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# ON THE POSSIBILITY OF PREDICTING THE SUCCESS OF A BULL'S DAUGHTERS FROM HIS BLOOD TYPE

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Since it became evident that several of the chromosome pairs in cattle are marked by blood group genes, the question of whether these genes would have any useful association with production or fitness traits of cattle has been studied by numerous workers (DUNLOP 1951, MC CLURE 1952, NAIR *et al.* 1955, LABEN and STORMONT 1958, BOUW 1958, MITSCHERLICH *et al.* 1959, RENDEL 1959 and 1961, LARSEN *et al.* 1959, TOLLE 1960, NEIMANN-SØRENSEN and ROBERTSON 1961, SMITH and PFAU 1962, BARR 1960, MUNKÁCSI 1962, CONNEALLY 1962, SALERNO 1963, CONNEALLY and STONE 1965). Although conflicting in many cases, the results have shown that it is possible to detect some correlations between blood groups and polygenic traits. This was to be expected, because the genes determining a quantitative trait are probably distributed evenly over all the chromosomes. On the other hand, one such connection between a production gene and a blood group gene would have very little practical importance, because the elimination of the variation caused by a single gene does not noticeably decrease the variance of the polygenic trait. This reasoning has gained support from the extensive study of NEIMANN-SØRENSEN and ROBERTSON (1961). This rather pessimistic and at the same time very realistic view must not, however, be allowed to prevent a study of the same situation in other breeds, because further research often suggests new ideas, not necessarily related to the original problem. The purpose of the present paper is to present the results of a search for an association between the blood groups of bulls and their progeny-testing results in Finnish Ayrshire cattle.

## Materials and methods

The collection of blood samples for this study was planned so that it should be possible to perform the comparisons on the basis both of bull progeny group means and of individual daughters within sires. The two kinds of comparisons were considered to complement each other: in the former the genotypes with regard to production traits and blood types can be determined with better accuracy, while in the latter there is less selection which would decrease the genetic variation in production traits. By utilizing all the milk-recorded daughters for judging an A. I. bull, it is easy to achieve an accuracy of 80 % in evaluating the genetic quality with regard to production traits by the former method. The systematic environmental differences between bulls can largely be eliminated by

expressing the yields of daughters as so-called relative yields (= 100 × individual yield/herd average), by correcting for age and by making the comparisons within A. I. units. Within each A.I. unit the distribution of daughters of different bulls with regard to herd environments and to quality of dams can be considered to be random. The possible influence of variation in gene frequencies between families can be eliminated by performing the calculations within sires of the bulls.

The blood groups were determined by the haemolytic technique. To enable analyses to be made of the individual daughter records as well, blood samples were taken from both the daughters and their dams, which facilitated the determination of the genetic blood types of the sires. The analyses for the present study consisted of comparing the progeny-testing results of Ayrshire bulls with and without certain blood group genes. This comparison was made with regard to the five most frequent alleles of the B-system in this breed ($O_1$, E'$_3$, $O_1$A', PI' and B$O_1$Y$_2$D'), each of which had a frequency of at least 5 %, and with regard to the factor A in the AH-system, L in the L-system, $S_2$ in the SU-system, Z in the Z-system and V in the FV-system. In addition, homozygous bulls (F/F and V/V) were compared to heterozygous (F/V) bulls in the FV-system.

The following production traits were included in the study:

(1) Fat percentage as the absolute average of the daughters of a bull. It was not considered necessary to express the fat percentage as a deviation from the herd average, since the absolute and relative fat percentages have proved to give equal accuracies in progeny testing (VARO 1960).

(2) Milk production value as the average deviation of the daughters' relative milk yields from the average relative milk yield of cows of the same breed at corresponding ages (relative milk yield = operational year's individual record × 100/herd average).

(3) Regressed milk production value = milk production value × repeatability of a progeny test with a given number of daughters.

(4) Plus-% = percentage of daughters with positive deviations of the relative milk yields from the age & breed averages (see item No. 2).

(5) S. D. = standard deviation of the relative milk yield deviations of daughters of a bull.

The last measure was included mainly for the sake of comparing the homozygous FF and VV animals with heterozygous FV bulls.

For making comparisons within sires of the bulls, at least two sons of each sire were required. The minimum number of daughters required for a progeny test was 10, but the average number was 156 daughters per bull. The total number of bulls was 448, and these had 81 different sires.

A hierarchical variance analysis with unequal subclass number was chosen as the method of analysis, in order to determine the relative importance of blood groups in the variation of the progeny-testing results. Negative variance components were considered as zeros in computing the percentages, except in the pooled results.

In cases where significant differences between the blood group classes were found, the direction and size of the effect was computed according to the formula

$$\bar{D} = \frac{\Sigma wd}{\Sigma w}, \text{ where } w = \frac{n_1 n_2}{n_1 + n_2} \text{ and } d = \bar{X}_1 - \bar{X}_2$$

within each sire (NEIMANN-SØRENSEN and ROBERTSON 1961). The standard error of this difference was computed according to the formula

$$SE_{\bar{D}} = \sqrt{\frac{\sigma^2_w}{\Sigma w}}, \text{ obtained from the same source.}$$

Here $\sigma^2_w$ means the total variance within sections of progeny groups.

## Results

As can be seen from Table 1., there were significant ($P < 0.05$) differences between the blood group classes in three cases. It should be

Table 1. Components of variance in progeny tests of Ayrshire bulls.
*Taulukko 1. Ayrshiresonnien jälkeläisarvostelutulosten muuntelun syitä.*

| Blood group *Veriryhmä* | Degrees of freedom *Vapausasteita* | | % of the total variance in different traits *% eri ominaisuuksien kokonaismuuntelusta* | | | | |
|---|---|---|---|---|---|---|---|
| | | | Fat-% *Rasva-%* 1 | Milk *Maito* 2 | Regr. milk *Korjattu maito* 3 | Plus-% 4 | S.D. *Hajonta* 5 |
| | Betw. blood groups *Veriryhmäluokk.väl.* | Within blood groups *Veriryhmäluokk.sis.* | Blood group differences as a cause of variance *Veriryhmäerot muuntelun syynä* | | | | |
| $O_1$ | 57 | 310 | 0.00 | 4.63 | 2.10 | 0.88 | 14.44* |
| $E'_3$ | 42 | 325 | 0.00 | 2.79 | 2.24 | 0.00 | 1.45 |
| $O_1A'$ | 44 | 323 | 15.44* | 2.48 | 3.20 | 0.00 | 0.00 |
| PI' | 34 | 333 | 10.31 (*) | 1.48 | 1.72 | 0.00 | 0.00 |
| $BO_1Y_2D'$ | 27 | 340 | 0.00 | 2.03 | 0.39 | 7.06 | 5.53 |
| V | 44 | 323 | 6.36 (*) | 0.00 | 0.00 | 0.00 | 6.02 |
| A | 31 | 336 | 0.00 | 4.26 | 1.33 | 9.35 (*) | 21.83* |
| L | 47 | 320 | 3.21 | 3.48 | 4.33 | 1.22 | 0.00 |
| $S_2$ | 41 | 326 | 0.00 | 0.00 | 0.00 | 0.00 | 0.00 |
| Z | 47 | 320 | 3.77 | 2.86 | 0.00 | 0.00 | 0.00 |
| FF & VV | 47 | 320 | 0.42 | 0.00 | 0.00 | 0.00 | 0.00 |
| | Pooled *Keskimäärin* | | 2.00 (*) | 0.52 | —0.34 | —0.15 | 0.19 |
| | Total *Yht.* | Betw. sires *Isien väl.* | Sire differences as a cause of variance *Isien väliset erot muuntelun syynä* | | | | |
| $O_1$ | 447 | 80 | 21.35*** | 5.55 | 0.99 | 6.88 (*) | 0.00 |
| $E'_3$ | » | » | 23.12*** | 3.40 | 1.96 | 7.83* | 0.00 |
| $O_1A'$ | » | » | 9.84* | 3.64 | 1.34 | 5.32 (*) | 0.00 |
| PI' | » | » | 11.96* | 7.15 | 0.95 | 7.42* | 7.32 |
| $BO_1Y_2D'$ | » | » | 21.25*** | 6.55 | 1.88 | 1.55 | 0.00 |
| V | » | » | 16.13** | 8.82 (*) | 7.30 | 5.42 (*) | 0.00 |
| A | » | » | 26.21*** | 2.04 | 2.49 | 0.00 | 0.00 |
| L | » | » | 18.37*** | 3.16 | 0.80 | 4.22 (*) | 6.72 |
| $S_2$ | » | » | 23.20*** | 8.09 (*) | 7.35 | 5.68 (*) | 7.85 |
| Z | » | » | 17.78*** | 3.37 | 4.58 | 8.82 (*) | 5.98 |
| FF & VV | » | » | 20.11*** | 8.75 (*) | 6.69 | 6.43 (*) | 0.00 |
| | Pooled *Keskimäärin* | | 18.66*** | 5.89** | 3.07* | 5.70** | —0.08 |
| | | | Values of some statistical characteristics *Eräiden tilastollisten tunnuslukujen arvot* | | | | |
| Mean ($\bar{X}$) *Keskiarvo* | | | 4.599 | 0.400 | 0.410 | 52.44 | 11.98 |
| $\delta$ within sires *Isien sisäinen hajonta* | | | 0.145 | 3.120 | 2.393 | 11.47 | 1.86 |
| Coeff.var., % *Muuntelukerroin* | | | 3.151 | 779.1 | 583.2 | 21.87 | 15.55 |

*** $P < 0.001$; ** $P < 0.01$; * $P < 0.05$; (*) $P < 0.2$

remembered, however, that in this kind of statistics, where there are several independent comparisons, the conventional levels of probability do not apply (NEIMANN-SØRENSEN and ROBERTSON 1961). The pooled estimates similarly show that the presence of stars in column 5 can be explained by chance. In fact, the figure on line L in the 5th column would have been about —14% if the negative variance component had been taken at its face value.

In column 1, concerning the fat percentage, the pooled average of the 11 lines is about 2%,

and thus there is a certain probability that real differences exist in the fat content between the blood group classes. On comparing the pooled values of the blood group components with those of the sire components in the lower part of Table 1, however, one sees that the sire is a much more important source of variance than the blood type. In fact, the progeny-testing result of a half-brother seems to be several times as accurate as his own blood type in predicting the progeny-testing result of a bull. On the other hand, if the result concerning the effect of blood group $O_1A'$ on fat content could be confirmed at the level shown in Table 1, it would have practical importance alone, without the other blood groups.

The result concerning the effect of the A-factor on the standard deviation finds some support from its effect on the percentage of plus-daughters, which is also dependent on the variability of a daughter group. The effect of the A-factor was such that the standard deviation of progeny was $0.78 \pm 0.28$ units higher for bulls which did not have the A-factor than for bulls having it. The former group had $2.53 \pm 1.75$ %-units more plus-daughters than the latter group.

Bulls which did not have the allele $O_1$ had progeny groups with $0.163 \pm 0.197$ units higher standard deviations than their half-brothers having the allele. With regard to the allele $O_1A'$ the corresponding difference in the fat percentage was $-0.019 \pm 0.018$ %-units. All these differences can be transformed to differences between individual cows by multiplying by two.

## Discussion

As far as the present author is aware, the effect of the allele $O_1A'$ has not been studied elsewhere, since its frequency is generally low. The most suitable breeds for studying its effects are the Swedish Polled Cattle ($q = 10.2$ %, RENDEL 1958) and the Icelandic Cattle ($q = 6.4$ %, BRAEND *et al.* 1962). For the present, it appears rather unlikely that the result could be confirmed, since this study for its part did not confirm the results of RENDEL (1959), NEIMANN-SØRENSEN and ROBERTSON (1961) and CONNEALLY and STONE (1965), concerning the relation of the alleles $BO_1Y_2D'$ and $BO_1Y_1D'$ to the fat content. This lack of agreement may depend on differences in the genic environment of the allele in question in the different breeds. It could also be in the method of analysis, but since a similar method was used by RENDEL (1959 and 1961), this alternative does not seem very probable.

The two stars in column 5 are rather surprising, since this statistic was only included for the sake of comparing homozygous bulls with heterozygous bulls in the FV-system. Although the pooled result at the bottom seems to indicate that the stars can be explained by chance alone, it is not entirely impossible to find biological explanations, too. For example, the factor A could play a decisive rôle in some epistatic relationships or interactions. There may be reason to study, for example, whether it plays a rôle in the fertility disturbances which cause abnormally long calving intervals. For the standard deviation tends to be larger than average for bulls which have many daughters with long calving intervals. This is a special feature of milk records measured on an operational year basis, depending on the fact that a prolonged calving interval decreases the production per unit time. However, the effect of the A-factor on the service period was negligible in the study of NEIMANN-SØRENSEN and ROBERTSON (1961).

Thus, the only conclusion which can be safely drawn from the present study is that the relative importance of blood groups in predicting breeding values for production traits is probably low, on the average, but that the effects of some blood groups deserve further study. It may be reasonable to study the effect of the factor A on various fertility traits.

## Summary

A total of 448 progeny-tested sons of 81 Finnish Ayrshire bulls were grouped according to the presence or absence of certain blood-

group alleles of systems AH, B, FV, L, SU, and Z in their blood type. Variance analyses performed within sires showed that these classifications were rather unimportant sources of variance in the progeny-testing results of the sons as compared with the differences between sires. The progeny-testing result of a half-brother was thus several times as accurate as his own blood type in predicting the progeny-testing result of a bull.

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## REFERENCES

BARR, H. L. 1960. The association between certain extracellular factors of erythrocytes and several measurable performance traits in dairy cattle. Diss. Abstr. 21: 734.

BOUW, J. 1958. Blood group studies in Dutch cattle breeds. Thesis, 84 p. Wageningen.

BRAEND, M., RENDEL, J., GAHNE, B. & ADALSTEINSSON, S. 1962. Genetic studies on blood groups, transferrins and hemoglobins in Icelandic cattle. Hereditas 48: 264—283.

CONNEALLY, P. M. 1962. Population genetics of cattle blood groups. Diss. Abstr. 23: 765.

—»— & STONE, W. H. 1965. Association between a blood group and butterfat production in dairy cattle. Nature 206: 115.

DUNLOP, A. A. 1951. Type differences in blood antigens in a Guernsey herd. J. Dairy Sci. 34: 156—166.

LABEN, B & STORMONT, C. 1958. Genetic analysis of the B, FV and Z blood group loci in an inbred Jersey herd. J. Anim. Sci. 17: 1 139—1 140.

LARSEN, B., NEIMANN-SØRENSEN, A. & ROBERTSON, A. 1959. Blodtyper og produktionsegenskaber hos kvaeg. Ann. Rep., Sterility Res. Inst., Royal Vet. Agric. Coll., Copenhagen, 234—241.

MCCLURE, T. J. 1952. Correlation study of bovine erythrocyte antigen A and butterfat test. Nature 170: 327.

MAIJALA, K. & LINDSTRÖM, GUNVOR 1965. The inheritance of the new blood group factor SF3 in cattle. Ann. Agric. Fenn. 4: 207—214.

MITSCHERLICH, E., TOLLE, A. & WALTER, E. 1959. Untersuchungen über das Bestehen von Beziehungen zwischen Blutgruppenfaktoren und der Milchleistung des Rindes. Z. Tierz. Zücht. biol. 72: 289—301.

MUNKÁCSI, F. 1962. A vércsoportgenetikai kutatások felhasználásának lehetősége a szarvasmarha szelekciójában (The possibility of using blood group genetics in the selection of cattle). Állattenyésztés 11: 5—10.

NAIR, G., LUDWICK, T. M., LAZEAR, E. J. & FERGUSON, L. C. 1955. Preliminary report comparing cellular antigens with type defects in dairy cattle. J. Dairy Sci. 38: 615—616.

NEIMANN-SØRENSEN, A. & ROBERTSON, A. 1961. The association between blood groups and several production characteristics in three Danish cattle breeds. Acta Agric. Scand. 11: 163—196.

RENDEL, J. 1958. Studies of cattle blood groups. IV. The frequency of blood group genes in Swedish cattle breeds, with special reference to breed structure. Ibid. 8: 191—215.

—»— 1959. A study on relationships between blood groups and production characters in cattle. Rep. VI Int. Congr. Blood Group Res. in Animals. Munich, 8—23.

—»— 1961. Relationships between blood groups and the fat percentage of the milk in cattle. Nature 189: 408—409.

SALERNO, A. 1963. (Investigations on the relationships between blood groups and age at first calving, calving interval and service period in the Romagna breed.) Prod. anim. 2: 403—412.

SMITH, W. C. & PFAU, K. O. 1962. The utility value of blood group genes in a herd of Holstein-Friesian cattle. Proc. VIII Anim. Blood Group Conf. in Europe, Ljubljana.

TOLLE, A. 1960. Grundlagen und Untersuchungsergebnisse von Beziehungen zwischen Blutgruppenfaktoren und Färsenlaktation. Züchtungskunde 32: 324—335.

VARO, M. 1960. Avkommebedömningen av semintjurar i Finland. VII NØK-møtet: 17—23.

SELOSTUS

# Mahdollisuudesta ennustaa sonnin tyttärien menestyminen sen verityypistä

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Tutkimuksen aineistona oli 448 vähintään 10 tyttären perusteella jälkeläisarvosteltua ayrshiresonnia, jotka olivat 81 eri isän poikia. Keskimääräinen tytärluku jälkeläisarvostelussa oli 156. Tutkimus suoritettiin siten, että kunkin isän pojat jaettiin kahteen ryhmään sen mukaan, oliko niillä tietty veriryhmä vai ei. Ryhmittely tehtiin 10 eri alleeliin nähden, joista 5 kuului B-järjestelmään, yksi AH-, yksi L-, yksi SU-, yksi FV- ja yksi Z-järjestelmään. Lisäksi verrattiin toisiinsa homotsygoottisia (F/F ja V/V) ja heterotsygoottisia (F/V) veljesryhmiä.

Tutkimusmenetelmänä käytettiin varianssianalyysia, jossa päähuomion kohteena oli edellä mainitun veriryhmäjaoittelun merkitys sonnien jälkeläisarvostelutulosten muuntelun syynä. Laskelmat suoritettiin seuraaviin jälkeläisarvostelutuloksiin nähden:

(1) Tyttärien keskimääräinen rasva-% sellaisenaan.
(2) Suhteellisen maitotuotoksen poikkeama samanikäisten keskiarvosta.
(3) Sama tyttärien lukumäärään nähden korjattuna.
(4) Plus-tyttärien %-osuus kaikista tyttäristä.
(5) Tyttärien suhteellisten maitotuosten poikkeamien hajonta.

Varianssianalyysien tulokset osoittivat, että sonnien veriryhmien perusteella tehty jaoittelu oli sonnien jälkeläisarvostelutulosten muuntelun syynä vähäpätöinen verrattuna eri isien poikaryhmien välisiin eroihin. Siten puoliveljen jälkeläisarvostelutulos oli monta kertaa varmempi sonnin jälkeläisarvostelutuloksen ennustamisperuste kuin sonnin oma verityyppi.

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Seria ANIMALIA DOMESTICA N. 16 — Sarja KOTIELÄIMET n:o 16

# FINNISH EXPERIENCES OF PARENTAGE TESTING OF CATTLE BY BLOOD TYPING

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The overwhelmingly most important practical application of immunogenetics to cattle breeding at the present time is its use in parentage determination, the importance of which has been considerably increased by the expansion of A.I. during the last 20 years. This aspect of immunogenetics in cattle has been studied by numerous workers including HUMBLE (1952) and STONE and PALM (1952) in USA, MOUSTGAARD and NEIMANN-SØRENSEN (1955), NEIMANN-SØRENSEN (1956, 1958), LARSEN (1957) and MOUSTGAARD and MØLLER (1961) in Denmark, RENDEL (1956, 1958) and RENDEL and GAHNE (1961) in Sweden, GASPARSKI and GASPARSKA (1960) and SPRYSZAK and ROMANIUK (1960) in Poland, SCHMID (1962) and BEUCHE (1963) in Germany, and HOSODA *et al.* (1963) in Japan. ROBERTSON (1956) has presented some theoretical calculations of the effectiveness of blood group factors in parentage tests, and RENDEL *et al.* (1962) have studied the frequency of cows served while pregnant, on the basis of parentage tests.

In the present report, preliminary information will be given of the need and value of blood typing for determining parentage in Finland.

## Materials and methods

In order to form an idea of the need for parentage tests, the frequency of erroneously stated parentages was calculated from three different materials. The first consisted of 432 Finnish Ayrshire bulls and 156 Finncattle bulls offered for sale in the auctions arranged by the respective herd book societies in the years 1957—1962. These can be considered to be random samples of animals from bull-producing herds, because it was only a matter of checking the parentage of the animals, in whose pedigrees nothing was known or suspected to be wrong before the blood typing. The second material consisted of 714 young cows or heifers blood-typed in connection with a special research project, for which daughters of A.I. bulls with their dams were selected for study (MAIJALA 1966). This part of the data originates from the area of Uusimaa A.I. Society. The third material consists of similar data from the area of the Southwest Finland A.I. Society, comprising 650 dam-daughter pairs.

To see the value of blood typing in solving

Table 1. The frequency of incorrect parentages in different materials.
*Taulukko 1. Virheellisten polveutumistietojen lukuisuus eri aineistoissa.*

| Material *Aineiston laatu* | No. of cases *Tapausten luku* | Wrong sire *Väärä isä* | | Wrong dam *Väärä emä* | | Wrong damsire *Väärä emänisä* | |
|---|---|---|---|---|---|---|---|
| | | No. *Luku* | % | No. *Luku* | % | No. *Luku* | % |
| 1. Auction bulls *Huutokauppasonnit* | 588 | 12 | 2.04±0.58 | 2 | 0.34 | — | — |
| Cows: *Lehmät:* | | | | | | | |
| 2. Uusimaa A.I. Society *Uudenmaan k.s. yhdistys* | 714 | 37 | 5.18±0.83 | 1 | 0.14 | 25 | 3.50±0.69 |
| 3. Southwest Finland *Lounais-Suomen k.s. yhdistys* | 650 | 22 | 3.38±0.71 | 2 | 0.31 | 16 | 2.46±0.61 |
| Cows pooled *Lehmät yhteensä* | 1 364 | 59 | 4.33±0.55 | 3 | 0.22 | 41 | 3.01±0.46 |
| Difference betw. societies *Yhdistysten välinen ero* | | | 1.80±1.10 | | | | 1.04±0.92 |

disputable parentages, 454 cases in which two different bulls were reported as possible sires were analyzed. The value of blood typing in detecting erroneously stated paternities was elucidated on the basis of 597 cases where the offspring, dam and reported sire were blood-typed to verify the paternity.

