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Environmental effects, population genetic parameters, breeding value, phenotypic and genetic trend for age at first calving of Limousin cows

Populációgenetikai paraméterek, tenyészértékek, fenotípusos és genetikai trendek limousin tehenek első ellési életkorára

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ABSTRACT

Some environmental effects, population genetic parameters, breeding value of Limousin breeding bulls, also phenotypic and genetic trends in the age at first calving (AFC) of cows between 1992 and 2013 were estimated. Data were served by the Limousin and Blonde d'Aquitaine Breeders Association, in Hungary. The study was extended to three herds and 1157 cows. GLM method was used for the study of different effects, the BLUP animal model for estimation of population genetic parameters and breeding values (BV), and one-way linear regression analysis for trend calculations. The overall mean value of the AFC was estimated to be 34.7±0.4 months. The contribution of the evaluated factors to the phenotype was as follows: herd 73.51%, birth year of cow 13.02%, sire 6.74%, birth season of cow 1.62%. The heritability of AFC proved to be low (h^2 = 0.08±0.07 and h^2 = 0.01±0.04). There were relatively small differences in the estimated BV of the studied sires for the AFC. Based on the phenotypic trend calculation, the AFC of cows decreased by an average of 0.33 months per year, however no significant change was found in the genetic trend during the study period.

Keywords: age at first calving, Limousin, population genetic parameters, breeding value, trend

ÖSSZEFOGLALÁS

A Szerzők a Limousin és Blonde d'Aquitaine Tenyésztők Egyesületének országos adatbázisát felhasználva néhány környezeti tényező hatását vizsgálták limousin tehenek első ellési életkorára vonatkozóan 1992 és 2013 között. A munka során az első elléskori életkor populációgenetikai paramétereit, a tenyészbikák tenyészértékét, valamint a tulajdonság fenotípusos és genetikai trendjét is megbecsülték. A munkát három nagy tehénlétszámmal rendelkező tenyészetre és 1157 tehénre terjesztették ki. A környezeti tényezők hatásának vizsgálatára GLM (univariate analysis of variance) eljárást, a populációgenetikai paraméterek és tenyészértékek meghatározására BLUP egyedmodellt, a fenotípusos és genetikai trend számításához egytényezős lineáris regresszió analízist használtak. Az első ellési életkor átlaga 34,7±0,4 hónap volt. A környezeti tényezők szerepe a fenotípus kialakításában a következőképp alakult: tenyészet 73,51%, születési év 13,02%, apa 6,74%, születési évszak 1,62%. Az első elléskori életkor tulajdonság öröklődhetősége kicsi volt (h^2 = 0,08±0,07 and h^2 = 0,01±0,04). A tenyészbikák első ellési életkor tulajdonságra becsült tenyészértéke között meglehetősen kicsi különbségeket találtak. A fenotípusos trendszámítás eredményei alapján a vizsgált időszakban a limousin tehenek első ellési életkora évenként 0,33 hónappal csökkent. A genetikai trendszámítás eredményei nem jeleztek érdemi változást a vizsgált tulajdonság átlagos tenyészértékének évenkénti alakulásában.

Kulcsszavak: első ellési életkor, limousin, populációgenetikai paraméterek, tenyészérték, trend

INTRODUCTION AND LITERATURE REVIEW

The age at first calving (AFC) of cows is a trait of great importance in cattle breeding. Until the first calving, the female animal usually does not produce profit and the costs associated with raising it increase in proportion to the time until the first calving. As a result, in many breeds today young heifers are mated earlier than the optimal age indicated in the textbooks, i.e. the first calving age is reduced. However, premature mating can have adverse effects, such as calving difficulty, unsuccessful re-conception, decrease in the later performance and shorter longevity.

Dákay et al. (2006a) summarized the AFC of different beef cattle breeds. According to their data, the AFC of Limousin cows was 33.8 months. Zsuppán et al. (2010) obtained similar results in their work. In the study of Ráki and Szajkó (1986), the AFC of Limousin cows proved to be 34.5 months.

The AFC can be influenced by several factors - breed, herd, season of birth, etc. - (Magana and Segura, 1997; Dákay et al., 2006b; Boligon and Albuquerque, 2011). According to DeRouen and Franke (1989), the sire had a statistically significant effect on the AFC of his daughters. According to the results of Chiaia et al. (2015) the AFC was also influenced by the genotype x environment interaction.

