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Original article

Statistical analysis of some factors affecting the number of horse births in France

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Abstract – Declarations of matings (535 746) and 308 549 consecutive declarations of birth from 1989 to 1999 were analysed by logistic regression in order to determine the effects of year, breed and age of parents on numerical productivity (the number of foals declared per mated mare per year). For the years 1994 to 1999, the status of the mare, type of mating and month of first mating, were also available. The effect of inbreeding and, for warm-blooded horses, the effect of the level of performances or the effect of the level of breeding value estimation were also analysed. The main results are the following: numerical productivity progressed in France more for draught breeds than for saddle breeds and trotters. Thoroughbreds progressed less and just reached the level of significance. Cold-blooded horses, however, appeared less productive than warm-blooded horses for which thoroughbreds were at the lower level. It cannot be concluded if this figure reveals biological differences in fertility or if it is only the result of differences in managing the official declarations. For warm-blooded horses, the absence of negative relationships between the trends of selection and numerical productivity results appeared clearly. A high performance level for the mare was positively associated with higher productivity results in sport and trotting horses and showed no significant influence for galloping horses. The relationships with breeding value estimation illustrated the same trends.

horse / fertility / logistic model / factors of variation / selection / inbreeding

1. INTRODUCTION

French horse population is characterised by having an important stock of cold-blooded horses. The reason for this is French horse meat consumption. The permanent pastures in some areas and deeply enrooted traditions have allowed the conservation of our draught breeds. The most important cold-blooded breeds were the following: Breton, Comtois, Ardenne, Percheron, and the Boulonnais. Table I shows the breed statistics in 1999.

For warm-blooded horses, the early development of betting (Pari Mutuel Urbain) was the source of prosperity of two racing breeds, the Thoroughbred and the French trotter. The latter differ significantly from the American Standardbred because a great part of the races are under the rider and the mean distance of the races is 2400 m instead of 1600 m.

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Table I. 1999 breed statistics in France.

	Active stallions	Mares in pure breeding	Mares in cross-breeding	Numbers of breeders
Cold-blooded breeds				
Breton	476	3092	6444	–
Comtois	562	3395	6734	–
Ardenne	214	1329	1438	–
Percheron	173	1719	1367	–
Boulonnais	48	680	270	–
Warm-blooded breeds				
Thoroughbred	394	6912	1012	2922
French trotter	628	17336	958	7317
French saddlebred	680	12971	13875	7998
Anglo-Arab	186	2527	288	1673

–: Not documented.

Similarly, the development of the riding sport, mainly jumping in France, has led to the development of the French saddlebred and the Anglo-Arab.

Administratively the strong historical involvement of the Ministry of agriculture through the national studs in the horse industry allowed a kind of integration. For example, since 1974 the implementation of the computerised information system for the identification of French Equids (SIRE)* allows us to dispose of a great amount of administrative data concerning the production of all French- breeds, not only for the Thoroughbred. In parallel, the collection of performance data was done for warm-blooded horses by racing societies for trot and gallop and the Equestrian Federation for sports.

It is in this context that our institute (INRA) was solicited to conduct research on nutrition, reproduction and applied genetics. Let us put nutrition to the side. The application of new findings in reproduction should have produced some progress in the field. For applied genetics, new measuring criteria both for performances (annual indexes) and breeding value estimations (BLUP) were produced.

Because of this long process, we currently have a lot of computerised information not sufficiently used up to now. In this paper we want to answer the questions:

"Did reproduction performances evolve in the last decade and if so, what are the reasons?"

"Are some genetic problems connected with inbreeding or selection interfering with reproductive performance?"

To deal with these subjects, we widened our field of investigation to the different available variation factors of reproductive performance such as breed, age of parents, status of mare, type of mating and month of first mating.

We finally discussed the results obtained and we propose an interpretation.

2. MATERIALS AND METHODS

Declarations of mating (535 746) and 308 549 consecutive declarations of birth from 1989 to 1999, concerning warm-blooded and cold-blooded horses were analysed. A few embryo transfers (no more than 200 per year) were excluded and only pure breeding

* SIRE: Système d'Identification Répertoriant les Équidés.

was considered. For warm-blooded horses, 409 247 declarations of mating were followed by 120 726 declarations of a male foal and 122 750 females. The corresponding numbers for cold-blooded horses were 30 828 males and 34 245 females.

