BREEDING FOR PERFORMANCE IN HORSES - A REVIEW

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SUMMARY

The paper gives a review of the literature related to performance traits in horse breeding. In the future, traits which are measureable in all horses should be used in prediction of breeding values and genetic trend. Further, corrections for important environmental effects, e.g. the trainer effect, are proposed included in genetic evaluations, and efficient breeding programs have to be developed.

INTRODUCTION

In the western world the requirement for horses for heavy work has dramatically decreased the last decades, while the demand for horses for leasure and sporting activities has steadily increased. This general trend in addition to some early results on the inheritance of performance in Thouroughbreds (Pirri and Steels, 1952) has stimulated the adaption of results in general animal breeding to the field of horse breeding. So far the effort has mainly been consentrated on performance traits due to the fact that these are most easily measured.

In the recent years a whole body of results has shown that also some frequently occuring injuries as osteochondrosis and carpitis show quantitative genetic inheritance and should be included in future breeding plans (Falk-Rønne and Kristoffersen, 1980; Hoppe and Philipsson, 1985; Dolvik and Klemetsdal, 1986; Schougaard et al., 1987). However, this review will focus on generally known results and unsolved problems in breeding for performance in racing and riding horses. In this context preventive breeding against genetic diseases will only be included in the first topic covered; definition of proper breeding goals.

BREEDING GOALS AND PERFORMANCE

One major problem in horse breeding relative to most other livestock productions is a lack of precisely defined breeding goals. This is especially relevant for performance traits and it is often claimed that the genetic gain in these traits is not associated with profit. In fact Hill (1988) questions if it is any point doing selection for performance at all. Actually in a situation where the political system accept a horse industry of a certain size there has to exist economic arguments to justify selection for performance. Such arguments exist in horse breeding since genetic improvement will:

- o Stimulate the domestic horse production, reduce the cost connected with import and increase the income from export of animals.
- o Reduce the labour cost attached to prepare a horse for competitions.
- o Reduce the frequency of injuries and hence labour and recruiting cost.

Therefore the total economic renevue, the traits relative contribution to improvement of the economic efficiency of horse production leading to economic weights has to be calculated. The definition of the breeding objectives should be based on these results. Which traits that should be included in the indices are determined by the potential for genetic improvement (e.g. genetic variability) and the cost of an accurate estimation of genetic merit of all animals for the traits (Harris, 1970).

Hitherto the geneticists have mainly been concerned about utilization of competition results for breeding evaluation since these are available to minor cost. It is only in riding horses that other initiatives have been taken to improve the breeding programme.

PREDICTION OF BREEDING VALUES

BLUP methodology and the animal model (Henderson, 1973, 1977) has become the standard method for genetic evaluation in horse breeding since:

- It maximizes accuracy of breeding values and the expected genetic gain from selection (Bulmer, 1980, 1982).
- It yields unbiased estimators of genetic and environmental trends in the population (Henderson, 1988).

Both results rest on the assumptions that the model is correct and consequently the selection does not depend on the fixed effects, data on all animals taking part in the selection process are included, the distribution is multivariate normal, the model is additive genetic and the genetic and environmental variances and covariances are known to proportionality. In the following these assumptions will be discussed with reference to estimation of genetic parameters, prediction of breeding values and genetic trend in racing and riding horses.

Racing horses

Racing horses comprise the American Standardbred pacer, the American Quarter Horse and different Thouroughbred and trotter populations. A common feature of these populations is a continuous accumulation of data from races and the request for using these data for selection purposes. A major problem accomplished with such data is the special structure due to preselection of animals for racing. According to Im et al. (1988), studying selection from a missing data theory view point, this kind of selection should not be ignored. Therefore, one should concentrate on using performance traits for which unselected data can be obtained in prediction of breeding values. One way of handling this problem would be to use earnings of all horses born and put into training. Missing values should be assigned to horses which had never beed trained. Then all animals which actually takes part in the real selection process would have been included in the data and one of the most severe assumptions for BLUP is fullfilled. On the other hand, inclusion of non-starters in the data creates distributional problems as stated by Katona and Distl (1989) and Minkema (1989) both working with data in Standardbred Trotter. Unfortunately, it is not possible by any statistical tranformation to remove the cluster of non-starters creating the left end of this distribution. Then fullfilling one of the assumptions for BLUP clearly creates another and choosing among them are not straight forward. However, since the BLUP-methodology has been shown to be robust to deviations from normality in analysis of all-or-non data (Hoeschele, 1988), the assumption of normality in this kind of data is assumed to be be the less critical of the two assumptions considered.

