Estimates of GxE Effects for Economic Efficiency among Daughters of Canadian and New Zealand Sires in Canadian and New Zealand Dairy Herds

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Summary

The existence of genotype by environment interaction (GxE) was tested for economic efficiency, first lactation and mature weight among daughters of Canadian and New Zealand sires in Canadian and New Zealand herds. The economic efficiency traits were evaluated using both British Columbia fluid milk pricing and Ontario component pricing systems for Canada and the New Zealand component pricing system for that environment. The GxE was tested at the macro level (strain by environment) and at the micro level (sires within strain by environment). Among economic efficiency traits a significant macro GxE was found only for lifetime economic efficiency when using the British Columbia milk payment system for Canada. Only protein yield and percentage, among the production traits, had significant GxE at the macro level. At the micro level significant GxE were found for all economic efficiency traits for both sire strains. Significant interactions were also found for first lactation yield traits among Canadian bulls. These later results indicate that sires rank differently in the two environments tested and that breeding values estimated in one production system may not be good predictors of merit in the other.

Introduction

The importation of germplasm, be it in the form of semen, embryos, or live animals, serves to broaden the existing genetic base. Regardless of this, however, the daughters of imported sires have to be competitive and indeed comparable to the daughters of native sires in their performance particularly in terms of their economic efficiency. Economic efficiency is a value trait or combination of many characteristics into a holistic value of the individual animal's genotype. To justify the importation of germplasm, the resulting progeny should be equally, if not more, profitable than daughters of local sires.

Currently dairy cattle are evaluated genetically for individual traits or for an index base on conditions in the production environment where the genetic evaluation is done. The existence of a genotype by environmental interaction (GxE) for a simple trait such as protein yield means that an individual may be genetic superiour in one environment but only average or below in a different production system. Economic efficiency, arguably the most important trait, is a composite value based on other individual traits (e.g., production, longevity, etc.). This complex trait may have important GxE even when the individual sub-traits that make up the holistic value do not show a GxE (Namkoong, 1985).

The objective of this study was to test for macro and micro GxE interactions between Canadian and New Zealand AI sires in the Canadian and New Zealand production environments.

Materials and Methods

The data used in this study were from the Canadian B New Zealand Genotype x Environmental Interaction Trial (CANZ Trial), (Peterson, 1988). The trial involved mating 20 Canadian and 20 New Zealand Holstein sires to cows in 20 New Zealand and 10 Canadian herds in a factorial arrangement. Project sires were selected from available proven AI bulls in the two countries. Lifetime production records were obtained from national milk recording agencies in Canada and New Zealand. In Canada, live animal weights were available from birth to first calving and through the course the first and later lactation (a minimum of 11 weights). In New Zealand, weights were recorded at birth and at approximately at 6, 12 and 30 months of age. After all edits the data contained 596 lactation records from 250 animals in 6 herds in Canada and 2811 lactations from 670 cows in 19 New Zealand herds. Strain of sire (Canada or New Zealand), sires within group and production environment (Canadian or New Zealand herds) provide the contrasts to test for a GxE for economic efficiency.

Two economic efficiency traits were developed for this study: economic efficiency to the end of lactation one (PF_1), and lifetime economic efficiency (PF_L).

$$PF_k = \$R_k/FR_k$$

$\$R_k$ is the dollar value of milk produced by a given cow over period k (1st lactation or lifetime). This is simply the milk, fat and protein yield from the official milk recording agency times the milk price used in the production environment. New Zealand uses a component price system based on fat and protein volume. Two milk payment systems were used for the Canadian environment to contrast the fluid milk market of British Columbia (BC) and the mixed manufacturing and fluid market of Ontario (ON). The BC system is based on volume plus a differential for fat content and ON uses a component pricing system of fat, protein and other solids. All prices used in this study were from 1995/96. FR_k is the energy cost in Mcal for a cow over period k. This was estimated as the sum of the metabolizable energy for maintenance, growth, pregnancy and milk production. The estimation of energy required for maintenance and growth were based on the growth curves of individual animals estimated from live animal weights. The Von Bertalanffy (1957) model was used to estimate the growth curve and mature weight of individual animals. Refer to Charagu (1997) for details on the growth curve, estimation of energy requirements and milk prices used in this study.

The GxE interactions were considered at two levels, macro and micro. GxE at the macro level was estimated by the interaction between strain and production environment and at the micro level the interaction between sire within strain and production environment. The existence of a GxE interaction at the macro level is explained by changes in the ranking of strains or magnitude of differences between strains in different environments. The micro GxE is the same except the interest is at the individual genotype level (sire) rather strain of sire.