The age at first calving is related to many traits. According to Gutiérrez et al. (2002), the AFC showed a close genetic correlation with the conformation scoring result of the cows. Bourdon and Brinks (1982) found that the AFC was in negative genetic correlation with growth traits in Angus and Hereford herds. According to López-Paredes et al. (2018), there was a 0.27 genetic correlation between the AFC and the calving difficulty at first calving in Blonde d'Aquitaine herds. In the Nellore herd Costa et al. (2019) found negative (-0.23 and -0.52) correlation between AFC and longevity. According to the results of Lesmeister et al. (1973), the average annual calf rearing capacity of early mated heifers was higher than that of those calved later. Lifetime performance was significantly affected by early calving, too.

The heritability (h^2) of age at first calving trait is usually low (Segura-Correa et al., 2012). Castro-Pereira et al. (2007) and Baldi et al. (2008) found the h^2 of AFC of Canchim cows to be 0.09-0.10. Their results suggest that selection for postnatal growth traits may reduce the AFC. According to Vergara et al. (2009), in a multi-breed beef cattle population, the heritability value of AFC was 0.15. Smith et al. (1989) and Martínez-Velázquez et al. (2003) estimated the h^2 of the AFC in the mixed genotype herd, while Forni and Albuquergue (2005) in the Nellore herd. They found that heritability of the AFC was below 0.15. According to Bormann and Wilson (2010), the breeding value (BV) of Angus sires for the AFC varied between -46.6 and +45.9 days.

Several literature sources (Hare et al., 2006; Ansari-Lari et al., 2009) have reported a decreasing trend in the AFC. According to Vergara et al. (2009) the phenotypic trend of the AFC showed a decreasing direction between 1989 and 2004. Hossein-Zadeh (2011) published a decreasing AFC, a negative phenotypic and genetic trend in the Holstein-Friesian breed between 1990 and 2007.

Analyzing the appropriate literature, we have found few information on the age at first calving of large framed, late maturing beef cattle breeds - such as Limousin - in recent years. Therefore, the aim of this study and the questions were as follows: 1. What effect has the sire, the breed, the year of birth, and the season on the age at first calving of Limousin cows? 2. What is the heritability of the age at first calving? 3. What are the differences in breeding value for age at first calving between the Limousin sires? 4. Is there any difference in the ranking of sires obtained by different models? 5. What are the phenotypic and genetic trends for the trait in question in the studied Limousine population?

MATERIAL AND METHODS

The database

During the study the national database of three biggest herds belonging to the Limousin and Blonde d'Aquitaine Breeders Association in Hungary was used. Difference between the birth date and the first calving date was considered as the age at first calving of the cows. Similarly to the study of López-Paredes et al. (2018), data only from cows that were between 24 and 48 months old at the time of first calving were processed. Thus, a total of 1157 cows born between 1992 and 2003 were included in the evaluation. The studied cows were offspring of 59 sires and 788 dams (Table 1).

The Kolgomorov-Smirnov test was used to check the normal distribution of the AFC in the database. The homogeneity of variances was examined by Levene test.

Table 1. The structure of the starting database for Limousin population

Starting parameters	Used database
Time period of examination, the birth date of cows	1992-2013
Number of herds	3
Number of cows	1157
Breed of cows	Limousin
Number of the examined sires (sire of cow)	59
Breed of sires	Limousin
The average number of female progeny (cow) per sire	19.6
Number of the examined dams (dam of cow)	788

Examining the effects of different factors

The effect of the factors influencing the AFC was evaluated by General Linear Model (GLM) univariate analysis of variance (Table 2). Sire was considered random effect, while the other examined factors - herd, birth year of cow, birth season of cow - as a fixed effect. The estimation model used was described as follows:

$$\hat{y}_{hijk} = \mu + S_h + F_i + Y_j + M_k + e_{hijk}$$

(Where: $\hat{y}_{hijk}$ = the AFC of cow; born from sire "h", in herd "i", year "j", season "k"; μ = mean of all observations; S_h = effect of sire; F_i = effect of herd; Y_j = effect of birth year of cow; M_k = effect of birth season of cow of; e_{hijk} = random error)

The GLM method was based on to Harvey's (1990) "Least Square Maximum Likelihood" procedure using the "Harvey" program (Bene, 2013).

