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Efficiency of past selection of the French Sport Horse: Selle Français breed and suggestions for the future

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Abstract

Parameters of genetic trend of Selle Français (SF) horse breed were studied from 1974 to 2002 and detailed since 1991 because historical BLUP animal model genetic evaluation for jumping competition was available since 1989. During this period, annual births varied from 6000 to 10,000. The annual genetic trend for show jumping was 0.055 of genetic standard deviation between 1985 and 1995 and 0.096 since 1995 without unfavourable trend for dressage (ΔG=+0.002) and eventing (ΔG=+0.011). The three parameters of genetic trend: the selection intensity (i=1.95 for males, 0.48 for females), the accuracy (r=0.66 for males, 0.60 for females), and the generation interval (L=12.0 years for males, 11.5 for females) explained this result. Particularities were: a higher number of progeny for best sires which induced true selection intensity equal to 2.21, a new and important selection on progeny (46% births form sires tested on progeny between 2000 and 2002), a high rate of own performance test in competition for mares (45%) which induced high accuracy of mare pathway. However, demographic possibilities were not reached, the possible selection rate for male (1.5%) and females (49%) should increase genetic gain +14% and +11% respectively. The generation interval was too long: a better selection at first stage for males, with equal rapid test on progeny and a shorter period of reproduction, i.e. a higher number of foals per sire, should decrease the relative importance of progeny test and should decrease generation interval. The drop of mares aged more than 10 at first progeny should decrease 1.2 year generation interval without loss on accuracy. If breeders keep the same structure (test of stallion and majority of mares on their own performance), they could add new criteria (conformation, gaits...) in the breeding value estimation for SF and maintain the high genetic trend on jumping.

Keywords: Horse; Genetic trend; Selection; Jumping

1. Introduction

During the last 40 years, the Selle Français (SF) has been selected mainly for show jumping from results in competition. But, despite this single objective, the French breeding scheme contained a lot of rules. These rules were function of the age of the candidate and there were different ways to become an approved stallion. A 3 years old male candidate may be selected from gaits and conformation test. Then at 4, 5, 6 years or more male candidates may be selected by truncation threshold on breeding evaluation or on own performance in competition or may also pass an examination by a special commission. Whatever the age of selection, all approved stallions passed an X-ray test. All females born in the breed may become broodmares. Their selection is therefore totally breeder dependant.

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Were these rules efficient for the improvement of jumping ability? What were the consequences on the other disciplines: dressage and eventing? As other warmblood horse breeds all over the world (Koenen et al., 2004) breeders want to increase the number of traits in breeding objective. In addition to show jumping, they would like to select all horses on gaits, conformation, behaviour, fertility, and health. To add all these criteria by keeping an effective breeding scheme, it was initially necessary to identify the qualities and the drawbacks of the current plan of selection. For all these reasons, we analysed passed selection in SF since 1974 according to the parameters of genetic trend.

2. Materials

2.1. Genealogical data

The data used was provided by the national horse register, "Système d'Identification Répertoriant les Equidés" (SIRE) from the Haras Nationaux. This file included all the Selle Français (SF) born from 1974 to 2002 and their known ancestors. From 1974 to 1987 there were about 6000 births per year, then there was an increase of births until 1993 (10,000 births), then a decrease and now, since 1998, there was a stabilization about 7500 births per year. Since 1998, these births were performed by 870 stallions 580 of them were SF and they were responsible for 85% of the total births. This file contained for each horse registered: an identification number (ID), the name, the sex, the breed, the date of birth, the ID number of sire and dam. It contained 314,564 horses including 222,978 SF. The particular SF horse called AQPS (Autre Que Pur Sang), with more than 90% of thoroughbred genes, was not included on the study because it was bred for steeple-chasing and not for sport. The information was complete except for the date of birth that was missing for 2.8% of the horses. These horses with missing birth date were horses for which one or two parents were unknown (92%) and 46% of horses with one unknown parent had a missing date of birth.

The SF was the product of a long selection process that has been developed during the 20th century. First, it was called "demi-sang" and was the progeny of Thoroughbred stallions and local mares. It was only in 1958, that the name Selle Français appeared. Between 1958 and 1994, the stud book was open and a lot of crossings were possible. The decree of January 1995 closed partially the stud book and only the progeny with at least one parent SF could be recorded on the SF stud book.

2.2. Competition data

Since 1972, results in competition have been computer recorded, only for horses with earnings until 1984 and then for all horses which have participated to a competition. Competitions in jumping, dressage and eventing begin at 4 years old with special competition for young horses from 4 years old to 6 years old. This was called "circuit classique". The percentage of SF horses with performance in jumping at 4 years old was stable from 1981 to 1996: about 28%, then increased with the decrease of births and was 36% in 2000. At 5 years old, the percentage of horses with at least one year of competition (at 4 or 5 years old) increased from 1981 to 1987 from 39% to 46%. Then it was stable about 44% and now increased to 53% for births in 1999. Finally, at 7 years old, it was about 57% of SF horses which had a performance in jumping competition in France.