For each mare mated in a year, a bimodal variable was created. It takes the value 1 if there is a declaration of birth following the mating and 0 if no declaration is received.

The factors of variation were studied by a logistic regression using SAS 1999 [1] which is the appropriate method for such a bimodal variable [2].

– The breeds were the following: Thoroughbred “Pur-Sang” (PS), French Trotter “Trotteur Français” (TF) the reference, French- Saddle- Breed “Selle Français” (SF), Anglo-Arab (AA), Breton (BR) Comtois (COM), Ardenne (ARD), Percheron (PER), Boulonnais (BOUL).

– The years studied were from 1989 – the reference year to 1999.

– The age of mare at mating, from 2 to 27 years with 5 year-old as the reference, was studied.

– The age of stallion at mating, from 2 to 29 years with 5 year-old as the reference, was studied.

– The status of the mare is described as being one of two levels: (1) did not declare a foal for the preceding mating-year- the reference; (2) declared a foal.

For the years 1994 to 1999 concerning only 295 526 declarations of matings and 172 756 declarations of birth, the following factors were added to the analysis. i.e.:

– The status of the mare: 3 levels were considered because maiden mares were separated from barren mares in the previous category of mares that did not declare a foal. The criteria used for assignation as maiden was the following: not having been mated at least 5 years before.

– The type of mating: fresh AI (Artificial Insemination with fresh semen), froz AI (frozen), cool AI (cooled) F (free natural mating), H (hand traditional mating)-the reference.

– The month of first mating: (1) January–February; (2) March; (3) April; (4) May-the reference; (5) June; (6) July–August; (7) September–October; (8) November–December.

In a second step by breed categories (draught, saddle, trotter and thoroughbred), the effect of the year was examined as a co-variable in order to obtain an estimation of the slope.

The inbreeding coefficient of the sire, mare and offspring expressed in % were also integrated as co-variables in the models studied. They were calculated using PEDIG software according to [3].

The levels of performances of the mares were evaluated for warm-blooded horses according to the earnings in competitions. Four levels were defined according to the yearly indexes which are normalised earnings standardised on a mean of 100 and a standard-deviation of 20: (1) no earnings; (2) poor earnings (index < 100); (3) moderately good earnings (100 < index > 120); (4) best earnings (index > 120) – For more explanations see [4, 5].

The breeding value of the mare was also evaluated for warm-blooded horses according to a BLUP animal model on yearly earnings. Three levels were defined: (1) those worth 15%; (2) those 70% around the mean; (3) the best 15%. Breeding value estimations of the mare including the information performance of the mare and the effect of the latter were therefore not examined simultaneously with the effects of breeding value but separately by two different models.

For the results, we chose to present an odds ratio (O.R.) which was obtained by taking the exponential of the coefficients of the logistic regression. It expresses the chance to get a given value of the bi-modal dependent variable with regards to a certain level of the independent variable chosen as the reference (O.R. = 1). An independent variable or a level of a factor of variation having a positive effect has an O.R. > 1. If this effect is negative it has an O.R. < 1.

Table II. Complementary results for the effects of year, inbreeding, individual performances and genetic level on the numerical productivity (odds ratio).

	Draught breeds	Saddle breeds		French Trotter		Thoroughbred	
No. of matings	111 273	117 216		189 310		67 258	
No. of declared birth	56 831	68 063		118 210		36 325	
Covariable mating year 1989→1998	1.042	1.015	1.013	1.016	1.009	–	1.009
95% confidence interval	1.038; 1.046	1.011; 1.020	1.009; 1.018	1.013; 1.019	1.006; 1.013	1.000; 1.011	1.004; 1.015
Covariable inbreeding coef. in %							
Sire	1.018	1.017	1.017	–	–	–	–
Mare	–	0.989	0.985	0.987	0.986	–	–
Offspring	0.991	–	–	0.991	0.984	0.977	0.978
Individual performances level							
No earnings		1.061		–		0.853	
Small earnings		1		1		1	
Middle earnings		–		–		–	
Good earnings		1.073		1.042		–	
Genetic level							
Low			0.928		0.928		–
Middle			–		1		1
Good			1.110		1.169		–

All the other effects are included except the type of mating and month of first mating.
–: Non significant at the 5% level.

