Genetic Differences in Health Problems and Calving Difficulty in Dairy Cattle

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Animal breeders have developed methods of sire selection and evaluation that when used by dairymen have produced rather dramatic genetic improvement in milk production. From 1960 to 1975, 25% of the total improvement in Holstein first lactations reported to USDA was due to selection of sires; however, from 1968 to 1975, 86% of all improvement was due to sire selection. Veterinary medicine has also made great advances in treating disorders of domestic animals. Additionally, and perhaps of more importance, veterinarians have been effective in preventative medicine by use of herd health programs and vaccines. Perhaps veterinarians and animal breeders have not been as effective working together to produce productive and healthy animals as they could have been.

Veterinarians involved in herd health programing that integrates all management decisions relating to production are conscious of the genetic inputs. Consequently, recommendations for efficient improvement of traits that can be selected for requires substantial knowledge of animal breeding.

This paper considers two areas of our research. The first is results of an experiment where selection is only for milk production with recording and measurement of all production- and health-related differences. This is done cooperatively with the Iowa State University Department of Veterinary Clinical Science. The second is the results of a research project which developed procedures for ranking sires for calving difficulty. This work has been adopted by the National Association of Animal Breeders and is now being used on a national basis.

Selection Experiment

Foundation cows were purchased as open heifers in 1968. Heifers were purchased from breeders in multiples of two for high and low milk production based on pedigree estimates of their milk producing ability. They were brought to Ankeny, Iowa and one half of the high and low selected heifers were bred to the highest AI sires in the nation selected for only PD milk; the other one half was bred to sires selected to be between 0 and +300 lbs. PD milk. Offspring of high sires are bred to high sires and offspring of average sires bred to average sires, thus any differences that are generated are perpetuated.

The expected versus observed difference in milk production between the high and low groups of pedigree selected heifers was 46 lbs. of milk in the first lactation and 139 lbs. of milk in the second lactation. The prediction of differences between group averages was quite accurate. For generation one data, the progeny of high sires produced 3429 lbs. of milk and 122 lbs. fat, on a mature equivalent basis, more than the progeny of average sires. The difference in actual milk production was 2760 lbs. of milk and 93 lbs. of fat. Percent fat was .03 and % solids-not-fat was .22 lower for the progeny of high sires. This clearly demonstrates that selection for milk was effective. The following discussion considers general reproduction and total health related to these genetic differences for milk production.

General Reproduction

Reproductive data from the selection experiment is given in Tables 1 through 4. These data are from all genetic groups. The averages for reproductive measures and recorded problems are in Table 1. All cows were given reproductive examinations at 30 days postpartum and diagnosed pregnant, as minimum examinations. Any additional problems, such as a retained placenta or failure to show visible heat, result in additional examinations. Cows are not bred until uterine involution is normal and continue to be bred until 308 days postpartum if not pregnant. This results in higher averages in Table 1 than some commercial herds; but, if the ability of the cow is to be measured experimentally all cows must have an equal opportunity to respond, which is chosen as 308 days. All cow culling has been involuntary in these data.

The minimum and maximum values for each trait are shown in Table 1. Most, that are not self-explanatory, are given as percent incidence. Calving assistance was coded as: 1 = no problem and 4 = extreme problem. For ovarian condition at 30 days, 1 = normal activity on at least one ovary, 2 = no significant structures on either ovary and 3 = cystic structure on at least one ovary. Uterine involution was scored 1 = good, 2 = fair and 3 = poor at 30 days. To be coded as an embryonic death a cow was diagnosed pregnant, returned to heat, and the horn in which the pregnancy was diagnosed had to be enlarged. So, these are minimum frequencies for embryonic death. The standard deviation is an indication of the varia-

Table 1

Averages, Standard Deviations, Minimum Value and Maximum Value of the Reproductive Traits*

Trait	Average	Std. Deviation	Min. Value	Max. Value
Conception interval**	146	86	24	308
Conception rate***	87	33	0	100
Deviation milk production****	700	3021	-12293	+8512
Lactation number	1.97	1.07	1	4
Calving assistance	1.85	1.01	1	4
Retained placenta***	9	28	0	100
30-day reproductive treatment***	22	41	0	100
30-day ovarian condition	1.22	0.58	1	3
30-day uterine involution grade	1.23	0.47	1	3
Embryonic death***	4	19	0	100
Cystic follicle***	12	32	0	100
Cystic corpus luteum***	4	20	0	100
Luteal cysts***	2	12	0	100
No significant structure***	14	35	0	100
Hormonal ovarian treatment***	10	30	0	100
Manual ovarian treatment***	2	12	0	100
Systemic uterine treatment***	5	22	0	100
Local uterine treatment***	16	36	0	100
Poor uterine involution grade***	5	22	0	100
Fair uterine involution grade***	26	44	0	100
Reproductive exams	5.27	2.54	2	9
Times bred	2.51	1.68	0	6