In dressage, the percentage of SF with a performance reached only 1% at 4 years old, 2% at 5 years old and 7% all over the life.

In eventing, the percentage of SF with a performance reached only 1% at 4 years old, 4% at 5 years old and 8% all over the life.

2.3. Breeding evaluation

Since 1976, breeding values have been estimated from competition results and since 1989 an animal model was implemented. The performance was the logarithm of annual earnings of the horse since 1972 (Langlois, 1980; Langlois and Blouin, 2004), to which the criterion of the underlying performance responsible for ranks was added since 1985 (Tavernier, 1991; Ricard, 1997). The parameters used on breeding evaluations for jumping were as follows: Heritability was 0.27 for Log(annual earnings) and 0.16 for underlying performance responsible for ranks in every events. Repeatability was 0.47 (between years) and 0.29 (between events) respectively.

Since 1999, horses had also breeding evaluations for dressage and eventing. The traits and models used were the same as for show jumping. For dressage, genetic parameters were: heritability 0.34 and 0.20, repeatability 0.60 and 0.35, maternal effect 0.05 and 0.03 for earnings and rankings respectively. For eventing, heritability was 0.14 and 0.07, repeatability was 0.45 and 0.34 and maternal effect was 0.03 and 0.03 for earnings and rankings respectively. All correlations between random effects genetic, common environment and maternal were nearly 0.90.

2.4. Sample used

The objective was to estimate the accuracy and the genetic superiority at moment of selection. It was important to notice that horse was selected on genetic evaluation calculated at the end of the year (n), the year $n+1$ covering occurred and the year $n+2$ the first generation of progeny was born. Because Animal Model BLUP breeding value estimation have been available only since 1989, all measurements of accuracy and genetic superiority of horses selected before 1989 were not possible. So these parameters were only computed from the year of birth 1991 to 2002. The percentage of horses with a known selection intensity and a known accuracy when their sire have been selected increased from 10% in 1991 to 71% in 2002 (around 70% since 1998). The percentage of horses with a known selection intensity and a known accuracy when their dam have been selected increased regularly from 30% to 92% from 1991 to 2002. There was no such restriction to compute generation interval which was computed from 1974 to 2002 births.

The other restriction on the data was that a horse was known to be a stallion or a mare only when it had progeny and so this time depended on the age at first foal. The number of horses born during the period 1991/2002 which become stallions was about 80 in 1991–1993 and fell to 4 in the last year available: 1997. On this sample, 13% and 45% of the selection intensity and accuracy of their sires and mares respectively were known. On the pathway sires of dam and dam of dam, the percentage of known selection intensity and known accuracy started respectively at 8% and 24% and reached 60% and 70% in 1997. The same restriction for the computation of interval of generation on the 4 pathways of selection was applied.

3. Method

3.1. Estimation of genetic trend

The realized genetic trend was computed as the average of genetic evaluation in function of the birth year of the SF population.

3.2. Estimation of the three parameters of genetic trend

As proposed by Rendel and Robertson (1950), the annual genetic trend expressed in genetic standard deviation was developed as:

$$\sigma_g = \frac{i_{SS}r_{SS} + i_{SD}r_{SD} + i_{DS}r_{DS} + i_{DD}r_{DD}}{L_{SS} + L_{SD} + L_{DS} + L_{DD}}$$

with S for Sire and D for Dam, i selection intensity, r accuracy, L generation interval.

The 3 parameters were estimated for each stage of the selection. The first stage of selection was selection on ancestors and relatives and eventually own performance. This selection occurred for males and females 2 years before the first births of their progeny. For sires, a second stage of selection was possible when the first generation of progeny had result on competition. First results in competition are obtained at 4 years old. So this selection was 4 years after the first births of progeny and progeny resulting from the progeny selection was born 6 years after the first generation.

The three parameters of the genetic trend observed were calculated on the 4 pathways: sire of sire, sire of dam, dam of sire, dam of dam. The calculation on these four pathways was often difficult. As mentioned above, the data used to compute these parameters were censored in the left hand side and also on the right hand side. So, in addition to the 4 pathways studied, the path sire of progeny and dam of progeny were also computed.

The parameters of genetic trend were calculated according to the birth year of the parent, the birth year of progeny and age of parent as a longitudinal study or cross-sectional study. The results were given with and without weight of progeny. The results were distinguished according to the breed of the parent as parent of SF.

The selection intensity was the average of the standardised genetic superiority (i):

$$i = \frac{\text{Breeding Evaluation} - \mu}{\sigma}$$

With the breeding evaluation of the selected horse of the years of selection, μ is the average of breeding evaluation of the year of selection of SF born the same year as the selected horse, and σ is the standard deviation of breeding evaluation of the year of selection of the SF born the same year as the selected horse.

