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STUDIES ON THE GENETICS OF TROTTING PERFORMANCE IN *DUTCH TROTTERS*

II. — A METHOD FOR THE BREEDING VALUE ESTIMATION OF *TROTTER* STALLIONS

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SUMMARY

In order to select *Trotter* stallions on the basis of the performance of their progeny, an index has been developed.

This index is based on the earnings of progeny, being in various stages of their trotting career. The earnings are corrected for annual fluctuations and for sex differences.

The mean of each age class of progeny of a given stallion is corrected for the mean performance of the dams, by taking into account the regression of progeny performance on dam's performance. For each stallion the corrected mean earnings of progeny of the various age classes are joined. For this purpose weighting factors are developed according to the selection index theory, taking into account the number of progeny in the various age classes.

I. — INTRODUCTION

Only *Trotter* stallions with an excellent own trotting career are accepted for breeding purposes by the studbook of the *Dutch Trotting Association*. Besides their own performance also the merits of close relatives like parents, full and half sibs, are taken into account. As soon as possible during their active breeding life trotter stallions are judged on the performance of their progeny. A first judgement usually takes place in the autumn of the year in which the eldest progeny of a stallion is 4 years old. This implies that the first three yearly crops of progeny could have trotted : the progeny consists of 2-years-old, 3-years-old and 4-years-old trotters.

If no definite conclusion can be drawn the judgement of the progeny may be repeated later on. In that case the progeny includes even more age classes. In order to combine the information from progeny of different age classes, an index has been constructed for the estimation of the breeding value of trotting sires.

II. — FACTORS INFLUENCING PROGENY MEANS

In the first study in this series (MINKEMA, 1975) it was concluded that the actual earnings of a *Trotter* provided the best performance criterion for selection purposes, since this trait allows to take also non-starters into account; the earnings of non-starters can be taken as 0 guilders. The total amount of money, won during his whole trotting career, provides the best measure of trotting ability of a horse. However, since female trotters are not allowed to start after their 8th year of life, it is advisable to ignore the amount of money won by male trotters after their 8th year of life in order to make both sexes better comparable. This is justified since the amount of money, won by a *Trotter* after his 8th year, contributes very little extra information to his breeding value.

So as the final performance criterion has been chosen the total amount of money, won by a *Trotter* from his 2nd up to and including his 8th year, in the first study defined as 2-8-*y*-actual earnings (in this study the symbol y_8 will be used). Furthermore earnings can be transformed by taking the square root since this supplies a more reliable measure of the performance of a horse than the actual earnings (MINKEMA, 1975). This is mainly caused by the fact that the distribution of transformed earnings is approaching better the normal distribution, although the class of non-starters is still providing a discontinuity.

The true breeding value T of a stallion for his total actual earnings (y_8) will be estimated from the earnings of his progeny. However, besides the breeding value of the sire, also other factors are influencing the performance of the progeny. These factors are schematically presented in figure 1 and will be discussed below.

It is necessary to correct for these factors in order to obtain an unbiased estimate of a sire's breeding value.

2. 1. — *Years, in which the progeny have trotted*

In the first study (MINKEMA, 1975) it was found that the earnings are heavily influenced by economic fluctuations. In order to compare the breeding value of stallions, whose progeny raced in different periods, it is necessary to correct the earnings of the horses for these annual fluctuations. The amount of money won by a horse in a given year is corrected by a multiplication factor to a standard yearly earnings, viz. 1 500 guilders for 2-year-old earnings and 4 000 guilders for earnings of horses older than 2 years. These conversion factors are based on the average amount of money available per trotter starting in that particular year. Now all yearly earnings of a horse are multiplied by the appropriate correction factors The sum of the corrected yearly earnings of a horse constitutes his total corrected earnings. The method is described in detail by MINKEMA (1975). These total corrected earnings, both untransformed and transformed by square root transformation, are used for the estimation of the breeding value of trotter sires.

2. 2. — *Sex of progeny*

Since the sex distribution usually is unequal among the progeny of a sire and since male trotters win more money than female *Trotters* (MINKEMA, 1975) the