The blood-typing technique used has been described by MAIJALA and LINDSTRÖM (1965).

## The need of blood typing

The frequencies of incorrectly stated parentages in the three groups of data are shown in Table 1.

It can be seen that 12 of the 588 bulls had a wrongly stated sire, and that 2 bulls had a wrong dam due to an interchange of calves. The percentage of bulls having an incorrectly stated parentage is thus 2.38 %. In the cow data the frequency of wrong sires was about twice as high as in the bull material, and the total frequency of wrong sires and/or dams was 4.55 %. The frequency of wrong sires seems to be 15—20 times higher than that of wrong dams.

There were also dam-sires with blood types that did not agree with those of the dams. Their frequency in the cow data was 3 %. When this is added to the wrong parentages, it appears that more than 7 % of the pedigrees up to and including grandparents were incorrect.

There was a difference of 1.80 % between the A.I. units in the frequency of wrong paternities. The statistical significance of this difference is a little under 90 %. Because the difference in the dam-sires was in the same direction, with ca. 70 % significance, it appears that there may be differences in the carefulness of data-recording in different A.I. units.

## The value of blood typing

With regard to the efficiency of blood typing in solving disputable paternities, it was found that of the 454 cases with 2 possible sires solved in the years 1955—63, one of the bulls could be excluded in 377 cases or 83.04 %, while 16.96 % remained unsolved. In the years 1955—60, 49 out of 237 cases (=20.68 %) remained unsolved, while the respective figures from the years 1961—63 were 28/217 = 12.90 %. Thus, there seems to be some tendency towards greater efficiency as the number of available reagents and amount of experience increase.

When the cases in which one of the bulls could be excluded and the other accepted as sire were classified according to the interval between the two services in question, the following results were obtained:

| Service interval | 1 | 2 | 3 | 4 | 5 | 6—19 | 20—38 days: |
|---|---|---|---|---|---|---|---|
| No. of cases: ..... | 151 | 91 | 44 | 8 | 8 | 10 | 12 |
| Last bull not sire, No.: | 52 | 22 | 3 | 0 | 3 | 2 | 3 |
| » » » » , %: | 34 | 24 | 7 | 0 | 38 | 20 | 25 |

The figures on the far right especially, indicate that there is a certain proportion of cows which show oestrus and become inseminated while pregnant.

In checking the 597 paternities with one reported sire, the sire was accepted in 549 cases or 91.96 %. For 35 cases or 73 % of the remaining 48 cases the right sire was found among the other bulls in use on the day of insemination. In another group of 3 cases, where the sire was unknown but the insemination day was known, a sire was found in each case.

In all 11 cases where there has been uncertainty about the dams of 1 or 2 calves, it has been possible to decide the maternity.

## Discussion

The percentage of incorrectly stated parentages in the cow data from ordinary herds appears rather high. On the other hand, it is in a reasonable accord with the results obtained in other Scandinavian countries (MOUSTGAARD and NEIMANN-SØRENSEN 1955, RENDEL 1956, 1958). Furthermore, the fact that the errors were more frequent in the cow data from ordinary herds than in the bull data is in accord with the Danish results (BRUMMERSTEDT-HANSEN *et al.* 1962). The reason for this difference between bull-producing and ordinary herds is obviously to be found in the care taken over book-keeping. The sign of the difference is reassuring, when one takes into account the importance of bulls in A.I.

The errors in stated paternity may originate from some or several of the following situations:

(1) A bull or bull-calf belonging to the same herd or to the neighbouring herd has served the cow »by stealth».
(2) The bull of a bull-keeping society or neighbour has been changed, but this was not noticed by the herd owner.
(3) The recorder has made a transfer error in book-keeping, e.g. by reading from the wrong line.
(4) The herd manager's deputy has not marked the calves born simultaneously during his holiday or dayoff.
(5) An error has been made in the marking of semen ampoules at the A.I. station.
(6) The A.I. technician has made an error in noting the service sire.
(7) It has not been realized that even a pregnant cow may show symptoms of oestrus (RENDEL *et al.* 1962) and so the bull used last has been recorded as sire.
(8) The great variation of gestation length has not been realized (RENDEL 1959), and hence the sire used most closely to 9 months before parturition has been recorded as sire.
(9) In cases where two different sires have been used either at one heat or in successive heats, the more famous one may have been noted as sire as a matter of dishonesty.

The errors caused by repeated services can be avoided when deepfrozen semen is used. Errors (7) and (8) can largely be eliminated by education, but the first 6 types of errors are human ones, and difficult to get rid of. So one is bound to have a certain frequency of errors, which makes the pedigrees unreliable, the more so the further back one goes in the pedigree, and hence some form of parentage checking is continuously needed, particularly in the case of A.I. bulls.

The percentage of disputable paternity cases solved with the aid of blood groups was also in a good agreement with the results obtained by RENDEL (1958), RENDEL and GAHNE (1961) and SCHMID (1962). It is obvious that better results will be obtained when additional blood-group factors and systems are available for use.

## Summary

The frequency of incorrectly stated paternities in random samples of 1 364 cows and 588 bulls were 4.33 % and 2.04 %, respectively. The percentage of wrongly stated dams was about 0.2 % and of wrong dam-sires ca. 3 %. Of 454 cases where 2 different bulls were reported as possible sires, one bull could be excluded in 83 %. In checking 597 paternities with one reported sire, the sire was accepted in 92 % of the cases, and for the majority of the remaining ones the right sire was found among the other bulls used on the day of insemination. There appears to exist a constant need for pedigree control, and the blood typing technique seems to be a satisfactory and continuously improving method for meeting this demand.


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## REFERENCES


BEUCHE, H. 1963. Der serologische Abstammungsnachweis beim Rind unter besonderer Berücksichtigung der B-system-Allele und der Serumtypenbestimmung. Züchtungskunde 35: 168—179.

BRUMMERSTEDT—HANSEN, E., HESSELHOLT, M., LARSEN, B., MOUSTGAARD, J. MØLLER, I., BRÄUNER NIELSEN, P. & PALLUDAN, BIRTHE 1962. Recent progress in immunogenetic research. Rep. 8th Anim. Blood Group Conf., Ljubljana 1962, 19 pp.

GASPARSKI, J. & GASPARSKA, J. 1960. (Blood groups in cattle and an analysis of their inheritance. I. Attempt to determine parentage on the basis of blood group phenotypes and genotypes.) Roczn. Nauk.rol. B. 76: 547—563.

HOSODA, T., ABE, T. & KOSAKA, S. 1963. (Studies on blood groups in dairy cattle. I. Determination of parentage by the use of polyvalent heteroimmune serum.). Bull. nat. Inst. Anim. Ind. (Chiba) 3: 99—103.

HUMBLE, R. J. 1952. Report at the Second Bovine Blood-typing Conference, Ohio State Univ., Columbus, Ohio.

LARSEN, B. 1957. Undersøgelser over faderskabet ved 2 gange inseminering hos kvaeg. Ugeskr. Landm. 102: 503—505.

MAIJALA, K. 1966. On the possibility of predicting the success of a bull's daughters from his blood type. Ann. Agric. Fenn. 5: 65—70.

—»— & LINDSTRÖM, GUNVOR, 1965. The inheritance of the new blood group factor SF3 in cattle. Ibid. 4: 207—214.

MOUSTGAARD, J. & MØLLER, I. 1961. Serumtyper hos kvaeg. (Fortsatte undersøgelser). Aarsberetn., Inst. Sterilitetsforskn. 1961: 115—123.

—»— & NEIMANN—SØRENSEN, A. 1955. Blodtypebestemmelser af afkommeprøvestationernes kvier. Ugeskr. Landm. 100: 797.

NEIMANN-SØRENSEN, A. 1956. Blood groups and breed structure as exemplified by three Danish breeds. Acta Agric. Scand. 6: 115—137.

—»— 1958. Blood Groups of Cattle. Thesis, 177 pp. København.

RENDEL, J. 1956. Föräldraskapsbevisning i nötkreatursaveln. SRB-tidskr. 29(2): 48—54.

—»— 1958. Studies of cattle blood groups. II. Parentage tests. Acta Agric. Scand. 8: 131—161.

—»— 1959. Factors influencing gestation length in Swedish breeds of cattle. Z. Tierz. Züchtungsbiol. 73: 117—128.

—»— BOUW, J. & SCHMID, D. O. 1962. The frequency of cows served twice which remain pregnant to first service: a study of results from parentage tests. Anim. Prod. 4: 359—367.

—»— & GAHNE, B. 1961. Parentage tests in cattle using erythrocyte antigens and serum transferrins. Ibid. 3: 307—314.

ROBERTSON, A. 1956. Blood grouping in dairy cattle improvement. Proc. 7th int. Congr. Anim. Husb., Sect. 2: 79—83.

SCHMID, D. O. 1962. (Determination of parentage in cattle by blood typing.) Zuchthyg. Fortpfl. Stör. Besam. Haust. 6: 95—99.

SPRYSZAK, A. & ROMANIUK, J. 1960. (The use of cattle blood groups in determining the parentage of calves born as a result of artificial insemination). Med.wet. 16: 358—364.

STONE, W. H. & PALM, J. E. 1952. A disputed parentage case in cattle involving mosaicism of the erythrocytes. Genetics 37: 630.

SELOSTUS

# Kotimaisia kokemuksia nautakarjan polveutumisen tarkistamisesta veriryhmien avulla

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Ylivoimaisesti tärkein veriryhmätutkimuksen käytännöllinen sovellutus on toistaiseksi sen käyttö polveutumisen tarkistamiseen, minkä merkitys on huomattavasti lisääntynyt keinosiemennyksen yleistymisen johdosta. Tämän tutkimuksen tarkoituksena on antaa alustavia tietoja veriryhmityksen tarpeesta ja tehokkuudesta polveutumisen tarkistamisessa Suomessa.

Veriryhmätutkimuksen t a r p e e l l i s u u d e n selvittämiseksi laskettiin virheellisiksi osoittautuneiden polveutumistietojen suhteellinen lukuisuus 1 364 hiehon ja 588 jalostusyhdistysten huutokauppoihin tarjotun sonnin umpimähkäisnäytteissä, jotka oli tutkittu Keinosiemennysyhdistysten Liiton veriryhmälaboratoriossa v. 1957—63. Hiehoista oli 714 Uudenmaan ja Kymen Keinosiemennysyhdistyksen sonnien tyttäriä ja 650 Lounais-Suomen Keinosiemennysyhdistyksen sonnien tyttäriä. Väärien isyyksien osuus sonninäytteessä oli 2.04 % ja hiehonäytteessä 4.33 %. Ilmoitetuista emistä osoittautui n. 0.2 % ja emänisistä n. 3 % vääriksi. Virheellisiä isyyksiä oli siis 15—20 kertaa niin paljon kuin vääriä emyyksiä. Kun väärien emänisien luku lisätään väärien isien ja emien lukuun voidaan päätellä, että kaksi vanhemmaissukupolvea käsittävistä polveutumistauluista yli 7 % on vääriä. Tämä luonnollisesti vähentää polveutumisen merkitystä eläinten arvostelussa. Väärien isien ja emänisien lukuisuudessa oli kahden keinosiemennysyhdistyksen välillä lähes tilastollisesti merkitsevät erot.

Isyysmääritysten t e h o k k u u d e n tutkimiseksi analysoitiin 454 tapausta, joissa mahdollisiksi isiksi oli ilmoitettu kaksi eri sonnia ja joissa molemmista sekä eläimen emästä oli käytettävissä verinäyte. Selviin ratkaisuihin, joissa toinen isistä voitiin sulkea pois ja toinen hyväksyä, päästiin 83.04 %:ssa tapauksista. Vuosina 1955—60 tämä osuus oli 79.32 % ja vuosina 1961—63 87.10 %, joten tehokkuus näyttää parantuneen sitä mukaa kuin käytettävissä olleiden testiseerumien luku ja henkilökunnan kokemus ovat kasvaneet. Kaksi kertaa siemennettyjen tapausten lähempi tarkastelu osoitti, että noin $^1/_4$ oli tiinehtynyt edellisestä siemennyksestä. Kiiman esiintyminen tiineillä lehmillä ei siis ole harvinaista. Tarkistettaessa 597 eläimen isyyksiä, joille oli ilmoitettu vain yksi isä, osoittautui niistä noin 92 % oikeiksi, ja noin $^3/_4$:lle jäljelle jääneistä voitiin löytää isä muiden samana päivänä käytössä olleitten sonnien joukosta.

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# FREQUENCIES OF BLOOD GROUP GENES AND FACTORS IN THE FINNISH CATTLE BREEDS WITH SPECIAL REGARD TO BREED COMPARISONS

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Knowledge of the occurrence and frequency of different blood group factors and genes in various breeds is of value in estimating the efficiency of blood grouping in parentage tests and twin diagnoses, as well as in studying the genetic relationships between breeds and their subgroups. Such information also makes it possible to study various problems related to zygosity. Following the qualitative recognition of considerable inter-breed differences in the occurrence of blood group factors (OWEN *et al.* 1944 and 1947), quantitative information on the frequencies of blood group factors and genes has been published in many countries. Thus, information is available concerning at least 4 breeds in the U.S.A. (STORMONT *et al.* 1951, STORMONT 1952, RAUSCH *et al.* 1965), 3 breeds in Holland (BOUW 1960, KRAAY and BOUW 1964, NASRAT *et al.* 1964), 7 breeds in Germany (BUSCHMANN 1962, SCHMID and ERHARD 1963, ERHARD and SCHMID 1964), 6 breeds in France (GROSCLAUDE and MILLOT 1962, GROSCLAUDE 1965), 3 breeds in Denmark (NEIMANN—SØRENSEN 1958, LARSEN 1961), 4 breeds in Norway (BRAEND 1959, BRAEND *et al.* 1964), 3 breeds in Sweden (RENDEL 1958), 3 breeds in Switzerland (MÜLLER 1960, SCHINDLER 1961, 1963), 2 breeds in Yugoslavia (SCHMID and MANCIC 1964, JOVANOVIC and KONCAR 1965), in Czechoslovakia (MATOUSEK *et al.* 1961) and in Japan (HOSODA *et al.* 1965), and one breed in Hungary (MARKUS 1962), in Poland (GASPARSKI *et al.* 1960, NEIMANN—SØRENSEN and SPRYSZAK 1959, RAPACZ *et al.* 1965), in Iceland (BRAEND *et al.* 1962) and in some other countries (HESSELHOLT *et al.* 1965).

Some breeds have been studied in several countries, as for example Friesians in the U.S.A., Holland, Denmark, Sweden and Japan, and Brown Swiss in the U.S.A., Germany and Switzerland. Most of the studies have shown that the B system is particularly valuable in differentiating between breeds.

An increasing amount of similar information has in recent years been provided by studies concerning serum proteins. One class of these, viz. transferrin, has been studied in Finland (VASENIUS 1965).

The purpose of the present paper is to give some information on the blood group genes and factors occurring in the Finnish breeds, as compared with other Scandinavian cattle breeds.

## Materials

For a long time, there have been only two cattle breeds in Finland, namely the Finncattle and the Finnish Ayrshire cattle. In recent years, representatives of the Swedish Friesians and of some beef breeds have been imported into Finland, but their numbers are too small, to

allow their inclusion in the study for the present.

The Finncattle breed has been developed from the original native breed of the country, and a systematic breeding programme with it was begun at the end of the last century. The cattle were different in colour in different parts of the country, viz. brown in the western parts, piebald brown in the eastern parts and mostly white in the northern parts. Since the fusion of the respective herd book societies in 1947, the different colour types have begun to mix in such a way that the brown type has spread over the areas of the other types. All the types are almost exclusively polled. More detailed data on the breed has been given by KORKMAN (1961).

The Finnish Ayrshire population is based on about 1 600 head imported from Scotland and Sweden during the years 1847—1923. Since the establishment of the Finnish Ayrshire Society in 1901, the population has continuously expanded and spread over the whole country, partly by up-grading from other breeds. About 94 % of the genes of a random sample of 50 herd-book cows born in 1955 originated from imported animals, mostly from Scotland. The proportion of Scotch genes had increased from 65 % in 1915 to 89 % in 1955. For further details of the breed reference should be made to the papers of KORKMAN (1961) and VASENIUS (1965).

Only bull samples have been utilized for the analyses for the present, because they are easier to classify according to their genotypes in the complex systems, by using information obtained from progeny. Two kinds of data were used for the bulls. Firstly, the genotypes of 1 300 Ayrshire bulls with regard to the systems A, B, FV, L, SU and Z, and those of 540 Finncattle bulls with regard to the systems B and FV were transferred to punch cards, following a suitable coding system. For each particular system only those bulls were utilized in which at least one allele was determinable. In Table 1 the bulls are classified as regards their zygosity and the nature of the information available.

Most of the 540 Finncattle bulls belonged to the brown-coloured West-Finnish type, and the genetical analysis concerning the B system was performed both with and without the 96 bulls of the East-Finnish and North-Finnish types. The smaller number of Ayrshire bulls in the B and FV systems is mainly due to the fact that these systems were coded earlier than the others.

The second group of data consisted of the phenotypic reactions of largely the same bulls to different blood-typing reagents. The total number of Ayrshire bulls in this material was 1 299 and that of Finncattle bulls 861. All the blood samples had been tested by the conventional

Table 1. Classification of the blood types of the Ayrshire and Finncattle bulls used in the studies with regard to the systems A, B, FV, L, SU and Z.

*Taulukko 1. Tutkimuksessa käytettyjen ayrshire- ja suomenkarjasonnien verityyppien luokittelu järjestelmiin A, B, FV, L, SU ja Z nähden.*

| Category *Luokka* | Numbers of the bulls — *Sonnien luku* | | | | | | | |
|---|---|---|---|---|---|---|---|---|
| | Ayrshire | | | | | | Finncattle *Suomenkarja* | |
| | A | B | FV | L | SU | Z | B | FV |
| Homozyg. recess. /recessive | 151 | 4 | — | 546 | 269 | 948 | 13 | — |
| » domin./dominant | 13 | 30 | 855 | 3 | 5 | 22 | 3 | 370 |
| Heteroz. domin./recessive | 193 | 27 | — | 374 | 330 | 310 | 47 | — |
| » domin./dominant | — | 876 | 365 | — | 0 | — | 272 | 170 |
| Both alleles determinable — *Molemmat alleelit määritettävissä* | 357 | 937 | 1 220 | 923 | 604 | 1 280 | 335 | 540 |
| 1 allele known, no extra factors — *1 alleeli tunnettu, ei ylimääräisiä tekijöitä* | 943 | 283 | — | 377 | 692 | 20 | 101 | — |
| 1 allele known + extra factors — *1 alleeli tunnettu + ylim.tekijöitä* | — | 17 | — | — | 4 | — | 8 | — |
| Grand total — *Yhteensä* | 1 300 | 1 237 | 1 220 | 1 300 | 1 300 | 1 300 | 444 | 540 |

haemolytic technique, using iso-immune cattie sera. The reagent battery had undergone several changes during the history of the laboratory, but the reactions to 58 different test sera were transferred to punch cards for the present study. These were as follows: A H Z'—B $D_2$ $D_4$ $G_1$ $G_2$ $I_1$ $I_2$ K $O_1$ $O_2$ $O_3$ P Q $T_1$ $T_2$ $Y_1$ $Y_2$ $A'_1$ $A'_2$ B' $D'_1$ $D'_2$ $E'_1$ $E'_2$ $E'_3$ G' I' J' K' O' Y' SF1 — $C_1$ $C_2$ E $R_1$ $R_2$ W $X_1$ $X_2$ $X_3$ L' — F V — J — L — M — $S_1$ $S_2$ $U_1$ U' — Z Z/Z — R' — S F3. The last-mentioned is a new antigenic factor, which up to now has resisted our attempts to allocate it to previously known blood group systems, in spite of considerable effort (MAIJALA and LINDSTRÖM 1965). Some of the reagents had been used only for a very small proportion of the animals, as can be seen from Table 8.

In both groups of data, the bulls of each breed were divided into four groups according to the year of birth, in order to bring to light any time trends in the frequencies. Group I consisted of bulls born in 1949 or earlier, group II of bulls born in 1950—54, group III in 1955—59 and group IV in 1960—64.

## Statistical methods

The existence of genetic equilibrium, which is assumed in almost every method of gene frequency estimation, was studied on the basis of the FV system. The gene frequencies in this system were obtained simply by counting the genes. In the A, J, L, M, Z and SF3 systems the estimates were obtained by the square root method, based on the frequency of homozygous recessive genotypes or of non-reactors. Thus, the A system was handled as a simple system, excluding the factors H and Z' from consideration. In this way, the frequencies are easier to compare with those reported from other Scandinavian breeds. It has also proved to be difficult to classify animals according to their genotypes in the A system, if other factors are taken into account besides the A factor.

The Z system was also treated as a simple system, based on the reactions to Z reagent only, because the Z/Z reagent had been available only for a part of the animals. However, a trial was made utilizing the Z/Z reactions also, but the results agreed very well with those based on the reactions to Z serum. In cases where the frequencies of these simple systems were compared, the standard errors were computed according to the formula

$$s = \sqrt{\frac{1-q_a^2}{4n}}$$

where $q_a$ is the relative frequency of the recessive gene and n is the number of animals (NEIMANN—SØRENSEN 1958).

In the B system the main method was the improved square root method of BRAEND (1963), but some analyses were also made by a simple gene count of bulls in which both B alleles were determinable. In the SU system the allocation method developed by NEIMANN—SØRENSEN was applied.

To measure the similarity of two series of B allele frequencies, correlation coefficients were computed according to the formula

$$r = \frac{\Sigma x_i\ y_i}{\sqrt{\Sigma x_i^2 + \Sigma y_i^2}},$$

where $x_i$ = the frequency of the $i^{th}$ B allele in one series and $y_i$ = the frequency of the same allele in the other series. This correlation should give an idea of how large a share of the B alleles are common to the two series in question.