Table 2. The applied models for the estimations

Type of model	GLM method	BLUP animal model
Random effects		
- sire (sire of cow)	+	+
- dam (dam of cow)	-	+
- cow (animal)	-	+
Fixed effects		
- herd	+	+
- birth year of cow	+	+
- birth season of cow	+	+
Examined trait		
- age at first calving	+	+

+ = the model include this effect; - = the model doesn't include this effect

Estimation of population genetics parameters and breeding values

Among genetic variance (σ^2_d), within environmental variance (σ^2_e), phenotypic variance (σ^2_p), and heritability value (h^2) were determined. Both GLM method and BLUP animal model (Henderson, 1975) was applied in the study.

The used GLM method to estimate the parameters was the same as above. The calculation procedure of the components in case of GLM method was described in our previous work (Bene, 2013), therefore it is not detailed here.

Using the BLUP model, two matrices were created. One of these was the database matrix and the other was the pedigree matrix. In the BLUP animal model the same fixed effects were considered as in the case of the GLM method (Bene et al., 2020). A random effect was the individual. The pedigree matrix of relatives included pedigree data for full sibs, half sibs, sires, dams, and grandparents. The animal model used was as follows:

$$y = Xb + Zu + e$$

(where: y = vector of observation; b = vector of fixed effects; u = vector of random effects; e = error vector; X = matrix of fixed effects; Z = matrix of random effects)

Population genetic parameters were estimated using the DFREML (Meyer, 1998) and MTDFREML (Boldman et al., 1993) programs, based on the guidelines of Szőke and Komlósi (2000) and Lengyel et al. (2004).

In both models BV of the sires for the AFC trait was estimated. In case of GLM method, estimated progeny difference (EPD) was determined as the difference between the mean value of the progeny group of a sire and the mean value of the performance of the contemporary offspring population. The BV was calculated as twice the EPD. In case of BLUP model, the animal model communicated the values of BV directly. Breeding values are only shown for the 15 sires with the most offspring due to size reasons.

In the two different models, two different rankings were established based on the estimated BV of the sires based on the AFC trait. The effect of the model on the rank of sires was determined by Spearman's rank correlation (Spearman, 1904) calculation, similar to the studies of Núnez-Dominguez et al. (1995) and Lengyel et al. (2004).

Calculating phenotypic and genetic trends

When calculating the phenotypic trend, the AFC of cows born in the same year was averaged, and then the mean values were plotted against the year of birth. A one-way linear regression analysis was used for fitting function to the resulting set of points. The dependent variable was the AFC and the independent variable was the birth year of cow. The values of the constant (a), the slope (b) and the fit (R^2) and their statistical reliability were also determined.

The genetic trend of the studied trait was determined in two ways. On the one hand, from the BV of all individuals born in the same year, on the other hand, from the BV of sires born in the same year (for sires, separately BV with GLM method and BV with BLUP animal model). The BV of the individuals (or sires) born in the same year were averaged, and then the obtained values were plotted against the year of birth. Linear lines were fitted to the resulting point sets using one-way linear regression analysis. The dependent variable was the mean of AFC breeding value and the independent variable was the year of birth. Similar to the phenotypic trend calculation, the values of the constant (a), the slope (b) and the fit (R^2), as well as their statistical reliability was determined.

RESULTS

Effect of environmental factors

Based on the results, the overall mean of the AFC of Limousin cows was 33.9±0.2 months (Table 3). Subtracting the average gestation length of cattle (9.5 months) from the first calving age, it can be concluded that the Limousine heifers in the study were exposed for breeding around an average age of two years.

Among the examined factors, the effect of the sire, the herd and the birth year of cow on the AFC was significant ($P<0.01$) (Table 4). The effect of the birth season of cow was not found to be significant. The proportion of evaluated factors in phenotype was as follows: herd 73.51%, birth year of cow 13.02%, sire 6.74%, and birth season of cow 1.62%.

