January 1971

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Abstract

Information on the presence or absence of bacterial infections and abnormal secretions in each quarter of cows in their initial survey on the New York State Veterinary College Mastitis Program was used to obtain several criteria of udder infection. Year-season and stage of lactation effects were statistically significant for several criteria of infection in first, second, and later lactation groups but did not explain much of the variation in any infection criterion. Age within first and second lactation group also accounted for little of the variation in infection although age within later lactations accounted for up to 5% of the variation in some criteria.

Heritabilities from sire components of variance were all low for first, second, and later lactation cows. Heritabilities from daughter-dam regression were low for first and second lactation cows but moderately high for later lactation cows. Regression of second lactation infections on first lactation infections, later lactation infections on first lactation infections, and later lactation infections on second lactation infections were moderately high. Heritabilities from sire components of variance were not increased by using two surveys per cow, by using only herds with high incidence of infections, or by using only sires with large numbers of daughters. Phenotypic relationships between milk yield and infections were all low. Some of the overall measurements of infection on later lactation cows had genetic correlations of approximately .3 with first lactation milk production.

Introduction

The continuing problem of economic losses in the dairy industry due to udder infections dictates that all methods of reducing infections be examined. The possibility of selection to reduce infection rates has been raised by indications of genetic resistance to udder infections (1, 6, 8, 12). Other work, however, has found either no genetic resistance (10) or varying estimates depending on the criterion of infection (11). Precision in estimation of genetic parameters, as well as in control programs and control and production studies, can be increased by information on the influence of various environmental factors on udder infections.

The purpose of this paper is to provide further information on the effects of year-season, stage of lactation, and age on udder infections and on genetic resistance to udder infections as measured by several different criteria in three lactation groups of cattle.

Materials and Methods

Data on udder infections were from the New York State Veterinary College Mastitis Program from January 1, 1959 to December 31, 1965 for 638 herds. Information on the presence or absence of *Streptococcus agalactiae*, other streptococci and hemolytic *Staphylococcus* as well as other bacterial organisms and on the presence or absence of abnormal secretions were obtained for each quarter of each cow in the herds on the program. An overall clinical rating was assigned if there was any evidence of abnormal secretions from any quarter or of unusual hardness or swelling of the udder.

Varying numbers of surveys were made in each herd. Data on the first survey in a cow's lactation were used, except where noted otherwise, to avoid the complication of treatment effects following the initial survey. Infection was measured by percentage of cows with a clinical rating or with some kind of infection, by number of quarters per cow with abnormal secretion or with some kind of infection, by number of kinds of infection per cow, and by number of infections of all kinds per cow.

Milk yield and pedigree information were from the Cornell University Dairy Records Processing Laboratory. The three lactation groups were cows calving at less than 36

Received for publication January 26, 1971.

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Financial assistance Eastern Artificial Insemination Cooperative, Ithaca, New York, for key punch support is gratefully acknowledged.

TABLE 1. Extent of udder infection in initial survey for three age groups.

	Age groups					
	<36 Months		36–47 Months		>47 Months	
Number of cows	12,392		10,697		25,469	
Criteria of udder infections	Mean	SD[a]	Mean	SD	Mean	SD
Per cent with clinical infection	2.6	16.2	5.8	23.3	12.9	33.1
Per cent of cows with at least one quarter						
Clinical	2.0	13.9	4.1	19.8	8.7	27.9
With *S. agalactiae*	2.6	15.8	4.8	22.8	11.2	31.3
With other streptococci	19.0	39.0	25.1	43.1	37.4	47.7
With hemolytic *Staphylococcus*	8.9	28.3	17.0	37.4	29.2	45.1
With *S. agalactiae,* other streptococci or hemolytic *Staphylococcus*	27.6	44.5	41.0	48.9	61.4	47.5
Number of quarters per cow						
Clinical	.02	.16	.05	.24	.10	.35
With *S. agalactiae*	.04	.29	.10	.46	.22	.70
With other streptococci	.27	.63	.36	.72	.60	.92
With hemolytic *Staphylococcus*	.11	.41	.25	.62	.46	.83
With *S. agalactiae,* other streptococci or hemolytic *Staphylococcus*	.41	.78	.68	.99	1.20	1.20
Number of kinds of infections per cow	.32	.55	.51	.66	.83	.75
Number of infections of all kinds per cow	.44	.85	.74	1.09	1.34	1.37

