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VARIATION ASSOCIATED WITH INTERACTIONS OF SIRE OF FETUS, SIRE OF COW, AND HERD-YEAR-SEASON IN JERSEY PRODUCTION AND REPRODUCTION

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ABSTRACT

Records of Jersey production and reproduction (n = 14, 147) from four southeastern states in the United States of America were analyzed to estimate magnitude of two-factor interactions involving (A) herd-year-season, (B) sire of cow, and (C) sire of fetus. Each interaction was estimated singly in a model containing only A, B, and C, since program capability did not permit solution of larger models; there were a total of 1893 main effects classes and 12,716 two factor interaction classes. Statistical analyses were by mixed model methodology (Henderson Method 3) and minimum variance quadratic estimation (zero prior) procedures. Estimates expressed as a percentage of total, for the two procedures, for milk yield, fat yield, fat %, days open, and gestation length, were AB: 1.1 and .5, 1.7 and .4, 2.1 and .8, 2.5 and .8, and 4.1 and 1.7; AC: 6.5 and 1.8, 4.8 and 2.2, 6.4 and 3.7, .4 and -.1, and 3.3 and 1.3; BC: 2.5 and 1.3, 2.9 and .7, 4.7 and 1.1, 4.4 and 1.4, and 2.8 and 1.1. AB is a common definition of environmental correlation, and estimates for milk and fat yield were lower than some, but not all previous estimates. Estimation of magnitude of interactions from more extensive and sophisticated mathematical models and procedures seems warranted.

INTRODUCTION

Nearly 60 years ago Lush (1931, 1935) emphasized the importance of including a correction factor that described heterogeneity of conditions under which

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different sets of dairy half-sisters were kept, in equations to estimate breeding values of their sires. He symbolized it e^2 and quoted unpublished research from Sewall Wright and other authors; Lush (1931) discussed implications of e^2 for dairy sire proofs.

The extra correlations which paternal half-sisters may share besides a common sire was symbolized c^2 by Bereskin and Lush (1963, 1965). Correlated environmental effects, correlation between breeding values of mates of the sire, correlations between breeding values of the sire and his mates, correlations involving both environmental and genetic effects, distribution of daughters among herd-year-season (HYS) groups, and various adjustments used in computing deviation records were identified by these authors as prominent causes which increased c^2. Until recently, in formulas used by the United States Department of Agriculture to compute Predicted Difference and Repeatability, c^2 of .14, was used (Dickinson *et al.*, 1974, 1976; Norman *et al.*, 1974, 1979; Plowman and McDaniel, 1968). This value was obtained from a nationwide sample of data.

Environmental correlations among paternal half-sisters in the same herd were estimated by Van Vleck (1966), Thomson and Freeman (1970), Arora and Freeman (1971) and Hargrove *et al.* (1981). As recognized by Arora and Freeman, the definition of c^2 has varied and at least five different methods to estimate it can be identified. Four are based on obtaining c^2 as the difference between intraclass correlations among daughters in one herd versus daughters in many herds.

Factors that make sire genetic estimates representative of their genetic transmitting ability were reviewed by Norman (1974), and the role that environmental correlations play was stressed. He identified failure to remove all HYS interaction effects, and the fact that paternal half-sisters might be managed and fed more alike than other cows in the same HYS, as possibly the most important causes of environmental correlation. If paternal half sisters were managed and fed more alike than other cows in the same HYS, their response should be confounded with HYS x sire of cow (SOC) interactions.

Theoretical connotations of treating c^2 as an interaction between environment and SOC were studied extensively by Henderson (1953, 1973). Most analyses to estimate variance components using Henderson (1953) Method 1 found only small values for herd x SOC interaction variance (Legates and Verlinden, 1956; Allaire and Gaunt, 1965; Bereskin and Lush, 1965; Norman *et al.*, 1972). Research by Lee (1976) is the only known attempt to use Henderson (1953) Method 3 to estimate variance components for herd x SOC interaction. This research showed that Method 3 consistently yielded more positive and fewer negative estimates of interaction variance for milk yield (MILKYD) than Method 1. Table I summarizes results obtained by different researchers estimating c^2 using different methods.

Table I - Summary of research on environmental correlations involving milk and fat yields[1].

