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Variation factors for the use of foal heat in warm and cold-blooded horses

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Abstract:

In order to study variation factors affecting the use of foal heat in the breeding of warm-blooded and cold-blooded horses, French administrative data covering the breeding seasons between 1994 and 2008 were analysed; i.e. 306,540 foaling-first mating intervals in warm-blooded animals and 204,329 in cold-blooded animals. The GLM procedure under SAS was used for statistical analyses. The factors of variation targeted were; year, age of the mare, month of mating, breeding area and breed. The same analysis was also performed using the Logistic procedure from SAS on a bimodal variable which took values of 1 if the interval was <=14 days and 0 if >14 days. The two methods produced exactly the same results. Foal heat is used more intensively in cold-blooded breeds, and marked differences can be seen between breeds. However, intra-breed genetic analyses using ASREML on a maternal animal model that split the effects of the mare into an additive genetic part and an environmental part revealed low levels of heritability of the foaling-first mating interval (between 0 and 0.10) and not inconsiderable effects of the environment common to the same mare (between 0.03 and 0.11). A seasonal effect and the age of the mare (mainly for in warm-blooded breeds) revealed some physiological influences on the occurrence, or not, of foal heat. However, the most important factor for variation appeared to be the breeding management techniques applied, as shown by the effects of the breeding region and year. The sustained decline over the years in the use of foal heat is a matter for concern, and this trend needs to be reversed as it exerts a negative impact on the productivity rates of our breeds because it reduces the number of opportunities to get a mare into foal.

Key words:

Horse, foal heat, factors of variation, heritability, repeatability

Introduction

The particular features of horse reproduction are described in many handbooks (Nishikawa 1959, Nishikawa and Hafez 1968, 1974) and reviews (Nagy et al. 2003, Blanchard and Macpherson 2011). One of these specificities is that mares go into heat very soon after foaling. As we showed recently (Langlois et al., 2011) as a continuum of the work by Mattews et al. (1967), the interval between birth and the next mating has a bimodal distribution that is not normal. As shown in Figure 1, the first peak observed before 14 days centres around 8-9 days and corresponds to foal heat. The second peak is smoother, occurring at around 29-30 days and corresponding to the first normal heat. Subsequent heat periods, every 21 days to 90 days, cannot be clearly identified. Despite its non-normal distribution, this interval clearly reflects the intensity of the use of foal heat in breeding and we used it as a basis for our analyses. In order to avoid any problems connected with non-normality, we also used one, none or all variable, taking a value of 1 if the mare was mated during the 14 days following foaling and zero if it was covered later. The aim of this study was to analyse effects of year, age of the mother, season, breed and breeding area on the use of foal heat for breeding. After identifying the principal factors for variation, we then performed a breed-by-breed genetic analysis to estimate the heritability and repeatability of this interval between foaling and first mating.

Materials and methods

French administrative data on breeding seasons between 1994 and 2008 were analysed and this produced 306,540 foaling-first mating intervals for warm-blooded horses and 204,329 intervals for cold-blooded horses.

As explained above, two variables were analysed: the GLM procedure under SAS (2002-2003) was applied to the intervals observed. The logistic procedure under SAS (2002-2003) was used when considering none or all variables.

The factors thus analysed were:

Year of mating: 15 levels from 1994 to 2008, 1994 being the reference.

Age of the mare at mating: 19 levels from 2 to 20 or older, with 6 years old being the reference.

Month of mating: 12 levels from January to December, with April being the reference.

Breeding area: 10 levels, as described in the study on foetal losses (Langlois et al. 2010), with Region III (Normandy-Western France) being the reference.

The breed effect was considered in different ways, depending on the file being analysed. To prevent a proliferation of levels, we first of all considered the sire's breed and then whether the mother's breed was identical (with pure breeding as the reference) or different (crossbreeding effect), which only added two levels. For the general database, only the difference between warm and cold blooded animals was, with warm-blooded being the reference. For the sub-file defined by warm-blooded sire breeds, five levels were considered: Thoroughbred (TH), Arab (AR), Anglo-Arab (AA), French Saddle (FS) and French Trotter (FT), which acted as the reference. For the sub-file defined by cold-blooded sire breeds, eight levels are considered: Percheron (PER),Boulonnais (BOU), Trait du Nord (TDN), Auxois (AUX), Ardennais (ARD), Cob Normand (CBN), Comtois (COM) and Breton (BRE), which acted as the reference.