[a] Within year-season, stage of lactation and age standard deviation.

months of age, cows calving at 36 to 47 months of age or at younger ages but having had a previous lactation, and cows calving at greater than 47 months of age or at younger ages but having had two previous lactations. Records were classified as to the year-season, stage of lactation, and age at which the survey was made as follows:

Year-season: January-March, April-June, July-September, and October-December of each of the 7 years involved.

Stage of lactation: 30-day periods up to 270 days and a 35-day period from 270 to 305 days.

Age within lactation: 2-month periods from 24 to 46 months with younger cows included in the first group for first lactation cows; 2-month periods from 36 to 58 months with younger cows included in the first group for second lactation cows; yearly periods from 4 to 13 years with younger cows included in the first group and older cows in the final group for later lactation cows. Age within lactation depended on age at calving and time from calving to survey.

Effects of year-season, stage of lactation, and age within lactation group were determined by least-squares procedures with all factors assumed fixed and all interactions between factors to be zero. The importance of the effects was measured by the differences in reduction of sum of squares for fitting full and reduced models.

Heritabilities were estimated from sire components of variance and from daughter-dam regressions. Components of variance for sire, herd, sire × herd, and error were estimated by Henderson's Method I. Heritabilities from daughter-dam regressions included only the oldest daughter when information was available on more than one daughter. Heritabilities were also estimated by sire components of variance of measurements based on two surveys per cow, from data including only sires with over 40 daughters each, and on first

TABLE 2. Per cent reduction in sums of squares due to year-season, stage of lactation and age.

Criteria of udder infection	Cows under 36 months of age			Cows 36 to 47 months of age			Cows over 47 months of age		
	Year-season	Stage of lactation	Age	Year-season	Stage of lactation	Age	Year-season	Stage of lactation	Age
Per cent of cows clinical	.3	.1	.1*	.5*	.2*	.3*	.4*	.2*	1.4*
Per cent of cows with at least one quarter									
Clinical	.3	.1	.1*	.6*	.2*	.1	.6*	.2*	.6*
With *S. agalactiae*	.6*	.1*	.2*	.5*	.1	.2*	.6*	.1*	.7*
With other streptococci	1.1*	.1*	.1	1.2*	.1	.1	.5*	.1*	2.1*
With hemolytic *Staphylococcus*	.5*	.2*	.2*	.5*	.2*	.2*	.3*	.0	1.3*
With *S. agalactiae*, other streptococci or hemolytic *Staphylococcus*	1.0*	.1	.1	.7*	.2	.3*	.5*	.2*	3.7*
Numbers of quarters per cow									
Clinical	.3	.1	.1	.5*	.2*	.2*	.6	.2*	.6*
With *S. agalactiae*	.6*	.2*	.3*	.5*	.1	.3*	.7	.2*	.9
With other streptococci	1.1*	.1*	.1	1.4*	.1	.1	.7*	.1*	2.7*
With hemolytic *Staphylococcus*	.6*	.2*	.2*	.5*	.3*	.2*	.3*	.1	1.3*
With *S. agalactiae*, other streptococci or hemolytic *Staphylococcus*	1.1*	.1	.1	.9*	.2	.3*	.7*	.3*	5.2*
Number of kinds of infection per cow	1.1*	.1	.1	.9*	.2*	.3*	.6*	.1*	4.3*
Number of infections of all kinds per cow	1.2*	.1	.1	1.0*	.2*	.2*	.8*	.2*	5.5*

* P (< .05).

survey data from herds in which several cows had infections. Numbers of high infection incidence herds were about 25% of the total number of herds for minima of 3 *S. agalactiae,* 12 other streptococci or 9 hemolytic *Staphylococcus* infections.