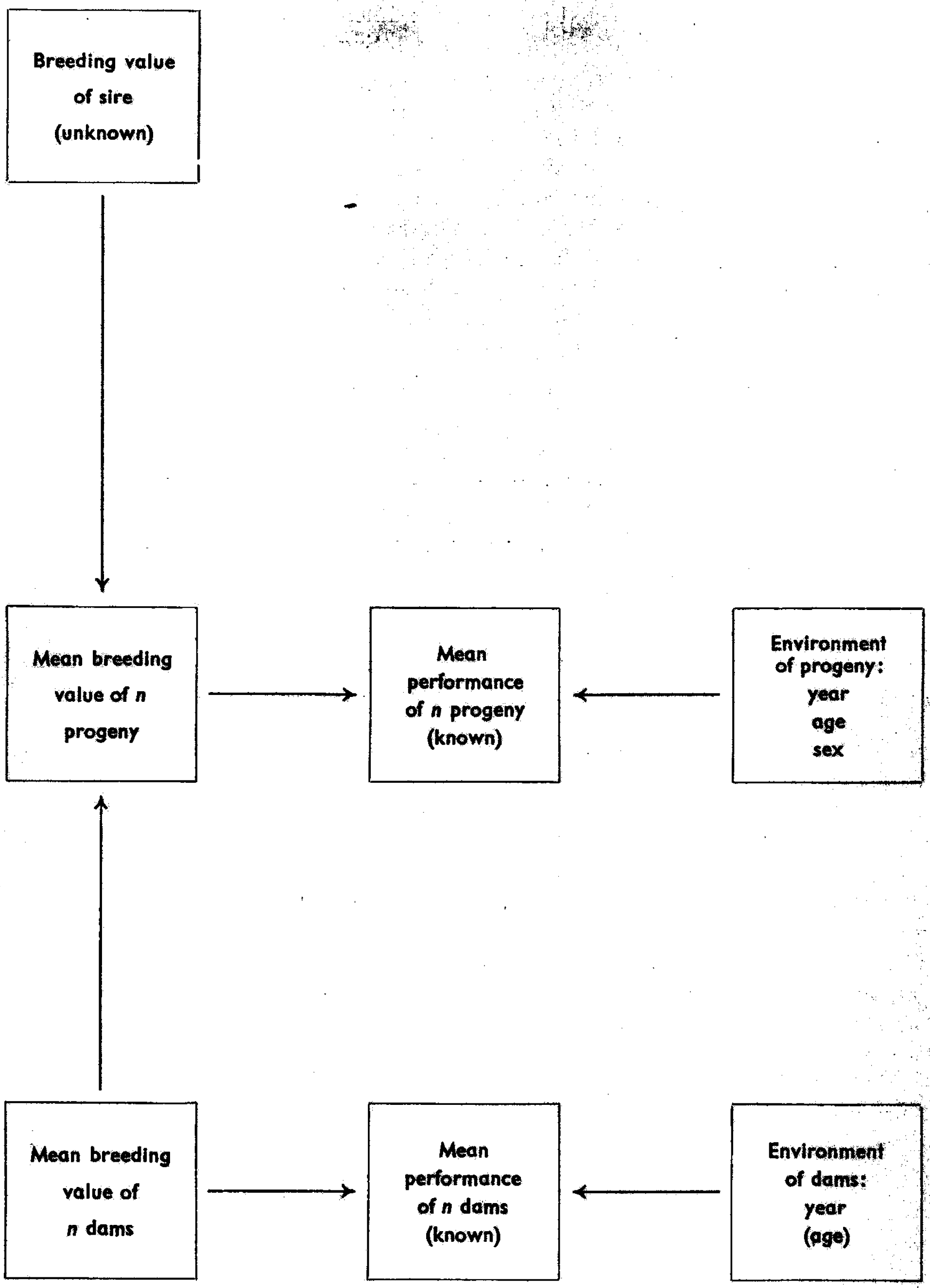

FIG. 1. — *Factors influencing the mean performance of a sire's progeny group*
Facteurs influençant la performance moyenne d'un groupe de descendants d'un mâle

progeny means must be corrected for these sex differences. Sex differences become more pronounced with increasing length of trotting career, so correction factors have to be obtained for each age class separately.

Because progeny means are corrected for mean dam's performance, as explained ater, it is advisable to correct the earnings of male progeny to the level of female progeny. The ratio of mean earnings of female *Trotters* to mean earnings of male *Trotters* provides the appropriate multiplication factor. These mean earnings of both sexes, as well as their ratios, are listed in table 1. They are based on the actual earnings, corrected for annual fluctuations, of all *Trotters* born between 1929 and 1971. The means are slightly different from those given in the first study (MINKEMA, 1975), as these latter were based on horses born between 1929 and 1958.

The means for the transformed earnings (by taking the square root) are also given in table 1.

TABLE I

Mean of corrected total earnings per age class of female and male Trotters *and ratio of both means* (= sex multiplication factors)

Moyenne des gains totaux corrigés par classe d'âge des Trotteurs *mâles et femelles et rapport des deux moyennes*

	♀♀		♂♂		Ratio (untrans-formed)
	Untrans-formed	Trans-formed	Untrans-formed	Trans-formed	
Y_2 = 2-years-old-earnings	428	7.9	430	7.8	1.00
Y_3 = 2-3-years-old-earnings	2 269	27.5	2 365	27.7	.96
Y_4 = 2-4-years-old-earnings	4 484	46.5	5 158	50.4	.87
Y_5 = 2-5-years-old-earnings	6 820	60.3	8 534	69.4	.80
Y_6 = 2-6-years-old-earnings	8 770	68.5	11 536	81.6	.76
Y_7 = 2-7-years-old-earnings	10 403	73.7	14 100	89.9	.74
Y_8 = 2-8-years old-earnings	11 902	78.4	16 200	95.8	.73

The multiplication factors are only given for the untransformed earnings, since the square root transformation is applied after correction for sex differences.

