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HERITABILITY ESTIMATES OF UDDER DISEASE AS MEASURED BY VARIOUS TESTS AND THEIR RELATIONSHIP TO EACH OTHER AND TO MILK YIELD, AGE, AND MILKING TIMES [1]

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ABSTRACT

Paternal half-sib heritability estimates of milk yield, number of quarters infected with mastitis organisms, and number of quarters showing abnormal milk were obtained from an analysis of milking and mastitis data of 2,865 Holstein cows. The within-herd heritability estimate for daily milk yield was 0.353 and that for the number of quarters infected with *Streptococcus agalactiae* 0.196. The heritability estimates for the number of quarters infected with organisms other than *Streptococcus agalactiae*, number of quarters infected, and number of quarters showing abnormal milk were all below 0.1.

Within-herd correlation coefficients were calculated among daily milk yield, milking data, age, and mastitis indicators. Age, stripping time, and machine-on time were positively correlated with daily milk yield. Older cows had longer machine-stripping times and machine-on times than younger cows. Older cows also showed higher values for all indicators of mastitis.

Mastitis is caused by bacteria; however, there is some evidence to indicate that genetic differences in the susceptibility of cows' udders to infection and clinical mastitis exist. An infected quarter is defined as one whose milk contains demonstrable mastitis-causing bacteria. Clinical mastitis is used to define a quarter that produces abnormal milk or is abnormal in appearance.

Murphy et al. (6) found that the infection rate of three daughters and two granddaughters of a cow with a high infection rate was considerably higher than that of four daughters and two granddaughters of another cow in which no infections were noted during one lactation. Legates and Grinnells (4) obtained a heritability estimate of resistance to mastitis of 0.27. A cow was regarded as susceptible if the milk of one of the quarters contained over 500,000 leucocytes per cubic centimeter of milk and demonstrable streptococcus or staphylococcus organisms. Lush (5) obtained an intraherd daughter on dam regression of 0.19 for cows showing abnormal quarters or abnormal milk by the time they reached 8 yr of age. O'Bleness et al. (7) obtained a heritability estimate of 0.05 for the incidence of mastitis. This was based on the dairyman's knowledge of whether the cow had produced abnormal milk previously. Young et al. (9) found the heritability estimates of clinical mastitis, as defined by the percentage of months of the lactation during which the cow had an abnormal appearance of the udder or its secretion, to be 0.06 and 0.79 when calculated on a daughter-dam regression and paternal half-sib correlation, respectively. In the same study the heritability estimates of bacterial infection were 0.18 and 0.87 and those for leucocyte counts of the milk were 0.38 and 0.23 on a daughter-dam regression and paternal sister correlation, respectively.

Because of the lack of agreement in the previous estimates, and because various types of bacteria cause mastitis, further evidence is presented on the heritability estimates of mastitis indicators and their relationship to daily milk yield, machine-stripping times, and machine-on times.

EXPERIMENTAL PROCEDURE

In a previous report (8) data on the milking procedures, milking installations, milk production, and the incidence of udder infections and abnormal milk on 195 New York dairy farms were summarized. The information was given on a herd basis, whereas this report deals with measurements on individual cows. Data were available on 6,301 cows. During the year, each farm was visited by one technician for two milkings and he obtained the times of each step followed in milking each cow. A few days later, a field veterinarian of the New York

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State Mastitis Control Program visited each farm and performed a mastitis survey on the cows in each herd. This consisted of a strip plate examination of the foremilk from each quarter. The milk was considered abnormal if it contained large flakes or clots, blood or pus, or if the milk was abnormal in color. A strict foremilk sample was obtained aseptically, from which 0.01 ml was streaked on one-fourth of the surface of a 5% bovine blood agar plate. The plates were incubated at 37 C for 24 and 48 hr. The organisms detected on the plates were divided into four groups, *Streptococcus agalactiae (Strep. ag.)* other streptococci, staphylococci, and miscellaneous organisms.

A copy of the dairyman's DHIA or owner-sampler, centrally processed report for the month of the milking routine survey was obtained from the New York Dairy Records Processing Center. From this, the test day production, age at calving, and number of days in milk for each cow were obtained. The registration number of the sire of each cow, if available, was obtained from the records located at the processing center.

The following variables on each cow were analyzed: (1) test day milk yield, (2) days in milk of the lactation, (3) age at start of lactation, (4) number of quarters infected with *Strep. ag.* organisms, (5) number of quarters infected with organisms other than *Strep. ag.* (*Strep.* non-*ag.*) (6) total number of quarters infected, (7) number of quarters showing abnormal milk, (8) machine-stripping time, and (9) machine-on time.

RESULTS AND DISCUSSION

Correlation coefficients on a within-herd basis of the nine variables were calculated and they are given in Table 1. Correlation coefficients as low as ± .081 are statistically significant from zero at the 1% level of probability, with 1,000 degrees of freedom. There were over 6,000 degrees of freedom for correlation coefficients in this study; consequently, only those correlation coefficients over ± .10 have been arbitrarily selected as important. From these values, it will be noted that the daily milk yield is inversely related to the number of days in milk and positively related to age, stripping time, and machine-on time. The rather high negative correlation between daily yield and days in milk would be expected, because of the decline in milk production during a normal lactation curve.

