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Detrimental effect of selection for milk yield on genetic tolerance to heat stress in purebred Zebu cattle: Genetic parameters and trends

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ABSTRACT

In an attempt to determine the possible detrimental effects of continuous selection for milk yield on the genetic tolerance of Zebu cattle to heat stress, genetic parameters and trends of the response to heat stress for 86,950 test-day (TD) milk yield records from 14,670 first lactations of purebred dairy Gir cows were estimated. A random regression model with regression on days in milk (DIM) and temperature–humidity index (THI) values was applied to the data. The most detrimental effect of THI on milk yield was observed in the stage of lactation with higher milk production, DIM 61 to 120 (−0.099 kg/d per THI). Although modest variations were observed for the THI scale, a reduction in additive genetic variance as well as in permanent environmental and residual variance was observed with increasing THI values. The heritability estimates showed a slight increase with increasing THI values for any DIM. The correlations between additive genetic effects across the THI scale showed that, for most of the THI values, genotype by environment interactions due to heat stress were less important for the ranking of bulls. However, for extreme THI values, this type of genotype by environment interaction may lead to an important error in selection. As a result of the selection for milk yield practiced in the dairy Gir population for 3 decades, the genetic trend of cumulative milk yield was significantly positive for production in both high (51.81 kg/yr) and low THI values (78.48 kg/yr). However, the difference between the breeding values of animals at high and low THI may be considered alarming (355 kg in 2011). The genetic trends observed for the regression coefficients related to general production level (intercept of the reaction norm) and specific ability to respond to heat stress (slope of the reaction norm) indicate that the dairy Gir population is heading toward a higher production level at the expense of lower tolerance to heat stress. These trends reflect the genetic antagonism between production and tolerance to heat stress demonstrated by the negative genetic correlation between these components (−0.23). Monitoring trends of the genetic component of heat stress would be a reasonable measure to avoid deterioration in one of the main traits of Zebu cattle (i.e., high tolerance to heat stress). On the basis of current genetic trends, the need for future genetic evaluation of dairy Zebu animals for tolerance to heat stress cannot be ruled out.
Key words: genotype by environment interaction, Gir, heat stress, reaction norm, temperature–humidity index

INTRODUCTION

Zebu cattle are recognized to be well adapted to harsh environments. According to Turner (1980), Zebu cattle are exceptionally adapted to hot climates as a result of their coat, skin, and hematological and physiological attributes, and are valuable animals for crossing with *Bos taurus*, permitting the exploitation of heterosis in production and reproductive traits. The growing concern over global warming (Porter et al., 2014) and its effect on animal production and economy (St-Pierre et al., 2003; West, 2003) should contribute to an increased use of Zebu cattle, especially as crossbreds.

In view of the importance of the effect of heat stress on the production of milk and its components, several studies have been conducted to model this effect in genetic evaluations of dairy cattle breeds reared in subtropical environments (Ravagnolo and Misztal, 2000; Bohlouli et al., 2013; Carabaño et al., 2014). As evidence of the genotype by environment interaction (**G × E**) due to heat stress, the authors cited above observed heterogeneity in additive genetic variances depending on the production environment (defined as temperature-humidity index or only temperature). In

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this respect, Ravagnolo and Misztal (2000), Bohmanova et al. (2005), and Freitas et al. (2006) concluded that continuous selection for milk yield ignoring the genetic component of heat stress would reduce the tolerance of US Holstein cattle to heat stress.

