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Relationships among Type Traits and Milk Yield of Brown Swiss Cattle

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ABSTRACT

Variances and covariances for herd-year, sire, and residual effects were estimated for 10 standard type traits and milk yield from type records on 12,838 Brown Swiss cows and milk records on 5,911 of these. A total of 712 sires and 824 herds was involved. The model was a random two-way, cross-classified model (herd-year and sire of cow) with no interaction. Covariances with descriptive type traits scored in categories as present or absent also were estimated as were variance-covariance matrices for descriptive type traits when each category was a separate trait. Genetic correlations of standard type traits with final classification score were large and positive. Genetic correlations of desirable categories of descriptive type traits with final classification also were positive. Standard type traits and final score had positive genetic correlations with milk yield generally ranging from .18 to .29 except for feet and legs .03.

INTRODUCTION

Correlations among type traits and with production have been reviewed by White (15), but no reports have included Brown Swiss data under the evaluation system the Brown Swiss Association of America (BSAA) began in 1971. Quaas and Van Vleck (11) have developed a best linear unbiased prediction (BLUP) sire evaluation procedure for categorically scored traits such as descriptive type traits. The method requires variances of and covariances among categories for a trait with each category

a separate trait scored as present or absent. The purpose of this study was to estimate those variances and covariances for descriptive traits of Brown Swiss cattle, to estimate covariances between descriptive traits and standard type traits as well as with production, and covariances among the standard type traits and with production. These variances and covariances then can be used to develop BLUP procedures for type evaluation.

MATERIALS AND METHODS

The same basic set of official classification records of 15,697 Brown Swiss cows classified by 47 mo of age and between 1971 and 1976 were used as in (8) which estimated heritabilities of standard and descriptive type traits. Standard type traits were adjusted to the basis of a lactating cow, 47 mo of age, and classified in the fall (7). Descriptive traits were not adjusted. A further restriction on the data for this report was that each sire had to have daughters in more than one herd. This restriction reduced the number of sires by more than half and the data to the number of records in Table 1. Averages for the traits are in Table 2 and are only slightly lower than averages for the larger data set (8). The remaining set of 12,838 records was matched with official DHIR production records and 5,911 records matched as shown in Table 1.

Variances and covariances were estimated from the larger data set for type traits, and covariances with production were estimated from the smaller data set. Variances also were estimated from the smaller data set for comparison with the larger data set and for calculation of correlations with milk yield.

Henderson's Method I (3) was used to estimate variances and covariances for the following model for any two traits A and B:

$$y_{Aijk} = M_A + H_{Ai} + S_{Aj} + e_{Aijk}$$

$$y_{Bijk} = M_B + H_{Bi} + S_{Bj} + e_{Bijk}$$

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TABLE 1. Number of cows, sires, herds, and herd-years included in the data sets.

| Number | Data | |
|------------|--------|---------------|
| | Type | Type and milk |
| Cows | 12,838 | 5,911 |
| Sires | 712 | 593 |
| Herds | 824 | 474 |
| Herd-years | 2,295 | 1,291 |

where the y_{ijk} 's are the records on traits A and B of the k th daughter of the j th sire freshening in the i th herd-year. The effects in the model are random, except for constant M 's, with zero means and corresponding variances. Only covariances between the following pairs of variables were nonzero: H_{Ai} and H_{Bi} , S_{Aj} and S_{Bj} , and e_{Aijk} and e_{Bijk} .

The genetic covariance between traits A and B was estimated as $4 \text{Cov}(S_A, S_B)$ and the phenotypic covariance, $\text{Cov}(S_A, S_B) + \text{Cov}(e_A, e_B)$. Heritabilities were estimated within herd-year as four times the ratio of the sire variance to the sum of the sire and error variances.

For the analysis of descriptive traits, each category was a separate trait. The observation is 1 if scored in that category and 0 otherwise.

RESULTS AND DISCUSSION

Heritabilities for categorical traits are difficult to interpret since in genetic evaluation the complete variance-covariance structure among the categories for a trait is needed (11). For comparative purposes, however, heritabilities are in Table 2 for the two subsets of the data. Excluding data from single herd sires reduced heritabilities from those in (8) by from .04 to .07 for final score and the component traits (the first 10 type traits) and are in Table 2. The estimates are similar to those reported by Norman et al. (9) for Jerseys and for studies summarized in that report and by White (15). Estimates from the data matched with milk yield are similar to those from (8). A general impression of heritabilities for the descriptive traits is that the

estimates from the analyses including single herd sires were larger than from analyses excluding single herd sires.

