Phenotypic Relationship of Yield and Type Scores from First Lactation with Herd Life and Profitability

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ABSTRACT

Milk records from Ayrshire, Brown Swiss, Guernsey, Jersey, and Milking Shorthorn cows that first calved between 18 and 35 mo were combined with scores for linear type traits collected before 43 mo during first lactation to study herd life and lifetime profitability. Profitability (discounted relative net income) was the value of milk, calves, and cow salvage minus fixed costs, operating costs, and cow depreciation costs. Cows were included if they appeared only in a single herd and if the herd remained on test for 72 mo after birth date of the cow. Phenotypic correlations were computed for milk and fat yields and for 14 type traits during first lactation with nine variables for lifetime performance from 3895 Ayrshire, 7997 Brown Swiss, 20,179 Guernsey, 71,731 Jersey, and 628 Milking Shorthorn cows. Multiple correlations for predicting discounted relative net income for the four breeds with the most data were 0.43 to 0.46 from milk and fat yields (linear and quadratic effects) during first lactation, 0.11 to 0.29 from final score, and 0.21 to 0.33 from all type traits. Type scores had considerably less predictive ability than yield during first lactation for predicting profitability and had limited predictability after yield was included. Final score increased multiple correlations only 0.00 to 0.02 above that for yield for the same four breeds. Final score plus 13 type traits (linear, quadratic, and interaction effects) increased multiple correlations only 0.02 to 0.04 above that for yield. Because of the limited value of some of the linear type traits, an effort should be initiated to eliminate them from programs of breed associations.

(**Key words**: milk yield, type, herd life, lifetime profit)

Abbreviation key: **DPL** = days of productive life, **DRNI** = discounted RNI, **LFTT** = linear functional type trait, **RNI** = relative net income.

Received December 12, 1994.
Accepted November 27, 1995.

INTRODUCTION

Cows with higher yield during first lactation also have higher yield during later lactations (26, 28) and longer herd life (14, 26, 28). Gill and Allaire (9) reported that herd life accounted for 81% of the variation in cow profit. Sustained participation in type programs has been due in part to the belief that type scores identify cows that are capable of withstanding the stress of high yield and, thus, those that have longer herd life. Disposal studies (4, 27) confirm that a number of traits, including milk yield, reproduction, mastitis, and conformation, affect herd life. Several studies (6, 7, 10, 12, 13, 16, 18, 21) have examined the relationships among type traits and measures of longevity for dairy cows. Two of those studies (10, 16) related type traits to lifetime economic values. Earlier reports of studies included literature reviews and provided insight into the worth of classification programs with data from Holsteins (2, 7, 12, 13, 21, 22) and Jerseys (16). In a review, Funk (8) indicated that herd life studies consistently showed that, after selection for yield, the traits of udder depth, fore udder attachment, and teat placement are the most important type traits to consider when selecting for longevity. He also indicated that most studies show that cows with smaller body size have longer herd life, particularly for grade cattle, and that the relationship is small between feet and leg scores and herd life.

Since 1979, all breed associations and many AI organizations in the US have implemented a linear functional type trait (**LFTT**) program similar to that described by Wilson (29). This conversion was made partly because of obvious deficiencies in previous classification procedures, which were discussed by Norman et al. (17). Conversion to LFTT was done without extensive prior research and was based on the assumption that answers to the many remaining questions on type could be obtained if data were collected on a sound scientific basis. Linear type programs usually have 1) evaluation of single traits, 2) sufficient scoring categories to support maximum genetic gain from selection, and 3) provisions for scoring grade as well as registered animals. More timely herd visits to ensure scoring of cows at a young age has been implemented by several breed associations.

The optimal value for each trait should be determined by analyzing accumulated data rather than by having a committee establish an arbitrary standard at the onset of the program. Objectives of this study were 1) to determine whether final score and the 13 LFTT are related to herd life and profitability and, if so, 2) to determine optimal scores for each trait for maximum lifetime profit.

MATERIALS AND METHODS

Data

Type data were provided to the Animal Improvement Programs Laboratory by the American Guernsey Association, American Jersey Cattle Association, American Milking Shorthorn Society, Ayrshire Breeders Association, and Brown Swiss Cattle Breeders' Association. Type data were after January 1980 for Ayrshires, Guernseys, and Jerseys; after January 1981 for Milking Shorthorns; and after January 1982 for Brown Swiss. Type information included final score and up to 13 LFTT as described by Norman et al. (17). No data for foot angle were available for Brown Swiss because foot angle was not included as a trait when the Brown Swiss Cattle Breeders' Association implemented its LFTT program. Most cows were registered; the percentage of grade cows that participated in testing or type programs was small. Nevertheless, any grades scored during special appraisal programs were included.

Scores for type traits were combined according to parity with milk yield data available from the National Cooperative DHI Program. Only records from cows that were 18 to 35 mo at the start of first lactation and had first appraisals prior to second calving and 43 mo were included. Data restrictions and standardization were the same as for the study by Norman et al. (17). Records were further limited to cows that had an opportunity to reach 72 mo of age as defined by requiring 1) at least one reported calving in the herd each 6 mo for 72 mo after the birth date of the cow, 2) all records of a cow to be in the same herd, and 3) no termination code for any records that indicated that the cow had been sold for dairy purposes or had a missing segment of lactation.

Lifetime variables for each cow included 1) number of calvings; 2) total DIM summed across all lactations (≤305 d per lactation); 3) days of productive life (**DPL**), defined as the interval between the initial day of the first lactation and the final day of the last lactation; 4) actual lifetime milk yield, defined as the sum of yield across all lactations (≤305 d per lactation); 5) actual lifetime fat yield (≤305 d per lactation); 6) value of actual lifetime milk and fat yields; 7) relative net income (**RNI**); and 8) discounted RNI (**DRNI**).

