Impact of Changes in Genetic Improvement Programs and Annual Cycles on Holstein Service Sire Merit

R. L. POWELL and H. D. NORMAN
Animal Improvement Programs Laboratory
Agricultural Research Service, USDA
Beltsville, MD 20705

ABSTRACT

Monthly averages of Holstein service sire PD from January 1960 through December 1985 were examined to determine if a relationship existed with changes in evaluation methodology. Monthly average of service sire PD for registered cows from January 1971 through December 1985 suggested three linear periods of increase. Regression of PD on sequential month were significantly different for periods defined by hypothesized points of rate change (January to February 1975 and February to March 1984). Rate change points determined from data corresponded reasonably well to times of methodology changes, which can be attributed to new evaluations and accompanying educational programs. Changes in service sire PD by calendar month also were studied. After adjustment for general trend, PD for service sires of registered cows were slightly lower in December and January and about 20 kg lower in June and July than for the highest months. The unexpected bimodal oscillation was nearly the same as for percentage of services that were AI. Apparently, less AI is used in the 2 mo preceding availability of semiannual sire evaluations and in summer months. For a typical 100-cow herd, a dairy producer annually would sacrifice $121 in gross sales, because AI usage was less than in the highest month, February, and $1381 because AI was not used exclusively. Corresponding amounts for the nation would be $12.3 million and $140.9 million.
(**Key words**: service sire, genetic evaluation, genetic merit)

Received July 10, 1989.
Accepted October 16, 1989.

INTRODUCTION

Rate of genetic improvement is impacted by changes in information available, particularly accuracy of genetic evaluations, and changes in use of information both by individuals and organizations. Improvement is expected over time in accuracy of genetic merit estimation and in ability of breeders and AI organizations to use that information. This improvement might be expected to occur at a fairly uniform rate. However, major changes in evaluation methodology may result in a marked change in improvement rate because of increased accuracy in identifying top sires or educational effort that accompanies a major innovation. Lee et al. (3) suggested that changes in rate of genetic change in PD for sires of registered Holsteins coincided with changes in evaluation methodology in 1967 and 1974. Data from USDA indicated that revision of PD in 1967 and adoption of the Modified Contemporary Comparison (MCC) in late 1974 led to changes in rate of genetic progress as indicated by average Cow Indexes (4). However, USDA data used estimates of sire merit of cows born or first calving in a given year. Estimates of service sire merit by year-month would define more clearly the relationship between changes in evaluation methodology and change in genetic merit of service sires.

Considerable discussion has occurred over many years (1, 2) on the relative merits of fixed, stepwise, and moving genetic bases. The major issue is which base results in the greatest genetic improvement with the least educational effort. A pertinent question is whether lower or negative evaluations (as found with stepwise or moving bases) affect sire usage. Have educational programs that stress use of top bulls regardless of magnitude (or sign) of evaluations been sufficiently effective so that the base is irrelevant? A positive effect on service sire merit from a base change would support future base changes. The primary objective of this study was to determine if changes in genetic information impact rate of genetic improvement. Of particular interest was effect of the base change in January 1984. A secondary objective relating to annual cycles of service sire merit developed during the course of the study.

MATERIALS AND METHODS

Service sire identification and frequency of usage were obtained for registered and grade Holstein cows with data in pedigree files at USDA's Animal Improvement Programs Laboratory (AIPL). Service date was approximated by subtracting 279 d from cow birth date and ranged from January 1971 to December 1985. The pedigree file consisted of data provided by the Holstein Association, Brattleboro, VT, and those acquired from DHI lactation records. Thus, data were available for registered cows nearly 2 yr earlier than for grades. Means for sire merit by month and year were calculated separately for grade and registered female populations because the latest data would not contain a representative distribution of the two groups. Emphasis was on registered cows because those data were more current and more complete (no loss due to lack of sire identification and no requirement for cows' being on official test or even freshening). Currentness was important for examining possible effect of the genetic base change in January 1984.

Earlier data for merit of service sires for grade cows in 1960 through 1973 also were examined to verify the suggestion by Lee et al. (3) of a rate change from 1967 to 1968. Location of such a point for these grade data was expected also to apply to registered data, which were not examined for this early period.

