415. Testing phenotypes for degree of resilience using fluctuations in milk yield of dairy cows in sub-Saharan Africa

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Abstract

Despite the relevance of dairy production in the fight against food insecurity and unemployment in sub-Saharan Africa (SSA), negative effects of climate change and general changes in the production environment pose huge challenges to its profitability. Thus, there is a need to improve resilience capacity of dairy animals to adapt to this changing environment. In the current study, we tested two indicators of resilience, log-transformed variance (LnVar) and Skewness (Skew) of deviation, based on fluctuations in animals' milk yield. Further, we assessed the effects of genotype, agroecological zone, and genotype by agroecological zone (G×E) interaction for these phenotypes. Cows with less than 50% of exotic genetics had higher degree of resilience ($P<0.05$). Cows performing in semi-arid zones had higher resilience capacity compared to those in semi-humid environment ($P<0.05$). G×E did not significantly influence both indicators. The results provide valuable information that would inform dairy cattle improvement initiatives in SSA.

Introduction

An animal's degree of resilience to a disturbance is its capacity to be minimally affected by the perturbation or rapidly return to the state pertained before exposure to the disturbance. The performance of the resilient animal need not be the same as without a disturbance, but rather, the negative change in its performance should be relatively lower compared to non-resilient individuals performing in the same conditions. Dairy production in sub-Saharan Africa (SSA) is still low compared to the demand. As a result, pressure for genetic improvement for milk production is still accumulating. However, in the wake of climate change, general environmental changes and their impact, the focus of dairy production must shift from increased production to efficiency and sustainability of milk production. Sustainable dairy production practices that ensure food security to the growing population and overcome the negative impacts of climate change on dairy cattle need to be adopted. SSA is confronted with environmental disturbances, most of which are causes of nature that cannot be modified in the favor of the cattle through good husbandry practices. Therefore, one robust way into this is through breeding for resilience in dairy cattle to enhance their ability to withstand environmental stressors and maintain optimal production levels. Deviations from the normal performance has been utilized to derive indicators that can quantify the general resilience of the animals (Berghof, *et al.*, 2019; Elgersma *et al.*, 2018; Poppe *et al.*, 2020). However, these methods have so far not been applied in SSA. The current study aimed to test two indicators of resilience based on deviation in milk yield and to assess the effect of genotype, agroecological zone and their interaction on these indicators.

Materials & methods

Data used in this study came from dairy cows from three different herds, each representing one of the following agroecological zones of Kenya: semi-arid arable (SAA), semi-arid pasture-based (SAP), and semi-humid (SH). All the herds are kept under extensive dairy production system with occasional supplementation feeding for the lactating cows. Rotational cross breeding is adopted for two herds performing in the semi-arid regions. The herd in semi-humid zone is made up of a stable intermating population of composite cattle originating from crossbred parents.

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Data. The original data set for this analysis contained 2,640 lactations with 62,321 bi-monthly milk yield records of 1,490 multibreed cows from three large-scale dairy farms in Kenya born between January 2000 to December 2017. Data for the first parity were extracted and assessed for quality before the analysis. Cows that had at least two breed types in their genetic make-up based on the information provided by the farmers were used. All cows were required to have 5 or more milk records per lactation and all records were used up to 400 days after calving. To correct for season and year of calving, contemporary grouping of year-season (YS) was done with 17 possible years of calving (2003-2019) and 4 possible seasons. YS groups with less than 5 lactations were excluded from the analysis. After editing the data, 14,278 milk yield records from 745 cows were used for the analysis. These animals were grouped into two genotypic classes based on the proportion of exotic genetics in their breed composition, genotypic class 1 (GC1) (≤50% exotic, n=325) and GC2 (>50% exotic, n=420).

Defining resilience indicators based on fluctuations in milk. The deviations in daily milk yield from the mean production was used to define two resilience indicators: log-transformed variance of deviation (LnVar) and skewness of deviations (Skew). LnVar indicates the impact of the disturbance to the performance of an individual animal. Because resilient animals are less affected by the disturbances in their environments, they have a smaller range of deviation from their average performance. Therefore, they have low variance of deviation. Skew indicates the direction of the deviation and captures the level of severity of the disturbance experienced by an individual animal. Resilient animals have skewness around zero because they have almost equal numbers of negative and positive deviations. The less resilient animals are more influenced by disturbances and thus have more negative than positive deviations which leads to a negative skewness. The LnVar of j^{th} individual was calculated as:

$$ln(variance_j) = ln\left(\frac{\sum_{i=1}^{n_j}(x_{ij}-\bar{x}_j)^2}{n_j-1}\right) \tag{1}$$

where x_{ij} is deviation i of the j^{th} individual, $\bar{x}_j$ is the mean of deviations of the j^{th} individual, and n_j is the number of deviation observations of the j^{th} individual. The skewness of deviation j^{th} individual was calculated as:

$$skew_j = \frac{n_j}{(n_j-1)(n_j-2)}\sum_{i=1}^{n_j}\left(\frac{x_{ij}-\bar{x}_j}{\sqrt{s_j^2}}\right)^3 \tag{2}$$

where n_j is the number of deviation observations of the j^{th} individual, x_{ij} is deviation i of the j^{th} individual, $\bar{x}_j$ is the mean of deviations of the j^{th} individual, and s_j is the variance of deviations of the j^{th} individual.

