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Abstract
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Mating bull was significant for gestation length and for percent pregnant on a given service but not on first or first four services. Selection groups differed in gestation length only. Variance components for mating bulls for all traits and for sire of cow for gestation length were all less than 10% with most less than 3%.

Reproductive performance of offspring from selection of bulls solely for milk in first lactation was not inferior to that of offspring of bulls selected less intensely for milk.

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Reproductive Performance from Daughters of Single and Multiple Trait Selected Sires[1]

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ABSTRACT

Sires selected for milk in first lactation (Yield) and those selected for udder conformation, percentage of daughters culled in first lactation, and fat-corrected milk (Merit) were mated randomly to cows in the Beltsville herd. Subsequent offspring were mated to bulls from the same selection group as their sires. Reproductive traits were numbers of heats and services, age at first heat, gestation length, and age at first calving for heifers and numbers of heats and services, gestation length, days to first heat postpartum, and calving interval for cows. Selection groups differed only for gestation length with Merit females having a 2 day longer gestation than Yield females. Yield females calved earlier (12 days) and had shorter calving intervals (14 days) than Merit females.

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INTRODUCTION

Efficient reproductive performance is necessary to reduce cost of production. Reproductive problems long have been a major reason for removing cows from dairy herds. Selection of bulls with high predicted (PD) milk has prompted concern about how reproductive performance may be affected.

In field data (2, 4, 6, 14, 17, 18, 20) the relationship between milk yield and reproductive performance was little or nil. No biological relationship between services per conception and milk fat production was found by Touchberry et al. (26). However, in (4, 7, 21) a negative relationship between conception rate and milk production was suggested, although cause and effect were uncertain. Spalding et al. (25) reported lower conception rates among higher producing cows than lower producing cows. Lower conception rates among higher producing cows were reported by Olds et al. (17), but additional services per conception for higher producing cows were only one-third of those reported by Spalding et al. (25).

Few planned experiments have studied the relationship of genetic ability for milk production and reproductive performance. Gianola and Tyler (8) and Whitmore et al. (27) reported a factorial experiment including factors of genetic potential for milk yield, date of postpartum insemination, and nutritional regimen. Genetically high-producing cows compared to low producing cows had longer postpartum intervals to first ovulation and to first estrus and also had a higher frequency of retained placentas. Genetic groups did not differ in conception rate. However, the interaction of genetic group × nutritional regimen for days open was significant. Cows in the high genetic group had gestations 3.4 days longer than those in the low groups. A later report from this

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experiment (16) indicated a) significant variation among sires for traits days to first heat, days to first breeding, conception rate, and services per conception, and b) no differences between genetic groups of sires. Shanks et al. (22, 23) reported results of an experiment designed to evaluate direct response to milk yield and correlated responses in traits including reproduction. In (23), daughters of high-milk sires had 8% fewer systemic uterine treatments than daughters of low-milk sires. In a second report (22), data pooled from both genetic groups were analyzed to relate milk yield of the cow to her conception rate and conception interval. A 45-kg increase in milk yield was associated with a significant .24% increase in conception rate and a .16 day reduction in conception interval. When cows that failed to conceive were omitted, a 45-kg increase in milk yield was associated with a significant .15-day increase in conception interval.

Examination of male fertility traditionally has been treated separately from reproductive efficiency of the female though one-half of the genes of the cow come from her sire. Artificial insemination (AI) units must select for fertility of sires. Low conception accounts for nearly 33% of all the culling of dairy bulls in AI units in the United States (15). Again, little work has been done where groups of bulls differing in predicted difference (PD) milk were compared for reproduction traits. Objectives of this study were to determine differences in reproductive performance among bulls selected solely for first lactation milk (Yield) and among bulls selected for udder conformation, percentage of daughters culled, and fat-corrected milk (Merit), and to determine reproductive differences among their daughters.

