Reproductive Traits of Holsteins and Jerseys. Effects of Age, Milk Yield, and Clinical Abnormalities on Involution of Cervix and Uterus, Ovulation, Estrous Cycles, Detection of Estrus, Conception Rate, and Days Open[1]

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ABSTRACT

Two hundred and twelve Holstein and Jersey cows were in a study to determine factors that affected reproductive traits. First ovulation occurred about 3 wk postpartum, and interval to first ovulation was greater in cows that had clinical abnormalities postpartum than in normal cows. Jerseys producing more milk ovulated sooner postpartum than lower producing herdmates. Involution of cervix and uterus occurred later postpartum in cows that had clinical problems postpartum. Involution of genital tract occurred later postpartum in older cows and sooner postpartum in cows that had higher milk yields. Duration of first postpartum estrous cycle was 4 days less than for second postpartum cycle. Percentages of estrous cycles detected by standing estrus were 43 and 73% for Holsteins and Jerseys. Estrous detection rates were highest for cows that produced slightly above the mean milk yield and did not differ between cows in highest and lowest milk production quartiles. First detected estrus and days to first insemination occurred later postpartum in Holsteins as milk yield deviation from herdmates increased, regardless of sign. In Jerseys, days to first insemination and days open increased linearly as milk yield increased. Days to first insemination and conception were greater in cows with postpartum clinical problems. Conception rate at first insemination postpartum increased in proportion to concentration of progesterone in blood samples collected during 12 days before first insemination. Overall, clinical problems at parturition and postpartum lowered reproductive performance in both breeds. There was a slight antagonism between milk yield and reproductive performance (days open) in Jerseys but not in Holsteins.

INTRODUCTION

Reproductive performance is economically important in dairy cattle because it affects milk yield per cow per day of herd life, number of replacements produced per cow, and culling practices (2, 3, 4, 21, 23, 27, 29, 32, 35, 36). Controversy exists over how reproductive performance is affected by milk yield. Some surveys found that certain measures of reproductive performance were lowest for cows producing most milk in commercial herds (2, 19, 21, 32, 35). In controlled studies, this negative relationship has not been found (27, 29, 30). But with selection in dairy cattle principally toward higher milk yield (24), it is important to know if and how milk yield affects reproductive performance.

Several traits are included in a cow's reproductive performance. Reproductive performance frequently is measured by calving interval or some component of calving interval such as days open (days nonpregnant). Calving interval combines days open and length of gestation. Duration of gestation cannot be altered appre-

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ciably without affecting survival of the neonate. Consequently, variation of calving interval essentially results from changes of days open. Days open is a function of interval from parturition to first insemination, rates of conception at first and subsequent inseminations, and intervals between successive inseminations. Intervals from calving to first insemination and intervals between successive inseminations are dependent on rate of detection of estrus.

If milk production affects reproductive performance, then traits such as involution of the uterus and cervix, interval from parturition to first and subsequent ovulations, rate of detection of estrus, and rate of conception should differ among cows with different milk yields. Our study was to identify relationships among milk yield, age, clinical abnormalities, and several reproductive traits of Jerseys and Holsteins that exhibited wide variation within breed in milk producing ability.

MATERIALS AND METHODS

Data were obtained from cows that calved in one Jersey (Randleigh Foundation) and two Holstein (North Carolina State University Units 2 and 3) herds from July 1, 1977, through June 30, 1978. Milk yields of cows that had calved were screened before this study, and approximately the top and bottom thirds of multiparous cows were utilized. All cows that calved for the first time (primiparous) during the study were used. Programs for selection in the three herds required that all primiparous cows be given the opportunity to complete at least one lactation. Consequently, 57% of the Jerseys and 59% of the Holsteins in our study were primiparous. Of the remaining cows, 67% were in their second or third lactation.

Management of Herds

Jersey cows were housed in open-sided free stall type buildings in which concrete alleys were flushed with water daily to remove waste. Jersey cows were provided with access to dirt exercise lots about 12 h daily and were milked in a double-two side opening parlor. Holstein cows in Unit 2 were milked and fed twice daily in a stanchion barn and were run in groups (about 12 to 20 cows per group) on permanent pasture during periods between feeding and milking. Holstein cows in Unit 3 were fed a grain mix and hay twice daily in a stanchion barn and were milked in a three-stall side opening parlor. Between milkings, cows in Unit 3 were run together on permanent pasture.

In all three herds, cows generally were fed according to current guidelines (22), but some feeding trials were conducted. The Jersey milking herd received ad libitum a blended ration that included corn silage, soybean meal, corn, minerals, and vitamins. Jersey cows also received about 1.4 kg of alfalfa hay per day. Holstein cows in Unit 2 received their grain mix (17% crude protein plus vitamins and minerals) and roughage separately. During the first 5 mo of lactation, cows were fed corn silage supplemented with peanut hulls to provide two percents of crude fiber (14 or 17%). Within crude fiber, 0, 20, or 40% of the crude fiber was from peanut hulls. After 5 mo of lactation, all Holsteins in Unit 2 were fed corn silage and alfalfa hay as roughage sources. Holstein cows in Unit 3 received a grain mix (18% crude protein plus vitamins and minerals) according to production plus corn silage ad libitum. The corn silage included enough peanut hulls so that each cow received 1 to 2 kg of peanut hulls daily.

Nonlactating cows in all three herds were fed roughage (supplemented with appropriate minerals and vitamins) until about 3 wk before calving. During 3 wk before calving, cows gradually were shifted to feeds for the milking herd, and appropriate amounts of the grain mix were fed if the grain mix was fed separately. All three herds were under the same veterinary care, and cows with similar clinical problems received similar treatments.

Collection of Data

Three measures of milk yield were recorded for each cow. The cumulative daily production during 70 days postpartum (70-day milk) was used to estimate yield during early lactation. We thought this yield was unaffected by days open or pregnancy. Lactation yield was obtained from Dairy Herd Improvement (DHI) records and was adjusted to 305-day, mature equivalent, milk-fat corrected basis (305-day ME). Milk fat corrections were on a 4% fat basis for Jerseys and 3.7% fat basis for Holsteins. The third measure of milk yield was current herdmate deviation (CHDEM) from Dairy Herd

Improvement (DHI). A cow's CHDEM was the difference between her 305-day, ME milk yield and the average production of herdmates that calved during the same season.

Beginning 2 to 3 days after calving, the reproductive tract of each cow was examined per rectum twice weekly (Mondays and Thursdays or Tuesdays and Fridays) until first insemination or 70 days postpartum, whichever came first. Diameter of the cervix and each uterine horn at the external bifurcation was estimated. Days to involution of the cervix and previously gravid uterine horn were calculated from changes in diameter. The cervix and uterus were considered involuted when there was no further change of diameter between two consecutive examinations. Cows with ovarian follicles ≥ 2.5 cm in diameter that persisted for at least 2 wk in absence of a corpus luteum (CL) were considered to have cystic ovaries. When a CL was detected in the same ovary at the same position for six consecutive examinations and when serum progesterone remained ≥ 1 ng/ml during this period, the CL was considered to be persistent (prolonged luteal phase).

Blood samples for determination of progesterone were collected into evacuated tubes by puncture of the coccygeal artery or vein. Samples were collected twice weekly (same schedule as palpations) until at least 40 days after conception or until the cow was culled. Cows were not culled before 305 days postpartum unless a clinical disorder or injury prevented them from staying in the herd. Blood samples were transported to the laboratory within 1 to 2 h of collection and stored at 4°C until serum was removed by centrifugation. Serum was stored at −20°C until hormones were assayed. Progesterone was assayed by radioimmunoassay procedures (8, 14) validated in our laboratory. The inter- and intraassay coefficients of variation for progesterone assays were 16 and 10%.