The information on earnings of a horse can be accumulated over a specified timeperiode or directly stored as repeated measures in single races. The latter method has the advantage to the former that it allows correction for environmental factors associated with each race. Other relevant performance traits are the weighted rank at finish proposed by Katona and Distl (1985) and the binary trait starting frequency introduced by Klemetsdal et al., 1985. The latter trait is also used by Katona and Distl (1989) although they call it percent of raced progeny. Published heritability estimates obtained for these traits are given in table 1.

Table 1. Heritability estimates obtained for traits observed on unselected animals.

Reference	Trait	Transformation	Method	Adjustment	Age	Sex	h^2
1.	Earnings	✓	Regression dam - offspring within sire	Precorrection for year	2	♀	0.22
					2	♂	0.24
					2-3	♀	0.22
					2-3	♂	0.31
					2-4	♀	0.25
					2-4	♂	0.36
					2-8	♀	0.23
					2-8	♂	0.40
2.	Earnings	✓	Paternal half-sib correlation	Correction for sire group, mother group, mother within group, sex and age	2-3	♀+♂	0.22
					2-7	♀+♂	0.21
	Percent of raced progeny	None			2	♀+♂	0.15
					2-3	♀+♂	0.21
					2-5	♀+♂	0.27
3.	Starting frequency	None	Paternal half-sib correlation	Correction for sex and birth year	3	♀+♂	0.09
					3-4	♀+♂	0.15
					3-6	♀+♂	0.20
4.	Starting frequency	None	Paternal half-sib correlation	Correction for sex and birth year	3-6	♀+♂	0.10

1. = Minkema (1982), 2. = Katona and Distl (1989), 3 = Klemetsdal (1989a), 4. = Arnason et al. (1989).

The heritability estimates in table 1 are of intermediate values and show a tendency to increase with increasing length of the accumulation period. The estimated heritability for starting frequency is surprisingly high although somewhat lower than for accumulated earnings.

Bendroth et al. (1985) and Langlois (1984a) observed the highest heritability estimates for racing perfomance in three year old trotters. This was also observed by Minkema (1975a) when data was restricted to accumulated earnings of those trotters who had been raced. On unrestricted data the corresponding heritability estimates were much lower clearely demonstrating the basic difference between these two definitions of the trait.

Minkema (1982) reported extremely high genetic correlations between accumulated earnings in different timeperiods. This tendency is also found by several authors studying performance of raced trotters (Bendroth et al., 1985; Langlois, 1984a) and Thouroughbreds (Langlois and Chico, 1989).

The estimation method used by Minkema (1982) and Katona and Distl (1989) corrects for the existence of assortative mating while the paternal half-sib analysis used by Klemetsdal (1989a) and Arnason et al. (1989) does not correct for this effect. In the past years several authors have pointed out the existence of assortative mating in horse breeding and the necessity of correcting for it (Arnason et al., 1982; Field and Cunningham, 1976, Katona and Distl, 1984; Langlois, 1980a; Langlois and Chico, 1989; Minkema, 1976; Tavernier, 1986). As illustrated by Kennedy et al. (1988) the animal model corrects automatically for non-random mating and should be the standard method for estimation of variance components in future horse breeding as it has become the method of choise in prediction of breeding values in race horses during the last ten years. (Arnason et al., 1989; Chico et al., 1989; Klemetsdal, 1986; Leroy et al., 1989; Tavernier, 1989; Wilson et al., 1988).

In addition to the ability to correct for non-random mating the animal model has several favourable properties. First of all it has the ability to improve estimation of fixed effects and to utilize all available information in prediction of breeding values. Therefore the breeding values are directly comparable among horses. Furthermore, the genetic trend in the population may be predicted by averaging the breeding values of all animals by birth year.