Assuming a selection by truncation of a normal distribution, this superiority can be linked to a theoretical rate of selection (p):

$$i = \frac{z}{p}$$

with z ordinate of the normal distribution function at the point of truncation given by statistical tables, p the fraction of selected animals.

The accuracy was computed as the correlation between breeding value estimation and true genetic value.

Generation intervals were computed as the average age of parents at the birth of their offspring.

3.3. Estimation of selection rate

As seen previously, the selection intensity gave an equivalent *theoretical* selection rate. On the contrary, the realized selection rate was calculated as the percentage of males or females which become parents in their own birth year. It was not possible to calculate the realized selection rate in recent years because the total number of horses born which could become parent was not yet known (right censoring). So, the realized selection rate was calculated from 1974 to 1991 for males and 1974 to 1989 for females to avoid this censoring.

According to possibilities of demographic parameters, another selection rate was calculated: the possible selection rate, assuming a regular use of mares and stallions and knowing the variations in the total number of births registered. The demographic parameters were the sex-ratio (0.5), the fertility for female (0.55) and the average number of progeny per stallions per years was between 9.7 and 15.7 during the period considered. The fertility and the average number of progeny were calculated with the SIRE data. The number of stallions and mares for replacement was estimated according to the number of foals they produced during their period of activity due to the age at the first progeny and the generation interval. According to these parameters, the possible selection rate was calculated for generation born from 1974 to 1995 and 1974 to 1996 for males and females respectively. For the male, a possible selection rate was also calculated with a higher but biologically easily feasible number of progeny per stallions per years: 50. In this case, it was considered that fewer stallions were approved with no decrease in the length of reproductive life.

4. Results

4.1. The genetic trend

Fig. 1 shows the genetic trend realized between 1974 and 2002 for jumping, eventing and dressage. For jumping, there were three different phases. In the first one between 1974 and 1985, there was a slow progress ($\Delta G=0.007$ genetic standard deviation/year). In the second phase between 1985 and 1995, the progress increased and was about 0.056 genetic standard deviation/year. During the last phase, between 1995 and 2002, the genetic trend was higher ($\Delta G=0.096$ genetic standard deviation/year). For eventing, the progress was smaller ($\Delta G=0.011$ genetic standard deviation/year) and for dressage, we did not observe any damage over the period ($\Delta G=0.002$ genetic standard deviation/year). In fact, there was a slight decline up to 1985 followed by a slight improvement.

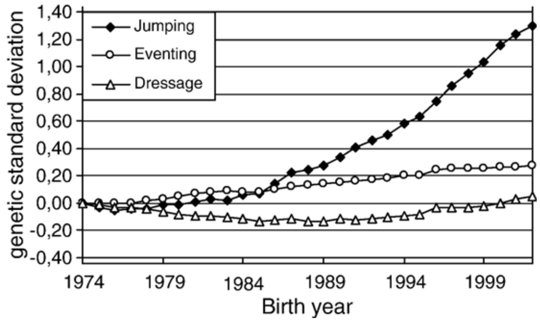

Fig. 1. The effective genetic trend in jumping, eventing and dressage.

4.2. The parameters of genetic trend for the first stage of selection

4.2.1. The 4 pathways

The first method was the cross-sectional study. All the results are presented in the Table 1. There were differences between the four pathways for the selection intensity, as expected for the sires compared to the dams but also with a higher selection for the sires and dams of sires compared to the selection of sires and dams of dams. The theoretical fraction of selected sires corresponding to selection intensity 2.69 on the sire/sire pathway was 0.9%. The theoretical fraction of selected sires corresponding to selection intensity 2.21 was 3.5%. So the selection rate to become sires of sires among all sires was 0.9/3.5 = 26%. To become mares of sires among all mares, the same calculation gave a selection rate of 9%. There was no difference between the way sires of dams and sires of progeny but there was a selection for the choice of dams of dams comparing to dam of progeny. The accuracy was higher for the sire ways than the dam ways: the difference was 0.06. The generation interval was long and slightly higher for the sire way than the dam way. There was no difference between the ways to produce progeny or mares. To produce stallions, the generation interval was longer for the sire/sire path (+0.8 year), and lower for the mare/sire ways (−1.0 year), but it did not induce any change on the accuracy.

