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Optimal reproductive policies for Italian Heavy Draught Horse

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ABSTRACT
This study has aimed to identify the risk of unsuccessful reproduction in mares after a first foaling at age of 3 or 4 years (AFF) combined or not with different rearing systems (RS) and the condition for use of young stallions (YS) rather than the proven counterparts. This with the general aim of optimizing the Italian Heavy Draught Horse (IHDH) stud farms' reproductive policies. Reproductive performance at 1st and 2nd foaling of 1513 mares were used. Mares had normally 1st foaled at 3 (no.=745) or 4 yrs of age (no.=768) and were from stud farms based on stables (S; no.=488), wild (W; no.=345) or semi wild (SW; no.=680) rearing systems. Logistic analysis were carried out modelling the risk of unsuccessful reproduction in the subsequent season, considering both AFF and RS (separately or in combination). As regard the condition for use of YS, this was estimated by regressing the least square means obtained form a mixed model analysis for repeated measures carried out on differences in estimated breeding values (EBVs), at 1st and up to 7th subsequent evaluations, between young (mean no.=45/yr) and all proven stallions (mean no.=483/yr). Seven generations of young stallions were used (i.e., birth year from 1999 to 2005), allowing 2-7 repeats/YS. Differences in EBVs were expressed as global selection index (mean of 100 and s.d. of 10). Results obtained were a higher risk of unsuccessful reproduction on the 2nd foaling season for 3 yrs first foaling mares (+40%, P<0.01). In comparison with the best reproductive success at 2nd foaling (S-4 yrs), the highest risk of unsuccessful reproduction was in W-3 yrs (+167%), followed by SW-3 yrs (+91%). No significant differences were observed for other combinations of AFF-RS. As regard the use of YS, that showed a 0.50 standard deviation (sd) higher EBV at 1st evaluation than proven stallions, the estimated annual decrease in EBV was equal to 0.07 sd/yr. Optimal reproduction policies could be obtained in IHDH stud farms by limiting foaling at 3 yrs, particularly in W and SW rearing system, and using a YS for 3-4 yrs to maintain a sufficiently high selection differential with proven stallions.

INTRODUCTION
Many physiological aspects related to breeding management in horse reproduction are nowadays well known, and modulations of oestrus cycle (Gordon, 1997), use of artificial insemination and/or procedures for overcome fertility problems in both stallions and mares have been widely studied (see for review Guillaume et al., 2006 and Ellis et al., 2006). Moreover, new technologies are available in order to increase reproduction efficiency in this specie (Camillo et al., 2006). However, few studies have been focussed on the management of mares' reproductive career (i.e., better age at first foaling for a successful reproductive career) or on the use of stallions rather than the proven stallions to speed up genetic progress. In comparison, dairy cattle have been widely studied form this point of view. For example, correct growth (Heinrichs and Hargrove, 1987; Hoffman, 1997), feeding plans (Davis Rincker et al., 2008) and quality of feeding (Waldo et al., 1997) have been studied to assure a rapid growth and early calving, aiming to reduce the replacement costs. On the other hand, an extensive literature could be found on the advantage of using young sires rather than proven sires for the genetic progress of dairy populations (McDaniel and Bell, 1992; Meinert et al., 1992; Weigel et al., 1995; Abdallah and McDaniel, 2000 and 2002).