Here the choice of the predicted modality was to have a foal declared.

3. RESULTS

One can first consider (Fig. 1 and Tab. II) that numerical productivity progressed in France from 1989 to 1999, even though this latter year was particularly bad. However (Fig. 2) cold-blooded horses with 52 declared births for 100 mares mated appeared less productive than the thoroughbred (54), saddle breeds (58) and French Trotter (62). Their progression (= 4%/year) was, however, greater than that of warm-blooded horses (= 1%/year). This progression in terms of the odds ratio expresses the mean ratios for two consecutive years and not the absolute increase in numerical productivity. For example, for cold-blooded horses $0.54 \times 1.04 - 0.54 = 0.02$. The slope in numerical productivity was therefore around 2% per year and less than 1% per year for warm-blooded horses. One can note that thoroughbreds progressed even less and just barely reached the level of significance (between 0 and 0.5%).

The effect of the age on the numerical productivity of the mare (Fig. 3) first increased from 2 to 3 years, reaching a plateau from 4 to 6 years, and decreased after with a relative rapid slope up to 25–26 years where it was quasi null. Numerical productivity of the stallion (Fig. 4) also first increased from 2 to 4 years, reached a plateau from 5 to 8 years and decreased slowly after. Males appeared to mature later than females and aged later and slower. By comparing the 95% confidence intervals of the odds ratio

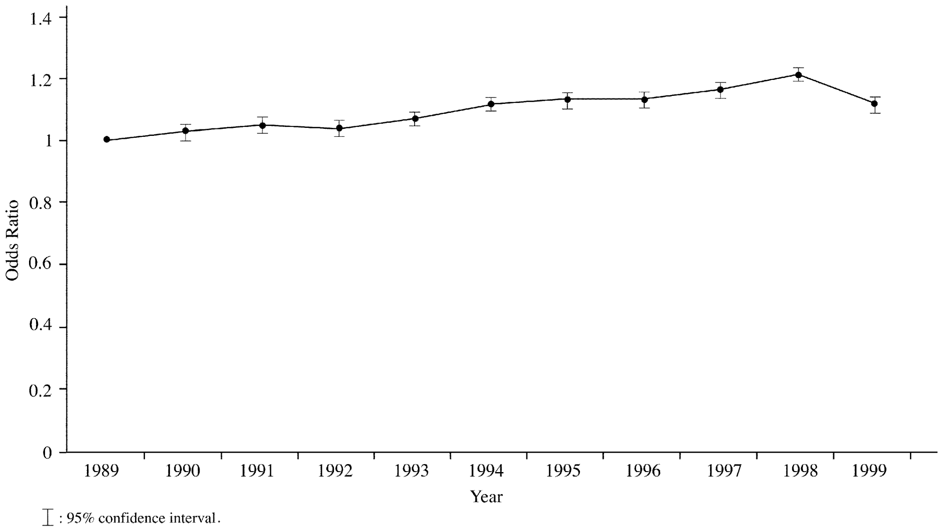

Figure 1. Effect of the mating year on the numerical productivity.