MATERIALS AND METHODS

Design of Experiment

The selection project was begun in 1970 at the Beltsville Agricultural Research Center with the formation of two sire selection groups. Yield bulls selected annually were the two active AI sires with the highest PD for milk on only AI first lactation daughters and with repeatability greater than 40%. The two bulls (pair-mates) with the highest udder type index (based on Holstein Friesian Association (HFA) percent acceptable for four descriptive traits) were selected each year for the Merit group from among bulls with PD (4% FCM) greater than 181 kg, repeatability greater than 40%, and less than 10% of their daughters culled in first lactation. A repeat mating system suggested by Hickman and Freeman (13) was used within each selection group. A detailed account of the design is in (19).

Heats were recorded after 12 mo of age. All heifers were bred at first heat after 14 mo of age. Cows were bred at first heat after 55 days postpartum. No female was to receive more than eight services, and the breeding period was not to exceed 10 mo. If the first four services were unsuccessful, subsequent services for the

TABLE 1. Arithmetic means of reproductive traits[a] for heifers and cows for Yield and Merit selection groups.

Animal and trait	Merit $\bar{X}$	Merit N	Yield $\bar{X}$	Yield N
All heifers				
NH	4.10	129	3.73	123
NS	2.27	129	2.01	123
AFH (days)	389.81	129	385.78	123
Heifers with normal[b] calvings				
NH	3.88	111	3.53	110
NS	2.08	111	1.83	110
AFH (days)	390.58	111	385.73	110
AFC (days)	778.13	111	766.25	110
GL (days)	279.14	111	277.46	110
All cows				
NH	3.88	166	3.51	169
NS	2.46	166	2.35	169
DFH (days)	42.83	166	44.43	169
Cows with normal[b] calvings				
NH	3.71	99	3.30	114
NS	2.37	99	2.16	114
DFH (days)	40.17	99	42.88	114
GL (days)	279.48	99	277.84	114
CAI (days)	398.24	99	385.43	114

[a]NH = number of heats; NS = number of services; AFH = age at first heat; AFC = age at first calving; GL = gestation length; DFH = days at first heat postpartum; CAI = calving interval.

[b]Gestation length > 265 and < 290 days and nonaborted birth.

cow were assigned to the first service sire's year-pair mate.

Data

Three daughters of each bull each year were reserved for evaluation and were maintained under standard nutritional regimens. The standard nutritional regimen for first lactation females included grass-legume hay, corn and grass silage, and concentrates (19). Cows on second and third lactations were randomized to two complete feeds differing in percentage of corn and silage. Other project offspring not reserved were available for other experimental use. Data set I included only daughters of project bulls that were mated with project bulls and fed the standard rations. These data were used to analyze female and male traits. Additional analyses of the male (mating bull) traits included daughters of project bulls (Set II) and daughters of nonproject bulls (Set III) maintained on nonstandard nutritional regimens. Approximately 225 heifer and 335 later service periods from 225 cows were in analyses of female traits, and 3000 services in 1300 service periods from Sets I, II, and III were in analyses of male traits.

Reproductive traits for heifers included number of heats (NH), number of services (NS), age at first heat (AFH), gestation length (GL), and age at first calving (AFC). Traits examined for cows included NH, NS, GL, days to first heat postpartum (DFH), and calving interval (CAI). The traits NH, NS, and AFH for heifers and NH, NS, and DFH for cows can be viewed

TABLE 2. Mean squares for various effects for heifer data (I)[a].

		Mean squares[c]				
Trait	Data set[b]	Month[d] (11)	Year[d] (5)	Selection group (1)	Sire[e] (26)	Error[e] (208)
Age at first heat	All	2685	5394[f]	314	1822	1986
Age at first heat	Normal	2933	6242[f]	3289	1688	1795
Number of heats	All	7.69[f]	7.09	.22	2.92	3.99
Number of heats	Normal	5.57	6.10	.21	2.25	3.17
Number of services	All	5.59[g]	4.01	.52	1.65	2.32
Number of services	Normal	2.76	2.98	.94	1.19	1.71
Age at first calving	Normal	10022[f]	8105	2322	4685	3617
Gestation length	Normal	28.50	8.31	145.50	21.07	17.05

[a]Daughters of project sires bred to project service sires on standard regimen (19).