*388 observations; **days; ***percent of observations; ****pounds

tion in each trait. For example, for milk production each record is expressed as a difference from herd average and about 67% of the variation would be included by taking the average of 700 lbs. + 3021 = 3721 and 700 - 3021 = -2321 lbs.

Table 2 shows the differences in conception interval, days from calving to successful breeding, and conception rate for each of the traits. The differences for level or occurrence of each trait is statistically adjusted for all other traits. For example, the difference in embryonic mortality is adjusted by least squares (L.S.) for differences in all other traits like parity, calving assistance, etc. The levels within a trait that are significantly different, not likely to occur by chance at the 5% probability level, are indicated by a different letter. For example, conception rate is 42% higher for cows that have good or fair 30-day uterine involution grades than those that had poor grades. Differences between good and fair grades at 30 days did not reflect real differences in conception rate or interval. Those levels that have no letters as superscripts are not significantly different at the 5% level and may be occurring by chance. Parity differences, after adjusting for the other traits, is an example. Cows that had extreme difficulty in calving actually had a 17% higher conception rate than those with no calving problems. This is not generally typical and probably occurred in this herd because more veterinary attention was given to these cows with greater problems. Cows that had a diagnosed embryonic mortality had a 48-day longer conception interval and 26% lower conception rate than cows that did not experience an embryonic death. No significant differences were found for most of the traits such as retained placenta or whether or not a cow had any reproductive treatment at 30 days. Many problems that occurred before 30 days had been treated and responded. Thus, any differences due to these problems were not reflected in higher calving interval or conception rate.

Cows with luteal cysts had a 40-day shorter conception interval and 36% higher conception rate than cows without luteal cysts. This seems contradictory to expectation; however, most cows with cystic follicles were not treated, particularly before 60 days postpartum. Only 6 cows were diagnosed to have luteal cysts and these were promptly and effectively treated. It is also possible that cystic follicles and luteal cysts were not always diagnosed correctly.

Cows with poor uterine involution grades which were found at all times of examination had a 22% lower conception rate. The previous reduction of 42% was when the poor classification was found at 30 days. As is obvious, the more reproductive exams required and more times bred resulted in an increased conception interval, but conception rate was nearly equal for the first through fourth breedings.

Increasing 100 lbs. milk production, deviation about herd average, is associated with a significant ($P < .05$) increase of 0.24% in conception rate and a 0.16 reduction in conception interval. The increased fertility was a result of open infertile cows giving less milk than pregnant cows. Excluding open cows from the analysis, 339 records remained. In cows which conceived during the lactation, a hundredweight in deviation milk production was associated with a significant ($P < .05$) 0.15-day increase in conception interval. For a +5000 lbs. cow this would only amount to about an 8-day increase in conception interval.

Table 3 gives the correlations among the reproductive traits. Those values marked by one or two asterisks are significantly different from zero at the indicated probability level. A correlation of +1.0 indicates perfect positive association between two traits (they vary together perfectly), a -1.0 perfect negative association and 0.0 no association. Study of the correlations marked by asterisks shows the association among traits.

Repeatabilities are given in Table 4. This is the correlation for a given trait from one parturition to the next. Repeatability indicates the accuracy of predicting the occurrence of a trait or problem from one lactation to the next. The correlation between conception intervals from one lactation to the next was 0.203. Milk production is about 50% repeatable, that between parities is just the conception rate of 86.5%. Most of these repeatabilities are about 15-20%, with a few being higher or lower. Generally, most reproductive traits are not highly repeatable. The causes of

Table 2

Frequencies, Least Squares Difference and Standard Errors for Conception Interval and Conception Rate