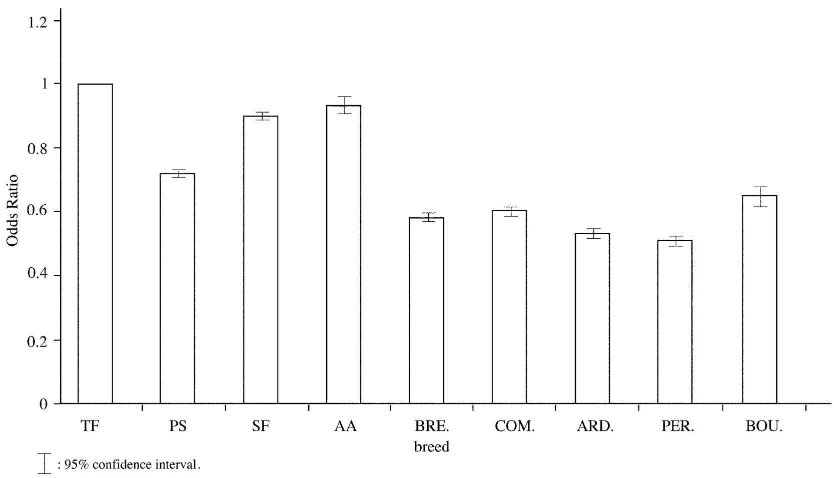

Figure 2. Effect of the breed on the numerical productivity.

at each age points the significant differences between sexes can be ascertained. This was particularly clear for age 3 (no superposition of the confidence intervals) and the significant exclusion of the reference value 1 starting with age 7 for mares and age 9 for stallions.

It clearly appeared (Fig. 5) that mares that declared a foal the preceding mating-year were more fertile than those not having declared a foal. (35% more). This was in contradiction with the supposed negative effect of lactation on fertility [6–8]. Instead of lower pregnancy losses [6] and other

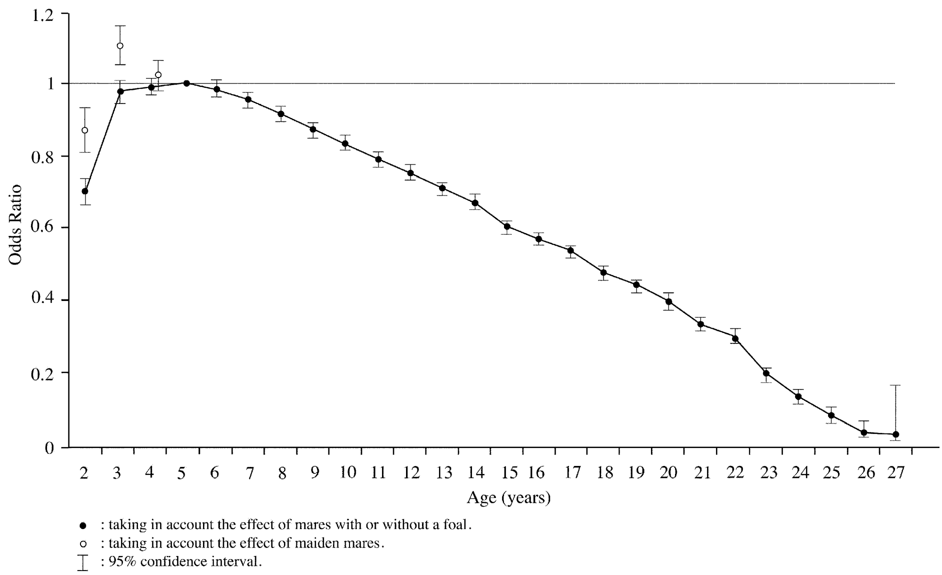

Figure 3. Effect of the mare's age on the numerical productivity.