2. 3. — *Age class of progeny*

At a given moment the progeny of a stallion belongs to different age classes. The total earnings of the older progeny give a more reliable picture of their trotting ability than those of the younger (MINKEMA, 1975). This implies that the progeny mean for each age class has to be estimated first (after correction for year and sex). The progeny means of the various age classes can be taken together by using appropriate weighting factors, a.o. depending upon the number of progeny in the various age classes. In chapter 4 the derivation of these weighting factors will be explained.

2. 4. — *Performance level of dams of progeny*

Some stallions are mated with better mares than others. Therefore the mean performance level of the dams of the progeny from a given sire has to be taken into account. At the time their progeny is trotting the dams have completed their trotting career, almost without any exception. This implies that the 2-8-year actual earnings = y_8 of the dams can be taken as their performance criterion.

So for each age class of progeny the average total earnings (corrected for year nfluences) of their dams has to be computed. The total earnings of dams born before 1929 are not involved in the data base. The earnings of these dams are fixed to the population mean of female *Trotters* (= 11 902 guilders, see table 1). The same procedure is followed for imported dams, whose performance is not comparable with *Dutch Trotters*, although imported mares usually belong to the better part of their population of origin. However, possible errors introduced by this procedure will be small because of the relative low number of imported female trotters.

The deviation of dam's mean from the population mean is a measure of dam's nferiority or superiority. So the progeny means can be corrected for these deviations. The correction factors used are the regressions (within sires) of progeny performance on dam's total earnings.

These coefficients of regression c_{i8} are estimated for each age class of earnings of progeny to dams total earnings from the same material as used in the first study (table 2). The calculation is only done for the first 3 age classes of earnings and for the total earnings, for male and female progeny separately.

For correction purposes the unweighted mean of the coefficients of regression of both sexes are used. The coefficients for the age classes between y_4 and y_8 are derived by interpolation. The coefficients of regressions, obtained in this way, are listed in table 3. The fact that progeny means are corrected for mean dam's performance is the reason why the earnings of male progeny are converted to the level of female *Trotters*!

TABLE 2

Within sire coefficients of regression (c_{i8})
of part earnings of progeny on total earnings (Y_8) *of dams*

Coefficients de regression intra-père (c_{i8})
des gains partiels des descendants sur les gains totaux (Y_8) *des mères*

Trait of progeny	Untransformed		Transformed	
	♀	♂	♀	♂
Y_2 = 2-y-earnings	.009 ± .003	.007 ± .002	.048 ± .010	.029 ± .009
Y_3 = 2-3-y-earnings.....	.058 ± .010	.032 ± .011	.139 ± .021	.077 ± .021
Y_4 = 2-4-y-earnings.....	.121 ± .022	.080 ± .024	.199 ± .029	.138 ± .030
Y_8 = 2-8-y-earnings.....	.148 ± .028	.107 ± .037	.228 ± .035	.177 ± .039

2. 5. — *Number of progeny*

The greater the number of progeny, the more reliable the breeding value of a sire can be estimated. The number of progeny in the different age classes affect the weighting factors for the progeny means in the breeding value estimation. This will be taken into account in the derivation of these weighting factors, see chapter 4.

TABLE 3

Within sire coefficients of regression of progeny on dams (c_{i8}) to be used in correction for dam performance in breeding value estimation

Coefficients de régression intra-père descendants sur les mères (c_{i8}) utilisé pour correction pour la performance de la mère dans l'estimation de la valeur d'élevage

Age class	Symbol	Coefficient of regression	
		Untransformed	Transformed
Y_2 = 2-*y*-earnings	c_{28}	.01	.04
Y_3 = 2-3-*y*-earnings	c_{38}	.05	.11
Y_4 = 2-4-*y*-earnings	c_{48}	.10	.17
Y_5 = 2-5-*y*-earnings	c_{58}	.11	.18
Y_6 = 2-6-*y*-earnings	c_{68}	.12	.19
Y_7 = 2-7-*y*-earnings	c_{78}	.13	.20
Y_8 = 2-8-*y*-earnings	c_{88}	.13	.20

III. — CONSTRUCTION OF AN INDEX FOR BREEDING VALUE ESTIMATION

Suppose a stallion has offspring, which all have completed their trotting career. This implies that the total actual earnings (y_8) of all offspring are known. Corrections for annual fluctuations and sex differences give the progeny mean $\overline{Y}_8$. If dam's performance of the progeny is unknown, then the best estimate of sire's breeding value is:

$$I = b_8\,(\overline{Y}_8 - \overline{M}_{8♀}) + \overline{M}_8 \qquad (1)$$

where b_8 is the regression of the breeding value of the sire on the mean performance of the progeny; $\overline{M}_{8♀}$ is the mean corrected total actual earnings of all female trotters, and $\overline{M}_8$ is the mean corrected total actual earnings of all trotters (male and female).