The gap in horse studies on reproductive policies is probably mainly due to athletic activity that characterise both sexes of many horse breeds. In sporting horses, mares' reproduction often has to deal with problems of old aged animals, while stallions are usually reproduced after a successful sport career and their reproductive value increases with the increased number of their successful sons and daughters that exhibit sport attitudes. On the contrary, horse heavy draught breeds (such as many pony or saddle horse breeds used for leisure) have usually reproductive policies similar to other farm animals, since sport activity is moderate or absent. In these situations optimal reproductive management should be encouraged to increase the annual income from the stud farm. In Italy, the most diffused heavy draught breed is the Italian Heavy Draught Horse (IHDH), which population account for about 6,000 animals widespread all along the national territory (Mantovani et al., 2005). Historically, the northern population have been gradually diffused to the centre and south part of the country. This distribution of the IHDH population has also contribute to the development of new and bigger stud farms and different rearing systems. Indeed, in the north animals are mainly reared in stables (S), while moving to the centre and south of Italy, a semi wild (SW) or wild systems (W) are more common, due to the progressive warm winter that allows animals outdoor for longer periods during the year. However, both SW and W rearing systems require a more careful growth and reproductive management of maiden mares. In recent years the number of maiden mares allowed to reproduction at three years of age has increased in the population, aiming to reduce replacement costs. This has lead to the need of evaluating the early start of the reproductive career in light of the subsequent reproductive performance and longevity of the mares. On the other hand, younger stallions have been allowed to reproduction at two years of age, in order to speed up genetic progress. However, some problems still exist in males' reproduction: 1) it is based mainly on stallions' natural services, i.e. artificial insemination involves only 10% of the whole females' population, and 2) breeders are still reluctant to use many young stallions and have more confidence in using few older proven stallions. The aim of this study was to investigate the optimum reproductive policies in Italian Heavy Draught Horse stud farms evaluating both the effect of age at first foaling (AFF) and different rearing conditions (RS: S, W or SW) of maiden mares on subsequent reproductive performance and the conditions and time for use of young stallions rather than proven stallions in the population.

MATERIALS AND METHODS

Data on 1513 mares born after 1990 and with 1^{st} foaling normally recorded were used to evaluate the effects of AFF and RS on the subsequent reproductive performance. Animals that entered the data-set had a reproductive performance registered in a subsequent reproductive season, i.e. foaling, abortion or involuntary not conception (i.e., open mares). The latter two causes were both considered unsuccessful reproduction and with the foaling (successful reproduction), dealt as dummy variables. In case of foaling in the subsequent season, animals retained for analysis had a foaling interval between 11 and 17 months (12.2±1.0). Mares were classified on the basis of the rearing system (RS) adopted in the stud-farm: stable (S), semi-wild (SW) or wild (W) all the year and age at 1^{st} foaling (AFF). To this regard, maiden mares with age at first foaling between 33 to 42 months were classified as 3 yrs. AFF, while those with AFF between 45 and 54 months as 4 yrs. Table 1 give some descriptive statistics as regard the number of maiden mares in each class considered.

Table 1. Distribution of maiden mares used in the study on the basis of different age at first foaling and rearing system adopted by the stud farm

Rearing System:	Age at first foaling		Total maiden mares
	3 years	4 years	
Semi-Wild	334	346	680
Wild	131	214	345
Stables	280	208	488
Total maiden mares	745	768	1513

Logistic regression analysis (SAS Institute, 2000), modeling the risk of unsuccessful reproduction accounting separately for AFF (2 levels) and RS (3 levels) effects or combining AFF-RS (6 levels), was performed for the 1513 reproductive events registered one season after first foaling.

For young stallions (YS) a total of 312 animals (on average 45 young stallion/birth year) were considered. Data analysed were expressed as differences of individual estimated breeding value (EBV) of each young stallion within birth year (from 1999 to 2005) from the average EBV of proven stallions in a given year of genetic evaluation (mean no. of 483 proven stallion/yr). For each young stallions' birth year the first evaluation considered was that obtained at two years of age (time of admission to the stud book), and based on the own records of each YS obtained by linear type evaluation recorded within the suckling period. In subsequent years, new rounds of genetic evaluation were considered and individual differences in EBVs obtained within each birth year as repeats of the first difference measured. This allowed a various number of replicates for each young stallion: from 2 (for 2005 birth year considering 2007 and 2008 genetic evaluation) to 7 replicates (for 1999 birth year considering from 2001 to and 2007 genetic evaluation), for a total no. of 1438 observations (table 2).

Table 2. Data structure for young stallions' (YS) study

Birth year of YS	No. of YS	Reference genetic evaluations for comparison with proven stallions		No. of subsequent replicates/YS
		First	Last	
1999	35	2001	2007	7
2000	35	2002	2008	7
2001	41	2003	2008	6
2002	65	2004	2008	5
2003	51	2005	2008	4
2004	48	2006	2008	3
2005	37	2007	2008	2

These were analyzed by PROC mixed (SAS Institute, 2000), and treated as repeated measures on young stallion within birth year, using an ante-dependence covariance structure (SAS Insitute, 2000) and a hierarchical linear model as follows:

$$y_{ijk}=\mu+BY_i+YS(BY)_{k:i}+REP_j+e_{ijk}$$

Were:

y_{ijk} = individual difference of a k young stallion in birth year i;

BY_i = fixed effect of birth year (i=1999,….2005);

$YS(BY)_{k:i}$ = random effect of young stallion within birth year (error term for the BY_i effect);

REP_j = repeated effect j of differences over time and due to subsequent genetic evaluations (j=2,….7, depending from the birth year of each young stallion);

e_{ijk} = random error term ~N(0, σ_e^2).