[b]All = all heifers; Normal = all heifers with gestation length > 265 and < 290 days and nonaborted birth.

[c]Numbers in parenthesis = degrees of freedom.

[d]Month and year of birth.

[e]The df for normal data are 24 for sires and 179 for error.

[f]$P<.05$.

[g]$P<.01$.

as two sets of traits, those associated with all females exposed to service and those associated with females with normal calvings. Normal calvings were defined as nonaborted births with gestation lengths between 265 and 290 days.

Reproductive traits for analysis of mating bulls included percent pregnant on first service (PFS), on a given service (PGS), on first four services (PF4), and gestation length (GL). Pregnancy was confirmed by birth of a calf. The traits PFS, PGS, and PF4 were distributed binomially.

Methods of Analysis

A variety of techniques was used to determine differences between groups for male and female reproductive traits. The general mixed model was:

$$y = X\beta + Zu + e$$

- y is an observation for a reproductive trait.
- β includes fixed effects of month and year of birth (heifers), previous calving (cows), or service period (male traits), nutritional regimen, and selection group. For male traits, service number may be included.
- u includes the random effects of sire of cow within selection group (female traits), mating bulls within selection group (male traits), and cows within sires (female traits).

TABLE 3. Mean squares for various effects for cow data (I)[a].

		Mean squares[c]						
Trait	Data set	Nutritional regimen[d] (4)	Month[e] (11)	Year[e,f] (5)	Selection group (1)	Sires[f] (22)	Cows[f] (153)	Error[f] (138)
Days to first heat post-partum	All	702	1088[g]	613	1	780	873	519
Days to first heat post-partum	Normal	506	714	400	3	565	612[h]	404
Number of heats	All	1.02	4.59	1.49	12.69	11.45[h]	5.65[h]	3.53
Number of heats	Normal	.94	5.35	1.07	6.87	5.91	4.22	3.02
Number of services	All	.38	3.74	.45	2.78	6.99	3.36[g]	2.46
Number of services	Normal	1.27	3.69	.37	2.32	5.05[h]	2.93	2.26
Calving interval	Normal	2743	3734	701	10958	6175	3785	2129
Gestation length	Normal	7.95	15.01	3.13	137.18[h]	25.14	19.75[h]	13.50

[a]Daughters of project sires bred to project service sires on standard nutritional regimen (19).

[b]All = all cow records; Normal = all records from cows whose calvings had gestation lengths of > 265 and < 290 days and were nonaborted.

[c]Numbers in parenthesis = degrees of freedom.

[d]Nutritional regimen partially confounded with age of cow.

[e]Month and year of previous calving.

[f]Degrees of freedom for years, sires, cows, and error for normal data are 4, 20, 104, 68, respectively.

[g]$P<.05$.

[h]$P<.01$.

e includes random residual effects.

X and **Z** are known fixed incidence matrices of ones and zeros.

Expectations of **u**, [E(**u**)], and **e**, [E(**e**)] are assumed null, and cows, sires, and errors are distributed with variances σ_c^2, σ_s^2, and σ_e^2 and with zero covariances.

Analysis of variance was used to test for group differences. For female traits, mean squares for groups were tested against mean squares for sires within groups. For male traits, mean squares for groups were tested against mean squares of mating bulls within groups. The exception to this test was for GL when the test was by Satterthwaite procedures (24). This test was necessary since the model for GL included both mating bull and sire nested within selection group and the expected mean square for selection groups contained mating bulls and sires.

Heifer traits were analyzed by analysis of variance and by mixed model procedures. When σ_s^2 and σ_e^2 are known, estimates of yield-merit group solutions from the mixed model equations are generalized least square (GLS) solutions and are best linear unbiased estimates (BLUE) (12). Exact χ^2 tests than can be constructed from those solutions. Variance components for the mixed model procedure were estimated by Henderson's Method III (11). When Method III estimates are used in the mixed model procedure, the tests are approximate but generally yield smaller sampling variances than standard fixed analysis of variance procedures (12).