The regression b_8 of sire's breeding value on progeny mean depends upon the number of progeny (n_8) and the heritability (h_8^2) of total earnings:

$$b_8 = \frac{\frac{1}{2}\, n_8\, h_8^2}{1 + (n_8 - 1)\,\frac{1}{4}\, h_8^2}$$

as can be found in most textbooks on animal genetics.

If the performance of the dams of the offspring are known, the mean of the corrected total earnings of the dams, $\overline{D}_8$, can be estimated, and the best estimate for sire's breeding value now becomes:

$$I = b_8\,\{(\overline{Y}_8 - \overline{M}_{8♀}) - c_{88}\,(\overline{D}_{8_8} - \overline{M}_{8♀})\} + \overline{M}_8 \qquad (2)$$

where:

c_{88} = coefficient of regression within sires of total earnings of progeny on total earnings of dams,

$= \frac{1}{2} h_8^2$ of total earnings.

$\bar{D}_{8_8}$ = mean corrected total actual earnings of dams of progeny, belonging to the 8th age class.

However, in practice the progeny of a sire belongs to different age classes. The contributions of the different age classes must be summed, to give the final index :

$$I = \Sigma_{i=2}^{8} \left[b_i \left\{ (\bar{Y}_i - \bar{M}_{i♀}) - c_{i8} (\bar{D}_{8_i} - \bar{M}_{8♀}) \right\} \right] + \bar{M}_8 \quad \ldots\ldots\ldots\ldots \quad (3)$$

where :

i = 2, 3, 4, 5, 6, 7, 8, referring to the age classes : 2-years-old, 3-years-old, etc. up to 8-years-old.

b_i = weighting factor to be used for the i-th age class of a stallion's progeny.

$\bar{Y}_i$ = mean corrected actual earnings of sire's progeny, belonging to the i-th age class.

The earnings are corrected for annual fluctuations and sex differences:

Y_2 = corrected actual earnings of 2-years-old progeny = amount of money won as 2-years-old trotter,

Y_3 = corrected actual earnings of 3-years-old progeny = amount of money won as 2-years-old and 3-years-old trotter, etc.

$\bar{M}_{i♀}$ = mean corrected actual earnings of all female trotters of i-th age class. These means are listed in table 1.

c_{i8} = within sire coefficients of regression of actual earnings of progeny of i-th age class to the total actual earnings (Y_8) of dams. These coefficients are listed in table 3.

$\bar{D}_{8_i}$ = mean corrected total actual earnings (Y_8) of dams of progeny, belonging to the i-th age class.

$\bar{M}_{8♀}$ = mean corrected total actual earnings of all female trotters (table 1).

$\bar{M}_8$ = mean corrected total actual earnings of all male and female trotters. This mean is calculated as the unweighted mean of both sex means, given in table 1.

The means so obtained are: untransformed earnings: 14 050
transformed earnings : 87.1

IV. — WEIGHTING FACTORS FOR PROGENY MEANS OF VARIOUS AGE CLASSES

The derivation of the correct weighting factors b_i, to be used in the breeding value estimation, remains. These factors must be chosen in such a way that the resulting index is an optimum combination of the progeny information available.

A useful solution is given by the theory of construction of a selection index (see e. g. HENDERSON, 1963). The procedure will be discussed in matrix terms. The following matrices and vectors are essential for the solution.

T = true breeding value of sire = additive genetic value of sire for total actual earnings = X_8. Since only one trait is involved in the true breeding value, T is a scalar.

v = relative economic value of the traits involved in T. Since one trait is involved, this relative economic value is a scalar and can be fixed to 1.

Y = $\overline{Y}_2, \overline{Y}_3, \ldots \overline{Y}_8$ = a vector of the 7 phenotypic progeny means for the 7 age classes, to be included in the index I.

b = $b_2, b_3, \ldots b_8$ = a vector of weighting factors to be used in the index I.

P = a 7 × 7 matrix of phenotypic covariances between the 7 progeny means in Y.

A = a vector of genetic covariances between the 7 progeny means in Y and the additive genetic value for total actual earnings (= X_8).

G = a scalar, representing the genetic variance of X_8.

The weighting vectors b_i in I are obtained by maximising the correlation r_{TI} between the true breeding value T and the index I. This is reached by solving the index equations $Pb = Av$.

The variances and covariances have to be known to set up the matrices and vectors.

Matrix P is of the following form:

$$\begin{array}{c} \\ \overline{Y}_2 \\ \vdots \\ \overline{Y}_i \\ \vdots \\ \overline{Y}_8 \end{array} \begin{array}{c} \begin{array}{ccc} \overline{Y}_2 & \overline{Y}_j & \overline{Y}_8 \end{array} \\ \left[\begin{array}{ccc} \sigma(\overline{Y}_2, \overline{Y}_2) \ldots\ldots & \sigma(\overline{Y}_2, \overline{Y}_j) \ldots\ldots & \sigma(\overline{Y}_2, \overline{Y}_8) \\ \vdots & \vdots & \vdots \\ \sigma(\overline{Y}_i, \overline{Y}_2) \ldots\ldots & \sigma(\overline{Y}_i, \overline{Y}_j) \ldots\ldots & \sigma(\overline{Y}_i, \overline{Y}_8) \\ \vdots & \vdots & \vdots \\ \sigma(\overline{Y}_8, \overline{Y}_2) \ldots\ldots & \sigma(\overline{Y}_8, \overline{Y}_j) \ldots\ldots & \sigma(\overline{Y}_8, \overline{Y}_8) \end{array}\right] \end{array}$$

The rows are indicated by i, the columns by j.

