 68 mo of age having the opportunity to survive to 72 and 84 mo, assuming the herd remained on test, was scored zero for survival to 72 and 84 mo.

The model was

$$y_{ijkl} = h_i + g_j + s_{k(j)} + e_{ijkl}$$

where y_{ijkl} = a milk, fat, or stayability record of the l^{th} daughter of the k^{th} sire initiated in the i^{th} herd-year-season,

h_i = an unknown constant associated with records started in the i^{th} herd-year-season,

g_j = an unknown constant associated with records made by sires in the j^{th} genetic group,

$s_{k(j)}$ = effect of the k^{th} sire within the j^{th} genetic group, random with mean zero and variance σ_s^2, and

e_{ijkl} = residual effect associated with the $ijkl^{th}$ record, random with mean zero and variance σ_e^2.

Thus, observations have expectation $E(y_{ijkl}) = h_i + g_j$ and variance $V(y_{ijkl}) = \sigma_s^2 + \sigma_e^2$. Covariances between random effects were zero. Seasons based on date of first freshening were December to April and May to November. Sires were assigned to genetic groups of size 100 according to date of entry into AI service except that Canadian sires were assigned to a separate group. Data from other foreign sires were excluded.

Records in herd-year-season subclasses in which only one sire was used were deleted as those records would not contribute to that sire's solution. Exclusion of all but first daughters increased the amount of data deleted more than otherwise would have been; 46% of the herd-year subclasses containing 19% of the records from 3% of the sires were deleted. Loss of data was similar for each opportunity group.

Data in disconnected sire by herd-year-season subclasses also were deleted (14). Connectedness in a data set was quantified by number of pairs of compared sires, which is the number of nonzero off-diagonal elements of the sire equations after absorption of herd-year-season equations (8, 17). Average connectedness among sires was similar among opportunity groups (Table 1).

Variance components were estimated by several procedures (9). Only results by Henderson's (7) Method 3 are reported here, because all methods gave similar results. Heritability of stayability independent of influence of milk production was estimated by adjusting variation in stayability for that accounted for by milk yield. For example, the correlation between sire effects on milk production and stayability to 48 mo was:

$$r_{s_{m,48}} = \sigma_{s_{m,48}} / \sqrt{(\sigma_{s_m}^2 \sigma_{s_{48}}^2)}$$

Then the sire variance of stayability adjusted for variation accounted for by milk is:

$$\sigma_{s_{48|m}}^2 = (1 - r_{s_{m,48}}^2)\sigma_{s_{48}}^2$$

Similar adjustment was made to error variance. Adjusted heritability is:

$$h_a^2 = 4\sigma_{s_{48|m}}^2 / (\sigma_{s_{48|m}}^2 + \sigma_{e_{48|m}}^2)$$

Results for Ayrshire, Brown Swiss, Guernsey, and Jersey breeds are available from the authors. Results for Holsteins are discussed next.

RESULTS AND DISCUSSION

Components of variance, heritabilities, and correlations from the 84-mo opportunity group data (Tables 2 and 3) were similar to those from other opportunity groups. For example, in the 48-mo opportunity group, heritabilities for milk and fat production and survival to 36 and 48 mo were .30, .30, .02, and .04. Therefore, only results from the 84-mo opportunity group data are discussed.

Heritabilities for milk and fat production (Table 2) were similar to .29 and .28 from an identical model on Canadian data (16). Heritability .25 currently is used for both milk and fat production in calculating the Northeast AI Sire Comparison (NEAISC) (6). Using the new estimate would increase the range in sire proofs, but the ranking of sires would be unlikely to change much.

Heritabilities for stayability (Table 2) were low, in agreement with (10, 13, 15). As age at

TABLE 1. Number of sires, herd-year seasons, and records in each opportunity group.

	Opportunity group (mo)				
	36	48	60	72	84
Sires	2,532	2,216	1,931	1,706	1,487
Herd-year-seasons	41,091	36,864	32,185	27,575	23,107
Records	171,081	155,252	135,605	116,531	97,555
Average connectedness among sires	49.62	50.62	50.52	48.89	46.38

which survival was measured increased from 36 to 72 mo, so did heritability, but heritability of survival to 84 mo was lower than at 72 mo. Increasing heritabilities may be caused by reduction in proportion of cows surviving to successive ages, because variance of a binomial trait increases with more equal proportions in each category. Everett et al. (5) reported stayability decreased from 98% at 36 mo to 37% at 84 mo. Miller et al. (10) found heritability of herd life was relatively constant across opportunity groups.

Removing variation in stayability explained by variation in milk production reduced heritability of stayability at all ages by an average of 35% (Table 2). Adjusted heritability increased with survival age from 36 mo to 84 mo. Miller et al. (10) reported that heritabilities of herd life were 30% lower when herd life data were adjusted by simple regression of herd life on milk production compared with estimates from unadjusted data. Reduction was similar when heritability of herd life was estimated within deciles for milk production. Heritabilities in the lowest decile were higher than in other deciles, possibly because of more intense selection for milk among low producing cows (10).