The significances of differences in the frequencies of positively reacting animals were determined by the chi-square test.

## Factor frequencies

The relative frequencies of various blood group factors in the Finnish breeds are shown in Table 2 together with the corresponding frequencies in some other Scandinavian breeds.

Table 2. The frequency of various blood group factors in the Finnish breeds as compared with some Scandinavian breeds.

*Taulukko 2. Eri veriryhmätekijöitten tiheys Suomen karjaroduissa eräisiin pohjoismaisiin rotuihin verrattuna.*

| System *Järjestelmä* | Factor *Tekijä* | No. of animals *Eläinten luku* | | Frequency of positively reacting animals, % *Positiivisesti reagoineitten eläinten tiheys, %* | | | | | | | | |
|---|---|---|---|---|---|---|---|---|---|---|---|---|
| | | Finn-cattle | Finn. Ayrsh. | Finn-cattle | Finn. Ayrsh. | Swedish breeds (1) *Ruotsin rotuja* | | | | Norwegian (2 & 3) *Norjan rotuja* | | |
| | | *Sk* ♂ | *Ay* ♂ | *Sk* ♂ | *Ay* ♂ | SAB ♂ | SRB ♂ | SLB ♂ | SKB ♂ | T ♂ ♀ | D ♂ ♀ | SV ♂ ♀ |
| A | A .... | 861 | 1 299 | 60.6[3] | 88.6 | 43.9[3] | 66.5[3] | 62.1[3] | 42.6[1] | 35.4[3] | 42.7[3] | 31[3] |
| | B .... | 607 | 717 | 22.1[3] | 54.5* | | | | | | | |
| | Z' ... | 260 | 657 | 0.0 | 0.0 | 0.0 | 0.0 | 0.0 | 0.0 | 0.0 | 0.0 | 0 |
| B | B .... | 861 | 1 299 | 36.7[3] | 20.0 | | | | | | | |
| | $D_2$ ... | 294 | 515 | 46.6[3] | 25.2 | | | | | | | |
| | $D_4$ ... | 419 | 438 | 11.0[3] | 0.2 | | | | | | | |
| | $G_1$ ... | 860 | 1 299 | 34.7[3] | 17.2 | | | | | | | |
| | $G_2$ ... | 62 | 86 | 43.5[2] | 15.1 | | | | | | | |
| | $I_1$ .... | 859 | 1 293 | 6.6[3] | 0.0 | | | | | | | |
| | $I_2$ .... | 437 | 368 | 22.0[3] | 0.3 | | | | | | | |
| | K .... | 847 | 1 279 | 14.3[3] | 1.8 | | | | | | | |
| | $O_1$ ... | 858 | 1 291 | 35.3[3] | 79.8 | | | | | | | |
| | $O_2$ ... | 546 | 737 | 37.7[3] | 80.7 | | | | | | | |
| | $O_3$ ... | 453 | 942 | 35.5[3] | 81.5 | | | | | | | |
| | P .... | 860 | 1 299 | 6.3[3] | 17.7* | | | | | | | |
| | Q .... | 860 | 1 299 | 1.5[3] | 15.3 | | | | | | | |
| | $T_1$ ... | 489 | 995 | 2.5 | 1.2 | | | | | | | |
| | $T_2$ ... | 720 | 984 | 2.1 | 1.5 | | | | | | | |
| | $Y_1$ ... | 575 | 615 | 16.2[3] | 3.3* | | | | | | | |
| | $Y_2$ ... | 860 | 1 297 | 55.5[3] | 28.1 | | | | | | | |
| | $A_1$ ... | 821 | 1 100 | 39.7[2] | 32.7 | | | | | | | |
| | $A_2$ ... | 364 | 829 | 57.4[3] | 39.4 | | | | | | | |
| | B' ... | 746 | 1 015 | 3.6[3] | 0.0 | | | | | | | |
| | $D'_1$ ... | 858 | 1 298 | 26.6[3] | 12.9 | | | | | | | |
| | $D'_2$ .. | 428 | 355 | 32.7[3] | 11.5 | | | | | | | |
| | $E'_1$ ... | 847 | 1 278 | 14.2[3] | 7.2 | | | | | | | |
| | $E'_2$ ... | 542 | 963 | 26.6[3] | 7.4 | | | | | | | |
| | $E'_3$ ... | 861 | 1 299 | 37.7[3] | 47.1 | | | | | | | |
| | G' ... | 284 | 143 | 33.1[3] | 4.2 | | | | | | | |
| | I' .... | 850 | 1 295 | 9.3[3] | 21.4* | | | | | | | |
| | J' .... | 859 | 1 298 | 1.3[3] | 6.2* | | | | | | | |
| | K' ... | 861 | 1 299 | 1.3[3] | 6.5 | | | | | | | |
| | O' ... | 845 | 1 264 | 9.0* | 9.7 | | | | | | | |
| | Y' ... | 831 | 1 230 | 14.3[3] | 0.7 | | | | | | | |
| | SF1 .. | 430 | 379 | 0.2[2] | 1.8 | | | | | | | |
| C | $C_1$ ... | 787 | 1 155 | 67.1[3] | 51.9 | 54.9 | 41.3[2] | 67.2[1] | 92.6[2] | 74.4 | 66.1 | 69 |
| | $C_2$ ... | 859 | 1 293 | 75.3[3] | 61.9 | 13.4[3] | 8.4[3] | 8.0[3] | 1.1[3] | | | |
| | E .... | 861 | 1 294 | 56.0 | 60.0 | | | | | 91.5[3] | 63.1[1] | 56 |
| | $R_1$ ... | 611 | 973 | 0.0 | 0.0 | 0.0 | 0.0 | 31.6[3] | 0.0 | 0.0 | 0.2 | 2 |
| | $R_2$ ... | 743 | 1 277 | 46.2[3] | 76.1 | | | | | | | 21[3] |
| | W ... | 861 | 1 299 | 41.7[3] | 60.0 | 61.2 | 88.3[3] | 63.8 | 78.7[3] | 50.5[2] | 61.2[3] | 54[3] |
| | $X_1$ ... | 801 | 1 190 | 3.6 | 3.0 | 18.5[3] | 0.5[3] | 8.6[3] | 2.1 | 0.2[3] | 6.5[2] | 7[2] |
| | $X_2$ ... | 857 | 1 297 | 32.3[3] | 62.8 | 6.9[3] | 18.1[3] | 33.3[3] | 10.6[3] | 39.6[2] | 30.7 | 23[3] |
| | $X_3$ ... | 580 | 858 | 35.2[3] | 62.8 | | | | | | | |
| | L' ... | 856 | 1 283 | 28.0[3] | 1.5 | | | | | 34.4[1] | 11.6[3] | 16[3] |

3 = significance of difference 99.9 % *eron merkitsevyys* (Finncattle, SAB, SRB, SLB compared to Finnish Ayrsh.) *(Sk. SAB, SRB, SLB verrattuna suomalaiseen ayrshireen)*

2 = significance of difference 99 % *eron merkitsevyys*

1 = significance of difference 95 % *eron merkitsevyys* (SKB, T, D, SV compared to Finncattle) *(SKB, T, D, SV verrattuna Suomen karjaan)*

* = significant ($P < 0.05$) differences between birth year groups within breed *merkitseviä eroja ($P < 0.05$) syntymävuosiluokkien välillä rodun sisällä*

(1) RENDEL (1958), (2) BRAEND (1959), (3) BRAEND *et al.* (1964)

Table 2. (cont.)
*Taulukko 2. (jatkoa)*

| System *Järjestelmä* | Factor *Tekijä* | No. of animals *Eläinten luku* | | Frequency of positively reacting animals, % *Positiivisesti reagoineitten eläinten tiheys, %* | | | | | | | | |
|---|---|---|---|---|---|---|---|---|---|---|---|---|
| | | Finncattle | Finn. Ayrsh. | Finncattle | Finn. Ayrsh. | Swedish breeds (1) *Ruotsin rotuja* | | | | Norwegian (1 & 3) *Norjan rotuja* | | |
| | | *Sk* ♂ | *Ay* ♂ | *Sk* ♂ | *Ay* ♂ | SAB ♂ | SRB ♂ | SLB ♂ | SKB ♂ | T ♂ ♀ | D ♂ ♀ | SV ♂ ♀ |
| FV | F .... | 861 | 1 299 | 95.8 | 96.2 | 98.2 | 94.1 | 99.4 | 96.8 | 100.0 | 99.6 | 97.7 |
| | V .... | 861 | 1 299 | 34.4 | 34.1 | 25.1[2] | 40.9[1] | 9.0[3] | 33.8 | 3.3[3] | 14.6[3] | 27.5[2] |
| J | J .... | 861 | 1 299 | 41.2 | 54.1 | 65.4[1] | 30.2[3] | 21.8[3] | 14.9[3] | 30.0[3] | 41.2 | 35.0[1] |
| L | L .... | 860 | 1 299 | 42.7[3] | 58.7 | 47.5[1] | 11.4[3] | 43.7[1] | 19.1[3] | 67.1[3] | 30.4[3] | 57.6[3] |
| M | M ... | 842 | 1 267 | 6.3[3] | 0.0 | 3.0[3] | 19.2[3] | 2.9[3] | 1.1[1] | | | 0.0[3] |
| SU | $S_1$ .... | 859 | 1 297 | 19.9[3] | 1.8 | | | | | 45.5[3] | 38.3[3] | 41[3] |
| | $S_2$ .... | 859 | 1 298 | 63.9[3] | 79.3 | 79.1 | 76.2 | 85.6 | 88.3[2] | 27.5[3] | 33.0[3] | 48[3] |
| | $U_1$ ... | 834 | 1 272 | 0.1 | 0.1 | | | | | | | 2[3] |
| | U' ... | 861 | 1 297 | 6.7[3] | 0.2 | | | | | 24.6[3] | 5.3 | 0.4[3] |
| Z | Z .... | 861 | 1 298 | 56.4[3] | 26.9 | 41.4[3] | 44.0[3] | 45.5[3] | 37.2[1] | 75.2[3] | 52.8 | 54.1 |
| | Z/Z .. | 440 | 932 | 12.3[3] | 2.4 | | 5.7[3] | | | 22.6[3] | 8.8 | 11.0 |
| R'S' | R' ... | 127 | 43 | 9.4[1] | 25.6 | | | | | | | |
| SF3 | SF3 .. | 418 | 408 | 15.1[2] | 24.5 | | | | | | | |
| No. of animals *Eläinten luku* | | | | | | 335 | 630 | 174 | 94 | 1 000 | 1 000 | 1 075 |

The Finnish breeds deviate significantly from each other with regard to the frequencies of animals positive to 48 different reagents, that is about 83 % of the reagents used. The Finncattle breed showed the higher frequency in 28 cases and the Ayrshire stock in 20 cases. The latter entirely or almost entirely lacks the factors $D_4$, $I_{1-2}$, B', Y', M and U', which occur in the Finncattle with reasonable frequency. The situation is almost the same with regard to factors K, L' and $S_1$, while the reverse is the case with regard to factors Q, J', K', and SF1. In general, it can be observed that there are more extreme frequencies in the Ayrshire column than in the Finncattle column. Accordingly, the standard deviation of the Ayrshire frequencies was 29.0 %, whereas the corresponding figure for Finncattle was 22.3 %. Thus, more antigenic factors seem to have disappeared from the Ayrshire cattle than from the Finncattle.

There are also significant differences between the other Scandinavian native breeds (SKB, T, D and SV) on the one hand and Finncattle on the other. The same applies to the comparisons between the Finnish Ayrshire and the »international» Swedish breeds (SAB, SRB and SLB). It is curious to observe that within the SRB breed the Swedish Ayrshire line (SAB) deviates almost as much as the main line of SRB or the SLB breed from the Finnish Ayrshire.

## Test for genetic equilibrium

For many reasons, accurate breed comparisons are difficult on the basis of the phenotypic factor frequencies, and hence it is important to strive for genetic frequencies. Because most methods of gene frequency estimation depend on the existence of genetic equilibrium, the results of tests for genetic equilibrium in the FV system of both Finnish breeds are presented in Table 3.

Table 3. Tests for genetic equilibrium in the FV system of Ayrshire and Finncattle bulls.
*Taulukko 3. FV- järjestelmän perinnöllisen tasapainon testaus ay- ja sk-sonneilla.*

| Birth year *Synt. vuosi* | Degr. fr. *Vap. ast.* | Numbers of bulls in different genotype classes — *Sonnien luku eri genotyyppiluokissa* | | | | | | | | | | | | | |
|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|
| | | Ayrshire | | | | | | | Finncattle — *Suomenkarja* | | | | | | |
| | | F/F | | F/V | | V/V | | | F/F | | F/V | | V/V | | |
| | | Obs. *Hav.* | Exp. *Odot.* | Obs. *Hav.* | Exp. *Odot.* | Obs. *Hav.* | Exp. *Odot.* | $\chi^2$ | Obs. *Hav.* | Exp. *Odot.* | Obs. *Hav.* | Exp. *Odot.* | Obs. *Hav.* | Exp. *Odot.* | $\chi^2$ |
| —1949 | 1 | 66 | 63.38 | 24 | 29.25 | 6 | 3.38 | 3.09 | 36 | 36.00 | 17 | 16.99 | 2 | 2.00 | 0.00 |
| 50—54 | 1 | 111 | 112.32 | 56 | 53.35 | 5 | 6.33 | 0.43 | 36 | 57.40 | 38 | 35.21 | 4 | 5.40 | 0.62 |
| 55—59 | 1 | 350 | 347.69 | 169 | 173.63 | 24 | 21.67 | 0.39 | 130 | 129.49 | 57 | 58.01 | 7 | 6.50 | 0.06 |
| 1960— | 1 | 283 | 284.28 | 116 | 113.41 | 10 | 11.31 | 0.22 | 124 | 121.28 | 58 | 63.43 | 11 | 8.29 | 1.41 |
| Total *Yhteensä* | 4 | 810 | 807.37 | 365 | 370.19 | 45 | 42.43 | 4.13 | 346 | 343.96 | 170 | 174.03 | 24 | 22.01 | 2.09 |
| Pooled $\chi^2$ (1 d.f.) *Yhdist.* | | | | | | | | 0.24 | | | | | | | 0.28 |
| Heterogeneity $\chi^2$ (3 d.f.) *Heterogeenisuus* | | | | | | | | 3.89 | | | | | | | 1.80 |

As can be seen, there were no significant deviations from the equilibrium in any of the birth year groups, although there were more homozygous bulls than expected in the oldest Ayrshire group ($P < 0.1$). The heterogeneity of the chi-squares was also nonsignificant. The existence of genetic equilibrium can thus be assumed in estimating the gene frequencies.

## Gene frequencies

The gene frequency estimates concerning the systems A, FV, J, L, M, SU, Z and SF3 are presented in Table 4. For comparison, the corresponding frequencies from other Scandinavian breeds are included in the table. These have partly been derived from the factor frequencies of simple systems presented by the respective authors.

In agreement with Table 2, there are also significant differences between the two Finnish breeds with regard to the gene frequencies in most of the systems except the FV system. Similarly, there are considerable differences between the Finnish Ayrshire and the »international» Scandinavian breeds, and between the Finncattle and other Scandinavian native breeds. The frequency of the gene determining the reactions of the A factor is higher in the Finnish Ayrshire than in the other breeds, excepting the Danish Jersey. Even the Swedish Ayrshire (SAB) deviates essentially from the Finnish Ayrshire.

In the FV system the differences are smaller in magnitude; only the Danish Jersey differs more clearly from the general level. In the J system the highest frequencies of the positive allele were found in the Swedish and Finnish Ayrshires, while the lowest figures occurred on the Danish Friesian (SDM) and Swedish Polled (SKB). Corresponding extremes in the L system are represented by the Norwegian Telemark and Finnish Ayrshire on the one hand and the Danish Red and Swedish Red & White on the other.

The frequency of the gene M in the M system is fairly low in all the breeds considered. The highest figures occur on the Red Danish and the Swedish Red & White, while the Finnish Ayrshire and the Norwegian breeds SV and ST lack it entirely. It does not occur in the Icelandic cattle either (BRAEND *et al.* 1962).

Table 4. Frequencies of alleles of the systems A, FV, J, L, M, SU, Z and SF3 in bull samples of some Scandinavian breeds.

*Taulukko 4. Veriryhmäjärjestelmiin A, FV, J, L, M, SU, Z ja SF3 kuuluvien alleelien tiheyksiä eräiden pohjoismaisten rotujen sonninäytteissä.*

| System *Järjestelmä* | Allele *Alleeli* | Frequency of the gene in different breeds, % — *Perintötekijäin tiheys eri roduissa*, % | | | | | | | | | | | |
|---|---|---|---|---|---|---|---|---|---|---|---|---|---|
| | | Finland — *Suomi* | | Denmark — *Tanska* (1) | | | Sweden — *Ruotsi* (2) | | | | Norway — *Norja* (3 and 4) | | | |
| | | Ay | Finn. *sk* | RDM | Jersey | SDM | SRB | SLB | SKB | SAB | T | D | SV | ST |
| A | A .... | 66.2 | 37.2 | 23.8 | 100.0 | 22.1 | 42.1 | 38.4 | 24.2 | 25.1 | 19.6 | 24.3 | 16.9 | 8.4 |
| | a .... | 33.8 | 62.8 | 76.2 | 0.0 | 77.9 | 57.9 | 61.6 | 75.8 | 74.9 | 80.4 | 75.7 | 83.1 | 91.6 |
| FV | F .... | 81.4 | 79.8 | 96.4 | 56.5 | 84.8 | 76.8 | 95.4 | 81.4 | 86.6 | 98.4 | 92.5 | 85.1 | 97.1 |
| | V .... | 18.6 | 20.2 | 3.6 | 43.5 | 15.2 | 23.2 | 4.6 | 18.6 | 13.4 | 1.6 | 7.5 | 14.9 | 2.9 |
| J | J .... | 32.2 | 23.3 | 10.8 | 32.0 | 8.2 | 16.4 | 11.6 | 7.8 | 41.2 | 16.3 | 23.3 | 19.4 | 10.0 |
| | j ..... | 67.8 | 76.7 | 89.2 | 68.0 | 91.8 | 83.6 | 88.4 | 92.2 | 58.8 | 83.7 | 76.7 | 80.6 | 90.0 |
| L | L .... | 35.7 | 24.3 | 2.7 | 28.0 | 28.1 | 5.9 | 25.0 | 10.1 | 27.5 | 42.6 | 16.6 | 34.9 | 30.1 |
| | l ..... | 64.3 | 75.7 | 97.3 | 72.0 | 71.9 | 94.1 | 75.0 | 89.9 | 72.5 | 57.4 | 83.4 | 65.1 | 69.9 |
| M | M ... | 0.0 | 3.2 | 20.6 | | | 10.1 | 1.5 | 0.5 | 1.5 | 0.0 | 0.0 | 0.0 | 0.0 |
| | m .... | 100.0 | 96.8 | 79.4 | | | 89.9 | 98.5 | 99.5 | 98.5 | 100 | 100 | 100 | 100 |
| SU | $S_1$ .... | 0.7 | | | | | | | | | | | | |
| | $S_1U'$ . | 0.2 | | | | | | | | | | | | |
| | $S_2$ .... | 47.3 | | (43.7) | (59.2) | (89.4) | (51.2) | (62.1) | (65.8) | (54.3) | | | | |
| | U' ... | 0.1 | | | | | | | | | | | | |
| | s ..... | 51.7 | | (56.3) | (40.8) | (10.6) | (48.8) | (37.9) | (34.2) | (45.7) | (60.4) | (76.9) | (33.2) | (44.7) |
| Z | Z .... | 14.5 | 34.0 | 15.0 | 46.3 | 7.9 | 24.8 | 26.2 | 20.7 | 23.4 | 48.9 | 30.8 | 30.3 | 23.1 |
| | z .... | 85.5 | 66.0 | 85.0 | 53.7 | 92.1 | 75.2 | 73.8 | 79.3 | 76.6 | 51.1 | 69.2 | 69.7 | 76.9 |
| SF3 | SF3 .. | 13.1 | 7.9 | | | | | | | | | | | |
| | sf3 ... | 86.9 | 92.1 | | | | | | | | | | | |
| No. of bulls *Sonnien lukum.* | | 1 300 | 861 | 793 | 54 | 89 | 630 | 174 | 94 | 335 | 1 000* | 1 000* | 847* | 935* |

* = the samples were not limited to bulls — *näytteet eivät rajoittuneet vain sonneihin*

(1) NEIMANN-SØRENSEN (1958) (2) RENDEL (1958) (3) BRAEND (1959) (4) BRAEND *et al.* (1964)

Bold face type = Finncattle, Danish breeds, SRB, SLB and SAB significantly different from Finnish Ayrshire

*Lihavat numerot = Suomenkarja, Tanskan rodut, SRB, SLB, ja SAB merkitsevästi suomalaisesta ayrshiresta poikkeavia.*

= SKB and Norwegian breeds significantly different from Finncattle

= *SKB ja Norjan rodut merkitsevästi suomenkarjasta poikkeavia.*

The bracketsi ndicate that the figures are not fully comparable to the frequencies of the SU system in the Finnish Ayrshire cattle.

*Suluissa olevat luvut eivät ole täysin vertailukelpoisia Suomen ayrshirekarjan SU-järjestelmän vastaaviin tiheyksiin.*

In the SU system comparisons are difficult, because the factor $S_2$, previously called H', was treated as a separate system by NEIMANN—SØRENSEN (1958) and RENDEL (1958). It can be seen, however, that in the Finnish Ayrshire breed the predominant alleles are $S_2$ and s, with about equal frequencies. In the Danish and Swedish studies H' and h' similarly had about equal frequencies in most of the breeds. Comparable information is available for the Icelandic cattle, in which the allele $S_1$ is more frequent and the allele s rarer than in the Finnish Ayrshire (BRAEND *et al.* 1962).

The Danish Jersey and Norwegian Telemark showed the highest frequency of the Z gene, while the other Danish breeds and Finnish Ayrshire had low figures. The new factor SF3 had a higher frequency in the Finnish Ayrshires than in Finncattle.