Day of each ovulation was determined from palpation and estrous data and serum progesterone concentrations by the following criteria: ovulation occurred on the day following an observed estrus if progesterone was ≤ 1 ng/ml on the day of estrus and subsequently increased according to a normal profile; when estrus was not observed, ovulation occurred 2 to 4 days before any increase in progesterone that exceeded basal (estrus) concentrations but was <2 ng/ml; and when estrus was not observed, ovulation occurred 4 to 6 days before progesterone increased from basal concentrations to >2 ng/ml.

The experimental period was divided into four seasons of calving: December through February (season 1), March through May (season 2), June through August (season 3), and September through November (season 4).

Clinical abnormalities at parturition were dystocia, retained placenta, death of calf, birth of twins, and milk fever. Clinical abnormalities postpartum were metritis, ovarian cyst, prolonged anestrus, and injury or disease. For statistical comparisons, cows that had clinical problems at parturition were grouped into a single abnormal class, and cows that had clinical abnormalities postpartum were grouped into another abnormal class.

Statistical Analysis

Least squares analyses of variance (1) were conducted separately for Jersey and Holstein data. The general model was:

$$Y_{ijklm} = \mu + H_i + S_j + C_k + A_l + \beta_1(X_{ijkl}) + \beta_2(X_{ijkl})^2 + \beta_3(X_{ijkl})^3 + \cdots \beta_n(X_{ijkl}) + \beta_{n+1}(X_{ijkl})^2 + \beta_{n+2}(X_{ijkl})^3 + E_{ijklm}$$

where Y_{ijklm} is the ijklmth observation of the trait in question, μ is the overall mean, H_i is the effect of the ith herd (Holstein herds only), S_j is the effect of the jth season, C_k is the effect of the kth clinical condition at parturition (normal or abnormal), A_l is the effect of the lth clinical condition postpartum (normal or abnormal), β_1 to β_n are the linear regression coefficients of the trait on designated independent variables (such as milk yield, age, etc.), $\beta_2 \cdots \beta_{n+1}$ and $\beta_3 \cdots \beta_{n+2}$ are the corresponding quadratic and cubic coefficients, and E_{ijklm} represents the random residual associated with the mth observation. When milk yield was a significant variable in statistical models, only one measure of milk yield was included. The measure of milk yield used in the model was chosen on the basis of which yield contributed most to variation of the trait in question. Least squares estimates for effects of season of calving or clinical abnormalities were

expressed as deviations from season 4 (season with most calvings) or from the normal classifications. Only variables of statistical significance were incorporated in reduced models; variables that were not significant were deleted in a stepwise fashion.

Cows were divied into four milk yields during 70 days postpartum (70-day milk). Divisions were within first or subsequent parity within breed by first dividing cows into two groups based on mean cumulative yield during 70 days postpartum. Each group then was subdivided into two groups based on the average yield for that group. Differences of accuracy of detection of estrus among these four groups were determined by Bonferroni chi-square tests (17). Differences of progesterone concentrations during sampling periods before and after first insemination were determined by *t* test if variances were homogenous and approximate *t* tests if variance were heterogenous (31). Differences of conception rates among first through fourth and subsequent services were determined by Chi-square tests (17).

RESULTS

Number and disposition of Holsteins and Jerseys are in Table 1. A total of 212 cows calved during the year; 17 were culled for various reasons before insemination, and 195 were inseminated at least once.

Means, standard deviations, minimums and maximums, and number of observations for various traits are in Table 2. Differences in number of observations for traits in Table 2 were due to exclusion of data from cows that had abnormalities associated with a specific trait (e.g., data from cows that had cystic ovaries before first ovulation were not included in means for days to first ovulation). Otherwise all data from a cow were included in averages until the cow was culled.

Abnormalities at or After Calving

Calvings were normal in 85% of Holsteins and Jerseys (Table 3). The primary anomaly at parturition in Holsteins was retained placenta, and the principal problem in Jerseys was milk fever. Of 96 Holsteins, 71 (74%) were free of clinical problems postpartum; similarly, 77% (89 of 116) of Jerseys were normal postpartum. For Holsteins, uterine infection was the most prevalent clinical condition during the postpartum period, and for Jerseys ovarian cysts ranked first following closely by injury or disease and uterine infection.

Prolonged luteal phase (CL persisted for >21 days) occurred during single estrous cycles in 24 cows. In 8 of 13 Holsteins and 6 of 11 Jerseys, uterine infection occurred prior to the prolonged luteal phase. In 22 of 24 cases, the prolonged luteal phase was during the first estrous cycle postpartum.

Days to First Ovulation

Days ($\bar{X} \pm SD$) from calving to first ovulation were 20.8 ± 13.2 and 20.0 ± 14.4 for Holsteins and Jerseys (Table 2). Days from calving to first ovulation were not distributed normally. Medians were 16 and 15, and modes were 14 and 11 for Holsteins and Jerseys. Excluding cows with cystic ovaries, one Holstein and five Jerseys ovulated first after day 45; all others ovulated before day 45.

The model that best accounted for variation of days from calving to first ovulation of Holsteins (Table 4) included effects of season of calving, abnormalities after calving, and age at calving and accounted for 18.5% of variation of days to first ovulation. Cows that calved during season 1 (December to February) had 6.5 ± 2.9 more ($P<.05$) days to first ovulation than

TABLE 1. Number and disposition of cows.

Disposition	Holstein	Jersey	Total
No. calved	96 (100)[a]	116 (100)	212 (100)
No. culled before first insemination	8 (8.3)	9 (7.8)	17 (8.0)
No. inseminated at least once	88 (91.7)	107 (92.2)	195 (92.0)

[a]Percentage of total.

TABLE 2. Means, standard deviations, minimums (min) and maximums (max), and number of observations for selected traits of Holstein and Jersey cows.

Trait	Holsteins					Jerseys				
	No. observations	Mean	SD	Min	Max	No. observations	Mean	SD	Min	Max
Days from calving to first ovulation	96	20.8	13.2	9	93	114	20.0	14.4	8	90
Interval to cervix involution (days)	96	23.7	6.9	14	70	116	20.9	4.6	11	33
Interval to uterus involution (days)	96	23.8	8.4	13	70	116	21.7	5.3	13	47
Interval between first and second ovulation (days)	83	17.1	4.2	10	26	98	17.2	4.4	9	28
Interval between second and third ovulation (days)	88	21.4	2.3	11	26	104	21.1	2.7	11	26
Interval from calving to first detected estrus (days)	89	66.9	33.9	11	186	116	37.2	27.3	8	143
Interval from calving to first insemination (days)	88	87.6	26.4	51	186	107	85.0	15.9	55	143
Interval from calving to conception (days open)	79	109.2	38.4	56	238	100	94.8	28	61	206
Conception rate at first insemination (%)	88	49	50	0	100	107	72	45	0	100
12-day progesterone (ng/ml)	85	3.7	1.4	.3	8.4	105	3.7	1.5	.4	8.7
70-day milk (kg)	96	1846	511	942	3024	116	1230	294	627	1871
305-day ME fat-corrected milk (kg)	96	8260	1426	2476	11650	114	5766	1016	2144	7994
Current herdmate deviation (kg)	81	314	1183	−2643	3210	85	6	848	−2807	1946
Age at calving (months)	96	33.6	12.1	21	75	116	38.6	20.5	23	115

cows that calved during season 4 (September to November). Cows with abnormalities after calving had 8.8 ± 3.0 more days to first ovulation than normal cows (Table 5). There was a cubic relationship between days to first ovulation and age at calving (Figure 1). Between about 33 and 60 mo of age, younger cows had their first ovulation earlier than older cows. The decline for older cows may have been associated with a limited number of observations of cows beyond 65 mo of age at calving.