Profit functions similar to those of Norman et al. (16), but with prices and costs updated (values suggested by R. E. Pearson and by personnel from the breed associations, 1990, personal communications), were used to measure individual cow income and expense: RNI = (net percentage)(lifetime yield value) + (number of lactations)(net calf value) + salvage value − value at first calving − DPL(daily feed cost for maintenance + daily fixed cost + daily operating cost) − feed cost for growth after first calving. Net percentage was 80% (18% of the milk income needed for feed to support yield and 2% of the milk discarded). The milk price and the fat differential used for each breed to calculate lifetime yield value were determined from the mean blend price received by US dairy producers for each year of the period represented by these data. Prices of milk (3.5% fat) per kilogram were $0.06410 for Ayrshires, $0.06175 for Brown Swiss, $0.06515 for Guernseys, $0.0648 for Jerseys, and $0.0625 for Milking Shorthorns; fat differentials (price per kilogram per 0.1% increase in fat percentage above base test) were $0.154, $0.145, $0.151, $0.152, and $0.153, respectively. Net calf value was $32 (calf value of $60, insemination cost of $20, and feed cost of $8 to support gestation). Salvage value was $400 for Ayrshires and Milking Shorthorns, $425 for Brown Swiss, $375 for Guernseys, and $300 for Jerseys. Value at first calving was calculated as age at first calving in days times $1.233 for Ayrshires, Brown Swiss, and Milking Shorthorns; $1.199 for Guernseys; and $1.096 for Jerseys, which was $900, $875, and $800, respectively, for first calvings at 24 mo. Daily feed cost for maintenance plus daily fixed cost plus daily operating cost was $2.25 for Ayrshires and Milking Shorthorns, $2.30 for Brown Swiss, $2.16 for Guernseys, and $1.96 for Jerseys. Feed cost for growth was calculated as days to 42 mo or disposal (whichever occurred first) times $0.20 for Ayrshires and Milking Shorthorns, $0.225 for Brown Swiss, $0.18 for Guernseys, and $0.15 for Jerseys.

Data to reflect differences among individual cows in health costs and reproductive efficiency beyond that given by calving interval were not available and, thus, not included in the analysis. However, Tigges et al. (24) reported a relative net income function that accounted for 95% of the variation in profit when health, mastitis, and breeding costs were considered.

Unfortunately, complete health data usually are available only from a few experimental herds; therefore, conclusions about the value of specific type traits from such herds should be considered with caution because of the small number of observations.

Information on DIM and milk and fat yields after 305 d was not available from yield data provided by the National Cooperative DHI Program. Therefore, DIM, lifetime milk and fat yields, and lifetime yield value were underestimated for cows with lactations >305 d. In contrast, DPL was underestimated only for the last lactation of a few cows. Therefore, the economic variables (RNI and DRNI) were biased downward because cows with long lactations did not receive credit for all yield.

Discounting puts a premium on more rapid return of investment. If two cows had the same RNI, the one with earlier returned income was more profitable for DRNI. Smith (23) indicated that the discounting rate should be the inflation-free interest rate, which typically was about 4%. Then DRNI would reflect profit more closely than the other seven lifetime variables. For this study, DRNI was calculated as (net percentage)$[\Sigma_{i=1}^{n} 1/(1 + d)^{B}]$(value of milk yield for lactation i) + $[\Sigma_{i=1}^{n} 1/(1 + d)^{C}]$(net calf value) + $[1/(1 + d)^{D}]$(salvage value) − $[1/(1 + d)^{E}]$(value at first calving) − $[\Sigma_{i=1}^{n} 1/(1 + d)^{F}]$(lactation feed cost for maintenance + lactation fixed cost + lactation operating cost) − $[1/(1 + d)^{G}]$(feed cost for growth after first calving), where n = number of calvings, d = discounting rate = 0.04, B = age of cow at 120 DIM (for last lactation, B = age at 35% into the lactation), C = calving age, D = disposal age, E = 0.5 times age at first calving, F = age of cow at 180 DIM (for last lactation, F = 0.5 × DIM), and G = mean of age at first calving and the smaller of either 42 mo or disposal age. Van Arendonk (25) suggested that opportunity cost should be considered when calculating net income to account for revenue forfeited by keeping a cow that was already in the herd instead of allowing a replacement heifer to calve. However, Cassell et al. (3) found correlations >0.95 among RNI, RNI adjusted for opportunity cost, and DRNI for equal herd life opportunities. Therefore, the effect of adjustment for opportunity cost was not examined in this study.

Phenotypic Relationships

All phenotypic relationships among yield traits, type traits, and lifetime variables were calculated within herd, date of scoring, and lactation stage at scoring as defined by Norman et al. (17). Lifetime variables were predicted using multiple regression from linear and quadratic effects for milk yield, fat yield, final score, and 13 LFTT during first lactation as well as from 14 interactions of value of milk and type traits and 13 interactions of final score and LFTT.

RESULTS AND DISCUSSION

Means and Standard Deviations

Table 1 presents breed means and standard deviations within herd, date of scoring, and stage of lactation at scoring for yield and type traits during first lactation and variables for lifetime performance. Number of cows per scoring group was largest for Jerseys. Mean age at first calving ranged from 26.0 mo for Jerseys to 29.0 mo for Ayrshires, which was similar to mean ages reported in other studies (17, 19). Means for yield and type were similar to results from an earlier study (17) that did not include the restriction that herds remain on test. The number of calvings per cow ranged from 2.8 for Guernseys to 3.3 for Jerseys, which compared favorably with results from other studies (9, 11, 14, 15, 16, 28). Confounding between breed and management level for traits was possible. Because of the limited information available, no attempt was made to determine genetic differences among breeds for any trait.

Phenotypic differences among breeds were apparent for DIM and DPL. Lifetime yield values ranged from \$3536 to \$5040; RNI ranged from −\$19 to \$1322. Some of the differences in breed means and standard deviations for lifetime variables were due to differences in yield opportunity after 72 mo of age. Linear type programs for Milking Shorthorns and Brown Swiss were initiated in 1981 and 1982; programs for the other three breeds started in 1980. Clearly, DPL had a large impact on lifetime yield value, RNI, and DRNI. Comparison among breeds for variables such as RNI and DRNI, which do not consider a number of inputs and costs, would not be appropriate from this study. The breed means derived for RNI and DRNI depended on the parameters assigned for breed inputs and outputs, and many of these parameters have a large influence on RNI and DRNI. Nevertheless, any inaccuracies that might occur in incorporating these breed parameters in RNI and DRNI would be expected to have little negative influence on comparisons of cattle within each breed.

Phenotypic Relationships

Phenotypic correlations among the eight lifetime traits are shown in Table 2. No attempt was made to

TABLE 1. Means[1] and standard deviations[2] for first lactation yield and type traits and lifetime variables for cows with an opportunity for yield to 72 mo of age by breed.