Heritability for first lactation milk yield is on the upper end of previous estimates (5, 12) but is similar to those for mature equivalent records (10). Norman et al. (10) have discussed the possibility of confounding between herds and sires as a cause of inflated heritabilities. The average first lactation (mature equivalent) milk yield also is high relative to DHIA averages but probably reflects the management in those herds which classify their cows and are also on DHIA testing.

Phenotypic correlations between milk yield, final score, final classification, and the eight standard type traits and for those with the descriptive categories are in Table 3. Similarly, genetic correlations are in Table 4. The general pattern in the correlations is similar to those for Holstein (1, 2) and Jersey (9) data. Genetic correlations generally are larger than the phenotypic correlations. There are large positive genetic correlations between final type score and desirable type traits. (The most desirable score for final score and the standard type traits is 1 and the least desirable is 6.) Genetic correlations for final classification with the first (desirable) category for descriptive traits are all positive and moderately high. Conclusions of the previous studies seem valid in suggesting that if improved type scores are desired, then selection for final score alone will be effective in improving the scores for all traits so that selection for individual traits is not necessary (1, 9, 14).

The pattern is different for correlations of milk yield with type traits. Sizes of genetic correlations are similar to those for Holstein data (2) but are the opposite in sign except for dairy character. Since standard type traits were measured from 1 (best) to 6 (worst) the negative correlations reflect a tendency for increased milk production to be associated with more desirable type scores.

Both phenotypic and genetic correlations for milk yield with categories of descriptive traits are generally not large and vary within a trait from positive to negative in sign as expected because of the property of the category frequencies summing to one. The largest genetic correlation was .82 for bulgy or loose fore udder with milk yield. The genetic correlation

TABLE 2. Averages and within herd-year heritabilities.

| Trait ^a | Averages (Data with type) | Within herd-year heritability | |
|-----------------------|------------------------------|----------------------------------|----------------------------|
| | | Data with type | Data with type and milk |
| Milk | 6,916 ^b | ... | .56 |
| Final score | 84.45 | .37 | .40 |
| Final classification | 2.58 | .30 | .36 |
| General appearance | 2.61 | .32 | .39 |
| Feet and legs | 2.59 | .19 | .26 |
| Rump | 2.72 | .37 | .44 |
| Dairy character | 2.05 | .22 | .25 |
| Body capacity | 2.09 | .29 | .36 |
| Mammary system | 2.67 | .24 | .21 |
| Fore udder | 2.69 | .25 | .23 |
| Rear udder | 2.49 | .23 | .24 |
| Stature | | | |
| Upstanding | .41 | .25 | .27 |
| Intermediate | .54 | .15 | .19 |
| Low set | .05 | .11 | .15 |
| Head | | | |
| Superior | .25 | .09 | .11 |
| Acceptable | .65 | .04 | .05 |
| Plain | .09 | .09 | .12 |
| Weak | .01 | .05 | -.20 |
| Front end | | | |
| Smooth, strong | .32 | .10 | .10 |
| Desirable | .56 | .05 | .07 |
| Coarse | .05 | .07 | .08 |
| Narrow, weak | .04 | .08 | .20 |
| Low | .02 | .03 | -.03 |
| Back and loin | | | |
| Straight, strong | .40 | .20 | .21 |
| Medium strength | .48 | .14 | .12 |
| Low chine | .02 | .06 | .12 |
| Weak | .10 | .10 | .17 |
| Rump | | | |
| Long, wide, level | .10 | .12 | .13 |
| Medium | .42 | .09 | .12 |
| High tailhead | .34 | .19 | .20 |
| Narrow pins | .05 | .06 | .05 |
| Sloping | .09 | .09 | .07 |
| Hind legs | | | |
| Strong, clean, square | .17 | .08 | .07 |
| Acceptable | .53 | .08 | .05 |
| Sickled | .27 | .17 | .21 |
| Bone too light | .02 | .06 | .08 |
| Coarse hocks | .01 | -.00 | -.18 |
| Feet | | | |
| Well formed | .23 | .08 | .04 |
| Acceptable | .56 | .04 | .06 |
| Front toe out | .03 | .03 | -.06 |
| Shallow heel | .12 | .03 | .06 |
| Weak pastern | .06 | .08 | .09 |
| Fore udder | | | |
| Firm attachment | .14 | .13 | .14 |
| Acceptable attachment | .50 | .05 | .06 |
| Short | .22 | .15 | .18 |
| Bulgy or loose | .13 | .06 | .05 |
| Broken | .01 | .07 | .01 |
| Rear udder | | | |
| Firm, high, wide | .17 | .10 | .11 |