Trait	Level or Occurrence	No. of Obs.	Conception Interval (days) L.S. Difference from Lowest	S.E.	Conception Rate (%) L.S. Difference from Lowest	S.E.
Parity	first	174	0	17	2	11
	second	102	5	18	0	11
	third	60	11	18	2	11
	fourth or more	52	13	18	0	11
Calving Assistance	none	211	5	17	0 (a[1])	10
	manual	45	5	18	3 (ab)	11
	moderate	112	−2	17	0 (a)	11
	extreme	20	0	20	17 (b)	12
Retained Placenta	no	354	6	16	0	10
	yes	34	0	19	2	12
30-Day Reproductive Treatment	no	304	0	17	0	11
	yes	84	6	18	0	11
30-Day Ovarian Condition	normal	334	16	17	0	11
	nss	22	5	19	1	12
	cystic	32	0	19	8	12
30-Day Uterine Involution Grade	good	308	6 (a)	18	42 (a)	11
	fair	71	0 (a)	19	42 (a)	12
	poor	9	87 (b)	22	0 (b)	13
Embryonic Mortality	no	373	0 (a)	15	26 (a)	10
	yes	15	48 (b)	21	0 (b)	13
Year-Season	summer '68	7	2	24	10	15
	winter '68	8	14	23	10	14
	summer '69	16	50	19	3	12
	winter '69	30	9	19	14	11
	summer '70	22	12	19	5	12
	winter '70	38	25	19	0	12
	summer '71	26	0	18	12	11
	winter '71	37	1	19	7	12
	summer '72	29	16	19	0	12
	winter '72	50	19	18	8	11
	summer '73	37	23	19	3	12
	winter '73	67	22	17	10	10
	summer '74	21	38	20	8	12
Cystic Follicle	no	343	0	17	4	11
	yes	45	4	18	0	11
Cystic Corpus Luteum	no	372	0	16	0	10
	yes	16	18	20	4	12
Luteal Cyst	no	382	40 (a)	16	0 (a)	10
	yes	6	0 (b)	23	36 (b)	14
No Significant Structures	no	334	14	18	0	11
	yes	54	0	18	4	11
Hormonal Ovarian Treatment	no	348	0	18	8	11
	yes	40	4	18	0	11
Manual Ovarian Treatment	no	382	8	16	0	10
	yes	6	0	23	0	14
Systemic Uterine Treatment	no	368	0	16	12	10
	yes	20	14	20	0	12
Local Uterine Treatment	no	327	4	17	0	11
	yes	61	0	18	0	11
Poor Uterine Involution Grade	no	369	0	18	22 (a)	11
	yes	19	16	19	0 (b)	12
Fair Uterine Involution Grade	no	289	8	18	0	11
	yes	99	0	18	6	11

Table 2

Frequencies, Least Squares Difference and Standard Errors for Conception Interval and Conception Rate

Trait	Level or Occurrence	No. of Obs.	Conception Interval (days) L.S. Difference from Lowest	S.E.	Conception Rate (%) L.S. Difference from Lowest	S.E.
Reproductive Examination	2	74	0	20	19 (a)	12
	3	43	11 (ab)	20	15 (ac)	12
	4	56	25 (bc)	19	14 (ac)	12
	5	57	32 (c)	19	20 (a)	11
	6	31	25 (bc)	20	19 (a)	12
	7	29	70 (d)	19	0 (b)	12
	8	12	66 (de)	18	11 (abc)	11
	9 or more	86	91 (e)	16	5 (bc)	10
Times Bred	1	142	0 (b)	17	35 (c)	11
	2	81	18 (c)	18	35 (c)	11
	3	69	53 (a)	19	32 (c)	11
	4	26	50 (a)	20	34 (c)	12
	5	25	104 (d)	19	22 (ac)	12
	6 or more	39	138 (e)	18	0 (b)	11
Deviation Milk Production[2]	linear		-0.16	0.08	0.24	0.05

[1]The difference between two levels within a source is significantly different (P<0.05) if the levels do not have at least one letter in common.

[2]Units of regression are days per 100 lbs. and % per 100 lbs.

these repeatabilities are both genetic and managemental.

Health Differences Related to Genetic Groups

The averages and standard errors of the averages are given in Table 5 for the zero generation or foundation cows selected by pedigree. If an average for a trait is greater than two times its standard error, it can be considered significantly different from zero. Also, the standard error gives an idea of the variation expected in the mean values, as described earlier for milk. The only significant difference between high and low pedigree selected cows is in milk production, for which selection was practiced. Small differences exist, but they are not consistantly associated with high or low pedigree groups.