By definition, the reference level had an effect that was equal to zero in GLM analyses and an odds ratio of 1 in logistic analyses. An odds ratios >1 indicated a positive effect and an odds ratio <1 a negative effect.

A Dam animal model adding the random effects of the mare's genotype and of the common environment she shared with all her offspring was then adjusted using ASREML software (Gilmour *et al.* 2009). This was applied to all breeds where the number of animals enabled correct estimations of the genetic parameters. The data restricted to pure breeding and mares with at least two gestations are shown in Table 1.

Table 1: Data structure of the sub-files studied.

To explain these models in a more mathematical manner: let D_{ik} be the duration of the foaling-first mating interval of dam i at her kth gestation, added to a corresponding vector for fixed effects and the general mean μ. μ is the mean interval for the reference levels of all factors of variation.

To simplify, let us ignore the complex indices of elements b in the B vector. Note that every b is a deviation from the reference level of the corresponding factor, and every b is estimated independently of all other fixed and random effects:

$$Dik = \mu + B + A_{mi} + C_{mi} + E_{ik}$$

Where $A_{mi} + C_{mi}$ are the maternal effect with its additive genetic part A_{mi} and its common environmental part C_{mi}, and E_{ik} is a random error.

The variance-covariance structure supposes independence between genotypes and the environment, but the genotypes are correlated through the coefficient of relationship of the dams. The maternal environment is also correlated intra-mare but not between mares. All other correlations are supposed to be zero. This enables an estimation of the different variance components: Var(Am) and C^2m leading

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respectively (when expressed as a percentage of phenotypic variance) to the definition of heritability (h^2= Var(Am) and repeatability (r = Var(Am) + C^2m).

Results

All the effects described below were found to be significant in the analyses using the GLM and Logistic procedures in warm-blooded and cold-blooded horses, and in general. However, the magnitude of the effect of the mother's age was not sufficient to be significant in cold-blooded horses. For reasons of simplicity, we have limited ourselves to presenting the GLM results because the Logistic analyses produced almost the same results in a symmetrical manner, and because effects expressed in days were easier to understand than when expressed as odds ratios.

Year

Figure 2 shows that there was a general trend towards increasing the foaling first-mating interval, with the exception of the 2002 mating year 2002 which displayed a very low value.

Figure 2: Effect of the year on the foaling first-mating interval.

Age of the mare

Figure 3: Effect of the age of the mare on the foaling first-mating interval.

Among warm-blooded mares (Figure 3), there was a clear minimum for the foaling first-mating interval in those aged 8-10 years. This was not observed in cold-blooded mares, where the shortest delays were observed among 3-year-olds and values appeared to stabilise thereafter.

Season

There was a general trend (Figure 4) towards increasing the interval during the year, and two waves corresponding to the spring and autumn could clearly be seen. Breeding in January was mainly through the use of foal heat. Breeding on foal heat was common between February and April in warm-blooded horses, and between February and may in cold-blooded breeds. Use then declined until July-August, when the curve for mainly cold-blooded breeds starts to rise again.

Figure 4: Effect of the season on the foaling-first mating interval

Breeding area

Figure 5 shows that regions I (East), II (Brittany), V (Centre-Poitou), VI (South-West), VII (Auvergne), IX (Mediterranean regions) and X (Mountainous areas) displayed clearly longer intervals than others with shorter intervals (regions III (Normandy-Western France), IV (Northern France + Ile de France) and VIII (Burgundy)). The results shown in Figure 5 were then used to produce the map shown in Figure 6.

Figure 5: Effect of the breeding area on the foaling-first mating interval.

Figure 6: Map of breeding areas as a function of their use of foal heat.

Breed

All warm-blooded breeds (Figure 7) had longer intervals than the French Trotter which served as a reference. Boulonnais, Trait du Nord, Auxois and Ardennais breeds had shorter foaling-first mating intervals than the Breton, Cob Normand, Comtois and Percheron breeds (Figure 8).

Figure 7: Effect of a warm-blooded sire's breed on the foaling-first mating interval.

Figure 8: Effect of a cold-blooded sire's breed on the foaling-first mating interval.