The model that best accounted for variation of days from calving to first ovulation of Jerseys included effects from abnormalities after calving, age at calving, and 305-day ME milk yield, and this model accounted for 21% of the variation of this trait (Table 4). Cows with abnormalities after calving took 14.7 ± 3.1 more ($P<.01$) days to have their first ovulation than normal cows (Table 5), and there was a linear decline of days from calving to first ovulation as 305-day ME yield increased (Figure 2).

Involution of Cervix

Days to involution of the cervix were calculated from estimates of diameter twice weekly. The regression model for Holstein data accounted for 41% of variation of days to cervix involution (Table 4). Days to involution of cervix were greater for Holsteins that had abnormalities at parturition or postpartum than for normal cows (Table 5) and increased ($P<.01$) with age at calving (Figure 3). Involution of the cervix occurred sooner ($P<.10$) after calving for higher producing Holsteins (Figure 4).

For Jerseys, factors that affected involution of the cervix were similar to those for Holsteins (Table 4), and the regression model for Jerseys accounted for 34% of variation of this trait. Interval to involution of the cervix for Jerseys increased with age up to about 60 mo and then tended to decline (Figure 5); interval to involution decreased as milk production increased (Figure 6).

Involution of Uterus

Days to involution of the uterus were calculated by the same method as for cervix. Involution of the uterus closely paralled involution of the cervix for both breeds (Tables 2 and 4). Holsteins that had abnormalities at parturition or postpartum and Jerseys that had abnormalities postpartum had more days to involution of the uterus than normal cows (Table 5). Age affected involution of the uterus of Jerseys but not of Holsteins. Older Jerseys had longer ($P<.01$) intervals to involution of the uterus (Figure 7). Milk yield affected involution of the uterus of both breeds. Effects were similar so only Jersey data are illustrated (Figure 8). Days to involution of the uterus declined as 70-day milk yield increased up to 1400 kg, then there was a gradual increase at higher production.

Durations of First and Second Postpartum Estrous Cycles

Duration of first postpartum estrous cycle (interval from first to second ovulation) was shorter than duration of second cycle for both Holsteins and Jerseys (Table 2). Data were excluded from cows that had prolonged luteal

TABLE 3. Frequency of abnormalities at parturition or postpartum for Holsteins and Jerseys.

Parturition	Jersey	Holstein	Postpartum	Jersey	Holstein
Dystocia	0[a]	2	Injury or disease	7	4
Twins	1	0	Uterine infection	6	12
Retained placenta	4	6	Cystic ovary	8	4
Dead calf	2	1	Prolonged anestrus[b]	5	1
Milk fever	11	0	Two or more conditions	1	4
Two or more conditions	0	5	Normal	89	71
Normal	98	82			

[a]Number of cows affected.

[b]Ovulated first after day 45 postpartum.

TABLE 4. Degrees of freedom, F's, residual mean squares, and coefficients of determination (R^2) for regression models for intervals to ovulation, involution of cervix and uterus, and duration of first two estrous cycles postpartum.

		Dependent variables									
		Days from parturition to:									
		First ovulation		Involution of cervix		Involution of uterus		Duration of first estrous cycle		Duration of second estrous cycle	
Independent variables	df	H[a]	J[a]	H	J	H	J	H	J	H	J
Season	3[b]	1.9	...	...	.9	...	...	...	1.5	2.2	.9
Abnormalities at parturition	1[c]	...	...	3.6	...	13.9	...	2.6	...	2.3	...
Abnormalities postpartum	1	8.7	22.1	7.5	...	6.5	8.8	...	2.0	...	2.4
Age	1	7.4	1.1	7.9	29.6	...	15.6	5.2	7.0	1.1	8.0
Age^2	1	7.4	...	...	21.3	...	9.4	5.4	...	...	5.8
Age^3	1	7.2	...	...	...	...	...	5.4	...	...	4.3
Milk	1	...	3.9[e]	6.4[e]	5.5[d]	5.1[e]	3.3[d]	3.5[d]	3.7[d]	1.4[e]	...
Milk^2	1	...	...	3.9	...	3.9	2.9	...	3.4	1.7	...
Milk^3	1	...	...	2.8	...	3.1	...	...	...	...	...
Residual mean squares	>70	153	178	30	15	46	18	16	16	4.9	6.5
R^2		.185	.211	.412	.343	.381	.397	.143	.238	.150	.181

[a]H = Holstein, J = Jersey.

[b]For 3 df, $P<.10$ for $F\geq 2.2$, $P<.05$ for $F\geq 2.8$, $P<.01$ for $F\geq 4.2$.

[c]For 1 df, $P<.10$ for $F\geq 2.8$, $P<.05$ for $F\geq 4.0$, $P<.01$ for $F\geq 7.1$.

[d]Milk yield expressed as cumulative yield for 70 days postpartum.

[e]Milk yield expressed as 305-day, mature equivalent, fat-corrected.

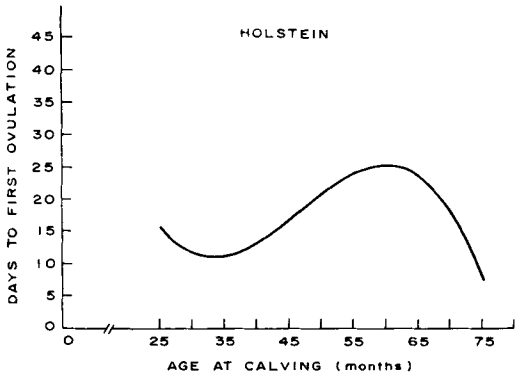

Figure 1. Partial regression of days to first ovulation on age at calving for normal Holstein cows.

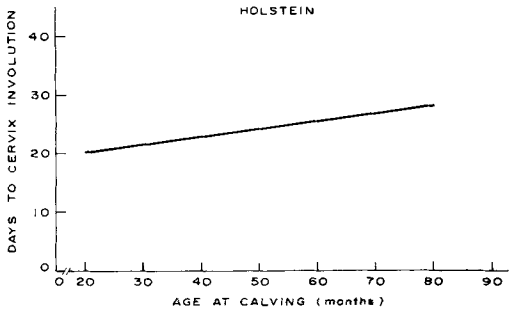

Figure 3. Partial regression of days to involution of the cervix on age at calving for Holstein cows.

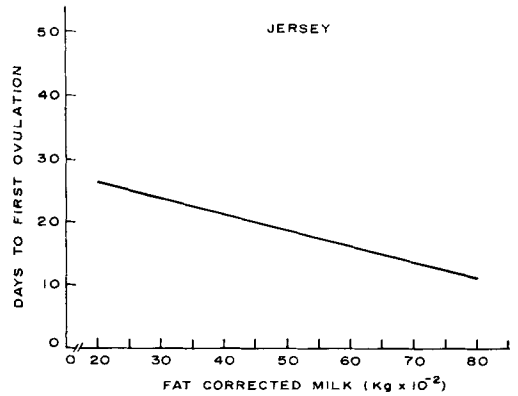

Figure 2. Partial regression of days to first ovulation on milk yield (305-day, mature equivalent, 4% fat-corrected milk) for normal Jersey cows.