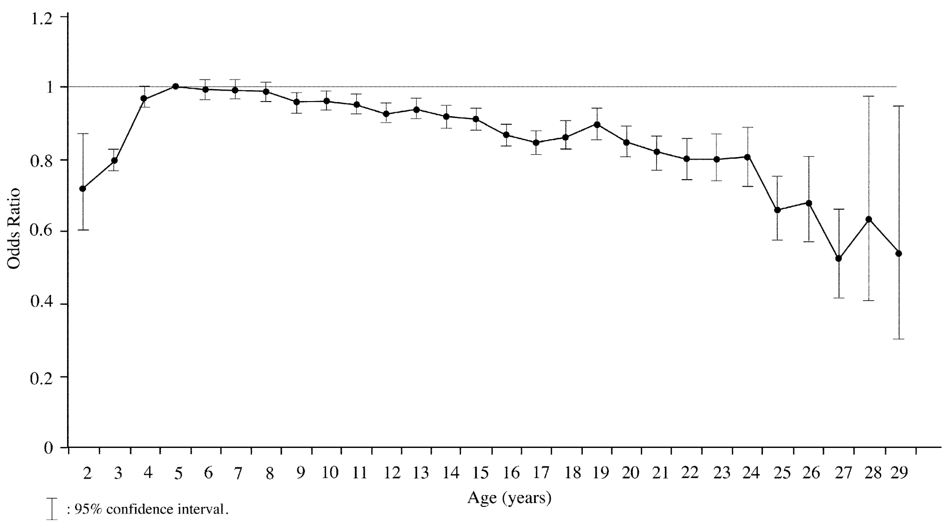

Figure 4. Effect of the stallion's age on the numerical productivity.

fertility results [49], maiden mares appeared as significantly lower reproducers (21% less than barren mares).

The type of mating (Fig. 6), artificial insemination (fresh, cooled and frozen semen) by hand or free running natural matings, had a highly significant effect on numerical productivity. On the contrary to the experimental results, [9–11], AI with fresh semen showed the best results in the field. AI with

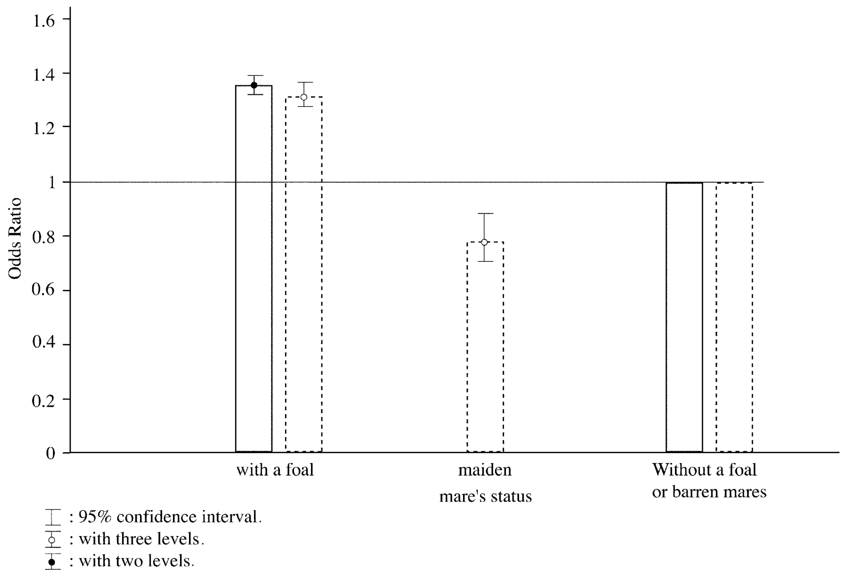

Figure 5. Effect of the mare's status with two or three levels on the numerical productivity.

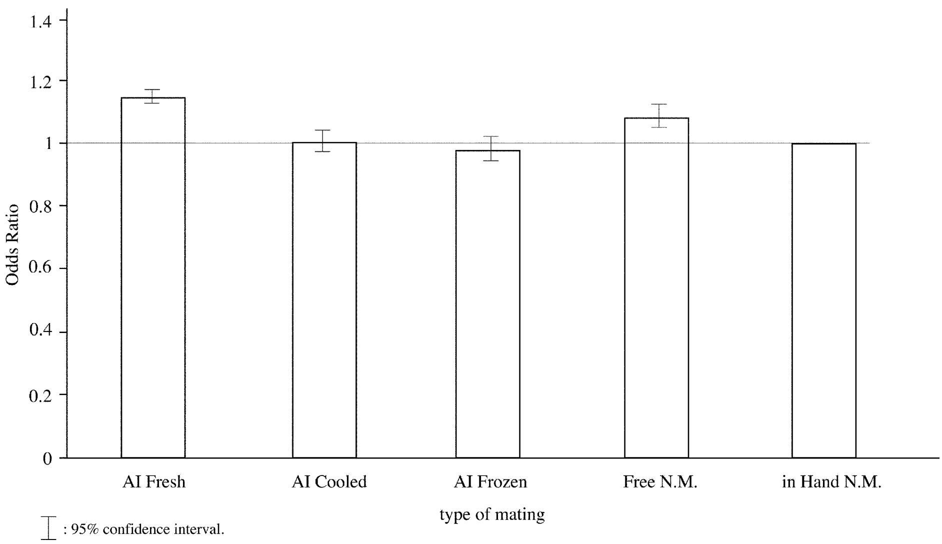

Figure 6. Effect of the type of mating on the numerical productivity.

