https://doi.org/10.22319/rmcp.v11i2.5152

Article

Phenotypic and genetic trends for peak yield, milk yield, and lactation persistency in the Murciano-Granadina breed

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Abstract:

This study evaluated the genetic (TG) and phenotypic (TF) trends for the peak yield (PP), milk yield (RL), and lactation persistency (P) traits of the Murciano-Granadina (MG) goat lactation curve obtained from 80,872 lactations of 85,404 goats (historical records from 1990-2012). The biomodelling of lactation curves allowed us to estimate the PP, RL, and P traits using the Spline model in the “R” software. The genetic values (VGs) were obtained using the univariate animal model with repeated observations, employing the

MTDFREML package. The TG and TF were estimated via the least-squares regression of the average of VGs and known yield information according to the year of birth. While calculating the TG and TF, linear regression coefficients (*b*) were obtained, where the *b* values for PP, RL, and P were +0.00071, +0.00698; +0.00114, +0.01117; and +0.00002, -0.00076, respectively. The TG and TF for the PP and RL behaved similarly following an upward trend line with increasing and decreasing intervals. The TG for P showed seasonal variations while the TF followed a downward trend with more consistent points in its trajectory; supporting the idea that high yields are detrimental to the P. These results inform the breeders about the behavior of these traits and provide the basis for the incorporation of the lactation persistency as a selection criteria in the genetic program of the MG breed.

Key words: Breeding program, Goat, Milk, Genetic value.

Received: 19/11/2018

Accepted: 19/03/2019

Introduction

Goats are relevant worldwide, especially in developing countries, where they are bred with multifunction criteria(1). However, dairy goat breeds are especially important in the southern European livestock, and even though their census is low compared to the total global population, France and Spain have achieved considerable yield increases and more extended lactation periods. This productive efficiency responds to the need to provide large quantities of milk to the high-quality goat-cheese industry, linked to deep-rooted cultural traditions in some European countries, which continue to offer an optimistic perspective for the goat sector(2).

The Murciano-Granadina (MG) breed is part of a select group of specialized dairy goats, becoming one of the leading dairy breeds of Spain, both in census (104,000 breeding females included in the Breed Registry) and yields (584.4 kg of milk per lactation)(3). This information positions the MG breed in the first order, next to the Florida and Malagueña breeds, due to its high potential yield compared to other native Spanish breeds like the Guadarrama, Majorera, Palmera, Payoya, and Tinerfeña goats.

The MG breed was officially recognized in the seventies, and since then, there are references on the Scheme for the Genetic-Functional Assessment of Reproductive Males (Resolution of March 28, 1979, of the Directorate General for Agricultural Products(4)). The current animal genealogical and functional records integrate a robust database, which allows breeders to perform genetic evaluations.

The current MG selection program has been consolidated after 29 yr of selection, emphasizing traits like milk yield, fat, protein, and dry extract yield. In this case, the estimation of genetic trends (TG) is important to evaluate the efficacy of the applied breeding schemes and to provide the breeders with information that will allow them to develop more efficient selection programs(5).

Also, the evaluation of TG and phenotypic trends (TF) improves the understanding and helps transmit the selection effect compared to previous generations(6,7), as well as to contrast the obtained results depending on the proposed scheme, allowing to correct any deviation from the expected.

In reference studies performed in dairy species, researchers have generally focused on the TG and TF for milk yield (RL) and composition traits; however, the genetic behavior of other traits related to the lactation curve has not been reported (8).

Furthermore, this is the first study of the TGs for lactation curve parameters, peak yield (PP) and persistency (P) in particular, in MG goats. This study aims to justify the consolidation of these traits for their inclusion as selection criteria in the MG breeding program. Therefore, this study aimed to evaluate the TG and TF for the PP, RL, and P traits in the Murciano-Granadina (MG) breed.

Material and methods

Data and editing procedures

The genealogy and functional information used in this study belong to the historical archives of the MG goat official breeding program. The original database included 180,872 lactations, adjusted to 210 d (A4 method of ICAR (9)), from 85,404 goats from 229 livestock farms, encompassing the birth years of 1990-2012. During the exploratory analysis, the database was edited and standardized to eliminate the data considered anomalous: repeated data, lactations with less than six controls, daily yields exceeding 10 kg of milk or below 0.2 kg, and null values; based on the standardization carried out by the MG goat breeding program.

Genetic analysis and statistical models

The biomodelling of individualized lactation curves allowed to estimate the PP, RL, and P traits using the *Spline* model for its best fit for the breed, R^2, and flexibility(10). Also, for the model resolution, it was used the statistical software "R" version 3.2.3(11). The P values of lactation are mainly expressed as dimensionless measures(12).