The situation was the same for the "none or all" variable, but the difference between the Cob Normand and Ardennais breeds was not as marked. In general, all cold-blooded breeds had shorter intervals than the reference, while in the Breton and Comtois breeds, foal heat was used more for mating. When crossing breeds, the interval was reduced by 2.5 days in warm-blooded breeds and by only 0.5 days in cold blooded breeds. On average, the interval was 2.7 days shorter than in warm-blooded breeds. The corresponding odds ratios was that there a 1.904 greater chance of using foal heat in cold-blooded breeds than in warm-blooded breeds. This value was 1.376 when crossing warm-blooded breeds and only 1.063 when crossing cold-blooded breeds.

Breed per breed, genetic analyses (Table 2) revealed few intra-breed additive genetic effects and not inconsiderable maternal effects. Indeed, despite significant breed effects, the values for intra-breed heritabilities only ranged from 0.00 to 0.10. However, values for a common environment shared by the same mare ranged from 0.03 to 0.11, which as a function of the breeds gave rise to repeatability values of between 0.07 and 0.16.

Table 2: Genetic parameters regarding the length of gestation in French horse breeds

Discussion

The two methods used for these analyses produced almost the same results. Therefore, despite the bimodal distribution of the foaling first-mating interval, the effects in days of the different variation factors might be preferred to the odds ratios produced by logistic regression. However, the latter is statistically the most convenient and should serve as the reference in the rare cases where these two approaches do not generate similar results.

The year effect revealed a steady increase in the foaling-last mating interval, with the exception of 2002. This reflected a symmetrical decline in the use of foal heat for breeding. It is possible that the development of AI and the payment of fees for each dose rather than per mated mare might have impacted this feature. Social trends towards more amateurism and anthropomorphism might also have caused this negative impact.

As for age, the shortest foaling-last mating interval was observed in warm blooded mares aged between 8 and 10 years. However, in cold-blooded mares, the minimum for 3 year-olds was followed by relative stability. In fact, this effect is not significant regarding the "none or all variable" in cold-blooded horses. However, the maximum use of foal heat in animals aged between 5 and 9 years was confirmed for this variable in warm-blooded horses. In most cases, foal heat was not used for breeding in young mares (including a large number of primipara) and older, warm-blooded mares.

Season effect: It was seen that as the year progressed, the foaling first-mating interval tended to lengthen.   However, seasonal waves of shorter intervals could be observed between February and May and in September-October. These waves were confirmed on the diagram of foal heat utilization, where the minimum was clearly situated in the summer between June and August. As suggested by Koskinen (1991), some physiological reasons could be put forward to explain why a larger proportion of mares display foal heat in the spring and autumn, including the photoperiod (Malschitzky et al., 2001; Sumeet Sharma et al., 2010).

Breeding area: The map shown in Figure 6 could be deduced from analysis of the two variables. Regions marked in green were those with a more intensive use of foal heat for breeding.

Indeed, this map reflects the regions traditionally linked with the breeding of warm-blooded horses. These include the national studs in Saint Lô, Le Pin, Angers, La Roche/Yon, Compiègne and Cluny. Should we therefore conclude that breeders in these regions are less reluctant than others to use foal heat for breeding?

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As we indicated previously, the breeders of cold-blooded horses breeders use more foal heat than those of warm-blooded horses (Langlois *et al.* 2011). Among the latter, the French Trotter is the warm-blooded breed where foal heat is most widely used; at the other end of the scale, the Thoroughbred and Arab breeds are very shy and the technique is little employed, while the Anglo-Arab and Selle Français saddle breeds lie in between. Among cold-blooded horses, foal heat is most frequently used in the Breton breed, but the levels do not differ significantly from those seen in the

Ardennes, Cob Normand, Comtois and Percheron breeds. However, the heavy Auxois, Boulonnais and Trait du Nord breeds make significantly less use of this method.

It is not possible to determine whether these differences in the use of foal heat are a result of breeding management methods or because of the occurrence, or not, of this special heat. It is likely that the two causes coexist. The breed effect determined during this study is indicative of possible genetic influences. The season effect also revealed some physiological influences. On the other hand, it was difficult to explain the sustained decline in the use of foal heat over the years (except for 2002) by factors other than breeding practices. Indeed, if heat fertility is lower during foal heat (Lowis and Hyland, 1991; Davies Morel et al., 2009; Blanchard and Macpherson, 2011), fertility at the end of the season is higher when using foal heat because there are more opportunities to get the mare in foal (Langlois *et al.,* 2011). We would therefore recommend a correction to this negative trend.

