Heritability and Repeatability of Fertility of Dairy Sires

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ABSTRACT
Heritabilities and repeatabilities were derived from nonreturn data of young sires in the sire sampling program and of the proven sires in the Eastern Artificial Insemination Cooperative, Inc., 1965 through 1974. Effects of season and time were minimized by deviation of monthly nonreturn rate for each sire from the monthly average of his contemporary group. The weighted average of deviations was the fertility rating. Heritabilities from half-sibs were for young sires .21 on 274 sons, .22 on 252 sons, for proven sires .35 and 28 sires (liquid semen), and from regression of son on sire .20 on 161 pairs. Repeatability was .12 on 34 sires which had fertility ratings with frozen semen as young sires and as proven sires. There was considerable selection of sires when frozen semen was from proven sires. Some sires had only 12% of their services to cows in Dairy Herd Improvement Associations while others had as high as 51%. Where random-like service exists as in a well-designed young-sire-sampling program, genetic differences among sires in nonreturns can be discerned.

INTRODUCTION
Research on heritability of measures of fertility in dairy cattle largely has centered on differences among cows. Studies generally indicate heritabilities of less than .10 (1, 4). The kinds of measures of female fertility and the small number of services per cow in her lifetime limit the opportunity to measure genetic influence on female fertility. In contrast, on the sire's side, the large number of inseminations per sire through artificial insemination (AI) presents the opportunity to minimize effects of specific environmental factors and thereby maximize genetic differences among sires. Research on heritability of fertility of dairy sires has been limited.

Shannon and Searle (7), in a large study of ratings of sire fertility in AI on liquid semen in New Zealand, indicated that heritability was about .30. Maijala (5) studied the heritability of the annual conception rate of liquid semen of AI Finnish Ayrshire sires and found in three separate sets of data involving 122, 140, and 90 sire-son pairs heritabilities of .38, .15, and .47. He also estimated repeatability of annual conception rating in data from 839 sires as .61. Further, he looked at the repeatability of the nonreturn rate of 42 bulls, and it was .45 where sizes of progeny groups were around 300. However, in a more recent report, Maijala (6) showed average heritability was .18.

Evidence to support genetic differences in fertility among sires comes from studies of semen characteristics of bulls used in Sweden and Finland. From data on 628 to 1336 sire-son pairs in Sweden, Hultnas (3) obtained heritability estimates of sperm concentration .32, total number of sperm per ejaculate .50, initial mobility index .45, frequency of sperm with abnormal heads .48, frequency of sperm with proximal cytoplasmic drops .40, and ejaculate volume .06. Maijala (5) found heritabilities with 337 Finnish sires of .37 for number of ejaculates per day, .14 for sperm concentration, .29 for number of live sperms, and .05 for ejaculate volume.

The objective of the present study was to estimate heritability and repeatability of fertility of dairy sires.

EXPERIMENTAL PROCEDURE
Nonreturn (60 to 90 day) data were gathered on dairy sires that had the least selection

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bias with the largest number of services. A source of data is sires in a young sire sampling program in AI where only service is to cows in DHIA herds and service is randomized. Such information was collected from the Eastern Artificial Insemination Cooperative, Inc., from 1964 through 1974 on 274 Holstein sires. To be included a sire had to have at least 300 services within 4 mo as a young bull.

In addition, nonreturn data on mature sires (AI proven), 6 to 8 yr old, were collected from the Eastern Artificial Insemination Cooperative. Fertility also was studied in nonreturn data of sires first used in artificial insemination as young sires in the sire sampling program and later as AI proven sires.

To minimize bias due to year and month, nonreturn rates to first service of young sires for each month were expressed as deviations from the mean nonreturn rate for all young Holsteins used that month. Deviations then were weighted by the number of services, and a single value was computed. Means were calculated similarly for mature sires by expressing their rates as deviations from the monthly stud average for mature sires.

Bulls were grouped according to sires, and variance was analyzed.

The model was \( Y_{jk} = u + s_j + e_{jk} \)

where

\( Y_{jk} \) = represents the nonreturn record of fertility of the son,
\( u \) = an effect common to all observations,
\( s_j \) = effect of the sire,
\( e_{jk} \) = random effect peculiar to each son's fertility record,

Effects of sire and other causes are random effects with means equal to zero and variances equal to \( \sigma^2_x \) and \( \sigma^2_e \).

