Genotype by environment interaction for milk yield of Canadian Holstein Friesian on large scale dairy farms in Malawi

Mizeck G. Chagunda[1,3], Erich W. Bruns[1], John M. King[1,2], Clemens B. A. Wollny[3]

[1]Institute of Animal Breeding and Genetics and [2]Institute for Crop and Animal Production in the Tropics and Sub Tropics, Georg-August-University of Göttingen, Germany
[3]Department of Animal Science, Bunda College of Agriculture, University of Malawi.
email: mchagun@gwdg.de, ebruns@gwdg.de, ClemensWollny@malawi.net

Abstract

The importance of genotype by environment interaction on milk yield of Holstein Friesian cows performing on large scale farms in Malawi was investigated. Genetic parameters of 130 sires whose daughters have production records both in Malawi and Canada were utilized in the study. Malawian data comprised 1651 lactation-yield milk records of Holstein Friesian cows performing on large scale dairy farms. The average first lactation milk yield was 3119.21 kg (SD = 1027.81). (Co)variance components were estimated through the restricted maximum likelihood (REML) procedure. Genetic correlation for milk yield between the two populations was derived from the estimated correlation of breeding values of the sires. The heritability estimate for milk yield in Malawian population was lower than for the Canadian population (0.16 vs 0.30) suggesting a relatively high influence of environmental factors on Malawian milk production. Genetic correlation for milk yield in the two countries was estimated as 0.44. Also, the ranking of sires based on their daughters' performance in Malawi significantly ($p<0.05$) differed from the ranking in Canada indicating a substantial genotype by environment interaction. Concluding, there is need to revise the breeding strategy to find the most suitable bulls for the production system in Malawi.

***Key words**: Genotype by environment interaction, Holstein Friesian, Canada, Malawi*

Introduction

The commercial dairy industry in Malawi is located in the cool, semi-arid, tropical highlands. In the last two decades, dairy cattle management has been oriented towards increasing milk yield per animal. One element in this process has been the dependence for the breeding policy on Holstein Friesian bull semen from the temperate, continental region of Canada. A concern about such a breeding strategy is the possible existence of an interaction between genotype and environment. This kind of interaction can have implication on the selection and use of bulls as it leads to reranking of bulls in different countries. Genotype by environment interaction , is reflected by differential expression of genotypes over environments (Mathur and Horst, 1994). As described by Stanton et al. (1991), and Ron and Hillel (1993), in this respect the term environment does not only comprise the physical and climatic factors but also the production and health management, the economic constraints, the prevailing agricultural policies, and / or a combination of these. Numerous studies on genotype by environment interaction have previously been done. These studies can be grouped as: a) interaction between genotype and environment in different management systems (or regions) within the same country (Carabano et al., 1990; Sahota and Gill, 1991; Swalve et al., 1993); b) genotype by environment interaction between countries in the same ecological zone (Petersen, 1975; Georgoudis et al, 1994); and c) genotype by environment interaction between countries in different ecological zones (Stanton et al., 1991; Brown et al, 1981; Rorato et al, 1992). Results from different studies, however have been inconsistent, suggesting that genotype by environment interaction should be investigated in different situations according to prevailing conditions.

The assumption in the large scale dairy farms in Malawi is that the environment is sufficiently similar to that of Canada, that genotypes selected in Canada will perform equally well in Malawi. To test this hypothesis the genotype by environment interaction on milk yield of Holstein Friesian cows on large scale farms in Malawi was investigated.

Materials and Methods

Data source and environment

Data were collected from the three farms belonging to the then parastatal organization, Malawi Dairy Industries (MDI). Katete and Capital Hill dairy farms are situated about 8 km west and 12 km east of Lilongwe in the central region of Malawi respectively. Ndata Farm is situated about 35 km to the south-east of Blantyre in the Southern region of Malawi. With the altitude that ranges from 52 to about 1632 m above sea level (in the arable region), Malawi lies between latitude 9°S and 17°S and longitude 32° 42’E and 36° 36’E. During the period for which data was corrected (1986 to 1996) the mean annual temperature in the study locations was 21°C. The warmest month was November, with an average maximum temperature of 29.5°C with the standard deviation (SD) of 1.9 and the coolest was July with the average maximum temperature of 22.8°C SD 1.1. The highest average minimum temperature of 18.4°C SD 0.9 was in December while the lowest average minimum temperature of 10.1°C SD 1.8 was in July. The rainfall pattern is unimodal, confined to the period from early November to April and peaks in January. The rainfall data from July, 1986 to June , 1997 ranged from 540.7 to 1719.2 mm per year. According to Trail and Gregory (1984), this area is categorised into the semi-arid to humid, tsetse-free ecological zone. The three dairy farms were established under the Malawi Canada Dairy Development Project to provide Malawi with a foundation herd of Holstein Friesians.