Relationships between milk yield and infections were measured by phenotypic and genetic correlations within herds. Milk yield was measured by the 305-day yield in the same lactation as the mastitis survey and as the 305-day yield in the lactation preceding the survey. Cows having an infection in any survey in the preceding lactation were excluded from correlations between infection and preceding milk yield. Genetic correlations were from sire components of variance and covariance.

Results and Discussion

The degree of udder infection increased considerably from first to second to later lactation groups for all measures of udder infection (Table 1). Age effects within lactation groups, with stage of lactation and year-season effects eliminated, were negligible in first and second lactation groups but were of some importance in the later lactation group (Table 2). Increases in udder infection with age have been found previously for leukocyte score (14) and California mastitis test scores (3), for bacterial infection (11, 14), and for clinical mastitis (11, 12).

Stage of lactation had little effect on udder infection in any lactation (Table 2) as measured by amount of variation explained although the F ratios were statistically significant for several measurements of infection. There was evidence of decreasing infections from other streptococci and increasing hemolytic *Staphylococcus* infections through the lactation for first lactation cows but increasing infections from other streptococci and constant hemolytic *Staphylococcus* infections for later lactation cows (Table 3). In contrast Schmidt and Van Vleck (11) found negative linear regressions of number of quarters infected on stage of lactation for cows of all ages. Work on leukocyte counts (2, 3) has indicated higher counts in early and late lactation. There may, however, be reasons other than infections for high counts at these times.

Year-season did not have much effect on udder infections in any lactation as measured by amount of variation explained although the F ratios were again statistically significant for several measurements of infection. Work by Afifi (1) indicated higher leukocyte counts in November but attributed these to a higher number of cows in late lactation.

The sire component of variance was a small percentage of total variation, and heritabilities were low for all measurements of udder infection in all lactation groups (Table 4). The somewhat more continuous data on number of quarters infected gave similar results to per-

TABLE 3. Differences between udder infections at various stages of lactation relative to infections in final stage of lactation group as determined by least squares with age within lactation and year-season effects taken into account.

Stage of lactation (days)	Per cent of cows with at least one quarter with:							
	S. agalactiae		Other streptococci		Hemolytic *Staphylococcus*		Any of three infections	
	Months		Months		Months		Months	
	<36	>47	<36	>47	<36	>47	<36	>47
<30	−2.1	−2.5	4.1	−5.6	−5.4	−1.0	−1.6	−7.0
30–59	−1.5	−6.4	3.0	−4.7	−4.6	1.1	−1.5	−3.6
60–89	−1.7	.2	3.7	−3.4	−4.5	.1	−1.1	−1.9
90–119	−1.5	.7	1.8	−4.6	−4.8	.3	−2.9	−3.3
120–149	−2.1	.3	1.8	−2.1	−3.7	.6	−2.3	−2.0
150–179	−2.2	.7	1.0	−4.1	−2.7	1.9	−2.0	−2.5
180–209	− .7	.4	.1	−2.5	−5.1	.4	−4.1	−2.6
210–239	− .5	− .3	−1.8	−4.7	−1.5	−1.8	−2.1	−4.6
240–269	−1.9	1.0	−1.5	−3.5	−2.1	− .1	−3.8	−1.7
270–305	0	0	0	0	0	0	0	0
SE[a]	.5	.8	1.3	1.2	1.0	1.1	1.5	1.2

[a] Standard error of the difference between any two stage of lactation groups.

TABLE 4. Heritabilities from sire components of variance for resistance to udder infections as measured from one survey per cow.