cooled and frozen semen did not differ from that in natural by hand mating. The great advantage of the running free system in experimental conditions [9, 12–21] was not confirmed on the field, but it remained better than the most common by hand system.

The month of first mating (Fig. 7) naturally favoured an early mating (March), giving

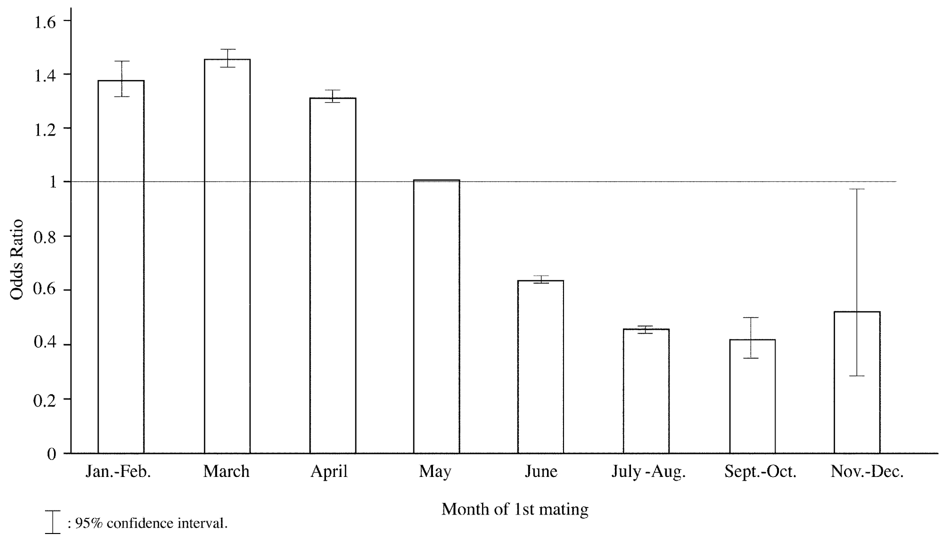

Figure 7. Effect of month of first mating on the numerical productivity.

more opportunities to the mare to become pregnant. Very early mating (January–February), however, did not totally valorise this advantage because many mares were not in oestrus at this time. Autumn- matings were rare and led to poor reproductive performances.

For inbreeding (Tab. II), numerical productivity was generally shown to decrease by 0.5 to 1% with a 1% increasing coefficient of inbreeding of mares and offspring. But some paradoxical opposite results were obtained in draught and saddle breeds with the inbreeding coefficient of the sire.

For warm-blooded horses, the absence of negative relationships between the trends of selection and numerical productivity results appeared clearly (Tab. II). A high performance level for the mare was positively associated with higher productivity results in sport and trotting and showed no significant influence for galloping. However, thoroughbred mares without any performances had lower productivity results. This confirmed our preceding results [4]. Relationships with breeding value estimation illustrated exactly the same figure, a high breeding value estimation was positively associated with higher productivity results in sport and trotting horses and showed no significant influence for galloping horses.