Merit of service sires was obtained from AIPL sire files and included PD for all sires with evaluations through January 1988, including those with fewer than 10 daughters. Monthly means for PD milk for service sires of registered cows were analyzed to determine time at which rate of increase changed for sire merit. Three periods of essentially linear increases for registered data were suggested by the plot of means against time (Figure 1). These segments are more clearly defined in Figure 2, which shows the plot of mean PD for only 1 mo (December) across time. December was chosen in order to include the latest month in the last segment. Using only 1 mo/yr removes the obscuring fluctuations caused by including all calendar months. From Figure 2, changes in rate of increase in PD appear to be in late 1974 and late 1984. Separate regressions were determined for the three time periods with observations ignored near the two apparent points of rate change. Computed points of rate change were determined by computing the value for the sequential month (independent variable) at which predicted average service sire PD was equal from equations for adjacent periods. Rate change points indicated when ma-

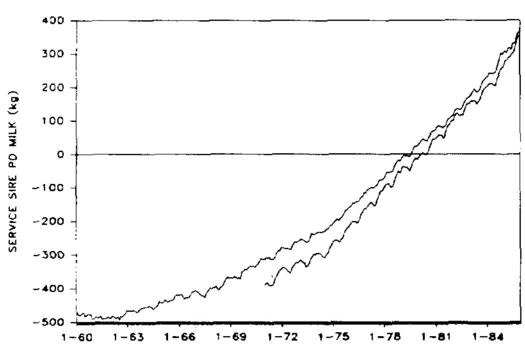

Figure 1. Genetic merit of service sires of Holstein cows from January 1960 through December 1985 by registry status (upper line = registered, lower line = grade).

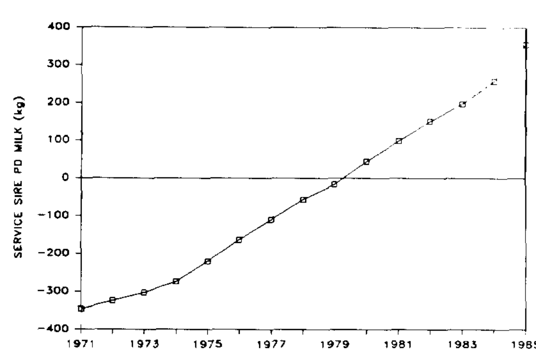

Figure 2. Genetic merit of service sires of registered Holstein cows in December from 1971 through 1985.

jor changes in rate of genetic improvement occurred through service sires.

Three periods were defined, each with an assumed linear trend, using the following model:

$$\overline{Y}_{ij} = u + bX_{ij} + m_i + e_{ij} \qquad [1]$$

where $\overline{Y}_{ij}$ is average service sire PD for year j and calendar month i, u is intercept, X_{ij} is sequential month, b is linear regression of $\overline{Y}$ on X, m_i is fixed effect of calendar month i, and e is residual.

Initial plots of service sire merit against time suggested repeatable monthly patterns across years. Therefore, the pattern in PD across calendar months was analyzed. Least squares means for calendar months were determined by Model [1] and also by a model that included separate regressions and intercepts for the three previously determined time periods and using all monthly data:

$$\overline{Y}_{ij} = u_k + b_kX_{ij} + m_i + e_{ij} \qquad [2]$$

where k = time period 1, 2, or 3.

The foregoing analysis was directed at determining points of rate change from the data and then comparing them with the times of events hypothesized to result in rate changes. The reverse approach was to begin with the times of the events hypothesized to have an effect on rate of genetic progress and compute regressions for periods thus defined. Regressions with Model [1] for the resulting periods were tested to see if they were different from regressions for adjacent periods. The squared multiple correlation was compared with that from a model that also included quadratic effect of time to see if increases in PD within periods could be adequately described by the linear term.

RESULTS AND DISCUSSION

Monthly means of service sire PD milk over time are in Figure 1 for services resulting in registered and grade daughters. By inspection of the registered data in Figure 1, changes in rate of increase in service sire merit appeared to occur in September 1974 and September 1984. To avoid including points of rate change in data from which they were to be calculated, the three initial data subsets were defined as January 1971 through December 1973, January 1976 through June 1983, and September 1984 through December 1985. The range for the most recent subset was much closer to its apparent point of rate change because of the short time period and the desire to include as much data as possible. Excluding data from the months surrounding the hypothesized points is important because differing rates of adoption will result in a curvilinear response in the vicinity of the triggering event. Innovators modify selection practices in anticipation of a new procedure or base, whereas others adopt technology more slowly. Including the transition period could be a source of error in locating the underlying event.