Table 6 gives comparable data for daughters of high and average sires. Milk produced is significantly different between groups, as expected. Daughters of high sires had no systemic treatment for uterine problems, while 8% of the daughters of average bulls did have. This was a significant difference between sire groups, but only one such difference existed from 42 tests of significance in Tables 1 and 2. Certainly there is no evidence to support greater reproductive problem in daughters of high sires than average sires. The same is true in the foundation cows.

Table 7 gives incidences of digestive, respiratory and skin or skeletal disorders by genetic groups. Zero generation cows were those selected by pedigree. All health disorders reported are those induced by the cow and as likely to occur in one group as another, as opposed to those purposely induced by management such as treatment for parasites or sprayed for lice. Group differences were tested with chi-square. No single digestive disorder had a significantly different incidence in either the zero or non-zero generation; however, the high pedigree group had 15 more total cases (9%) of digestive disorders than the low pedigree group.

There was no real difference in the incidences of respiratory disorders between the pedigree or between the sire groups. The incidence of respiratory disorders in the sire groups was higher than in the pedigree groups because the daughters of high and average sires were observed since birth compared with only observations following the purchase of open heifers for the pedigree groups. Observations were defined as time periods in the animal's life to give an indication of the opportunity for genetic groups to have disorders. This was used in the chi-square statistic. One observation period was from birth or purchase to first parturition. Additional periods were between consecutive parturitions.

Classified under skin and skeletal disorders, the high pedigree group had 7 more cases (5%) of foot rot than the low pedigree group. The high pedigree group had 19 more total cases (14%) of skin or skeletal disorders than the low pedigree group. The high sire group had more joint or leg injuries and less mammary cuts, but 29 more total cases (13%) of skin and skeletal disorders than the average sire group.

Mammary disorders are summarized in Table 8. The high pedigree group had more udder edema, especially above the rear udder, and they received more edema treatment than the low pedigree group. The high sire group had 19% more udder edema and received more treatment for this edema than the low sire group. The high pedigree group had more months of production affected by mastitis than the low pedigree group. The incidence of mastitis was not significantly different between the high and average

Table 3: Residual Correlations, Holding Year-Season Constant, Among the Reproductive Traits†

Trait	(2)	(3)	(4)	(5)	(6)	(7)	(8)	(9)	(10)	(11)
(1) Conception interval	-0.72**	-0.04	-0.03	0.08	0.18**	0.08	0.22**	0.34**	0.27**	0.13*
(2) Conception rate		0.22**	0.02	-0.06	-0.17**	-0.06	-0.25**	-0.26**	-0.15**	-0.02
(3) Deviation milk production			-0.06	-0.03	-0.12*	-0.08	-0.15**	0.05	0.14**	0.07
(4) Calving assistance				0.09	-0.02	-0.07	0.02	-0.10	-0.06	0.04
(5) Retained placenta					0.00	-0.05	0.09	0.03	0.04	0.01
(6) 30-day reproductive treatment						0.02	0.60**	-0.05	0.08	-0.03
(7) 30-day ovarian condition							0.14**	-0.02	0.25**	0.08
(8) 30-day uterine involution grade								-0.04	0.06	0.01
(9) Embryonic mortality									0.06	-0.04
(10) Cystic follicles										0.17**

†388 lactations -13 year-seasons. *P<0.05. **P<0.01.