The animal model will in the near future be used routinely in prediction of breeding values in the North-Swedish Trotter (Arnason et al., 1989), Norwegian Trotter (Klemetsdal, 1989a), French Trotter (Tavernier, 1989) and in Thouroughbreds in France (Langlois and Chico, 1989). In Sweden and Germany a sire model has been adapted for progeny testing of the Standardbred Trotter (Arnason et al., 1989; Katona and Distl, 1989) while the selection index is used for calculation of individual indices of the Standardbred Trotter in Sweden, for progeny testing of Dutch Trotters (Minkema, 1976, 1989) and for calculation of individual and performance testing indices in Finland (Ojala, 1986, 1989).

For further information on the inheritance of racing performance in racing horses one is refered to extensive reviews (Hintz, 1980; Katona, 1985; Langlois, 1980a, 1982, 1984b; Tolley et al., 1985) and the most recent publications related to trotter breeding (Arnason et al., 1989; Bendroth et al., 1985; Katona and Distl, 1989; Klemetsdal, 1989a; Ojala, 1987a, 1987b), in Thouroughbreds (Chico et al., 1987; Gaffney and Cunningham, 1988; Langlois and Chico, 1989; Preisinger et al., 1989; Schulze-Sleppinghoff et al., 1985), and in the American Quarter Horse (Buttram et al., 1988).

One special problem attached to the breeding of Thouroughbreds is the size of the genetic correlation between racing in flat- and obstacles. Richard (1984) has examined this problem and in fact found it to be positive. However, Langlois and Chico (1989) point out the nessecity of solving this fundamental problem in the near future e.g. by using a multivariate REML-procedure.

Riding horses

Riding horses covered are restricted to the Warmblood riding horse and the Icelandic Toelter Horse since these have been most frequently studied. Breeding problems discussed however, are relevant to other riding and working horses as well.

The general breeding goal in riding horses is more complex than in race horse breeding. An ideal Warmblood riding horse must be competitive in dressage, showjumping and three days events while the most valuable Icelandic Toelter Horse should have an easy, smooth, natural and well balanced action in walk, trot, galop, pace and toelt (Arnason, 1984a).

In the Warmblood riding horse this complex breeding goal is manifested in a sophisticated, widely used performance testing system. In fact, Germany, The Netherlands, Denmark and Sweden all use stationary performance testing of their three year old stallions (Bruns, 1989; Hedebro-Velander et al., 1989; Huizinga et al., 1989; Jensen and Staun, 1989). These tests last 100 and 240 days in Germany, 90 days in Denmark and 3-4 repeated one week tests are used in Sweden. In Germany, stationary performance testing of Holsteiner mares has been developed (Nissen et al., 1986) and it is steadily growing in popularity (Bruns, 1989). In addition, field performance testing of mares is frequently used in Germany (Meinardus et al., 1986), The Netherlands, Denmark and Sweden. In Denmark and Sweden an additional test is performed at four years of age and has shown to be useful (Jensen and Staun, 1989; Thafvelin et al., 1980). In fact the latter test, the riding quality test, is used for progeny testing of stallions in Sweden and a further improvement of the breeding program rest on a larger participation in this test (Hedebro-Velander et al., 1989). For exemplification of traits used as for drawing further results, the estimated heritabilities for traits recorded in the different German tests are listed in table 2.

Table 2. Heritability estimates from performance testing of German riding horses.

Reference	Test	Method	Adjustment	Trait	h^2
1.	SPT-stallions	Paternal half-sib correlation	Year	Riding ability	0.36
				Gaits	0.50
				Jumping ability	0.72
				Cross country	0.33
				Racing time	0.53
				Character/temp.	0.25
2.	SPT-mares	REML-animal model	Testing period and breeder (random)	Riding ability	0.08
				Jumping ability	0.00
				Character/temp.	0.00
			Testing period and stage of pretraining	Riding ability	0.27
				Jumping ability	0.42
				Character/temp.	0.41

SPT = Stationary performance test
FPT = Field performance test
1. = Bruns et al. (1985), 2. = Presinger et al. (1987).