Two situations can be distinguished to obtain the necessary elements of the matrix:

For $i = j$:
$$\sigma(\overline{Y}_i, \overline{Y}_i) = \frac{1 + (n_i - 1) \cdot \frac{1}{4} h_i^2}{n_i} \cdot \sigma_i^2$$

For $i \neq j$:
$$\sigma(\overline{Y}_i, \overline{Y}_j) = \tfrac{1}{4}\, r_{a_{ij}}\, h_i h_j\, \sigma_i \sigma_j$$

where i and j refer to the age classes: 2, 3, 4, 5, 6, 7, 8

n_i = number of progeny in i-th age class.

h_i^2 = heritability of actual earnings of trotters of i-th age class.

σ_i = standard deviation of actual earnings of trotters of i-th age class.

$r_{a_{ij}}$ = genetic correlation between earnings of i-th and j-th age class.

The vector A is as follows:

$$
\begin{array}{c} X_8 \\ \end{array}
\qquad
\begin{array}{c} \overline{Y}_2 \\ \vdots \\ \overline{Y}_i \\ \vdots \\ Y_8 \end{array}
\begin{bmatrix} \sigma(\overline{Y}_2, X_8) \\ \vdots \\ \sigma(\overline{Y}_i, X_8) \\ \vdots \\ \sigma(\overline{Y}_8, X_8) \end{bmatrix}
$$

To obtain the elements of this vector it holds:

$$\sigma\,(\overline{Y}_i, X_8) = \frac{1}{2}\, r_{a_{i8}}\, h_i h_8\, \sigma_i \sigma_8.$$

The genetic parameters are partly derived from the first study (MINKEMA, 1975) where 2-year-old-earnings (Y_2), 2-3-years-old-earnings (Y_3), 2-4-years-old-earnings (Y_4) and total earnings (Y_8) have been analized. Heritabilities and genetic correlations of the intermediate earnings are estimated by interpolation. Unweighted means of both sexes are used. Furthermore the genetic correlations-diagram is an idealized version of the figures actually found. This procedure was thought to be permitted, because of the large standard errors of the genetic correlations estimated. The phenotypic standard deviations are actually calculated from the earnings of female horses, born between 1929 and 1971. Here the calculation was restricted to the female trotters, because in the estimation of the breeding value all earnings of male trotters are corrected to the level of female trotters. The parameters used are listed in table 4, for untransformed and transformed earnings separately.

TABLE 4

Genetic parameters used for the setting up of the necessary matrices and vectors in the construction of an index

Paramètres génétiques utilisés pour écrire les matrices et les vecteurs nécessaires à l'élaboration d'un index

Trait	Heritabilities		Standard deviations (rounded figures)	
	Untransformed	Transformed	Untransformed (guilders)	Transformed
Y_2	.14	.18	1 400	19
Y_3	.25	.36	4 900	39
Y_4	.26	.40	7 200	48
Y_5	.26	.40	9 800	57
Y_6	.26	.40	12 500	65
Y_7	.26	.40	15 100	71
Y_8	.26	.40	17 600	76

TABLE 4

Genetic correlations between earnings of different age classes
(above diagonal : untransformed earnings
below diagonal : transformed earnings)

	Y_2	Y_3	Y_4	Y_5	Y_6	Y_7	Y_8
Y_2		.99	.95	.90	.85	.80	.75
Y_3	.99		.99	.95	.90	.85	.80
Y_4	.97	.99		.99	.95	.90	.85
Y_5	.94	.97	.99		.99	.95	.90
Y_6	.90	.94	.97	.99		.99	.95
Y_7	.85	.90	.94	.97	.99		.99
Y_8	.80	.85	.90	.94	.97	.99	

In the breeding value estimation of stallions it is necessary to get the weighting factors b_i by solving $Pb = Av$ for each stallion separately, since each stallion has his own specific combination of number of progeny in the different age classes.

V. — RELIABILITY OF BREEDING VALUE ESTIMATION

In chapter 4 it was shown that the index I is constructed in such a way that the correlation r_{TI} between the true breeding value T and the index I is maximised.

This correlation can be computed as

$$r_{TI} = \frac{\sigma_{TI}}{\sigma_T \cdot \sigma_I} = \frac{\sigma_I}{\sigma_T} = \sqrt{\frac{b'\,Pb}{G}}$$

since $\sigma = \sigma_I^2 = b'Pb$ and

$\sigma_T^2 = v'\,Gv = G$, since $v = v' = 1$

and where : b' = transpose of b

v' = transpose of v

The necessary elements for the computation are already given in chapter 4, except for G.