TABLE 2 (Continued). Averages and within herd-year heritabilities.

| Trait ^a | Averages (Data with type) | Within herd-year heritability | |
|-------------------------|------------------------------|----------------------------------|----------------------------|
| | | Data with type | Data with type and milk |
| Intermediate | .52 | .03 | .05 |
| Low, but firm | .19 | .06 | .10 |
| Narrow | .09 | .10 | .15 |
| Loose or broken | .03 | .06 | .02 |
| Udder support and floor | | | |
| Strong suspension | .40 | .17 | .15 |
| Acceptable | .47 | .07 | .08 |
| Floor too low | .02 | .08 | .10 |
| Tilted floor | .10 | .14 | .16 |
| Broken or weak | .02 | .18 | .14 |
| Udder quality | | | |
| Soft, pliable | .57 | .15 | .17 |
| Intermediate | .39 | .13 | .13 |
| Could not determine | .03 | .04 | -.00 |
| Meaty | .01 | .03 | .11 |
| Persistent edema | .00 | -.07 | -.13 |
| Teat size and placement | | | |
| Plumb, desirable | .40 | .22 | .22 |
| Acceptable | .38 | .13 | .09 |
| Wide front | .13 | .18 | .17 |
| Undesirable placement | .05 | .13 | .18 |
| Objectionable teats | .04 | .16 | .16 |

^aMilk, kg; final score, 70 to 92; final classification through rear udder in categories of 1 to 6 with 1 being most desirable; all other descriptive traits scored in categories as present, 1, or absent, 0, so that the averages are frequencies of occurrence.

^bFrom data set with type and milk.

for bulgy or loose udder with final score was in the opposite direction, $-.35$.

Variances and covariances necessary for multiple trait evaluation (4) of milk yield, final classification, final score, and the other eight standard type traits are in Table 5.

Another object of the study was to estimate the variances and covariances of categories within each descriptive type trait for use in best linear unbiased prediction of categorical frequencies. The number of such tables is too large for inclusion here, but the tables can be obtained by writing for the supplement to this article (13).

An example is in Table 6 for two descriptive traits of much interest, fore and rear udder. Covariances between categories of both also are presented. Such covariances for categories of one descriptive trait with categories of another were not computed for any other pairs of

descriptive traits because of the large number and the small chance they would ever be used. Although the genetic correlation is high (.81) between the most desirable fore and rear udder categories, the phenotypic correlation is much lower (.23). Correlations between the fifth categories (broken and/or very faulty and loosely attached and/or broken) are similar: genetic, .58, and phenotypic, .25.

CONCLUSIONS

Genetic correlations among type traits for Brown Swiss cattle confirm results with Holsteins (1, 2, 14) and Jerseys (9) that selection for final score could be effective in improving scores of all type classification traits. Genetic correlations with milk yield are small but not antagonistic with milk yield in contrast to the Holstein study (2). In neither that set of data

TABLE 3. Phenotypic correlations within herd-year among first lactation milk yield and type scores and with categories of descriptive traits.