The correlation coefficient between daily milk yield and machine-on time would probably be much higher if the dairymen removed the machines when the cows are milked out. Dairymen who overmilk their cows tend to leave the units on a certain amount of time, regardless of the amount of milk produced by the cow. This is particularly true in the lower-producing herds, as shown in Table 2. The herds were placed in 1,000-lb groups according to the last 12-month average. The actual machine-on time was obtained from the previous report (8) and the test-day production was summarized from the monthly DHIA and owner-sampler records. The required machine-on time was calculated from the regression formula reported by Clough and Dodd (1). The formula is: machine-on time including machine stripping (min) = 0.164 times the pounds milk + 2.33. This formula may not apply exactly to high-producing Holstein cows; however, the general trend of overmilking in the lower-producing herds is quite evident.

Partial correlation coefficients among daily milk yield, days in milk, age, stripping time, and machine-on time were calculated. When

TABLE 1

Within-herd correlation coefficients of the nine variables used in the study

	Daily milk yield	Days in milk	Age	Stripping time	Machine-on time	Quarters infected with *Strep. ag.*	Quarters infected with *Strep.* non-*ag.*	Quarters infected
Days in milk	−.691							
Age	.242	−.056						
Stripping time	.167	−.114	.152					
Machine-on time	.293	−.207	.248	.275				
Quarters—*Strep. ag.*	.029	.008	.259	.066	.040			
Quarters—*Strep.* non-*ag.*	.058	−.003	.284	.048	.079	−.042		
Quarters infected	.064	.002	.392	.073	.082	.588	.761	
Quarters—abnormal milk	−.014	−.015	.148	.049	.082	.172	.134	.213

TABLE 2

Relationship of the required milking times to actual milking times of Holstein cows grouped according to herd averages

	Less than 10,000	10,000 to 10,999	11,000 to 11,999	12,000 to 12,999	13,000 to 13,999	14,000 to 14,999	Over 15,000
Number of herds	24	29	25	28	39	21	29
Test day production *(lb milk)*	25	29	32	36	40	42	44
Actual machine-on time *(min)*	5.97	7.05	6.50	6.57	6.07	6.02	5.81
Required machine-on time *(min)*	4.38	4.71	4.95	5.28	5.61	5.77	5.94
Overmilking time *(min)*	1.59	2.34	1.55	1.29	0.46	0.25	−0.13

the effect of days in milk was removed, the correlations became:

Yield and age = +.281

Yield and stripping time = +.117

Yield and machine-on time = +.212

Also, holding milk yield constant, the correlations were:

Age and stripping time = +.117

Age and machine-on time = +.192

Days in milk and stripping time = +.002

Days in milk and machine-on time = −.007

The correlations between daily milk yield and stripping time and machine-on time remained relatively high when they were calculated independent of days in milk.

It will be noted that age plays an important role in machine-stripping time and machine-on time. These correlation coefficients indicate that as the cow becomes older, an increase in machine-stripping time and machine-on time occurs, independent of the yield of milk. Dodd (2) also found that the total duration of milking increases with age, independent of changes in milk yield. The regression of stripping yield on age, independent of milk yield, in Dodd's study (2) was positive, but not significantly different from zero at the 5% level of probability.

The very small correlations between days in milk and stripping time and machine-on time independent of milk yield indicate that advancing lactation has little if any effect on the machine-stripping time and machine-on time and the changes that occur in these are dependent upon changes in milk yield. Dodd (2) found that the machine-on time before stripping increased with the interval after calving, independent of milk yields.

The correlation of mastitis indicators with other measurements are also given in Table 1. From these values it is apparent that the incidence of infection and the presence of abnormal milk increased with advancing age. This appears to be a common observation and is also reported by Legates and Grinnells (4). The correlations of the indicators of mastitis and daily milk yield, days in milk, stripping time, and machine-on time were all less than 0.09.

The heritability estimates of the indicators of mastitis are given in Table 3. These were calculated from paternal half-sib correlations from a sire × herd analysis on observations of 2,865 cows for which sire information was available. Method I reported by Henderson (3) was used. The observations were first cor-

TABLE 3

Heritabilities of mastitis indicators and milking measurements

Measurement	Heritability: Popu-lation	Heritability: Within herd	Mean	Total variation	Variation due to: sire (%)	Variation due to: herd (%)
Milk yield *(lb)*	.235	.353	43.8	154.4	5.9	35.4
No. quarters—*Strep. ag.*	.141	.196	.36	0.57	3.5	27.7
No. quarters—other than *Strep. ag*	.086	.099	.83	0.95	2.1	13.7
No. quarters infected	.040	.047	1.13	1.17	1.0	13.6
No. quarters—abnormal milk	.072	.075	.175	0.18	1.8	3.9

rected by regression to the representative herd means as follows:

Observation (y)	Corrected for (x)	b_{yx}
Daily milk yield (*lb*)	Days in milk	+.122
No. quarters with *Strep. ag.*	Lactation age (months)	−.0076
No. quarters with *Strep.* non-*ag.*	Lactation age (months)	−.0101
No. quarters infected	Lactation age (months)	−.0168
No. quarters abnormal milk	Lactation age (months)	−.0025

From results in Table 3, it will be noted that the heritability estimates of daily milk yield on a population and within-herd basis agree quite well with the heritability estimates reported for lactation milk yields. It will be seen that the heritability estimate for number of quarters infected with *Strep. ag.* is considerably higher than those for the three other indicators of mastitis. A larger proportion of the variation in *Strep. ag.* infections was also due to herd differences. This corresponds with the previous observation of these data (8), that the per cent of cows showing *Strep. ag.* infections decreases as the herd production increases; whereas the per cent of cows showing *Strep.* non-*ag.*, staphylococci, and miscellaneous organisms remains about the same as the production level of the herd increases.

Considerable differences in heritability estimates on the incidence or susceptibility of mastitis appear in the literature. Many of these differences are due to various definitions of mastitis. In some cases (4, 6) the infection rate is used, whereas in others (5, 7, 9) clinical mastitis is used. The manner of expressing the susceptibility of incidence of mastitis may affect the heritability estimate.

The chance of a cow's udder becoming infected depends upon its susceptibility, invasive ability of the pathogens, and degree of exposure to the pathogens. The susceptibility may be related to inherited factors, to nongenetic and physiological changes, such as age and stage of lactation, and to the husbandry and environment of the cow. Ideally, the genetic aspects of susceptibility should be measured directly in terms of the factors responsible for it, such as the bacteriocidal activity of the milk and the factors within the streak canal that prevent the penetration of the bacteria. Since direct measures of this are not available, indirect measures must be used. The best indirect measure is the number of infections that a cow incurs during a lifetime. It would be extremely expensive to collect these data on a large number of cows; consequently, the presence or absence of infection is measured at a specific time.

The frequency or absence of mastitis based on abnormal milk is a reasonable measure, since mastitis occurs only with infection; however, this measurement has a number of weaknesses. There is no objective measurement of mastitis and workers in the field have different criteria for measuring it. Cows are often infected without showing mastitis. Therefore, the heritability estimate based on mastitis may measure the genetic factors that control the seriousness of the disease in the infected animal rather than the factors that control the resistance of the animal against infection. All of these measures of heritability are useful, but they should not be expected to be similar, for they use completely different data and may well measure different things.

It would appear that some progress could be made in selecting cows with a lower infection rate, especially for *Strep. ag.* When selecting for two traits with equal heritabilities and low genetic correlations, the relative rate of progress for one trait is $1/\sqrt{2}$, or 0.706, as fast as if selection were for a single trait. Even though the heritability estimates are not equal, it serves as an estimate of the relative rate of progress. There are small but positive correlations between milk yield and the infection rates used in this study, which indicates that selecting for high-producing cows will result in a somewhat higher infection rate. Probably the most progress in dairy production can be made by selecting for production and attempting to reduce the infection rate and the incidence of mastitis by controlling the environment through better management. This is particularly true for *Strep. ag.*, which can be eliminated from a herd by effective therapy, culture methods, and management.

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REFERENCES

(1) Clough, P. A., and Dodd, F. H. 1959. Measurement of Performance in Machine Milking. N.A.A.S. Quart. Rev., 43: 103.

(2) Dodd, F. H. 1953. Normal Variations in the Rate of Machine Milking. J. Dairy Research, 20: 301.

(3) Henderson, C. R. 1953. Estimation of Variance and Covariance Components. Biometrics, 9: 226.

(4) Legates, J. E., and Grinnells, C. D. 1952. Genetic Relationships in Resistance to Mastitis in Dairy Cattle. J. Dairy Sci., 35: 829.

(5) Lush, J. L. 1950. Inheritance of Susceptibility to Mastitis. J. Dairy Sci., 33: 121.

(6) Murphy, J. A., Pfau, K. O., Lepard, O. L., and Bartlett, J. W. 1944. Comparison of the Incidence of Udder Infection and Mastitis in Two Cow Families. Cornell Vet., 34: 185.

(7) O'Bleness, G. V., VanVleck, L. D., and Henderson, C. R. 1960. Heritabilities of Some Type Appraisal Traits and Their Genetic and Phenotypic Correlations with Production. J. Dairy Sci., 43: 1490.

(8) Schmidt, G. H., Merrill, W. G., and Guthrie, R. S. 1964. Relationship of Milking Times, Procedures, and Installations to Level of Milk Production and Incidence of Mastitis. Cornell Agr. Expt. Sta., Bull. 996.

(9) Young, C. W., Legates, J. E., and Lecce, J. G. 1960. Genetic and Phenotypic Relationships Between Clinical Mastitis, Laboratory Criteria, and Udder Height. J. Dairy Sci., 43: 54.