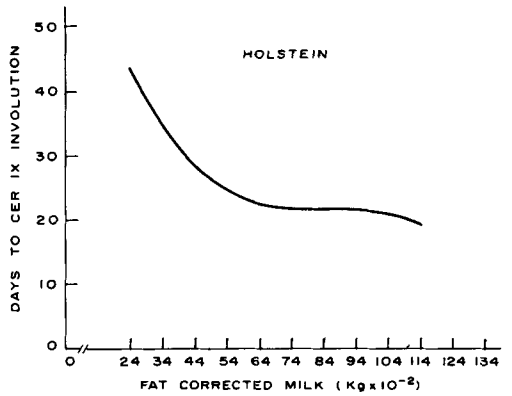

Figure 4. Partial regression of days to involution of the cervix on milk yield (305-day, mature equivalent, 3.7% fat-corrected milk) for Holstein cows.

TABLE 5. Effect of clinical abnormalities at parturition or postpartum on reproductive traits of Holsteins and Jerseys.

Trait	Holsteins				Jerseys			
	Parturition		Postpartum		Parturition		Postpartum	
	$\bar{X}$	SE	$\bar{X}$	SE	$\bar{X}$	SE	$\bar{X}$	SE
Days from calving to first ovulation	...		8.8	3.0[a]	...		14.7	3.1
Days to involution of cervix	3.5	1.8	4.3	1.5	...		...	
Days to involution of uterus	8.6	2.3	4.9	1.9	...		2.9	1.0
Days from calving to first detected estrus	17.0	9.7	...		...		23.3	5.8
Days from calving to first insemination	...		14.2	6.8	...		7.3	3.9
Days from calving to conception	...		16.6	10.8	−20.2	9.6	15.1	7.0

[a]Mean ± SE expressed as a deviation from normal cows; positive means a longer interval.

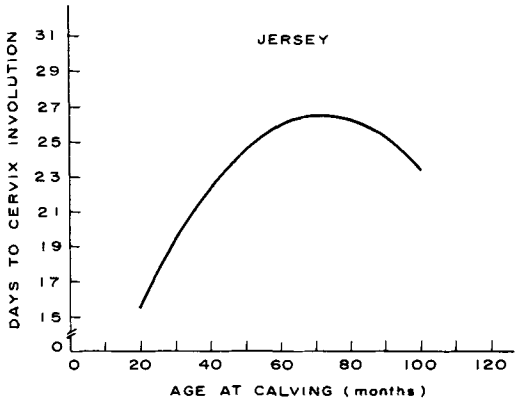

Figure 5. Partial regression of days to involution of the cervix on age at calving for Jersey cows.

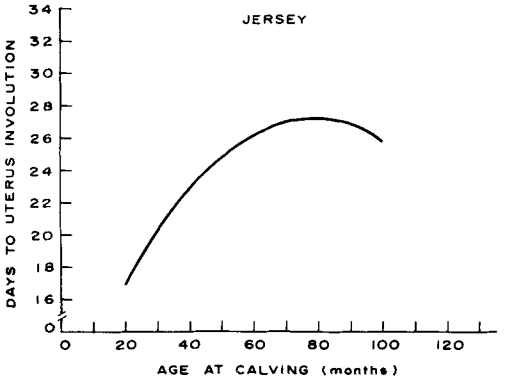

Figure 7. Partial regression of days to involution of the uterus on age at calving for normal Jersey cows.

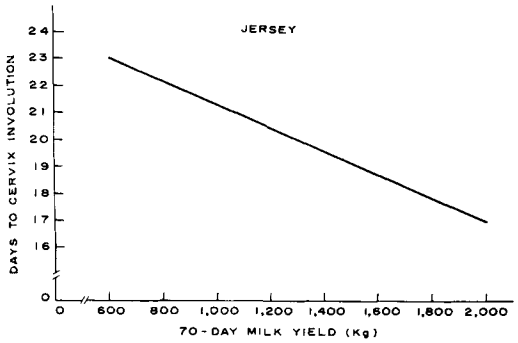

Figure 6. Partial regression of days to involution of the cervix on 70-day milk yield for Jersey cows.

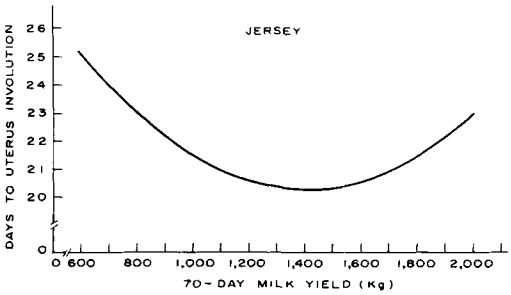

Figure 8. Partial regression of days to involution of the uterus on 70-day milk yield for Jersey cows.

phases or palpable abnormalities of the uterus or ovaries that may have affected duration of estrous cycles, so means in Table 2 represent only cycle lengths of normal cows. Coefficient of variation for duration of first postpartum cycles averaged over breeds was 25.1%, which was over twice the 11.5% for second cycles. Thus, lengths of first postpartum cycles were more variable than of second cycles. Regression models for duration of first and second postpartum estrous cycles accounted for 14 to 24% of variation of these traits depending on cycle number and breed (Table 4). For both Jerseys and Holsteins, duration of first postpartum estrous cycle tended ($P<.10$) to increase as 70-day milk yield increased. However, this increase was small, .23 to .29 days for each 100 kg increase of milk yield. For Jerseys, first postpartum estrous cycle was .72 ± .27 days longer for each 10-mo increase of age at calving. For Holsteins, duration of first postpartum cycle varied in a cubic fashion according to age at calving; shortest cycles occurred for cows calving at 60 mo of age with longer cycles for older and younger cows. Duration of second postpartum estrous cycle was marginally ($P<.10$) affected by season of calving of Holsteins. For Jerseys, duration of second postpartum estrous cycle was affected ($P<.05$) by age at calving with longest cycles for cows that calved at 50 mo of age and shorter cycles for younger or older cows.

Detection of Estrus

Percentage of Holsteins and Jerseys detected

in estrus at each postpartum cycle are in Table 6. Percentage of Jerseys detected in estrus increased from 47 at first cycle to 68 to 88 for subsequent cycles ($P<.05$). Percentage of Holsteins detected in estrus increased linearly from 12 at first cycle to 77 for cycles 7 to 11 ($P<.05$). Overall, 73 and 43% of the cycles of Jerseys and Holsteins were detected by standing estrus. Rate of detection of estrus did not differ among production groups except for Jerseys where rate of detection for cows in group 2 was higher ($P<.05$) than for cows in group 3. For Holsteins, rate of detection of estrus for cows in group 2 tended to be higher than for the other three groups.

Days from calving to first detected estrus were 66.9 ± 33.9 ($\bar{X}$ ± SD) and 37.2 ± 27.3 for Holsteins and Jerseys (Table 2). The statistical model that best accounted for variation of days to first detected estrus of Holsteins included effects due to clinical abnormalities postpartum and milk yield (CHDEM), and this model accounted for 27.3% of variation of this trait (Table 7). Days to first detected estrus were 17 ± 9.7 days greater for cows that had clinical abnormalities postpartum (Table 5) and were lowest for cows that produced from 0 to 1000 kg below herdmates (Figure 9).