| Trait | Milk | Final score | Final classification | General appearance | Feet and legs | Rump | Dairy character | Body capacity | Mammary | Fore udder | Rear udder |
|----------------------|------|-------------|----------------------|--------------------|---------------|------|-----------------|---------------|---------|------------|------------|
| Milk | | .20 | -.19 | -.11 | -.05 | -.05 | -.33 | -.10 | -.17 | -.12 | -.20 |
| Final score | .20 | | -.91 | -.76 | -.50 | -.56 | -.50 | -.49 | -.77 | -.70 | -.67 |
| Final classification | -.19 | -.91 | | .74 | .47 | .53 | .46 | .45 | .74 | .66 | .63 |
| General appearance | -.11 | -.76 | .74 | | .59 | .67 | .36 | .44 | .43 | .39 | .39 |
| Feet and legs | -.05 | -.50 | .47 | .59 | | .30 | .20 | .25 | .29 | .24 | .28 |
| Rump | .05 | -.56 | .47 | .67 | .30 | | .21 | .33 | .32 | .30 | .28 |
| Dairy character | -.33 | -.50 | .46 | .36 | .20 | .21 | | .21 | .34 | .29 | .34 |
| Body capacity | -.10 | -.49 | .45 | .44 | .25 | .33 | .34 | | .27 | .82 | .78 |
| Mammary system | -.17 | -.77 | .74 | .43 | .29 | .32 | .29 | .27 | .27 | .27 | .23 |
| Fore udder | -.12 | -.70 | .66 | .39 | .24 | .28 | .34 | .23 | .82 | .82 | .58 |
| Rear udder | -.20 | -.67 | .63 | .39 | .28 | .28 | .34 | .23 | .78 | .58 | |
| Stature | | | | | | | | | | | |
| Upstanding | .05 | .26 | -.24 | -.30 | -.18 | -.15 | -.19 | -.26 | -.09 | -.07 | -.08 |
| Intermediate | -.02 | -.16 | .15 | .20 | .13 | .11 | .14 | .17 | .06 | .05 | .06 |
| Low set | -.05 | -.21 | .19 | .22 | .10 | .09 | .12 | .21 | .06 | .06 | .05 |
| Head | | | | | | | | | | | |
| Superior | .06 | .22 | -.20 | -.23 | -.14 | -.15 | -.17 | -.20 | -.12 | -.12 | -.10 |
| Acceptable | -.04 | -.10 | .09 | .10 | .06 | .08 | .09 | .11 | .05 | .05 | .04 |
| Plain | -.01 | -.14 | .12 | .13 | .09 | .07 | .10 | .09 | .08 | .07 | .07 |
| Weak | .01 | -.07 | .06 | .07 | .03 | .05 | .02 | .08 | .04 | .03 | .03 |
| Front end | | | | | | | | | | | |
| Smooth, strong | .04 | .30 | -.28 | -.32 | -.18 | -.22 | -.22 | -.27 | -.16 | -.15 | -.14 |
| Desirable | .0 | -.11 | .10 | .13 | .08 | .10 | .05 | .14 | .07 | .07 | .06 |
| Coarse | -.09 | -.14 | .14 | .12 | .06 | .05 | .27 | -.01 | .09 | .07 | .09 |
| Narrow, weak | -.03 | -.19 | .17 | .19 | .13 | .14 | .04 | .24 | .08 | .09 | .06 |
| Low | .02 | -.08 | .08 | .11 | .02 | .07 | .05 | .06 | .03 | .02 | .01 |
| Back and loin | | | | | | | | | | | |
| Straight, strong | -.01 | .25 | -.23 | -.32 | -.18 | -.32 | -.07 | -.20 | -.11 | -.11 | -.09 |
| Medium strength | .01 | -.12 | .12 | .14 | .09 | .17 | .03 | .13 | .07 | .06 | .05 |
| Low chine | -.02 | -.07 | .06 | .09 | .05 | .07 | .04 | .05 | .02 | .03 | .01 |
| Weak | .0 | -.15 | .14 | .22 | .10 | .19 | .05 | .07 | .06 | .06 | .06 |
| Rump | | | | | | | | | | | |
| Long, wide, level | .01 | .23 | -.21 | -.28 | -.13 | -.45 | -.09 | -.16 | -.13 | -.12 | -.12 |
| Medium | .01 | .20 | -.20 | -.25 | -.09 | -.37 | -.04 | -.09 | -.12 | -.10 | -.09 |
| High tailhead | .0 | -.14 | .14 | .20 | .03 | .39 | .02 | .08 | .08 | .08 | .05 |
| Narrow pins | .0 | -.09 | .09 | .09 | .08 | .11 | .02 | .08 | .06 | .04 | .06 |
| Sloping | -.03 | -.28 | .26 | .33 | .19 | .39 | .11 | .13 | .16 | .14 | .15 |

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TABLE 4. Genetic correlations within herd-year among first lactation milk yield and type scores and with categories of descriptive traits.