Authors	Herd. Dev. Rec.		ME Records	
	MILKYD	FATYD	MILKYD	FATYD
Plowman and McDaniel (1968)	.140			
Van Vleck[2] (1966)	.082			
Thomson and Freeman[3] (1970)	.102		.005	
Arora and Freeman[2] (1971)	.016	.036	.014	.046
Arora and Freeman[3] (1971)	-.010	.002	.064	.095
Arora and Freeman[4] (1971)	.016	.024	.059	.068
Arora and Freeman[5] (1971)	.108	.116		
Hargrove *et al.*[4] (1981)	.080	.110		
Legates and Verlinden[6] (1956)			.010	.005
Burdick and McGilliard[6] (1963)			.0	.040
Allaire and Gaunt[6] (1965)			.030	
Norman *et al.* (1979)	.08	.15	-.01	-.05
Lee[6] (1976)			.002	
Lee[7] (1976)			.020	

[1] All estimates based on Holsteins except that Burdick and McGilliard (1963) and Legates and Verlinden (1956) also utilized Guernseys and the latter also utilized Jerseys.

[2] $c^2 = [(\sigma^2_S - \sigma^2_h)/t] - (\sigma^2_S/\sigma^2_t)$

[3] $c^2 = [(h^2/4) + t + c^2] - (h^2/4) - t$

[4] $c^2 = [(h^2/4) + c^2] - (h^2/4)$

[5] $c^2 = \sigma^2_{h(3)}/\sigma^2_s + \sigma^2_{h(3)} + \sigma^2_e$

[6] Method 1 variance component estimate for herd x SOC

[7] Method 3 variance component estimate for herd x SOC

Falconer (1983) mentioned complications that arise in estimating variance components if genotype-environment correlations and/or interactions exist, and how problems can be overcome by assigning these sources of variation to the genotypic and environmental variance. He divided environmental variance into two components $V_E = V_{Ec} + V_{Ew}$. The common environmental variance component V_{Ec} is caused by the common environment that members of a family share and cause similarity between members of the group. V_{Ew} is the within family source of variation, assumed to be transient, truly random error.

If daughters of better sires are given preferential treatment, or a tendency exists to use better sires in better herds, i.e. SOC are not used randomly across HYS, this can be measured through the interaction HYS x SOC. Further, quantification of interactions HYS x sire of fetus (SOF) and SOC x SOF would give useful information about existence of covariances between the main effects. These interactions may be pooled together and would constitute environmental correlation. Interactions of SOF with HYS and SOC and their role in the constitution of c^2 apparently have not been studied. Moya *et al.* (1989) showed in their data set that when the SOF variance components were estimated by themselves, they were smaller than when combined with interactions. This suggested existence of interactions among SOF and HYS, and SOF and SOC. In developing dairy production areas, knowledge of the magnitude of c^2 is required, if such areas are to develop efficient dairy sire proving problems.

For the present research mixed model analyses of variance, incorporating concepts of Henderson (1953) Method 3, and MIVQUEO (Hartley *et al.*, 1978) with comparable models, were used to estimate variance components for HYS x SOC, HYS x SOF, and SOC x SOF. The role of these interactions on the constitution of c^2 was explored.

MATERIALS AND METHODS

Data

Basic data set consisted of 2,241,025 records produced by four major dairy breeds in the Southeastern United States of America. All records that were abnormal, three-times-a-day milking, nondairy breeds for SOC and SOF, missing or invalid values for MILKYD, date of birth, calving date, or breeding date, missing gestation lengths (GESTL), or values shorter than 250 or longer than 300 days and less than four observations for HYS, SOC and SOF categories were eliminated. The latter restriction was arbitrary, with objective of obtaining a large but manageable data set. A subset of 14,147 Jersey records was obtained after screening. Editing procedures and characteristics of data sets were described by Moya *et al.* (1989). By state, numbers of records were: North Carolina, 1984; South Carolina, 5237; Georgia, 2677; Florida, 4249. Analyses for variance components were performed on residuals obtained after adjusting the original lactation records for linear, quadratic and cubic terms of age of cow at parturition and length of record. Models and computing techniques used also were given by Moya *et al.* (1989). Overall there were 1893 main effect classes and 12,716 two factor interaction classes (Moya *et al.*, 1987).

