Heifer Fertility and Its Relationship with Cow Fertility and Production Traits in Holstein Dairy Cattle

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ABSTRACT

Breeding receipts from three AI units were merged with Ontario Dairy Herd Improvement Corporation and Record of Performance production records. Data comprised 53,705 heifer, 41,253 lactation 1, 14,688 lactation 2, and 3054 lactation 3 records by daughters of 2150 sires represented in 15,877 herd-year-seasons of birth. Three measures of heifer fertility, three measures of cow fertility, and three measures of production were investigated. Measures of heifer fertility were ages at first and last breeding and number of inseminations per conception. Cow fertility traits were days from calving to first breeding, days open, and number of inseminations per conception. Production traits were breed class average milk, breed class average fat, and fat percentage. Relationships among these nine traits for the first three lactations were estimated using a maximum likelihood multiple-trait procedure. The linear mixed model for each trait included fixed effects of herd-year-season of birth and genetic groups of sire and the random effect of sire. Transformations of the data for nonnormality had no influence on the estimates of genetic and phenotypic parameters. The heritability of .12 for age at first insemination, which was higher than other heifer fertility traits, indicated that selection would result in genetic response. Genetic and phenotypic correlations between heifer fertility and cow fertility and production traits in all three lactations were not different from zero. There was no genetic antagonism between fertility and subsequent production traits.

INTRODUCTION

Very little is known about heifer fertility, especially relationships between heifer fertility and later lactation fertility and production performance. Although Gaillard et al. (5) and Janson (13) suggested that fertility in females is most accurately measured in heifers, very few heifer fertility data are available for analysis.

Previous studies of artificial insemination data (6, 8, 12) have shown higher heritabilities for heifer fertility than for cow fertility. Heifer and cow fertility may not be related (11). Some estimates of genetic correlations between heifer fertility and cow fertility in first parity indicate a close genetic association between heifer and cow fertility (4, 10, 12, 13). In contrast, other studies (2, 8, 14, 15, 16) have not shown any genetic association between heifer fertility and first lactation fertility.

Objectives of this study were to determine the phenotypic and genetic relationships of heifer fertility with cow fertility and production traits for the first three lactations using a multiple-trait maximum likelihood procedure to account for selection of cows from one lactation to the next.

MATERIALS AND METHODS

Data

Approximately 1.14 million breeding receipts were recorded by three Ontario AI units from September 1981 through December 1985. Ontario Dairy Herd Improvement Corporation and Record of Performance production records were obtained from the Livestock Production Division, Agricultural Canada, Ottawa, Ontario.

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Cows with first calvings between 18 and 40 mo of age were assigned to parity 1. Later parities were numbered consecutively. Data were kept on cows calving from December 1980 onward with valid sire identification, provided first record was before 40 mo of age. Daughters of American sires were eliminated due to a lack of breeding receipt information on these sires. The production data consisted of 417,985 records of which 194,285, 134,486, and 89,214 were for lactations 1 to 3, respectively. The breeding receipts were matched with production records for each parity separately. Heifer records were extracted by matching to first parity records. At least 264 d were required between last breeding and first calving. Heifers bred before 9 or after 36 mo of age for the first time were discarded, as such extreme ages may result from an incorrect date of birth or insemination. Heifers having more than 294 d between last breeding and first calving were considered unmatched. A total of 53,705 heifers by 2150 sires in 15,877 herd-year-seasons of birth met these criteria. These heifers were matched separately with second and third parity data. Previous lactation reproduction data were not required. Two seasons of birth (i.e., March to August and September to February) were assigned.

Various measures of heifer and cow fertility were calculated. The 305-d milk and fat yields, adjusted for age and month of calving, and number of observations for heifers and cows in lactations 1 to 3 are in Table 1. The much smaller number records in second and third lactations is due to the short period (1981 to 1985) covered by the data and the lack of opportunity of many cows to have later lactations in this period.

Number of inseminations per conception equaled the number of breeding receipts with at least 2 d between consecutive breeding dates. Number of inseminations per conception and days open were calculated only if the following calving date was known. Breedings before 25 d postpartum were not included in the data.

TABLE 1. Number of observations for cow[1] fertility and production traits in different lactations.

	Lactation number		
Traits	1	2	3
Production traits			
Breed class average–milk	41,252	14,688	3054
Breed class average–fat	41,252	14,688	3054
Fat percentage	41,252	14,688	3054
Cow fertility traits			
Days between calving and first insemination	41,252	14,688	3054
Days open	13,870	3226	528
Number of inseminations per conception	13,870	3226	528

[1]Data were matched with heifer data, including age at first insemination, age at last insemination, and number of inseminations per conception for 53,705 heifers. Breed class average = the 305-d yield expressed as a percentage of the least squares mean for the appropriate age and month of calving.