Days to first detected estrus for Jerseys were affected significantly ($P<.001$) by clinical abnormalities postpartum (Tables 5 and 7). Cows with clinical abnormalities after calving had 23.3 ± 5.8 more days to first detected estrus than normal cows. Days to first detected estrus in Jerseys were affected marginally ($P<.2$) by milk yield; higher producers tended to be detected in estrus sooner postpartum than lower producers.

TABLE 6. Percentage of Jerseys and Holsteins detected in estrus preceding each postpartum ovulation.

Cycle number[a]	Breed[b]	Number of cows per cycle	70-day milk yield group[c]				Total
			1	2	3	4	
1	J	116	40	54	29	64	47
	H	96	8	15	11	6	12
2	J	114	72	80	46	73	68
	H	96	29	41	25	29	31
3	J	110	84	88	79	79	83
	H	96	29	56	36	35	40
4	J	95	75	89	86	86	84
	H	82	57	52	48	53	52
5	J	52	93	83	92	67	85
	H	53	50	65	71	75	64
6	J	25	71	100	100	83	88
	H	35	90	55	80	50	71
7–11	J	22	92	57	...	100	82
	H	47	58	89	89	57	77
Average	J	534	73	78	63	75	73
	H	505	40	50	41	38	43

[a]Determined by progesterone in blood samples collected twice weekly.

[b]J = Jersey, H = Holstein.

[c]Mean 70-day yield (kg): Jerseys, 1 = 1491, 2 = 1309, 3 = 1132, 4 = 996; Holsteins, 1 = 2114, 2 = 1890, 3 = 1811, 4 = 1451.

TABLE 7. Degrees of freedom, F's, residual mean squares, and coefficients of determination (R^2) for regression models for intervals to first detected estrus, insemination, and conception, conception rate, and 12-day progesterone.

		Dependent variables									
		Days from parturition to:									
		First detected estrus		First insemination		Conception		Conception rate at first insemination		12-day progesterone	
Independent variables	df	H[a]	J[a]	H	J	H	J	H	J	H	J
Season	3[b]	...	...	...	3.7	...	...	...	2.2	...	2.8
Abnormalities at parturition	1[c]	3.1	...	...	...	...	4.5	...	...	...	...
Abnormalities postpartum	1	...	16.0	4.4	3.5	2.4	4.7	...	...	...	1.3
Age	1	...	...	...	4.8	2.2	3.7	...	...	.9	...
Age^2	1	...	...	...	3.4	2.3	3.6	...	...	1.1	...
Age^3	1	...	...	...	2.6	2.4	3.2	...	...	1.6	...
Milk	1	8.8[f]	2.2[e]	5.5[f]	6.4[d]	3.6[f]	5.0[d]	2.9[d]	...	1.7[e]	...
$Milk^2$	1	13.0	1.9	6.3	...	.1	...	2.8	...	1.3	...
$Milk^3$	1	3.8	...	3.2	...	2.5	...	2.8	...	1.0	...
12-day progesterone	1	...	...	...	...	...	...	11.0	6.1	...	...
Herd	1	...	...	...	...	...	...	...	...	4.5	...
Change in body weight	1	...	...	...	...	...	...	...	...	...	7.6
Residual mean squares	>70	880	658	632	228	1463	698	.22	.19	16.8	20.2
R^2		.273	.154	.177	.167	.127	.164	.167	.096	.209	.156

[a]H = Holstein, J = Jersey.

[b]For 3 df, $P<.10$ for $F\geq 2.2$, $P<.05$ for $F\geq 2.8$, $P<.01$ for $F\geq 4.2$.

[c]For 1 df, $P<.10$ for $F\geq 2.8$, $P<.05$ for $F\geq 4.0$, $P<.01$ for $F\geq 7.1$.

[d]Milk yield expressed as cumulative yield for 70 days postpartum.

[e]Milk yield expressed as 305-day, mature equivalent, fat-corrected.

[f]Milk yield expressed as current deviation from herdmates.

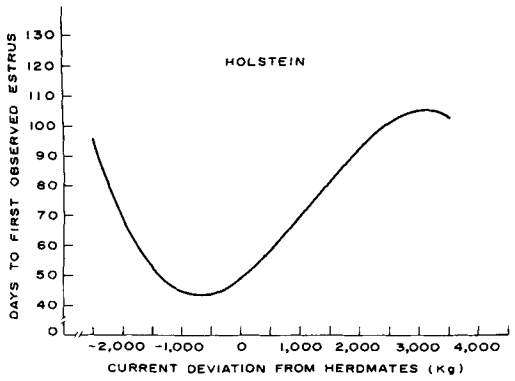

Figure 9. Partial regression of days to first observed estrus on milk yield, expressed as a current deviation from herdmates for Holstein cows.

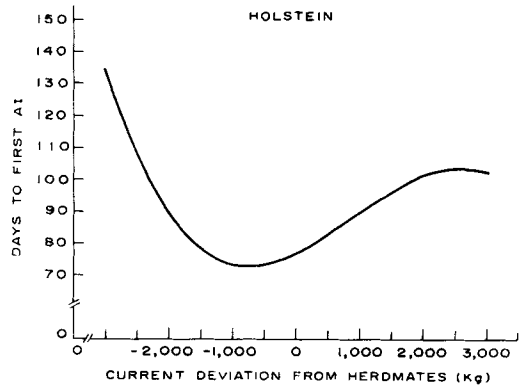

Figure 10. Partial regression of days to first insemination on milk yield, expressed as a current deviation from herdmates for Holstein cows.

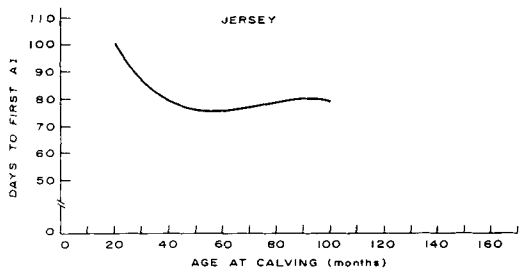

Figure 11. Partial regression of days to first insemination on age at calving for Jersey cows that calved during season 4 (September to November).

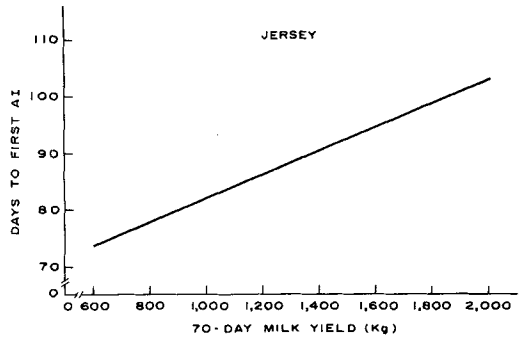

Figure 12. Partial regression of days to first insemination on 70-day milk yield for Jersey cows.

Days from Parturition to Artificial Insemination

Interval from calving to first insemination for Holsteins was described best by the statistical model that included effects due to clinical abnormalities postpartum and milk yield (Table 7). Cows with abnormalities postpartum were first inseminated 14.2 ± 6.8 days later ($P<.05$) postpartum than normal cows (Table 5). Cows whose lactation yields ranged from 0 to 1000 kg below herdmates had the fewest days to first insemination whereas cows that produced lower or higher had progressively longer intervals to first insemination (Figure 10).

