January 1969

Relationship Between Type Traits and Longevity of Daughters of Hew York Holstein Sires

L. Dale Van Vleck
University of Nebraska-Lincoln, dvan-vleck1@unl.edu

D. B. Filkins
Cornell University

H. W. Carter
Cornell University

C. L. Hart
Cornell University

Relationship Between Type Traits and Longevity of Daughters of New York Holstein Sires

L. D. VAN VLECK, D. B. FILKINS, H. W. CARTER, and C. L. HART
Department of Animal Science, Cornell University, Ithaca, New York 14850

Abstract

The percentage of 40 or more daughters having four lactations of 81 New York Holstein artificially insemination sires was correlated with the percentage of daughters in 66 type categories measured in the first lactation and their average first-lactation milk yield. Multiple regression on these type and production traits accounted for 92% of the variation in percentage of daughters having four lactations. A subset of 33 traits accounted for 82% of the variation. Traits with the largest standard partial regressions for longevity were milk production (.41), udder edema (.87 and .71), deep body (.53), medium upstandingness (.41), fore udder attachment (−.86 and −.67), deep udder (−.73) and udder halving (−.64 and −.75). Traits having the largest correlations with the percentage of daughters having four lactations were: first-lactation milk (.54), plumb rear teat position (.38), sharp dairy character (.35), no breeding trouble (−.30), intermediate thurls (.26), typical head (.25), and fast milking speed (.25).

Introduction

Some relationship between type traits and herd life is assumed by many dairymen concerned about longevity and herd life. Specht, Carter, and Van Vleck (8) reported a correlation of 0.2 between first classification score and herd life. Carter (1) and Miller, Van Vleck, and Henderson (5) found that production was the most important factor affecting longevity. Beltsville research (6) indicated a small but positive correlation between longevity and first-lactation production. Several authors have suggested the importance of increasing longevity because of economic considerations (2, 4).

The purpose of this study was to determine the relationship between daughter averages for some type appraisal traits and average daughter longevity for sires used in artificial insemination.

Received for publication January 28, 1969.

Data and Methods

Holstein sires with artificially sired daughters in New York which appeared on the Cornell Daughter Level Report from December, 1957, to January, 1964, were selected for study. Each sire was required to have 20 or more daughters type appraised before the age of 48 months. (Only six of these sires had less than 40 appraised daughters.) Each sire was required to have 40 or more daughters with an opportunity for four or more lactations. Eighty-one sires met these requirements. All their daughters with milk and type appraisal records were studied.

The first lactation on file began before the age of 36 months and was defined as an animal's first record. Each subsequent record was counted as an additional record for the cow. Herd life was then measured as the number of recorded lactations. To allow cows equal opportunity to begin a specific number of lactations, each was assigned to one of three opportunity groups by date of first calving according to whether the interval from first calving to November, 1966, allowed opportunity for two, three, or four lactations. Seventeen months from first calving was defined as adequate opportunity to initiate a second record and 15 months sufficient interval for each subsequent calving (5). The fraction of daughters in each opportunity group having that many or more lactations was recorded for each sire.

Milk production was measured as the average deviation of the 305-day, 2 times, mature equivalent milk record from the adjusted herdmate average (7) for all first-lactation daughters. Incomplete records were extended to 305 days. Type appraisal of the cows was completed by New York Artificial Breeders Cooperative (now Eastern Artificial Insemination Cooperative) fieldmen and New York extension personnel. Each cow was appraised according to the Individual Dairy Cow Type Appraisal Record (Fig. 1) developed by the Extension Division of the Department of Animal Science. These data were summarized for each sire by calculating the percentage of daughters in each category (subtrait) for each trait.

TABLE 1. Subtraits in regression analyses, means, and correlations with no mastitis, no breeding trouble, per cent with four lactations, and average first-lactation milk.