In countries such as Brazil, Zebu breeds have been selected for milk yield and other traits of economic interest for more than 2 decades (Vercesi Filho et al., 2010). The dairy Gir breed perfectly illustrates this scenario. In 1985, the Brazilian Dairy Gir Breeding Program was created. The progeny testing program of the Gir breed started in the same year and contributed to population growth and increased production of this breed. The first result of the genetic evaluation of milk and fat production was published in 1993 for a group of 9 Gir bulls. At present, the Brazilian Dairy Gir Breeding Program contains about 296 proven bulls and about 195 bulls that are currently being proven. Traits such as milk yield and composition, management, and conformation are usually evaluated together with molecular data of alleles A and B of the κ-CN and β-LG genes. Today, the mean 305-d milk yield of the breed is 3,000 ± 1,500 kg. Notably, any aspect related to heat tolerance has been ignored during the process of selection of this breed throughout all these years, most likely due to the fact that these animals are considered perfectly adapted to the environmental conditions of their production systems. The production systems of Zebu cattle are mainly based on the use of pasture, and the animals are therefore constantly exposed to stressful environmental factors such as climate, diseases, and endo- and ectoparasites.

In an attempt to determine the possible detrimental effects of continuous selection for milk yield on the genetic tolerance of Zebu cattle to heat stress, genetic parameters of the response to heat stress for test-day (**TD**) milk yield records of first-lactation dairy Gir cows were estimated. Additionally, trends of the genetic components and breeding values were investigated.

MATERIALS AND METHODS

Data

The data set comprised 86,950 TD milk yield records from 14,670 first lactations of purebred dairy Gir cows, daughters of 1,061 sires and 6,969 dams, calved between 1983 and 2014, belonging to 334 herds located in 179 municipalities of 19 Brazilian states. Age at calving ranged from 22 to 60 mo. The data were obtained from the Brazilian Association of Dairy Gir Cattle Breeders (Associação Brasileira dos Criadores de Gir Leiteiro, Uberaba, MG, Brazil). Test-day records obtained between d 5 and 305 of lactation were used. Only cows with at least 3 individual TD records during lactation were included in the analysis, with the first test being performed up to 45 d after calving. The contemporary groups were defined as herd-year-month-day of test, with the restriction that each group should contain at least 5 animals. The climate variables were daily dry bulb temperature (T; in °C) and relative humidity (RH; in %) recorded by the Instituto Nacional de Meteorologia (INMET, Brasília-DF, Brazil) on the same day as the milking record at 85 weather stations located less than 50 km away from the farms. Temperature and humidity were combined in an index (**THI**) using the equation described by NRC (1971):

$$\mathrm{THI} = \{(1.8 \times \mathrm{T} + 32) - [0.55 - (0.0055 \times \mathrm{RH}) \times (1.8 \times \mathrm{T} - 26)]\}.$$

The average daily THI was obtained by averaging THI at 0900, 1500, and 2100 h. The average daily THI obtained 3 d before the test date was assigned to each TD record. Summary statistics of the weather and production data set after editing is shown in Table 1.

Statistical Model

The following random regression model was applied to the data:

$$y_{ijklm} = CG_i + MF_j + \sum_{p=1}^{2} b_p x_l^p + \sum_{n=1}^{q} \kappa_n \omega_n(d) + \sum_{n=1}^{q} \psi_n \omega_n(t) + \sum_{n=1}^{q} \beta_{ln} \omega_n(d) + \sum_{n=1}^{q} \gamma_{ln} \omega_n(d) + \sum_{n=1}^{q} \delta_{ln} \omega_n(t) + \sum_{n=1}^{q} \varepsilon_{ln} \omega_n(t) + e_{ijklm},$$

where y_{ijklm} was the mth TD milk yield record of the lth cow; CG_i was a fixed effect of the ith contemporary group (defined as above); MF_j was jth milking frequency (2 or 3 times per day); b_p is the regression coefficient for the linear ($p = 1$) and quadratic ($p = 2$) effects of cow's age at calving, x_l, in months; κ_n was the nth fixed regression coefficient by DIM; ψ_n was the nth fixed regression coefficient by THI; β_{ln} was the nth random regression coefficient for the additive genetic effect of lth cow by DIM; γ_{ln} was the nth random regression coefficient for the permanent environmental effect of lth cow by DIM; δ_{ln} was the nth random regression coefficient for the additive genetic effect of lth cow by THI; ε_{ln} was the nth random regression coefficient for