4.2.2. According to the breed of parents

17% of births were from other sires than SF and 18% from other mares than SF. These births were mainly performed by racing breeds (Thoroughbred and French Trotter) or horses issued from non registered animals

Table 1
Selection intensity, theoretical rate of selection, accuracy and generation interval for Selle Français parents of Selle Français offspring born from 1991 to 2002

	Pathway					
	Sire/sire	Dam/sire	Sire/dam	Dam/dam	Sire/progeny	Dam/progeny
Total number of couples	296	328	6019	5998	85794	85661
With known data	15%	45%	32%	43%	54%	65%
Selection intensity	2.69	1.94	2.26	0.76	2.21	0.48
Theoretical rate of selection	0.9%	6.6%	3.0%	52.0%	3.5%	71.0%
Accuracy	0.64	0.62	0.65	0.58	0.66	0.60
Generation interval (years)	12.8	10.5	12.1	11.4	12.0	11.5

and not by foreign sport horses on the studied period. Results for the other breeds than SF are in Table 2.

The selection controlled by the SF rules on their own horses was the only one which was effective. There was nearly no selection of males from other breed comparing to the mean level of the population of SF and there was a selection in the bad way for mares because they were worst than the mean of SF population. There was the same phenomenon for the pathways of parents but it concerned few parents. In fact, for sires SF 14% have a sire non SF and 5% a dam non SF and for dams SF 16% of sire and dams were not SF. The accuracy for parents from other breed was largely lower than SF parents. The mating with sires and mares from other breeds had also a negative effect for the generation interval which was higher for both ways.

4.2.3. According to the age at selection

The mean of age at selection was 4.4 years for stallions and 5.2 years for mares. So, age was higher for mares. This was explained first because they were not all pregnant at first year of covering and second because they must stop their activities in jumping before having progeny. For mares, the distribution of this age had a large range of variation, which began at 2 years old and decreased with age: 26% were aged 2, 15% aged 3, 12% aged 4 and still 13% were aged 10 and more (Fig. 2). The distribution revealed that there was smaller variation for stallions: 51% were aged 4 at selection, 21% were aged 3 and 12% aged 5, and 16% were older.

The Table 3 gives the selection intensity and accuracy according to the age at selection. The selection intensity was the lowest for sires at 4 years old whereas the majority of sires were selected. This selection intensity was higher for selection of stallions before any performances (3 years old) or for confirmed stallions (5 years or more) before decreasing with very old stallions (after 8 years). For mares, selection without any performances gave high selection intensity for very young mares (2 years old) but not for mares aged 3. After performances, there was also a high variation according to the age of end of competition. The better return to breeding was performed at age 5 and then at age 10, so after the second year of specific competition for young horses or after an effective career in jumping.

For sires, the accuracy was lower for 3 years old, as expected because of the lack of own performance. The

Table 2
Selection intensity, theoretical rate of selection, accuracy and generation interval for breed other than Selle Français parents of Selle Français offspring born from 1991 to 2002

	Pathway	
	Sire/progeny	Dam/progeny
Total number of couples	18103	18236
With known data	36%	65%
Selection intensity	0.31	−0.66
Theoretical rate of selection	83%	Worst 59%
Accuracy	0.54	0.49
Generation interval (years)	13.9	12.4

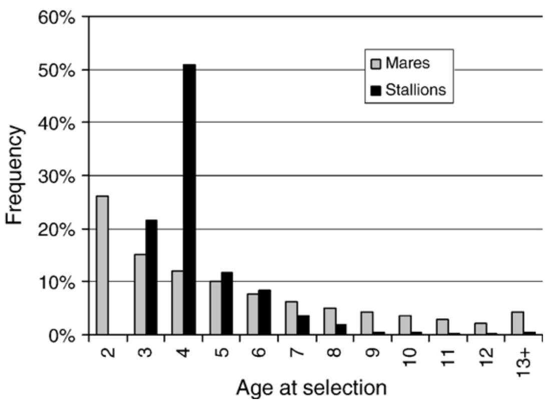

Fig. 2. Distribution of age at selection of Selle Français mares and Selle Français sires of offspring born between 1991 and 2002.

Table 3
Selection intensity, accuracy and frequency of mares with own performances according to age at selection for Selle Français parents of Selle Français offspring born from 1991 to 2002

	Age at selection (years)	Pathway		Frequency of mares with own performance
		Sire/progeny	Mare/progeny	
Selection intensity	2		0.61	
	3	2.59	0.39	
	4	2.06	0.43	
	5	2.27	0.56	
	6	2.34	0.47	
	7+	2.29	0.43	
Accuracy	2		0.53	0%
	3	0.60	0.52	0%
	4	0.65	0.57	42%
	5	0.68	0.62	66%
	6	0.69	0.64	74%
	7+	0.71	0.66	82%

accuracy reached 0.65 for 4 years old and stabilized about 0.70 for 5 years old and more. The percentages of sires which had own performance at the age of selection was 83% (89% for 4 years old) and 94% of stallions had performance already for the second stage of selection. Sires without performances were mainly horses which have competed only in foreign countries, so they were not registered with performance in France and young stallions which were approved at 3 years old.