Table 3. Descriptive statistics of age at first calving trait of Limousin cows

Parameters	Value
N	1157
Mean (month)	33.9
Standard error (SE) (month)	0.2
Standard deviation (SD) (month)	5.9
Coefficient of variation (cv%)	17.4
Median (month)	32.9
Minimum (month)	24
Maximum (month)	48
Kolgomorov-Smirnov test † (p)	0.000

† if P>0.05, the normal distribution is confirmed

Table 4. The effect of different factors on the age at first calving of Limousin cows

Trait		Age at first calving	
Factor	Classes	The effect and rate of factors in phenotype	
		P-value	%
Sire of cow	59	<0.01	6.74
Herd	3	<0.01	73.51
Birth year of cow	22	<0.01	13.02
Birth season of cow	4	NS	1.62
Residual	-	-	5.11
Total	-	-	100.00

NS = not significant

The effect of the examined environmental factors on the AFC is summarized in Table 5. The estimated adjusted mean of the AFC by GLM method proved to be 34.7±0.4 months. The highest AFC (38.0±0.9 months) was found in herd number 2. This value was on average 4-6 months higher than that observed in the other two herds. Note, that 24% of the cows in herd 1, 72% of the cows in herd 2, and 41% of the cows in herd 3 were born in spring. By examining the effect of the birth year of a cow, it was found that the AFC of the cows born in early years of examined period was 6-7 months longer than that observed in the case of the cows born later.

Table 5. The effect of the environmental factors on the AFC of Limousin cows

Trait	N	Age at first calving (month)	
Corrected overall mean±SE	1157	34.7±0.4	
Environmental factors		Mean±SE	Deviation from overall mean
Herd (code)			
- 1	745	31.9±0.6	-2.8
- 2	344	38.0±0.9	+3.3
- 3	68	34.2±0.9	-0.5
Birth year of cow			
- 1992	37	39.5±1.9	+4.8
- 1993	59	38.7±1.8	+4.1
- 1994	58	38.2±1.7	+3.5
- 1995	65	37.7±1.6	+3.0
- 1996	93	37.5±1.4	+2.8
- 1997	81	36.5±1.4	+1.8
- 1998	35	35.1±1.5	+0.5
- 1999	48	34.8±1.4	+0.1
- 2000	63	32.1±1.2	-2.6
- 2001	66	32.6±1.3	-2.1
- 2002	42	30.9±1.4	-3.8
- 2003	46	32.6±1.3	-2.1
- 2004	122	33.6±1.2	-1.1
- 2005	52	32.6±1.4	-2.1
- 2006	47	36.7±1.9	+2.0
- 2007	45	33.8±1.5	-0.9
- 2008	41	34.4±1.8	-0.3
- 2009	35	31.7±2.3	-3.0
- 2010	66	32.7±2.3	-2.0
- 2011	12	30.0±2.4	-4.7
- 2012	15	32.8±2.8	-1.9
- 2013	29	31.7±3.0	-3.0
Birth season of cow			
- winter	241	34.5±0.5	-0.2
- spring	484	34.9±0.4	+0.2
- summer	242	34.8±0.5	+0.1
- autumn	190	34.5±0.5	-0.2

Population genetics parameters, breeding values

Between the mean values of AFC of the progeny groups of various sires different results were obtained with the two models (Table 6).

Estimated by GLM method, the lowest breeding value in AFC (-9.4 month) was found in case of id. number 12481 sire. The highest breeding value in AFC (+6.2 months) was shown by the id. number 20695 sire. The difference between these two extremes was 15.6 months. Contrary to our expectations, with the BLUP animal model, only 0.6-month difference of BV of the sires was observed.

Despite the above partial difference, we found a moderately close, positive rank correlation (r_{rank} = 0.65; P<0.01) between the rankings of sires set up in two different models.

The heritability of AFC trait proved to be very small in the examined Limousin population (Table 7). Values of h^2 = 0.08±0.07 were estimated for the GLM method and h^2 = 0.01±0.04 for the BLUP animal model.

Phenotypic and genetic trends

During the calculation of the phenotypic trend of the examined trait (Table 8; Figure 1), the AFC of Limousin cows decreased by 0.33 months per year (b = -0.33±0.06; p<0.01). The fit of the phenotypic trend (R^2 = 0.60; P<0.01) was medium, and significant.