Trait: Subtrait	Subtrait no.	Mean	Correlations: No mastitis (%)	No breeding trouble (%)	Per cent 4 lactations	First-lactation milk
Number of daughters type appraised	1	141	−.24	−.03	.16	.22
Taped weight (kg)	2	503.2	−.05	−.48	.15	.14
Temperament (%)						
Quiet	3	83.3	.29	.04	.03	−.18
Feeding habits (%)						
Aggressive feeder	4	59.1	.12	−.19	−.01	−.05
Incidence of mastitis (%)						
None	5	90.6		.01	−.10	−.39
Breeding trouble (%)						
None	6	94.4	.01		−.30	−.25
Milking speed (%)						
Fast	7	60.7	.29	−.07	.25	−.03
Average	8	31.9	−.34	.01	−.24	.06
Milk leak (%)						
Nonleaker	9	96.6	.11	.00	−.18	−.31
Udder edema (caked) after calving (%)						
None to slight	10	55.7	.07	−.10	−.05	−.02
Moderate	11	38.7	−.03	.09	.08	−.04
Persistence of udder edema (%)						
One week	12	71.4	.35	−.02	−.06	−.22
Two weeks	13	23.9	−.28	.02	.06	.16
Dairy character (%)						
Sharp angular	14	63.3	−.07	−.15	.35	.38
Head (%)						
Typical for the breed	15	84.2	.20	−.14	.25	−.01
Shoulder (%)						
Not winged tight	16	78.0	.22	.05	.07	−.37
Back (%)						
Straight	17	70.5	−.04	−.09	.19	−.03
High chine	18	8.7	−.03	−.09	−.03	.08
Low loin	19	10.0	.19	.07	.00	−.08
Slightly swayback	20	7.1	−.05	.21	−.17	.06
Hind legs (side view) (%)						
Nearly straight	21	44.6	.08	.07	−.18	−.26
Intermediate	22	48.5	.00	−.12	.16	.26
Hind legs (rear view) (%)						
Toe-out; none-to-slight	23	50.6	−.05	.00	−.05	−.08
Pasterns (%)						
Strong	24	54.3	.04	−.03	−.06	−.11
Intermediate	25	40.8	.02	.00	.08	.08
Depth of body (%)						
Deep for age	26	47.6	.13	−.26	.17	−.01
Intermediate for age	27	48.4	−.16	.28	−.13	.03
Rump levelness and tail setting (%)						
Nearly level, smooth pelvic arch	28	9.1	.19	.01	−.08	−.28
Nearly level, notched pelvic arch	29	12.4	−.07	−.33	.08	−.08

Trait: Subtrait	Subtrait no.	Mean	Correlations: No mastitis (%)	No breeding trouble (%)	Per cent 4 lactations	First-lactation milk
Nearly level, high pelvic arch	30	48.5	.08	.17	−.02	.11
Nearly level, high tail head	31	6.2	−.13	−.02	.07	.00
Slightly sloping, relatively smooth pelvic arch	32	14.3	−.04	.00	.03	.02
Rump rear view (%)						
High thurls, square	33	29.4	.14	−.13	−.13	−.15
Intermediate thurls	34	54.7	−.16	.10	.26	.18
Heel depth (%)						
Deep	35	35.2	.00	−.01	−.02	−.10
Intermediate	36	54.4	−.08	.07	.06	.04
Upstandingness (consider breed and age (%)						
Tall	37	50.6	.11	−.08	−.17	−.15
Medium	38	42.6	−.09	.03	.17	.14
Udder shape (rear) (%)						
Long	39	19.0	.11	−.07	.16	.08
Intermediate length	40	57.0	−.12	.26	−.05	−.16
Short	41	16.4	.03	−.03	−.12	−.02
Udder shape (fore) (%)						
Long	42	22.0	.17	−.30	.08	.04
Intermediate length	43	58.1	.06	.28	−.13	−.31
Short	44	11.2	−.08	.06	−.02	.12
Udder texture (%)						
Collapsed after milking	45	70.7	.16	.00	.00	−.28
Depth of udder (%)						
Deep	46	20.9	−.07	−.29	.11	.27
Shallow	47	71.1	.05	.23	−.08	−.21
Levelness of udder floor (%)						
Nearly level	48	76.7	.12	.01	.14	−.20
Slight tilt	49	15.7	−.07	−.05	−.11	.13
Height of rear udder attachment (%)						
High	50	30.0	.10	−.06	.18	.10
Intermediate	51	59.6	−.05	−.01	−.13	−.06
Strength of udder attachment (rear) (%)						
Strong	52	64.0	.10	−.06	−.03	−.09
Intermediate	53	32.1	−.04	.01	.03	.08
Strength of udder attachment (fore) (%)						
Strong	54	75.7	.23	.06	−.11	−.31
Intermediate	55	21.4	−.16	−.09	.12	.30
Udder halving (%)						
Cleft 1 to 2 finger width	56	46.2	−.05	.09	.16	.11
Cleft 2 to 3 finger width	57	49.1	.08	−.02	−.24	−.18
Udder quartering (%)						
Floor nearly flat	58	80.9	.22	.14	−.23	−.17
Teat position (rear) (%)						
Plumb	59	91.7	.27	−.15	.38	.12
Pointing forward	60	4.2	−.22	.13	−.31	−.20