All tests were approximate F tests because of unequal numbers and possible nonnormality. No transformations were made on the percent pregnant traits because mean percentages were not expected to be extreme. Mixed model tests will reduce sampling error of the tests if variances for the traits are known. Chi-square tests were used for the female traits, number of live births, still births, and multiple births.

RESULTS

Characterization of the selected bulls and their daughters' performances is in (19). Yield bulls and their daughters were superior to Merit bulls for both milk and fat but inferior for final type score.

Arithmetic means for reproductive traits of heifers and cows are in Table 1. Females with normal calvings (GL > 265 and < 290 days and nonaborted birth) generally had fewer heats and services per service period than did groups that included all records. Yield females had fewer heats and services per service period than did Merit females. The AFH, AFC, and GL were 5, 12, and 2 days shorter for Yield heifers than for Merit heifers. The GL was nearly 2 days shorter for Yield cows also. The DFH were 2 days longer for Yield cows, but their CAI was 14 days shorter than that of Merit cows.

Analyses of variance for heifers and cows (I)

TABLE 4. Estimates of variance components[a] for reproduction traits for heifer and cow data (I)[b].

Trait[c]	$\hat{\sigma}_e^2$	$\hat{\sigma}_s^2$	$\hat{\sigma}_c^2$
All heifers			
NH	100	N[d]	. . .
NS	100	N	. . .
AFH	100	N	. . .
Heifers with normal calvings			
NH	100	N	. . .
NS	100	N	. . .
AFH	100	N	. . .
AFC	96	4	. . .
GL	97	3	. . .
All cows			
NH	65	12	23
NS	73	12	15
DFH	72	N	28
Cows with normal calvings			
NH	73	7	20
NS	74	11	15
DFH	74	N	26
GL	72	5	23
CAI	58	11	31

[a]Variance components estimated by Henderson's Method III and are expressed as a percentage of total variation.

[b]Daughters of project sires bred to project service sires on standard nutritional regimens (19).

[c]NH = number of heats; NS = number of services; AFH = age at first heat; AFC = age at first calving; GL = gestation length; DFH = days at first heat postpartum; CAI = calving interval.

[d]N = negative estimate was negative so assumed to be zero for percentage computations.

are in Tables 2 and 3. Effects of month and year of birth for heifers and month and year of previous calving for cows were variable depending on the trait and data set. Selection group differences (averaged over sires or cows or both) appear only for GL. Sire affected NH and NS whereas cows affected DFH, NH, NS, and GL.

Sire, cow, and error variance components for the various traits are in Table 4. Sire components for heifers were all negative or small. Variance among cows ranged from 15 to 26% of the total variation whereas variance among sires ranged from negative to 12%. These estimates suggest little additive genetic variability with the possibility of moderate permanent environmental and nonadditive genetic variability. With a few sires (22 to 28) and cows (126 to 177), sampling variances were high. Estimates of heritability for gestation length from paternal sisters were 12% for heifers and 20% for cows. Selection groups did not differ for mean numbers of live births, still births, or multiple births.

Arithmetic means for mating bull data by selection group are in Table 5. Cow and heifer data were combined for mating bull analyses. Yield mating bull performance for all traits relating to percent pregnant was 2 to 5% higher than for Merit bulls.

Analysis of variance is in Table 6. Cow effects have been ignored. Nutritonal regimen (confounded partially with age of the cow) appeared to affect PF4 and PGS but not PFS. Effects of year and month of initiation of the service period were nearly always significant for pregnancy traits. Effects of service number also were important whereas effects of mating bull were important only for PGS. Despite pooling of cow and heifer data and changes in the model compared to that in the female analyses, selection group differences for GL were significant.

Variance components for sire and mating bull are in Table 7. Components of variance of mating bulls for PFS, PGS, and PF4 were all 2% or less. Components of variance for mating bulls ranged from 9.2 to 7.5% for GL, and the sire component was 5.9%

Arithmetic means for percent PGS are in Table 8. Percent pregnant was highest on first services (38%) and lowest on sixth service

TABLE 5. Arithmetic means of male traits by selection groups.