In contrast to the phenotypic trend calculation, the genetic trend failed to show a clear trend of BV at the AFC. Based on the estimated BV of the sires by GLM method, the breeding value of the sires for the age at first

Table 6. The effect of sire on the age at first calving trait of Limousin cows

Trait	N	Age at first calving (month)			
Corrected overall mean (mean±SE)	1157	34.7±0.4			
		GLM method			BLUP animal model
Sire of cow (registration number)		Mean of progeny (mean±SE)	Estimated Progeny Difference	Breeding value	Breeding value
- 12015	96	33.2±1.5	-1.5	-3.0	+0.0
- 12481	19	30.0±2.1	-4.7	-9.4	-0.2
- 12483	23	31.5±2.0	-3.2	-6.4	+0.0
- 12946	37	33.3±1.4	-1.4	-2.8	-0.1
- 13098	67	32.9±1.3	-1.8	-3.6	+0.0
- 13869	22	31.4±1.6	-3.3	-6.6	-0.3
- 14474	28	35.7±1.8	+1.1	+2.2	+0.3
- 14476	19	35.4±1.9	+0.7	+1.4	+0.0
- 14684	107	35.9±1.1	+1.2	+2.4	+0.3
- 15250	61	35.1±1.2	+0.4	+0.8	-0.1
- 16444	38	36.5±1.4	+1.8	+3.6	+0.2
- 17031	28	35.6±1.6	+0.9	+1.8	+0.0
- 18750	27	33.1±2.0	-1.6	-3.2	-0.1
- 18853	20	35.1±1.9	+0.4	+0.8	+0.0
- 20695	22	37.8±2.5	+3.1	+6.2	+0.1
Spearman rank-correlation value (r_{rank})			0.65 (P<0.01)		

Table 7. Population genetic parameters of the age at first calving of Limousin cows

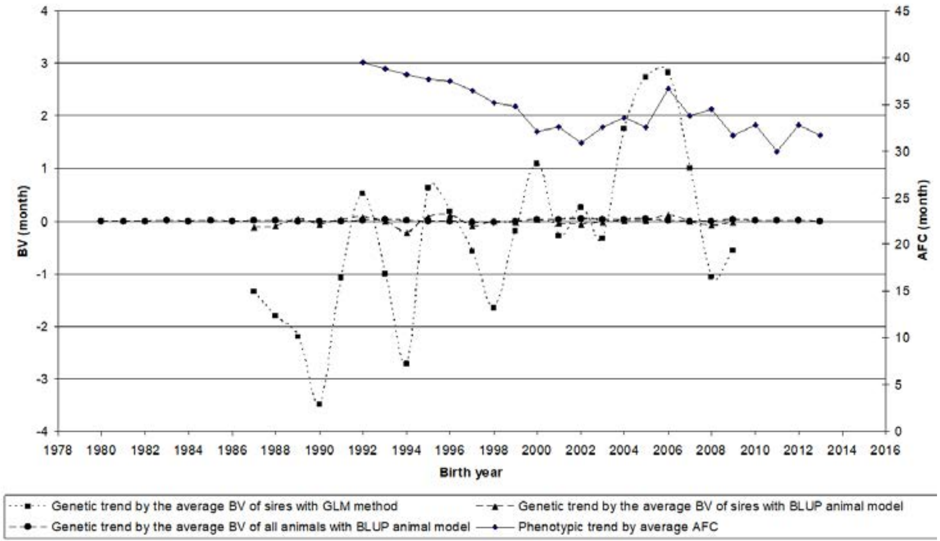
Parameters	Age at first calving	
	GLM method	BLUP animal model
Additive direct genetic variance (σ^2_d)	2.20	0.30
Residual variance (σ^2_e)	26.13	26.37
Phenotypic variance (σ^2_p)	28.33	26.67
Heritability (h^2)	0.08±0.07	0.01±0.04

Table 8. Endophytic isolates obtained from two soybean cultivars

Trend	Y	Slope			Intercept			Fitting	
		bX			a				
		b	SE	P	a	SE	P	R^2	P
P	AFC	-0.33	0.06	<0.01	691.18	119.47	<0.01	0.60	<0.01
GSA	AFC^{BV}	+0.14	0.05	<0.05	-282.91	98.20	<0.05	0.32	<0.05
GSB	AFC^{BV}	+0.00	0.00	NS	-2.59	5.90	NS	0.01	NS
GAB	AFC^{BV}	+0.00	0.00	NS	-0.84	0.08	NS	0.06	NS