4. DISCUSSION

Differences between breeds in numerical productivity and yearly progress must be interpreted with care. There are differences in administrative declarations of mating and birth, thus reflecting real fertility with some errors. The difference in numerical productivity between cold-blooded and warm-blooded horses could be due to the non declaration of 13.5% of the foals in Draught horses. We could not, however, exclude the possibility of a higher mortality rate in young male foals generally having a higher birth weight [22–29]. The observed 47.4% male births for these heavy breeds with regards to 49.6% for warm-blooded horses could be explained by more dystocies for males [30]. This possible phenomenon, however certainly did not reach the necessary level to obtain the low observed numerical productivity results in cold-blooded horses. It was due, more probably, to the absence of the declaration of a part of foals in draught breeds when their chances to become reproducers were very low. This can be retained as the main reason, even if a lower fertility can be admitted [31]. The greater increase of productivity in these breeds may be due to the progressive resolution of this practice. Differences in observed numerical productivity between breeds can also be due to differences in mortality of the mares which seems to be maintained in production as much as they can. From demographical parameters, a replacement rate of 1/7 for cold-blooded mares and 1/10 for warm-blooded mares is acceptable. If this is done by death before the birth it may introduce great changes in the estimations of numerical productivity. This is one reason to promote a real management of the mare's reproductive life.

For warm-blooded horses, the poor productivity results of thoroughbreds and the lack of improvement is due to the highly traditional breeding management used instead of modern breeding technologies such as AI that have not been introduced. This may also be attributed to a significant percentage of mares mated in France and having been declared a product in another country. This product is then quoted only if it returns to France. On the contrary, the results for French trotters may be influenced by another practice. Due to the limitation of the number of mares allowed to be mated by one stallion, the stallion's owner tends to declare mated, only the pregnant ones. The situation of saddle horses therefore gives the less biased image of the numerical productivity achieved in French horse breeding i.e. 0.58 progressing from 0.008 per year. Breed differences may exist but were not confirmed. This is the great limitation of these administrative data. In this condition, statistics about the fertility of stallions are very ambiguous and must be considered with caution.

For other effects when the causes of untrue declarations are randomly distributed, the figures obtained are more reliable. This is the case for age: this effect has been documented for a long time [32–35], and is generally admitted in all studies [6, 20, 36–48]. The curves here are the first that give such a precision on the evolution of fertility with the age of mares and stallions. This is a zootechnical result that may differ slightly from the physiological one. For example when the status of the maiden mare is considered, fertility for ages 2, 3, and 4 is higher as shown in Figure 3. However, in a prospect of breeding intensification, the periods of full productivity of females (4 to 6 years) and males (5 to 8 years) should be considered. If we allow a decrease in fertility not greater than 10%, mares older than 8 years should not be used. Stallions, on the contrary, can be used as in the current conditions up to 20 years but with progressively limiting their yearly number of mated mares going actually from 25 in plenitude (5–8 years) to 14 (around 20 years) for warm-blooded stallions and from 11 (5–8 years) to 6 (around 20 years) for cold-blooded horses. This modulation of the number of mated mares according to the capacity of the stallions may explain the much lower slope of decrease of fertility according to age. The physiological requirements are, however, quite different: mostly spermatogenesis for males but ovogenesis and endometrical requirements for females. The latter seems to be the main limiting factor responsible for the rapid ageing of the females [36, 38, 39].

For the effect of the status of the mare, those with a foal at feet showed a much greater fertility. The supposed negative effect of lactation on reproduction was not observed. To have declared a foal for the preceding mating season seemed to be a good marker not only of the reproductive aptitude but also of good environmental conditions. Practically, a barren mare over 8 years of age could be proposed for culling.

Maiden mares are not so fertile probably because first oestrus is not easy to detect but also because the pre-selection of fertile females is not made at this stage.

The effects of the type of mating are not as expected from the experimental results. The significantly better result of AI with fresh semen is probably due to the better technical environment of the mare and the stallion when using this technique. AI with cooled or frozen semen does not differ significantly from by hand natural mating probably for the same reasons. Indeed, in stallions used via AI, all mares inseminated get the optimal dose of spermatozoa while by natural cover, the fertility may be reduced if the stallion has to cover more than one mare per day. The big advantage of free natural mating in experimental conditions is, however, considerably reduced in the field due to loose management. It has been said [12–15, 17–19] that the advantage of this technique is a better detection of the return to heat by the stallion but that it does not dispense following the mares and even planning of the herd. Putting a stallion together with some mares is not sufficient to get the full potential of the technique.