The individual values of the traits (PP, RL y P) in the lactation curves were analyzed using an animal model with repeated observations and the univariate option (single trait). The single trait model used is written in matrix notation (13).

$$\mathbf{y = Xb + Z_a a + Z_p p + e}$$

Where:

y= is the phenotypic information vector of the analyzed PP, RL, and P traits.

b= vector of the fixed effects (contemporary group of herd-year-season (HYS-unified), lactation number, birth type, and age (covariable)).

a= vector of the additive random effect of the animal.

p= vector of the permanent environmental effect.

e= vector of residual effects for the analyzed traits.

X, **Za**, and **Zp**: incidence matrices (known) of fixed effects (**X**) and random effects (**Za** and **Zp**).

The variance components for all the random effects were estimated with the Multiple Trait Derivate Free Restricted Maximum Likelihood (MTDFREML) program(14) and adjusting the univariate animal model (described previously). To evaluate the logic estimations, we used a convergence criterium of $\mathrm{Var}\,[-2\log(L)] < 1\mathrm{x}10^{-9}$ (where L represents the likelihood function).

The genetic values (VG) for the traits of interest were estimated using the best linear unbiased prediction method (BLUP) (15). To estimate the TG and TF, the estimated VGs were adjusted in a fixed-effects model with the year of birth as the only fixed effect. Alternatively, for the traits of interest, we also estimated the environmental trends (TA) using the predictions from the linear regression coefficients (b) obtained from the average of the VGs expressed by year of birth and known yield information in that year. These procedures were carried out with the statistical program "R"(11).

Results

The descriptive statistics for the analyzed traits revealed a typical mean and deviation of 1.05 ± 0.32 and 1.21 ± 0.35 kg of milk for RL and PP, respectively, and 1.03 ± 0.35 for P.

Figures 1-6 show the TG and TF regarding the year of birth for the analyzed traits with their respective linear regression coefficient (b). These results suggest dynamic variations for the MG goat population, detecting a rebound stationary point in 1999, which coincides with the start of the modern selection scheme based on the BLUP evaluations. Subsequently, oscillations around the X-axis for these three traits reveal that for 22 year, the PP and RL traits showed an upward trend behavior and similar magnitudes; meanwhile, the P trait showed a stationary to a downward trend.