Trait: Subtrait	Sub-trait no.	Mean	Correlations: No mastitis (%)	No breeding trouble (%)	Per cent 4 lactations	First-lactation milk
Teat position (fore) (%)						
Plumb	61	88.5	.27	−.16	.07	−.10
Pointing forward	62	4.3	−.20	.03	.00	.08
Placement (%)						
Well-spaced	63	66.9	−.01	.03	.17	.06
Rear too close	64	19.5	.18	−.14	−.12	−.07
Side view close	65	5.3	−.25	.00	.04	.03
Additional traits added						
Number of first-lactation daughters	66	915	−.34	−.07	.14	.20
First-lactation milk production (kg)	67	−23.3	−.39	−.25	.54	
Per cent survival (%)						
Two lactations	68	80.9	−.06	−.09	.62	.36
Three lactations	69	61.9	.00	−.21	.79	.45
Four lactations	70	46.2	−.10	−.30		.54

TABLE 2. Summary of some regression analyses of fraction of daughters with four or more lactations on type appraisal traits and milk.

Independent variables [a]	No.	F-Ratio [b]	Multiple correlation coefficient squared, R^2	Adjusted R^{2c}
All, 1 to 67	67	2.11	.92	.48
Less milk, 1 to 66	66	2.11	.91	.48
Less milk, numbers, and weight 3 to 65	63	2.16	.89	.48
Management traits				
3 to 13	11	1.96	.24	.12
5, 6, 8, 11	4	5.02	.21	.17
Body traits				
14 to 35	25	2.13	.49	.26
14, 17 to 23, 27 to 28, 33 to 34, 37	12	4.79	.46	.36
Udder traits				
39 to 65	27	1.95	.50	.24
39, 49, 52 to 53, 55 to 59, 62, 64	11	5.52	.47	.38
Maximize adjusted R^2				
All those below	33	6.40	.82	.69
Management: 3, 4, 6, 12 to 13	5	1.64	.10	.04
Body: 14 to 16, 23, 26 to 34	13	2.25	.30	.17
Udder: 38, 40 to 41, 43, 45 to 46, 53-57, 59, 62, 64	14	2.72	.37	.23
Milk: 67	1	32.25	.29	.28

[a] See Table 1.
[b] Degrees of freedom: numerator, no. variables = p; denominator, n−p−1, where n = no. of observations = 81.
[c] Adjusted $R^2 = 1 - [(n-1)/(n-p-1)]\ (1-R^2)$.

Results and Discussion

The means of the sire means for the 67 subtraits in the regression analyses are shown in Table 1. These subtraits do not include all those shown in Figure 1. If the over-all average per cent of cows in a subtrait was below 5, the subtrait was eliminated. At least one subtrait was eliminated for each type appraisal trait because of dependence, since the total per cent for subtraits within a trait was 100.

All correlations among the 70 subtraits were calculated using the sire averages as observations. The correlations for each subtrait with the subtraits of no mastitis, no breeding trouble, milk in first lactation, and longevity to four lactations are shown in Table 1, because these four traits are among the most important economic traits of dairy cattle.

Expectations of these correlations are someplace between genetic and phenotypic correlations. The numerators are estimates of genetic covariances, but the denominator components contain a function of the residual variances. The numerators may also contain some phenotypic covariance, depending on how many daughters are the same in both sets of averages.

Nearly all the correlations are less than .25. The largest correlations with first-lactation milk are the longevity measures, no mastitis, no breeding trouble, milk leak, dairy character, tight shoulder, hind legs, udder texture, and strength of attachment. The traits having the largest correlations with no mastitis are milking speed, persistence of udder edema, teat position, and first-lactation milk. Body weight and depth of body were the most highly correlated with no breeding trouble. The traits most highly correlated with longevity to four or more lactations were: previous survival, milk yield, no breeding trouble, milking speed, dairy character, and rear teat position. The nature of cause-and-effect relationships among such a large number of traits seems difficult to determine, but perhaps these correlations provide a basis upon which to decide which ones to investigate more fully.

The major purpose of the analysis was to arrive at an equation for predicting average longevity to four or more lactations from averages of daughters in type appraisal categories and milk yield, all measured in the first lactation.