The gene frequencies in the B system of the Finnish breeds are presented in Table 5.

Table 5. Estimates of the frequencies of alleles in the B system in bull samples of Finnish cattle breeds.
*Taulukko 5. B -veriryhmäjärjestelmän perintötekijöitten tiheysarvioita Suomen karjarotujen sonninäytteissä.*

| Code No. *N:o* | Allele *Perintötekijä* / Phenogroup *Veriryhmä* | Relative frequency, % — *Tiheys, %* | | | |
|---|---|---|---|---|---|
| | | Ayrshire | | Finncattle — *Sk* | |
| | | I | II | I | II |
| 1 | b | 1.79 | 2.02 | 13.24 | 13.89 |
| 2 | B | | | 0.95 | 0.26 |
| 3 | $BGKY_2E'_2O'$ | 0.16 | 0.15 | 0.27 | 0.45 |
| 4 | $BGKE'_2$ | | | 3.38 | 3.88 |
| 5 | $BGKE'_2O'$ | 0.87 | 0.63 | 1.76 | 1.36 |
| 6 | $BGO_1$ | 0.60 | 0.46 | 1.08 | 1.13 |
| 8 | $BGO_1Y_2E'_3G'$ | 2.60 | 2.52 | 0.14 | 0.12 |
| 9 | BIQJ'O' | | | 0.27 | 0.23 |
| 10 | $BO_1Y_2D'$ | 6.99 | 6.05 | 1.62 | 2.00 |
| 12 | $BO_1A'E'_3$ | 0.11 | 0.04 | | |
| 17 | $BY_1A'_2E'_3G'$ | 0.43 | 0.34 | 0.14 | 0.15 |
| 18 | $BD'_2J'O'$ | 0.16 | 0.16 | | |
| 20 | $BA'D'_2$ | 0.05 | 0.04 | 1.89 | 1.57 |
| 21 | $BGKY_2A'E'_3O'Y'G'$ | | | 1.08 | 1.24 |
| 22 | BGKA' | | | 2.03 | 1.99 |
| 23 | $BGKA'E'_3O'$ | | | 0.14 | |
| 24 | BGKA'O' | | | | 0.33 |
| 25 | BI | | | 2.97 | 3.02 |
| 28 | BOA' | | | 0.54 | 0.56 |
| 30 | BP | | | 1.76 | 0.44 |
| 31 | $BPY_1Y'$ | | | 0.14 | 0.12 |
| 32 | $BPY_2Y'$ | | | 0.81 | 0.12 |
| 33 | $BY_1D'_2Y'$ | | | 0.54 | 0.45 |
| 37 | BIQ | | | 0.14 | 0.12 |
| 38 | $BGKY_2E'_2$ | | | 0.14 | 0.12 |
| 39 | $BY_1$ | | | 0.14 | 0.12 |
| 40 | $BD4I_2D'_2$ | | | | 0.12 |
| 41 | $BI_2$ | | | | 0.12 |
| 47 | $GO_1$ | | | 1.22 | 1.21 |
| 48 | $GO_1T_2D'G'SF1$ | 0.60 | 0.45 | 0.14 | 0.12 |
| 49 | $GO_1Y_2$ | 0.27 | 0.30 | 7.16 | 8.18 |
| 50 | $GY_2E'_1$ | 4.39 | 3.11 | 0.41 | 0.44 |
| 51 | GI'O' | 0.76 | 0.56 | | |
| 52 | GO' | 0.27 | 0.27 | | |
| 55 | $GY_2E'_3$ | | | 0.14 | 0.12 |
| 56 | $GY_2O'$ | | | 0.68 | 0.79 |
| 58 | $GE'_2$ | | | 0.14 | |
| 63 | I | | | 0.95 | 0.46 |
| 65 | $I_2$ | | | 1.76 | 1.54 |
| 66 | $I_2Y_2E'_1Y'$ | | | 0.27 | 0.23 |
| 68 | $O_1$ | 22.43 | 31.10 | 1.62 | 1.66 |
| 70 | $O_1TY_2E'_3K'$ | 0.22 | 0.30 | 0.54 | 0.44 |
| 71 | $O_1Y_1$ | | 0.02 | 0.14 | |
| 72 | $O_1Y_1E'_3$ | 0.05 | 0.04 | 0.27 | 0.23 |
| 73 | $O_1Y^2$ | 0.38 | 0.36 | 0.41 | 0.48 |
| 74 | $O_1Y_2D'$ | | | 1.08 | 1.32 |
| 76 | $O_1A'$ | 13.11 | 15.52 | 1.62 | 1.56 |
| 78 | $O_1E'_1G'$ | | | 1.76 | 1.22 |
| 79 | $O_1YE'_3I'$ | | 0.04 | | |
| 80 | $O_1T_1E'_3K'$ | | | 0.14 | 0.12 |
| 84 | $O_1E'_3G'$ | | | 0.14 | 0.12 |
| 85 | $O_1J'K'$ | | | 0.14 | 0.12 |
| 86 | $O_2QJ'K'O'$ | 1.68 | 1.40 | 0.27 | |
| 87 | $O_2QK'O'$ | 1.57 | 1.15 | | |
| 88 | $O_2J'K'O'$ | | | 0.14 | 0.23 |
| 89 | $O_1A'E'_1$ | | 0.04 | | 0.12 |
| 90 | $O_2E'_2$ | | | | 0.12 |

Table 5. (cont.)
*Taulukko 5 (jatkoa)*

| Code No. *N:o* | Allele / Phenogroup *Perintötekijä / Veriryhmä* | Relative frequency, % — *Tiheys, %* | | | |
|---|---|---|---|---|---|
| | | Ayrshire | | Finncattle — *Sk* | |
| | | I | II | I | II |
| 94 | P | | | 0.14 | |
| 95 | PI' | 12.03 | 8.96 | 1.08 | 1.01 |
| 96 | $PY_1$ | 0.05 | 0.04 | | |
| 97 | $PY_2$ | | | 0.14 | |
| 101 | QA' | 1.30 | 1.10 | 0.27 | 0.12 |
| 102 | $QE'_3$ | 4.39 | 3.88 | | |
| 103 | QJ'K'O' | 0.05 | 0.04 | | |
| 111 | $TYA'E'_3G'$ | | 0.04 | | |
| 113 | TI' | | | 0.14 | 0.12 |
| 114 | $T_1B'$ | | | 0.14 | 0.12 |
| 115 | $Y_1$ | | 0.02 | 0.41 | 0.41 |
| 116 | $Y_1A'Y'$ | | | 0.27 | 0.23 |
| 117 | $Y_1E'_1Y'$ | 0.05 | 0.04 | 0.41 | 0.33 |
| 118 | $Y_1E'_3G'$ | | | 0.27 | 0.57 |
| 119 | $Y_1E'_3G'I'$ | 0.22 | 0.15 | | |
| 120 | $Y_1E'_3G'Y'$ | 0.27 | 0.23 | 1.08 | 1.23 |
| 122 | $Y_1A'E_3G'$ | | | 0.27 | 0.23 |
| 123 | $Y_1I'Y'$ | | | 0.41 | 0.23 |
| 125 | $Y_2$ | 0.22 | 0.17 | 1.22 | 1.45 |
| 126 | $Y_2A'$ | 0.65 | 0.45 | 1.76 | 2.81 |
| 128 | $Y_2E'_3$ | | | 0.14 | 0.12 |
| 129 | $Y_2D'G'$ | | | 9.73 | 10.63 |
| 131 | $Y_2I'$ | | | 0.14 | 0.12 |
| 132 | $Y_2I'Y'$ | | | 0.27 | 0.33 |
| 134 | $Y_2A'D'$ | | | | 0.12 |
| 138 | $A'_1$ | 1.19 | 1.24 | 11.76 | 13.91 |
| 141 | $A'_1O'$ | | | 0.14 | 0.12 |
| 142 | $A'_1E'_3$ | | | 0.27 | 0.12 |
| 143 | $A'_1E'_1I'$ | | | 0.14 | 0.12 |
| 144 | $A'_2$ | | | | 0.33 |
| 148 | $A'_2E'_3$ | 0.22 | 0.30 | | |
| 149 | $A'_2D'$ | 0.05 | | 0.14 | 0.12 |
| 153 | $B'D'E'_3G'$ | | | 0.95 | 0.79 |
| 155 | $D'E'_3$ | | | 0.41 | 0.33 |
| 157 | $E'_1$ | 0.05 | 0.04 | 5.14 | 5.24 |
| 158 | $E'_1G'I'$ | | | 0.41 | 0.44 |
| 169 | $E'_3$ | 18.14 | 15.07 | 3.11 | 3.18 |
| 170 | $E'_3I'$ | 0.16 | 0.11 | | |
| 171 | $E'_3O'$ | 0.11 | 0.07 | 0.14 | |
| 172 | $E'_3G'I'$ | | 0.04 | | |
| 178 | I' | 1.30 | 0.99 | 2.03 | 0.23 |
| 179 | I'Y' | 0.05 | | 0.14 | |
| 180 | Y' | | | 0.68 | 0.24 |
| | Total — *Yhteensä* | 99.99 | 100.01 | 100.20 | 100.09 |
| | No. of bulls — *Sonnien luku* | 923 | 1 237 | 370 | 444 |

I= Simple gene count based on bulls with 2 determinable alleles
*Yksinkertainen geenilaskenta, perustuen sonneihin, joilla molemmat geenit tunnettavissa*

II = BRAEND's square root method
BRAEND*'in neliöjuurimenetelmä*

Finncattle I: All three types of Finncattle included
*Mukana suomenkarjan kaikkia kolmea tyyppiä*

Finncattle II: Only bulls of the West-Finnish type included
*Mukana vain länsisuomalaisen tyypin sonneja*

Table 6. The 10 most frequent alleles of the B system in bull samples of Finnish Ayrshire and Finncattle (West-Finnish type) and their frequencies in some other Scandinavian breeds.

*Taulukko 6. Ay -karjan ja suomenkarjan (LSK) sonninäytteiden 10 yleisintä B-järjestelmän perintötekijää ja niiden tiheydet eräissä muissa pohjoismaisissa roduissa.*

| B allele *E-järjestelmän perintötekijä* | Frequency in different Scandinavian breeds, % — *Tiheys pohjoismaiden eri roduissa*, % | | | | | | | | | |
|---|---|---|---|---|---|---|---|---|---|---|
| | Finnish Ayrshire *Suomal. ay.* | Finn-cattle *Suomenk.* | Swedish breeds (1) *Ruotsin rotuja* | | | Danish breeds (2) *Tanskan rotuja* | | | Norwegian (3) *Norjan rotuja* | |
| | | | SKB | SRB | SLB | RDM | SDM | Jersey | SV | ST |
| | ♂ | ♂ | ♂ | ♂ | ♂ | ♂ | ♂ | ♂ | ♂+♀ | ♂+♀ |
| $O_1$ | **31.10** | 1.66 | **5.02** | 0.42 | — | 0.2 | — | 0.9 | **3.5** | 1.3 |
| $O_1A'$ | **15.52** | 1.56 | **10.24** | 1.58 | — | — | 0.4 | — | 0.2 | **2.0** |
| $E'_3$ | **15.07** | **3.18** | **12.05** | — | — | — | **4.0** | — | 0.9 | — |
| PI' | **8.96** | 1.01 | — | 0.08 | 0.43 | — | **2.6** | 0.9 | — | 0.2 |
| $BO_1Y_2D'$ | 6.05 | **2.00** | — | **9.06** | **4.32** | — | 1.7 | — | 0.3 | 0.5 |
| $QE'_3$ | **3.88** | — | — | — | — | 0.8 | — | **4.8** | — | — |
| $GY_2E'_1$ | **3.11** | 0.44 | — | 2.65 | **16.12** | — | **12.3** | — | **16.7** | — |
| $BGO_1Y_2E'_3G'$ | 2.52 | 0.12 | — | — | — | — | — | — | — | — |
| b | 2.02 | **13.89** | **11.66** | **34.19** | **29.51** | **10.1** | **27.8** | — | **14.4** | **27.2** |
| $O_2QJ'K'O'$ | 1.40 | — | — | 2.32 | — | — | — | — | — | 0.5 |
| A' | 1.24 | **13.91** | — | — | — | — | — | — | — | — |
| $Y_2D'G'$ | — | **10.63** | — | — | — | — | — | — | — | — |
| $GO_1Y_2$ | 0.30 | **8.18** | — | — | — | — | 1.3 | — | — | — |
| $E'_1$ | 0.04 | **5.24** | — | — | 1.08 | — | 1.1 | **8.7** | 0.6 | 1.3 |
| $BGKE'_2$ | — | **3.88** | — | — | — | — | — | — | — | — |
| BI | — | **3.02** | 1.06 | — | 1.74 | — | — | — | — | — |
| $Y_2A'$ | 0.45 | **2.81** | — | 1.50 | — | — | — | — | — | — |
| No.of animals — *Eläinten luku* | 1 237 | 444 | 94 | 630 | 174 | 885 | 140 | 62 | 847 | 935 |

Bold face type: the allele belongs to the 10 most frequent B alleles of the breed
*Lihavat numerot: k.o. perintötekijä kuuluu rodun 10 yleisimmän B -tekijän joukkoon*

1) RENDEL (1958), 2) NEIMANN-SØRENSEN (1958), 3) BRAEND *et al.* (1964)

There are some differences between the two series of estimates concerning Ayrshire bulls. The inclusion in the second series of bulls with only one determinable allele increases the estimates of those alleles (e.g. $O_1$, $O_1A'$ and b), which are easily covered by themselves or by other phenogroups, while the frequencies of some other alleles (e.g. $GY_2E'_1$, PI', $QE'_3$ and $E'_3$) decreases. Some differences are caused by the fact that the interpretation of some alleles has changed since the first estimate was made. In any case, the correlation between the two series of estimates is as high as 0.973, as determined by the formula previously shown.

Since the corresponding correlation between the two series concerning Finncattle was 0.992, in spite of the differences in the composition of the two samples in question, it can be concluded that the gene-counting method can safely be used for obtaining approximative estimates of the frequencies of alleles in the B system. Its usefulness seems to improve the greater the number of different B alleles there are in the breed to be studied. For there were more than 80 different alleles in the Finncattle breed, but only 47 phenogroups in the Ayrshire sample.

In order to facilitate comparisons between breeds, the 10 most frequent B alleles of each of the Finnish breeds studied are presented, along with the frequency estimates of the same alleles in some other Scandinavian breeds in Table 6.

Considerable differences are to be seen between the breeds. Many of the 10 most frequent alleles of the Finnish breeds were not encountered at all in the samples of the other Scandinavian breeds. Only 3 of the 10 most frequent Ayrshire alleles were represented among those of Finncattle. The allele $Y_2D'G'$ can be considered an exceptionally characteristic allele of Finncattle, since it has not been found in

Table 7. The distribution of the 11 most frequent B alleles and that of FV alleles of Finnish Ayrshire cattle in different lines of breeding.

*Taulukko 7. Suomen ayrshirekarjan 11 yleisimmän B -tekijän sekä FV-tekijöiden jakautuminen rodun eri ryhmissä.*

| Allele *Tekijä* | Frequency in different lines of bulls (%) *Tiheys eri sonniryhmissä, %* | | | |
|---|---|---|---|---|
| | A | B | C | D |
| $O_1$ | 27.36 | 19.95 | 24.87 | 20.94 |
| $E'_3$ | 8.78 | 19.48 | 13.59 | 26.23 |
| $O_1A'$ | 10.81 | 9.62 | 13.33 | 11.70 |
| PI' | 11.82 | 15.96 | 12.05 | 9.81 |
| $BO_1Y_2D'$ | 7.77 | 4.46 | 9.23 | 7.36 |
| $GY_2E'_1$ | 3.04 | 2.82 | 3.85 | 7.74 |
| $QE'_3$ | 2.70 | 10.09 | 2.05 | 2.83 |
| $BGO_1Y^2E'_3G'$ | 5.07 | 0.94 | 5.38 | 0.38 |
| — (b) | 1.69 | 0.94 | 3.33 | 1.13 |
| $O_2QJ'K'O'$ | 7.43 | 0.47 | 1.03 | 0.57 |
| $O_2QK'O'$ | 8.11 | — | 0.51 | 0.38 |
| F | 86.25 | 82.29 | 86.41 | 72.19 |
| No. of bulls — *Sonnien luku* | 200 | 240 | 320 | 347 |

other breeds, in spite of its high frequency in Finncattle.

There is a striking difference between Finncattle and the Swedish Polled breed (SKB), although these breeds are believed to have originated from the same Scandinavian native cattle. In fact, the Swedish Polled cattle have more alleles in common with Ayrshire than with Finncattle. However, there are traces of the most frequent Ayrshire alleles in Finncattle and vice versa, which is apparently due to the fact that there has been some crossing between these breeds, followed by up-grading in both directions.

When the Finnish Ayrshire bulls were divided into four groups according to their line of breeding, the frequencies of the commonest alleles proved to vary according to the line, as can be seen from Table 7, which is based on bulls with two determinable B alleles.

The grouping of the breeding material was done in 1961—62 on the basis of relationships in the breed, in order to avoid unnecessary inbreeding by a rotational crossbreeding between groups within the breed. It appears from the table that the line A is best characterized by the alleles $O_2QJ'K'O'$ and $O_2QK'O'$, while the allele $QE'_3$ is fairly typical of the line B. The frequency of the allele $E'_3$ is highest in line D, but it is fairly frequent in the other lines as well. This is simply because the Scotch bull South Craig Snowball AAA 3 399 and his son Öfverby Smörboll AAA 5 400 — the progenitors of the D-line — were the individuals overwhelmingly most related to the whole breed at the time of grouping. One of them obviously happened to have the V gene of the FV system, as revealed by the lower frequency of the F gene in the D-line (bottom of Table 7). In fact, when 783 bulls were sorted according to their coefficient of relationship to Öfverby Smörboll, the frequency of the V gene varied as follows:

| Relationship to Smörboll, % | 0— 4 | 5—19 | 20— |
|---|---|---|---|
| Frequency of V gene, (%): | 13.95 | 19.41 | 28.49 |

With regard to the relationship to Snowball the corresponding figures were 16.67 %, 18.06 % and 20.72 %.

## Measurement of the genetic relationship between breeds and lines

Although the frequencies of the various blood group genes give some idea of the relations between different breeds, it is desirable to express the relationship between any two breeds with

Table 8. Correlations of blood group gene frequencies among some Scandinavian and Dutch cattle breeds.
*Taulukko 8. Pohjoismaisten ja hollantilaisten karjarotujen veriryhmägeenitiheyksien välisiä vuorosuhteita.*

| Breeds compared *Vertailtavat rodut* | | Data from *Tietojen alkuperä* | *Vuorosuhde eri järjestelmissä* Correlation in different systems | | |
|---|---|---|---|---|---|
| | | | I | II | III |
| 1. | 2. | | % | | |
| Finnish — *Suomen* Ayrshire | × Finncattle — *Suomen karja* .... | This report — *Tämä tutkimus* | 78.1 | 19.2 | 15.0 |
| Swedish — *Ruotsin* Ayrshire (SAB) | × Red & White (SRB) — *punakirjava* ..... | RENDEL (1958) | 82.1 | 70.9 | 58.2 |
| » | × Friesian (SLB) — *mustankirjava* | » » | 85.6 | 66.2 | 56.7 |
| » | × Polled (SKB) — *nupokarja* ..... | » » | 83.2 | 32.9 | 27.4 |
| Red & White (SRB) *Punakirjava* | × Friesian (SLB) — *mustankirjava* ..... | » » | 92.8 | 79.1 | 73.4 |
| Red & White (SRB) *Punakirjava* | × Polled (SKB) — *nupokarja* ..... | » » | 93.3 | 25.6 | 23.9 |
| Friesian (SLB) *Mustankirjava* | × Polled (SKB) — *nupokarja* ..... | » » | 92.9 | 27.7 | 25.7 |
| Danish — *Tanskan* Red (RDM) *Punainen* | × Friesian (SDM) — *mustankirjava* ..... | NEIMANN—SØRENSEN (1958) | 91.0 | 20.5 | 18.7 |
| Red (RDM) *Punainen* | × Jersey — *jersey* ..... | » » | 18.1 | 1.5 | 0.3 |
| Friesian (SDM) *Mustankirjava* | × Jersey — *jersey* ..... | » » | 17.8 | 0.9 | 0.2 |
| Norwegian — *Norjan* Telemark (T) | × Døla (D) ..... | BRAEND (1959) | 84.3 | 55.2 | 46.5 |
| South & West (SV) | × Trønder (ST) ..... | BRAEND et al. (1964) | 96.6 | 38.7 | 37.4 |
| Dutch — *Hollannin* Friesian (F.H.) *Mustankirjava* | × Red & White (M.R.Y.) — *Punakirjava* ..... | BOUW (1960) | 89.6 | 88.6 | 79.4 |
| Friesian (F.H.) *Mustankirjava* | × Red & White (M.R.Y.) — *Punakirjava* ..... | KRAAY & BOUW (1964) | 82.9 | | |
| Friesian (F.H.) *Mustankirjava* | × White Faced (G.B.) — *Groningen karja* ..... | » » | 90.6 | | |
| Red & White *Punakirjava* | × White Faced (G.B.) — *Groningen karja* ..... | » » | 93.2 | | |

I = A, FV, J, L, M and Z systems; II = B system; III = I and II combined
*I = A-, FV-, J-, L-, M- ja Z-järjestelmät; II = B-järjestelmä; III = I ja II yhdistetty*

a single value. The number of different B alleles common to the breeds has been used for this purpose (STORMONT *et al.* 1951), but because of the great variation in the frequencies of the shared alleles, this method does not permit accurate comparisons. In the present study, an attempt has been made to compute a correlation coefficient showing the proportion of alleles of each blood group system (locus) that are common to the two breeds compared. This has been done by dividing the sum of products of the allelic frequencies by the geometric mean of the sums of squares of the same allele frequencies within each system. The results concerning different systems were combined by multiplication. Three different correlations were computed for each comparison. The first was based on the non-complicated systems A, FV, J, L, M and Z, in which only two alleles were involved in each. The second correlation was computed on the basis of B allele frequencies and the third was a combination of these two coefficients. For comparison, similar coefficients were computed for some other European breeds. Because of the variations in the collection and specificity of reagents in different laboratories at different

Table 9. Correlations of B allele frequencies between lines of bulls within Finnish Ayrshire and Swedish Friesian.
*Taulukko 9. Suomen ayrshirekarjan ja Ruotsin mustankirjavan karjan sonniryhmien B -geenitiheyksien välisiä vuorosuhteita.*

| Breed and lines<br>*Rotu ja ryhmä* | No. of genes counted<br>*Tutkittujen geenien luku* | Correlation<br>*Vuorosuhde*<br>% | Number of different common alles<br>*Erilaisten yhteisten tekijöiden luku* |
|---|---|---|---|
| Finnish Ayrshire — *Suomen ayrshire* | | | |
| Line A × line B — *Ryhmä A × ryhmä B* | 296+426 | 84.7 | 19/(21 and 30) |
| » A × » C — » *A* × » *C* | 296+390 | 94.2 | 18/(21 and 30) |
| » A × » D — » *A* × » *D* | 296+530 | 82.0 | 18/(21 and 29) |
| Line B × line C — *Ryhmä B × ryhmä C* | 426+390 | 91.6 | 22/(30 and 30) |
| » B × » D — » *B* × » *D* | 426+530 | 93.7 | 23/(30 and 29) |
| Line C × » D — *Ryhmä C × ryhmä D* | 390+530 | 91.6 | 24/(30 and 29) |
| Swedish Friesian (Rendel 1958)<br>*Ruotsin mustan kirjava* | | | |
| Scania line × Halland A | 336+268 | 32.0 | 9/(18 and 15) |
| » » × » B | 336+340 | 58.8 | 12/(18 and 19) |
| » » × » D | 336+264 | 55.4 | 11/(18 and 17) |
| Halland A × Halland B | 268+340 | 36.3 | 10/(15 and 19) |
| Halland A × » B | 268+264 | 33.5 | 10/(15 and 17) |
| Halland B × » D | 340+264 | 80.8 | 14/(19 and 17) |

times, only those comparisons are tabulated in Table 8 where the gene frequencies of the two breeds to be compared have been published by the same author simultaneously.