Source	(12)	(13)	(14)	(15)	(16)	(17)	(18)	(19)	(20)	(21)	(22)
(1)	0.02	0.04	0.25**	-0.06	0.24**	0.06	0.22**	0.05	0.69**	0.70**	0.15**
(2)	0.05	-0.03	-0.17**	0.05	-0.28**	-0.08	-0.30**	-0.01	-0.38**	-0.32**	-0.15**
(3)	-0.01	-0.10	0.09	0.09	-0.05	-0.14**	-0.14**	-0.07	0.02	0.12*	-0.12*
(4)	-0.01	0.05	-0.02	-0.02	-0.00	0.07	0.05	0.01	-0.02	-0.03	-0.25**
(5)	0.06	0.31**	-0.01	-0.02	0.03	0.11*	0.10	0.28**	0.23**	0.04	0.02
(6)	0.08	-0.00	0.06	-0.02	0.16**	0.09	0.32**	0.30**	0.21**	0.03	0.08
(7)	0.03	-0.03	0.17**	0.11*	0.03	0.10	0.08	-0.02	0.12*	0.04	0.05
(8)	0.10	0.06	0.03	0.06	0.24**	0.25**	0.39**	0.41**	0.28**	-0.06	0.17**
(9)	-0.03	0.03	0.02	-0.03	0.01	-0.06	-0.05	0.06	0.23**	0.28**	0.11*
(10)	0.13*	-0.04	0.30**	0.20**	0.02	0.13*	0.13*	0.10	0.38**	0.21**	0.03
††(11) Cystic	-0.01	0.07	0.22**	0.10	-0.03	0.08	0.02	-0.06	0.17**	0.07	-0.02
(12) Luteal cyst		0.14**	0.16**	0.29**	-0.07	0.11*	0.24**	0.09	0.12*	0.05	0.08
(13) No signif. structures			-0.00	0.08	0.12*	0.25**	0.26**	0.37**	0.26**	-0.03	0.09
(14) Hormonal ovarian treatment				0.16**	0.05	0.09	0.07	0.06	0.28**	0.23**	0.01
(15) Manual ovarian treatment					-0.05	0.07	0.04	0.09	0.08	-0.12*	-0.04
(16) Systemic uterine treatment						0.16**	0.31**	0.11*	0.23**	0.04	0.06
(17) Local uterine treatment							0.23**	0.36**	0.22**	-0.09	0.04
(18) Poor uterine involution grade								0.18**	0.23**	-0.06	0.14**
(19) Fair uterine involution grade									0.30**	-0.04	0.10*
(20) Reproductive examinations										0.49**	0.11*
(21) Times bred											0.04
(22) Parity‡											

‡All correlations involving parity are simple correlations.
††Cystic corpus luteum
*P<0.05. **P<0.01.

sire groups. Incidence of mastitis was generally low. Cows in the zero generation are older and have had more time to be affected by digestive and mammary disorders than cowsin the non-zero generations.

Economic Analysis of Ankeny Results

Each of the dollar values in Table 9 is a function of incidence level and severity of the disorders. The cost of a specific disorder was the same for pedigree or sire groups. All income and cost values were for an entire lactation, including the dry period, and were adjusted for the year of parturition. The economic results for the group effects are given in Table 9.

The high pedigree group had $59.26 more income over feed cost than the low pedigree group. The high pedigree group incurred more health costs of $1.83 for skin or skeletal disorders, $2.01 for mammary disorders and $5.03 for milk that was discarded, than the low pedigree group incurred. The high sire group had $88.10 more income over feed costs than the average sire group. The high sire group had more reproductive costs than the average sire group because semen of high bulls was more expensive. The reproductive costs adjusted for years was $9.79. Daughters of high sires used 2.48 ampules of semen at $6.25 per ampule for a semen cost of $15.50 per lactation. Daughters of average sires used 2.67 ampules of semen at $1.75 per ampule for a semen cost of $4.67 per lactation. The difference in semen cost of $10.83 is one dollar more than the adjusted reproductive cost.

The sum of the adjusted health costs in Table 10 was the sum of the reproductive, digestive, respiratory, skin or skeletal, mammary and milk-discarded costs with each adjusted for the year of parturition. Each cost was adjusted to minimize the effect of a price change in any one trait. The net value in Table 10 was the difference between adjusted income over feed costs and the sum of the adjusted health costs. The high pedigree group incurred $12.46 more health costs and netted $45.80 more per lactation than the low pedigree group. Daughters of high sires incurred $9.69 more health costs, primarily semen cost, and netted $77.64 more per lactation than the daughters of breed average sires.

Table 4

Repeatabilities and Standard Errors of the Reproductive Traits

Trait	Repeat-ability	Standard Error*
Conception interval	0.203	0.067
Conception rate	0.268	0.066
Deviation milk production	0.527	0.052
Parity	0.865	0.018
Calving assistance	0.184	0.068
Retained placenta	-0.046	0.068
30-day reproductive treatment	0.194	0.068
30-day ovarian condition	-0.039	0.068
30-day uterine involution grade	0.204	0.067
Embryonic mortality	0.010	0.069
Cystic follicles	0.197	0.068
Cystic corpus luteum	0.138	0.069
Luteal cyst	0.062	0.069
No significant structures	0.170	0.068
Hormonal ovarian treatment	0.091	0.069
Manual ovarian treatment	0.359	0.062
Systemic uterine treatment	0.417	0.059
Local uterine treatment	0.018	0.069
Poor uterine involution grade	0.200	0.067
Fair uterine involution grade	-0.068	0.068
Reproductive examinations	0.214	0.067
Times bred	0.108	0.069

*Approximate formula from Swiger, et al.