In all the three farms, herd management was basically the same. The herds were rotationally grazed on a predominantly *Chloris gayana* pasture during the wet season and kept in free-stalls during the dry season. In the free-stall, an *ad libitum* supply of *Chloris gayana* and *Zea mays* silage for the dry cows and heifers, and cows-in-milk respectively was offered. Concentrate supplementation was done during milking at the rate of 1 kg of feed for every 2.5 kg of milk produced. The crude protein in this concentrate ranged from 18 to 21 %. Dry cows were offered the concentrate at 4 kg a day. The cows were machine-milked twice a day. Milk yield was recorded once every week during both milking times on the recording day. Todate, individual cow’s milk components like protein and butter fat content are not recorded. Calves were separated from their dams one or two days after birth and bucket fed until weaning. Neither the calves nor the cows were weighed routinely. All heifers raised in the herd except for a few with poor growth, were retained for breeding consequently milk production. Low yielding and infertile cows were culled. Herd health practices included regular dipping in acaricide, vaccination, drenching and treatment for mastitis and other illnesses.

Data

The initial data set of 1651 records of lactation one to three from three large scale farms of Katete, Capital Hill and Ndata in Malawi was utilised. Records were of animals calving between 1986 and 1996. Seasons of calving were defined as Hot-Wet (December to April), Cold-Dry (May to August) and Hot-Dry season (September to November). Lactation milk yield, represented by the standard 305-day milk yield were computed from weekly milk records. The following categories of records were not included in the analysis: cows having less than 19 months and more than 49 months age at first calving, lactation yield less than 499 and more than 8000 kg; and cows with both parents missing. Only first lactation data were included for analysis. After editing, the data set had 730 first lactations cows whose sires had daughters in both Malawi and Canada. Table 1 provides the structure of the data.

Table 1: Some descriptive statistics for lactation yield, lactation length, age at first calving, and calving interval of Holstein Friesian cows at large scale dairy farms in Malawi (raw data)

Trait	Mean	SD	CV %
305d Milk yield (kg)	3119.21	1027.81	32.95
LL (days)	289.00	76.56	26.49
AFC(mo)	30.34	4.99	16.45
CI (days)	399.37	76.39	19.13

SD = standard deviation, CV = coefficient of variation, LL = lactation length, AFC = age at first calving,
CI = calving interval, n = 730

Analysis

Initially, data were subjected to analysis of variance in order to determine the non-genetic factors affecting the lactation milk yield using the GLM procedure of SAS. The fixed factors included in the mixed model for analysis were: herd effect, year of calving and season of calving. Age at first calving was included as a covariate.

(Co)variance components for milk yield within and among parities were estimated through restricted maximum likelihood (REML) procedure in an animal model using VCE 4.2 (Groeneveld, 1998). Genetic correlation between some traits and also between milk yield for different lactations were obtained. Since season of calving showed no significant effect ($P>0.05$) in the initial analysis, it was not included in the model for analysis to determine (co)variance components. The model equation used for the analysis was:

$$Y_{ij} = \mu + b(AC) + HY_i + a_j + e_{ij}$$

where:

Y_{ij}	=	305-day milk yield of cow j within the i^{th} herd-year class in the first parity
μ	=	overall population mean;
$b(AC)$	=	age at calving as a covariate with b being the linear regression coefficient
HY_i	=	herd-year class
a_j	=	random additive genetic effect of cow j, $a_j \sim N(0,A\sigma_a^2)$; A is the additive genetic relationship matrix
e_{ij}	=	random residual (error) effects, $e_{ij} \sim N(0,A\sigma_e^2)$;

Heritability was determined as the ratio of additive genetic variance (σ_A^2) to the total variance (σ_P^2). Breeding values were determined as estimates ($\hat{a}_j$) of the random additive genetic effects of cow (a_j). Product-moment correlation was calculated as described by Mathur and Horst (1994) between breeding values of sires estimated from the Malawi data set and those obtained from Holstein Canada. Genetic correlation was then calculated as:

$$r_g = r_{\hat{A}1\,\hat{A}2} \;/\; t_1 t_2$$

where, r_g is the genetic correlation; $r_{\hat{A}1\,\hat{A}2}$ is the correlation between Malawian and Canadian breeding values; and t_1t_2 is the product of the accuracy of prediction for the two sets of breeding values. Ranking of the sires was done using the ranking procedure of SAS.