Trait	Ayrshire		Brown Swiss		Guernsey		Jersey		Milking Shorthorn	
	$\bar{X}$	SD	$\bar{X}$	SD	$\bar{X}$	SD	$\bar{X}$	SD	$\bar{X}$	SD
First lactation yield										
Age at first calving, mo	29.0	2.4	28.3	2.4	27.6	2.5	26.0	2.4	28.3	2.5
Standardized milk, kg	6700	917	7250	1122	5991	982	5955	941	5987	1143
Standardized fat, kg	262	35	291	45	273	41	283	42	213	40
Value of milk and fat, $	1837	237	1918	287	1769	268	1688	254	1544	284
First lactation type[3]										
Age at first appraisal, mo	34.6	3.1	33.9	3.9	33.0	3.1	31.3	3.0	33.7	3.4
Final score	78.5	5.2	83.4	2.7	77.9	5.9	77.6	5.9	83.5	2.8
Stature	75.7	6.6	27.7	5.3	78.4	7.5	75.5	6.1	27.0	6.3
Strength	81.4	4.9	29.4	5.5	79.4	6.2	79.0	5.8	30.4	6.0
Dairy character	82.4	4.5	29.1	5.9	80.5	6.8	80.6	6.7	30.6	5.6
Foot angle	70.3	4.0	...	...	70.9	5.5	70.2	5.3	23.9	5.0
Rear legs (side view)	78.0	4.9	26.1	4.8	79.0	6.2	78.3	5.6	28.7	4.8
Pelvic angle	78.2	3.8	25.6	5.0	76.9	5.8	76.7	5.1	27.8	4.6
Thurl width	79.6	4.3	27.7	4.6	78.6	5.5	77.5	5.3	29.6	4.7
Fore udder attachment	79.2	5.3	28.6	5.8	77.7	6.4	77.7	6.4	29.1	5.1
Rear udder height	79.4	4.5	29.2	5.6	80.2	5.3	80.7	5.4	29.9	5.4
Rear udder width	80.5	4.3	28.2	5.6	77.5	5.3	79.2	5.3	29.7	5.9
Udder depth	80.2	2.9	29.1	3.9	79.9	4.6	78.6	4.2	29.5	3.4
Suspensory ligament	81.4	4.4	25.5	4.9	78.5	4.8	78.8	5.2	29.5	4.5
Teat placement	72.5	4.6	25.6	4.8	71.5	5.3	71.2	5.6	23.2	4.9
Lifetime variables										
Calvings, no.	3.2	1.7	3.0	1.7	2.8	1.5	3.3	1.8	2.9	1.5
Total DIM	859	498	805	503	769	460	899	525	761	405
Productive life, d	1071	665	1005	670	964	621	1113	692	980	576
Actual milk yield, kg	18,283	12,165	17,265	12,988	14,819	10,082	16,601	11,272	13,685	8717
Actual fat yield, kg	720	473	702	524	680	463	796	534	490	307
Actual value of milk and fat, $	5027	3316	4596	3436	4392	2980	5040	3391	3536	2228
RNI,[4] $	951	1284	737	1411	819	1185	1322	1491	−19	722
Discounted RNI, $	663	996	488	1140	584	960	1009	1188	−138	589
Cows, no.	3895		7997		20,179		71,731		628	
Herd, appraisal date, lactation stage groups, no.	778		1755		3598		9736		174	

[1]Scores from 1 to 50 assigned to individual linear functional type traits for Brown Swiss and Milking Shorthorns and from 50 to 99 for Ayrshires, Guernseys, and Jersyes.

[2]Calculated with herd, 6 dates of scoring and stages of lactation at scoring.

[4]Adjusted for age and stage of lactation.

[4]Relative net income.

test for significance of differences in correlations. The actual size of correlation seemed to be a better indicator of the importance than statistical significance, which was expected even for minor effects because of the large numbers of observations (especially for Jerseys). Corresponding relationships were similar to those previously reported for Holsteins (11) and Jerseys (16).

Simple and multiple correlations (linear and quadratic effects) of yields or type traits and number of calvings are presented in Table 3 by breed. First lactation yield—expressed either as milk, fat, or value of milk and fat—had a higher correlation (linear and quadratic effects) with number of calvings (0.24 to 0.29) than did first lactation final score (0.12 to 0.23) or any LFTT (0.01 to 0.24). Correlations between first lactation yield and number of calvings were lower than those (0.36 to 0.38) reported by Hargrove et al. (11). Final score had a higher correlation with number of calvings than did any LFTT for all breeds except Milking Shorthorn. Rogers et al. (20) also found that final score had the highest correlation with length of productive life for Jerseys. Whether this correlation of final score and number of calvings was caused by intentional culling by some dairy producers on final score or on cow appearance because of promotional value was not examined in this study. However, studies of Holsteins by Dentine et al. (5), Rogers et al. (21), and Short and Lawlor (22) suggested that the value of type (as determined by culling on type) was markedly different for registered and grade cows; therefore, much of the value of final score for influencing herd life might be created artificially from voluntary culling practices. Because nearly all data for the present study were from registered cows, results for Holsteins (5, 21, 22) could not be confirmed in this study of Ayrshires, Brown Swiss, Guernseys, Jerseys, and Milking Shorthorns. However, most of the cows in production testing programs from these breeds are registered; therefore, culling differences based on type traits might not be as important for these breeds as for Holsteins.

Dairy character had nearly as high a correlation (linear and quadratic effects) with number of calv-

TABLE 2. Phenotypic correlations[1] between lifetime variables[2] by breed.