Table 5

Averages and Standard Errors of the Averages for Reproductive Traits by Genetic Pedigree Groups

	Zero Generation Pedigree Groups			
	High		Low	
Trait	Average	Std. Error	Average	Std. Error
Conception interval*	146	8.57	141	7.46
Conception rate**	85	3.41	87	2.95
Deviation milk prod.***	125	29.03	-8†	25.17
Parity	2.25	0.106	2.37	0.099
Calving assistance	1.92	0.098	1.88	0.091
Retained placenta	1.08	0.026	1.10	0.026
30-day repro. treatment	0.21	0.038	0.26	0.038
30-day ovarian condition	1.15	0.048	1.26	0.057
30-day uterine involution grade	1.21	0.040	1.29	0.044
Embryonic death	0.06	0.022	0.03	0.015
Cystic follicle	0.14	0.033	0.10	0.026
Cystic corpus luteum	0.06	0.023	0.03	0.015
Luteal cysts	0.01	0.009	0.02	0.011
No significant structure	0.14	0.033	0.13	0.029
Hormonal ovarian treatment	0.10	0.028	0.11	0.028
Manual ovarian treatment	0	0	0.01	0.008
Systemic uterine treatment	0.06	0.023	0.05	0.018
Local uterine treatment	0.17	0.036	0.20	0.035
Poor uterine involution grade	0.05	0.021	0.05	0.018
Fair uterine involution grade	0.23	0.040	0.30	0.040
Reproductive exams	5.52	0.257	5.17	0.220
Times bred	2.55	0.160	2.36	0.143
Observations	112		131	

*days; **percent; ***ten pound units, difference from herdmates; †difference significant ($P<0.05$), between high and low groups.

Sire Evaluation For Calving Difficulty

Research was started in 1972 to determine whether there were genetic differences between Holstein sires in the level of birth difficulty of their calves. This work was done cooperatively with Midwest Breeders Coop. and later with Select Sires, Inc. Results of this research have been adopted by the National Association of Animal Breeders, and dairy bulls in all studs in the U. S. are currently being evaluated for dystocia. Dr. Jeff Berger programed the analysis that is being run by Bliss Crandall's DHI Computer Service at Provo, Utah. The first ranking of sires was completed last summer and is currently published for individual sires by the AI stud who owns the sire.

The basic data originated from dairymen who scored the difficulty of birth, with 1 as no problem up to 5 representing extreme difficulty. Calf size was also subjectively scored from 1 = very small to 5 = very large. Cow size was scored but proved to be of little value. In addition fresh date, breeding date, sire-of-calf, sire-of-dam, breed-of-dam, and sex-of-calf were recorded. Currently, calf condition at birth and calf liveability are recorded.

First-calf heifers have significantly more dystocia than older cows. There is little difference between the level of dystocia in second and later calvings, though the level is slightly greater in third and later calvings. Larger calves were born with more difficulty. The dystocia scores by calf size were: very small, 1.10; small, 1.17; average, 1.27; large, 1.70; very large, 2.54. The latter two scores are significantly different from the first three.

Sex-of-calf has a large effect on birth difficulty. Table 11 shows the average calving difficulty scores for male and female calves by age-of-dam. The Table shows that the difference in birth difficulty between males and females is .48 units when they are out of first-calf heifers. The total range in the scale is 5 units, so this is nearly 10% of the total range in scoring. Males are born with more difficulty than females from cows of all ages; however, the difference in difficulty between male and female births diminishes as age-of-dam increases.

Table 12 shows that calf size increased as age-of-dam increases, and that males are larger than females from all ages of dam, as expected. The differences between the size of male and female calves is nearly constant across ages-of-dam.

Table 13 shows the relation of gestation length to dystocia and calf size scores. Maximum difference in dystocia scores are associated with average differences of only 2.3 days gestation length, while maximum difference in calf size scores are associated with 8.4 days in gestation length. In both cases, longer gestation length was associated with higher dystocia and calf size scores. The phenotypic correlation (due to both genetic and environmental causes) between gestation length and difficulty was 0.10 and between gestation length and calf size was 0.29.