Results and Discussion

Generally, milk yield on the farms included in the curent study, was lower (Table 1) than that of Holstein Friesian cows in the same region. For example, Wollny et al. (1989) reported an average of 5589 kg per cow per year in a study done on one farm in Southern Malawi, while Makuza and Mc Daniel (1996) reported an average of 4791kg for first lactation cows in

Zimbabwe.Estimates of variance components and the heritability values after the rounds or iteration had reached convergence are in Table 2.

Table 2.: Variance components and heritability values for some traits of Holstein Friesan cows on large scale farms in Malawi

Trait	SD_{adj}	σ^2_A	σ^2_{error}	h^2	SE
Milk yield (kg)	706.75	421663.21	77836.23	0.16	0.058
LL (days)	60.41	50.31	3598.74	0.02	0.041
AFC(mo)	3.93	3.03	12.40	0.20	0.062

SD_{adj} =adjusted standard deviation, σ^2_A = additive genetic variance, σ^2_{error} = residual (error) variance,
h^2 = heritability, SE = standard error, LL = lactation length, AFC = age at first calving

The heritability estimate for milk in the Malawian population (0.16 with standard error (SE) of 0.06) was smaller than reported estimates in the Canadian population. However, Malawian estimate is slightly lower than the estimate of 0.21 (SE = 0.04) (Wollny et al., 1998) in a study at one private large scale farm in Malawi; Makuza and Mc Daniel (1996) (0.35); and 0.32 by Rege, (1991) in Zimbabwe and Kenya respectively. However, the estimate in the current study agree with those reported by Carabano et al. (1989) of 0.16 for a Spanish Holstein Friesian population. A possible explanation for the small heritability estimate for the Malawian population is the relatively high influence of environmental conditions related to management and nutrition on milk yield. These influences limit the expression of genetic potential of superior cows hence restricting differences in yield due to genetic value among animals (Carabano, et al., 1989). The other reason could also be due to less accurate pedigree recording which contributes to lower estimates of genetic variance. This difference between Malawian and Canadian heritability estimates was, however, taken into consideration when calculating the genetic correlation between the two countries by accounting for the accuracy of estimation in the formula. Genetic correlation between milk yield in lactation 1 and 2 was 0.17 with the standard error (SE) of 0.63 and that between first lactation milk yield and lactation length was 0.724 (SE = 1.88).

There was quite difference in the range of the estimated breeding values of the sires (Table 3). There was a wider range in the breeding values estimated using Canadian daughters (-2225 to 1788) as compared to those from Malawian daughters (–350 to 223). The mean from Canada was large but negative (-619.43, SD = 870.01) while that in Malawi was small but positive (0.93, SD = 94.15). Although these are old bulls with current breeding values, the smaller range of the Malawian breeding values as compared to the Canadian ones, reflects the less genetic variation available in the Malawian herd, an attribute of the high influence of the non genetic factors on milk yield. The large average difference between Malawian breeding values and Canadian breeding values for the same sires (620, SD = 866.05) demostrates the differences in ranking the sires would obtain in the two environments.

Table 3.: Means, standard deviations and ranges of the estimated breeding values for milk yield (kg) of the sires with daughters in Malawi and Canada

Variable	Mean	SD	Min	Max
Can. EBVs	-619.43	870.01	-2225	1788
Mal. EBVs	0.93	112.54	-351	348
EBV difference	620.36	866.05	-1715	2255

number of sires = 130, SD = standard deviation, Can EBVs and Mal EBVs = Canadian and Malawian estimated breeding values respectively, EBV difference = Mal EBV minus Can EBV

The correlation coefficient of Malawian and Canadian estimated breeding values was relatively low (0.096) leading to the low genetic correlation of 0.44. This is substantially less than 0.8 , the genetic correlation below which Robertson (1959) suggested that genotype by environment interaction is of biological and agricultural importance. This indicates a different genetic basis for milk yield in Malawi and Canada, showing a significant genotype by environment interaction. Ranking of sires in Malawi was significantly ($p<0.05$) different from the ranking in Canada indicating that the top ranking bulls in Canada are not necessarily the best for the Malawian conditions in as far as milk yield is concerned.

Conclusion

Estimates of genetic correlation for Holstein Friesian milk between Malawi and Canada was relatively low and the ranking of the sires significantly different, suggesting a substantial genotype by environment interaction. There is need therefore, to revise the breeding strategy to find the most suitable bulls for the production system in Malawi.