Figure 1: Peak yield genetic trend

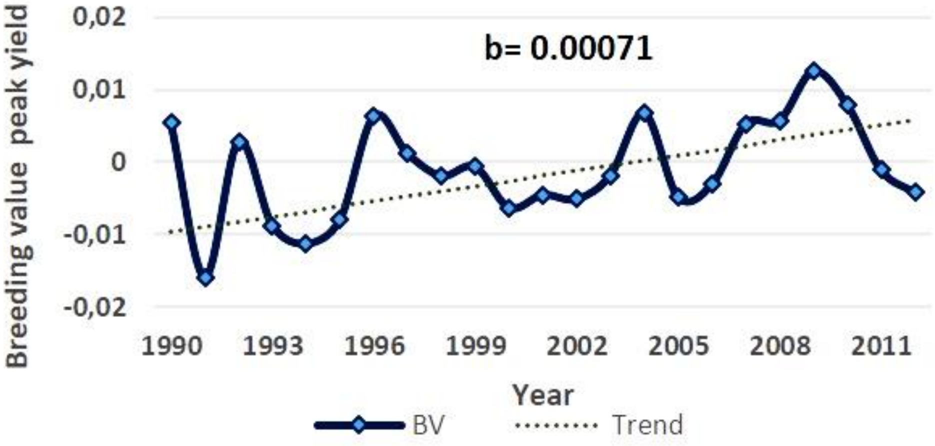


Figure 2: Yield genetic trend

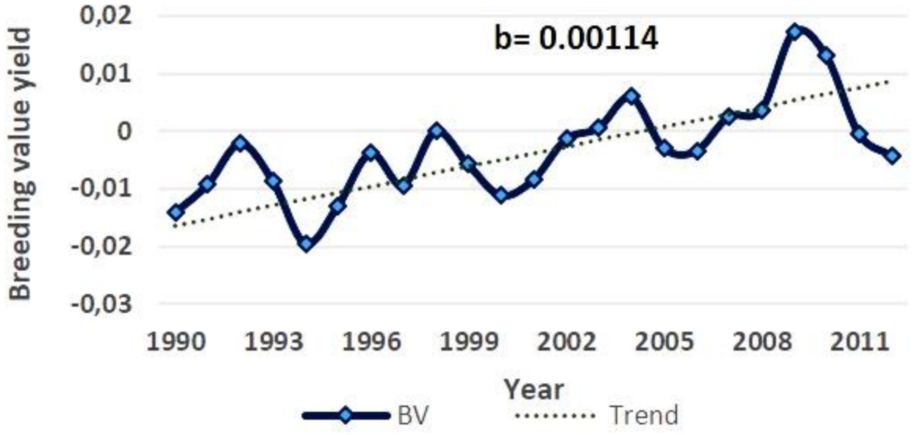


Figure 3: Persistency genetic trait

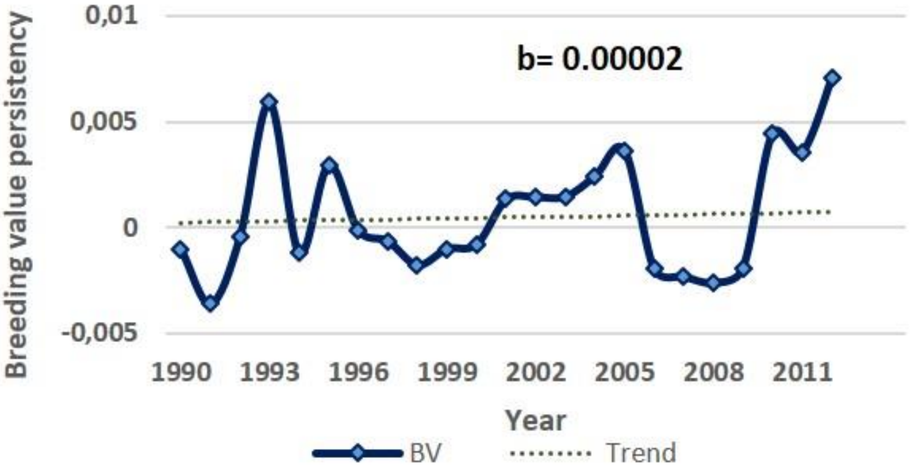


Figure 4: Peak yield phenotypic trend

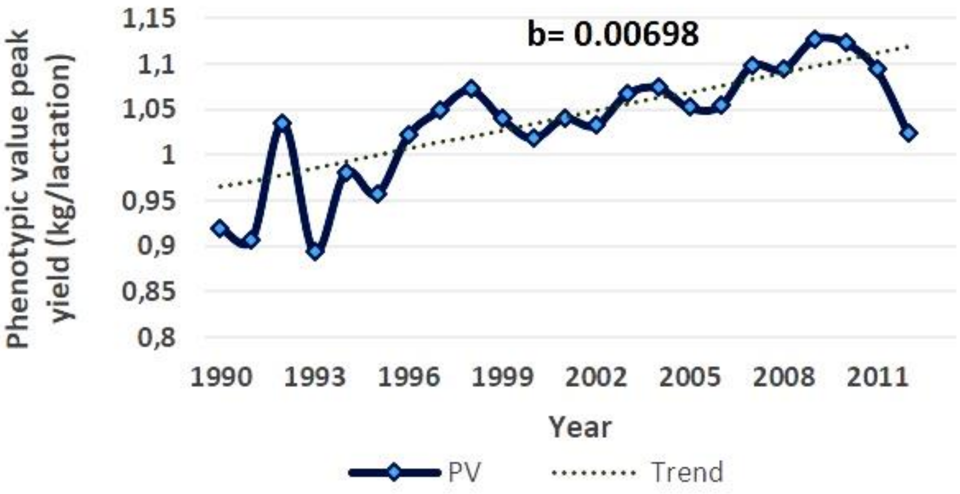


Figure 5: Yield phenotypic trend

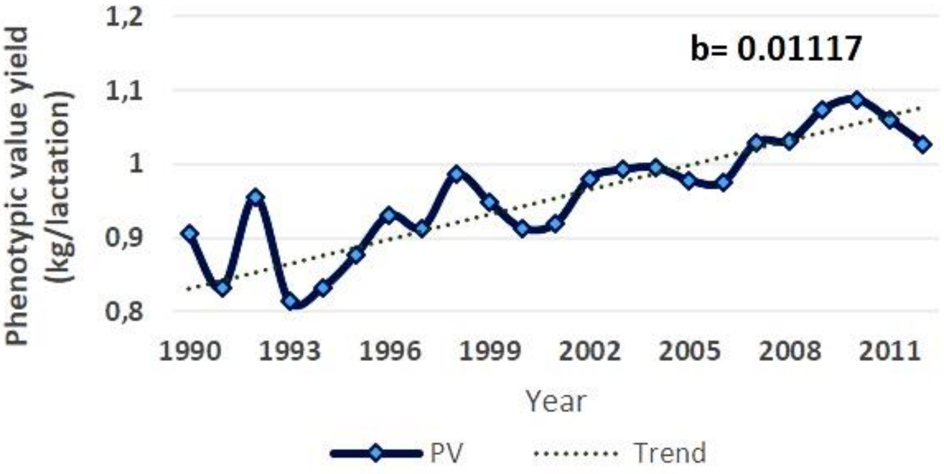
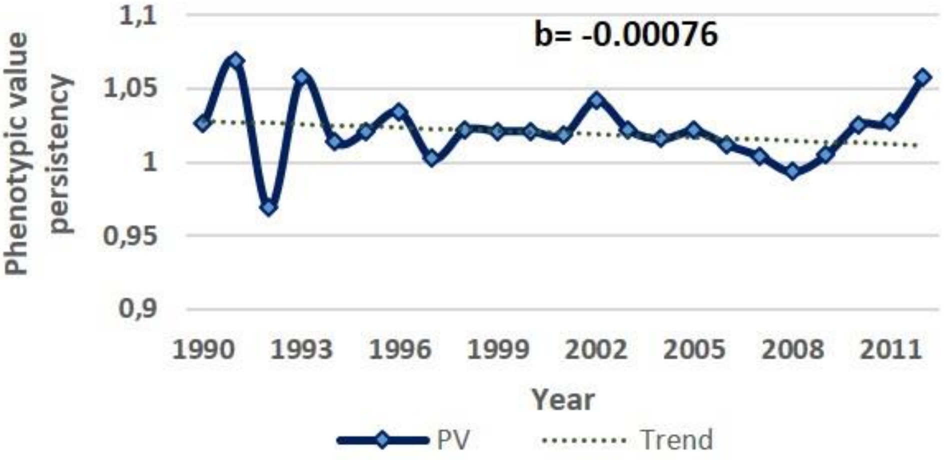


Figure 6: Persistency phenotypic trend



The TGs for PP and RL over the analyzed years (1990 to 2012) showed an irregular behavior with increasing and decreasing intervals (Figures 1 and 2) but following an upward trend line with coincident peaks in the years 1992, 1996, 2004, and 2009. For these same traits, the TFs (Figures 4 and 5), also show upward trend lines with regular and consistent fluctuations in the increasing/decreasing intervals (coincident prominent peaks in the years of 1992 and 1998).

The TG for the P trait shows an irregular behavior with increases, decreases, and prominent peaks in the years of 1993, 1995, 2005, 2010, and 2012, unlike the behavior of the other traits that show a stationary trend line (Figure 3).

Particularly, we observed a positive TG for PP and RL and irregular deviations from linearity (Figure 1 and 2). The increase for these treats was significant ($P<0.05$) with a b of 0.00071 kg/year and 0.00114 kg/year for PP and RL, respectively. Similarly, the TG for P was also positive with prominent peaks (1993, 1995, 2005, 2010, and 2012) and notorious decreases (1992, 1998, 2006 to 2009), showing irregular fluctuation between them with a no-significant increase ($P>0.05$) and a b of 0.0000219 units/year with a stationary trend line (Figure 3).