P = phenotypic trend; GSA = genetic trend, BV of sires with GLM method; GSB = genetic trend, BV of sires with BLUP model; GAB = genetic trend, BV of all animal with BLUP model

X = birth year; AFC = average age at first calving (month); AFC^{BV} = average breeding value in age at first calving (month); BV = breeding value



BV=breeding value; AFC = age at first calving

Figure 1. Phenotypic and genetic trend of the age at first calving of Limousin cows

calving increased on average by 0.14 months per year (b = +0.14±0.05; P<0.05). The fit of the trend based on the GLM method showed a low value (R^2 = 0.32; P<0.05), but was significant value. In the case of the BLUP animal model, the trend calculation based on the estimated BV of the sires or the total herd did not show significant change. In both cases, the slope was zero and the fit value of the equations remained below 10%. Yet according to the results estimated with the animal model, no significant change was found in the average breeding values during the study period.

DISCUSSION

In this study, the average AFC of Limousin cows was similar to that reported by Dákay et al. (2006ab) and Zsuppán et al. (2010). This result indicates that Limousin cows were exposed to first mating approximately at the age of two years.

Results for the effect of the birth year of cows on the AFC were similar to the studies of Dákay et al. (2006b) and Boligon and Albuquerque (2011). The magnitude of the sire effect, however, lagged behind the data reported by DeRouen and Franke (1989). Similarly to the results of Magana and Segura (1997), the effect of birth season of cow was not found to be significant for the studied trait. Contrary to the data of Zsuppán et al. (2010), this study verifies the effect of herd on the AFC.

There are few research results in the literature on the BV of beef cattle breeding for the AFC. In the case of Limousin sires, no such published data were found. The BV estimated with the BLUP animal model were smaller than the data reported by Bormann and Wilson (2010) for the BV of the AFC of Angus sires.

Similarly to some research results data in the literature (Forni and Albuquergue, 2005; Castro-Pereira et al., 2007; Vergara et al., 2009), the heritability of the AFC in this study was small. Available sources of publication reported h^2 values between 0.05-0.15, however the values estimated in this study were lower than in the mentioned publications. The very low heritability of the AFC on the one hand supports the very significant herd effect experienced during in this work and on the other hand draws attention to the importance of environmental factors that have a great influence on the trait evaluated.

The results of our phenotypic trend calculation clearly indicate a decrease in the AFC in the studied Limousin population. A similar trend was reported for dairy herds by Hare et al. (2006), Ansari-Lari et al. (2009), and Hossein-Zadeh (2011) and for beef herds by Vergara et al. (2009).

Ansari-Lari et al. (2009) and Hossein-Zadeh (2011) also observed a decrease in the genetic trend of the AFC in Holstein-Friesian herds. However, no clear genetic trends in this study were found in Limousin population. Based on our results it seems there are no appreciable genetic changes in the AFC of Limousin population during the evaluated period.

CONCLUSIONS

Based on our study the age at firs calving of Limousin cows was mostly influenced by the herd effect. This large herd effect - as an environmental effect - resulted in a very low heritability of this trait. Moreover little differences in the BV between sires were found. The similarity between sires in BV led to the fact that the genetic trend of the trait showed a stagnant, year-on-year similar appearance. The possible cause of this situation is that BV for the AFC is not estimated and published by the breed association, so the breeders have no chance for selection to this trait.

The AFC mostly depends on the age when young heifers are mated. Practically the mating age is not determined genetically, but is a decision of the breeder. Breeders consider the maturity, which is judged based on age, live weight, body proportions and biological conditions (cyclic oestrus etc.) of heifers when they decide to breed them. Under given operating and economic conditions, the assessment of breeding maturity is primarily a management activity which together with other factors, manifests itself as the effect of herd.

The breeding technology used on the farm may also be part of the herd or farm effect. In addition to the classical cyclic, the breeding practice is important as breeding heifers that do not become pregnant in the summer may have an additional breeding period in the autumn or wait a year until the next summer breeding period. These situations also pay an important role in the AFC.

In many cases, breeders have an economic (lower rearing costs) or a breeding interest (replacement of cull cows) for earlier breeding. In general, without conscious selection for the AFC, the herd or farm effect may be stronger than the genetic background inherited from the parents.

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