Since only one trait is involved in the true breeding value T, i.e. X_8, G is the genotypic variance of $X_8 = h_8^2 \sigma_8^2$.

The correlation r_{TI} is a measure of the accuracy of the prediction of the breeding value and can be computed for each index.

Stallions with the same index value may not have the same true breeding value T.

The standard error of true breeding values T for animals with the same index I_0 can be written as $\sigma_{T|I = I_0}$

For this standard error it holds:

$$\sigma_{T|I = I_0} = \sqrt{\sigma_T^2 - \sigma_I^2} = \sqrt{(1 - r_{TI}^2)} \cdot \sigma_T$$

The computation of this standard error gives a meaningful additional information in the estimation of breeding values of stallions (RÖNNINGEN, 1975).

As mentioned earlier in the Netherlands *Trotter* stallions are first judged on the performance of their progeny, when their eldest progeny are 4 years old.

In order to get an idea of the reliability of the breeding value estimation of stallions at this particular moment in their active breeding life, the weighting factors b_i, the correlation r_{TI} and the standard error $\sigma_{T|I = I_0}$ have been computed for the following combinations of n_2, n_3 and n_4:

$$n_2 = 0, 10, 20, 50$$
$$n_3 = 0, 10, 20, 50$$
$$n_4 = 0, 10, 20, 50$$

and furthermore $n_5 = n_6 = n_7 = n_8 = 0$.

The results of the computations for the $4^3 - 1 = 63$ combinations are given in table 5, for both untransformed and transformed earnings.

From this table it is seen that the accuracy of the breeding value estimation increases with increasing number of progeny in the older age classes. If the number of 4-years-old progeny is high, then the 2-years-old and 3-years-old progeny add only little to the reliability of the breeding value estimation. Transformation of the earnings increases the correlation r_{TI}.

The values of the weighting factor for earnings of 2-years-old trotters are higher than those for earnings of 3-years-old or 4-years-old trotters for the same number of trotters in each age class. However, this does not imply that more weight is attached to the earnings of younger horses. The misleading impression is caused by the scale effect since the standard errors or earnings of younger horses are quite substantially smaller than those of older horses. The correct relative weighting factors are obtained by multiplying the weighting factor b_i^1 by the ratio of the standard errors : $\frac{\sigma_i}{\sigma_8}$.

Finally a practical example might demonstrate the computation of the index of a certain stallion, with progeny data as shown below.

Age class of offspring	Number of offspring	Mean corrected actual earnings (untranformed) of progeny	Mean corrected total earnings (untranformed) of corresponding dams of progeny
i	n_i	$\overline{Y}_i$	$\overline{D}_{8i}$
2 years	20	650	13 500
3 years	10	2 100	12 600
4 years	0	—	—

TABLE 5

Weighting factors and accuracy for some situations in the breeding value estimation of stallions

Facteurs de pondération et précision dans quelques cas d'estimation de la valeur d'élevage des étalons

5. I. — *Untransformed data*
Données non transformées

Number of progeny in respective age classes			Weighting factors to be used for respective progeny means			Accuracy	Standard error (guilders)
n_2	n_3	n_4	b_2	b_3	b_4	r_{TI}	$\sigma T \mid I = I_0$
0	0	10	—	—	1.70458	.544	7529
0	0	20	—	—	2.41752	.648	6834
0	0	50	—	—	3.22743	.749	5946
0	10	0	—	2.34475	—	.506	7742
0	10	10	—	1.58851	1.27418	.628	6982
0	10	20	—	1.17876	1.96455	.686	6533
0	10	50	—	.61712	2.91084	.757	5862
0	20	0	—	3.34964	—	.605	7149
0	20	10	—	2.47234	1.03471	.671	6658
0	20	20	—	1.92808	1.67661	.709	6334
0	20	50	—	1.08521	2.67071	.763	5798
0	50	0	—	4.50914	—	.702	6396
0	50	10	—	3.71130	.69901	.726	6175
0	50	20	—	3.11692	1.21977	.743	6005
0	50	50	—	1.99156	2.20574	.775	5670
10	0	0	6.80098	—	—	.384	8289
10	0	10	4.20466	—	1.47345	.589	7252
10	0	20	2.94583	—	2.18785	.666	6692
10	0	50	1.36421	—	3.08544	.752	5913
10	10	0	4.37726	1.97826	—	.557	7452
10	10	10	3.04288	1.40322	1.15711	.648	6835
10	10	20	2.26679	1.06878	1.83009	.696	6448
10	10	50	1.13556	.58128	2.81103	.759	5839
10	20	0	3.16017	2.97166	—	.627	6994
10	20	10	2.34143	2.25044	.96612	.681	6569
10	20	20	1.81221	1.78426	1.59059	.715	6280
10	20	50	.95826	1.03203	2.59825	.765	5781
10	50	0	1.59018	4.25310	—	.706	6355
10	50	10	1.28304	3.52878	.67793	.729	6148
10	50	20	1.05120	2.98205	1.18964	.745	5987
10	50	50	.60506	1.92994	2.17438	.776	5664
20	0	0	10.78106	—	—	.483	7859
20	0	10	7.11170	—	1.31364	.618	7055
20	0	20	5.14975	—	2.01603	.680	6584
20	0	50	2.48983	—	2.96828	.755	5886
20	10	0	7.43637	1.72214	—	.591	7243
20	10	10	5.34278	1.26318	1.06862	.663	6721
20	10	20	4.05928	.98181	1.72376	.703	6380