		Selection group means			
		Merit		Yield	
Trait	Data set[a]	N	$\bar{X}$	N	$\bar{X}$
Pregnant on first service (PFS)	I–II	662	.36	630	.40
Pregnant on first service (PFS)	I	303	.35	316	.40
Pregnant on given service (PGS)	I–III	1545	.33	1393	.35
Pregnant on given service (PGS)	I	708	.33	697	.36
Pregnant on first 4 services (PF4)	I–III	662	.70	630	.72
Pregnant on first 4 services (PF4)	I	303	.70	316	.74
Gestation length (GL)	I–II	255	279.3	276	277.8
Gestation length (GL)	I	216	279.3	239	277.7

[a]I, Daughters of project sires bred to project service sires on standard nutritional regimen (19). II, Daughters of project bulls bred to project service sires on nonstandard nutritional regimens (19). III, Daughters of non-project bulls bred to project service sires on nonstandard nutritional regimens.

TABLE 6. Mean squares for various effects for mating bull reproductive traits.

Trait	Data set[a]	Mean squares[b,c] Nutritional regimen[d] (6)	Year of service (5)	Month of service (11)	Service number[e] (8)	Selection group[f] (1)	Mating bull (28)	Sire (26)
Pregnant on first service	I–III	.387	1.806[h]	.586[h]	....	.292	.252	....
Pregnant on first service	I	.132	.581[g]	.393[g]	....	.108	.281	....
Pregnant on given service	I–III	.789[h]	3.277	.440[g]	.461[g]	.022	.417[h]	....
Pregnant on given service	I	.394	1.419[h]	.333	.266	.008	.372[h]	....
Pregnant on first 4 services	I–III	.591[h]	4.909[h]	.441[h]	16.201[h]	.002	.085	....
Pregnant on first 4 services	I	.385[h]	2.079[h]	.252[h]	9.589[h]	.030	1.001	....
Gestation length	I	18.98	7.80	14.14	....	149.07[e]	36.80[h]	33.77[h]
Gestation length	I	17.95	6.82	20.00	....	150.69[e]	37.40[h]	30.99[h]

[a]I, Daughters of project sires bred to project service sires on standard nutritional regimen (19). II, Daughters of project bulls bred to project service sires on nonstandard nutritional regimens (19). III, Daughters of non-project bulls bred to project service sires on nonstandard nutritional regimens (19).

[b]Numbers in parenthesis = degrees of freedom.

[c]Not all effects were included in all models.

[d]Nutritional regimen is partially confounded with age of cow.

[e]Service number degree of freedom equals 3 for pregnant on the first four services.

[f]Selection group tested against service sire except for gestation length where Satterthwaite was formed.

[g]$P<.05$.

[h]$P<.01$.

[i]Gestation length > 265 and < 290 days.

(24%). The arithmetic mean number of services per service period per conception are in Table 9. Although differences were not significant, Yield bulls and Yield daughters required slightly fewer services per conception than Merit bulls and daughters. Average services per sire per conception period are artificially lower than the average number of services per service period per conception because bulls were bred only four consecutive times to a particular female.

Frequency distributions of number of days between services for heifers and for cows are in Table 10. Services with 4 or fewer days between them were omitted, since it is likely most were associated with the same heat. Over 33% of repeat services were between 20 and 22 days after the last service. There were secondary peaks in the distribution at 41 to 43 days and 62 to 64 days after the last service. These two peaks suggest that earlier heats were missed. Average number of days in a service period for all females inseminated was 73.

Percent twinning in this herd was .4 for

TABLE 7. Estimates of variance components[a] for mating bull reproductive traits.

Trait	Data set[b]	No. observations	σ^2[c] Sire	σ^2[c] Mating bull	σ_e^2
Gestation length	I–II	531	5.9	7.5	86.6
Gestation length	I	455	5.9	9.2	84.9
Pregnant on first service	I–III	1292	...	.5	99.5
Pregnant on first service	I	619	...	1.9	98.1
Pregnant on a given service	I–III	2938	...	1.2	98.8
Pregnant on a given service	I	1405	...	2.0	98.0
Pregnant on first 4 services	I–III	1292	...	N[d]	100.0
Pregnant on first 4 services	I	619	...	.2	99.8

[a]Variance components estimated by Henderson's Method III and are expressed as percentage of total variation.