Breed and variable	Number of calvings	DIM	DPL	Lifetime milk yield	Lifetime fat yield	Lifetime yield value	RNI	DRNI
Ayrshire (above diagonal) and Brown Swiss (below diagonal)								
Number of calvings	1.00	0.98	0.98	0.96	0.96	0.96	0.88	0.87
DIM	0.98	1.00	0.99	0.98	0.98	0.98	0.91	0.89
DPL	0.96	0.97	1.00	0.97	0.97	0.97	0.89	0.87
Lifetime milk yield	0.96	0.97	0.95	1.00	0.99	1.00	0.96	0.95
Lifetime fat yield	0.95	0.97	0.95	0.99	1.00	1.00	0.96	0.95
Lifetime yield value	0.96	0.98	0.95	1.00	1.00	1.00	0.97	0.96
RNI	0.86	0.88	0.95	0.94	0.94	0.94	1.00	1.00
DRNI	0.83	0.85	0.75	0.91	0.91	0.91	0.99	1.00
Guernsey (above diagonal) and Jersey (below diagonal)								
Number of calvings	1.00	0.98	0.97	0.95	0.95	0.95	0.86	0.84
DIM	0.98	1.00	0.98	0.97	0.97	0.97	0.89	0.87
DPL	0.98	0.98	1.00	0.96	0.96	0.97	0.85	0.82
Lifetime milk yield	0.96	0.97	0.96	1.00	0.99	1.00	0.95	0.94
Lifetime fat yield	0.96	0.97	0.96	0.99	1.00	1.00	0.95	0.94
Lifetime yield value	0.96	0.98	0.97	1.00	1.00	1.00	0.96	0.94
RNI	0.89	0.91	0.88	0.97	0.97	0.97	1.00	0.99
DRNI	0.88	0.90	0.87	0.98	0.96	0.96	1.00	1.00
Milking Shorthorn								
Number of calvings	1.00	0.97	0.97	0.93	0.93	0.93	0.62	0.59
DIM		1.00	0.98	0.97	0.97	0.97	0.69	0.66
DPL			1.00	0.94	0.94	0.95	0.60	0.56
Lifetime milk yield				1.00	0.99	1.00	0.82	0.78
Lifetime fat yield					1.00	1.00	0.82	0.79
Lifetime yield value						1.00	0.82	0.79
RNI							1.00	0.99
DRNI								1.00

[1]Calculated within herd, date of scoring, and stage of lactation at scoring.

[2]DPL = Days of productive life, RNI = relative net income, and DRNI = discounted RNI.

ings for Guernseys and Jerseys (0.12 and 0.18) as did final score (0.16 and 0.22) and a higher correlation (0.24 vs 0.23) with number of calvings for Milking Shorthorns. Boldman et al. (1) reported dairyness to be the linear trait with the highest relationship with true herd life for Holsteins. Correlations (linear and quadratic effects) of rear udder height and rear udder width with number of calvings were 0.07 to 0.15 for all five breeds. The relationship with number of calvings was primarily linear for most traits but primarily quadratic for a few others (for example, udder depth for Guernseys and Jerseys).

As might be expected (although not presented in the tables), first lactation yield had higher correlations (linear and quadratic effects) with lifetime yield value (0.35 to 0.38) than with number of calvings (0.24 to 0.29). For Guernseys and Jerseys, dairy character also was more highly correlated with lifetime yield value (0.20 and 0.25) than with number of calvings (0.12 and 0.18). Most other correlations of final score or LFTT were similar for these two lifetime variables for all breeds.

Correlations (linear and quadratic effects) of first lactation yield (0.42 to 0.45) and dairy character (0.26 to 0.30) with DRNI were even greater than those with lifetime yield value for Guernseys and Jerseys (Table 4). Correlations between LFTT and DRNI were not always consistent across breeds, perhaps partially because of the small number of observations for some breeds. For Guernseys and Jerseys, dairy character had the highest correlation with DRNI (0.26 and 0.30), and final score had the second highest correlation (0.25 and 0.29); suspensory ligament, rear udder height, rear udder width, and udder depth had moderate correlations (0.07 to 0.20). For Ayrshires, rear udder width (0.13) and rear udder height (0.12) had higher correlations with DRNI than did final score (0.11) and dairy character (0.08). Again, relationships with DRNI were primarily linear for most yield and type traits.

Multiple correlations for predicting lifetime variables are listed in Table 5. Type traits during first lactation (final score and LFTT) had less predictive ability than did yield except for number of calvings for Milking Shorthorns. For all three lifetime variables, the combined effect of the 13 LFTT usually had higher correlations than did final score. When final score and LFTT were considered together, correlations increased to 0.06 above that from LFTT, indicating that final score had predictive value beyond the contribution of its components, either because of its own merit or because of the voluntary culling practices that have evolved through producer acceptance of industry programs and the promotional value associated with final score.

TABLE 3. Simple and multiple correlations[1] between number of calvings and first lactation yield or type traits by breed.

	Ayrshire		Brown Swiss		Guernsey		Jersey		Milking Shorthorn	
Trait	L[2]	L, Q	L	L, Q	L	L, Q	L	L, Q	L	L, Q
First lactation yield										
Age at first calving	−0.02	0.05	−0.02	0.03	−0.08	0.08	−0.05	0.05	−0.01	0.08
Standardized milk yield	0.27	0.28	0.26	0.26	0.21	0.24	0.27	0.28	0.29	0.29
Standardized fat yield	0.25	0.26	0.23	0.24	0.23	0.25	0.25	0.26	0.26	0.27
Yield value	0.27	0.28	0.25	0.26	0.23	0.25	0.27	0.28	0.28	0.29
First lactation type[3]										
Final score	0.12	0.12	0.18	0.18	0.16	0.16	0.22	0.22	0.23	0.23
Stature	0.05	0.05	0.04	0.04	−0.06	0.08	0.04	0.05	0.12	0.12
Strength	0.04	0.04	0.03	0.04	−0.01	0.06	0.04	0.05	0.09	0.12
Dairy character	0.06	0.06	0.09	0.09	0.11	0.12	0.18	0.18	0.24	0.24
Foot angle	0.01	0.03	...	...	0.03	0.04	0.03	0.04	−0.03	0.05
Rear legs (side view)	−0.03	0.05	−0.02	0.04	−0.04	0.09	−0.01	0.04	−0.01	0.01
Pelvic angle	0.00	0.01	−0.01	0.02	−0.01	0.04	0.01	0.03	0.03	0.03
Thurl width	0.04	0.05	0.04	0.05	−0.02	0.05	0.06	0.06	0.06	0.07
Fore udder attachment	0.05	0.05	0.06	0.06	0.05	0.08	0.05	0.07	0.11	0.11
Rear udder height	0.10	0.10	0.09	0.09	0.08	0.08	0.14	0.14	0.10	0.11
Rear udder width	0.10	0.10	0.11	0.11	0.07	0.07	0.14	0.14	0.15	0.15
Udder depth	0.01	0.02	0.02	0.03	0.01	0.07	0.01	0.05	0.05	0.05
Suspensory ligament	0.03	0.04	0.07	0.07	0.08	0.09	0.10	0.10	0.08	0.08
Teat placement	0.02	0.05	0.03	0.05	0.03	0.06	0.06	0.08	0.09	0.11

[1]Calculated within herd, date of scoring, and stage of lactation at scoring.