| Trait | Milk | Final score | Final classification | General appearance | Feet and legs | Rump | Dairy character | Body capacity | Mammary | Fore udder | Rear udder |
|----------------------|------|-------------|----------------------|--------------------|---------------|------|-----------------|---------------|---------|------------|------------|
| Milk | .27 | .27 | -.23 | -.18 | -.03 | -.29 | -.26 | -.19 | -.23 | -.23 | -.16 |
| Final score | .27 | | -1.00 | -.91 | -.68 | -.79 | -.66 | -.78 | -.89 | -.86 | -.82 |
| Final classification | -.23 | -1.00 | | .92 | .69 | .80 | .68 | .79 | .90 | .88 | .82 |
| General appearance | -.18 | -.91 | .92 | | .78 | .88 | .61 | .77 | .67 | .63 | .64 |
| Feet and legs | -.03 | -.68 | .69 | .78 | | .53 | .42 | .49 | .49 | .44 | .54 |
| Rump | -.29 | -.79 | .80 | .88 | .53 | | .44 | .64 | .59 | .55 | .54 |
| Dairy character | -.26 | -.66 | .68 | .61 | .42 | .44 | | .59 | .56 | .52 | .55 |
| Body capacity | -.19 | -.78 | .79 | .77 | .49 | .64 | .59 | | .57 | .57 | .47 |
| Mammary system | -.23 | -.89 | .90 | .67 | .49 | .59 | .56 | .57 | .97 | .97 | .93 |
| Fore udder | -.23 | -.86 | .88 | .63 | .44 | .55 | .52 | .57 | .97 | .97 | .84 |
| Rear udder | -.16 | -.82 | .82 | .64 | .54 | .54 | .55 | .47 | .93 | .84 | |
| Stature | | | | | | | | | | | |
| Upstanding | .13 | .46 | -.44 | -.53 | -.43 | -.38 | -.38 | -.33 | -.24 | -.16 | -.27 |
| Intermediate | -.07 | -.44 | .41 | .52 | .45 | .40 | .37 | .31 | .25 | .16 | .31 |
| Low set | -.23 | -.39 | .41 | .41 | .25 | .23 | .29 | .31 | .15 | .13 | .11 |
| Head | | | | | | | | | | | |
| Superior | -.02 | .60 | -.60 | -.56 | -.49 | -.43 | -.43 | -.62 | -.51 | -.41 | -.52 |
| Acceptable | .03 | -.35 | .37 | .29 | .26 | .26 | .24 | .35 | .29 | .20 | .30 |
| Plain | .01 | -.42 | .41 | .42 | .40 | .27 | .33 | .44 | .38 | .35 | .37 |
| Weak | * | -.21 | .15 | .30 | .04 | .20 | .06 | .24 | .10 | .07 | .14 |
| Front end | | | | | | | | | | | |
| Smooth, strong | .02 | .67 | -.67 | -.70 | -.46 | -.52 | -.55 | -.74 | -.48 | -.46 | -.35 |
| Desirable | .14 | -.55 | .55 | .56 | .48 | .42 | .34 | .67 | .46 | .41 | .30 |
| Coarse | -.09 | -.19 | .20 | .18 | -.03 | .10 | .58 | -.02 | .15 | .14 | .18 |
| Narrow, weak | -.18 | -.37 | .33 | .38 | .17 | .36 | -.03 | .48 | .18 | .21 | .20 |
| Low | * | -.11 | .15 | .20 | .12 | .08 | .30 | .19 | -.04 | -.04 | -.19 |
| Back and loin | | | | | | | | | | | |
| Straight, strong | -.20 | .31 | -.34 | -.46 | -.27 | -.54 | -.18 | -.44 | -.11 | -.09 | -.08 |
| Medium strength | .30 | -.05 | .10 | .19 | .15 | .27 | .17 | .25 | -.13 | -.15 | -.09 |
| Low chine | .10 | -.22 | .18 | .27 | .12 | .24 | .04 | .05 | .26 | .20 | .20 |
| Weak | -.10 | -.51 | .50 | .56 | .27 | .60 | .06 | .47 | .40 | .42 | .29 |
| Rump | | | | | | | | | | | |
| Long, wide, level | .22 | .57 | -.56 | -.62 | -.34 | -.86 | -.17 | -.56 | -.36 | -.31 | -.37 |
| Medium | .11 | .68 | -.70 | -.81 | -.54 | -.89 | -.35 | -.46 | -.49 | -.42 | -.50 |
| High tailhead | -.05 | -.39 | .40 | .51 | .22 | .71 | .06 | .33 | .21 | .19 | .18 |
| Narrow pins | -.24 | -.36 | .38 | .37 | .41 | .42 | .26 | .40 | .28 | .16 | .31 |
| Sloping | -.32 | -.69 | .71 | .69 | .55 | .62 | .49 | .44 | .59 | .54 | .69 |