For mares, the same phenomenon was observed for the 2 and 3 years old. The accuracy was lower around 0.53. It increased for 4 and 5 years old and was stabilized for 6 years old around 0.65. Overall births from 1991 to 2002, mares were 45% to have own performance when they were selected, that explained this high accuracy. Note that this percentage of mare with performance was a mean of young mares selected obviously without performance and mare selected aged 4 which were 42% to have performance and older mares (6+) which were between 70% and 80% to have own performances.

4.2.4. With no weight due to the number of progeny

All previous results were given weighed by the number of progeny of each parent. A second analysis for the selection intensity and the accuracy was performed in a longitudinal way, for which each parent was counted only once. The theoretical selection rate passing from 2.21 to 1.95 (equivalent to a rate of selection of 6.5%) when selection intensity was weighted by the number of offspring compared when it was not weighted. This corresponded to a new selection of the best 54% when considering the number of offspring provided. The accuracy was quite the same weighed by the number of offspring or not.

4.3. The progeny selection for the male

Fig. 3 shows the distribution of SF born in 2001 and 2002 according to the stage of selection and the age of their sires at the moment of birth. On the period 2000–2002 where the effect of censoring on data should be low, 46% of horses have a sire selected on progeny, and 51% on own performance and ancestors only (3% unknown). The progeny selection gave a selection intensity of 2.75 for the pathway sire SF/progeny, calculated on 25201 offspring SF born from 1991 to 2002 (according to censoring, about 30% of measured selection intensity was known). This selection intensity corresponded to a theoretical selection rate of 0.8%, 23% of best stallions pass the progeny selection. As for the first stage of selection, it was verified that progeny selection of sires from other breeds than SF was lower than SF sires ($i=0.43$). An increase of selection intensity from $i=2.06$ to $i=2.75$ when weighting by the number of offspring corresponds to a selection rate passing from 5.1% to 0.8% that was an increase of 16%. The accuracy was 0.75 when selection on progeny was when first progeny were aged 4 and 0.81 when progeny were aged 5 (2 generations tested).

4.4. Realized and possible rate of selection

According to the demographic parameters, the possible rate of selection for males was 1.5% that corresponds to a possible intensity of selection of 2.52. Comparing to theoretical selection rate realized, i.e.; 3.5% on the way sire/progeny, only the best 42% stallions in activity should be kept. When considering

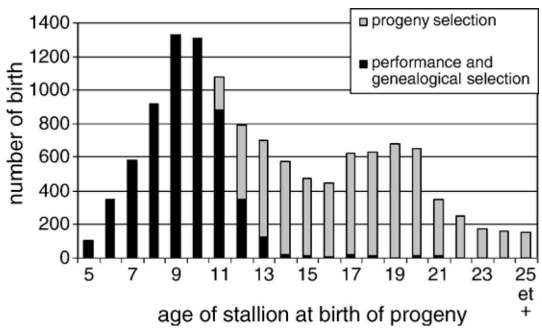

Fig. 3. Distribution of birth in 2001–2002 according to the age of sire at birth of progeny and the stage of selection.

50 offspring per stallions, the possible selection intensity was 2.96 and comparing to theoretical selection rate only the best 12% stallions in activity should be kept. The possible selection rate for females was 49%, corresponding to a selection intensity of 0.81. Comparing with the 71% realized, only 2/3 of mares should be kept.

4.5. Evolution of the parameters of genetic trend with time

Evolution of selection intensity of parents of SF born between 1993 and 2002 was reported on Fig. 4 for males and Fig. 5 for females according to the age at selection of the parents. The possible selection intensity corresponding to the possible rate of selection due to demographic possibilities was also reported. The evolution of selection intensity with the birth year of progeny depended on the age of selection of the sire. The higher selection intensity performed on stallions without performances (3 years) decreased whereas the selection of the majority of stallions (4 years) increased to converge to the same value in 2002. In the same period, the progeny selection appeared and increased. The demographic possibilities on the same period were stable. Selection intensity for young mares and old mares increased highly from 1991 to 2000, even during 1994–1996 as for the possible rate of selection due to variations in demography.

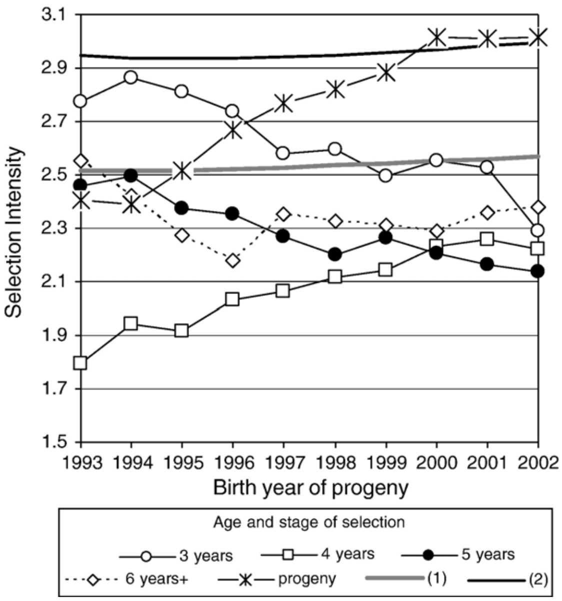

Fig. 4. Selection intensity of Selle Français sires (birth year 1993 to 2002) according to stage and age of selection of sires and possible selection intensity due to demographic parameters (1 = with actual number of offspring by stallion per year, 2 = with 50 offspring by stallions per year).