Table 3. Data on proven stallion used as reference for study on young stallions

Reference genetic evaluations (year)	No. of proven stallions	Mean EBV for proven stallions	standard error
2001	432	104.2	0.4
2002	439	106.0	0.4
2003	453	106.5	0.4
2004	495	107.1	0.4
2005	520	107.2	0.4
2006	520	107.3	0.4
2007	490	108.3	0.3
2008	513	108.4	0.3

All EBVs differences used were based on the total selection index (TSI) obtained combining indexes for head size and expression, blood, muscularity, fore and rear diameter estimated form linear type evaluation of foals within suckling period (Mantovani et al., 2005). All indexes, including TSI were expressed on an average of 100 and standard deviation of 10 (Mantovani et al., 2005). The mean EBVs on each yearly genetic evaluation and number of proven stallions used as reference to obtain individual EBVs differences are reported on table 3.

RESULTS AND DISCUSSION

Table 4 report the first model of logistic regression analysis carried out on mares' reproductive performance taking into account separately both factors investigated as possible sources of variation. Significant risk of unsuccessful reproduction in a second year after first foaling was detected when maiden mares were reproduced the first time at 3 yrs. of age rather than at 4 yrs. of age. Table 4 and figure 1a show the amount of this higher risk linked with getting a maiden mare pregnant at two years of age.

Table 4. Results of logistic regression on the risk of unsuccessful reproduction in a subsequent year after a normal first foaling considering separately the age at first foaling and rearing systems

Comparisons	Odd ratios	Wald Test Confidence limits at 95%		Prob. for Wald χ^2 test(*)
		Lower	Upper	
Age at First Foaling:				
- 3 yrs. vs. 4 yrs.	1.40	1.10	1.77	<0.01
Rearing System:				
- SW vs. S	1.36	1.03	1.79	n.s.
- W vs. S	1.57	1.13	2.17	<0.01

(*)Accepted as significant only when P<0.01 or lower

This risk resulted 40% higher for the more precocious gestation and foaling. On the other hand, no differences were found between stables system (used in this analysis as reference risk) and semi wild system, but the wild system resulted in a significant higher risk of unsuccessful reproduction as compared with the stables system (+57%). When both age at first foaling and rearing system factors were combined, still the foaling at 3 years of age resulted in higher risk of unsuccessful reproduction in a subsequent year when compared with the AFF-RS combination with lower risk, i.e. 4 yrs. on stables (table 5). In this analysis, the model showed a slightly better fitting than in separate analysis (-2 log Likelihood: 1693.5 vs. 1691.5 for separate or combined effects model, resp.).

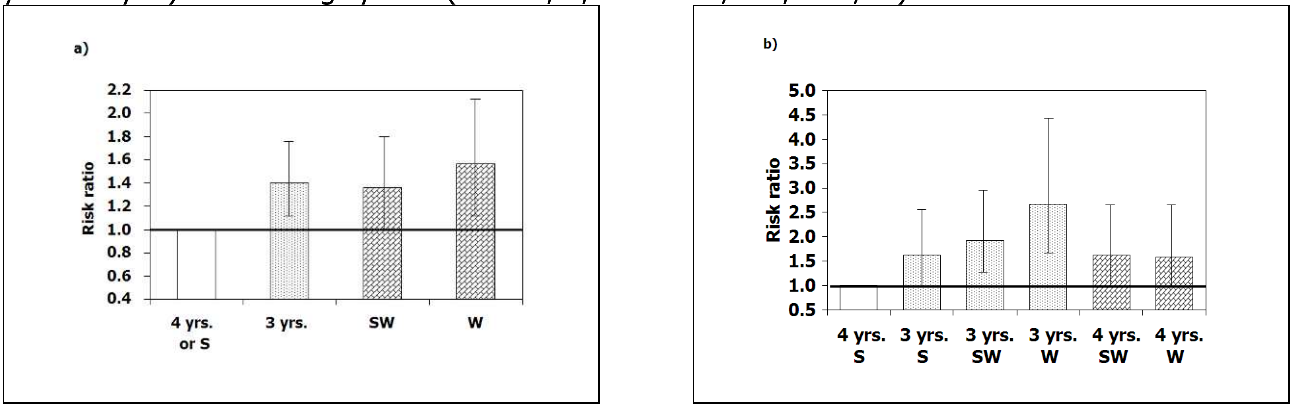
Table 5. Results of logistic regression on the risk of unsuccessful reproduction in a subsequent year after a normal first foaling combining age at first foaling and rearing systems