Criteria of udder infections	First Lactation (9,177 records in 620 herds by 379 sires) Variation due to (%):					Second Lactation (7,579 records in 606 herds by 367 sires) Variation due to (%):					Later Lactation (15,292 records in 638 herds by 398 sires) Variation due to (%):				
	Herd	Sire	Herd × sire	Total variation	h^2	Herd	Sire	Herd × sire	Total variation	h^2	Herd	Sire	Herd × sire	Total variation	h^2
Per cent of cows clinical	.6	−.8	.0	265	−.03	4.4	1.3	−2.1	552	.05	3.0	.5	4.7	1114	.02
Per cent of cows with at least one quarter:															
Clinical	.1	−.3	5.3	196	−.01	3.8	.6	4.8	399	.03	3.0	−.1	5.7	792	−.01
With *S. agalactiae*	6.5	−.3	17.4	257	−.01	12.5	.3	5.7	484	.02	19.5	.0	5.2	909	.00
With other streptococci	5.1	.2	2.1	1555	.01	3.8	.3	.8	1921	.01	4.4	1.2	10.3	2358	.05
With hemolytic *Staphylococcus*	3.7	−.3	6.6	815	−.01	8.8	.5	4.3	1403	.02	12.3	.5	10.6	2056	.03
With *S. agalactiae*, other streptococci or hemolytic *Staphylococcus*	.1	.5	4.4	2015	.02	4.7	1.0	1.0	2424	.04	4.9	1.7	11.3	2377	.07
Number of quarters per cow															
Clinical	.0	.4	7.9	.026	.02	3.7	2.5	4.4	.052	.11	3.3	−.1	4.6	.123	−.01
With *S. agalactiae*	6.1	−.9	17.8	.084	−.04	10.2	1.5	7.9	.197	.07	19.9	.0	6.7	.449	.00
With other streptococci	6.0	−.1	4.7	.422	−.01	5.7	.0	1.1	.549	.00	6.1	2.0	11.4	.891	.09
With hemolytic *Staphylococcus*	5.1	−.8	6.8	.168	−.03	10.5	1.1	6.2	.394	.05	14.2	1.0	10.5	.707	.05
With *S. agalactiae*, other streptococci or hemolytic *Staphylococcus*	6.3	.0	7.9	.626	.09	7.3	1.4	1.9	.999	.06	8.3	2.8	13.3	1.528	.12
Number of kinds of infection per cow	5.4	.4	8.6	.309	.02	5.7	.7	−1.1	.436	.03	6.0	1.5	12.2	.586	.07
Number of infections of any kind per cow	6.0	−.1	9.0	.754	−.00	7.3	1.2	.1	1.211	.05	8.2	2.5	13.1	2.006	.11

TABLE 5. Heritabilities from daughter-dam regressions for resistance to udder infections as measured from one survey per cow.

Criteria of udder infections	Lactation: First (605 pairs in 186 herds)	Second (426 pairs in 166 herds)	Later (854 pairs in 289 herds)
Per cent of cows clinical	−.11	−.22	.08
Per cent of cows with at least one quarter			
Clinical	−.03	−.08	.09
With *S. agalactiae*	.13	−.12	.04
With other streptococci	.11	−.13	.08
With hemolytic *Staphylococcus*	−.08	−.20	.23
With *S. agalactiae,* other streptococci or hemolytic *Staphyloccus*	.02	−.24	.22
Per cent of quarters per cow			
Clinical	−.03	−.17	.08
With *S. agalactiae*	.15	−.18	.07
With other streptococci	.15	−.19	.02
With hemolytic *Staphylococcus*	.11	−.20	.22
With *S. agalactiae*, other streptococci or hemolytic *Staphyloccus*	.15	−.09	.18
Number of kinds of infection per cow	−.00	−.14	.24
Number of infections of any kind per cow	.14	−.03	.16

SE (h^2) = .10 for first lactation, .16 for 2nd lactation, .08 for later lactation for h^2 = .10, equal variance for dams and daughters and numbers of pairs as presented.

centage data. Only number of quarters infected with one or more of the infections and total number of infections of any kind per cow in later lactations had heritabilities over .10. Components were estimated using data unadjusted for year-season, stage of lactation or age within lactation groups because of the general lack of importance of these effects. An analysis on later lactation cows with adjusted data produced similar heritabilities.

The herd component of variance as a per cent of total variation increased with advancing lactation number for *S. agalactiae* and hemolytic *Staphylococcus* infections. These percentages were somewhat lower than found by Schmidt and Van Vleck (11), but similar indications of low herd variability in abnormal secretions and higher herd variability in *S. agalactiae* infection were found.

Heritabilities from daughter-dam regressions were also low except for some measurements in later lactation (Table 5). Later lactation heritabilities for clinical mastitis and number of infections based on one survey per cow were slightly higher than those obtained by Young et al. (14) from all lactation animals with more frequent observations per lactation.