Models

The same model was assumed for all nine traits. The model was:

$$Y_{ijkl} = u + HYS_i + G_j + S_{jk} + e_{ijkl}$$

where:

Y_{ijkl} = observation on l^{th} heifer of k^{th} sire in j^{th} genetic group in the i^{th} herd-year-season of birth;
u = overall mean;
HYS_i = fixed effect of i^{th} herd-year-season of birth;
G_j = fixed effect of j^{th} genetic group;
S_{jk} = random effect of the k^{th} sire in the j^{th} genetic group; and
e_{ijkl} = random error.

Prior to statistical analysis the distributions of different measures of heifer fertility, cow fertility and production traits were examined. Milk production traits were normally distributed. Not all measures of heifer fertility and cow fertility were normally distributed. Therefore, the power transformation of Box and Cox (3) in the form of:

$$y^t = (y^t - 1)/t \text{ for t not equal to 0, and}$$
$$y^t = \log y \text{ for t equal to 0}$$

was performed over a variety of t values. A maximum likelihood estimate (MLE) of t for each measure of heifer and cow fertility was obtained according to (3). The MLE of t for age at first insemination, age at last insemination, days from calving to first breeding, and days open were 0, 0, –.3, and –.4, respectively. The power transformation was not suitable for traits like number of inseminations per conception, and therefore, the square root $[(\sqrt{y}) + (\sqrt{y+1})]$ transformation was used for this measure of fertility. Heritabilities and genetic and phenotypic correlations were reestimated after these transformations.

TABLE 2. Means, standard deviations, heritabilities, and coefficient of additive genetic variation (CVA%) for heifer fertility traits.

Trait[1]	Mean	SD	h^2	CVA%
AFI	580.27	100.14	.12	3.73
ALI	600.87	107.75	.10	3.89
NICH	1.38	.73	.04	9.39

[1]AFI = Age at first insemination (days), ALI = age at last insemination (days), and NICH = number of inseminations per conception.

Methods

The maximum likelihood for multiple traits was used on transformed observations based on a Cholesky decomposition (9) that made the residual variance-covariance (VCV) matrix become an identity. Missing traits for cows were permitted, for example, if the k^{th} trait of t traits was missing, then traits k + 1 to t were also assumed missing. This greatly simplified the construction of multiple-trait equations. Sires were assumed to be unrelated for this analysis. Solutions to the mixed model equations were obtained with an iterative procedure as outlined by Schaeffer and Kennedy (18). The details of the procedure are given by Schaeffer (17). Due to the high computing cost and slow rate of convergence, the VCV estimates were assumed to converge if the value of the convergence criteria (17) was less than 5%. Final values of VCV were used to compute heritabilities and genetic and phenotypic correlations.

RESULTS AND DISCUSSION

Means and standard deviations for different measures of heifer fertility are presented in Table 2. Only heifers with confirmed first calving were used to compute these parameters. Mean age at first insemination of 580 d corresponds to a calving age of 28 mo, and mean age at last insemination of 601 d implied that actual age at first calving was 28.8 mo. On average, 1.4 services were required per successful conception in heifers, which compared well with data of Hansen et al. (8), who included natural services.

The heritability estimate (Table 2) for number of inseminations per conception was low and agrees with other estimates (8, 20). Heifer fertility was slightly more heritable than cow fertility (8, 10, 12). Heritability of .12 for age at first insemination was larger than estimates obtained by others (8, 20) but smaller than the estimate of .246 by Jansen et al. (12). Heritability of .10 for age at last insemination was slightly smaller than estimates by Hansen et al. (8) and Jansen et al. (12). Both age at first and last insemination may be considered at least in part as measures of maturity as well as measures of fertility. Genetic differences in rate of maturity might have contributed to the higher estimates of heritabilities for these two traits.

Coefficients of additive genetic variation were calculated by dividing the additive genetic standard deviations by the mean times 100 (20) and are given in Table 2. Coefficients of additive genetic variation for heifer fertility traits ranged from 3.7 to 9.4% and are comparable with results of Hansen (7) and Hermas (10).

Genetic and phenotypic correlations among measures of heifer fertility are given in Table 3. Except for the correlation between age at first and last insemination, the genetic and phenotypic correlations among heifer fertility traits were small. The genetic and phenotypic correlations between age at first and last insemination were large and positive. The high genetic correlation (.76) indicates the high degree to which the same additive genes influence both of these measures of heifer fertility or that these may be two different measures of the same trait. The estimate of genetic correlation between age at first and last insemination was lower, but the phenotypic correlation between these two traits was somewhat higher than found by Hansen et al. (6). Both genetic and phenotypic correlations of number of inseminations per conception with age at first and last insemination were in the lower range of values

TABLE 3. Genetic correlations (above diagonal) and phenotypic correlations (below diagonal) among measures of heifer fertility.[1]

	AFI	ALI	NICH
AFI	. . .	.76	–.08
ALI	.81	. . .	.17
NICH	–.04	.30	. . .