The interactions relevant to GxE were tested using a General Linear Model (GLM) procedure. The model was Environment (Canadian or New Zealand herds), Herd within Environment, Strain (Canadian or New Zealand sire), the interaction between Strain and Environment, Sire within Strain, the interaction between Sire within Strain and Environment and Error. Sire within Strain and Error effects were assumed to be random effects and all other effects in the model were assumed fixed.

The presence of a micro GxE was further evaluated by testing the product moment correlations between breeding values of project sires estimated in the two environments. These correlations were tested against the expected values using the method given by Calo *et al.* (1973) and further developed by Bar-Anan *et al.* (1987). The breeding values were estimated for economic efficiency, production and mature weight within production environment using DFREML (Meyer, 1991) with the animal model $\mathbf{y} = \mathbf{Xb} + \mathbf{Za} + \mathbf{e}$. Where **b** is a vector of fixed herd and strain of sire effects, **a** is a vector of additive genetic values, **e** is a vector of errors and **X** and **Z** are design matrices of fixed and random animal effects.

Results and Discussion

Genotype by environment interaction at the macro level

The results from the GLM analyses are give for production traits in Table 1 and for economic efficiency and mature weight in Table 2. The least square means (within strain and environment) for all traits are given in Table 3. The Strain x Environment interaction was significant for first lactation protein yield and percent and for $PF_{L(BC)}$, (lifetime economic efficiency using BC prices for the Canadian environment). This indicates that a macro GxE was found for these traits but not for mature weight, other measures of economic efficiency or other first lactation traits.

Table 1. Analysis of variance (R^2 x 100) for first lactation yield and percentage traits.

	df	1st Lactation Yield and Percentage Traits				
		Milk	Fat	Protein	%Fat	%Protein
Strain of sire	1	1.1*	0.0+	0.0+	5.2*	5.1*
Sire (Strain)	38	7.3*	7.9*	7.5*	10.4*	11.6*
Environment	1	57.9*	45.7*	57.6*	23.8*	0.0+
Herd (Env.)	23	4.3*	7.8*	4.9*	8.9*	14.1*
Strain*Env	1	0.0+	0.0+	0.0+*	0.0+	0.0+*
Env*Sire (Strain)	38	2.5*	4.0*	2.8*	4.2*	2.4
Model	103	89.1*	85.1*	90.3*	52.7*	34.1*
Error	774					

* Effect significant at $P < 0.05$.
Env. = Environment

The existence of a significant Strain by Environment interaction for lifetime economic efficiency with BC but not Ontario prices implies that GxE can result the pricing system alone indicating this is an important component of the production environment. The lack of GxE using the Ontario pricing system could be due to the similarity of the system to that used in New Zealand as both are component pricing based on protein and fat volume. The significant interactions in yield and percentage of protein were due to the relatively large differences between the two strains in the New Zealand environment where Canadian sired cows produced more protein but at a significantly lower percentage. In Canada, on the other hand, there were no differences between the two strains. It was therefore due to a change in the magnitude of the difference between strains rather than a switching of ranks.

Table 2. Analysis of variance (R^2 x 100) for mature weight and economic efficiency traits.

	df	Weight	$PF_{1(ON)}$	$PF_{1(BC)}$	$PF_{L(ON)}$	$PF_{L(BC)}$
Strain of sire	1	0.0+*	0.0+	0.0+	0.0+	0.0+
Sire (Strain)	38	5.4*	6.1*	6.2*	6.9*	7.2*
Environment	1	50.7*	87.8*	88.6*	86.9*	87.5*
Herd (Env.)	23	7.9*	0.0+*	0.0+*	0.0+*	0.0+*
Strain*Env	1	0.0+	0.0+	0.0+	0.0+	0.0+*
Env*Sire (Strain)	38	4.5*	0.0+*	0.0+*	0.0+*	0.0+*
Model	103	69.4*	95.4*	96.1*	95.3*	96.1*
Error	774					

$PF_{k(ON)}$ and $PF_{k(BC)}$ economic efficiency use ON and BC milk prices, respectively, for the Canadian environment and New Zealand prices in New Zealand.
* effect is significant at $P < 0.05$
Env. = Environment

Table 3. Least squares means of project animals for first lactation yields, mature weight and economic efficiency within strain of sire and production environment.