The figures obtained from the six simple systems are much higher than those relating to the B system. Their ability to distinguish between different degrees of relationship between breeds appears to be questionable. For example in the study of Kraay and Bouw (1964) there was a correlation of 90.6 % between the Black & White Friesian (F.H.) and the White faced Groningen cattle (G.B.), while the correlation between the Black & White and Red & White Friesians (M.R.Y.) was only 82.9 %. It can also be observed that there is a lower correlation between the Ayrshire line of Swedish Red & White cattle and the main line of the same breed than between the Ayrshire line and Swedish Friesian or Swedish Polled breed. Further, the figures concerning the relationship of Swedish Polled cattle to Swedish Red & White and to Swedish Friesian are unreasonably high. On the other hand, the correlation of Danish Jersey to the other Danish breeds is low even on the basis of the six simple systems.

More significance can obviously be attached to the coefficients based on the B allele frequencies. These values agree better with previous knowledge of the history of the breeds. In the Swedish data, for example, the »international» breeds showed higher intercorrelations than their correlations to the native breed. The correlation between Finnish Ayrshire and Finncattle appears to be lower than those of the Swedish native breed (SKB) to the other Swedish breeds, but this difference might be explained by the fact that the frequencies of the Swedish Polled cattle were estimated on a very small sample (94 bulls) and that more reagents have been used in the present study than in the early study of Rendel (1958).

The correlation between Red Danish and Danish Friesian appears to be about the same as that between Finnish Ayrshire and Finncattle, whereas Danish Jersey seems to be very little related to the other Danish breeds. The values concerning Norwegian breeds are on an intermediate level, while the closest relationship occurs between the F. H. and M. R. Y. in Holland.

As a basis of comparison for the correlations between breeds, similar correlations between lines (groups) within two different breeds are presented in Table 9.

The values concerning Finnish Ayrshires are based on the same bulls as in Table 7, but only the bulls having determinable B alleles have been utilized for Table 9. The Swedish figures have

been computed from the data presented by RENDEL (1958).

The line A in the Finnish Ayrshire appeared to differ more from the lines B and D than the black & white Dutch breed from the red & white one. Still more pronounced differences were observed among the lines of Swedish Friesian, for the Halland A line had only $^1/_3$ of its B alleles in common with the other lines. Even the most closely related Swedish Friesian lines (Halland B and D) had a lower intercorrelation than the two Dutch breeds.

The figures in the rightmost column of Table 9 show that the numbers of different phenogroups shared by the breeds are in some agreement with the correlation coefficients, but that the picture given by them is by no means so clear as that given by the latter.

## Homozygosity

Because of the often expressed fear that the concentrated use of a small number of bulls in A.I. would lead to homozygosis too rapidly, some problems connected with zygosity were also investigated on the basis of the blood-typed bull material.

An idea of the general level of actual homozygosity and its trends can be obtained from Table 10, where the average frequencies of homozycous bulls with regard to the alleles of the B system are shown.

In the Ayrshire breed, 3.47 % of the bulls were homozygous, while the corresponding figure in Finncattle was 5.41 %. It can also be observed that the degree of homozygosity has increased in both breeds. The statistical significance of this trend, as determined by the chi-square test, is more than 95 %.

Another estimate of homozygosity was obtained by summing the squares of the allele frequencies in the B system. In the samples of bulls with two determinable B alleles this estimate was 12.54 % in Ayrshires and 5.66 % in Finncattle. When bulls with only one determinable B allele were included, the figures rose to 15.96 % and 6.73 %, respectively. According to this, the figures in Table 10 are biased downwards. The big difference between the two estimates of homozygosity in the Ayrshire bull sample can partly be explained by the fact that the actual inbreeding coefficient of a cow sample born in 1955 was only 2.25 %, whereas 4.33 % was to be expected on the basis of the coefficient of relationship in the breed. This can be considered evidence of a deliberate attempt to avoid inbreeding. The figure 3.47 % of Table 10 as the degree of homozygosity of Ayrshire bulls is in good agreement with the computed inbreeding coefficient of Ayrshire A.I. bulls. The average inbreeding coefficient of 145 Ayrshire bulls used at the Finnish A.I. stations in 1955 was 3.61 %, and the corresponding figure for 361 bulls used in 1960 was 2.81 %.

Table 10. Frequency of homozygous bulls among bulls with two determinable alleles at the B locus.
*Taulukko 10. Samansiinnöksisten sonnien tiheys niiden sonnien keskuudessa, joiden molemmat B-tekijät ovat tunnettavissa.*

| Birth year *Synt. vuosi* | Ayrshire | | | Finncattle — *SK* | | | Total — *Yhteensä* | | |
|---|---|---|---|---|---|---|---|---|---|
| | No. of bulls *Sonnien luku* | No. of homoz. *Saman siinn.* | % homoz. *Samansiinn.* | No. of bulls *Sonnien luku* | No. of homoz. *Samansiinn.* | % homoz. *Samansiinn.* | No. of bulls. *Sonnien-luku* | No. of homoz. *Samansiinn.* | % homoz. *Samansiinn.* |
| —1949 | 69 | 0 | 0.00 | 33 | 1 | 3.03 | 102 | 1 | 0.98 |
| 50—54 | 134 | 1 | 0.75 | 68 | 2 | 2.94 | 202 | 3 | 1.49 |
| 55—59 | 404 | 15 | 3.71 | 125 | 9 | 7.20 | 529 | 24 | 4.54 |
| 1960— | 315 | 16 | 5.08 | 144 | 8 | 5.56 | 459 | 24 | 5.23 |
| Total — *Yhteensä* | 922 | 32 | 3.47 | 370 | 20 | 5.41 | 1 292 | 52 | 4.02 |

## Discussion

The method of estimating gene frequencies on the basis of bull samples can be questioned as to the representativeness, for both NEIMANN-SØRENSEN (1958) and RENDEL (1958) have found significant differences between bull and cow samples in several systems. However, the correlation of B allele frequencies between a a sample of adult bulls and a sample of cows from ordinary herds was as high as 95.3 % in Danish Red, and the corresponding correlation in the Swedish Red & White was 97.2 %. Both these values are considerably higher than the correlations between these breeds and other breeds of the same countries in Table 8. Secondly, the bull samples can be considered to give advance information on the future cow population. As an example of the changes with time, it can be mentioned that the correlation of B allele frequencies of Finnish Ayrshire bulls born in 1949 or earlier to the corresponding frequencies of bulls born in 1950—54, 1955—59 and 1960—64 were 99.1 %, 98.8 % and 96.2 %, respectively. The correlation of bulls born in 1950—54 to bulls born in 1955—59 and 1960—64 was 98.7 % and 94.9 %, respectively, and the correlation between the two last-mentioned groups 98.1 %. The average correlation between groups born five years apart from each other was 98.6 %, while 10 years meant a correlation of 96.9 %. It can thus be concluded that bull samples can be used for estimating gene frequencies, and that young bulls will obviously give the most up-to-date information.

The analyses performed in the present study revealed considerable differences between the two Finnish breeds regarding the frequency of different blood group factors and genes. They also showed that both Finnish breeds differ from the other Scandinavian breeds as regards gene frequencies. These differences obviously make it possible in some cases to conclude the breed of an individual animal from its blood type. This would be valuable in cases where the pedigrees of good individuals are not known because of wars, fires, accidents and lack of proper recording.

It would be interesting to know whether the large differences found in the frequencies of blood group genes are reflected in the frequencies of polygenes determining production traits. If the same production trait is determined largely by different groups of genes in two breeds, then it would mean an irremediable loss of genes to cull one breed entirely because it happens to have a slightly poorer average genotype than the other breed. Such a situation should be met by crossing the two breeds, to create additional variation and to develop a new breed.

Especially the B system appeared to provide interesting information regarding the genetic relationships between breeds, making it possible to express the relationship in a quantitative way. Even though the measure used is only approximate, and subject to errors in identification or specificity of blood-grouping reagents, it is obviously not without interest from the viewpoint of the breed histories to try to make comparisons even between breeds which have not been studied in the same laboratory. International collaboration in comparing phenogroups determined in different laboratories, as suggested by RENDEL (1963), might make it possible to prepare correlation matrices and then to group the various cattle breeds occurring in Europe according to their origin, by using modern statistical methods.

Another future task would be to apply the method of measuring correlations between breeds to the C system, and to compare the results with those obtained from the B system.

The estimate of homozygosity based on the sum of squares of B allele frequencies in Ayrshire cattle (15.96 %) corresponds fairly closely to the average figure for the bull samples of Scandinavian breeds studied by RENDEL (1958) and NEIMANN-SØRENSEN (1958). It is possible that lower figures would be obtained for cows. RENDEL, for example, obtained 17.8 % as an estimate from a SRB cow sample, whereas bulls of the same breed gave an estimate of 24.8 %. This is supported by the fact that the average of

four Norwegian breeds studied by BRAEND (1959) and BRAEND *et al.* (1964) mainly on the basis of cows was about 10 %. These figures can best be compared with the degrees of inbreeding expected on the basis of the average coefficient of relationship among individuals within a breed.

On the other hand, the actual homozygosity of B alleles and the actual inbreeding coefficient (based on the mutual relationship of the actual parents) correspond to each other. There appears to be no clear discrepancy between these two measures, although the former tends to be underestimated, since not all homozygous animals can be recognized in regard to the blood groups. More data are needed to provide a definite answer to this question.

Although the information given by the phenotypic factor frequencies is not as useful as that given by gene frequencies in describing breeds, it appears to the present author that even the phenotypic frequencies should be published from every laboratory, in order to make comparisons possible.

## Summary

The frequencies of various blood groups and blood group genes in the Finnish Ayrshire cattle and in the Finnish native cattle (Finncattle) were studied on the basis of bull samples. The Ayrshire sample comprised 1 300 bulls, while 540 Finncattle bulls were available for determining the gene frequencies in the B system, and 861 bulls for the phenotypic frequencies as well as for the gene frequencies in the non-complicated systems.

Considerable differences in the frequencies were found between the Finnish breeds, as well as between these and other Scandinavian breeds. Especially the B system of blood groups seemed to offer possibilities to measure the genetic relationships between breeds or their subgroups, and thus to provide hints on the origin of the breeds. For example, there was a correlation of 19.2 % between the B allele frequencies of the Finnish breeds, while the corresponding figure between Danish Jersey and Danish Friesian was only 0.9 %, and that between the Black & White Dutch Friesian and the Red & White Dutch breed as high as 88.6 %. There were much lower correlations between lines within the Swedish Friesian than between these two Dutch breeds.

Information concerning blood groups of breeds seems to provide two means of estimating the degree of homozygosity in the breed. The first is the sum of squared allelic frequencies of the B system, and this corresponds to the expected coefficient of inbreeding. The second is the actual homozygosity of B alleles, and this corresponds to the actual inbreeding coefficient.

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## REFERENCES

BOUW, J. 1960. The genetical composition of the Dutch cattle breeds as determined by the frequencies of blood groups. Z. Tierz. u. Züchtungsbiol. 74: 248—266.

BRAEND, M. 1959. Blood groups of cattle in Norway. Thesis, 144 pp., Oslo.

BRAEND, M. 1963. Estimation of gene frequencies in the B-system of cattle. Immunogen. Letter 3: 43—48.

—»— BERG, H. & LIE, H. 1964. Blood groups of Norwegian cattle. Studies on South and West Norway Cattle (SV) and Coloursided Trønder Cattle (ST). Acta Agric. Scand. 14: 150—164.

BRAEND, M. RENDEL, J., GAHNE, B. & ADALSTEINSSON, S. 1962. Genetic studies on blood groups, transferrins and hemoglobins in Icelandic cattle. Hereditas 48: 264—283.

BUSCHMANN, H. 1962. Blutgruppengenetische Untersuchungen an süddeutschen Rinderrassen. Z. Tierz. u. Züchtungsbiol. 78: 12—25.

ERHARD, L. & SCHMID, D. O. 1964. Blutgruppenuntersuchungen beim Pinzgauer Rind. Züchtungskunde 36: 290—294.

GASPARSKI, J., RAPACZ, J. & RENDEL, J. 1960. (Blood groups in cattle and their heredity. Frequency of blood group genes in Polish red cattle from the Cracow region: B alleles). Roczn. Nauk. Rolnicz. B. 76: 565—568.

GROSCLAUDE, F. 1965. Studies on the S blood-group system in French cattle breeds. Proc. 9th Eur. Anim. Blood Group Conf.: 79—85.

—»— & MILLOT, P. 1962. Contribution á l'étude des groupes sanguins de la race bovine Montbéliarde. Ann. Biol. anim. Bioch. Biophys. 2: 185—208.

HESSELHOLT, M., LARSEN, B., NIELSEN, P. B. & PALLUDAN, B. 1965. Studies on blood groups in cattle, horses and pigs. Proc. 9th Eur. Anim. Blood Group Conf.: 49—61.

HOSODA, T., ABE, T. & KOSAKA, S. 1965. (Studies on blood groups of cattle. II. Identification of antisera with reference reagents and the frequencies of blood factors in Holstein—Friesian and native cattle breeds.) Bull. nat. Inst. Anim. Ind. (Chiba) 8: 55—61.

JOVANOVIC, V. & KONCAR, L. 1965. Blood typing of cattle of two indigenous breeds: Podolic and Red Spotted breed of Vojvodina (Yugoslavia), and of the original Simmental breed. Proc. 9th Eur. Anim. Blood Group Conf.: 453—455.

KRAAY, G. J. & BOUW, J. 1964. Frequencies of blood groups in Dutch cattle breeds. Immunogen. Letter 3: 119—129.

KORKMAN, N. 1961. Rinderrassen in Nordeuropa. Handb. Tierzüchtung, Bd. 3, Rassenkunde 1: 339—362.

LARSEN, B. 1961. Additional blood group factors of the A and B systems of cattle. Acta Agric. Scand. 11: 242—256.

MAIJALA, K. & LINDSTRÖM, GUNVOR 1965. The inheritance of the new blood group factor SF3 in cattle. Ann. Agric. Fenn. 4: 207—214 (Ser. Anim. Domest. No. 12).

MÁRKUS, J. 1962. Data relating to the gene frequency of the F—V and Z blood group factors in the Hungarian Spotted cattle. In Coll. vet. Sci., Budapest., Summ. Pap. sci. Sess., 175th Anniv., 1962: 94—96.

MATOUSEK, J., CUTA, J. & SREFL, J. 1961. Alleles of the B, C, FV, M and SU blood group systems of Bohemian brindled cattle. Fol. Biol. 7: 390—394.

MATOUSEK, J., DRÁBOVÁ, J., GLAZROVÁ, Z., MATOUSKOVA, V., SREFL, J. & SACHOVÁ, H. 1961. (Genetic frequency of the blood group systems A, FV, J, L, M, Z, Z' and of factors of the C system in Red Spotted cattle.) Zivocisná Výroba 6(34): 49—56.

MÜLLER, E. 1960. Contribution á l'étude des groupes sanguins de la race tachetée rouge du Simmental. Z. Tierz. u. Züchtungsbiol. 74: 89—105.

NASRAT, G. E., KRAAY, G. J. & BOUW, J. 1964. Frequencies of blood groups of the C-system in Dutch cattle breeds. Immunogen. Letter 3: 159—166.

NEIMANN-SØRENSEN, A. 1958. Blood groups of cattle. Thesis, 177 pp. København.

—»— & SPRYSZAK, A. 1959. Blood group studies on cattle of Red Polish breed. Anim. Prod. 1: 179—188.

OWEN, R. D., STORMONT, C. & IRWIN, M. R. 1944. Differences in frequency of cellular antigens in two breeds of dairy cattle. J. Anim. Sci. 3: 315—321.

—»—, —»—, & —»— 1947. An immunogenetic analysis of racial differences in dairy cattle. Genetics 32: 64—74.

RAPACZ, J., DOLA, L. & JAKÓBIEC, J. 1965. Blood group studies on B- groups in Polish Red Cattle. Proc. 9th Eur. Anim. Blood Group Conf.: 39—42.

RAUSCH, WAYNE H., BRUM, ELDON W., HINES, H. C. & LUDWICK, T. M. 1965. Cattle blood type phenogroup frequencies in the Ohio NC-2 herds. Immunogen. Letter 4: 76—80.

RENDEL, J. 1958. Studies of cattle blood groups. IV. The frequency of blood group genes in Swedish cattle breeds, with special reference to breed structure. Acta Agric. Scand. 8: 191—215.

—»— 1963. The organization of comparative breed studies in farm animals based on all available serological or biochemical markers. Rep. 1st Meet. FAO Panel of Blood Group Scientists: 24—25.

SCHINDLER, A. 1961. Blutgruppenbestimmungen bei der Freiburger Schwarzfleckviehrasse. Schw. Arch. Tierheilk. 103: 9—35.

—»— 1963. Blutgruppenbestimmungen beim Schweizerischen Braunvieh. Ibid. 105: 229—242.

SCHMID, D. O. & ERHARD, L. 1963. Blutgruppenuntersuchungen beim Murnau-Werdenfelser Rind. Züchtungskunde 35: 300—304.

—»— & MANCIC, D. 1964. Blutgruppenstudien beim podolischen Steppenrind aus Jugoslavien. Z. Tierz. u. Züchtungsbiol. 80: 216—223.

STORMONT, C. 1952. The F—V and Z system of bovine blood groups. Genetics 37: 39—48.

—»— , OWEN, R. D. & IRWIN, M. R. 1951. The B and C systems of bovine blood groups. Ibid. 36: 134—161.

VASENIUS, L. 1965. Transferrin polymorphism in Finnish Ayrshire cattle. Ann. Acad. Sci. Fenn., Ser. A. IV. Biol. 98: 1—58.

SELOSTUS

# Veriryhmätekijöiden ja -geenien lukuisuudesta Suomen karjaroduissa erityisesti rotuvertailuja silmällä pitäen

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Erilaisten veriryhmätekijöiden ja niitä säätelevien geenien suhteellisia lukuisuuksia Suomen ayrshirekarjassa ja suomenkarjassa tutkittiin sonniaineistojen valossa. Ayrshireaineisto käsitti 1 300 sonnia, kun taas suomenkarjasta oli käytettävissä 540 sonnia B-järjestelmän geenitiheyksien laskemiseen ja 861 sonnia yksinkertaisten järjestelmien geenitiheyksien arviointiin sekä fenotyyppisten lukuisuuksien laskemiseen.

Huomattavia eroja oli havaittavissa sekä Suomen karjarotujen välillä että niiden ja muiden pohjoismaisten karjarotujen välillä. Erityisesti veriryhmäjärjestelmä B näytti tarjoavan mahdollisuuksia eri rotujen tai niiden alaryhmien välisten perinnöllisten sukulaisuusasteiden mittaamiseen ja siten niiden alkuperän selvittämiseen. Esimerkiksi Suomen karjarotujen B-veriryhmäjärjestelmän geenitiheyksien välinen vuorosuhde oli 19.2 %, kun vastaava luku Tanskan jerseykarjan ja mustankirjavan karjan välillä oli vain 0.9 % sekä Hollannin mustankirjavan karjan ja punakirjavan karjan välillä peräti 88.6 %. Ruotsin mustankirjavan karjan eri linjojen välillä oli paljon löyhempiä vuorosuhteita kuin nämä Hollannin kahden karjarodun väliset.

Rotujen veriryhmistä käytettävissä oleva tieto näytti antavan kaksi keinoa rotujen samansiinnöksisyysasteen arvioimiseen. Toinen näistä on B-veriryhmäjärjestelmän geenitiheyksien neliöiden summa, ja se vastaa rodun eläinten välisen keskimääräisen sukulaisuuden perusteella odotettua sukusiitoskerrointa. Toinen keinoista on B-järjestelmän geenien todellisen samansiinnöksisyyden selvittäminen, ja tämä taas vastaa sitä todellista sukusiitoskerrointa, joka perustuu kunkin yksilön vanhempien keskinäiseen sukulaisuuteen.