Comparisons	Odd ratios	Wald Test Confidence limits at 95%		Prob. for Wald χ^2 test(*)
		Lower	Upper	
Different AFF-RS vs. 4 yrs.-S:				
- 3 yrs.-S	1.62	1.03	2.54	n.s.
- 3 yrs.-SW	1.91	1.23	2.95	<0.01
- 3 yrs.-W	2.67	1.60	4.46	<0.001
- 4 yrs.-SW	1.64	1.06	2.53	n.s.
- 4 yrs.-W	1.59	0.98	2.56	n.s.

(*)Accepted as significant only when P<0.01 or lower

Among the odd ratios obtained, all depicted in figure 1b, particularly high were those obtained for 3 yrs. first foaling in semi wild and wild conditions, that indicate a +91% and +167% risk of unsuccessful reproduction in a second year after a first foaling at 4 yrs. in stables. In all other comparisons, the risk increases of about 60%, but the probability for Wald chi-square test was not highly significant as expected. A confirmation of this not significant risk is given by the lower values of the Wald confidence limit, that were in both cases closer to 1, i.e., the reference baseline of relative risk.

Figure 1. Relative risk ratio in separate analysis (a) or combining (b) different age at first foaling (3 yrs. or 4 yrs.) and rearing system (stables, S; semi wild, SW; wild, W)



Summarising, the first foaling of maiden mares at three years of age results a risky practice for the subsequent reproduction of mares, particularly in semi wild and wild rearing conditions. Because a previous study in this breed have demonstrate that the first years of reproductive activity can greatly influence the longevity in the IHDH mares (Mantovani et al., 2007), it is important to notice that a too precious foaling in semi wild and wild condition could therefore compromise not only the subsequent year of reproduction, but all the reproductive career of a mare. The high risk of failing conception or abortion in the subsequent year after the first foaling could be mainly a matter of mares' correct growth. Despite it was not possible to take into account in this study the body weight or size of animals at time of first pregnancy, we could speculate that the unsuccessful reproduction following the first foaling at three years could be linked to an incomplete development of mares at time of first pregnancy due to an insufficient growth. The fact that both semi wild and wild condition resulted in a significant risk of unsuccessful reproduction when first foaling occur at three years, as compare with the stable system, could be an indirect confirmation of this hypotheses. Indeed, both these situations reflect longer time of animals on pasture and it is well known that both production and maintenance of condition score (Bargo et al., 2002) or the growth of young cattle (Camfield et al., 1999) are reduced when animal are reared on pasture. Aiken et al. (1989) have reported lower growth rate also in yearling geldings fed pasture without any supplementation. Moreover, complication of reproduction have been suggested even in dairy cows when bred too early and with insufficient body size (Hoffman, 1997).