	Canadian Herds		New Zealand Herds	
	Strain of Sire		Strain of Sire	
Traits	CN	NZ	CN	NZ
Milk (kg)	6254* (85)	6151 (94)	3755* (85)	3491 (51)
Fat (kg)	216 (3)	222 (4)	151 (2)	149 (2)
Protein (kg)	200 (2)	204 (3)	120* (1)	116 (2)
Fat %	3.50* (.04)	3.65 (.05)	4.08* (.03)	4.37 (.03)
Protein %	3.23 (.02)	3.27 (.03)	3.20* (.01)	3.33 (.01)
Mature Wt. (kg)	652* (10)	628 (12)	429* (5)	416 (5)
$PF_{1(ON)}$ ($/1000 Mcal)	235 (1)	236 (1)	-	-
$PF_{1(BC)}$ ($/1000 Mcal)	264 (1)	262 (2)	-	-
$PF_{1(NZ)}$ ($/1000 Mcal)	-	-	119 (1)	120 (1)
$PF_{L(ON)}$ ($/1000 Mcal)	234 (1)	234 (1)	-	-
$PF_{L(BC)}$ ($/1000 Mcal)	268* (1)	263 (2)	-	-
$PF_{L(NZ)}$ ($/1000 Mcal)	-	-	120 (1)	122 (1)

* differences between strain means significant at P # .0.05
(nn) standard error
$PF_{k(ON)}$, $PF_{k(BC)}$ and $PF_{k(NZ)}$ are based on ON, BC and New Zealand milk prices, respectively and are in $/1,000 Mcal units

There was no evidence of strain by environment (macro GxE) interaction in any of the remaining yield and profit traits and neither was there an interaction for mature weight. This means, generally, the differences between the two strains remained consistent across the two environments. Thus, even though, the populations have been selected for different goals, the New Zealand strain for fat and the Canadian for milk, and under different production environments, this did not create a GxE at the macro level.

Genotype by environment interaction at the micro level

Economic efficiency traits did show significant micro GxE based on the significant Sire (Strain) by Environment interaction in the GLM analyses, Table 2. The correlations between breeding values of sires measured in different environments (Table 4) were all significantly different from expected, except for $PF_{1(ON)}$ with Canadian sires. This means that sires within strain ranked differently in the Canadian environment than they did in New Zealand for economic efficiency. Note that, in general, the strains did not change order but sires within strain did. First lactation traits and mature weight also showed a significant Sire (Strain) by Environment interaction (Tables 1 & 2) suggesting a micro GxE. However, based on the correlations (Table 4), Canadian sires changed rank only for yield traits and New Zealand sires only for Fat % and neither sire group re-ranked with respect to mature weight. The implications are that the rank of sires based on proof in their native production system may not be appropriate for different environments.

Bar-Anan *et al.* (1987) also reported a GxE in daughter milk yield of New Zealand sires when tested in both New Zealand and Israel. Working with the same CANZ data set used in this study, Peterson (1991) found evidence of GxE at the micro level for first lactation milk, fat and protein yields adjusted for length of lactation.

Table 4. Product moment correlation (R) between breeding values of project sires estimated in Canadian and New Zealand production environments for each of the traits studied.

Traits	Canadian Sires R	Canadian Sires [1]E(r)	New Zealand Sires R	New Zealand Sires [1]E(r)
Milk (kg)	-0.18*	0.29	0.39	0.25
Fat (kg)	-0.04*	0.34	0.34	0.31
Protein (kg)	-0.08*	0.33	0.43	0.29
Fat %	0.40	0.52	0.09*	0.48
Protein %	0.26	0.42	0.41	0.38
Mature Wt. (kg)	0.45	0.55	0.19	0.50
$PF_{1(ON)}$, $PF_{1(NZ)}$	-0.03	0.26	-0.13*	0.24
$PF_{1(BC)}$, $PF_{1(NZ)}$	-0.18*	0.30	-0.15*	0.27
$PF_{L(ON)}$, $PF_{L(NZ)}$	-0.04*	0.38	-0.26*	0.35
$PF_{L(BC)}$, $PF_{L(NZ)}$	-0.07*	0.33	-0.12*	0.30

[1]E(r) is the expected value of the correlation (R).
*Correlations (R) significantly different from E(r) (P # 0.05).
$PF_{k(ON)}$, $PF_{k(BC)}$ and $PF_{k(NZ)}$ are based on Ontario, BC and New Zealand milk prices, respectively

In this study, economic efficiency which is a value (composite) trait, did exhibited a strain x environment interaction, at least with the BC system of milk pricing. Among the traits involved in the computation the composite trait, namely milk, fat and protein yields and body weight, only protein yield displayed an important interaction. The phenomenon postulated by Namkoong (1985) that even though individual traits might fail to show any GxE interaction, such an interaction might be exhibited by a value composite trait that is derived from a combination of several individual traits which individually do not exhibit any G x E.

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