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Seria ANIMALIA NOCENTIA N. 21 — Sarja TUHOELÄIMET n:o 21
Seria PHYTOPATHOLOGIA N. 13 — Sarja KASVITAUDIT n:o 13

# THE EFFECT OF VIRUS DISEASES TRANSMITTED BY THE LEAFHOPPER JAVESELLA PELLUCIDA (F.) ON THE CONCENTRATION OF FREE AMINO ACIDS IN OATS AND ON THE REPRODUCTION OF APHIDS

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The importance of insects as vectors of many plant viruses has increased interest in the interactions between insects and virus-diseased plants. Several investigations indicate that the development of aphids and leafhoppers is altered on virus-infected plants. SEVERIN (1946), ARENZ (1951), KENNEDY (1951), HIJNER and GORDON (1953), MARAMOROSCH (1958) and BAKER (1960) reported a positive effect of infected plants on the insect vectors. On the contrary, LOWE and STRONG (1963) observed that the fecundity of the peach aphid, *Myzus persicae* (Sulz.), on plants infected with cucumber mosaic virus was decreased in comparison with those on healthy plants. On the basis of the studies of AUCLAIR and MALTAIS (1950) they suggest that the altered amino acid composition of the virotic plants rendered them unsuitable as hosts.

MARKKULA and LAUREMA (1964) observed that the number of progeny of the pea aphid, *Acyrthosiphon pisum* (Harris), on young leaves of red clover with moderate symptoms of bean yellow mosaic virus (BYMV) was greater, but on leaves with strong symptoms less than healthy leaves. In the pea the fecundity of the aphid was the same whether the leaves were BYMV-infected or healthy. On oats infected with barley yellow dwarf virus (BYDV) the fecundity of the oat bird cherry aphid *Rhopalosiphum padi* (L.) was increased, but no difference in the reproduction of the English grain aphid *Macrosiphum avenae* (F.) or the rose grass aphid *Acyrthosiphon dirhodum* (Wlk.) was observed, although the concentration of free amino acids in the diseased plants was increased.

MARAMOROSCH and JENSEN (1963) have discussed the direct effect of plant viruses on the life activities, e.g. reproduction, of the insect vectors. On the other hand, the virus may have an indirect effect on the insects through the diseased plants. In practice it has been difficult to separate these effects from each other. BREMER (1965) overcame this difficulty by studying the reproduction of non-viruliferous *R. padi* and those carrying BYDV on *Arrhenatherum elatius* (L.), a plant which is resistant to this virus. No differences were found between the two groups of aphids (cf. MILLER 1962).

In the present work, attempts were made to exclude the direct effect of virus by studying the reproduction of the aphids *R. padi* and *M. avenae* on oats infected with two viruses transmitted by

the leafhopper *Javesella pellucida* (F.), namely oat sterile dwarf virus (OSDV) and European wheat striate mosaic virus (EWSMV).

## Materials and methods

The trial plants, oats of the variety Kultasade II, were sown in peat mould on April 28, 1965. There was one viruliferous *Javesella pellucida* nymph per plant during the period April 30 — May 7. On June 18 the plants with distinct virotic symptoms were separated for the test. The healthy control oats were grown separately without leafhoppers.

Analysis of amino acids. Samples for the amino acid analyses were collected in the morning on June 21 (healthy, OSDV and EWSMV) and on July 12 (healthy and OSDV). Leaves amounting to about 5 g fresh weight taken from the upper part of at least four plants were used as a sample.

The extraction of amino acids was performed by the method of MARBLE *et al.* (1959) with slight modifications: The weighed leaves were rinsed in deionized water, extracted with 10 ml boiling 80 % ethanol/g plant material for 10 minutes, and macerated in an »Ultra-Turrax» homogenizer. The solid residue was filtered off and washed with 80 % ethanol until the filtrate was colourless. 5 cc of Amberlite IR-120 cation exchange resin in the hydrogen form was added to the filtrate and agitated for one hour. The alcohol was then decanted off and the resin washed several times with deionized water. The amino acids were liberated from the resin with 15 ml of 10 % $NH_3$ with stirring for 15 minutes. The eluate was saved and the resin washed three times with water. The washings were combined with the eluate, evaporated to dryness at 52° c and dissolved in dilute HCl so that the concentration of the individual amino acids was about 0.1 micromole/ml and the final pH 2.8.

Quantitative determinations of the amino acids were performed by ion-exchange chromatography in accordance with the method of MOORE and STEIN (1951), using an »Auto-Analyzer» equipment of Technicon Instruments Co., Ltd.

In addition, on July 12 a determination was made from plants infected with OSDV and from healthy plants, using two-dimensional ascending paper chromatography (cf. MARKKULA and LAUREMA 1964).

Number of progeny and life-span of the aphids. The aphids *Rhopalosiphum padi* and *Macrosiphum avenae* used in the test belonged to one parthenogenetic line. The aphids, which were of the same age to the nearest day, were transferred to the leaves of the plants on June 24, when they had just become full-grown. The aphids were kept on the plants in special rearing cages described by MARKKULA (1963).

The cages were inspected at intervals of 6—7 days and the offspring removed and counted. The rearing was continued until the number of progeny and life-span of each parthenogenetic apterous female had been determined.

## Results

Concentration of amino acids. The amounts of all the amino acids identified were increased in the oats infected with OSDV or EWSMV as compared with the healthy oats (Table 1). The increase in the concentration of proline was conspicuous, especially in the oats infected by EWSMV.

On June 21, the total concentration of free amino compounds in the OSDV-infected oats was 2—3 times as great as in the healthy plants and in the EWSMV-infected oats about 5 times as great as in the healthy ones. On July 12, the concentration of free amino acids in the OSDV oats was about 1.5 times as great as in the healthy oats.

Glutamine and asparagine do not separate from serine in ion-exchange chromatography and threonine also separates from these so slightly that it was not possible to calculate the exact amount of threonine in the samples on June 21.

Table 1. Concentrations of free amino acids in healthy and virus-diseased oats. The concentrations are expressed as micromoles/g fresh weight. Abbreviations: + = present as trace, ND = present but not determined quantitatively.

| | Analysed on June 21 | | | Analysed on July 12 | |
|---|---|---|---|---|---|
| | Healthy | OSDV | EWSMV | Healthy | OSDV |
| Alanine | 1.00 | 1.55 | 2.23 | 1.73 | 1.84 |
| γ-aminobutyric acid | 0.24 | 0.71 | 0.84 | 0.79 | 1.29 |
| Arginine | + | 0.03 | + | + | + |
| Aspartic acid | 0.20 | 0.37 | ND | 0.06 | 0.19 |
| Glutamic acid | 0.28 | 0.56 | 0.35 | 0.24 | 0.26 |
| Glycine | + | 0.06 | 0.12 | 0.03 | 0.08 |
| Histidine | + | 0.05 | 0.11 | + | + |
| Isoleucine | 0.05 | 0.15 | 0.23 | 0.09 | 0.14 |
| Leucine | 0.05 | 0.22 | 0.22 | 0.13 | 0.18 |
| Lycine | 0.07 | 0.08 | 0.18 | 0.05 | 0.08 |
| Phenylalanine | 0.07 | 0.15 | 0.39 | 0.09 | 0.12 |
| Proline | 0.00 | 0.67 | 4.87 | + | + |
| Threonine | ND | ND | ND | 0.18 | 0.56 |
| Tyrosine | 0.03 | 0.07 | + | 0.08 | 0.09 |
| Valine | 0.13 | 0.33 | 0.59 | 0.16 | 0.28 |
| Serine + asparagine + glutamine | 0.31 | 1.45 | 2.03 | 0.22 | 0.63 |

According to paper chromatograms made on July 12, small amounts of free asparagine and glutamine were present in the plants, but on visual comparison there appeared to be no difference in the concentrations of these amides between the OSDV-infected oats and the healthy plants.

In addition to the compounds listed in the Table 1, the chromatograms also gave indications of methionine, cystine, ethanolamine or other ninhydrin-positive compounds which were not identified.

Number of progeny and life-span of the aphids. The average number of progeny and life-span of the aphids on the diseased plants differed clearly from those on the healthy plants. The differences in number of progeny were initially small, but became greater as reproduction proceeded (Fig. 1).

In the case of *Rhopalosiphum padi*, the number of progeny on OSDV-infected oats was significantly smaller than on healthy plants (after 12 days $P < 0.05$ and thereafter $P < 0.001$). On plants with EWSMV the difference was significant after 18 days and did not become greater after this. No significant differences in number of progeny were found between the plants infected with EWSMV and OSDV.

After 6 and 12 days the number of progeny of *Macrosiphum avenae* was significantly ($P < 0.05$) smaller on the OSDV-infected than on the healthy plants, but the differences were not significant 18 and 25 days after the start of the trial. Still later the number of offspring on the diseased plants was greater than on the healthy ones (Fig. 1). As regards the EWSMV-infected oats, the number of progeny was smaller on the diseased than on the healthy plants, the

Table 2. The number of progeny and the life-span (days) of *Rhopalosiphum padi* and *Macrosiphum avenae* on healthy and diseased oats.

| | *R. padi* | | *M. avenae* | | | *R. padi* | | *M. avenae* | |
|---|---|---|---|---|---|---|---|---|---|
| | n | $\bar{x}$ | n | $\bar{x}$ | | t | P | t | P |
| *No. of progeny* | | | | | | | | | |
| Healthy plants | 20 | 51.4 | 19 | 37.9 | healthy/OSDV | 3.88 | <0.001 | 2.43 | <0.05 |
| OSDV-diseased | 26 | 37.9 | 24 | 46.6 | healthy/EWSMV | 2.61 | <0.05 | 5.08 | <0.001 |
| EWSMV-diseased | 12 | 34.7 | 11 | 13.3 | OSDV/EWSMV | 0.51 | >0.05 | 6.50 | <0.001 |
| *Life-span* | | | | | | | | | |
| Healthy plants | 20 | 28.5 | 19 | 29.1 | healthy/OSDV | 2.00 | >0.05 | 4.61 | <0.001 |
| OSDV-diseased | 26 | 24.9 | 24 | 36.1 | healthy/EWSMV | 3.59 | <0.01 | 6.33 | <0.001 |
| EWSMV-diseased | 12 | 20.1 | 11 | 18.5 | OSDV/EWSMV | 2.13 | <0.05 | 9.15 | <0.001 |

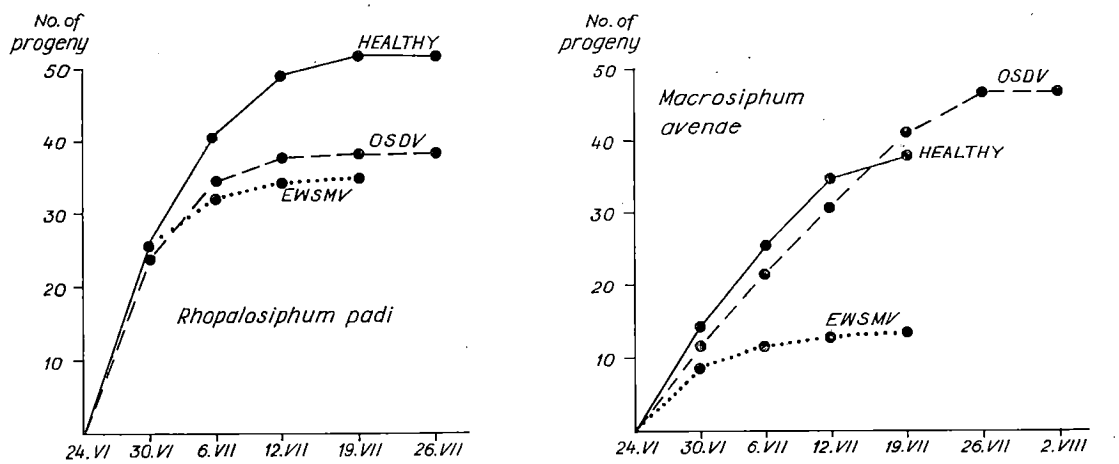


Figure 1. The fecundity of *Rhopalosiphum padi* and *Macrosiphum avenae* on healthy and virus-diseased oats.

differences being significant after six days and thereafter highly significant ($P < 0.001$). The number of progeny on EWSMV-infected plants was significantly smaller than on plants with OSDV (after 12 days $P < 0.01$ and thereafter $P < 0.001$).

The longevity of *R. padi* on EWSMV-infected plants was significantly reduced, but on the OSDV-infected plants there was no significant difference between the diseased and healthy plants. Concerning the life-span of *M. avenae*, there were highly significant differences between all the groups. The life-span was longest on the plants infected with OSDV and shortest on those infected with EWSMV (Table 2).

## Discussion

Several authors who have studied the concentration of free amino acids in virus-infected plants have reported pronounced quantitative or qualitative differences in comparison with healthy plants. DIENER (1963) discussed the physiology of virus-diseased plants and reviewed the observations made on the concentration of non-protein nitrogen compounds in diseased plants. He concluded that an accumulation of nonprotein nitrogen compounds, particularly amides, frequently occurs in the diseased leaves if the concentration of virus is not very high. Recent observations in this field have been made by BOZARTH and DIENER (1963), KARASEK (1963) and SEHGAL and BOONE (1964).

Evidently differences exist in the concentrations of individual amino compounds in different diseases in different plants or in different stages of a disease. In the present study this was found in respect to proline, the concentration of which was especially high in the oats infected with EWSMV. DIENER and DEKKER (1954) reported an accumulation of proline and pipecolic acid in Western X-diseased leaves of peach. BOZARTH and DIENER (1963) observed an increase in the amount of proline in tobacco plants infected with Potato Virus Y, but not in those infected with Potato Virus X.

Despite the accumulation of all the amino acids in the virus-infected oats, the fecundity of the aphids on the infected plants was reduced, except on those infected with OSDV towards the end of the test. This was evidently due to the fact that these plants continued growing for longer than the healthy plants. On the contrary, the shorter life-span of the aphids on the EWSMV-infected plants is understandable in view of the early withering of these plants.

Although the significance of free amino acids in the nutrition of phloem-sucking insects

seems to be generally accepted, the concentration of amino acids is obviously not always a growth-limiting factor for these insects. MARBLE *et al.* (1959) could not find any conclusive difference in the amount of free amino acids between alfalfa susceptible and resistant to *Therioaphis maculata* (Buckton). Similarly BANKS (1965) has concluded that the concentration of nutrients, particularly nitrogen, in the sap of two varieties of *Vicia faba* (L.) does not determine the fecundity of *Aphis fabae* (Scop.) on these plants.

Recent progress in the rearing of aphids on a chemically defined diet has offered new possibilities to study aphid nutrition in laboratory conditions. AUCLAIR (1965) reports that there is in fact an optimum concentration of amino acids for the pea aphid *A. pisum* reared on a synthetic diet. When the amino acid concentration was above this level the growth rate and survival of the aphid were significantly lower. Since this optimum concentration seems to be relatively low, only about twice the normal concentration of the amino acids in the aphid haemolymph and honeydew, it is possible that the poor development of aphids now observed, especially on the oats infected by EWSMV, is connected with the high concentration of free amino acids in the plants. Obviously, more information on the effect of individual amino compounds on aphid development is required before this question can be adequately solved.


## Summary

Quantitative determinations of free amino acids in oats infected with oat sterile dwarf virus (OSDV) and European wheat striate mosaic virus (EWSMV) indicated an increase in the concentration of all the amino acids identified. The concentration of proline was especially high in oats infected with EWSMV.

The fecundity of the oat bird cherry aphid, *Rhopalosiphum padi* (L.), was decreased on the diseased oats. No significant difference in the fecundity occurred between oats infected with OSDV and with EWSMV.

The fecundity of the English grain aphid *Macrosiphum avenae* (F.) on the OSDV-infected oats was increased and the reproductive period prolonged. On the oats infected with EWSMV the fecundity of the aphid was significantly reduced.

A positive correlation existed between the number of progeny and the longevity of the aphids.



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## REFERENCES


ARENZ, B. 1951. Der Einfluss verschiedener Faktoren auf die Resistenz der Kartoffel gegen Pfirsichblattlaus. Z. Pfl.bau Pfl.schutz 2: 49—62.

AUCLAIR, J. L. 1965. Feeding and nutrition of the pea aphid, *Acyrthosiphon pisum* (*Homoptera: Aphidae*), on chemically defined diets of various pH and nutrient levels. Ann. Entomol. Soc. Amer. 58: 855—875.

—»— & MALTAIS, J. B. 1950. Studies on the resistance of plants to aphids by the method of paper partition chromatography. Canad. Ent. 82: 175—176.

BAKER, P. F. 1960. Aphid behaviour on healthy and yellows-virus-infected sugar beet. Ann. Appl. Biol. 48: 384—391.

BANKS, C. J. 1965. Aphid nutrition and reproduction. Rothamsted Exp. Sta. Rep. 1964, p. 299—309.

BOZARTH, R. F. & DIENER, T. O. 1963. Changes in the concentration of free amino acids and amides induced in tobacco plants by potato virus X and potato virus Y. Virology 21: 188—193.

BREMER, K. 1965. Characteristics of the barley yellow dwarf virus in Finland. Ann. Agric. Fenn. 4: 105—120.

DIENER, T. O. 1963. Physiology of virus-infected plants. Ann. Rev. Phytopath. 1: 197—218.

—»— & DEKKER, C. A. 1954. Isolation and identification of l-pipecolic acid from Western X-diseased peach leaves. Phytopathology 44: 643—645.

HIJNER, J. S. & GORDON, F. M. 1953. De Vergelingsziegte der bieten. III. Meded. Inst. Suikerbiet., Bergen-o.-Z. 23: 251.

KARASEK, M. 1963. Changes in free and acetylated amino acids during tobacco mosaic virus multiplication. Biochem. Biophys. Acta 78: 644—648.

KENNEDY, J. S. 1951. Benefits to aphids from feeding on galled and virus-infected leaves. Nature 168: 825—826.

LOWE, S. & STRONG, F. E. 1963. The unsuitability of some viruliferous plants as hosts for the green peach aphid, *Myzus persicae*. J. Econ. Ent. 56: 307—309.

MARAMOROSCH, K. 1958. Beneficial effect of virus-diseased plants on non-vector insects. Tijdsschr. Pl.ziekt. 64: 383—391.

—»— & JENSEN, D. D. 1963. Harmful and beneficial effects of plant viruses in insects. Ann. Rev. Microbiol. 19: 495—530.

MARBLE, V. L., MELDEEN, J. C., MURRAY, H. C. & ZSCHEILE, F. P. 1959. Studies on free amino acids in the spotted alfalfa aphid, its honeydew, and several alfalfa selections, in relation to aphid resistance. Agron. J. 51: 740—743.

MARKKULA, M. 1963. Studies on the pea aphid, *Acyrthosiphon pisum* Harris (*Hom., Aphididae*), with special references to the differences in the biology of the green and red forms. Ann. Agric. Fenn. 2, Suppl. 1: 1—30.

—»— & LAUREMA, S. 1964. Changes in the concentration of free amino acids in plants induced by virus diseases and the reproduction of aphids. Ibid. 3: 265—271.

MILLER, J. W. 1962. The effect of bailey yellow dwarf virus on the biology of its vector, the English grain aphid, *Macrosiphum granarium* (Kirby). Doctoral Thesis, Pa State Univ. (Ref. MARAMOROSCH, K. & JENSEN, D. D. 1963).

MOORE, S. & STEIN, W. H. 1951. Chromatography of amino acids on sulfonated polystyrene resins. J. Biol. Chem. 192: 663—681.

SEHGAL, O. P. & BOONE, D. M. 1964. Amino acid and amide content of healthy and multiplier disease-affected strawberry plants. Phytopathology 54: 775—778.

SEVERIN, H. H. P. 1946. Longevity, or life-histories, of leafhopper species on virus-infected and healthy plants. Hilgardia 17: 121—133.

## SELOSTUS

### Viljakaskaan siirtämien virusten vaikutus kauran vapaiden aminohappojen määriin sekä kirvojen lisääntymiseen ja elinikään

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Tutkimuksessa selvitettiin kauran tyviversoviruksen ja vehnän viirumosaiikkiviruksen vaikutusta Kultasade II -kauran vapaiden aminohappojen määrään sekä kirvojen lisääntymiseen ja elinikään.

Ioninvaihtokromatografista analyysia käyttäen todettiin, että vapaiden aminohappojen määrä oli tyviversoviruksen saastuttamissa kauroissa kaksinkertainen ja viirumosaiikkiviruksen saastuttamissa viisinkertainen terveissä kasveissa olleeseen määrään verrattuna.

Tuomikirvan jälkeläismäärä oli terveissä kauroissa suurempi kuin tyviversoviroottisissa ja viirumosaiikkiviroottisissa. Myös viljakirva lisääntyi runsaammin terveissä kauroissa kuin viirumosaiikkiviruksen saastuttamissa. Lajin lisääntyminen terveissä kauroissa oli samoin aluksi runsaampaa kuin tyviversoviroottisissa, mutta kokonaisjälkeläismäärä jäi vähäisemmäksi. Kirvojen eliniän pituudessa oli todettavissa samansuuntaiset muutokset kuin jälkeläismäärässä.

Aikaisemmin suoritettujen tutkimusten perusteella oli odotettavissa, että kirvojen jälkeläismäärä olisi suurempi ja elinikä pitempi sellaisissa kasveissa, joissa vapaiden aminohappojen määrä ja väkevyys on suurempi. Tutkimus ei kuitenkaan antanut tällaista tulosta. Mikäli kirvojen lisääntymisen erot ovat riippuvaisia aminohapoista, on jatkotutkimuksissa kohdistettava päähuomio yksittäisten aminohappojen määriin ja aminohappojen runsaussuhteisiin.