Number of progeny in respective age classes			Weighting factors to be used for respective progeny means			Accuracy	Standard error (guilders)
n_2	n_3	n_4	b_2	b_3	b_4	r_{TI}	$\sigma T \mid I = I_0$
20	10	50	2.09424	.55103	2.72677	.761	5820
20	20	0	5.56918	2.68352	—	.643	6874
20	20	10	4.20797	2.07355	.91144	.690	6498
20	20	20	3.29907	1.66626	1.52001	.719	6234
20	20	50	1.78173	.98632	2.53599	.766	5767
20	50	0	2.94421	4.03509	—	.710	6320
20	50	10	2.39080	3.37118	.65974	.731	6124
20	50	20	1.96835	2.86439	1.16335	.747	5970
20	50	50	1.14368	1.87508	2.14646	.776	5658
50	0	0	16.61519	—	—	.600	7183
50	0	10	12.15322	—	1.03650	.666	6698
50	0	20	9.34429	—	1.68900	.704	6373
50	0	50	4.93098	—	2.71420	.761	5827
50	10	0	12.80626	1.27254	—	.645	6859
50	10	10	9.77637	.99321	.89805	.690	6497
50	10	20	7.72396	.80400	1.50638	.719	6239
50	10	50	4.24399	.48318	2.53783	.765	5777
50	20	0	10.26355	2.12204	—	.674	6634
50	20	10	8.06600	1.70792	.79842	.707	6348
50	20	20	6.49783	1.41240	1.36818	.730	6136
50	20	50	3.67828	.88107	2.39259	.769	5735
50	50	0	6.01959	3.53992	—	.719	6240
50	50	10	4.96050	3.00561	.61753	.737	6069
50	50	20	4.13069	2.58697	1.10137	.751	5931
50	50	50	2.45488	1.74153	2.07850	.778	5644

5. 2. — *Transformed data*
Données transformées

Number of progeny in respective age classes			Weighting factors to be used for respective progeny means			Accuracy	Standard error
n_2	n_3	n_4	b_2	b_3	b_4	r_{TI}	$\sigma T \mid I = I_0$
0	0	10	—	—	1.49386	.536	36.3
0	0	20	—	—	1.96024	.746	31.9
0	0	50	—	—	2.41206	.828	26.9
0	10	0	—	1.72962	—	.599	38.3
0	10	10	—	1.04665	1.07358	.723	33.1
0	10	20	—	.72593	1.57774	.774	30.3
0	10	50	—	.33218	2.19669	.833	26.5
0	20	0	—	2.31042	—	.693	34.5
0	20	10	—	1.58016	.85935	.757	31.3
0	20	20	—	1.16733	1.34517	.790	29.3