The effect of the month of first mating illustrated the amateurism of the breeding, with some mares being mated for the first time after June. From this figure we recommend a synchronisation of the first mating period in March. Good nutrition and a winter lighting treatment could help to obtain a result, for maiden and barren mares, [50–53]. Indeed, the length of night induces the production of a proportional quantity of the melatonin hormone signalling the beginning of winter ovarian inactivity. Lighting treatments allow to reduce the quantity of melatonin produced and therefore facilitate the apparition of cyclicity in early spring. However this works well only with well-fed mares in the autumn. The leptin hormone produced by the adipocytes is considered as the potential mediating signal which induces the strength of winter inactivity. In fact feeding at a low level induces a longer period of winter ovarian inactivity and a lower sensibility to lighting treatments. We therefore have to consider two archetype-cases: In extensive breeding, the mare presents a long period of winter inactivity and a short cyclicity starting at the end of May and finishing three or four cycles after, with foaling the following year being late. On the contrary, well-fed mares receiving a light treatment have a short period of winter inactivity, sometimes none. The start of cyclicity is advanced and this will at least add two cycles for conception. Foaling the following year will be earlier and it will be easier to maintain the mare on a one year interval between foalings. This phenomenon may explain the important effect of the month of first mating observed here.

For inbreeding, one must first say that there was relatively little variation in the coefficients calculated because horse breeding generally avoids close inbreeding. This explains the amount of non significant situations. However, for a one percent increase of the inbreeding coefficient of offspring in Draught and racing-breeds the numerical productivity decreases from 0.5% ($[0.99 - 1] \times 0.5 = -0.005$). The same trend was observed in saddle breeds and French trotters for the coefficient of the mare. On the contrary, an increase of nearly 1% ($[1.02 - 1] \times 0.5 = 0.01$) was observed for an increase of the inbreeding coefficient of the sire in draught breeds and saddle breeds. This paradoxical result could be due to better care with the reproduction of inbred stallions but we also noticed that the more homozygote the sires are, the more heterozygote the offspring will be.

For warm-blooded horses, the relation between numerical productivity and the selection trend shows no relation in thoroughbreds. Mares without any earnings in France declare fewer offspring than the others. This could be foreign mares returning home or poor level mares producing in an amateur environment. For trotter mares, the better the performances and the better the breeding value estimation the better the productivity results. A positive relationship may be due to special care of the best animals. For sport horses, mainly jumping in France, not having earnings led to slightly better productivity results than having small or average earnings. However, good earning mares had a higher productivity. For breeding value estimation, the better the evaluation, the higher the productivity. This could also be the better the breeding value estimation, the better the care. But in general from this result nobody can conclude on an antagonism between selection trends and numerical productivity.

5. CONCLUSION

The most important conclusion that appears from these results is that horse breeding belongs mainly to amateurism and this explains the poor productivity. When more care is given to the mare, the results are much better. The criterion having declared a foal the preceding mating-year seems to be a good marker not only for the reproductive aptitude of the mare but for the quality of her environment. They exhibit much better results (× 1.35) than the mares that did not declare a foal. Maiden mares show lower results (× 0.79) than barren mares. In practice, because they are difficult to identify they can be confused with barren mares. The paradoxical better results of AI are of the same order. They show a much better environment of the mare and stallion with AI than with by hand natural mating. The use of a more sophisticated technique leads to an increasing technical level of mating that largely counterbalances the real diminution of efficiency of the method. In this prospect, AI could be promoted to achieve the professionalisation of the reproduction working place and to finally obtain better productivity results.

Currently, too many variations of the performance of this working place were observed. Therefore a slight phenomenon cannot be shown by the administrative data concerning the stud-books. Breed differences are particularly questionable. For example, we do not know if there are more difficulties at birth for draft breeds than for warm-blooded horses and if they concern mainly male foals because of a high percentage of non declaration of foals in cold-blooded-horses.

The study allowed, however, the precise estimation of the age of reproducers on numerical productivity which is an appreciable result. This also showed the more evident effect of the month of first mating which proved the advantage of mating synchronisation in March. It is also clear that reproductive performance increased in France from 1989 to 1998. It is also clear that no antagonism could be shown between the selection trends for sport, trotting and flat races and the numerical productivity results.

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