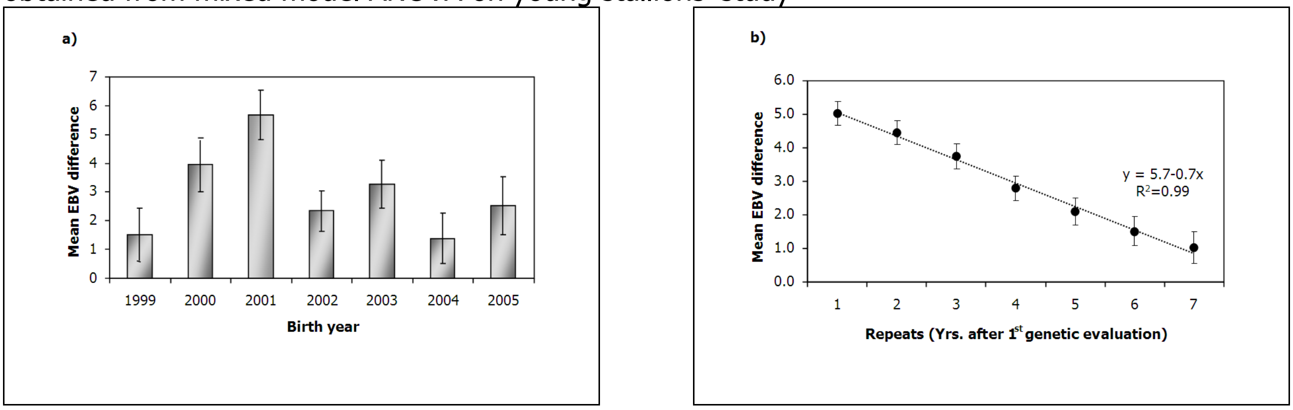
Table 6. Results of mixed model ANOVA for time of use of young stallions

Effect	Numerator d.f.(*)	Denominator d.f. (*)	F value	P
Birth Year	6	305	2.97	0.008
Repeats	6	1165	26.38	<0.001

(*) d.f.: degrees of freedom

Mixed model analysis on EBVs differences of young stallions from proven stallions indicated both significance for birth year and repeats effects. As regard the birth year, figure 2a shows the up and down mean breeding values of young stallions on proven counterparts. On average the young stallions showed a 0.3 standard unit higher EBVs than proven stallions in subsequent birth years (or generations), but the trend was not consistently increasing over time. This indicates that selection of young stallions is not always focussed in increasing the EBV for the total selection index. As previously reported (Mantovani et al., 2005), the total selection index is not always the only criterion assumed for selecting young stallions. A minimum morphology score is indeed required for allowing young males to be registered as "stallions" and fertility, moreover, could be a source of variability influencing young stallion admission to the stud book. Figure 2b shows the LSMEANS trend for the repeats effect. Since any repeats was linked to subsequent genetic evaluation of animals over time, this trend could represents the genetic lifespan from first evaluation of the young stallions. A simple regression of LSMEAN indicates a yearly decrease of 0.07 standard deviation (s.d.) per year. Using the regression equation it can be estimated that the selection differential between young and proven stallion at first evaluation (0.5 s.d.) results halved after 3.6 years. After 4 years from first evaluation, young stallion looses, on average, almost 0.3 standard deviations. Therefore, young stallion, that always have a EBV higher than proven animals, could be safely used for at least 3-4 years, allowing a speed up of the genetic progress at lower costs, considering the higher costs required for proven stallions' services. This aspect confirms findings reported previously for young dairy sires to be used in substitution of proven sires (McDaniel and Bell, 1992; Abdallah and McDaniel, 2000). However, it has to be pointed out that a reproductive policy based the use of many young stallions in a stud farm and their rapid change, following a schedule similar to that adopted in many dairy herds (Abdallah and McDaniel, 2002), could be effective only in big stud farm (i.e., sufficient number of mares to be bred with many stallions), situation not always common in the IHDH population. The use of AI, still not common in IHDH population, should give an additional help to such reproductive policy.

Figure 2: Birth year (a) and regression on repeats (b) LSMEANS (and standard error of LSMEANS) obtained from mixed model ANOVA on young stallions' study



CONCLUSIONS

This study has shown some practical implications for a correct reproductive management of both mares and stallions in Italian Heavy Draught Horse breed. Particularly it has been demonstrated that optimal reproductive policy in IHDH stud farms should consider a correct growth of maiden mares to allow animals to early foaling (3 yrs.), particularly in wild or semi wild rearing conditions. This open the debate and address the research to a better knowledge of a correct growth to reach an adequate body weight and size at first insemination also for this animal category. As regard the male side, the study shows that the use of many young stallions as possible in each stud farm rather than proven stallions with rapid change in 3-4 yrs. of time, before genetic value reduction due to the selection process, represents a convenient reproductive policy aimed to reduce cost of speeding up genetic progress.

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