[2]L = Linear; Q = quadratic.

[3]Adjusted for age and stage of lactation.

TABLE 4. Simple and multiple correlations[1] between discounted relative net income and first lactation yield or type traits by breed.

	Ayrshire		Brown Swiss		Guernsey		Jersey		Milking Shorthorn	
Trait	L[2]	L, Q	L	L, Q	L	L, Q	L	L, Q	L	L, Q
First lactation yield										
Age at first calving	–0.06	0.07	–0.08	0.08	–0.13	0.13	–0.07	0.07	–0.08	0.09
Standardized milk yield	0.45	0.45	0.42	0.42	0.43	0.43	0.44	0.44	0.52	0.53
Standardized fat yield	0.43	0.43	0.41	0.41	0.44	0.44	0.42	0.42	0.51	0.51
Yield value	0.46	0.46	0.43	0.43	0.45	0.45	0.45	0.45	0.53	0.53
First lactation type[3]										
Final score	0.11	0.11	0.18	0.18	0.25	0.25	0.28	0.29	0.24	0.25
Stature	0.05	0.04	0.05	0.05	0.00	0.04	0.06	0.07	0.11	0.11
Strength	0.03	0.02	0.03	0.03	0.04	0.06	0.05	0.06	0.07	0.11
Dairy character	0.08	0.08	0.14	0.14	0.26	0.26	0.29	0.30	0.28	0.28
Foot angle	0.00	0.04	...	...	0.03	0.05	0.03	0.04	0.02	0.03
Rear legs (side view)	–0.01	0.02	–0.01	0.03	–0.03	0.08	0.00	0.04	0.02	0.04
Pelvic angle	0.00	0.00	0.00	0.00	0.00	0.03	0.03	0.04	0.05	0.05
Thurl width	0.03	0.04	0.05	0.05	0.02	0.05	0.08	0.09	0.12	0.13
Fore udder attachment	0.00	0.01	0.04	0.04	0.01	0.07	0.02	0.06	0.07	0.07
Rear udder height	0.11	0.12	0.11	0.11	0.12	0.12	0.18	0.18	0.17	0.18
Rear udder width	0.12	0.13	0.14	0.14	0.15	0.15	0.20	0.20	0.18	0.18
Udder depth	–0.04	0.05	–0.03	0.05	–0.08	0.10	–0.04	0.07	–0.12	0.13
Suspensory ligament	0.03	0.03	0.08	0.08	0.10	0.11	0.12	0.12	0.12	0.13
Teat placement	0.00	0.03	0.02	0.03	0.03	0.05	0.05	0.07	0.08	0.12

[1]Calculated within herd, date of scoring, and stage of lactation at scoring.

[2]L = Linear; Q = quadratic.

[3]Adjusted for age and stage of lactation.

TABLE 5. Multiple correlations[1] between lifetime variables and standardized first lactation yield (milk and fat), final score, and linear functional type traits (LFTT) by breed.

Lifetime variable and first lactation trait	Effect[2]	Ayrshire	Brown Swiss	Guernsey	Jersey	Milking Shorthorn
Number of calvings						
Yield	L, Q	0.28	0.26	0.26	0.29	0.29
Final score	L, Q	0.12	0.18	0.16	0.22	0.23
LFTT	L, Q	0.15	0.16	0.21	0.21	0.33
All type	L, Q, L × Q	0.19	0.20	0.23	0.23	0.38
Yield and final score	L, Q, L × Q	0.29	0.28	0.27	0.31	0.33
Yield and LFTT	L, Q, L × Q	0.31	0.29	0.31	0.31	0.42
Yield and all type	L, Q, L × Q	0.33	0.31	0.32	0.32	0.45
Lifetime value of product						
Yield	L, Q	0.39	0.37	0.38	0.39	0.46
Final score	L, Q	0.12	0.20	0.22	0.27	0.29
LFTT	L, Q	0.16	0.19	0.26	0.27	0.38
All type	L, Q, L × Q	0.20	0.23	0.28	0.29	0.44
Yield and final score	L, Q, L × Q	0.40	0.39	0.39	0.41	0.50
Yield and LFTT	L, Q, L × Q	0.41	0.39	0.42	0.41	0.55
Yield and all type	L, Q, L × Q	0.42	0.40	0.42	0.42	0.58
Discounted relative net income						
Yield	L, Q	0.46	0.43	0.45	0.45	0.54
Final score	L, Q	0.11	0.18	0.25	0.29	0.25
LFTT	L, Q	0.18	0.20	0.30	0.31	0.39
All type	L, Q, L × Q	0.21	0.23	0.32	0.33	0.44
Yield and final score	L, Q, L × Q	0.47	0.43	0.46	0.47	0.56
Yield and LFTT	L, Q, L × Q	0.48	0.44	0.48	0.47	0.61
Yield and all type	L, Q, L × Q	0.49	0.45	0.49	0.47	0.62

[1]Calculated within herd, date of scoring, and stage of lactation at scoring.

[2]L = Linear; Q = quadratic.

The ability to predict lifetime variables sometimes was not appreciably better from yield and type than from yield alone for all breeds except Milking Shorthorn. Multiple correlation for DRNI was raised only marginally for yield and type based on 59 variables above that for yield based on 4 variables for these four breeds. Addition of all type traits to first lactation yield increased multiple correlations to predict DRNI by 0.03 for Ayrshires, 0.04 for Guernseys, and 0.02 for Brown Swiss and Jerseys. The increase in correlation was highest for Milking Shorthorns, probably because of few data and the large number of variables for prediction.

Differences were calculated between multiple correlations for models with yield with or without final score in addition to the individual type trait and multiple correlations for the corresponding model without the type trait (Table 6). These differences were used to compare the value of individual type traits for predicting DRNI. Because the differences were so small, they were presented to three decimal places so that rounding would not distort a comparison of the relative increase among traits. When yield information was included, most type traits had little additional value for predicting lifetime performance. The multiple correlation was increased by ≥0.005 for only 10 of 55 traits for breeds other than Milking Shorthorn. Stature, final score, thurl width, and rear legs provided supplemental information for Guernseys. Final score, rear udder height, fore udder attachment, and udder depth provided supplemental information for Jerseys; rear udder height contributed for Ayrshires; and final score helped the predictability for Brown Swiss.