Henderson Method 3

To obtain Henderson Method 3 variance component estimates for first order interactions PROC VARCOMP from SAS 82 (SAS Institute Inc., 1982) computer software system with TYPE1 option (Henderson Method 3) was used. For each run first order interactions were fitted last after the three main effects. Type I Sums of Squares (Sequential Sums of Squares) provided by SAS 82 for these models are in Table II. Thus σ^2_{AB}, σ^2_{AC} and σ^2_{BC} were obtained. The summation of variance components of main effects obtained by Moya *et al.* (1989), first order interactions obtained here, and the residual, in a model fitting main effects and all first order interactions, were considered to equal total variance. The residual variance was computed directly from filled ABC cells as $\{y'y = R(\mu, ABC)\} \div (N\text{-}s)$ where s = number of cells.

Table II - Type I sums of squares (SS) in reduction SS notation to estimate interactions.

Effect[1]	Type I SS		RSS
A	$R(A\|\mu)$		$R(\mu, A) - R(\mu)$
B	$R(B\|\mu, A)$		$R(\mu, A, B) - R(\mu, A)$
C	$R(C\|\mu, A, B)$		$R(\mu, A, B, C) - R(\mu, A, B)$
AB	$R(AB\|\mu, A, B, C)$		$R(\mu, A, B, C, AB) - R(\mu, A, B, C)$
		or	
AC	$R(AC\|\mu, A, B, C)$		$R(\mu . A, B, C, AC) - R(\mu, A, B, C)$
		or	
BC	$R(BC\|\mu, A, B, C)$		$R(\mu \|, A, B, C, BC) - R(\mu, A, B, C)$

[1] A = herd-year-season, B = sire of cow, C = sire of fetus.

MIVQUEO

The use of MIVQUEO (Hartley *et al.*, 1978), which considered zero as a prior estimate of the variance components to be estimated, was reasonable given the small magnitude of the variance components expected for these interactions. Variance components for first order interactions were calculated in a manner similar to that for Method 3. PROC VARCOMP from SAS 82 again was used, but in this case with the MIVQUEO option. Total variances were estimated in the same manner as for Method 3 estimates.

RESULTS AND DISCUSSION

Estimates of variance components for first order interactions among HYS, SOC and SOF and total variance by states are presented in Tables III and IV. Comparing these results with those obtained with Henderson Method 1 and MIVQUEO with comparable models obtained by Moya *et al.* (1989), it is apparent that values obtained here for first order interactions tended more often to be positive, and lower in absolute value. These values agreed with findings reported by Lee (1976) for the interaction herd x SOC.

Tabela III - Mixed model analyses of variance estimates of variance components for first order interactions of herd-year season (HYS), sire of cow (SOC) and sire of fetus (SOF), by state.

Effect	Milk yield	Fat yield	Fat%	Days open	Gestation length
North Carolina					
HYS x SOC	-45414	-254	-.000003	93	.50
HYS x SOF	64471	16	.000001	67	2.34
SOC x SOF	-72276	-393	.000000	165	.53
Total	2666909	6996	.000027	2672	28.12
South Carolina					
HYS x SOC	19667	219	.000001	89	1.01
HYS x SOF	68685	477	.000001	-19	.86
SOC x SOF	-3684	373	.000001	132	1.62
Total	3488569	8870	.000028	2931	29.53
Georgia					
HYS x SOC	23944	-275	.000003	-37	2.76
HYS x SOF	594253	480	.000009	123	-.41
SOC x SOF	479893	180	.000006	23	.75
Total	3762771	13915	.000109	2798	31.26
Florida					
HYS x SOC	120118	459	.000002	129	1.02
HYS x SOF	313119	599	.000004	-66	1.36
SOC x SOF	62409	525	.000003	223	.07
Total	3794561	8492	.000058	3314	32.53

Table IV - Mixed model MIVQUEO estimates of variance components for first order interactions of herd-year-season (HYS), sire of cow (SOC) and sire of fetus (SOF), by state.