Nicholson et al. (11) calculated sire proofs from second or third lactation records after adjustment for selection on first lactation records. Percent daughter survival was more highly correlated with second or third lactation milk proofs based on data adjusted for selection than with proofs based on unadjusted data. Second lactation proofs of sires whose daughters are culled heavily on first lactation records will be biased upward so that proofs based on unadjusted data will have lower variance than those calculated from adjusted data. The biggest adjustments for selection will be on proofs of sires with low daughter averages for survival; hence, the correlation between later lactation proofs and percentage daughter survival will be increased by adjustment for selection. Parker et al. (13) obtained heritabilities of age at disposal in institutional

TABLE 2. Components of variance and heritabilities for milk and fat production and stayability in the 84-mo opportunity group.

	Milk (kg)	Fat (kg)	Survival age (mo)				
			36	48	60	72	84
Unadjusted							
Sire variance	100,711.52	149.22	.0005	.0018	.0029	.0030	.0023
Error variance	1,192,527.04	1,840.66	.0806	.1825	.2264	.2203	.1825
Heritability	.31	.30	.0223	.0397	.0500	.0529	.0507
Adjusted for milk yield							
Sire variance			.0003	.0011	.0017	.0020	.0018
Error variance			.0769	.1702	.2131	.2105	.1775
Heritability			.0160	.0252	.0312	.0371	.0407

TABLE 3. Genetic and phenotypic correlations for milk, fat, and stayability in the 84-mo opportunity group.[a]

	(1)	(2)	(3)	(4)	(5)	(6)	(7)
Milk (1)		.82	.56	.64	.65	.58	.47
Fat (2)	.86		.47	.60	.58	.54	.46
36-mo Stayability (3)	.22	.21		.80	.76	.70	.72
48-mo Stayability (4)	.27	.25	.51		.95	.95	.89
60-mo Stayability (5)	.25	.24	.34	.66		1.00	.91
72-mo Stayability (6)	.22	.20	.24	.48	.72		.96
84-mo Stayability (7)	.17	.16	.18	.35	.53	.73	

[a]Genetic correlations above the diagonal; phenotypic correlations below the diagonal.

herds in which there was no culling of cows for production that were not significantly different from zero.

The positive relationship between milk production and stayability was demonstrated further by genetic and phenotypic correlations (Table 3). Similar associations between production and longevity have been reported (5, 10, 15). Genetic correlation between milk production and stayability was higher at 48 mo or 60 mo than at other ages. The phenotypic correlation peaked at 48-mo stayability. If ages in this study correspond to initiation of successive lactations, then 36-mo stayability represents survival to the beginning of second lactation. Prior to this age, either information on first lactation production is incomplete or the cow will be close to calving. If once a decision to cull on low production has been made a cow is retained until returns from milk are lower than feed costs, then most culling on low production in first lactation will occur after the cow reaches 36 mo of age. Thus, differences in first lactation milk production will have a greater influence on stayability to 48 mo of age than to 36 mo of age. However, a substantial amount of selection on incomplete records must be prior to 36 mo of age as correlations between first lactation milk and 36-mo stayability indicate. Allaire et al. (1) reported the percentage of disposals for low production was higher in the 37- to 48-mo age class (24%) than in the 25- to 36-mo age class (14%). Beyond 48 mo of age, the percentage of cows culled for low production decreased (1). Other studies (3, 12) also indicated that the proportion of cows culled for low production decreases with advancing age because of higher involuntary culling for reproductive problems and disease. Thus, the relationship between milk production and stayability decreases at higher ages. Correlations between fat production and stayability follow the same pattern as those between milk and stayability (Table 3).

Correlations between stayability to different ages were high (Table 3) in agreement with (5, 15). Correlations between stayability to a given age and stayability to any other age increased as the difference between the two ages decreased. Genetic correlations between 36-mo stayability and stayability to other ages were lower than genetic correlations between stayability to any other pair of ages. This might be expected because of less influence of milk on stayability to 36 mo compared with the influence of milk on stayability to later ages. Everett et al. (5) recommended survival to 48 mo as an overall measure of stayability because genetic correlations with stayability to older ages were high and because sires can be evaluated sooner if there is no waiting time for data on daughter survival to later ages.

Arguments against active selection pressure for longevity include low heritability, increased generation interval necessary to obtain survival information, and automatic selection because long-lived cows contribute more offspring to subsequent generations than do short-lived cows (10, 11, 13, 15). However, Van Vleck's (18) procedure for evaluating sires for stayability may reduce the waiting period for a proof. Bakker et al. (2) showed stayability may be important in determining expected net profits from one conception. Their results were obtained from genetic correlations of Everett et al. (5), which were similar to those reported here. Thus, prediction of stayability proofs may be warranted for inclusion in profitability indexes.

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