Regression coefficients in Table 1 were significantly different from each other ($P \leq .05$), which indicated different rates of improvement in service sire PD for the three periods. The squared correlations (R^2) indicated that the model was effective in explaining variation in the data. The R^2 from Model [2] was .999 compared with .997 from a model with an overall mean, calendar month effects, and linear and quadratic effects for time. That second order model has one less degree of freedom so it could be argued that the comparison was not fair. To answer that concern, Model [2] was used but with segments 2 and 3 combined so as to have the same degrees of freedom as for the second order model. That R^2 was .998, higher than for the second order model. Thus, the use of linear segments was more effective in explaining variation in service sire PD than was a second order model.

Points of rate change were computed by calculating the sequential month that satisfied regression equations for neighboring periods. For example, the sequential month, X, for the first point of rate change was determined by solving for X in the equality –695 + 2.3814(X) = –1035 + 4.2785(X) where X = 1 for January 1960. The solution was X = 179.2 mo or late November 1974. The other point was computed as 297.2 mo or late September 1984. Data from services to grade cows from 1971 through 1985 also provided an estimate for the first point of rate change of 178.8 mo or early November 1974, which was almost identical to that for data from registered cows.

The first MCC genetic evaluations were available in late November 1974; the first eval-

TABLE 1. Intercepts, regression coefficients, and multiple correlations squared (R^2) for analyses of three subsets of service sire merit of registered Holstein cows from January 1971 through December 1985.

Time subset	Intercept	Regression[1]		R^2
		Coefficient	SE	
January 1971 to December 1973	−695	2.3814	.1230	.954
January 1976 to June 1983	−1035	4.2785	.0202	.998
September 1984 to December 1985	−2148	8.0230	.0774	.999

[1]Regression of service sire PD milk on sequential month, where January 1960 is 1.

uations under the 1984 genetic base were available in late January 1984. Some lag between changes in evaluation methodology and trends in service sire merit would be expected because of delays between availability of the new information, its general distribution, and semen acquisition. Regardless of whether that lag is assumed to be 1, 2, or 3 mo, the estimated first point is earlier and the second one later than might have been expected. An earlier response could result because of anticipation of a change and a delayed response because of on-farm semen supplies or failure to adjust promptly to new information. Increasing regression coefficients by one SE for calculating the first point and decreasing by one SE for calculating the second resulted in late January 1975 and mid-September 1984 as estimated points of rate change. Thus, the first point is not significantly different ($P \leq .05$) from the hypothesized point of early 1975, but the second is later than the expected point of spring 1984.

Although calculated dates for changes in rate of genetic improvement in service sires did not correspond exactly with advent of the MCC and subsequent update of the genetic base, agreement is close enough to suggest that the hypothesis of a relationship is correct. No alternative explanation exists for why changes in rate of change are close to these referenced events. Time elapsed since the 1984 base change did not allow assessment of the nature of the change; i.e., a long-term change in rate of PD increase or a more likely short-term increase due to higher selection standards. Because of the variable adoption rate for new information, a hypothesized increase actually might be spread over many months and would appear as a rate change.

Calculations for grade data from January 1962 through December 1966 and January 1969 through December 1973 showed a change in rate at May 1968. This corresponds to the change in methodology in 1967. This lag is understandable considering that dissemination of genetic evaluations then was slower than at present and that trend in service sire PD was only +11 kg/yr before 1968.

Prior to study, changes in rate of improvement in service sire merit were hypothesized to occur between January and February 1975 and between February and March 1984. Thus, registered cow data were separated into three periods: January 1971 through January 1975, February 1975 through February 1984, and March 1984 through December 1985. Each

TABLE 2. Regression coefficients, multiple correlations squared (R^2), and added R^2 from addition of quadratic effect for month for analyses of three subsets of service sire merit of registered Holstein cows from January 1971 through December 1985.

Time subset	Regression[1]		R^2	Added R^2 from quadratic
	Coefficient	SE		
January 1971 to January 1975	2.19	.07	.968	.015
February 1975 to February 1984	4.31	.02	.999	.000
March 1984 to December 1985	7.35	.26	.992	.006

[1]Regression of service sire PD milk on sequential month.

TABLE 3. Calendar month constants for service sire PD milk in three discontinuous time periods and overall.