Two analyses of variances were made of young sire data. The first included all sons to avoid selection bias. The second excluded all single sire-son pairs since they could not contribute to both sire and error variance components. From estimates of variance components, heritabilities were derived as \( 4\sigma^2_x/(\sigma^2_x + \sigma^2_e) \). Heritability also was estimated by doubling the sire-son regression, and repeatability, by correlation of conception rates of sires when young and mature.

### RESULTS AND DISCUSSION

Heritabilities in Table 1 indicate that where the use of sires is randomized, genetic differences can be discerned. In all analyses for heritability service by sons was randomized, as the first two and the fourth are on use of sons in a randomized young-sire-sampling program in DHIA herds while the old sire service was liquid semen which results in randomization of service. However, the large standard errors indicate that these estimates are not statistically significant.

Selection can be a modifying factor in estimating differences as shown by high heritability and low repeatability. Not included in Table 1 was heritability of 1.37 ± .28 on data

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<th>TABLE 1. Heritabilities of fertility.</th>
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<tr>
<td></td>
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<tr>
<td>Kind of semen</td>
</tr>
<tr>
<td>No. of sires</td>
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<tr>
<td>No. of sons</td>
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<tr>
<td>Mean no. services per son</td>
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<tr>
<td>Range in mean no. of services</td>
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\(^a\)Sires, 23 liquid and 9 frozen semen; all sons are on frozen semen.

\(^b\)Sires had an average of 15,889 services with a range of 2,518 to 36,314.
TABLE 2. Nonreturn rates for 1st services in Eastern Artificial Insemination Cooperative, Inc.

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<tr>
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<th>1973</th>
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<tr>
<td></td>
<td>No.</td>
<td>Nonreturn rate</td>
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<tr>
<td>DHIA 1st services</td>
<td>173,103</td>
<td>64.8</td>
</tr>
<tr>
<td>Non-DHIA 1st services</td>
<td>484,767</td>
<td>69.7</td>
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<td>Difference</td>
<td>4.9</td>
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from old sires (11 sires and 28 sons) where frozen semen was used only. Since frozen semen offered the opportunity for intense selection on these AI proven bulls, this could have contributed to the high estimate as well as could chance due to small numbers. Repeatability was .12 ± .20 from data on 34 sires on frozen semen service only. Frozen semen service for sons was randomized but not when bulls were proven, so selection at this later age and the small number of bulls could have contributed to repeatability less than expected from heritability.

A special problem exists with AI proven sires where frozen semen is used. These bulls are not used in all situations in the same proportion. Of the bulls currently in service at Eastern Artificial Insemination Cooperative, Inc., some have as low as 12% DHIA breedings and others as high as 51%. Heifer breedings ranged from 2.3% to 23%, and registered cow breedings range from 6% to 39% for various bulls. A check of the herds in which these sires were used (Table 2) showed that DHIA herds had a lower fertility average than non-DHIA herds. Cows showed a lower nonreturn rate than heifers, and registered cows showed a lower fertility rate than grade cows. Hahn (2) also found differences of herd and heifer. His study showed heritability of nonreturn rates of virgin heifers in herds of low fertility was .17 while nearly 0 in herds with good fertility.

The differential use needs to be accounted for to evaluate properly ratings of sire fertility. This could be done by comparing the herd fertility rating of an individual sire with the average of fertility ratings of other sires in the same herd during the same period. This method needs to be compared with the method of factor adjustment where factors would be used to adjust for influences like type of herd, percent heifers and percent registered in the nonreturn rate.

There is sentiment in the industry that nonreturn rates are not useful measures of differences in fertility among sires. This may be where no attempt is made by design of adjustment to minimize significant nongenetic sources of variability, which is the situation generally today. In our study, use of young sires was randomized, their use restricted to DHIA herds, and the analyses were based on the deviation of a sire’s rating from the contemporary stud average. In the European (5) and New Zealand (7) studies, liquid semen was used, which forces randomization. Heritabilities in those studies, .15 to .30, agree with our study.

REFERENCES