Regressions of second lactation infections on first lactation infections and later lactation infections on second lactation infections were moderately high and larger than regressions of later lactation infections on first lactation infections (Table 6). These regressions indicate infections may be repeatable, but the cause may not be genetic.

The use of information on two surveys per cow rather than one did not lead to higher heritabilities (Table 7). The possible increase in accuracy of determining each cow's resistance to infection over a longer time was apparently ineffective or unimportant. More surveys might or might not have an effect and would increase the cost of measurements under field conditions.

Use of only herds with many incidences of a particular infection for determining the heritability of that infection also did not increase heritability (Table 8). Infection rates in these herds were, however, only slightly higher than in the population as a whole except for *S. agalactiae* rates, and an approach of using high percentage infections instead of high incidence might have given different results. Infection rates particularly in later lactations were, however, quite high in these data. There is no indication of a result similar to the

TABLE 6. Regressions of infections in various lactations on infections in a prior lactation.

Criteria of udder infections	Regressions of: Second lactation infections on first lactation infections (4,090 cows in 442 herds)	Later lactation infections on first lactation infections (2,672 cows in 364 herds)	Later lactation infections on second lactation infections (3,628 cows in 437 herds)
Per cent of cows clinical	.13[a]	.03[b]	.14[c]
Per cent of cows with at least one quarter			
Clinical	.17	.00	.11
With *S. agalactiae*	.09	.10	.06
With other streptococci	.11	.04	.18
With hemolytic *Staphylococcus*	.28	.16	.31
With *S. agalactiae,* other streptococci or hemolytic *Staphylococcus*	.16	.09	.21
Per cent of quarters per cow			
Clinical	.15	−.03	.12
With *S. agalactiae*	.10	.08	.11
With other streptococci	.15	.07	.25
With hemolytic *Staphylococcus*	.41	.25	.34
With *S. agalactiae,* other streptococci or hemolytic *Staphylococcus*	.28	.18	.30
Number of kinds of infection per cow	.21	.15	.27
Number of infections of any kind per cow	.27	.18	.31

[a] Standard errors = .02 for all criteria.
[b] Standard errors range from .03 to .05 for various criteria.
[c] Standard errors = .02 for all criteria.

higher heritabilities of fertility measurements from low fertility herds than from high fertility herds as indicated by Hahn (4).

Heritabilities for sires with at least 40 first lactation daughters, which more closely represents a population of sires available for selection from an initial sire proof, were nearly zero for all criteria of infections.

Possibilities for genetic progress in reducing infection rates may exist even with low heritabilities. For example, the expected genetic progress per generation for number of infections of any kind per cow in later lactation with an estimated heritability of .11 would be .21 infections per later lactation cow for progress from sire selection only, 40 daughters per sire, and the top 25% of sires selected. Generation intervals, economic values, and relationships with milk yield would need to be considered in determining if infection rates should be included in a selection program.

Phenotypic relationships within herds among measurements of the three main kinds of infections were low for both first and later lactation cows (Table 9). A low phenotypic relationship between *S. agalactiae* and other streptocci was also found by Schmidt and Van Vleck (11). Clinical measurements were also related to a small extent with any of the three main infections, in agreement with Schmidt and Van Vleck (11) and Young et al. (14). Infections of each kind and any measurement measuring overall infection were more highly related as would be expected by the part-whole relationship.

Milk yield in the lactation of the mastitis survey was negatively associated phenotypically with the extent of udder infection (Table 10) although all correlations were −.10 or less. Previous work indicated low relationships between daily milk yield and bacterial infections (11) and lactation yield and clinical

TABLE 7. Heritabilities from sire components of variance for resistance to udder infections as measured by two surveys per cow.