When both yield and final score were included, even fewer LFTT increased the multiple correlation by ≥0.005 for predicting lifetime variables. The LFTT with the most value were stature, thurl width, and strength for Guernseys. For other breeds, except Milking Shorthorn, no traits improved predictability by >0.003 beyond yield and final score.

Curves for Predicting Lifetime Profitability from LFTT

Curves were developed for all breeds using multiple regression equations to predict DRNI from each LFTT. Only curves for Jerseys are included in Figures 1 and 2 because Jerseys had the largest population size. Curves also were developed to predict DRNI from each LFTT given a fixed milk yield (breed average) both with and without fixed final score (breed average). These three curves for each LFTT depict

TABLE 6. Differences between multiple correlations with and without individual type traits for predicting discounted relative net income from yield and yield-final score models by breed.

	Ayrshire		Brown Swiss		Guernsey		Jersey		Milking Shorthorn	
Type trait	Yield model[1]	Yield-final score model[2]	Yield model	Yield-final score model	Yield model	Yield-final score model	Yield model	Yield-final score model	Yield model	Yield-final score model
Final score	0.003	...	0.006	...	0.007	...	0.012	...	0.021	...
Stature	0.000	0.001	0.002	0.003	0.012	0.016	0.000	0.000	0.008	0.002
Strength	0.000	0.001	0.000	0.001	0.004	0.007	0.000	0.001	0.008	0.000
Dairy character	0.000	0.003	0.001	0.000	0.001	0.002	0.001	0.001	0.020	0.009
Foot angle	0.001	0.001	...	...	0.001	0.000	0.001	0.000	0.004	0.001
Rear legs (side view)	0.001	0.000	0.001	0.001	0.005	0.003	0.001	0.000	0.001	0.001
Pelvic angle	0.000	0.001	0.000	0.001	0.001	0.000	0.000	0.000	0.000	0.000
Thurl width	0.000	0.001	0.000	0.000	0.006	0.009	0.000	0.001	0.010	0.005
Fore udder attachment	0.001	0.000	0.001	0.000	0.004	0.001	0.007	0.002	0.012	0.002
Rear udder height	0.005	0.003	0.003	0.001	0.002	0.000	0.008	0.001	0.013	0.009
Rear udder width	0.004	0.003	0.002	0.000	0.001	0.002	0.003	0.000	0.005	0.004
Udder depth	0.002	0.002	0.003	0.002	0.004	0.002	0.007	0.000	0.008	0.006
Suspensory ligament	0.002	0.001	0.003	0.001	0.004	0.001	0.003	0.003	0.011	0.004
Teat placement	0.002	0.002	0.001	0.000	0.001	0.000	0.004	0.000	0.011	0.003

[1]Calculated within herd, date of scoring, and stage of lactation at scoring.

[2]Adjusted for age and stage of lactation.

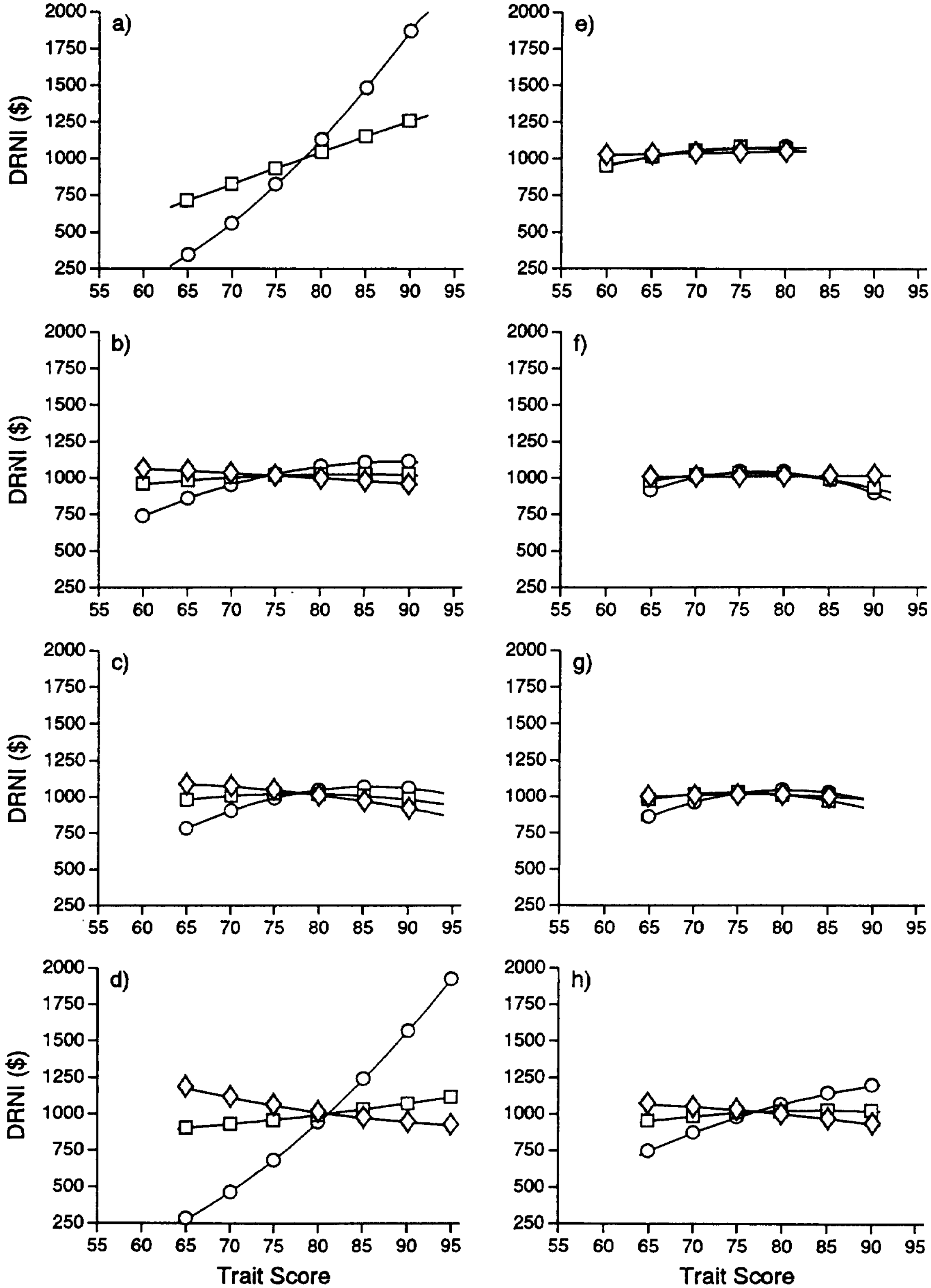

Figure 1. Prediction of discounted relative net income (DRNI) for Jerseys from type trait only (○), type trait plus yield (□), and type trait plus yield and final score (◊) for a) final score, b) stature, c) strength, d) dairy character, e) foot angle, f) rear legs (side view), g) pelvic angle, and h) thurl width.

the age-adjusted score that is associated with maximum profitability. The response is shown for ±2.5 standard deviations from mean.