As a first step, the first 67 variables listed in Table 1 were used to develop a multiple regression equation to predict longevity. The result of the analysis is shown in Table 2. The multiple correlation coefficient squared, R^2, was .92. There were, however, only 13 degrees of freedom for deviations from regression. When the number of independent variables equals the number of observations minus one, then the regression equation is forced to fit all observations perfectly. Econometricians use a correction to R^2 to adjust for degrees of freedom [see, for example, Waugh (10)]. Waugh states that with small numbers of observations the expected value of the computed R^2 is greater than the true R^2. Thus, a common correction is to calculate an adjusted R^2,

$$\overline{R^2} = 1 - [(n-1)/(n-p-1)]\ (1 - R^2)$$

where n is the number of observations and p is the number of independent variables. Maximizing the adjusted R^2 is equivalent to minimizing the residual mean square from regression, whereas maximizing R^2 is equivalent to minimizing the residual sum of squares from regression. Adjusting the R^2 of 67 variables gave a lower value of .48. Two other general equations were also tried: (1) all variables except milk, and (2) all type subtraits (excluding milk, number of daughters, and body weight). The adjusted R^2 values were the same to two decimal places as for all 67 variables.

A regression equation with fewer independent variables was desired. After considerable trial and error to find an equation which would maintain a nearly maximum R^2 with fewer variables, the following strategy was used to find the maximum adjusted R^2. Haitovsky (3) suggests discarding all variables whose "t"-statistics are less than unity. He proves this result for the case of discarding one variable whose "t"-statistic is less than unity. What was done was a modification of his procedure. The original equation from which variables were dropped was one which excluded numbers of records, since number of records may be correlated with production or longevity. All subtraits with "t"-statistics less than .5 were dropped and the regression analysis repeated. In subsequent rounds subtraits with "t"-statistics less than unity were dropped. This procedure was continued until "t"-statistics of all remaining subtraits were greater than unity. In this way a set including 32 type appraisal subtraits and first-lactation milk was found which gave the largest adjusted R^2 of .69. R^2 was .82, as shown in Table 2. The adjusted R^2 for the 33 subtraits is considerably higher than the adjusted R^2 values for equations with nearly all subtraits.

To compare the relative importance of management traits, body traits, udder traits, and

milk, several regression analyses were done for these sets of the subtraits. All subtraits in a subset were first tried and then subtraits discarded according to the previously described rules. Results are shown in the middle of Table 2, first for the complete subset and then for the reduced subset which maximized the adjusted R^2. Seven of the 11 management

Individual Dairy Cow Type Appraisal Record

Herd Owner's Name St Co Herd no. Breed Age months Index no. Barn name
Cow Reg or E.T. no. Sire Reg or E.T. no. Dam Reg or E.T. no. Date

Dairyman, answer Items 1 through 9
Appraiser, answer Items 10 through 36

1. Temperament 1) Quiet 2) Nervous 3) Dull, Stolid
2. Feeding habits 1) Aggressive feeder 2) Average 3) Slow
3. Incidence of mastitis 1) No mastitis 2) Mastitis—First lactation 3) Mastitis—Injury 4) Mastitis—Other causes
4. Ketosis—Milk Fever 1) Neither 2) Ketosis 3) Milk fever 4) Both
5. Breeding trouble 1) None 2) Cystic ovaries 3) Other (4 or more services)
6. Milking speed 1) Fast 2) Average 3) Slow
7. Milk leak 1) Nonleaker 2) Leaks milk (no injury)
8. Udder edema (caked) after calving 1) None to slight 2) Moderate 3) Severe
9. Persistence of udder edema 1) One week 2) Two weeks 3) More than two weeks