The results indicate moderate to high heritabilities for traits recorded in performance testing of stallions. On the other hand, the heritability estimates for mares on station are drastically reduced when a random breeder (trainer) effect is introduced in the model. This result is also of importance to horse breeding in general in connection with prediction of breeding values and genetic trend. In accordance to Fimland (1984) and Jansen (1987) the obvious solution will be to handle the trainer effect similar to herd effect in progeny testing of dairy cattle i.e. as a random effect to make optimal use of prior information in prediction of breeding values. This is especially important to riding horse breeding but relevant in race horse breeding as well.

So far prediction of breeding values in stationary performance testing in Germany has been calculated with a selection index. However, it is proposed replaced by an animal model (Bruns, 1989). On the other hand, in Sweden the stallions are already progeny tested by BLUP. Actually, a multitrait sire model has been adapted to the data from the riding quality test (Arnason, 1987a).

Data are available in all populations of Warmblood riding horses for prediction of breeding values from jumping and dressage competitions in addition to three day events. In the Icelandic Toelter Horse all data are accumulated in horse shows (Arnason, 1979). As for racing horses, riding horses taking part in competitions and horse shows are most likely a preselected group of animals. This preselection will reduce the value of this kind of data with respect to prediction of breeding values and genetic trend by an animal model (Arnason, 1984b, 1987b; Meinardus and Bruns, 1987; Tavernier, 1986, 1988) and may be severely biased. Hopefully, the magnitude of this problem will be clearified in both riding and racing horses in the near future.

As for the Thouroughbreds there seems to exist a very low genetic correlation between the two most important disiplines, in Warmblood riding horse breeding, i.e. between jumping and dressage (Bruns, 1981; Huizinga and van der Meij, 1989). However, the genetic correlations between the same traits in different age groups are high (Huizinga and van der Meij, 1989). Further results on genetic parameters in breeding of the Warmblood riding horse are reviewed by Hintz (1980). Results on performance test data are published by Bruns (1987), Jensen and Staun (1989), Nissen et al. (1986) and Thafvelin et al. (1980). With respect to genetic parameters based on data from riding horse competitions one is refered to Bruns (1981), Chachula and Kedzierski (1986), Huizinga and van der Meij (1989), Langlois (1980b), Meinardus and Bruns (1987) and Montavon (1987). In the Icelandic Toelter Horse the genetic parameters from different kind of horse shows have been published by Arnason (1984a).

PREDICTION OF GENETIC TREND

"Cunninghams paradox" is accomplished with the findings of Cunningham (1975) which showed that winning times in classic Thouroughbred races in England have made only a slight improvement during the recent decades. There have been proposed a lot of reasons for this development. Best known is the possible lack of genetic variance due to a small population size (Hill, 1988). However, the observed phenotypic trend may be a scale problem. Actually Ojala (1987b) observed a reduced variance of racing time in trotters when the mean improved. Later Gaffney and Cunningham (1988) have found a predicted genetic gain of 0.94 $\pm$ 0.13 TIMEFORM handicap rating units per year among Thouroghbreds. The studied trait is measured in raced horses only and express what a horse should carry in an average free-handicap race. Hill (1988) comments on the predicted gain in TIMEFORM handicap ratings and propose a resolution. As already discussed the heritability estimate and the predicted genetic trend are most severely biased since:

- o it is impossible to take preselection properly into account in the analysis using TIMEFORM handicap ratings as the performance trait studied.
- o it is not corrected for any trainer effect in the analysis. According to Preisinger et al. (1987) and Schulze-Sleppinghoff et al. (1985)

this has to be done to obtain unbiased breeding values for performance traits in horse breeding.

Other effects which may give severely biased prediction of breeding values and genetic trend, are environmental correlations between relatives and preferential treatment. The environmental correlations may be somewhat reduced by constructing efficient breeding programs while the correction for preferential treatment still is an unsolved problem in connection with prediction of breeding values and genetic trend in animal breeding (Henderson, 1988).