The low levels of performance in the studied herds compared to those of Holstein friesians in other herds within and outside Malawi indicate that considerable improvement could be achieved by improving the production environment. Need is therefore, apparent to identify the most effective management practices to circumvent the environmental constraints on genetic expression of yield in Malawi. The pedigree recording system also needs to be improved so as not to limit the estimation of the genetic variance.
In ancillary studies, traits like lactation length, age at first calving and calving interval should be included.

Acknowledgements

The authors wish to acknowledge Malawi Dairy Industries Corporation (MDI) for providing the data and Holstein Canada for the Canadian Breeding values. The financial assistance from the ‘Gesellschaft für Technische Zusammenarbeirt’ (GTZ) through DAAD is gratefully appreciated.

References

Brown, S. C., Nicholas, F. W. and Moran, C. (1981). An Australian investigation of genotype - environment interaction in relation to Friesian sires from England, New Zealand and New South Wales. Proceedings of the Second Conference, Australian Association of Animal Breeding and Genetics, University of Melbourne, Victoria, Australia, February 20 - 23, 1981, 114 - 115.

Carabano, M. J., Wade, K. M. and Van Vleck, L. D. (1990). Genotype by environment interaction for milk and fat production across regions of the United States. J Dairy Sci 73:
173-180.

Georgoudis, A., Abas, Z. and Zervas, N. (1994). Investigation of the genotype by environment interaction between Greece and some exporting countries of semen from progeny tested bulls. Epithoorese - Zootechnikes - Epistemes. 20:5 - 20.

Groeneveld, E. (1998). ftp:/ ftp.tzv.fal.de/pub/vce4.2;
http://www.hostein.ca/inquiry/animal/animal.html

Makuza, S. M. and McDaniel, B. T. (1996). Effect of days dry, previous days open, and current days open on milk yields of cows in Zimbabwe and North Carolina. J Dairy Sci 79:
702 - 709.

Mathur, P. K. and Horst P. (1994). Methods for evaluating genotype-environment interactions illustrated by laying hens. J. Anim. Breed.Genet. 111: 4, 265-288.

Petersen, P. H. (1975). Genotype-environment interaction in milk production under Danish and Bulgarian-Czechoslovakian conditions. Anim. Prod. 21: 101-108

Rege, J. E. O. (1991). Genetic analysis of reproductive performance of Friesian cattle in Kenya. 1 Genetic and phenotypic parameters. J. Anim. Breed. Genet. 108:6, 412-423.

Robertson, A., (1959). The sampling variance of the genetic correlation coefficient. Biometrics, 15: 469-485.

Ron, M. and Hillel, J (1983). Genotype x environment interaction in dairy cattle and its role in animal breeding programmes. Thoer Appl Genet 66: 93 - 99.

Rorato, R. P. N., Ribas, N. P., Lobo, R. B., Freitas, M. A. R. de, De Freitas, M. A. R. (1992). Genotype x environment interactions for milk yield of Holstein cows in Parana State. Revista-da-Sociedade-Brasileira-de-Zootecnia, 21: 1, 57-67.

Sahota, R. S. and Gill, G. S (1991). Genotype x environment interaction for some traits of economic importance of dairy cattle. Journal of Research, Punjab Agricultural University, 28:3, 395 -400.

SAS Institute Inc., (1989). SAS/STAT® User’s Guide, version 6, Fourth Edition, Volume 2, Cary, NC, USA.

Stanton, T. L., Blake, R. W., Quass, R. l., Van Vleck, L. D. and Carabano, M. J. (1991). Genotype by Environment interaction for Holstein milk yield in Colombia, Mexico and Puerto Rico. J. of Dairy Sci. 74: 1700 - 1714.

Swalve, H. H., Niermann, H. and Glodek, P. (1993). Genetic relationship between 1st lactation field performance and 2nd lactation test station records of potential bull dams. Archiv für Tierzucht 36: 1, 3-11.

Trail, J. C. M. and Gregory, K. E. (1984). Animal breeding in sub-Saharan Africa: Toward an Integrated program for improving productivity. In Livestock Development in Sub-Saharan Africa; Constraints, prospects, Policy. (Edited by Simpson, J. R.). Westview Press / Boulder, Colorado.

Wollny, C. B. A., Namwaza, A. G, Makamba, T. S. W. and Küttner, K. (1998). Zum Stand der Rinderzucht in Malawi. Arch. Tierz. Dummerstorf 41 (1998) 1/2, 33 - 44.