[1]AFI = Age at first insemination (days), ALI = age at last insemination (days), and NICH = number of inseminations per conception.

TABLE 4. Phenotypic (P) and genetic (G) correlations between heifer fertility and cow fertility and production traits in first lactation.

First lactation traits		Heifer fertility traits[1]		
		AFI	ALI	NICH
DCFI	P	.06	.05	.03
	G	.05	.04	.03
DO	P	.05	.06	.003
	G	.02	.03	.02
NICC	P	.01	.02	.02
	G	.002	.01	.01
BCA-M	P	–.13	–.12	.03
	G	–.10	–.08	–.02
BCA-F	P	–.15	–.12	.04
	G	–.06	–.06	–.02
Fat %	P	–.03	.02	.04
	G	.06	.04	–.02

[1]AFI = Age at first insemination (days), ALI = age at last insemination (days), NICH = number of inseminations per conception (heifer), DCFI = days between calving and first insemination, DO = days open, NICC = number of inseminations per conception (cow), BCA-M = breed class average - milk, and BCA-F = breed class average - fat.

reported by others (8, 20).

Table 4 contains the phenotypic and genetic correlations between heifer fertility and first lactation fertility and production. Most phenotypic correlations between heifer fertility and cow fertility in first lactation were positive but not different from 0. These correlations combined with low heritabilities revealed that the environmental conditions under which they were recorded were considerably different. Obviously first-calf heifers were under greater stress than heifers. Parturition and lactation could certainly influence the fertility level of first calf heifers. Also, housing and management conditions may be different for heifers and cows. All these factors would cause correlations to be small (1, 2, 8, 10). Phenotypic correlations of age at first and last insemination with first lactation production traits were negative but low (8).

Genetic correlations between heifer fertility and cow fertility in first lactation were positive but very close to 0. Batra et al. (1) also found low genetic correlations between heifer fertility and cow fertility. Hansen et al. (8) reported negative genetic correlations between heifer fertility and first lactation fertility, but standard errors of their estimates were very large.

Genetic correlations between heifer fertility and first lactation milk and fat yields were slightly lower than corresponding phenotypic correlations and were in a favorable direction, indicating that selection for increased yield would be expected to decrease the age at which heifers are bred (8, 20). Seykora and McDaniel (19) and Hermas (10) also found favorable genetic relationships between age at first calving and first lactation milk yield. These results are important, because age at first heat or insemination had significant additive variance and so is an obvious target for selection. The results for this data were not affected by selection on either yield or reproduction.

Phenotypic and genetic correlations between heifer fertility and cow fertility and production traits in second and third lactations were similar (not shown) to those for first lactations and not different from 0. The phenotypic correlations involving age at first and last breeding and production traits were of similar direction and magnitude as first lactation estimates. However, the corresponding genetic correlations for second lactation usually were smaller than for first lactation estimates. The genetic correlations in third lactation were smaller than second and first lactations but were still in a favorable direction.

Increased yield may be favorably related to improved heifer fertility, since genetic correlations of age at first and last insemination with production traits in all three lactations tended to be negative. Phenotypic and genetic correlations of 0 between heifer fertility and cow fertility in all three lactations indicate that heifer fertility and cow fertility seem to be independent genetically and phenotypically in agreement with other reports (2, 8, 11, 14, 15, 16). Results of this study contrast with those reported by Distl (4), Hermas (10), Jansen et al. (12), and Janson (13).

In agreement with Maijala (14), estimates of heritabilities and genetic and phenotypic correlations for fertility after transformation of data were very close to the estimates obtained from the raw data, indicating that transformation of data had no effect.

CONCLUSIONS

Heritabilities of heifer fertility were moderate for age at first and last insemination. Selection for one of these traits would result in genetic response without impairing milk production. No genetic association between heifer fertility and cow fertility was evident. Exclusive use of heifer records for evaluating bull fertility (5, 6, 13) is questioned. There does not appear to be any genetic antagonism between heifer fertility and subsequent production. Heifers that never conceived could not be included in this study. To account for selection bias from the heifer onward, it is necessary to have more accurate data on heifers, including disposals for reproductive failure. Computerization of breeding receipts should ensure that all information on heifer fertility and subsequent fertility and production records can be obtained easily. Transformation of discrete data had no effect on the estimates of heritabilities and genetic and phenotypic correlations.

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