Although the TF direction for PP and RL shows an upward trend line, the fluctuations of the increasing/decreasing intervals are also regular and consistent due to the proximity between the points (prominent coincident peaks in 1992 and 1998) and the trend line (Figures 4 and 5). Moreover, the TF for P (Figure 6) decreased when the fluctuations of the increasing and decreasing intervals were regular and consistent in time, with peaks in the years of 1991, 1993, 2002, and 2012.

Consequently, the TFs were positive for PP and RL showing a significant ($P<0.05$) increase in the TF average for these traits, where *b* was 0.0069821 kg/year and 0.0111697 kg/year, respectively (Figures 4 and 5). However, although the TF for P was negative with regular fluctuations and a significant ($P<0.05$) decrease with a *b* value of -0.0007629 units/year (Figure 6), there is also a slight increase in this trend since the year of 2009, which stabilizes during 2010, with an increase in 2011. The TA analysis for P suggests a negative influence, although not significant ($P>0.05$ with b of -0.00000293 units/year).

Discussion

The TGs monitor and evaluate the selection program efficiency(16). The TG evaluation of dairy traits indicates the direction of the breed selection vector, as well as the rate of genetic improvement due to the application of the breeding program(17). It is also essential to provide information to the breeders for them to develop more efficient selection programs(5).