Month	January 1971 to December 1973	January 1976 to June 1983	September 1984 to December 1985	Overall
	(kg)			
January	−.58	−.11	.52	.61
February	1.89	2.84	6.87	3.27
March	−1.67	2.61	−1.29	1.21
April	−9.10	−.35	−4.55	−2.70
May	−13.03	−7.44	−9.53	−9.05
June	−21.88	−17.61	−9.62	−17.57
July	−22.78	−18.99	−14.15	−19.35
August	−14.35	−12.83	−12.15	−12.81
September	−7.76	−3.49	−2.17	−5.09
October	−2.21	1.87	5.57	.91
November	3.30	4.17	5.69	3.49
December	0	0	0	0

period was analyzed with Model [1]. Resulting regressions and R^2 are in Table 2. Regressions were significantly different ($P \leq .05$) from each other, and effect of sequential month within period was essentially linear. Effect of month squared was statistically significant ($P \leq .05$) for all three periods but added little to R^2. Increase in R^2 with the quadratic model in the first and last periods may have been because of rather short periods and the greater impact of the curvilinear effect from varying rates of adoption.

Rates of change per year in service sire PD milk were +29 kg/yr from January 1971 through December 1973, +51 kg/yr from January 1976 through June 1983, and +96 kg/yr from September 1984 through December 1985. The last trend is especially high, and the analysis may not have separated effects of calendar month and regression accurately because of the short time period of only 16 mo. Therefore, data from September 1984 through December 1985 were preadjusted for calendar month effects estimated from the data subset for January 1976 through June 1983, and the simple regression was recomputed. The resulting point of rate change was 297.1 mo, practically the same as in the original analysis, which had only 3 df for error, and the trend in sire PD was also similar at +97 kg/yr.

A study of related data (5) quantified the superiority of AI over non-AI sires and showed that percentage AI in the most recent time period was higher than seemed reasonable unless AI daughters were registered more promptly. Thus, the recent trend may appear higher in this study's data than will be true when data are more complete. Estimates of the later change point should not be affected even if estimate of trend is inflated.

Time periods were redefined as January 1971 through October 1974, November 1974 through September 1984, and October 1984 through December 1985 based on points of rate changes previously discussed. To obtain estimates of calendar month effects in conjunction with adjustments for general trends in the three time periods (overall analysis), the 180 monthly means were analyzed with Model [2] containing three separate regressions and intercepts and 12 calendar month effects. Regressions and intercepts were close to those for the much shorter periods in Table 1. Estimated constants from analyses within initial time subsets and from the overall analysis just described are in Table 3. A similar pattern was found for all time periods as is shown for January 1976 through June 1983 (Figure 3): a bimodal curve with a major low in July and highs in November and February that bracket a minor low in December to January.

The oscillating pattern in Figures 1 and 3 was unexpected. Patterns were similar for service sires of grade cows but not as pronounced. Two factors may be operating. First, prior to semiannual release of new USDA-DHIA bull evaluations, the tendency may be to use natural service or leftover, lower PD semen from on-farm tanks rather than purchase semen, because new information will be available in 1 or 2 mo. That would explain the December to January depression and would contribute to the June to

TABLE 4. Monthly and annual losses in gross revenue from milk sales for a 100-cow herd as a result of AI usage less than in month of greatest use.

Month	AI usage[1]	Difference in AI usage from February	Services[2]	Difference in gross revenue[3]
	(%)			($)
January	80.40	−.43	9.6	−2.71
February	80.83	0	9.0	0
March	80.60	−.23	8.7	−1.31
April	80.21	−.62	7.6	−3.10
May	78.96	−1.87	7.9	−9.71
June	76.64	−4.19	7.8	−21.47
July	76.13	−4.70	7.5	−23.16
August	77.55	−3.28	6.8	−14.65
September	78.69	−2.14	7.8	−10.97
October	79.01	−1.82	8.7	−10.40
November	78.67	−2.16	8.9	−12.63
December	79.05	−1.78	9.7	−11.34
Overall	. . .	. . .	. . .	−121.45

[1]Least squares means.

[2]Percentage of annual services; estimated from successful services in 1984.

[3]Based on 292-kg difference in PD milk between AI and non-AI sires (5), milk value of $.25/kg, and 90% realization of PD in milk sales. Example calculation for January is $-.0043 \times .096 \times 292 \times .9 \times \$.25 \times 100 = -\$2.71$.

July depression. The major June to July depression may be due primarily to competition among dairy enterprise, crop production, vacations, fairs, etc. At times when attention is on field work, the tendency may be to use natural service with the resulting lower PD. A contributing factor could be real or perceived lower AI conception rate in the summer heat. Conversely, at other times, the frequency of AI is higher, and the average PD is higher. Figure 4 shows least squares constants by calendar month for percentage of registered Holstein services that were AI; the pattern is almost identical to that in Figures 3 for service sire PD. Correlation between calendar month constants for PD and AI percentage estimated separately was .88.