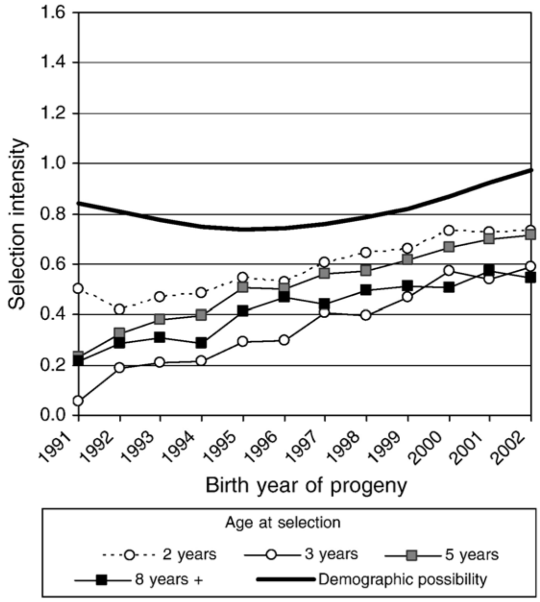

Fig. 5. Selection intensity of Selle Français mares of Selle Français born from 1991 to 2002 according to the age of mares at selection and maximum due to demographic possibilities.

The accuracy increased to 0.02 points from 1997 to 2002 for all stallions selected at age more than 3 (with performances) and was stable for stallions selected at 3 years old.

The evolution of generation interval for SF born from 1974 to 2002 with SF parents was reported in Fig. 6. A longer period was considered (data not censored). The generation interval on the sire pathway increased 4.1 years and 1.9 years between 1974 and 2002 and between 1991 and 2002. The more important evolution was performed in 4 years between 1999 and 2002: +1.6 years. For the mare pathway, on the same periods,

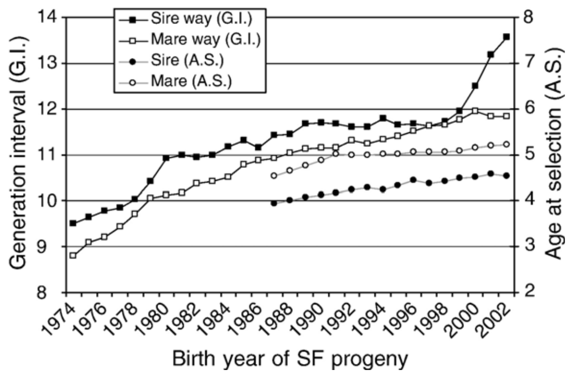

Fig. 6. Evolution of generation interval and age at selection of Selle Français parents of Selle Français progeny born from 1974 to 2002.

the increases were respectively 3.0 years and 0.7 year. From 1991 to 2002, the age at selection increased 0.4 year for the sires and 0.2 for the mares.

5. Discussion

5.1. Forces and weaknesses of the current breeding scheme for the show jumping

The selection intensity in first intention, i.e. if it is calculated on the genetic value of the approved stallion, independently of its respective use, is only 1.95, at the stage of selection on relatives and own performance and similar (2.06) at the second stage of selection on progeny. Thus, the selected stallions are only the 6.5% best males at the first stage and then rather all pass successfully the test on progeny. This is very far from the demographic possibilities which induce a possible selection rate of 1.5%. This is also far from the rate of selection really applied, which is 1.7%. The choice of the stallions is not efficient. In fact, this severe report is balanced by the practice of the breeders, independently of the initial choices. When the genetic values of the stallions are weighted by the number of their offspring, the selection intensity reaches 2.21 at the first stage of selection, thus a theoretical selection rate of 3.5% and 2.75 at the stage of progeny selection, thus a theoretical selection rate of 0.8%. An important improvement should be a strict selection of the best 1.5%, and an equal reproduction of all stallions selected. The selection intensity should be 2.52 (+0.31). The effect on genetic gain should be +14%. The second improvement should be to increase the number of foals by stallions with no change on the length of reproductive life. With 50 offspring per year and per stallion, the possible selection rate is 0.4%, the corresponding selection intensity of 2.96 (+0.75). A strict selection, an equal production of stallions and the increasing of the number of progeny per stallion/year to 50 could lead to an increase of 34% of the genetic progress.