Criteria of udder infection	Lactations		
	First lactation (2,831 records in 387 herds by 280 sires)	Second lactation (2,312 records in 370 herds by 275 sires)	Later lactation (4,729 records in 422 herds by 323 sires)
Per cent of cows clinical	.03	.07	.05
Per cent of cows with at least one quarter			
Clinical	.05	−.02	−.01
With *S. agalactiae*	−.04	−.06	.03
With other streptococci	.02	.11	.01
With hemolytic *Staphylococcus*	−.11	.08	.09
With *S. agalactiae,* other streptococci or hemolytic *Staphylococcus*	−.03	.03	.10

mastitis (10). However, work on milk yield from each quarter indicated reduced yield in infected quarters (5, 7, 13). Measurements of association between milk yield and infections could be affected in opposite ways by higher infection incidence reducing yield and by higher infection in higher yielding cows.

Milk yield in the preceding lactation was related to a very low extent with udder infections. This is in disagreement with McLeod and Wilson (9) but in agreement with Legates and Grinnells (6). Milk yield in the first lactation was positively related phenotypically to udder infection in later lactations but to a

TABLE 8. Heritabilities from sire components of variance for resistance to udder infections in herds with high[a] incidence of that particular infection.

Criteria of udder infection	Lactation		
	First	Second	Third
Per cent of cows with at least one quarter with *S. agalactiae*			
Heritability	.10	.01	.00
Infection rate in herds used (%)	5.2	10.8	21.0
Infection rate in population (%)	2.6	5.8	12.9
Per cent of cows with at least one quarter with other streptococci			
Heritability	.01	.07	.07
Infection rate in herds used (%)	20.4	27.1	41.8
Infection rate in population (%)	19.0	25.1	37.4
Per cent of cows with at least one quarter with hemolytic *Staphylococcus*			
Heritability	− .02	.04	.04
Infection rate in herds used (%)	10.5	21.0	35.5
Infection rate in population (%)	8.9	17.0	29.2

[a] At least 3 *S. agalactiae,* 12 other streptococci, or 9 hemolytic *Staphylococcus* infections, respectively.

TABLE 9. Within herd phenotypic correlations among measurements of udder infection.

		2	3	4	5	6	7	8	9	10	11	12	13
Per cent of cows clinical	1)	.85[a]	.14	.16	.14	.24	.81	.10	.13	.14	.21	.25	.22
		.81[b]	.15	.19	.15	.28	.76	.14	.15	.14	.25	.31	.28
Per cent of cows with at least one quarter													
Clinical	2)		.14	.13	.12	.20	.95	.11	.12	.13	.19	.23	.21
			.15	.16	.12	.23	.93	.15	.14	.12	.24	.28	.27
With *S. agalactiae*	3)			−.01	.04	.26	.14	.87	−.01	.04	.30	.30	.30
				−.05	−.01	.28	.15	.85	−.05	−.02	.36	.32	.34
With other streptococci	4)				.02	.78	.12	−.02	.86	.03	.68	.75	.67
					.02	.65	.14	−.07	.83	.01	.55	.68	.57
With hemolytic *Staphylococcus*	5)					.50	.12	.03	.03	.89	.44	.56	.46
						.49	.12	−.04	.01	.84	.45	.57	.46
With *S. agalactiae,* other streptococci or hemolytic *Staphylococcus*	6)						.19	.23	.67	.44	.84	.91	.80
							.21	.24	.54	.42	.77	.83	.72
Number of quarters per cow													
Clinical	7)							.12	.12	.15	.20	.22	.21
								.16	.14	.14	.25	.27	.28
With *S. agalactiae*	8)								−.02	.03	.34	.25	.33
									−.07	−.03	.41	.24	.39
With other streptococci	9)									.04	.80	.65	.78
										.01	.66	.57	.68
With hemolytic *Staphylococcus*	10)										.49	.49	.52
											.54	.47	.55
With *S. agalactiae,* other streptococci or hemolytic *Staphylococcus*	11)											.83	.97
												.77	.96
Number of kinds of infection per cow	12)												.87
Number of infections of any kind per cow	13)												.83

[a] First lactation.
[b] Later lactation.

TABLE 10. Within herd correlations between lactation milk yield and several criteria of udder infection.