Days from calving to first insemination of Jerseys were affected by season of calving, age at calving, clinical abnormalities postpartum, and milk yield (Table 7). Differences of days to first insemination associated with season of calving were less than 10.6 ± 4.5; cows calving during seasons 1 (December to February) and 2 (March to May) had fewer days to first AI than cows calving during seasons 3 (June to August) and 4 (September to November). Cows that had clinical abnormalities postpartum had 7.3 ± 3.9 more ($P<.1$) days to first insemination than normal cows (Table 5). Interval from calving to AI decreased ($P<.1$) as age at calving increased up to about 40 mo of age (Figure 11); thereafter, there was no difference due to age at calving. There was a 2.07 ± .8 day increase of interval to first insemination for each 100 kg of milk produced during the first 70 days of lactation (Figure 12).

Days Open

None of the models used to analyze days open in Holsteins was significant (Table 7), but

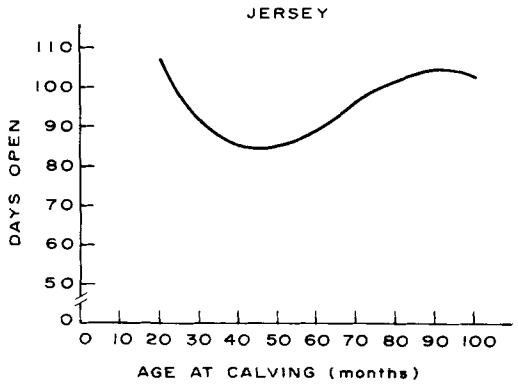

Figure 13. Partial regression of days open (days nonpregnant) on age at calving for Jersey cows.

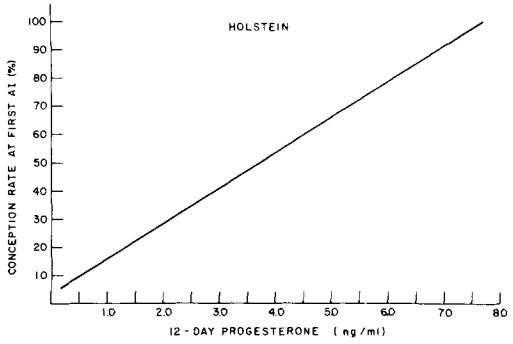

Figure 15. Partial regression of conception rate at first insemination on 12-day progesterone (progesterone during 12 days before first AI) for Holstein cows.

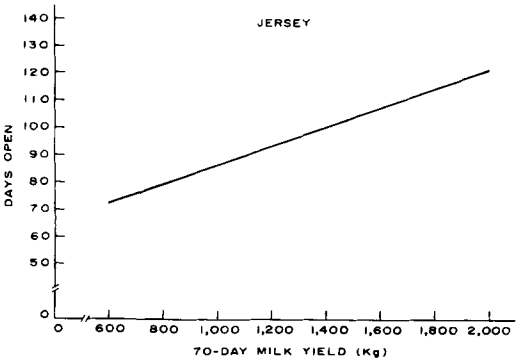

Figure 14. Partial regression of days open on 70-day milk yield for Jersey cows.

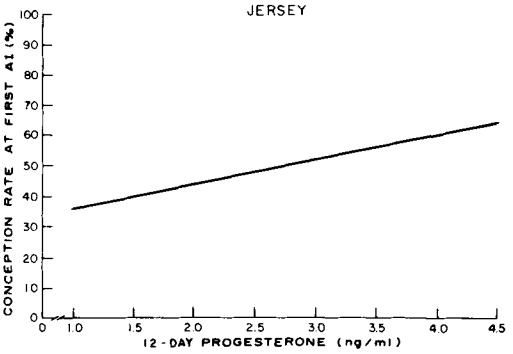

Figure 16. Partial regression of conception rate at first insemination on 12-day progesterone (progesterone during 12 days before first AI) for Jersey cows that calved during season 4 (September to November).

cows with clinical problems after calving averaged 16.6 ± 10.8 more ($P<.2$) days open than normal cows (Table 5). Each 100-kg increase in deviation from herdmates resulted in only a 1.3 ± .7 day increase of days open. Interval from calving to first AI was not included as an independent variable in models examined, because days from calving to first AI and days open were identical for cows that conceived at first insemination.

For Jerseys, days open was affected significantly by clinical abnormalities at parturition and postpartum, age at calving, and milk yield during the first 70 days of lactation (Table 7). Cows that had clinical problems postpartum were open 15.1 ± 7.0 days longer than normal cows, whereas cows that had problems at calving (11 of 18 were milk fever) had 20.2 ± 9.6 fewer days to conception than normal cows (Table 5). There was a nonlinear relationship between days open and age at calving for Jerseys (Figure 13); cows that calved at approximately 40 to 50 mo of age had the fewest days open. Each 100 kg increase in 70-day milk yield resulted in a 3.4 day increase ($P<.05$) of days open for Jerseys (Figure 14).

Conception Rate

Conception rate at first insemination was affected by average concentration of progesterone in blood samples collected during 12 days before first insemination (referred to as 12-day P) in both Holsteins (Table 7, Figure 15) and Jerseys (Table 7, Figure 16). For Holsteins,

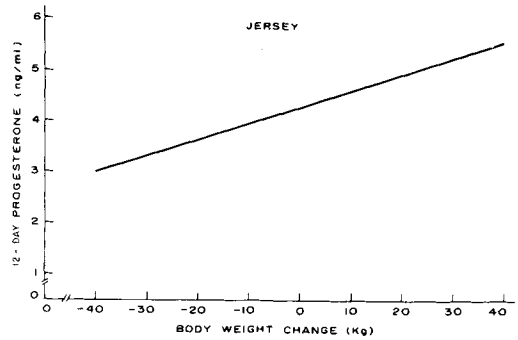

Figure 17. Partial regression of 12-day progesterone (average progesterone during 12 days before first AI) on change in body weight during 4 weeks before first insemination for Jersey cows that calved during season 4 (September to November).

conception rate at first insemination increased by 12.4 ± 3.7% for each ng/ml increase of 12-day P. Milk yield during 70 days postpartum had a marginal ($P<.1$) effect on conception rate of Holsteins. Cows that produced between 1400 and 2600 kg during 70 days postpartum had similar rates of conception. Conception rate increased ($P=.09$) for cows that produced less than 1400 kg and decreased ($P=.09$) for cows that produced more than 2600 kg. For Jerseys, conception rate increased by 7.4 ± 3.0% for each ng/ml increase of 12-day P (Figure 16). Jerseys that calved during December through May (seasons 1 and 2) had higher conception rates at first AI than their herdmates that calved during September through November (season 4).

Conception rates at first and subsequent services are in Table 8. For Holsteins there was a numerical increase ($P>.1$) of conception rate at second and third service followed by a decline at fourth and subsequent service. For Jerseys, conception rate declined with each subsequent service and was significantly lower ($P<.05$) at fourth and subsequent service compared to first service. For Holsteins, four cows were inseminated at their second postpartum cycle, but none conceived. Between third and eighth postpartum cycles of Holsteins, 12 to 46 inseminations were given at each cycle, and there was no significant variation of conception rate associated with cycle number (range of 47 to 61% conception among cycles 3 to 8). For Jerseys, one of two and four of seven cows conceived to inseminations given at their first or second postpartum cycle. Between the third and sixth postpartum cycles in Jerseys, 18 to 56 inseminations were given at each cycle, and there was no significant variation of conception rate associated with cycle number (range of 59 to 72% conception among cycles 3 to 6).