Calves born in the winter, October through March, had more difficulty during birth than those born in

Table 6

Averages and Standard Errors of the Averages for Reproductive Traits by Genetic Sire Groups

	Nonzero Generation Sire Groups			
	High		Average	
Source	Average	Std. Error	Average	Std. Error
Conception interval*	142	10.34	157	13.27
Conception rate**	93	3.60	85	5.15
Deviation milk prod.***	193	39.18	-74†	48.40
Parity	1.54	0.098	1.44	0.094
Calving assistance	1.76	0.129	1.60	0.142
Retained placenta	1.07	0.036	1.10	0.045
30-day repro. treatment	0.20	0.055	0.19	0.057
30-day ovarian condition	1.31	0.091	1.27	0.083
30-day uterine involution grade	1.13	0.053	1.31	0.085
Embryonic death	0	0	0.06	0.035
Cystic follicle	0.13	0.046	0.08	0.040
Cystic corpus luteum	0.04	0.026	0.02	0.021
Luteal cysts	0.04	0.026	0.02	0.021
No significant structure	0.09	0.040	0.23	0.061
Hormonal ovarian treatment	0.11	0.043	0.04	0.029
Manual ovarian treatment	0.06	0.031	0.02	0.021
Systemic uterine treatment	0	0	0.08†	0.040
Local uterine treatment	0.07	0.036	0.17	0.054
Poor uterine involution grade	0.04	0.026	0.08	0.040
Fair uterine involution grade	0.22	0.057	0.29	0.066
Reproductive exams	5.00	0.300	5.35	0.380
Times bred	2.48	0.221	2.67	0.265
Observations	54		48	

*days; **percent; ***ten pound units, difference in herdmates; †difference significant (P<0.05), between high and average groups.

the summer, April through September, Causality of this cannot be determined from these data. Possible reasons are lack of exercise in the winter. The other is that dairymen are closer to their cows in winter and tend to help them more, thus scoring the difficulty of birth a little higher.

Heritability estimates are given in Table 14 for calving difficulty by age-of-dam, calf size and gestation length. Heritability is the fraction of an animal's superiority or inferiority that it will transmit to its offspring. Stated differently, heritability is also the proportion of the total variation in a trait that is under genetic control. Heritability of calving difficulty is about 8% across all ages-of-dam, 17% for first-calf heifers, 8% for second calvers and 5% in third and older calving cows. Heritability of calf size was estimated at 18% from these data. Most studies show heritability estimates for calf birth weight as 0.4 to 0.5. Since these were estimates of size by dairymen, it is not surprising that this heritability is lower than if actual weights had of been available. Gestation length is rather highly heritable, estimated at 0.37 here, and about this same value in other studies. This indicates gestation length could be changed by selection, but if this were done other complications could develop.

Table 7

Number of Observations for Digestive, Respiratory and Skin or Skeletal Disorders by Genetic Groups

	Generation			
	Zero Pedigree		Nonzero Sire	
Source	High	Low	High	Average
Digestive Disorders				
High fever	1	0	0	0
Given magnet	3	2	0	0
Blood analysis	1	0	1	1
Kidney infection	1	1	0	0
Abdominal abscess	0	2	0	0
Ketosis	1	1	0	0
Milk fever	5	2	0	0
Hardware	1	1	1	0
Displaced abomasum	6	3	1	2
Off feed	7	4	2	1
Bloat	1	0	0	0
Diarrhea, scours	0	0	7	2
Surgery	1	1	0	0
Examinations	7	3	2	1
Total	35	20*	14	7
Respiratory Disorders				
Pneumonia	0	0	2	1
IBR	0	1	4	2
Examinations	0	2	6	6
Total	0	3	12	9
Skin or Skeleton Disorders				
Foot rot	15	8*	9	5
Joint or leg injury	2	3	9	2*
Foot trimming	46	42	31	23
Subtotal feet problems	63	53*	49	30
Ringworm	4	3	2	0
Extra teats	6	5	11	4
Warts	1	0	0	0
Pinkeye	3	3	10	5
Obturator paralysis	1	0	0	2
Peroneal paralysis	1	0	0	0
Body bruises	1	0	0	0
Hernia	1	0	1	0
Mammary cuts	3	1	0	3*
Total	84	65*	73	44*
Max. No. of Observations	171	187	136	107*

*P<0.10

Table 8

Number of Observations for Mammary Disorders by Genetic Groups

		Generation			
		Zero Pedigree		Nonzero Sire	
Source	Level	High	Low	High	Average
Udder edema	normal	69	97	29	34
	abnormal	54	47*	28	15*
Edema treatment	no	113	140	48	48
	yes	13	5*	10	1*
Months of mastitis					
no cases		1181	1279	970	877
1 or more cases		75	56*	15	12

*Difference significant (P<0.10), fewer abnormal than expected.