In this study, the direct estimation of the TG indicated that there was a significant and positive genetic improvement in all the studied traits, except for the P trait, which indicates that selection was effective, both in the period based in bulk selection (1990-1999) and in familiar information (1999-2012). Therefore, this information could be useful to evaluate previous efforts for the improvement and preservation of the genetic potential of these traits and to determine the future strategies and work in the population of MG goats.

It is important to consider that this is the first study in which the PP, RL, and P traits are evaluated as a group, RL being a trait routinely used for breed selection, while PP and P are candidate traits for possible inclusion in the selection scheme. Our results show that, in the 22 analyzed years, the PP and RL traits showed a similar and upward trend behavior, while the P trait showed a stationary to a downward trend, which supports the idea that high yields are detrimental to the P.

The results show that both the TG and TF for the three traits (PP, RL, and P) have an irregular behavior with fluctuating increasing and decreasing intervals, most noticeable in the years before 1999; until that year, the selection was based on the phenotype (bulk selection). However, since 1999, when the annual mean VG trends for the PP and RL traits present a more constant-positive evolution, consistent with the year when the work guidelines for the selection scheme of dairy goat stallions of the MG breed were established(4), based on family information and BLUP estimations, according to the guidelines published in the Resolution of May 12, 1999, of the Ministry of Agriculture, Fisheries, and Food.

Additionally, the reference points of the mean VGs are closer to the trend line, with prominent peaks in the years of 2004 and 2009, and noticeable decreases in the years of 2005, 2006, 2011, and 2012; according to MURCIGRAN (4), they could be related to the incorporation of animals to the selection schemes from livestock farms outside the selective nucleus in the mentioned years.

The TGs for PP and RL are parallel, prominent peaks are observed in years before 1999; the most noticeable decrease occurred in 2012. In this regard, in December 2011 it was officially agreed to merge the associations of CAPRIGRAN and ACRIMUR in MURCIGRAN(4), leading to the management of a single Breed Book, and therefore the data and records thereof, which would justify the noticeable decreases between 2011 and 2012 in both the TG and TF.

Even though the TG for P has prominent peaks (1993, 1995, 2005, 2010, and 2012) and notorious decreases (1992, 1998, 2006 to 2009) in addition to alternating and irregular between them (*sic*), it shows a positive seasonal trend line. Meanwhile, the TF is a discrete decreasing trend line with less prominent peaks in the years 1991, 1993, 2002, and 2012.

This information supports the idea of paying attention to the P trait and its group behavior with others because of its direct impact on the lactation curves. Lengthening the P would allow for flattening the declining part of the lactation curve, or at least mitigate the crucial peaks that affect the immune system (the antagonistic relationship between milk production and disease resistance traits) promoting a more efficient lactation with considerable benefits, such as avoiding animal health risks and associated costs(18,19).

In this regard, specific studies in dairy goats conclude that animal selection using P as a criterium and linked to the peak yield value is possible without changing the amount of total milk(20), and therefore genetically modify the lactation curve(19). Thus, early estimation of P in lactations in progress can represent a useful tool for both the breeding and management strategies(21), especially in the implementation of strategies to reduce the production of greenhouse gases derived from the fight for climate change mitigation(22).

The TG estimations evaluate the results of the program and inform the breeders about the selection decisions made, allowing the necessary adjustments to optimize the genetic progress of each population(23); therefore, the results of this evaluation allow to propose the incorporation on the P trait to the breeding program.

Finally, in general, the phenotypes and the breeding values for the PP and RL traits increased in the period of study; however, although the P trait was genetically stationary, its TF was decreasing, probably due to environmental factors, such as the change of management. Studies referred to in this regard indicate that the environment does not directly modify the genetic constitution of the individual. However, it does determine the extent of its expression and the genetic potential of animals, which will express to the extent that environmental conditions allow(24).

Conclusions and implications

The global analysis of the TG and TF for the analyzed traits demonstrated irregular dynamic variations with increasing and decreasing intervals, as well as peaks in determined points throughout the study. The genetic and phenotypic behaviors of these three traits indicate that, in 22 years, the PP and RL traits showed a similar upward trend and magnitude, while the P trait was stationary to decreasing. The latter supports the idea that high yields are detrimental to the P. In all cases, important events in the breeding program, like the federation of associations or the introduction of family selections, left their mark on trends. These findings will allow to inform breeders about the behavior of these traits and consider incorporating the P in the selection scheme.

Acknowledgements and conflict of interests

Authors thank the Spanish Federation of Goat Breeders, Murciano-Granadina (MURCIGRAN) breed. A special thanks to MsC. Bolívar Samuel Sosa Madrid for his valuable contributions to the manuscript. There is no conflict of interest.

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