Progesterone

Average progesterone (ng/ml) of blood serum samples collected during 12 days before first AI (12-day P) was not affected by any variables except herds for Holsteins. Cows in one herd had an average 12-day P of .67 ± .03 ng/ml higher ($P<.05$) than cows in the other herd. For Jerseys, progesterone was affected by season of calving and change in body weight (Figure 17). Cows that calved during season 4 (September to November) had higher progesterone than cows that calved during the other three seasons. Progesterone increased by .03 ng/ml for each kg increase in body weight during 28 days before first AI (Figure 17).

TABLE 8. Conception rates at first, second, third, and subsequent inseminations in Holsteins and Jerseys.

Insemination number	Holstein		Jersey	
	No.	% Conceiving	No.	% Conceiving
1	88	49[a]	107	72[a]
2	41	56[a]	31	52[a,b]
3	16	56[a]	12	42[a,b]
≥4	9	33[a]	10	30[c]

[a,b,c]Within a column percentages with unlike superscripts differ ($P<.05$).

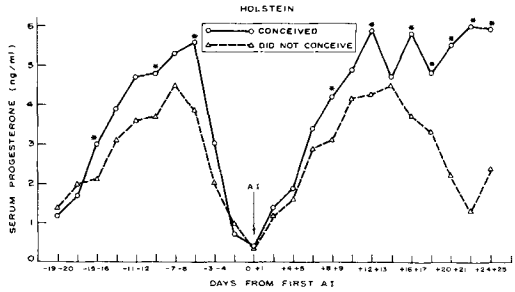

Figure 18. Serum progesterone before and after first insemination for Holstein cows that did or did not conceive. Means with an asterisk differ ($P<.05$).

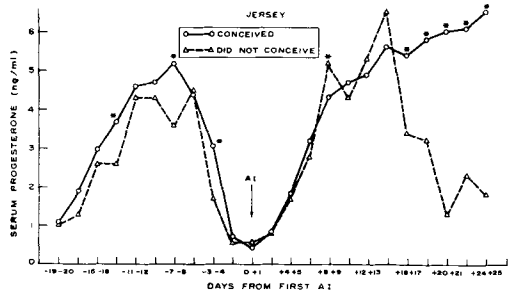

Figure 19. Serum progesterone before and after first insemination for Jersey cows that did or did not conceive. Means with an asterisk differ ($P<.05$).

Thus, cows that were gaining weight during the month before first AI had higher progesterone than cows that were losing weight.

Progesterone profiles for Jerseys and Holsteins from 20 days before first AI unit until 25 days after first AI are depicted in Figures 18 and 19. The mean for cows bled on those days is for any given pair of days. Because cows were bled twice weekly, all cows are not represented in all days. In Holsteins, serum progesterone during diestrus preceding AI and during 7 to 25 days after AI was consistently higher for cows that conceived compared with cows that did not conceive (Figure 18). Means differed significantly for 10 of 23 2-day sampling periods. This difference was not due to difference of postpartum interval to insemination because cows that conceived were inseminated at an average of 86.2 ± 3.2 days postpartum compared with 89.5 ± 4.4 days for cows that failed to conceive.

Progesterone profiles before and after first AI of Jerseys (Figure 19) were similar to those for Holsteins except during days 8 to 15 after AI when there was no difference of progesterone between cows that conceived and those that did not. There was no difference of days to first AI between Jerseys that conceived and those that did not (83.9 ± 1.6 vs. 87.6 ± 3.7 days).

DISCUSSION

Our results provide little support for the concept that early postpartum reproductive traits such as intervals to involution of cervix and uterus and first ovulation and duration of first two postpartum estrous cycles are affected adversely by higher milk yield. Age at calving and clinical abnormalities at parturition or postpartum influenced more traits than any milk yield criterion. Observations were similar in (11, 19, 21, 37).

Ranges of lactation yields among cows were 9174 and 5850 kg for Holsteins and Jerseys. These ranges were broad because cows were not culled for low milk production during early lactation. Consequently, cows expressed their reproductive ability regardless of yield. Studies on relationships between milk yields and reproductive traits, in many cases, have utilized cows in commercial herds (23, 32, 35) where selective culling of low producers may have caused biases of data.

Average age at calving for cows in our study was lower than that reported for commercial herds (11, 32, 35). Fertility declines as age increases, and older cows have higher yields and more clinical abnormalities (11, 21, 37). Thus, some of the discrepancies between our results and those by others may be related to differences of ages of cows. Older cows may be more susceptible to possible effects of higher milk yield on involution of the cervix and uterus and time of first postpartum ovulation. Recovery from clinical abnormalities may require more time for older cows because healing processes are slower.

Days to first ovulation postpartum were similar to (15, 16, 25, 28, 33, 34, 36) but were not greater for higher producing cows (33, 36). In fact, there was a significant negative relationship between days to first ovulation and 305-day milk yield of Jerseys (Figure 2). Holsteins were primarily (95.8%) in first, second, or third

lactation, so we cannot rule out the possibility that older, higher-producing Holsteins might have had longer intervals from calving to first ovulation.

Abnormalities postpartum prolonged interval from calving to first ovulation for both Jerseys and Holsteins. This observation is consistent with (36, 37). Abnormalities at parturition did not affect days to first ovulation. Presumably this means that prompt veterinary attention for cows that have clinical problems at parturition can eliminate most adverse effects of these conditions on subsequent reproductive performance.

Involution of both cervix and uterus occurred earlier for higher producing Holsteins and Jerseys. However, involution of the genital tract occurred later for older cows. These results could mean that, within a given age or parity, rate of genital tract involution reflects overall fitness of the animal, and rapid involution is accompanied by better performance in milk production (20, 29). Involution of the genital tract of Holsteins was slowed by abnormalities postpartum. For Holsteins, the most common abnormality postpartum was uterine infection whereas for Jerseys it was cystic ovaries. This difference may account for abnormalities postpartum not affecting involution of the genital tract of Jerseys.

Duration of first postpartum estrous cycle was about 4 days less than for second cycle. This observation agrees with (33). Milk yield (70-day yield) and age at calving had small effects on duration of first postpartum estrous cycle, but age at calving affected duration of second postpartum estrous cycle of Jerseys. These small effects are probably not of practical consequence. Duration of first and second postpartum cycles ranged from 9 to 28 days and 11 to 26 days, ranges broader than the cycles of 18 to 24 days that generally are accepted as normal. Data from cows with palpable abnormalities of the uterus or cervix or that had prolonged luteal phases were not used in calculating duration of the first postpartum estrous cycle. Thus, ranges in Table 2 represent data from clinically normal cows in these herds. Cycle lengths were based on changes of blood progesterone and may be more accurate estimates of lengths of estrous cycles than measurements based on estrus detection.

Luteal phases of estrous cycles were prolonged (>21 days) for 24 cows. Others made this observation (5). Of the 24 cases, 95% occurred during the first postpartum cycle, and the condition was preceded frequently (14 of 24 cases) by uterine infection. The mechanism whereby the uterus causes luteolysis apparently was affected by the infection. Reasons for prolonged luteal phase in the other cases are unknown. In total, 1039 cycles were monitored for these cows so the overall incidence of prolonged luteal phases was 2.3%.