TABLE 5. Variance-covariance matrices of residual, herd-year, and sire effects for first lactation milk yield and ten type traits.

| Trait | Milk ^a | Final score | Final classification | General appearance | Feet and legs | Rump | Dairy character | Body capacity | Mammary | Fore udder | Rear udder |
|------------------------------------------------|-------------------|-------------|----------------------|--------------------|---------------|---------|-----------------|---------------|---------|------------|------------|
| Variance-covariance matrix of residual effects | | | | | | | | | | | |
| Milk ^a | .8853 | .5356 | -.1058 | -.0656 | -.0371 | -.0142 | -.1695 | -.0449 | -.1196 | -.0860 | -.1497 |
| Final score | | 9.3506 | -1.7623 | -1.5240 | -1.1404 | -1.2274 | -.8170 | -.7858 | -1.8531 | -1.7942 | -1.5973 |
| Final classification | | | .4048 | .3081 | .2209 | .2482 | .1556 | .1495 | .3663 | .3456 | .3099 |
| General appearance | | | | .4497 | .2947 | .3376 | .1271 | .1503 | .2204 | .2134 | .1960 |
| Feet and legs | | | | | .5768 | .1699 | .0796 | .0996 | .1650 | .1488 | .1588 |
| Rump | | | | | | .6024 | .0824 | .1272 | .1859 | .1873 | .1614 |
| Dairy character | | | | | | | .3041 | .0571 | .1428 | .1289 | .1403 |
| Body capacity | | | | | | | | .3017 | .1089 | .1166 | .0922 |
| Mammary system | | | | | | | | | .6269 | .5464 | .4807 |
| Fore udder | | | | | | | | | | .7182 | .3775 |
| Rear udder | | | | | | | | | | | .6217 |
| S Y M M E T R I C A L | | | | | | | | | | | |

Variance-covariance matrix of herd-year effects

| | | | | | | | | | | | |
|----------------------|-------|--------|--------|--------|--------|--------|--------|--------|--------|--------|--------|
| Milk ^a | .4323 | .1892 | -.0361 | -.0370 | -.0325 | -.0351 | -.0341 | -.0447 | -.0311 | -.0153 | -.0221 |
| Final score | | 1.6830 | -.3053 | -.3166 | -.2261 | -.2637 | -.2236 | -.2748 | -.2796 | -.2579 | -.2745 |
| Final classification | | | .0552 | .0583 | .0430 | .0470 | .0435 | .0522 | .0499 | .0465 | .0502 |
| General appearance | | | | .0669 | .0485 | .0593 | .0473 | .0504 | .0519 | .0468 | .0521 |
| Feet and legs | | | | | .0746 | .0285 | .0406 | .0415 | .0347 | .0345 | .0451 |
| Rump | | | | | | .0833 | .0413 | .0337 | .0465 | .0417 | .0451 |
| Dairy character | | | | | | | .0542 | .0386 | .0404 | .0347 | .0450 |
| Body capacity | | | | | | | | .0665 | .0428 | .0413 | .0442 |
| Mammary system | | | | | | | | | .0551 | .0549 | .0526 |
| Fore udder | | | | | | | | | | .0633 | .0458 |
| Rear udder | | | | | | | | | | | .0671 |

S Y M M E T R I C A L

Variance-covariance matrix of sire effects

| | | | | | | | | | | | |
|----------------------|-------|-------|--------|--------|--------|--------|--------|--------|--------|--------|--------|
| Milk ^a | .1449 | .1020 | -.0170 | -.0147 | -.0025 | -.0303 | -.0135 | -.0121 | -.0161 | -.0180 | -.0115 |
| Final score | | .9427 | -.1750 | -.1745 | -.1115 | -.1902 | -.0861 | -.1161 | -.1726 | -.1811 | -.1546 |
| Final classification | | | .0326 | .0326 | .0209 | .0358 | .0166 | .0220 | .0324 | .0344 | .0289 |
| General appearance | | | | .0388 | .0259 | .0426 | .0161 | .0233 | .0264 | .0268 | .0246 |
| Feet and legs | | | | | .0286 | .0220 | .0096 | .0128 | .0166 | .0163 | .0177 |
| Rump | | | | | | .0610 | .0145 | .0243 | .0294 | .0295 | .0261 |
| Dairy character | | | | | | | .0181 | .0121 | .0151 | .0153 | .0144 |
| Body capacity | | | | | | | | .0236 | .0175 | .0190 | .0140 |
| Mammary system | | | | | | | | | .0401 | .0423 | .0363 |
| Fore udder | | | | | | | | | | .0472 | .0354 |
| Rear udder | | | | | | | | | | | .0378 |