[b]I, Daughters of project sires bred to project service sires on standard nutritional regimen (19). II, Daughters of project bulls bred to project service sires on nonstandard nutritional regimens (19). III, Daughters of project bulls bred to project service sires on nonstandard nutritional regimens (19).

[c]There were 28 sires and 30 service sires.

[d]N = negative estimate assumed zero for percentage computations.

calvings 1, 3.5 for calving 2, and 3.5 for calving 3.

DISCUSSION

Groups differed significantly for GL only. However, some nonsignificant differences worth noting are earlier AFH (5 days) and AFC (12 days) for Yield than for Merit heifers. Because Yield bulls were selected solely on PD derived from first lactations, some earlier maturing animals may have been selected. Means for DFH and CAI for Yield minus Merit cows were 2 and −14 days. Delayed first heats postpartum in high producing cows have been reported by others also (27); our results although not significant agree. The higher producing Yield cows had a 14 day shorter calving interval than Merit cows. These results differ from those of others (4, 7, 21, 25) who found that higher producing cows had more days open and longer calving intervals than lower producing cows.

Estimates of sire and cow variance components were relatively small. Differences between Yield and Merit bulls in percent pregnant for PFS, PGS, and PF4 (Table 5) were not large. Overall conception rate of 38% for first services was lower than the 43.3% reported for Israeli herds (10). The higher conception rate for Yield bulls and their daughters was contrary to results by Spalding et al. (25) and Olds et al. (17), who found that higher producers required more services. However, Whitmore et al. (27) also found that daughters of high milk sires had a higher rate of conception on first service (+1%) than did daughters of low-milk sires.

Variances among mating bulls were small for all traits except gestation length. Johnson and Van Vleck (personal communication) found variances of sire and mating bull for GL from field data were 5.5 and 7.5%. These results are close to ours (Table 7). Gianola and Tyler (8) reported a significant difference among sires for GL, although components of variance were not presented.

Heritabilities .12 and .20 for GL compare

TABLE 8. Arithmetic means of percent pregnant on a given service from Data Sets I and I–III.

Service number[a]	Number of services	% Pregnant
Data set I–III		
1	1292	.38
2	709	.33
3	396	.29
4	251	.31
5	146	.27
6	75	.24
⩾7	69	.29
Overall mean	2938	.34
Data set I		
1	622	.38
2	346	.37
3	183	.32
4	108	.25
5	70	.27
6	39	.18
⩾7	37	.30
Overall mean	1405	.35

[a]I, Daughters of project sires bred to project service sires on standard nutritional regimen (19). II, Daughters of project bulls bred to project service sires on nonstandard nutritional regimens (19). III, Daughters of nonproject bulls bred to project service sires on nonstandard nutritional regimens (19).

closely with the .17 by De Fries et al. (5). Bulls had been selected by AI studs for production and conformation of their daughters. Subsequently, some bulls in AI were selected for semen quality and fertility (15). This selection may have reduced variation among bulls.

Percent twinning of .4, 3.5, and 1% for first, second, and third calvings in this herd was lower than in (3) with twinning 1.0, 4.3, and 6.2 for the same calvings. Some results (10) suggest lower twinning rates in smaller herds. Average number of services per conception of 2.07 is similar to the number of 1.97 in Israel (10) and to the 1.9 to 2.0 range reported by Whitmore et al. (27). The high proportion of return intervals falling between 20 and 22 days (Table 10) is a result of failure to conceive. The secondary peaks in frequency at days 41 to 43 and 62 to 64 between services suggest missed heats. However, the large percentage of cows requiring another service 23 to 38 days (20%) does not fit the regular estrus pattern of the cow. Results in Wisconsin from the era of fresh semen use in AI indicated that 55.8% of all return intervals were greater than 22 days (9). Heiman (10) suggested that 50% of the return intervals greater than 24 days were due to early embryonic death. Results published by Bar-Anan et al. (1) seem to confirm Heiman's suggestion. In our study, 50% of all females had return intervals of greater than 24 days. Bar-Anan et al. (1) found no effect of service sire on early embryonic death but some slight effect of sire of cow. He hypothesized that early embryonic death may be from maternal genetic and environmental effects.