Prediction curves for DRNI from type traits alone were positive for most traits and often were nearly linear. Final score, dairy character, rear udder height

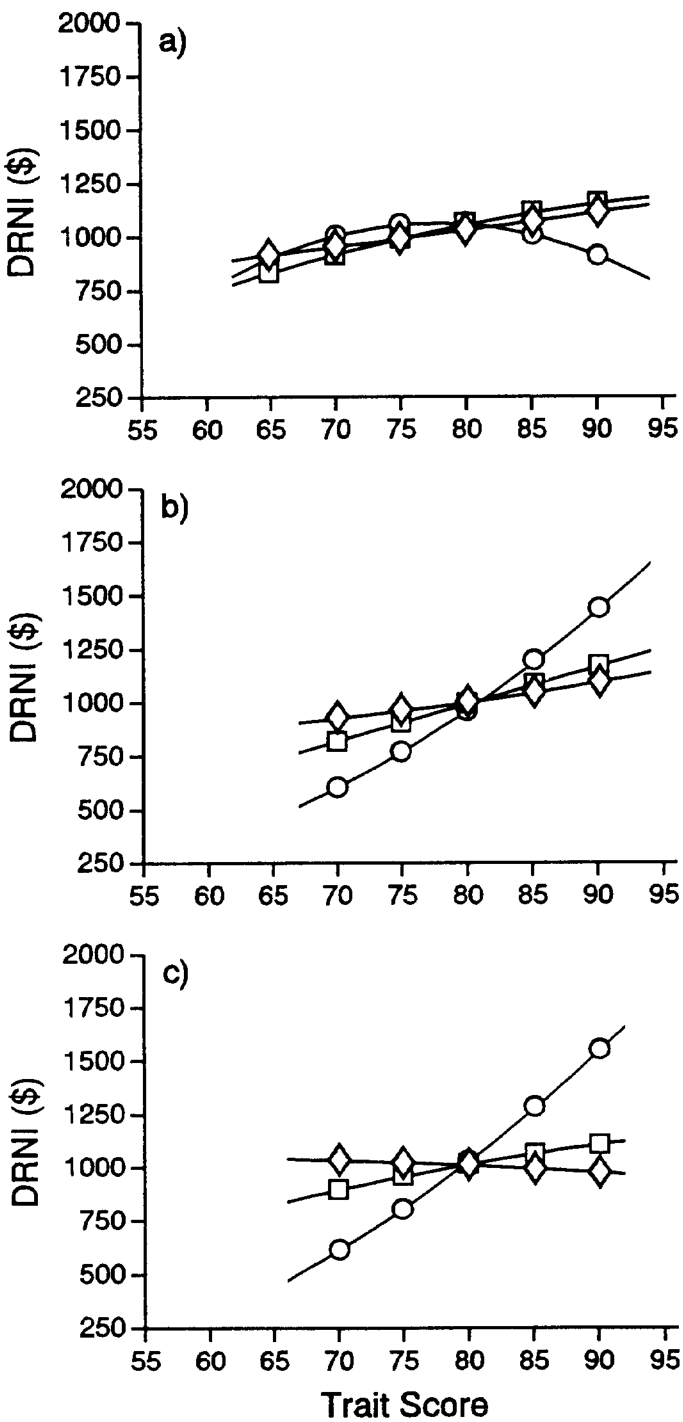

Figure 2. Prediction of discounted relative net income (DRNI) for Jerseys from type trait only (○), type trait plus yield (□), and type trait plus yield and final score (◊) for a) fore udder attachment, b) rear udder height, c) rear udder width, d) udder depth, e) suspensory ligament, and f) teat placement.

and width, and suspensory ligament had particularly strong positive relationships with DRNI. Udder depth had a strong negative relationship with DRNI. For foot angle, rear legs, pelvic angle, and fore udder attachment, midrange scores were optimal for DRNI.

Prediction curves for DRNI from type traits and yield often were similar to those from type traits alone, but slopes were considerably less for most traits. Relationship of udder depth with DRNI changed from negative to positive when yield was included. Optimal scores were slightly lower for rear legs and considerably lower for pelvic angle when yield was included, but optimal scores were higher for fore udder attachment. Midrange scores became optimal for suspensory ligament.

Many LFTT had little predictive ability for DRNI when final score and yield were considered with each trait. Those curves could reflect the true worth of each LFTT better than the curves for LFTT alone or LFTT with yield when a large part of culling on final score is voluntary and is influenced to a large extent by the final score assigned in the type program. For such herds, final score takes on an artificial value that is not warranted. The true worth of each LFTT likely is intermediate to the curve that considers yield and the curve that considers both yield and final score. Curves from a multiregression model with all the traits considered would not be preferable to the method used for assessing the value of each trait because many of the other correlated traits (although less valuable traits) could be accounting for a large portion of the specific traits being examined. The following results for LFTT were based on results from all breeds, but only curves for Jerseys are presented in Figures 1 and 2.

Stature. Tall cows had somewhat higher DRNI than did medium or short cows, except for Guernseys. For 1) constant lactation yield or 2) constant lactation yield and final score, the curves were independent of stature, except for Guernseys, for which taller cows had lower DRNI. Individual feed consumption was not available to include in DRNI; however, if size and feed intake were related positively, tall cows would be less profitable than the curves indicate.

Strength. Strong cows had higher DRNI than did weak cows. If individual feed consumption had been considered in calculating DRNI, this advantage for large cows would have disappeared. For a fixed yield and final score, those cows that scored high for strength were less profitable than those that scored low (a moderate relationship for Jerseys and Guernseys). These results suggested that strong cows (most likely the larger cows) were less profitable than average or weak cows.