S Y M M E T R I C A L

^aMilk yield in kg coded by dividing by 1136.

TABLE 6. Variance-covariance matrices of residual, herd-year and sire effects and phenotypic and genetic correlations among five categories of fore udder and five categories of rear udder descriptive type traits.

| | Fore udder attachment | | | | | Rear udder attachment | | | | |
|-----------------------------------------------------------------------------------------|-----------------------|-----------------|--------|--------|--------|-----------------------|-----------------|--------|--------|--------|
| | Firm | Accept- able | Short | Bulgy | Broken | Firm | Accept- able | Low | Narrow | Broken |
| Variance-covariance matrix of residual effects and phenotypic correlations ^a | | | | | | | | | | |
| Fore udder attachment | | | | | | | | | | |
| Firm | .1070 | -.0683 | -.0218 | -.0156 | -.0014 | .0250 | -.0034 | -.0120 | -.0057 | -.0038 |
| Acceptable | -.42 | .2384 | -.1025 | -.0613 | -.0064 | .0085 | .0137 | -.0058 | -.0086 | -.0078 |
| Short | -.19 | -.53 | .1535 | -.0259 | -.0032 | -.0180 | -.0010 | .0101 | .0082 | .0007 |
| Bulgy | -.15 | -.38 | -.21 | .1053 | -.0025 | -.0138 | -.0052 | .0073 | .0056 | .0061 |
| Broken | -.04 | -.12 | -.07 | -.06 | .0135 | -.0016 | -.0041 | .0004 | .0006 | .0047 |
| Rear udder attachment | | | | | | | | | | |
| Firm | .23 | .05 | -.14 | -.12 | -.04 | .1241 | -.0816 | -.0290 | -.0090 | -.0044 |
| Acceptable | -.02 | .06 | -.01 | -.03 | -.07 | -.47 | .2366 | -.0900 | -.0492 | -.0158 |
| Low | -.11 | -.03 | .07 | .06 | .0 | -.23 | .50 | .1360 | -.0127 | -.0043 |
| Narrow | -.08 | -.07 | .09 | .06 | .03 | -.11 | -.37 | -.12 | .0748 | -.0038 |
| Broken | -.07 | -.10 | .01 | .11 | .25 | -.08 | -.19 | -.07 | -.08 | .0284 |
| Variance-covariance matrix of herd-year effects | | | | | | | | | | |
| Fore udder attachment | | | | | | | | | | |
| Firm | .0091 | -.0015 | -.0055 | -.0017 | -.0005 | .0086 | -.0061 | .0000 | -.0027 | .0002 |
| Acceptable | | .0088 | -.0052 | -.0021 | .0000 | -.0019 | -.0003 | .0043 | -.0016 | -.0005 |
| Short | | | .0112 | -.0007 | .0002 | -.0056 | .0060 | -.0044 | .0039 | .0001 |
| Bulgy | | | | .0040 | .0005 | -.0006 | -.0007 | .0009 | .0001 | .0002 |
| Broken | | | | | -.0002 | -.0004 | .0011 | -.0008 | .0002 | -.0000 |
| Rear udder attachment | | | | | | | | | | |
| Firm | | | | | | .0132 | -.0059 | -.0024 | -.0045 | -.0004 |
| Acceptable | | | | | | | .0116 | -.0091 | .0031 | .0003 |
| Low | | | | | | | | .0184 | -.0055 | -.0014 |
| Narrow | | | | | | | | | .0060 | .0009 |
| Broken | | | | | | | | | | .0006 |
| S Y M M E T R I C A L | | | | | | | | | | |

^a Within herd-year phenotypic correlations below the diagonal.
^b Genetic correlations below the diagonal.

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