The use of the progeny selection is recent on the French breeding scheme (the end of 1990) and is efficient. But only 23% of stallions are kept after the test on progeny (at least according to the number of progeny, not by the real elimination of the stallion) and the proportion of births from sires selected on progeny is high: half of the births in 2000–2002. The distribution of the average age of the sires (Fig. 3) showed a significant disaffection for the stallions aged 6 to 8 years at the birth of their offspring. The comparison of these results with other optimisation studies of breeding program is difficult because they are based on many parameters (specific population structure, variety of values for all parameters). However, the study of Tavernier and Clerc (1994) is an optimisation study that is modelling a breeding scheme in similar conditions. Tavernier and Clerc (1994) recommended a rate of 1/3 of stallions kept between the two stages that is 10% more than in our study. But, the optimum of birth from stallions selected on progeny is far from the 50% calculated between 2000 and 2002 because it was only 15%. The selection scheme studied by Hugason et al. (1987) on Icelandic horse population or by Huizinga (1990) on the Royal Warmblood Studbook of the Netherlands (KWPN) concluded that for a high genetic response of the breeding program, the breeding scheme should include a high percentage of mating by young stallions intensively selected on the basis of pedigree and performance test. Hugason et al. (1987) estimated 69% to 95% percentage of mares which should be mated by young stallions tested on pedigree and performances. Although genetic parameters are different, these results are in close agreement with findings from Tavernier and Clerc (1994) but not from our studies. Moreover, Hugason et al. (1987) and Huizinga (1990) showed that the selection of stallions based on progeny is limited from a genetic point of view (increase of generation interval). All these studies demonstrated the importance of using young stallions which is not optimum on the actual French breeding scheme. The weak use of young stallions denotes a too low initial selection or lack of policy of promoting young horses with good own performances.

Alternative selection strategies for the Swedish warmblood horse were studied by Phillipsson et al. (1990) and showed that the most efficient strategies of selection for stallions are the selection after performance test as in the studies of Hugason et al. (1987), Huizinga (1990) and Tavernier and Clerc (1994). A progeny selection could be efficient under specific condition, a low heritability for the character of interest (Ström and Philipsson, 1978), and late results for performances on competition (Bruns and Schade, 1998). Today most of the French stallions were tested on specific young horses' competition and the heritability of results on competition is moderate. The selection should occur after young horses' competition and the young stallions should be used.

The generation interval on the male path is too long: It reached 13.6 years in 2002, after having stayed a long time about 12 years. This high generation interval should not be justified by the progeny test, because this one should remain marginal. It is not explained by the late setting of the reproduction of the stallions, since those have their first products on average at 6.4 years (so selected at the end of their 4th years), but by a too long utilisation period, that was deduced equal to 14.4 years. Time necessary to test the first generation in competition does not exceed 6 years, 7 years for two generations. The breeders should not use 7 years more on the stallions. In fact, this is the mark of a bad practice of the test on progeny. The selection is real but takes too much time. The young stallions do not produce enough offspring, to reach a sufficient accuracy quickly. It is urgent to encourage the use of young stallions without any change on age at selection which is necessary for the selection on own performance in competition. The 2 years between the intervals on the way sire/sire and sire/progeny continue to be justified by the use of males tested on progeny as sire of stallions.

All these improvements should be done without loss in accuracy. This accuracy is high due to the very high percentage of stallions with own performance.

In the absence of any policy, the selection is real on the mare path, equivalent to the 71% best and even the 52% best for mare/mare path. There is only financial incitement to keep best broodmares according to their own performances or performances of half-sibs from the same mare or progeny. There is also probably a true will of breeders to improve their broodmares. An improvement of 0.33 points on selection intensity could be gain using the demographic possible demographic selection rate (49%) close to the really applied one (54%). This leads to an increase of 11% of genetic gain. This improvement is difficult in practice because actual rate leaves only the possibility for the breeder to drop 1/4 of mares on other criteria than genetic evaluation on jumping ability. The mothers of stallions were also really selected as it corresponded to a theoretical selection rate of 6.6%. It is surprising that the age at first progeny is higher for mares than for sires: 7.2 years against 6.4 years, while at the same time the test on own performance in competition is not generalized on the mare way. On other hand, a mare cannot carry out a sporting and reproductive career simultaneously. To keep the high percentage of mare tested on own performance (45%), and, at the same time, to reduce age at first progeny, we should encourage mares aged 5, with one or two years in competition, to begin their reproductive life. In that case, the accuracy on mares will continue to be high with a decrease of generation interval. It is not interesting to keep females in competition a too long time. Only by removing the mares aged more than 10 years at first progeny, generation interval decreases 1.2 years. On the contrary it is not possible to decrease the length of reproductive life (8.6 years) without a decrease in the number of progeny left for replacement and so a decrease of selection intensity.