---

10. Taped weight 10 lb
11. Dairy character (Consider stage of lact.) 1) Sharp, angular 2) Moderate 3) Coarse or thick
12. Head 1) Typical for breed 2) Plain 3) Coarse or beefy 4) Weak
13. Shoulder 1) Not winged, tight 2) Slightly winged, loose 3) Severely winged
14. Back (hip to shoulder) 1) Straight 2) High chine 3) Low loin 4) Low chine 5) Roached 6) Slightly swayback 7) Severely swayed
15. Hind legs (side view) 1) Nearly straight 2) Intermediate 3) Sickled 4) Hind legs too straight
16. Hind legs (rear view) 1) Toe-out; none to slight 2) Moderate toe-out 3) Severe toe-out
17. Pasterns 1) Strong 2) Intermediate 3) Weak
18. Depth of body 1) Deep for age 2) Intermediate for age 3) Shallow for age
19. Rump levelness and tail setting 1) Nearly level, smooth pelvic arch 2) Nearly level, notched pelvic arch 3) Nearly level, high pelvic arch 4) Nearly level, high tail head 5) Slightly sloping, relatively smooth pelvic arch 6) Plain with low tail setting 7) Sloping
20. Rump rear view 1) High thurls, square 2) Intermediate thurls 3) Low thurls
21. Heel depth 1) Deep 2) Intermediate 3) Shallow
22. Upstandingness (consider breed and age) 1) Tall 2) Medium 3) Low-set
23. Udder shape (rear) 1) Long 2) Interm. length 3) Short 4) Bulgy 5) Funnel
24. Udder shape (fore) 1) Long 2) Interm, length 3) Short 4) Bulgy 5) Funnel
25. Udder texture 1) Collapsed after milking 2) Intermediate 3) Meaty
26. Depth of udder 1) Deep 2) Intermediate 3) Shallow 4) Too deep
27. Levelness of udder floor 1) Nearly level 2) Slight tilt 3) Fore higher than rear 4) Pronounced tilt 5) Rear higher than fore
28. Height of rear udder attachment 1) High 2) Intermediate 3) Low
29. Strength of udder attachment (rear) 1) Strong 2) Intermediate 3) Loose 4) Broken away
30. Strength of udder attachment (fore) 1) Strong 2) Intermediate 3) Loose 4) Broken away
31. Udder halving (rear view) 1) Cleft 1-2 FW[a] 2) Cleft 2-3 FW[a] 3) More than 3 FW[a] 4) Floor nearly flat
32. Udder quartering (side view) 1) Floor nearly flat 2) Cleft 1-2 FW[a] 2) Cleft 2-3 FW[a] 3) Cleft over 3 FW[a]
33. Teat position (rear) 1) Plumb 2) Pointing forward 3) Pointing sideways
34. Teat position (fore) 1) Plumb 2) Pointing forward 3) Pointing sideways
35. Placement 1) Well-spaced 2) Rear too close 3) Side view close 4) All bunched 5) Front too wide 6) Front and rear too wide

[a] FW, finger width.

FIG. 1. Type Appraisal Form used for evaluating type traits.

TABLE 3. Partial and standard partial regression coefficients and "t"-tests for variables to maximize the adjusted multiple correlation for the equation predicting survival percentage to four lactations from type appraisal percentages.

Subtrait (%)	No.	Regression coefficients		"t"-values
		Partial	Standard partial	
Quiet temper	3	.342	.28	2.88
Aggressive feeder	4	−.131	−.14	1.43
No breeding trouble	6	−.249	−.29	3.52
Udder edema (1 wk)	12	.583	.87	2.92
Udder edema (2 wk)	13	.543	.71	2.52
Sharp dairy character	14	.257	.30	2.94
Typical head	15	−.290	−.20	1.99
Not winged shoulder	16	.343	.32	3.22
Hind legs, no toe-out	23	.166	.20	2.33
Deep body	26	.392	.53	1.85
Intermediate deep body	27	.388	.45	1.62
Rump				
Level, smooth arch	28	−.341	−.23	1.93
Level, notched arch	29	.325	.21	1.89
Level, high arch	30	.296	.34	2.11
Level, high tail	31	.341	.16	1.97
Sloping, smooth	32	.474	.32	2.41
High thurls, square	33	.169	.33	2.28
Intermediate thurls	34	.189	.37	2.86
Medium upstanding	38	.188	.41	4.00
Rear udder				
Intermediate	40	−.206	−.18	1.98
Short	41	−.405	−.28	2.76
Fore udder, intermediate	43	−.189	−.18	1.76
Udder texture	45	.236	.24	2.23
Deep udder	46	−.516	−.73	5.34
Udder attachment				
Rear, intermediate	53	−.190	−.16	1.54
Fore, strong	54	−.918	−.86	2.82
Fore, intermediate	55	−.821	−.67	2.26
Udder halving				
Cleft 1-2	56	−.567	−.64	2.56
Cleft 2-3	57	−.716	−.75	2.90
Teat position				
Rear, plumb	59	.649	.37	4.10
Fore, pointing forward	62	.547	.18	2.17
Rear too close	64	−.238	−.24	2.95
First lactation milk (kg)	67	.0123	.41	3.73
Intercept		3.56		

traits, 12 of 25 body traits, and 16 of 27 udder traits were discarded without markedly decreasing R^2. Apparently, body ($\overline{R^2} = .36$) and udder ($\overline{R^2} = .38$) traits were nearly equal in importance in determining longevity, with management traits accounting for less than half as much variation ($\overline{R^2} = .17$) as either. Milk alone, as shown on the bottom of Table 2, was about three-fourths as important ($\overline{R^2} = .28$) as the selected body or udder traits. Naturally, these R^2 values are not independent. When the selected four management traits, 12 body traits, 11 udder traits, and milk were put into the regression equation, R^2 was .69 and adjusted R^2 was only .52.