As with early postpartum traits, age and clinical abnormalities at parturition or postpartum consistently affected more fertility traits such as estrous detection rates, conception rates, and days open than did any measure of milk yield. Clinical problems at parturition prolonged interval to first detected estrus (Holsteins), and clinical abnormalities postpartum prolonged interval to first detected estrus for Jerseys and interval to first insemination and days open for both breeds, although its effect on days open was marginal ($P<.2$) in Holsteins. In contrast, Jerseys that had clinical problems at parturition had fewer days open, probably because the major abnormality was milk fever and afflicted cows received prompt treatment. Others (10, 11, 27, 30, 37) also have observed that clinical abnormalities, especially uterine infections and cystic ovaries, prolong intervals to estrus, insemination, and conception. Cows that had clinical problems at parturition or postpartum received immediate veterinary attention, so effects attributed to these conditions are probably as small as can be achieved practically.

Effects of age on fertility traits were not as great as effects of age on early postpartum traits. Younger Jersey cows were inseminated later (Figure 11) than older cows because breeding policy was to inseminate primiparous cows at first estrus beyond 70 days postpartum compared to first estrus beyond 60 days postpartum for multiparous cows. Days open were greater for Jerseys whose ages were lower or higher than the mean (Figure 13). This was due to the policy of breeding younger cows later postpartum and probably due to lower fertility of older cows (10, 32). Ages of both Holsteins and Jerseys in our study were less than for commercial herds (32, 35) because nearly 60% of cows were primiparous and because multi-

parous cows were seldom kept beyond third parity. Consequently, the large reduction of fertility associated with increasing age in other studies (10, 32) was not observed in our study.

Milk yield affected days to first observed estrus (Holsteins), days to first insemination (Holsteins and Jerseys), and days open (Jerseys). Effects of milk yield on days to first observed estrus and days to first insemination were nonlinear in Holsteins; cows with the shortest intervals produced slightly below average (Figures 9 and 10). This finding was surprising, because percentage of estrous cycles detected by standing estrus did not differ among cows grouped according to milk yield during 70 days postpartum (Table 6).

Our results indicate that fertility traits measured for Holsteins that produced more than 1500 kg below herdmates were similar to those for cows that produced more than 1000 kg above herdmates (Figures 9 and 10). We have no explanation why Holsteins that produced slightly below average were detected in estrus and inseminated sooner than herdmates that had large deviations from herd average. It is possible that some unknown factors not detected in measurements of early postpartum traits accounted for this finding. For example, Holsteins that produced at the lower extremes may have had health problems that caused them to be less fit; but if such problems occurred, they were not detected. Longer intervals to first estrus and inseminations for higher producing Holsteins may have been associated with stresses resulting from higher production, but days open of Holsteins was not affected by milk yield. Thus, we found no evidence that longer open intervals in Holsteins reported by others (2, 32, 35) could be accounted for by any of the physiological traits measured.

Data from Holsteins differed from that reported in field surveys (2, 32, 35) where there were linear increases of days to first estrus, days to first insemination, and days open with increasing milk yield. We conclude that this discrepancy occurred because lowest producing cows in commercial herds are culled before they have the opportunity to express their reproductive potential. Thus, linear relationship between yield and fertility traits in field studies may be an artifact of selective culling of low producing, less fertile cows from populations sampled. A similar conclusion was made by Shanks et al. (30), who studied factors affecting conception in Holsteins in a dairy breeding research herd.

In contrast to results with Holsteins, there were linear increases of days to first insemination and days open of Jerseys associated with increased milk yield during 70 days postpartum. However, these findings contrasted with data on rate of estrous detection of Jerseys (Table 6) where there was no evidence that higher producing cows were detected at lower rates. In Jerseys, days to first insemination increased by 2.07 ± .8 for each 100 kg increase in 70 day milk yield. Days open increased by 3.44 ± 1.53 for a similar increase in yield. Thus, about 60% of the increase of days open associated with increased milk yield was accounted for by interval from calving to first insemination. The antagonism between yield and days to first insemination on days open for Jerseys appears to be smaller than that reported from field surveys with Holsteins (2, 32, 35). Perhaps under controlled experimental conditions where management is good, the adverse effects of yield on days open are minimized.

Conception rate at first insemination was affected by blood progesterone during 12 days before insemination (12-day P) in both breeds (Figures 15 and 16). Others have made this finding on limited observations (9, 12, 13, 26); however, such a relationship was not observed with milk progesterone (6).

Jerseys that calved during seasons 1 and 2 (December to May) had higher conception rates at first insemination than those that calved during season 4 (September to November). The reason for this difference is unknown.

Conception rates at second and third service in Holsteins (Table 8) were numerically but not statistically higher than at first service. Second and third services in Holsteins were given at fourth through eighth cycles postpartum. This corresponds to the period from about 80 to 160 days postpartum when feed intake peaks (7) and cows are in positive energy balance. Thus, the trend toward higher conception rates at second and third insemination might be related to feed intake or energy balance. However, a similar effect was not found in Jerseys.

Progesterone before first insemination in Jerseys increased linearly as weight increased during 28 days before first insemination (Figure 17). This suggests that a positive energy balance

might cause an increase of progesterone in serum. In addition, season of calving affected progesterone secretion. Cows that calved during season 4 had higher progesterone before first insemination (Table 8), but these cows had the lowest conception rates (Table 8). Thus, there was an effect of season on conception rate that was independent of progesterone concentration before first insemination.

Profiles of serum progesterone before and after first insemination for cows that conceived compared to cows that did not conceive indicated some of the differences after conception may be due to differences that were present before conception. Others (18) suggested that higher progesterone during 2 to 3 wk after insemination of cows that conceived were due to luteotropic effects of the embryo. But our data do not support this concept completely. For Jerseys, we found no differences of progesterone after first insemination for cows that conceived compared to those that did not until corpus luteum regression of nonpregnant cows. However, Jerseys that conceived at first insemination had higher progesterone before insemination than those that failed to conceive. In Holsteins, cows that conceived at first insemination had higher progesterone beyond day 8 after insemination than cows that did not conceive. However, these same cows also had higher progesterone before conception. Therefore, we question whether the embryo exerts a profound luteotropic effect (18) during the first 2 wk after conception for all breeds.

CONCLUSIONS

Age at parturition and clinical abnormalities at parturition or postpartum had greater effects on early postpartum reproductive traits than did milk yield of Jerseys and Holsteins. None of the early postpartum reproductive traits were related to milk yield in a manner that would suggest that higher yields adversely affected physiological processes. Involution of the cervix and uterus, interval from calving to first ovulation, and duration of first and second postpartum estrous cycles were nearly identical between Holsteins and Jerseys. Thus, physiological traits that should affect early postpartum reproductive performance were similar between these two breeds.

Fertility traits of Jersey and Holstein cows were affected by clinical abnormalities at parturition or postpartum, age at claving, and milk yield. Clinical problems resulted in longer intervals to first observed estrus, first insemination, and conception. Age at calving had minor effects on fertility traits of Jerseys but not of Holsteins; however, ages at calving for cows in both breeds were younger than ages of cows in most commercial dairy herds. Holsteins that had large absolute deviations from herdmates for milk yield had longer intervals to first detected estrus and insemination but not to conception. Higher producing Jerseys had longer intervals to first insemination and conception, but these effects appeared to be independent of effects of milk yield on physiological traits. Conception rate was affected by concentration of progesterone in blood during 12 days before first insemination for both breeds. Concentrations of progesterone in blood after insemination were higher for Holsteins that conceived compared to those that did not; however, no difference was observed for Jerseys. Overall, these results suggest that clinical abnormalities at parturition or postpartum are more important than age or milk yield for their effects on reproductive performance.

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