5.2. Evolution

Evolution with time cannot be related to demographic constrains. For example, selection intensity always increased for females, even when the increase of birth induced a higher number of mares in activity. Since 1974, we could only measure the increase of generation interval. During 1991–2002, the change of policy of selection could be measured on all the parameters of genetic trend. Mares are more and more selected, with and without own performances in jumping. The gain is 0.4 point of selection intensity. We hope that the slight flat evolution in the last years (2000–2002) is only temporary. For sires, early selection at 3 years old which is reserved to very exceptional sires (highest genetic superiority) is now more common (same genetic superiority than all sires). We must be cautious because accuracy at this age is low (without own performance). At the same time, selection at 4 years old, which is the most frequent, increased in efficiency. But genetic superiority of stallions selected at 5 years old, which should be the better age to select (compromise between accuracy and generation interval, Tavernier and Clerc, 1994), decreased. So evolution is not very consistent. The effort of selection for males aged 3 and 5 must be maintained. On the other hand, there is a discovery of progeny selection during the years 1996–2000, with an increase of genetic superiority of males selected on progeny, which was not the case before.

The evolution of accuracy is principally due to a change of criterion used in genetic evaluation rather than a change in policy. This new criterion uses each start in competition rather only a summary as annual earnings. As stallions have often more starts than average population, accuracy increased.

5.3. Comparison with rules of selection

Since 1991, stallions SF could be approved on genetic evaluation or on own performances or by a special commission which could approve stallions after phenotypic examination and knowing the pedigree.

When applying the truncation threshold for genetic evaluation and accuracy or on performances proposed by the rules of Stub Book policy all the theoretical rates are higher than the realized. The truncation thresholds for genetic evaluation increased. But there was no increase of selection intensity during the period corresponding to the successive rules. In fact, the relatively low selection intensity depends on selection by the commission without genetic evaluation or performance and not on the low level of genetic evaluation or performance required for the automatic approval. Nevertheless, other traits of interest measured by the commission, for example gaits and conformation, are not taken into account in genetic evaluation for jumping ability.

5.4. Contributions of the other breeds

During the studied period the percentage of crossbreed other than with foreign sport horses decreased from 24% in 1991 to 7% in 2002. So, the effect of crossbreeding measured here concerned in majority Thoroughbred, French trotter, Anglo-Arab. The influence of foreign sport horses is really recent because crossbreeding with foreign sport horses is now increasing exponentially: only 0.5% in 1995 and 6.3% in 2002. In this background, the effect of crossbred was negative for every parameter of genetic trend for show jumping. The selection intensity was very low on the way sire/offspring (0.31), and was unfavourable for the way dam/progeny (−0.59). The generation interval increased 2 years on the sire way and 1 year on the mare way. And the accuracy decreased more than 0.10 point. The question remains: why use such mares and sires. Breeders kept in mind the origins of SF which was a crossbreeding from thoroughbred sires and local mares. The percentage of thoroughbred genes in the present SF is more than 50% when recalling pedigrees' information. There is also 33% of genes provided by the ancestor of Selle Français the "Demi-Sang" which also provided some thoroughbred genes but difficult to quantify. So the habit of crossing with thoroughbred and the belief in the favourable effect of thoroughbred for any objective may explain these choices but have a negative effect on SF. The recent crossbreeding with foreign sport horses should be studied when their first offspring will be in competition (after 2006).

6. Conclusion

Selection of stallions for the objective of jumping competition is real (best 6.5%) but too weak compared with demographic possibilities (best 1.5%). To counterbalance, breeders used preferentially best stallions and so the effective genetic superiority of stallions, weighed with the number of offspring, reached 2.21 standard deviations, corresponding to a theoretical selection rate of 3.5%. Only recently (since 1996), after progeny test, breeders used also best stallions preferentially that leads to theoretical selection rate of 0.8%. Without any official rules but only financial incitement, mares are selected (best 71%). Accuracy is high because of high percentage of sires (94%) and mares (45%) have own performances in jumping. Finally, the annual genetic gain was 0.096 of genetic standard deviation for show jumping without any damage for dressage or eventing. So, due to these good results, the new improvements suggested are only marginal but possible in practice with a high contribution of breeders. The use of all the demographic possibilities for selection of females and males leads to +11% and +14% of genetic gain respectively. To encourage the return of breeding of females aged 4 and 5 years with performance but without a complete career in competition should increase the genetic gain by decreasing generation interval. A strict selection, an equal production of stallions and an increase of the number of progeny per stallion/year to 50 could lead to an increase of 34% of the genetic progress. The objective is now to add new traits such as conformation, gaits, health, behaviour, and reproduction, to the objective. As 3.5% and 71% of best males and female are now selected only 1.7% and 54% of births really used as parents, a rate of 1/2 and 3/4 can be used to select on other traits without loss in present genetic gain. The next study will model selection scheme based on this efficient basis with a multiple trait objective.

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