Dairy character. By itself, dairy character had a strong relationship with DRNI for every breed. When first lactation yield was considered, dairy character still had a positive relationship for Jerseys and Brown Swiss. When first lactation yield and final score were considered, dairy character score had a negative relationship with DRNI for Jerseys and Ayrshires.

Foot angle. Relationship of foot angle and DRNI was small. The small correlation that appeared for some breeds usually favored the intermediate and steeper foot angle.

Rear legs. Relationship with DRNI was small, but breed curves consistently indicated an intermediate leg set was preferable to extreme sickling.

Pelvic angle. Pelvic angle appeared to have little relationship to DRNI.

Thurl width. Relationships with DRNI were inconsistent across breeds. Cows with wider thurls were more profitable when other traits were ignored, but often those cows with wide thurls were less profitable given a fixed yield and final score.

Fore udder attachment. Guernseys and Jerseys with intermediate scores for fore udder attachment were the most profitable. For other breeds, the relationship was small; nevertheless, those with intermediate and high scores had higher DRNI. For Jerseys, when yield or yield and final score were fixed, higher scores had higher DRNI.

Rear udder height. High rear udders were generally associated with higher DRNI, regardless of whether only yield or both yield and final score were considered. No relationship was found for Guernseys.

Rear udder width. For a fixed yield, wider rear udders were associated with higher DRNI. However, for a fixed yield and final score, the relationship was near 0.

Udder depth. For a fixed yield and final score, cows with shallower udders were more profitable. This shift was the most evident among the curves and showed that first lactation cows with deeper udders were more profitable when yield and final score were ignored.

Suspensory ligament. Suspensory ligament had a small relationship with DRNI. Moderate clefts were the most desirable, except for Brown Swiss for which moderate and high scores were equally desirable and for Milking Shorthorns for which high scores were the most desirable.

Teat placement. Teat placement had a moderate relationship with DRNI. Centered or close teats were more favorable for higher DRNI than were wide teats.

Relationship of Yield and Type

Standardized partial regression coefficients for value of milk and fat and final score were calculated to quantify the relative importance of yield and type during first lactation for predicting lifetime variables (Table 7). Yield value was 1.5 to 3.4 times as effective as final score for predicting total number of calvings, 2.4 to 6.8 times as effective for predicting lifetime yield variables, and 3.8 to 15.7 times as effective for predicting DRNI. If information on health costs of individual cows had been available, type traits might have had somewhat more value relative to yield for predicting lifetime profit. Ratios of yield value to final score for Jerseys were similar to those calculated by Norman et al. (16) for all variables.

TABLE 7. Relative importance of value of first lactation yield and final score for predicting lifetime variables[1] by breed.

Breed and lifetime variable	Multiple correlations[2]	Standardized partial regression		Relative importance (yield value: final score)
		Yield value	Final score	
		(%)		
Ayrshire				
Number of calvings	0.28	77	23	3.4
DIM	0.31	81	19	4.2
Days of productive life	0.32	80	20	4.1
Lifetime milk yield	0.39	88	12	7.1
Lifetime fat yield	0.39	87	13	6.5
Lifetime yield value	0.39	87	13	6.8
RNI	0.44	93	7	14.1
DRNI	0.46	94	6	15.7
Brown Swiss				
Number of calvings	0.28	66	34	1.9
DIM	0.31	68	32	2.2
Days of productive life	0.31	67	33	2.1
Lifetime milk yield	0.38	76	24	3.3
Lifetime fat yield	0.39	77	23	3.3
Lifetime yield value	0.38	77	23	3.3
RNI	0.42	85	15	5.6
DRNI	0.43	86	14	6.0
Guernsey				
Number of calvings	0.24	74	26	2.8
DIM	0.26	76	24	3.1
Days of productive life	0.28	75	25	3.1
Lifetime milk yield	0.38	82	18	4.4
Lifetime fat yield	0.37	84	16	5.1
Lifetime yield value	0.37	83	17	4.7
RNI	0.44	88	12	7.1
DRNI	0.45	88	12	7.4
Jersey				
Number of calvings	0.30	63	37	1.7
DIM	0.32	66	34	1.9
Days of productive life	0.32	65	35	1.9
Lifetime milk yield	0.40	73	27	2.8
Lifetime fat yield	0.40	73	27	2.7
Lifetime yield value	0.40	73	27	2.7
RNI	0.45	78	22	3.6
DRNI	0.46	79	21	3.8
Milking Shorthorn				
Number of calvings	0.32	60	40	1.5
DIM	0.38	66	34	1.9
Days of productive life	0.38	62	38	1.6
Lifetime milk yield	0.48	72	28	2.5
Lifetime fat yield	0.48	70	30	2.4
Lifetime yield value	0.48	71	29	2.5
RNI	0.53	82	18	4.7
DRNI	0.54	85	15	5.5

[1]DPL = Days of productive life, RNI = relative net income, and DRNI = discounted RNI.

[2]Linear effects of yield value and final score.

CONCLUSIONS

Results of type trait studies are affected by the true biological relationships, owner preferences and prejudices toward type traits that influence culling practices, and characteristics of the type programs operated by the breed association. Determining the specific influence of these factors usually is not possible. However, if breed associations work together with a single type program (such as for Guernseys and Jerseys during this study), differences in results should be primarily a function of biological relationships and culling practices.

Yield traits were a moderately useful predictor of lifetime profitability. Type traits were somewhat useful for predicting lifetime profitability, although less so than yield. After yield was considered, type traits added only limited value to improving the prediction of lifetime profitability. Because of the limited value of some of the traits, an effort should be made to reduce the number of linear type traits recorded by breed programs.

Phenotypic relationships are especially useful for management decisions, and many of the breeding strategies of the past have been based on phenotypic relationships. Nevertheless, additional knowledge about genetic relationships among yield and type traits, herd life, and lifetime profitability would be helpful in determining which traits are important for breeding programs. A study should be made to ascertain if the genetic relationships among traits for these breeds support the same conclusions as the phenotypic relationships.

ACKNOWLEDGMENTS

Financial support of the American Guernsey Association, American Jersey Cattle Association, American Milking Shorthorn Society, Ayrshire Breeders Association, Brown Swiss Cattle Breeders' Association, and Red and White Dairy Cattle Association are acknowledged gratefully. Suggestions made by B. G. Cassell, S. M. Hubbard, G. W. Rogers, and R. D. Wilson either during the research effort or during preparation of the manuscript are appreciated.

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