The subsets included in the equation which maximized the adjusted R^2 were then analyzed separately, as shown in the bottom of Table 2. Of these subsets, milk was the most important subset ($\overline{R^2} = .28$), followed by udder traits ($\overline{R^2} = .23$), body traits ($\overline{R^2} = .17$), and management traits ($\overline{R^2} = .04$). Apparently, these subsets are less dependent than those discussed in the previous paragraph.

The partial regression coefficients for the equation which maximized the adjusted R^2 are given in Table 3. Also shown are the standardized partial regression coefficients and the "t"-statistics.

Comparisons of the standard partial regression coefficients and the partial regression coefficients indicate the amount of variation in the subtraits. The means of the subtraits also can be used to estimate the variance, since the means are essentially composed of binomial variables.

The largest positive standard partial regression coefficients are associated with udder edema, deep body, milk yield, and medium upstandingness. The largest negative values are associated with fore udder attachment, udder halving, and deep udder.

The regression coefficients for udder edema are much larger than would have been predicted from their correlations with longevity. The weights for udder edema of 1 and 2 weeks are nearly the same, and since these two categories of udder edema account for 95% of all cows, there would be little difference expected on predicting longevity due to differences in persistency of udder edema. The fraction rated with a typical head was positively correlated with longevity ($r = .25$), but the standard partial regression coefficient for longevity on typical head was negative ($b' = -.20$), which must have been caused by interrelationships of the other subtraits with the category of typical head. The same difference also occurs for some other subtraits, in particular for intermediate depth of body ($r = -.13$, $b' = .45$), rump view, high thurls ($r = -.13$, $b' = .33$), deep udder ($r = .11$, $b' = -.73$), intermediate for udder attachment ($r = .12$, $b' = -.67$), and udder halving, cleft 1-2 FW ($r = .16$, $b' = -.64$).

Conclusions

Milk production is the most important trait in determining average longevity of daughters of artificial insemination sires in New York Holsteins on Dairy Herd Improvement Association testing. These results agree with previous reports (5, 9, 11) that high-producing animals in the first lactation, as a group, stay in the herd longer than low producers.

Udder and body traits were much more important than management traits in determining longevity. Most correlations of these traits with longevity to four lactations are relatively low, but the joint effects of these traits appear to be important, as indicated by squared multiple correlation coefficients.

References

(1) Carter, H. W. 1968. Percentage of sire's daughters having a second, fourth, and sixth lactation. J. Dairy Sci., 51: 313.
(2) Gilmore, L. O. 1952. Dairy Cattle Breeding. J. P. Lippincott Company, New York.
(3) Haitovsky, Yoel. 1969. A note on the maximization of R^2. Amer. Stat., 23: 20.
(4) Lush, J. L. 1945. Animal Breeding Plans. 3rd ed. Iowa State College Press, Ames.
(5) Miller, P. D., L. D. Van Vleck, and C. R. Henderson. 1967. Relationships among herd life, milk production, and calving interval. J. Dairy Sci., 50: 1283.
(6) Parker, J. B., N. D. Bayley, M. H. Fohrman, R. D. Plowman. 1960. Factors influencing dairy cattle longevity. J. Dairy Sci., 43: 401.
(7) Spalding, R. W., C. R. Henderson, H. W. Carter, R. Albrechtsen, and A. M. Meek. 1963. The selection and evaluation of dairy sires. Cornell Ext. Bull. 1118.
(8) Specht, L. W., H. W. Carter, and L. D. Van Vleck. 1967. First classification score and length of herd life. J. Dairy Sci., 50: 1690.
(9) Van Vleck, L. D. 1964. First lactation performance and herd life. J. Dairy Sci., 47: 1000.
(10) Waugh, A. E. 1952. Elements of Statistical Method. p. 484. McGraw-Hill, New York.
(11) White, J. M., and J. R. Nichols. 1965. Relationships between first lactation, later performance, and length of herd life in Holstein-Friesian cattle. J. Dairy Sci., 48: 468.