Conclusion

The two methods proposed here were used to analyse variation factors with respect to the use of foal heat for breeding, and they produced exactly the same results. There was a clear difference in favour of cold-blooded breeds in terms of using foal heat, and differences between breeds were clearly demonstrated. The effects of the season and the mare's age (in warm-blooded breeds only) revealed the influence of physiological factors. However, the most important factors of variation are breeding management revealed by the effects of the breeding region and the year and the low estimations of the heritability.

The declining use of foal heat is a matter for concern and this trend needs to be reversed. Indeed, it exerts a negative impact on the productivity rates of our breeds because it reduces the number of opportunities to get mares into foal.

Conflicting interest

The authors declare that they have no conflicts of interest.

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Table 1: Structure of the data in the sub-files studied.

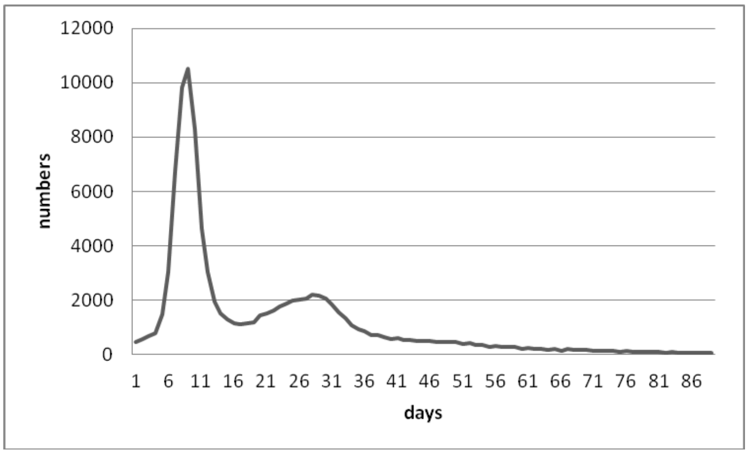
Breed	Observations	Mares	Sires of mares	Generations
Thoroughbred	47,149	12,239	3954	17
Arab	9977	2512	1652	23
Anglo-Arab	6400	1880	2317	22
French Saddle	47,256	13,045	6305	22
French Trotter	121,525	30,259	2815	14
Percheron	14,105	7343	1040	14
Ardennes	8621	2091	1269	16
Cob Normand	5046	1142	481	14
Comtois	34,546	8469	2889	19
Breton	38,928	9202	2960	17

Table 2: Genetic parameters affecting the foaling-first- mating interval in French horse breeds

Breed	Heritability	C²maternal environment	Repeatability
Thoroughbred	0.056 (0,007)*	0.062 (0.007)	0.118 (0.010)
Arab	0.052 (0.014)	0.052 (0.013)	0.104 (0.019)
Anglo-Arab	0.046 (0.023)	0.098 (0.024)	0.144 (0,032)
French Saddle	0.065 (0.008)	0.098 (0.009)	0.163 (0.001)
French Trotter	0.050 (0.004)	0.044 (0.004)	0.094 (0.001)
Percheron	0.102 (0.013)	0.030 (0.012)	0.132 (0.018)
Ardennes	0.000 (0.000)	0.103 (0.010)	0.103 (0.010)
Cob Normand	0.025 (0.017)	0.042 (0.017)	0.067 (0.024)
Comtois	0.050 (0.008)	0.110 (0.009)	0.160 (0.001)
Breton	0.033 (0.007)	0.085 (0.008)	0.118 (0.001)

* Standard deviations shown in brackets.

Figure 1: Distribution of the foaling-first mating interval



-Total for the 2005-2008 mating seasons 2005-2008 with respect to data between 1 and 90 days