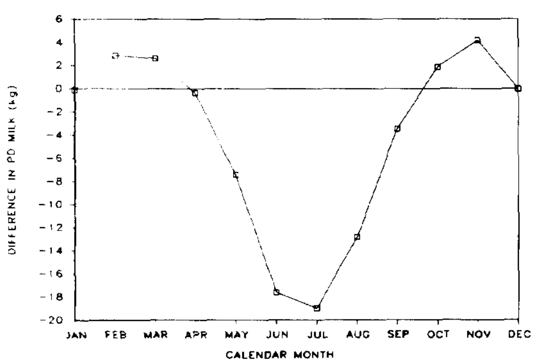

Figure 3. Effect of calendar month expressed as a difference from December effect on PD milk of service sires of registered Holstein cows from data from January 1976 through June 1983.

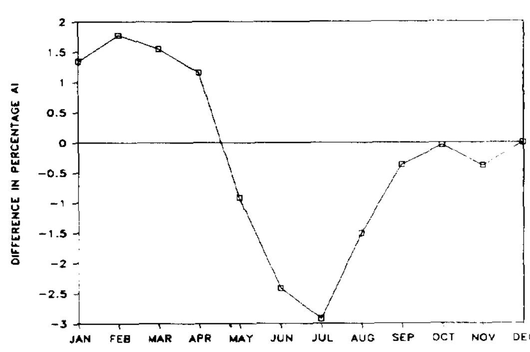

Figure 4. Effect of calendar month expressed as a difference from December effect on percentage of services that were AI for registered Holstein cows from data from January 1976 through June 1983 data.

Adding AI percentage to the model with sequential month and calendar month effects increased the R^2 only in the fifth decimal place, which further demonstrates the close relationship between AI usage and calendar month effect.

Decreased use of AI in some months not only explains oscillation in average PD but also represents a loss in potential revenue to dairy producers. Based on a 292-kg difference in PD milk between AI and non-AI sires (5), a milk value of $.25/kg and 90% realization of PD in milk sales, annual reduction in gross revenue in a 100-cow herd would be $121 (Table 4), which suggests a reduction of $12,342,000 for the national herd of 10.2 million dairy cows. This is the gross loss from milk sales just from less AI usage in other months than in February. Compared with 100% AI usage, the loss per typical 100-cow herd would be $1381, which would be a loss of $140,862,000 for the nation. Even this staggering amount is conservative because AI usage in Table 4 was from sire-identified cows, for which AI use is higher than in the general population.

CONCLUSIONS

Monthly means of service sire PD suggested three periods of differing rates of increase. Points of change in rate of genetic progress determined from regressions of these means corresponded reasonably well to times of changes in methodology or the genetic base. Regressions of PD on service month were significantly different ($P \leq .05$) for periods defined by hypothesized impacts of those changes. Increases in rate of genetic progress are attributed to both the new evaluations and to accompanying educational programs. Service sires of registered Holstein cows had slightly lower PD (by about 3 kg) in December and January than in adjacent months, and their PD were about 20 kg lower in June and July than in the highest months. That unexpected oscillation was due largely to varying percentage of AI services ($r = .88$). Apparently, there is a tendency to use less AI in the 2 mo preceding availability of semiannual USDA-DHIA bull evaluations and in the summer months.

ACKNOWLEDGMENTS

Computing advice and assistance of G. R. Wiggans and M. Sieber are gratefully acknowledged. Assistance in manuscript preparation from S. M. Hubbard is appreciated.

REFERENCES

1 Dickinson, F. N. 1973. A genetic base for estimating the genetic transmitting ability of dairy bulls in populations undergoing genetic change. Ann. Genet. Sel. Anim. 5: 267.

2 Dickinson, F. N. 1980. Alternative genetic bases for Sire Summaries and Cow Indexes. J. Dairy Sci. 63:1361.

3 Lee, K. L., A. E. Freeman, and L. P. Johnson. 1985. Estimation of genetic change in the registered Holstein cattle population. J. Dairy Sci. 68:2629.

4 Norman, H. D. 1986. Sire evaluation procedures for yield traits. Natl. Coop. Dairy Herd Improvement Progr. Handbook, Fact Sheet H-1, Washington, DC.

5 Powell, R. L., and H. D. Norman. 1989. Genetic differences among categories of service sires. J. Dairy Sci. 72:1847.