Table 9

Least Squares Estimates and Standard Errors of Genetic Differences for Income and Costs Parameters

Traits	Zero Generation Pedigree Group High - Low	Nonzero Generation Sire Group High - Average
Income over feed costs	\$59.26 ± 25.69*	\$88.10 ± 39.89*
Costs		
Reproductive	\$2.08 ± 2.27	\$9.79 ± 2.74***
Digestive	1.71 ± 1.31	-1.94 ± 1.95
Respiratory	0	0.48 ± 0.55
Skin or skeletal	1.83 ± 1.02†	0.82 ± 1.01
Mammary	2.01 ± 1.10†	-1.22 ± 1.29
Milk discarded	5.03 ± 1.47***	1.83 ± 1.79

†P<0.10; *P<0.05; ***P<0.001.

Table 10

Least Squares Estimates and Standard Errors of Genetic Differences for the Sum of the Adjusted Health Costs and Net Value

Traits	Zero Generation Pedigree Group High - Low	Nonzero Generation Sire Group High - Average
Sum of adjusted costs	\$12.46 ± 3.59***	\$ 9.69 ± 4.82*
Net value	45.80 ± 25.07†	77.64 ± 38.79*

†P<0.10; *P<0.05; ***P<0.001.

Table 11

Sex Differences Within Age Groups

Age	Calving Difficulty Male	Female	M-F
1	2.202	1.720	.482
2	1.607	1.258	.349
≥3	1.422	1.264	.158
All	1.678	1.385	.293

Table 12

Sex Differences Within Age Groups

Age	Calf Size Male	Female	M-F
1	3.233	2.855	.348
2	3.459	3.101	.358
≥3	3.562	3.249	.313
All	3.451	3.123	.328

Table 13

Dystocia and Calf Size Scores vs. Gestation Length

Dystocia	Gestation Length	Calf Size	Gestation Length
1	279.4	1	274.4
2	279.8	2	277.1
3	280.4	3	279.2
4	281.4	4	281.1
5	281.7	5	282.8

Table 14

Heritability Estimates

Calving difficulty (all ages)	.08 ± .02
Calving difficulty, 1st calf	.17 ± .05
Calving difficulty, 2nd calf	.08 ± .04
Calving difficulty, ≥3rd calf	.05 ± .02
Calf size	.18 ± .04
Gestation length	.37 ± .08

After characterizing the data to find the major classifiable variables affecting calving difficulty, an analysis was developed to rank AI sires on the ease with which their calves are born. The sire ranking procedure adjusts for the extraneous nongenetic effects that could cause biases in sire evaluation. The extraneous effects are: (1) herd in which the calf is born which also adjusts for scoring differences between herds, (2) age-of-dam effects. (3) sex-of-calf, and (4) season of birth. For the bulls being evaluated on the birth of their progeny, when their sires or maternal grandsires had other sons with progeny, the latter data was brought into the analysis as pedigree information. The sire evaluation procedure then gives a transmitting ability estimate, and a measure of accuracy of this transmitting ability estimate, for each sire. The average transmitting ability of sires can be estimated quite accurately with this procedure. For any trait where the heritability is not 1.0, there will be variation within sire progeny groups. So some calving difficulty can be expected from the bull ranked highest for ease of birth, and some calves will be born easily who are progeny of the sire ranked lowest for ease of birth. However, use of bulls ranked highest for ease of calving will minimize calving problems. Like other selection aids, using them just increases the probability of making a correct choice.

One potential problem exists. Will heifers that are born easily have difficulty giving birth? Heritability of dystocia as a trait of the dam was estimated as 0.11. The rank correlation between sire of calf and sire of dam was 0.16, and not significantly different from zero. The conclusion to date is that there is little genetic relation between the ease with which a heifer is born and the ease with which she later can give birth. We are continuing the investigation.

The recommendations from this work are:

1. Select bulls for production
2. Evaluate them for dystocia
3. Mate heifers to bulls whose offspring are born with the least difficulty.

Following these recommendations should allow dairymen to continue selection for production and soundness which will generate maximum income. He can also minimize dystocia by mating open heifers to bulls ranked highest for calving ease. In older cows, incidence of dystocia is much less. Following these recommendations should reduce dystocia without reducing selection for traits of greater economic importance.