Figure 2: Effect of the year on the foaling first-mating interval

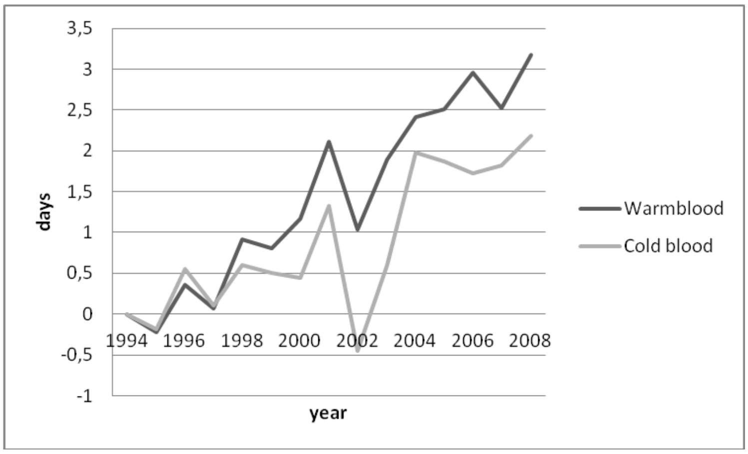


Figure 3: Effect of the mare's age on the foaling first-mating interval

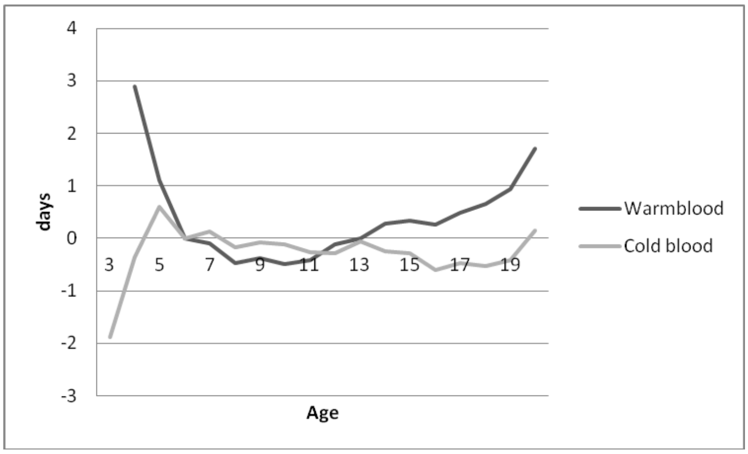


Figure 4: Effect of the season on the foaling-first mating interval

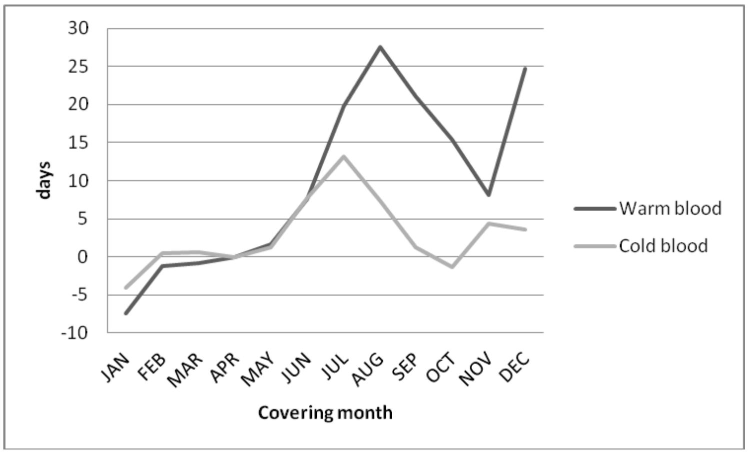


Figure 5: Effect of the breeding area on the foaling-first mating interval