Effect	Milk yield	Fat yield	Fat	Days open	Gestation length
North Carolina					
HYS x SOC	-6097	-103	-.000002	77	.25
HYS x SOF	43178	29	.000001	37	1.97
SOC x SOF	39666	-75	.000001	54	.53
Total	2522457	6310	.000026	2558	29.27
South Carolina					
HYS x SOC	-46858	39	-.000000	17	.30
HYS x SOF	66177	229	.000001	13	.20
SOC x SOF	19979	146	-.000000	-4	.32
Total	3175000	7518	.000023	2895	29.64
Georgia					
HYS x SOC	-2509	-259	.000001	-28	.85
HYS x SOF	33590	137	.000003	-21	-.58
SOC x SOF	152944	142	.000002	-25	.40
Total	3571941	10850	.000069	2713	32.44
Florida					
HYS x SOC	6250	45	.000000	42	.73
HYS x SOF	81223	167	.000001	-38	.52
SOC x SOF	-1030	-17	.000000	108	.19
Total	3571941	6676	.000041	3179	32.47

Henderson Method 3 variance components for the interactions HYS x SOC, HYS x SOF, and SOC x SOF expressed as percentage of the total variance by state are presented in Table V. Results are summarized using arithmetic means of state percentages and weighted means, using the number of observations in each state as weighting coefficients. Negative estimates were averaged as such, and not considered to be zero.

All weighted means of first order interaction, for production and as well as reproduction traits, were small and positive (.4 to 6.5%). The low values obtained in this research for the interaction HYS x SOC in milk yield using Henderson Method

3 (1.1%) agreed with values for the interaction herd x SOC obtained by Lee (1976) using Method 3, and other authors using Method 1.

Table V - Mixed model analyses of variance estimates of percentage of total variation associated with two factor interactions of herd-year-season, sire of cow, and sire of fetus, by state.

State	Milk yield	Fat yield	Fat%	Days open	Gestation length
			Herd-year-season by sire of cow		
North Carolina	-1.7[1]	-3.6	-12.1	3.5	1.8
South Carolina	.6	2.5	4.4	3.0	3.4
Georgia	.6	-2.0	3.6	-1.3	8.8
Florida	3.2	5.4	4.9	3.9	3.1
Arithmetic mean	.7	.6	.2	2.3	4.3
Weighted mean[2]	1.1	1.7	2.1	2.5	4.1
			Herd-year season by sire of fetus		
North Carolina	2.4	.2	3.7	2.5	8.3
South Carolina	2.0	5.4	5.7	-.6	2.9
Georgia	15.8	3.4	8.9	4.4	-1.3
Florida	8.2	7.1	7.1	-2.0	4.2
Arithmetic mean	7.1	4.0	6.4	1.1	3.5
Weighted mean	6.5	4.8	6.4	.4	3.3
			Sire of cow by sire of fetus		
North Carolina	2.7	-5.6	1.1	6.2	1.9
South Carolina	-.1	4.2	4.8	4.5	5.5
Georgia	12.8	1.3	5.9	-.8	2.4
Florida	1.6	6.2	5.5	6.7	.2
Arithmetic mean	2.9	1.5	4.3	4.1	2.5
Weighted mean	2.5	2.9	4.7	4.4	2.8

[1] Expressed as percentage of total variance.

[2] Weighting factor was number of observations.

MIVQUEO for HYS x SOC, HYS x SOF, and SOC x SOF are presented in Table VI. The weighted means for these variance components for first order interactions were similar to those obtained with Henderson Method 3 and followed the same trends, but they tended to be slightly smaller and some were negative (-.8 to 3.7%) and SOC x SOF (2.5 to 4.7% and .7 to 1.4%) tended to be slightly larger or more positive than those of HYS x SOC (1.1 to 4.1% and -.8 to 1.7%) even though they also were small.

Table VI - Mixed model MIVQUEO estimates of percentage of total variation associated with two factor interactions of herd-year-season, sire of cow, and sire of fetus, by state.