	Phenotypic				Genetic
Lactation of measuring yield	First	Later	Preceding	First	First
Lactation of measuring infection	First	Later	Later	Later	Later
Number of observations	9,072	8,676	2,164	5,672	5,672
Criteria of udder infections					
Per cent of cows clinical	−.06	−.10	−.03	.06	.67
Per cent of cows with at least one quarter					
Clinical	−.07	−.09	−.02	.03	.76
With *S. agalactiae*	−.01	−.06	−.02	.01	.18
With other streptococci	−.02	−.04	−.06	.06	.53
With hemolytic *Staphylococcus*	−.02	−.04	−.02	.02	−.35
With *S. agalactiae,* other streptococci or hemolytic *Staphylococcus*	−.02	−.08	−.06	.06	.27
Number of quarters per cow					
Clinical	−.06	−.09	−.03	.03	.50
With *S. agalactiae*	−.00	−.06	−.02	.01	.03
With other streptococci	−.00	−.03	−.04	.08	.45
With hemolytic *Staphylococcus*	−.03	−.05	−.04	.02	.02
With *S. agalactiae,* other streptococci or hemolytic *Staphylococcus*	−.02	−.08	−.07	.07	.30
Number of kinds of infection per cow	−.03	−.09	−.06	.07	.33
Number of infections of all kinds per cow	−.02	−.08	−.06	.08	.28

small extent. High producers within a herd do not necessarily have more infections in the next lactation than low producers nor do high producers in first lactation necessarily have more infections in their later lactations than do low producers.

Milk yield in first lactation, the common criterion for sire selection, was moderately related genetically with various criteria of infection in later lactations. The genetic correlations were about .30 between first lactation milk and criteria of overall infection rates, these having heritabilities close to .10. The correlated response in later lactation infections of any kind would be .013 more infections per later lactation cow each year for an annual genetic progress in first lactation milk yield of .1 standard deviation.

References

(1) Afifi, Y. A. 1967. Genetical and some environmental influences affecting the level of leucocyte counts in the milk of cows. Mededelingen Landbouwhogeschool, Wageningen 67–11.

(2) Blackburn, P. S. 1966. The variation in the cell count of cow's milk throughout lactation and from one lactation to the next. J. Dairy Res., 33: 193.

(3) Daniel, R. C. W., D. A. Barnum, and J. C. Rennie. 1966. Variation in modified California Mastitis Test Scores in dairy cattle. J. Dairy Sci., 49: 1226.

(4) Hahn, J. 1969. Inheritance of fertility in cattle inseminated artificially. J. Dairy Sci, 52: 240.

(5) Leffler, R. 1966. The relationship between milkability and udder health in Simmental cows in Switzerland. Dairy Sci. Abstr., 28: 33.

(6) Legates, J. E., and C. D. Grinnells. 1952. Genetic relationships in resistance to mastitis in dairy cattle. J. Dairy Sci., 35: 829.

(7) Lups, P., and H. C. Ritter. 1966. Relationship between chronic udder disease and milk yield of cows. Dairy Sci. Abstr., 28: 205.

(8) Lush, J. L. 1950. Inheritance of susceptibility to mastitis. J. Dairy Sci., 33: 121.

(9) McLeod, D. H., and S. M. Wilson. 1951. Milk yield in relation to infection with

Streptococcus agalactiae. J. Dairy Res., 18: 235.

(10) O'Bleness, G. V., L. D. Van Vleck, and C. R. Henderson. 1960. Heritabilities of some type appraisal traits and their genetic and phenotypic correlations with production. J. Dairy Sci., 43: 1490.

(11) Schmidt, G. H., and L. D. Van Vleck. 1965. Heritability estimates of udder disease as measured by various tests and their relationship to each other and to milk yield, age, and milking times. J. Dairy Sci., 48: 51.

(12) Van Vleck, L. D. 1964. Variation in type appraisal scores due to sire and herd effects. J. Dairy Sci., 47: 1249.

(13) Wheelock, J. V., J. A. F. Rook, F. K. Neave, and F. H. Dodd. 1966. The effect of bacterial infections of the udder on the yield and composition of cow's milk. J. Dairy Res., 33: 199.

(14) Young, C. W., J. E. Legates, and J. G. Lecce. 1960. Genetic and phenotypic relationships between clinical mastitis, laboratory criteria, and udder height. J. Dairy Sci., 43: 54.