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Seria ANIMALIA DOMESTICA N. 18 — Sarja KOTIELÄIMET n:o 18

# ÜBER DEN ZUSAMMENHANG DER BEI PFERDEN ZU ZÜCHTENDEN ZÜGE

## Die Stuten

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Verfasser dieses hat auch früher schon (VARO 1965a) durch Faktoranalysen die Interkorrelationen von Eigenschaften bei Pferden erforscht. Bei dem damals bearbeiteten Hengstmaterial sind vier Faktoren herausgestellt worden, die ausgereicht haben, den Hauptteil der zwischen den Eigenschaften bestehenden linearen Abhängigkeitsverhältnisse zu erklären. Material der nunmehr darzulegenden Untersuchung sind 997 vierjährig — von 143 Hengsten — und 1357 fünfjährig — von 193 Hengsten — in das Stammbuch eingetragene Stutennachkommen gewesen. Die Fortführung der Untersuchung mit Stutenmaterial ist darum vorgenommen worden, weil dieses, viel weniger ausgelesen als das Hengstmaterial, offenbar ein richtigeres und präziseres Bild von den hinter den Zusammenhängen zwischen den verschiedenen Eigenschaften bestehenden gemeinsamen Faktoren zu geben vermag. Da das Material auch diesmal aus stammbuchvermerkten Pferden besteht, ist es, genau genommen, auch jetzt keine aufs Geratewohl genommene Probe des gesamten Pferdematerials Finnlands. Doch ist es unmöglich, ein völlig unausgelesenes Material ohne hohe zusätzliche Kosten zu erhalten, denn über die in den Stammbuchprüfungen durchgefallenen Pferde sind nicht alle erforderlichen Angaben gesammelt oder registriert worden. Dies liegt daran, dass bei den abzulehnenden Pferden die Probe abbricht nach einer Leistung, die offenbar nicht zu einer Eintragung in das Stammbuch berechtigt. Wegen der hohen Anzahl der Ablehnungsbegründungen kommt die Auslese jedoch nicht dazu, sich auch nur irgendeiner Eigenschaft sehr wirksam zuzuwenden. Kann man doch sagen, dass eine der Anregungen zur Einleitung dieser faktoranalytischen Untersuchungen denn auch gerade das Bestreben gewesen ist, die Auslese zu intensivieren, indem man nach Mitteln zu ihrer Beschränkung auf wenigere Merkmale und zu ihrer Ausrichtung auf nunmehr einfachere Zielsetzungen mit grösserer Folgerichtigkeit als zuvor sucht. Die Beziehung der Ausmerzung zu einem einzelnen Zug wird bei der Auslese der Stuten ausserdem dadurch geschwächt, dass die Ausführungsreihenfolge der Versuche und Beurteilungen nicht ebenso streng einheitlich wie bei den Hengstvorführungen gewesen ist.

Aus dem grossen Stutenmaterial wurden für die vorliegende Untersuchung nur die vier grössten Jahrgänge ausgewählt, nämlich die in den Jahren 1952—55 für das Stammbuch gut-

geheissenen 4- und 5jährigen Pferde. So verfuhr man, um die entwicklungsbedingte Störung in den Korrelationen möglichst gering zu halten. Die angegebenen Jahrgänge wurden darum gewählt, weil auch bei dem früher untersuchten Hengstmaterial Pferde entsprechenden Alters einbezogen worden waren. Zur Berechnung der genetischen Korrelationen wurden für das Material ausserdem nur diejenigen Stuten gutgeheissen, deren Väter wenigstens vier Töchter hatten.

Das Faktorisieren des Hengstmaterials war seinerzeit nach der Zentroidmethode ausgeführt und die erhaltenen Faktoren gemäss der analytischen Kosinuslösung, mit anderen Worten, unter Anwendung der Schrägrotation (VAHERVUO und AHMAVAARA 1958), rotiert worden. Bei der nunmehr zu betrachtenden Untersuchung wurde das Faktorisieren (mittels Datenverarbeitungsmaschinen) gemäss der Hauptfaktor[1])-Lösung vorgenommen, und die endgültigen Faktorladungen wurden durch orthogonale Varimaxrotation gewonnen (HARMAN 1960). Die Ergebnisse brauchen somit nicht völlig miteinander übereinzustimmen.

## Mittelwerte und Streuungen des Materials

Das beste Bild vom Material vermittelt Tabelle 1, in der die Mittelwerte und Streuungen der verschiedenen Eigenschaften beider Altersklassen zusammengestellt sind. Die verschiedenen Altersklassen erweisen sich in ihr als erstaunlich übereinstimmend und, was am wenigsten zu erwarten gewesen ist, die 5jährigen in ihren Massen im allgemeinen als um eine Ahnung kleiner. Diese selbe Beobachtung hat Verfasser auch schon früher gemacht (VARO 1965). Dies dürfte daran liegen, dass 5jährig für das Stammbuch aus diesem oder jenem Grunde in verhältnismässig reichlicher Menge ein Material angeboten wird, das schwächer und langsamer als durchschnittlich entwickelt ist. Auch in ihren meisten Punktwerten sind die 5jährigen hinter den 4jährigen zurückgeblieben. Eine sehr markante Ausnahme von dieser Regel bilden sowohl die prozentuale als auch die nach Kilogramm bemessene Zugkraft, in denen die von den 5jährigen erlangten Ergebnisse sehr signifikant besser als die Leistungen der 4jährigen sind. Die Differenzen haben sich zugunsten der älteren Pferde nämlich auf $3.57 \pm 0.37$ % und $18.86 \pm 2.22$ kg belaufen. Auch der Unterschied der Stufenzahlen ist einer der statistisch signifikantesten, aber von entgegengesetzter Richtung: die 4jährigen scheinen bei stufenmässiger Messung stärker. Die offensichtliche und einfache Erklärung dieses Widerspruches liegt darin, dass die an die älteren Pferde auf den verschiedenen Stufen gestellten prozentualen Zugwiderstandforderungen gegenüber denen der 4jährigen übermässig hoch sind. Diesen Umstand hat Verfasser (VARO 1947) schon vor zwanzig Jahren bei Untersuchung der Zugfähigkeit von Hengsten beachtet. Auf die Ergebnisse der jetzt in Rede stehenden Untersuchung haben die Anforderungsunterschiede nicht eingewirkt, da die verschiedenen Alterklassen als getrennte Materialien bearbeitet worden sind, aber sie versetzen die alten Pferde in eine ungünstigere Stellung bei der abschliessenden Beurteilung der Versuche überhaupt. Die tatsächlich besseren Zugleistungen der älteren Pferde dürften zum mindesten teilweise auf eine bessere Einarbeitung zurückzuführen sein.

Auch waren Schritt- und Renngeschwindigkeit bei den älteren Pferden besser als bei den jungen; die Differenzen beliefen sich auf $3.41 \pm 1.49$ und $2.01 \pm 0.60$ Sek. Die statistische Signifikanz der Unterschiede war also nicht annähernd so gross wie bei der Zugkraft. Die signifikantesten Differenzen der Masse — die also im allgemeinen bei den 4jährigen am grössten waren—, bestanden im Knieumfang, $0.23 \pm 0.05$ cm, sowie in der Vorder- und Hinterbeinbreite, bei beiden $0.04 \pm 0.01$ cm. Sehr signifikant waren die Differenzen ausser-

[1]) principal factor

Tabelle 1. Mittelwerte und Streuungen der Stuten.
*Taulukko 1. Tammojen keskiarvot ja hajonnat.*

| Eigenschaft *Ominaisuus* | Einheit *Yksikkö* | Die Mittelwerte *Keskiarvot* | | Die Streuungen *Hajonnat* | |
|---|---|---|---|---|---|
| | | 4-j. *4-v.* | 5-j. *5-v.* | 4-j. *4-v.* | 5-j. *5-v.* |
| Widerristhöhe — *säkäkorkeus* | cm | 157.73 | 157.26 | 3.71 | 3.86 |
| Kruppenhöhe — *lautaskorkeus* | » | 157.82 | 157.36 | 3.58 | 3.73 |
| Rumpflänge — *vartalon pituus* | » | 167.90 | 167.28 | 4.57 | 4.57 |
| Brustumfang — *rinnan ympärys* | » | 187.92 | 187.80 | 5.60 | 5.90 |
| Brusttiefe — *rinnan syvyys* | » | 77.07 | 76.96 | 2.39 | 2.37 |
| Brustbreite — *ryntään leveys* | » | 45.56 | 45.79 | 2.34 | 2.13 |
| Vordere Kruppenbreite — *lautasen etuleveys* | » | 58.29 | 58.10 | 1.89 | 1.96 |
| Hintere Kruppenbreite — *lautasen takaleveys* | » | 54.87 | 54.80 | 1.90 | 1.93 |
| Knieumfang — *polven ympärys* | » | 33.25 | 33.02 | 1.17 | 1.22 |
| Umfang des Vorderbeines — *etusäären ympärys* | » | 20.32 | 20.22 | 0.74 | 0.77 |
| Vorderbeinbreite — *etusäären leveys* | » | 7.47 | 7.43 | 0.30 | 0.31 |
| Umfang des Hinterbeines — *takasäären ympärys* | » | 22.55 | 22.47 | 0.87 | 0.89 |
| Hinterbeinbreite — *takasäären leveys* | » | 8.68 | 8.64 | 0.35 | 0.36 |
| Gewichtsabschätzung [1]) — *painon arvio* [1]) | kg | 563.53 | 560.88 | 46.92 | 48.86 |
| Feistheitsgrad — *lihavuusaste* | p | 4.21 | 4.22 | 0.71 | 0.78 |
| Stufenzahl — *porrasluku* | kpl | 7.60 | 7.25 | 1.31 | 1.29 |
| Bewegungen — *liikkeet* | p | 2.32 | 2.27 | 0.53 | 0.54 |
| Charakter und Temperament — *luonne* | » | 4.42 | 4.43 | 0.68 | 0.68 |
| Typen — *tyypit* | » | 4.67 | 4.63 | 0.58 | 0.61 |
| Rumpf — *runko* | » | 5.60 | 5.55 | 0.83 | 0.90 |
| Beine — *jalat* | » | 3.50 | 3.46 | 0.55 | 0.57 |
| Zugkraft % — *vetovoima, %* | % | 75.46 | 79.03 | 8.63 | 9.21 |
| Zugkraft kg — *vetovoima, kg* | kg | 425.89 | 444.75 | 52.49 | 54.27 |
| Schrittschnelligkeit — *käyntiaika* | s | 8 min. 19.*45* s. | 8 min. 16.*04* s. | 35.36 | 36.26 |
| Rennschnelligkeit — *juoksuaika* | s | 2 min. 27.*26* s. | 2 min. 25.*25* s. | 14.26 | 14.77 |

[1]) Gewichtsabschätzung — *Painon arvio* $= \frac{ry^2 \cdot rp}{10\,000} - 30$

ry = Brustumfang — *rinnan ympärys*
rp = Rumpflänge — *rungon pituus*

dem in der Kruppenhöhe, in der Rumpflänge und im Vorderbeinumfang.

Bei den älteren Pferden ist die Streuung bei den meisten Eigenschaften grösser als bei den jungen ausgefallen, aber der Unterschied ist im allgemeinen nicht statistisch signifikant gewesen. Nur die beträchtlichere Streuungsgrösse der Kruppenbreite bei den jungen Pferden sowie die des Feistheitsgrades und des Rumpfes bei den älteren scheinen signifikant.

## Korrelationskoeffizienten

Die zwischen den Eigenschaften bestehenden Korrelationskoeffizienten sind in den Tabellen 2 und 3 dargestellt, in ersterer für die 4-, in letzterer für die 5jährigen Pferde. In dem oberen Feld der Matrizen — oberhalb und rechts der Mittelachse — stehen die Phänotyp- und im unteren die genetischen Korrelationen. Die letztgenannten sind, gegründet auf die zwischen den Vätern bestehenden Kovarianzkomponenten, aus den Halbgeschwistern väterlicherseits berechnet worden (FALCONER 1960). Es ist zu bemerken, dass in der Untersuchung der Zusammenhang der Schritt- und Rennneigungen mit den übrigen Eigenschaften als Korrelationen der Geschwindigkeit und nicht der Zeit dargestellt sind. Auf diese Weise ist man dazu gekommen, dass der positive Korrelationskoeffizient stets den Zusammenhang der

angestrebten Eigenschaften erweist. Als Masszahl der Geschwindigkeit ist die Ordnungszahl der Sekunden, aus dem Ergebnis des langsamsten Pferdes berechnet, benutzt worden. Schon aus den Korrelationskoeffizienten ist leicht zu schliessen, dass die verschiedenen Altersklassen hier, wie auch bei dem annähernd 10 Jahre früherenHengstmaterial (VARO 1965), stark miteinander übereinstimmen. Die Phänotypkorrelationen waren bei den 5jährigen im Mittel um weniger als 0.02 grösser, aber die genetischen waren um gleich viel kleiner als bei den 4jährigen. Auch die Phänotyp- und die Genotypkorrelationen waren einander sehr ähnlich. Die genetischen Korrelationen blieben bei den 4jährigen im Mittel um weniger als 0.02 und bei den 5jährigen um etwa 0.05 geringer als die Phänotypkorrelationen. Die durch den Korrelationskoeffizienten gemessene Übereinstimmung der einzelnen Koeffizienten belief sich bei den 4jährigen auf 0.97 und bei den 5jährigen auf 0.94. Schon auf Grund dieser Gleichmässigkeit scheint es offensichtlich, dass die Faktorenanalyse ungefähr ebenso gut aus dem Phänotyp- — wie aus den genetischen Korrelationen zu berechnen ist.

## Die Faktoren und ihre Auslegung

Die endgültigen rotierten Faktorladungen sind in Tabelle 4 so dargestellt, dass die Eigenschaften zur Erleichterung von Vergleichen in derselben Reihenfolge aufgeführt sind, wie sie es auch im Hengstmaterial waren (VARO 1965). Besonders aus der die Faktoren veranschaulichenden Figur 1 ist leicht festzustellen, dass die Ergebnisse, für jede der beiden Altersklassen wie auch aus den verschiedenen Korrelationskoeffizienten berechnet, praktisch übereinstimmend sind. Auch verglichen mit den für das Hengstmaterial erhaltenen Ergebnissen ist die Ähnlichkeit teilweise recht gross. Da man vorläufig nicht weiss, ob die Differenzen zwischen Hengst- und Stutenmaterial auf der Unterschiedlichkeit der Faktorisierungs- und der Rotationsmethode oder wirklich auf den Materialien selbst beruhen, bleibt ihr näherer Vergleich einem späteren Forschungsstand überlassen, bei dem die Ergebnisse gemäss gleichen Verfahrensweisen bearbeitet sein werden.

Man kann annehmen, dass fünf Faktoren die Zusammenhänge zwischen den Eigenschaften ziemlich genau widerspiegeln, denn nach dem fünften Faktor waren die restlichen schon sehr gering. Durchschnittlich waren sie in ihren absoluten Werten von der Grössenordnung 0.03, und nur rd. 5 % von ihnen erlangten wenigsten wenigstens den Wert 0.1.

## Deutung der Faktoren

In den Tabellen und Figuren sind die Faktoren in der Reihenfolge dargestellt, in der sie in den meisten Fällen als Ergebnis der Rotation erhalten worden sind. Diese Reihenfolge entscheidet keineswegs die Rangordnung der Faktoren, schon gar nicht bei der Züchtungsarbeit, wo der Betrag ihres Wertes vor allem Zielsetzung der Züchtungstätigkeit ist. In dem folgenden Versuch zur Auslegung der im erforschten Material herausgestellten Faktoren werden denn auch zunächst wenigstens die vom Blickpunkt der finnischen Pferdezucht wichtigsten »Leistungsfähigkeits-Faktoren» II und IV und dann erst die »Körperbaufaktoren» I, III und V besprochen. Diese Einteilung hat sich als zweckmässig auch darum erwiesen, weil die Faktoren der Leistungsfähigkeit schon beim Hengstmaterial als sehr ähnlich herausgestellt worden sind. Bei den Faktoren des Körperbaus hingegen haben zwischen dem Hengst- und dem Stutenmaterial mehr Unterschiede bestanden, obschon unter drei dieser Faktoren bei

Tabelle 2. Die Interkorrelationen der Eigenschaften bei 4jährigen Stuten. Im oberen Feld die phänotypischen, im unteren die genetischen Korrelationen

*Taulukko 2. Ominaisuuksien interkorrelaatiot 4-vuotiailla tammoilla. Yläkentässä fenotyyppiset, alakentässä geneettiset korrelaatiot.*

| | | 1 | 2 | 3 | 4 | 5 | 6 | 7 | 8 | 9 | 10 | 11 | 12 | 13 | 14 | 15 | 16 | 17 | 18 | 19 | 20 | 20 | 21 | 22 | 23 | 24 |
|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|
| Widerristhöhe — *säkäkorkeus* | 1 | | .969 | .705 | .581 | .706 | .299 | .588 | .468 | .591 | .561 | .485 | .460 | .483 | .677 | —.062 | —.067 | —.022 | —.008 | .206 | .122 | .016 | —.076 | .402 | .146 | —.012 |
| Kruppenhöhe — *lautaskorkeus* | 2 | .954 | | .705 | .573 | .678 | .305 | .570 | .468 | .583 | .549 | .489 | .461 | .488 | .671 | —.051 | —.065 | —.030 | —.014 | .177 | .102 | .013 | —.076 | .399 | .137 | —.024 |
| Rumpflänge — *vartalon pituus* | 3 | .726 | .719 | | .592 | .648 | .409 | .628 | .567 | .613 | .603 | .544 | .555 | .544 | .795 | .034 | —.087 | —.012 | .013 | .408 | .332 | .025 | —.069 | .469 | .101 | .001 |
| Brustumfang — *rinnan ympärys* | 4 | .522 | .501 | .570 | | .684 | .599 | .625 | .644 | .495 | .506 | .514 | .472 | .479 | .956 | .339 | —.161 | .073 | —.005 | .523 | .510 | .064 | —.130 | .513 | .057 | —.095 |
| Brusttiefe — *rinnan syvyys* | 5 | .726 | .701 | .671 | .722 | | .360 | .559 | .489 | .496 | .514 | .501 | .459 | .461 | .737 | .070 | —.085 | .033 | —.006 | .336 | .299 | .051 | —.083 | .430 | .044 | —.079 |
| Brustbreite — *ryntään leveys* | 6 | .147 | .139 | .335 | .516 | .222 | | .537 | .626 | .349 | .406 | .386 | .371 | .335 | .596 | .321 | —.064 | .115 | .052 | .496 | .526 | .076 | —.034 | .348 | .050 | —.017 |
| Vordere Kruppenbreite — *lautasen etuleveys* | 7 | .561 | .525 | .587 | .636 | .529 | .533 | | .807 | .575 | .557 | .486 | .527 | .486 | .689 | .147 | —.061 | .048 | .031 | .470 | .405 | .090 | —.036 | .414 | .107 | .016 |
| Hintere Kruppenbreite — *lautasen takaleveys* | 8 | .375 | .376 | .521 | .688 | .479 | .684 | .793 | | .483 | .483 | .459 | .476 | .463 | .684 | .292 | —.064 | .078 | .037 | .544 | .539 | .077 | —.035 | .408 | .089 | .011 |
| Knieumfang — *polven ympärys* | 9 | .447 | .433 | .534 | .457 | .393 | .349 | .605 | .506 | | .750 | .674 | .713 | .643 | .581 | —.040 | .002 | —.048 | .063 | .345 | .269 | .126 | —.015 | .398 | .107 | .084 |
| Umfang des Vorderbeines — *etusäären ympärys* | 10 | .471 | .440 | .562 | .525 | .459 | .407 | .571 | .465 | .735 | | .846 | .781 | .714 | .587 | —.022 | —.040 | —.038 | .023 | .372 | .285 | .131 | —.043 | .370 | .055 | .027 |
| Vorderbeinbreite — *etusäären leveys* | 11 | .353 | .334 | .439 | .561 | .473 | .420 | .453 | .429 | .632 | .858 | | .733 | .753 | .574 | .014 | —.032 | —.077 | .012 | .320 | .286 | .103 | —.044 | .366 | —.010 | .034 |
| Umfang des Hinterbeines — *takasäären ympärys* | 12 | .264 | .245 | .440 | .450 | .330 | .390 | .490 | .443 | .652 | .806 | .742 | | .864 | .546 | —.038 | —.015 | —.066 | .039 | .326 | .317 | .126 | —.010 | .358 | .007 | .031 |
| Hinterbeinbreite — *takasäären leveys* | 13 | .368 | .347 | .476 | .509 | .469 | .333 | .483 | .445 | .607 | .746 | .809 | .864 | | .549 | —.007 | .004 | —.097 | .033 | .300 | .252 | .092 | —.007 | .378 | .001 | .017 |
| Gewichtsabschätzung — *painon arvio* | 14 | .642 | .623 | .776 | .955 | .782 | .518 | .683 | .702 | .529 | .597 | .582 | .495 | .558 | | .271 | —.152 | .049 | .001 | .533 | .499 | .055 | —.122 | .551 | .078 | —.072 |
| Feistheitsgrad — *lihavuusaste* | 15 | —.187 | —.199 | —.031 | .324 | .031 | .328 | .162 | .324 | —.059 | —.036 | .066 | —.041 | —.012 | .239 | | —.060 | .073 | —.006 | .295 | .352 | .011 | —.032 | .127 | —.012 | —.030 |
| Stufenzahl — *porrasluku* | 16 | —.123 | —.106 | —.162 | —.182 | —.105 | —.104 | —.018 | —.013 | .006 | —.108 | —.094 | —.075 | —.024 | —.212 | —.021 | | .100 | .167 | —.027 | —.002 | .032 | .773 | .729 | .038 | .154 |
| Bewegungen — *liikkeet* | 17 | .081 | .054 | .082 | .055 | .082 | .100 | .130 | .178 | .056 | —.024 | —.129 | —.095 | —.127 | .059 | .045 | .105 | | .231 | .242 | .246 | .326 | .072 | .124 | .156 | .112 |
| Charakter und Temperament — *luonne* | 18 | —.177 | —.180 | —.095 | —.069 | —.191 | .103 | .025 | .067 | .207 | .054 | .001 | .074 | —.011 | —.087 | —.007 | .228 | .323 | | .144 | .183 | .213 | .152 | .140 | .224 | .492 |
| Typen — *tyypit* | 19 | .208 | .161 | .380 | .558 | .328 | .459 | .503 | .592 | .401 | .428 | .376 | .360 | .384 | .556 | .261 | —.067 | .294 | .148 | | .753 | .273 | —.041 | .341 | .139 | .051 |
| Rumpf — *runko* | 20 | .011 | —.028 | .244 | .512 | .189 | .543 | .411 | .583 | .281 | .293 | .321 | .371 | .299 | .473 | .297 | —.040 | .249 | .202 | .740 | | .194 | —.004 | .338 | .081 | .085 |
| Beine — *jalat* | 21 | —.016 | —.038 | —.025 | .072 | —.010 | .091 | .240 | .138 | .228 | .157 | .130 | .154 | .167 | .053 | .003 | .019 | .298 | .295 | .379 | .219 | | .020 | .067 | .116 | .114 |
| Zugkraft % — *vetovoima, %* | 22 | —.109 | —.108 | —.125 | —.187 | —.128 | —.025 | .013 | .008 | .013 | —.111 | —.116 | —.054 | —.051 | —.200 | —.001 | .846 | .117 | .206 | —.117 | —.039 | .009 | | .577 | —.013 | .125 |
| Zugkraft kg — *vetovoima, kg* | 23 | .328 | .328 | .388 | .494 | .442 | .269 | .445 | .467 | .366 | .318 | .319 | .275 | .361 | .497 | .122 | .734 | .141 | .137 | .327 | .289 | .054 | .615 | | .084 | .078 |
| Schrittschnelligkeit — *käyntiaika* | 24 | .121 | .088 | .121 | —.100 | —.044 | .054 | .107 | .029 | .195 | .047 | —.064 | —.112 | —.129 | —.037 | —.077 | .088 | .265 | .157 | .128 | .018 | .249 | .033 | .070 | | .286 |
| Trabschnelligkeit — *juoksuaika* | 25 | —.128 | —.189 | —.115 | —.207 | —.246 | —.042 | .030 | —.027 | .236 | .085 | .004 | .107 | .019 | —.207 | —.049 | .275 | .156 | .555 | —.036 | .062 | .250 | .245 | .111 | .317 | |