SUMMARY

Differences in reproductive performance of bulls selected for single and multiple traits and of their daughter groups were examined. Selection groups differed only for GL with daughters of sires selected for multiple traits

TABLE 9. Arithmetic mean number of services per service period per conception and services per sire per conception.[a]

Trait	Yield		Merit		Overall	
	N	$\bar{X}$	N	$\bar{X}$	N	$\bar{X}$
Average services per service period per conception	276	1.97	255	2.18	531	2.07
Average services per sire per conception	276	1.71	255	1.85	531	1.78

[a]Sires were used for 4 consecutive services and then a new sire was used for 4 additional services. After 8 services, nonpregnant females were removed from the herd. Only cows which later calved were included.

TABLE 10. Frequency distribution of number of days between services.

Days between services	Service periods[a]				
	Overall	0	1	2	>3
5–7	.25	.25	0	.50	
8–10	.93	.74	1.36	.34	1.00
11–13	1.05	1.72	1.16	0	1.00
14–16	1.05	.49	1.36	.34	1.75
17–19	6.63	9.09	6.78	5.50	4.74
20–22	33.50	27.52	35.66	36.43	34.66
23–25	15.79	12.04	17.83	17.87	15.46
26–28	4.27	2.70	4.07	3.09	6.98
29–31	1.86	1.48	1.16	3.09	2.24
32–34	1.18	.74	1.36	1.03	1.50
35–37	1.18	2.46	1.16	.34	.50
38–40	3.22	5.41	2.52	2.41	2.49
41–43	5.08	6.39	5.04	6.19	2.99
44–46	4.15	3.69	3.49	5.84	4.24
47–49	2.54	3.44	1.75	2.75	2.49
50–52	1.80	1.97	1.36	1.37	2.49
53–55	.68	1.72	.58	.34	0
56–58	1.30	1.47	1.36	1.38	1.00
59–61	1.49	1.97	1.55	1.38	1.00
62–64	1.92	2.95	1.94	1.03	1.50
65–67	.93	.74	.58	1.38	1.25
68–70	.87	.74	.97	1.03	.75
> 70	8.36	10.32	6.98	6.53	9.73

[a]Service period 0 corresponds to gestation 1 (heifer), and service periods 1, 2, ⩾3 correspond to gestations 2, 3, and ⩾4, respectively.

carrying their calves nearly 2 days longer than Yield females. On the average, Yield daughters calved earlier, had shorter calving intervals, and conceived with fewer services than did Merit daughters. Yield bulls required fewer services per conception than did Merit bulls. Results for service return interval suggested considerable early embryonic death.

Overall reproductive performance of the high PD sires (milk) and their daughters was above that of the Merit or lower PD sires (milk) and their daughters. These results are preliminary in that some project animals have not completed their reproductive lives. However, evidence of adequate reproduction of the daughters of high PD milk sires is encouraging for dairymen who select intensely for milk.

REFERENCES

1 Bar-Anan, R., K. Osterkorn, M. Krausslich, and M. Heimann. 1978. Genetic component affecting the interval between consecutive inseminations. EAAP Comm. An. Genet., Stockholm.

2 Boyd, L. J., D. M. Seath, and D. Olds. 1954. Relationship between level of milk production and breeding efficiency in dairy cattle. J. Anim. Sci. 13:89.

3 Cady, R. A., and L. D. Van Vleck. 1978. Factors affecting twinning and effects of twinning in Holstein dairy cattle. J. Dairy Sci. 46:950.

4 Carmen, G. M. 1955. Interrelationships of milk production and breeding efficiency in dairy cows. J. Anim. Sci. 14:753.

5 De Fries, J. C., R. W. Touchberry, and R. L. Harp. 1959. Heritability of the length of gestation period in dairy cattle. J. Dairy Sci. 42:598.