Number of progeny in respective age classes			Weighting factors to be used for respective progeny means			Accuracy	Standard error
n_2	n_3	n_4	b_2	b_3	b_4	r_{TI}	$\sigma_{T\|I = I_0}$
0	20	50	—	.58058	2.03564	.836	26.3
0	50	0	—	2.89336	—	.775	30.2
0	50	10	—	2.27634	.57981	.799	28.8
0	50	20	—	1.83782	.99188	.815	27.8
0	50	50	—	1.05307	1.72930	.843	25.8
10	0	0	3.03071	—	—	.450	42.8
10	0	10	1.53638	—	1.28772	.684	34.9
10	0	20	.95007	—	1.79297	.757	31.3
10	0	50	.30944	—	2.34502	.829	26.8
10	10	0	1.70840	1.44282	—	.643	36.7
10	10	10	1.03937	.93146	.98038	.736	32.4
10	10	20	.69415	.66759	1.48627	.779	30.0
10	10	50	.23931	.31994	2.15278	.833	26.5
10	20	0	1.14951	2.05264	—	.709	33.8
10	20	10	.76120	1.45279	.80837	.763	31.0
10	20	20	.53003	1.09569	1.28959	.793	29.1
10	20	50	.18582	.56397	2.00616	.836	26.2
10	50	0	.51037	2.75004	—	.778	30.1
10	50	10	.36926	2.18733	.56600	.800	28.7
10	50	20	.26734	1.78093	.97479	.815	27.1
10	50	50	.08150	1.03983	1.72021	.843	25.8
20	0	0	4.60700	—	—	.554	39.9
20	0	10	2.58323	—	1.14727	.706	33.9
20	0	20	1.66680	—	1.66678	.765	30.8
20	0	50	.56993	—	2.28859	.830	26.7
20	10	0	2.86818	1.24813	—	.671	35.5
20	10	10	1.82576	.84430	.90987	.745	31.9
20	10	20	1.24918	.62094	1.41313	.784	29.8
20	10	50	.44501	.30941	2.11504	.834	26.4
20	20	0	2.01902	1.85766	—	.721	33.2
20	20	10	1.37147	1.35067	.76749	.768	30.7
20	20	20	.96987	1.03625	1.24348	.796	29.0
20	20	50	.34810	.54945	1.98041	.837	26.2
20	50	0	.94640	2.62759	—	.780	29.4
20	50	10	.69028	2.10995	.55400	.801	28.7
20	50	20	.50271	1.73085	.95974	.816	27.7
20	50	50	.15492	1.02794	1.71203	.843	25.8
50	0	0	6.69683	—	—	.668	35.6
50	0	10	4.36962	—	.90758	.741	32.2
50	0	20	3.04514	—	1.42412	.780	30.0
50	0	50	1.15156	—	2.16259	.832	26.6
50	10	0	4.83939	.91721	—	.716	33.4
50	10	10	3.34364	.67607	.77377	.764	30.9
50	10	20	2.40114	.52412	1.26133	.793	29.2
50	10	50	.91894	.28517	2.02809	.835	26.4
50	20	0	3.69680	1.48142	—	.744	32.0
50	20	10	2.64268	1.13797	.68234	.779	30.0
50	20	20	1.93159	.90626	1.14264	.801	28.7
50	20	50	.73130	.51519	1.91961	.837	26.2
50	50	0	1.94178	2.34806	—	.786	29.6
50	50	10	1.44297	1.92851	.52587	.804	28.5
50	50	20	1.06558	1.61109	.92374	.817	27.6
50	50	50	.33713	.99839	1.69171	.843	25.8

It is supposed that the means are already corrected for annual and sex differences.

Now the index I of the stallion can be computed according to equation (3) in chapter 3, with the aid of the appropriate information in tables 1, 3 and 5.

$$I = 7.43637 \ \{(650 - 428) - 0.01\ (13500 - 11902)\} + \\ + 1.72214 \ \{(2100 - 2269) - 0.05\ (12600 - 11902)\} + 14050 = \\ = 15231.$$

VI. — DISCUSSION

In the Netherlands a database for trotters has been established, comprising the information of all *Trotters* born since 1929. For each horse own number, sire's number, dam's number, sex and year of birth are stored, together with its yearly earnings and time records. Each year the new yearly crop of foals is added, as well as the earnings and time records of trotters, which raced that year.

Now at the end of each year the index values of all trotting sires with progeny, which has trotted in that year, are computed, together with the standard error of their true breeding value and the correlation between the true breeding value and the index. This is done for both untranformed and transformed earnings.

Besides this also index values for the trotter stallions are computed in October of each year. For this purpose the earnings in the first 9 months of the current year are brought in into the database. These index values are used as an aid to the committee, that is examining the trotter stallions in the beginning of November each year.

Since the *Trotter* population is not stable, it is advisable to recalculate from time to time the genetic parameters, correction factors and population means of various age classes, used in the index computations. The conversion factors used for the correction of annual differences are debatable. These factors are based on the ratio of total amount of money, supplied to trots in a given year, divided by the number of *Trotters*, starting in that particular year. So these factors don't take into account the number of horses, that never start. When the percentage of non-starters varies between years or periods, these conversion factors could be somewhat inaccurate.

Finally the index developed could be improved by taking into account the genetic trend in the performance of trotters. Now all earnings are converted to the same standard earnings, so differences in mean genetic level of performance between years or periods are eliminated together with environmental (economic) differences. So strictly speaking only index values of contemporary stallions may be compared with each other.

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RÉSUMÉ

ANALYSE GÉNÉTIQUE DES PERFORMANCES EN COURSE DES *TROTTEURS HOLLANDAIS*

II. — MÉTHODE D'ESTIMATION DE LA VALEUR GÉNÉTIQUE DES ÉTALONS

Un indice de sélection des étalons *Trotteurs* a été mis au point sur la base des performances en course de leurs descendants. Cet indice est basé sur les gains de leurs descendants aux différentes

étapes de leur carrière en compétition. Les gains sont d'abord corrigés pour les fluctuations annuelles et pour le sexe. Les moyennes correspondant à chaque classe d'âge des descendants d'un étalon donné sont corrigées pour la moyenne des gains de leurs mères à partir de la régression des performances des descendants sur celles de leur mère. Pour chaque étalon, les gains moyens corrigés correspondant à chaque classe d'âge sont alors combinés. A cet effet, des coefficients de pondération sont mis au point conformément à la théorie des indices de sélection en tenant compte du nombre de descendants dans les différentes classes d'âge.

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