State	Milk yield	Fat yield	Fat%	Days open	Gestation length
			Herd-year-season by sire of cow		
North Carolina	.2[1]	-1.6	-7.7	3.0	.9
South Carolina	1.5	.5	0	.6	1.0
Georgia	-.1	-2.4	1.4	-1.0	2.6
Florida	.2	.7	0	1.3	2.3
Arithmetic mean	.4	.7	-1.6	1.0	1.7
Weighted mean[2]	.5	.4	.8	.8	1.7
			Herd-year-season by sire of fetus		
North Carolina	1.7[1]	.5	3.8	1.4	6.7
South Carolina	2.1	3.0	4.3	.5	.7
Georgia	.9	1.3	4.3	-.8	-1.8
Florida	2.2	2.5	2.4	-1.2	1.6
Arithmetic mean	1.7	1.8	3.7	0	1.8
Weighted mean[2]	1.8	2.2	3.7	-.1	1.3
			Sire of cow by sire of fetus		
North Carolina	1.6[1]	-1.2	3.8	2.1	1.8
South Carolina	.6	1.9	0	-.2	1.1
Georgia	4.3	1.3	2.9	.9	1.2
Florida	0	-.3	0	3.4	.6
Arithmetic mean	1.6	.4	1.7	1.6	1.2
Weighted mean[2]	1.3	.7	1.1	1.4	1.1

[1] Expressed as percentage of total variance.

[2] Weighting factor was number of observations.

As discussed by Moya *et al.* (1989), Henderson Method 3 variance components estimated for SOF pooled together with HYS x SOF, SOC x SOF, and HYS x SOC x SOF were larger than the variance components for SOF alone. This result suggested existence of sizable interaction among HYS, SOC and SOF. Differences between Method 3 variance components for SOF alone and SOF confounded with interactions, expressed as percentage of the total variance, were 4.3, 8.5, 4.2, 8.7 and 2.6% for MILKYD, fat field (FATYD), fat%, days open (DAYSOP) and GESTL weighted means. Summing Method 3 variance components for interactions HYS x SOF and SOC x SOF resulted in estimates of 9.0, 7.7, 11.1, 4.8 and 6.1%. Differences between these two sets of values may be attributed to the variance components for the three factor interaction, HYS x SOC x SOF.

Summation of variance components for first order interactions among HYS, SOC and SOF expressed as percentage of the total variation, is an estimate of environmental correlation c^2. Values obtained for the summation of Method 3 variance components for the three first order interactions were 10.1, 9.4, 13.2, 7.3 and 10.2% for MILKYD, FATYD, FAT%, DAYSOP and GESTL weighted means. Summation of MIVQUEO values for the same effects were 2.6, 2.5, 4.0, 2.1 and 4.1%.

During the present research, efforts were made to take into consideration the highly sparse nature of the data set. Nevertheless, future research oriented to obtaining mixed model estimates of c^2 in connected data sets, and studies of effects of disconnectedness on the estimates, would be of great importance. More sophisticated procedures, e.g. REML, as well as information from relatives doubtless are warranted.

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RESUMO

Dados de produção e reprodução em gado Jersey (n = 14, 147) de quatro Estados do Sudeste dos EUA foram analisados para estimar o grau de interação dos dois fatores envolvendo (A) rebanho-ano-estação, (B) pai da vaca e (C) pai do feto. Cada interação foi estimada individualmente segundo um modelo contendo somente A, B e C, uma vez que a capacidade do programa não permitiu solução para modelos maiores. Havia um total de 1893 classes de efeitos principais e 12.716 classes de interação de dois fatores. As análises estatísticas foram realizadas através da metodologia de modelo misto (método 3 de Henderson) e da estimação da variância mínima quadrática ("zero prior"). As estimativas expressas como uma porcentagem do total, nos dois procedimentos, para produção de leite, produção de gordura, % de

gordura, período de serviço e duração da gestação foram, respectivamente: AB: 1,1 e 0,5; 1,7 e 0,4; 2,1 e 0,8; 2,5 e 0,8; 4,1 e 1,7; AC: 6,5 e 1,8; 4,8 e 2,2; 6,4 e 3,7; 0,4 e -0,1; e 3,3 e 1,3 e BC: 2,5 e 1,3; 2,9 e 0,7; 4,7 e 1,1; 4,4 e 1,4 e 2,8 e 1,1. AB é uma definição comum da correlação ambiental e as estimativas para produção de leite e gordura foram menores do que algumas estimativas prévias. A estimativa da magnitude das interações através de modelos e procedimentos matemáticos mais extensos e sofisticados parecem estar corretas.

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