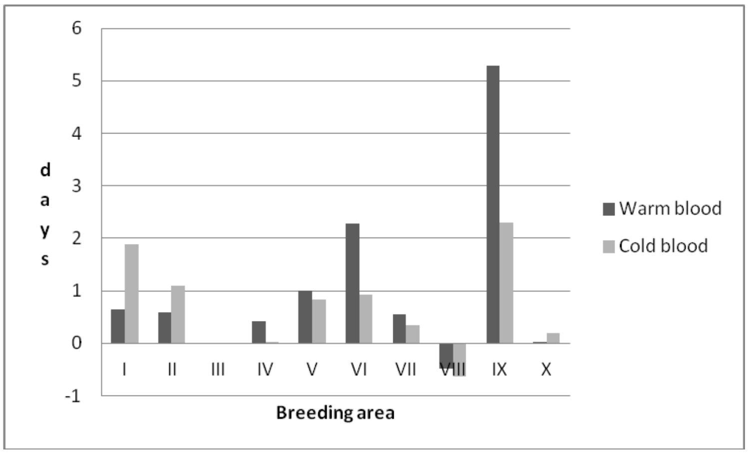


Figure 6: Map of breeding areas as a function of their use of foal heat

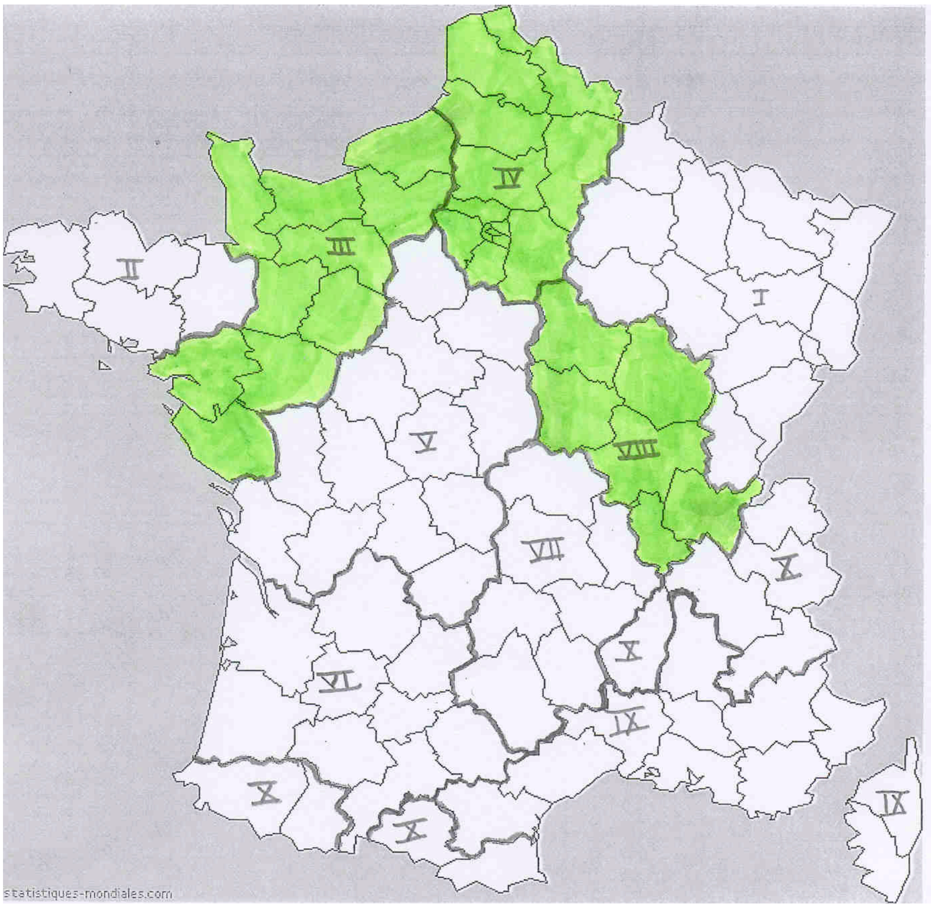


Figure 7: Effect of the breed of warm-blooded sires on the foaling-first mating interval

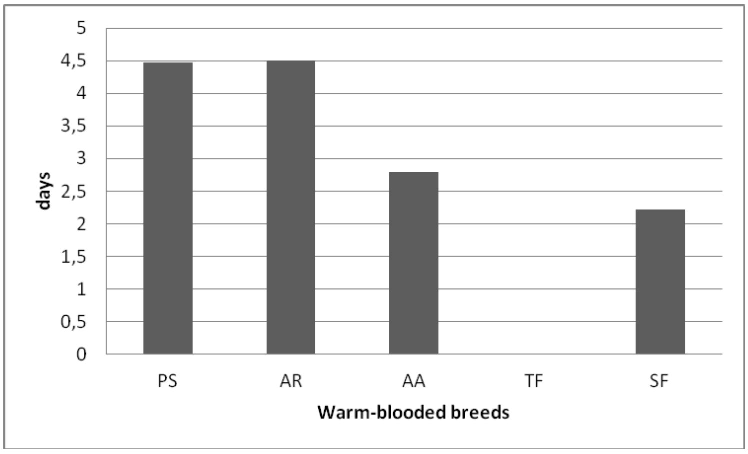


Figure 8: Effect of the breed of cold blooded sires on the foaling first mating interval