Data analyses. The effects of agroecological zone (environment) and genotype as well as the existence of their interaction in the two resilience indicators was analyzed. A multiple linear regression model with explanatory variables of genotypic class, agroecological zone, genotype by agroecological zone interaction, year-season of calving, day in milk (DIM) class of first day in lactation, DIM class of last day in lactation, age of calving, and squared term of age of calving was used. Analysis of variance was performed prior to fitting linear models to determine the significant factors of variation. The following model was fitted:

$$RI_{ijklmn} = U + G_i + E_j + G_i * E_j + YSC_k + dim.f_l + dim.l_l + Age_m + Age_m^2 + e_{ijklmn} \tag{3}$$

where RI_{ijklmn} is the resilience indicator (LnVar and Skew) measurement for n^{th} animal, U corresponds to the population mean, G_i is the i^{th} genotypic class (i = 1-2), E_j is the j^{th} agroecological zone (j=1-3), $G_i \times E_j$ is the interaction between i^{th} genotypic class and j^{th} agroecological zone, YSC_k is the k^{th} year-season of calving (k=1-53), dim.f_l and dim.l_l are the first and the last DIM classes, respectively of the l^{th} DIM (l=1-10), Age_m and Age_m^2 represent m^{th} age and its squared term, respectively (m=22-60) e_{ijklmn} is the residual error.

Least-square means (LSM) of the genotype classes within the different traits were calculated and contrasted across the 3 different agroecological zones.

Results

The raw average estimate (± standard deviation) for LnVar for the whole dataset was 1.4998±0.8420. The minimum and maximum LnVar values were -1.3587 and 3.8916, respectively. The Skew had a raw mean of -0.05316±0.7186 with a minimum of -2.4986 and a maximum of 3.6525. The significant sources of variation for LnVar were environment, genotypic class, age of the animal, and year season of calving. At population level, GC1 cows had significantly lower LnVar than GC2 cows ($P>0.05$). This shows that GC1 cows had a higher degree of general resilience than GC2 cows. Agroecological zone influenced LnVar, hence level of general resilience significantly ($P>0.001$). Animals performing SAA zone had lowest LnVar, followed by those in SAP and SH ($P<0.01$) (Table 1). Within agro-ecological zones, GC1 had significantly lower LnVar than GC2 cows in SAA ($P<0.001$) and SH ($P<0.05$) environments. However, in SAP, there was no significant difference in LnVar for the two genotypes groups (Table 2). The significant sources of variation for Skew were same as those of LnVar except age of the animal and its squared term. However, the skewness

Table 1. Least square mean (± standard error) for log-transformed variance (LnVar) and skewness (skew) of deviation in milk yield at genotypic class and agroecological zone levels.[1]

Variable and level	n	LnVar of deviation	Skew of deviation
% Exoticness			
GC1 (0-50%)	325	0.813±0.257a	-0.0455±0.251a
GC2 (>50%)	420	0.992±0.258b	-0.107±0.252a
Agroecological zone			
Semi-arid arable	352	0.541±0.262a	0.0531±0.256a
Semi-arid pasture-based	169	0.902±0.271b	-0.0721±0.264ab
Semi-humid	224	1.263±0.253c	-0.2099±0.247b

[1] The difference between GC1 and GC2 and among the agroecological zones that are significant at P<0.05 have been shown using different small letters. Similar letter denotes that the difference is not significant. GC1 and GC2 represent genotypic class 1 and genotypic class 2, respectively.

Table 2. Least square means (± standard error) for log-transformed variance (LnVar) and skewness (Skew) of deviation in milk yield of genotypic classes across the three agroecological zones.[1]

Resilience indicator	GC1 (0-50%)	GC2 (>50%)	Pairwise comparison (GC2-GC1)	Significance level
LnVar of deviation				
Semi-arid arable	0.405±0.266	0.678±0.264	-0.2726±0.0808	***
Semi-arid pasture-based	0.92±0.268	0.885±0.299	-0.0345±0.1709	ns
Semi-humid	1.114±0.267	1.413±0.254	0.2989±0.1249	*
Skew of deviation				
Semi-arid arable	0.1205 ±0.26)	-0.0143±0.257	-0.1348±0.0789	ns
Semi-arid pasture-based	-0.0866±0.262	-0.0576±0.292	0.0291±0.1668	ns
Semi-humid	-0.1706±0.26	-0.2492±0.248	-0.0786±0.1219	ns

[1] The difference between GC1 and GC2 that are significant have been shown. '***', and '*' indicate significant differences at $P<0.001$, and 0.05, respectively. ns denote not significant. GC1 and GC2 represent genotypic class 1 and genotypic class 2, respectively.

of deviation did not detect differences in resilience between the two genotypic classes. The only significant difference in skew was between the animals performing in SAA and those in SH where the animals in former environment had a positive and a closer to zero Skew signifying more degree of resilience than their counterparts ($P<0.01$). Genotype by environment (G×E) interaction was not significant for both resilience indicators.

Discussion

This study used deviations in milk yield to test two indicators of resilience for cows performing in the tropical environment of sub-Saharan Africa. The LnVar was stronger in showing resilience of the animals than the skew based on its ability to discriminate degree of resilience of cows more efficiently. Similar findings were reported in past studies (Berghof *et al.*, 2019; Poppe *et al.*, 2020). Animals with lower exotic genetic proportion had higher degree of resilience possibly due to the fact that they have a high proportion of Zebu genes in their genetic make-up which could have conferred the adaptation to the local production environments. The environment also affected the degree of resilience of the animals. In particular, animals performing in semi-arid zones, which are known to have many disturbances related to high temperatures and long periods of dry seasons, had better resilience capacity than those in semi-humid zone. Constant exposure of the animals to the disturbances in semi-arid zones could have activated their innate regulatory pathways and bettered their chances to survive environmental adversities in the long run (Colditz and Hine 2016). G×E interaction was not significant for both resilience indicators. This implies that a resilient genotype is capable of performing in a wide range of environments without its resilience capacity being altered. This study has shown the possibility of utilizing the deviations in milk yield to quantify general resilience of dairy cows performing in the tropical environment of SSA, where climate change is already affecting dairy production.

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