6 Everett, R. W., D. V. Armstrong, and L. S. Boyd. 1966. General relationship between production and breeding efficiency. J. Dairy Sci. 49:879.

7 Francos, G., and D. Rottner. 1975. On the relationship between milk production and fertility in Kibbutz dairy cattle herds. J. Agric. Sci. Camb. 85:527.

8 Gianola, D., and W. J. Tyler. 1974. Influences of birth weight and gestation period of Holstein-Friesian cattle. J. Dairy Sci. 57:235.

9 Hawk, H. W., W. J. Tyler, and L. E. Casida. 1955. Effect of sire and sytem of mating on estimated embryonic loss. J. Dairy Sci. 38:420.

10 Heiman, M. M. 1979. A.I. data effects of production and reproductive performance of Israeli dairy cattle. "ON" Artif. Insem. Coop. Rep.

11 Henderson, C. R. 1953. Estimation of variance and covariance components. Biometrics 9:226.

12 Henderson, C. R., Jr., and C. R. Henderson. 1979. Analysis of covariance in mixed models with unequal subclass numbers. Commun. Statist. Theor. Meth A 8(8):751.

13 Hickman, C. G., and A. E. Freeman. 1969. New approach to experimental designs for selection studies. J. Dairy Sci. 52:1044.

14 Kragelund, K., J. Hillel, and D. Kalay. 1979. Genetic and phenotypic relationship between reproduction and milk production. J. Dairy Sci. 62:468.

15 Kratz, J. L., C. J. Wilcox, F. G. Martin, and R. B. Becker. 1975. Dairy artificial insemination sire vital statistics. J. Dairy Sci. 58:141.

16 Mahanna, W. C., E. L. Jensen, A. R. Hardie, and W. J. Tyler. 1977. Variation in reproduction performance of Holstein heifers sired by high and low PDM bulls. J. Dairy Sci. 60(Suppl. 1):79. (Abstr.)

17 Olds, D., T. Cooper, and F. A. Thrift. 1979. Relationship between milk yield and fertility in dairy cattle. J. Dairy Sci. 62:1140.

18 Olds, D., and D. M. Seath. 1953. Repeatability, heritability and effect of level of milk production in the occurrence of first estrus after calving in dairy cattle. J. Anim. Sci. 12:10.

19 Pearson, R. E., R. H. Miller, J. W. Smith, L. Fulton, M. F. Rothschild, D. S. Balaine, and G. Coffey. 1981. Single and multiple trait selection. First lactation milk yield and composition, conformation, feed intake, efficiency, and net income. J. Dairy Sci. 64:77.

20 Schaeffer, L. R., and C. R. Henderson. 1972. Effects of days dry and days open on Holstein milk production. J. Dairy Sci. 55:107.
21 Shama, H., M. E. Wells, G. D. Adams, and R. D. Morrison. 1976. Factor affecting calving interval in dairy herds. J. Dairy Sci. 59:1334.
22 Shanks, R. D., A. E. Freeman, and P. J. Berger. 1979. Relationship of reproductive factors with interval and rate of conception. J. Dairy Sci. 62:74.
23 Shanks, R. D., A. E. Freeman, P. J. Berger, and D. H. Kelley. 1978. Effect of selection for milk production on reproductive and general health of the dairy cow. J. Dairy Sci. 61:1765.
24 Snedecor, G. W., and W. G. Cochran. 1967. Statistical methods. Iowa State University Press, Ames.
25 Spalding, R. W., R. W. Everett, and R. H. Foote. 1975. Fertility of New York artificially inseminated Holstein herds in dairy herd improvement. J. Dairy Sci. 58:718.
26 Touchberry, R. W., K. Rottenstein, and H. Anderson. 1959. Associations between service interval, from first service to conception, number of services per conception and level of butterfat production. J. Dairy Sci. 42:1157.
27 Whitmore, H. L., W. J. Tyler, and L. E. Casida. 1974. Effects of early post-partum breeding in dairy cattle. J. Anim. Sci. 38:339.