BREEDING STRATEGIES AND BREEDING PLANS

The possibilities for a large annual genetic improvement for performance traits in horse breeding is limited due to a long generation interval. The generation interval is determined by the joint action of the age at first mating, the reproductive life and the average number of oppspring per parent. These three factors in addition to the generation interval determine the fraction of selected animals in the population. Minkema (1975b) has reported 40-45% selected mares in Dutch trotter breeding and a 12.1 years interval between dam and offspring. The corresponding numbers in Norwegian Trotter breeding were 54% and 11.1 years, respectively (Klemetsdal, 1989b). Ojala (1982) has reviewed estimates of generation intervals in horse breeding and found them varying between 9.5 and 15.8 years for sire - son and to be in the interval 7.9 to 12.5 years for dam - offspring. Further Langlois (1986) reported a generation interval of 11.6 years in French Trotter and Hugason et al. (1985) reported a estimate of 9.7 years in the Icelandic Toelter Horse. However, for males the fraction of selected animals is low. In fact, it is possible to select less than 1 percent of the males in a small population as the Norwegian Trotter and still be in agreement with de Roo (1988) recommending 20-30 new sires in active breeding in each generation. This result clearly illustrate the possibilities to perform a strong selection of males in horse breeding. In the following the question of optimizing a breeding-programme will be discussed with respect to race and riding horses.

Racing horses

The relative importance of performance testing v.s. progeny testing in breeding for performance traits in trotters has been studied by Strøm and Philipsson (1978). When heritability was 0.2, the effectiveness of two stage selection exceeded that of mass selection by 17%. For a heritability of 0.3 the advantage of greater accuracy of breeding values was almost cancelled by the effect of the increased generation interval.

Riding horses

A main problem in optimizing breeding plans in the Warmblood riding horse is the long generation interval achieved from utilizing competition results (Philipsson et al. 1987). Therefore the optimizing of Strøm and Philipsson (1978), Philipsson et al. (1987) and Bruns (1988) all show a superiority of performance testing under natural mating conditions. However, with intensive use of AI, Bruns (1988) found inclusion of competition results in addition to stationary performance testing to be preferable. According to Philipsson et al. (1987), Bruns (1988) and Huizinga et al. (1989) a large number of stallions should be progeny tested to maximize genetic gain in dressage and jumping. The test should be followed by a high selection intensity among progeny tested stallions, a high number of matings per sire and a low generation interval. In addition Huizinga et al. (1989) pointed out the importance of a small fraction of sires to breed sires in such performance testing schemes. Finally, genetic progress due to selection of mares has been shown to be 25-35% of what can be gained by selection of stallions (Philipsson et al. 1987). With respect to the breeding objective, results of Bruns et al. (1985) and Philipsson et al. (1987) shows that both dressage and jumping should be included in the overall breeding goal.

From practical Warmblood riding horse breeding, Bruns (1989) reports a very low selection intensity in Germany. In fact 50-93% of all stallions pass the performance test in Germany while in Sweden (Hedebro-Velander et al. 1989), the selction intensity exeeds 50%. Hence there are still improvements to be made in future Warmblood riding horse breeding with respect to the selection intensity after performance testing.

Hugason et al. (1987) studied the efficiency of three stage selection of stallions. The authors conclude from a study in the Icelandic Toelter Horse that a large proportion of the young colts should pass the first stage of selection (castration) and take part in the important performance test. For all heritabilities included, the optimal proportion of mares mated with performance tested stallions was 50-75%. For a low heritability (h^2=0.1) only a small proportion of the mares should be mated with young colts while for a high heritability (h^2=0.6) relatively few mares should be mated with progeny tested stallions.

FINAL REMARK

Optimal selection policies when animals of different ages are rivals for selection have been covered by James (1987). He found it optimal to select the superior animals across age groups. However, the breeding programmes in horses should not be limited to calculation of breeding values with an animal model. Developments of breeding schemes which guarantee that the best animals have maximum influence on the genetic quality of the next generation and which takes the inbreeding into account are equally important. In addition emphasis should be put to standardization of performance traits among countries, and international genetic evaluations.

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