Tabelle 3. Die Interkorrelationen der Eigenschaften bei 5jährigen Stuten. Im oberen Feld die phänotypischen, im unteren die genetischen Korrelationen

*Taulukko 3. Ominaisuuksien interkorrelaatiot 5-vuotiailla tammoilla. Yläkentässä fenotyyppiset, alakentässä geneettiset korrelaatiot*

| | | 1 | 2 | 3 | 4 | 5 | 6 | 7 | 8 | 9 | 10 | 11 | 12 | 13 | 14 | 15 | 16 | 17 | 18 | 19 | 20 | 21 | 22 | 23 | 24 | 25 |
|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|
| Widerristhöhe — *säkäkorkeus* | 1 | | .967 | .715 | .592 | .727 | .365 | .560 | .488 | .647 | .601 | .517 | .515 | .481 | .682 | —.049 | —.081 | .024 | —.034 | .218 | .113 | .030 | —.039 | .422 | .068 | .044 |
| Kruppenhöhe — *lautaskorkeus* | 2 | .954 | | .714 | .591 | .712 | .371 | .550 | .483 | .646 | .598 | .527 | .518 | .495 | .681 | —.047 | —.077 | .013 | —.038 | .195 | .089 | .016 | —.033 | .425 | .052 | .027 |
| Rumpflänge — *vartalon pituus* | 3 | .619 | .615 | | .630 | .679 | .474 | .622 | .581 | .681 | .641 | .587 | .548 | .548 | .805 | .045 | —.058 | —.009 | —.013 | .410 | .339 | .037 | —.008 | .529 | .079 | .012 |
| Brustumfang — *rinnan ympärys* | 4 | .393 | .395 | .488 | | .730 | .639 | .657 | .680 | .554 | .563 | .558 | .535 | .500 | .963 | .384 | —.165 | .052 | —.035 | .532 | .516 | .011 | —.115 | .552 | .003 | —.078 |
| Brusttiefe — *rinnan syvyys* | 5 | .619 | .632 | .551 | .695 | | .423 | .579 | .535 | .584 | .575 | .579 | .538 | .516 | .775 | .095 | —.095 | .013 | —.044 | .371 | .328 | .036 | —.035 | .478 | —.021 | —.043 |
| Brustbreite — *ryntään leveys* | 6 | .257 | .268 | .401 | .541 | .229 | | .606 | .678 | .451 | .489 | .427 | .436 | .387 | .640 | .345 | —.023 | .117 | .072 | .528 | .548 | .077 | —.007 | .439 | .102 | —.006 |
| Vordere Kruppenbreite — *lautasen etuleveys* | 7 | .431 | .421 | .539 | .532 | .439 | .574 | | .825 | .595 | .573 | .475 | .528 | .460 | .700 | .257 | —.048 | .063 | .032 | .484 | .424 | .101 | —.031 | .459 | .093 | .003 |
| Hintere Kruppenbreite — *lautasen takaleveys* | 8 | .376 | .366 | .503 | .599 | .411 | .666 | .779 | | .543 | .543 | .462 | .501 | .462 | .705 | .357 | —.023 | .104 | .053 | .537 | .557 | .063 | —.018 | .481 | .078 | .007 |
| Knieumfang — *polven ympärys* | 9 | .515 | .539 | .572 | .413 | .404 | .423 | .547 | .479 | | .799 | .694 | .725 | .639 | .641 | .038 | .051 | —.042 | .049 | .379 | .298 | .092 | .046 | .500 | .133 | .062 |
| Umfang des Vorderbeines — *etusäären ympärys* | 10 | .441 | .456 | .502 | .490 | .403 | .550 | .549 | .527 | .751 | | .842 | .783 | .698 | .637 | .030 | —.005 | —.058 | .019 | .380 | .316 | .106 | .005 | .451 | .099 | .057 |
| Vorderbeinbreite — *etusäären leveys* | 11 | .245 | .282 | .381 | .522 | .439 | .410 | .364 | .386 | .553 | .776 | | .750 | .750 | .616 | .050 | .015 | —.127 | —.010 | .317 | .287 | .044 | .002 | .450 | —.017 | .031 |
| Umfang des Hinterbeines — *takasäären ympärys* | 12 | .323 | .362 | .466 | .458 | .357 | .452 | .510 | .468 | .656 | .774 | .703 | | .857 | .598 | .042 | .003 | —.094 | .004 | .318 | .304 | .106 | .022 | .430 | .049 | .029 |
| Hinterbeinbreite — *takasäären leveys* | 13 | .275 | .326 | .425 | .448 | .379 | .378 | .381 | .411 | .520 | .661 | .783 | .813 | | .557 | .050 | .010 | —.105 | .003 | .272 | .239 | .044 | .013 | .403 | —.024 | .028 |
| Gewichtsabschätzung — *painon arvio* | 14 | .515 | .520 | .701 | .958 | .737 | .574 | .601 | .648 | .508 | .560 | .546 | .517 | .493 | | .307 | —.146 | .038 | —.032 | .536 | .503 | .022 | —.092 | .594 | .028 | —.055 |
| Feistheitsgrad — *lihavuusaste* | 15 | —.267 | —.269 | —.030 | .367 | —.095 | .334 | .182 | .323 | —.013 | .020 | .096 | .042 | .058 | .286 | | —.070 | .099 | .031 | .333 | .378 | .025 | —.056 | .161 | —.028 | —.025 |
| Stufenzahl — *porrasluku* | 16 | —.186 | —.158 | —.039 | —.258 | —.224 | —.055 | —.140 | —.087 | .070 | —.074 | —.032 | —.039 | .013 | —.236 | —.039 | | .040 | .214 | .009 | .000 | .056 | .702 | .701 | .090 | .166 |
| Bewegungen — *liikkeet* | 17 | .214 | .178 | .109 | .032 | .097 | .082 | .073 | .197 | —.001 | —.056 | —.259 | —.186 | —.204 | .070 | —.005 | .003 | | .164 | .198 | .180 | .209 | .046 | .065 | .158 | .103 |
| Charakter und Temperament — *luonne* | 18 | —.088 | —.117 | —.080 | —.212 | —.188 | .065 | —.074 | —.029 | .038 | .030 | —.061 | —.023 | —.066 | —.189 | —.010 | .362 | .167 | | .167 | .128 | .157 | .141 | .154 | .291 | .465 |
| Typen — *tyypit* | 19 | .146 | .082 | .387 | .490 | .339 | .492 | .445 | .479 | .316 | .353 | .230 | .255 | .173 | .513 | .299 | —.053 | .191 | .096 | | .760 | .232 | —.000 | .394 | .114 | .018 |
| Rumpf — *runko* | 20 | .060 | .000 | .307 | .518 | .318 | .460 | .331 | .525 | .244 | .302 | .251 | .290 | .177 | .521 | .387 | —.105 | .174 | .071 | .738 | | .158 | —.004 | .363 | .084 | .016 |
| Beine — *jalat* | 21 | .006 | —.019 | .104 | .037 | —.008 | .183 | .265 | .117 | .199 | .188 | —.016 | .160 | .029 | .067 | .021 | .006 | .177 | .213 | .409 | .208 | | .052 | .065 | .090 | .060 |
| Zugraft % — *vetovoima, %* | 22 | —.171 | —.139 | —.031 | —.250 | —.204 | —.042 | —.134 | —.104 | .049 | —.067 | —.033 | —.011 | .002 | —.222 | —.011 | .823 | .030 | .295 | —.041 | —.094 | .017 | | .513 | .070 | .130 |
| Zugkraft kg — *vetovoima, kg* | 23 | .243 | .276 | .508 | .500 | .372 | .400 | .334 | .410 | .454 | .362 | .390 | .363 | .395 | .555 | .182 | .666 | .064 | .164 | .339 | .292 | .057 | .552 | | .098 | .096 |
| Schrittschnelligkeit — *käyntiaika* | 24 | .149 | .098 | .150 | —.126 | —.124 | .085 | .138 | .099 | .212 | .147 | —.136 | .059 | —.082 | —.044 | —.132 | .090 | .312 | .377 | .140 | .072 | .301 | .097 | .045 | | .333 |
| Trabschnelligkeit — *juoksuaika* | 25 | .057 | .022 | —.045 | —.240 | —.215 | .002 | —.044 | —.018 | .002 | .052 | —.021 | —.033 | —.036 | —.194 | —.067 | .123 | .085 | .485 | —.101 | —.093 | .056 | .117 | —.041 | .468 | |

Tabelle 4. Die aus dem Material 4- und 5jähriger Stuten erhaltenen rotierten Faktoren [1])

*Taulukko 4. Neli- ja viisivuotiaasta tamma-aineistosta saadut rotatoidut faktorit.* [1])

| | Aus den Phänotypkorrelationen berechnet *Fenotyyppikorrelaatioista laskettuna* | | | | | | | | | |
|---|---|---|---|---|---|---|---|---|---|---|
| | 4 | 5 | 4 | 5 | 4 | 5 | 4 | 5 | 4 | 5 |
| Zugkraft kg — *vetovoima, kg* | 41 | 45 | 79 | 75 | 30 | 33 | 06 | 06 | 22 | 22 |
| Zugkraft % — *vetovoima, %* | —10 | —05 | 90 | 87 | —04 | —05 | 06 | 08 | —01 | —01 |
| Schrittschnelligkeit — *käyntinopeus* | 27 | 11 | —05 | 01 | —05 | —01 | 59 | 67 | —12 | —05 |
| Stufenzahl — *porrasluku* | —09 | —10 | 95 | 94 | —07 | —05 | 11 | 13 | —01 | 02 |
| Trabschnelligkeit — *juoksunopeus* | —04 | 01 | 10 | 09 | —11 | —12 | 70 | 73 | 08 | 05 |
| Bewegungen — *liikkeet* | 00 | 13 | 07 | 01 | 29 | 25 | 50 | 39 | —19 | —38 |
| Charakter und Temperament — *luonne* | —04 | —07 | 13 | 14 | 03 | 08 | 73 | 73 | 04 | 01 |
| Typen — *tyypit* | 13 | 17 | —01 | 03 | 75 | 77 | 25 | 20 | 24 | 17 |
| Rumpf — *runko* | 05 | 07 | 03 | 03 | 80 | 82 | 22 | 14 | 20 | 16 |
| Beine — *jalat* | —12 | —08 | —05 | —01 | 18 | 18 | 49 | 37 | 18 | 11 |
| Widerristhöhe — *säkäkorkeus* | 90 | 92 | —00 | —01 | —03 | —04 | 03 | 04 | 28 | 22 |
| Kruppenhöhe — *lautaskorkeus* | 89 | 92 | 00 | —00 | —03 | —05 | 01 | 02 | 28 | 23 |
| Rumpflänge — *vartalon pituus* | 71 | 75 | 01 | 04 | 22 | 23 | 02 | 02 | 40 | 35 |
| Brustumfang — *rinnan ympärys* | 62 | 65 | —03 | —04 | 60 | 58 | —07 | —11 | 26 | 23 |
| Brusttiefe — *rinnan syvyys* | 74 | 77 | 00 | 01 | 23 | 24 | —04 | —07 | 27 | 27 |
| Brustbreite — *ryntään leveys* | 27 | 37 | 01 | 04 | 67 | 66 | 01 | 07 | 24 | 23 |
| Vordere Kruppenbreite — *lautasen etuleveys* | 57 | 59 | 01 | 01 | 43 | 50 | 05 | 06 | 37 | 26 |
| Hintere Kruppenbreite — *lautasen takaleveys* | 46 | 51 | 02 | 04 | 61 | 63 | 03 | 05 | 32 | 24 |
| Knieumfang — *polven ympärys* | 44 | 56 | 04 | 09 | 10 | 17 | 11 | 13 | 71 | 62 |
| Umfang des Vorderbeines — *etusäären ympärys* | 36 | 47 | —00 | 02 | 14 | 19 | 04 | 11 | 82 | 75 |
| Vorderbeinbreite — *etusäären leveys* | 29 | 39 | 01 | 05 | 16 | 17 | —02 | —01 | 83 | 79 |
| Umfang des Hinterbeines — *takasäären ympärys* | 25 | 36 | 03 | 04 | 15 | 19 | 01 | 05 | 87 | 82 |
| Hinterbeinbreite — *takasäären leveys* | 28 | 33 | 05 | 04 | 12 | 15 | —03 | —01 | 84 | 81 |
| Gewichtsabschätzung — *painon arvio* | 71 | 74 | —02 | —02 | 53 | 52 | —05 | —07 | 33 | 29 |
| Feistheitsgrad — *lihavuusaste* | —03 | —05 | —00 | —03 | 67 | 69 | —11 | —09 | —17 | —10 |
| | Aus den genetischen Korrelationen berechnet *Geneettisistä korrelaatioista laskettuna* | | | | | | | | | |
| | 4 | 5 | 4 | 5 | 4 | 5 | 4 | 5 | 4 | 5 |
| Zugkraft kg — *vetovoima, kg* | 38 | 33 | 81 | 79 | 31 | 38 | 04 | —08 | 20 | 26 |
| Zugkraft % — *vetovoima, %* | —11 | —11 | 92 | 89 | —06 | —10 | 08 | 12 | —06 | —02 |
| Schrittschnelligkeit — *käyntinopeus* | 19 | 16 | —01 | 02 | —09 | 05 | 66 | 80 | —14 | —06 |
| Stufenzahl — *porrasluku* | —10 | —12 | 95 | 94 | —07 | —11 | 11 | 13 | —05 | —01 |
| Trabschnelligkeit — *juoksunopeus* | —25 | —04 | 25 | 04 | —15 | —18 | 65 | 69 | 21 | 07 |
| Bewegungen — *liikkeet* | 17 | 35 | 07 | 04 | 25 | 26 | 60 | 34 | —30 | —49 |
| Charakter und Temperament — *luonne* | —25 | —14 | 20 | 33 | 09 | 03 | 65 | 66 | 12 | —02 |
| Typen — *tyypit* | 21 | 13 | —08 | 02 | 71 | 80 | 30 | 15 | 23 | 06 |
| Rumpf — *runko* | —01 | 03 | —01 | —02 | 79 | 82 | 21 | 04 | 21 | 08 |
| Beine — *jalat* | —06 | —03 | —08 | —07 | 17 | 33 | 62 | 50 | 15 | 04 |
| Widerristhöhe — *säkäkorkeus* | 93 | 92 | —02 | —10 | —06 | —01 | 03 | 08 | 18 | 16 |
| Kruppenhöhe — *lautaskorkeus* | 93 | 92 | —01 | —06 | —08 | —05 | —02 | 02 | 16 | 21 |
| Rumpflänge — *vartalon pituus* | 78 | 69 | —04 | 11 | 19 | 31 | 03 | 02 | 31 | 29 |
| Brustumfang — *rinnan ympärys* | 56 | 42 | —03 | —07 | 64 | 66 | —14 | —34 | 31 | 32 |
| Brusttiefe — *rinnan syvyys* | 80 | 72 | 02 | —06 | 23 | 28 | —16 | —30 | 22 | 20 |
| Brustbreite — *ryntään leveys* | 12 | 17 | —01 | 02 | 69 | 64 | 06 | 12 | 28 | 38 |
| Vordere Kruppenbreite — *lautasen etuleveys* | 55 | 41 | 09 | —09 | 47 | 52 | 18 | 13 | 36 | 37 |
| Hintere Kruppenbreite — *lautasen takaleveys* | 40 | 35 | 11 | —01 | 71 | 67 | 09 | 07 | 28 | 31 |
| Knieumfang — *polven ympärys* | 38 | 47 | 07 | 13 | 13 | 21 | 32 | 20 | 68 | 61 |
| Umfang des Vorderbeines — *etusäären ympärys* | 35 | 33 | —04 | —03 | 16 | 26 | 10 | 18 | 83 | 79 |
| Vorderbeinbreite — *etusäären leveys* | 23 | 15 | —02 | 05 | 23 | 19 | —06 | —14 | 84 | 85 |
| Umfang des Hinterbeines — *takasäären ympärys* | 13 | 22 | —00 | 02 | 20 | 21 | 02 | 06 | 90 | 85 |
| Hinterbeinbreite — *takasäären leveys* | 24 | 18 | 05 | 09 | 18 | 13 | —07 | —10 | 86 | 84 |
| Gewichtsabschätzung — *painon arvio* | 69 | 55 | —05 | —03 | 56 | 63 | —10 | —25 | 35 | 35 |
| Feistheitsgrad — *lihavuusaste* | —17 | —36 | 05 | 04 | 68 | 65 | —17 | —17 | —14 | 02 |

[1]) Die Ladungen ohne an der Stelle der Einer stehende Nullen und ohne Dezimalpunkte angegeben.

[1]) *Lataukset merkitty ilman kokonaisnollia ja desimaalipisteitä.*

beiden Stutenmaterialien und dem der 5jährigen Hengste ziemlich viele Berührungspunkte zu erkennen sind. Doch ist zu bemerken, dass die Faktoren in diesen verschiedenen Veröffentlichungen in ungleicher Reihenfolge angegeben sind.

In dem folgenden Deutungsversuch wird das Hauptgewicht möglichst auf die Faktorladungen gelegt, die sich auf die genetischen Korrelationen gründen.

## Die Faktoren der Leistungsfähigkeit

### *Faktor II*

Der zweite Faktor ist der sehr deutlich umrissene Zugkraftfaktor (V), der über beträchtlich grosse Ladungen in den nur die Zugkraft auf verschiedene Weise spiegelnden Eigenschaften verfügt. Alle übrigen Ladungen, besonders die im Phänotyp erkannten, sind so gering, dass die Zugkraft — nach Verfassers Anschauung — als eine ganz selbständige, mit keinem anderen Zug verknüpfte Eigenschaft angesehen werden muss. Eine unsichere Ausnahme bildet der Charakter, in dem der Faktor, besonders nach den genetischen Korrelationen beurteilt, eine wahrnehmbare Ladung besitzt. Die Stufenzahl erweist sich in der vorliegenden Untersuchung als bestes Mass der Zugkraft. [1]) Dieser Umstand betont seinerseits die Notwendigkeit, die für ungleichaltrige Pferde abzustufenden Widerstandsforderungen zu präzisieren, und zwar so, dass die verschiedenen Altersklassen bei der Endbewertung unter den der wirklichen Zugkraft entsprechenden Voraussetzungen miteinander wetteifern könnten.

### *Faktor IV*

Der andere Faktor der Leistungsfähigkeit, Nr. IV, ist der ebenfalls sehr deutlich abgehobene Geschwindigkeits- und Temperamentfaktor (NT), dessen grösste Ladungen in der Schritt- und Renngeschwindigkeit sowie im Charakter liegen, wenn die genetischen Korrelationen Ausgangspunkt der Berechnungen sind. Nach den Phänotypkorrelationen berechnet, ist die Grössenreihenfolge der Ladungen umgekehrt, obschon die Differenzen gring sind. Auch bei meinem früher (VARO 1965a) bearbeiteten Hengstmaterial hat der Charakter in dem entsprechenden Faktor eine so zentrale Stellung eingenommen, dass Verfasser ihn als Charakterfaktor bezeichnet hat. Wie oben bereits angeführt, dürfte dem Stutenmaterial sowohl wegen seines grösseren Umfangs als auch in Anbetracht der ihm zugewandten schwächeren Auslese eine beträchtlichere Bedeutung beizulegen sein, so dass es begründet gewesen ist, die Benennung des Faktors zu revidieren.

Dieser Faktor weist darauf hin, dass auch Geschwindigkeit und Charakter recht unabhängig vom Körperbau und auch von der Zugkraft sind. Eine deutliche Ausnahme bilden nur die Beine. Mit der grossen Geschwindigkeit scheint sich demgemäss eine durch Punkte gutgeheissene Beinbildung zu verbinden. Somit ist es vielleicht gelungen, die Beurteilung der Beine so zu fassen, dass sie die für Traber geeignete Beinbildung bevorzugt. Dies braucht indessen nicht unbedingt zu besagen, dass ein hoher Punktwert der Beine zugleich ein Indikator der für das Arbeitspferd am besten geeigneten Beinbildung wäre (vgl. VARO 1965b).

Insbesondere lassen die auf genetische Korrelationen gegründeten Faktorladungen des weiteren erkennen, dass der Faktor in den Umfangs- und Tiefenmassen der Brust negative, wenn auch schwache Ladungen hat. Dies kann wohl auf einen geringen Zusammenhang zwischen Geschwindigkeit und Hochbeinigkeit gedeutet werden.

Es dürfte nur natürlich sein, dass auch die Regelmässigkeit der Bewegungen zu denjenigen Eigenschaften gehört, die durch diesen Faktor

[1]) Dieses Resultat wird auch von der Heritabilitätsuntersuchungen Verfassers (VARO 1965b) gestützt.

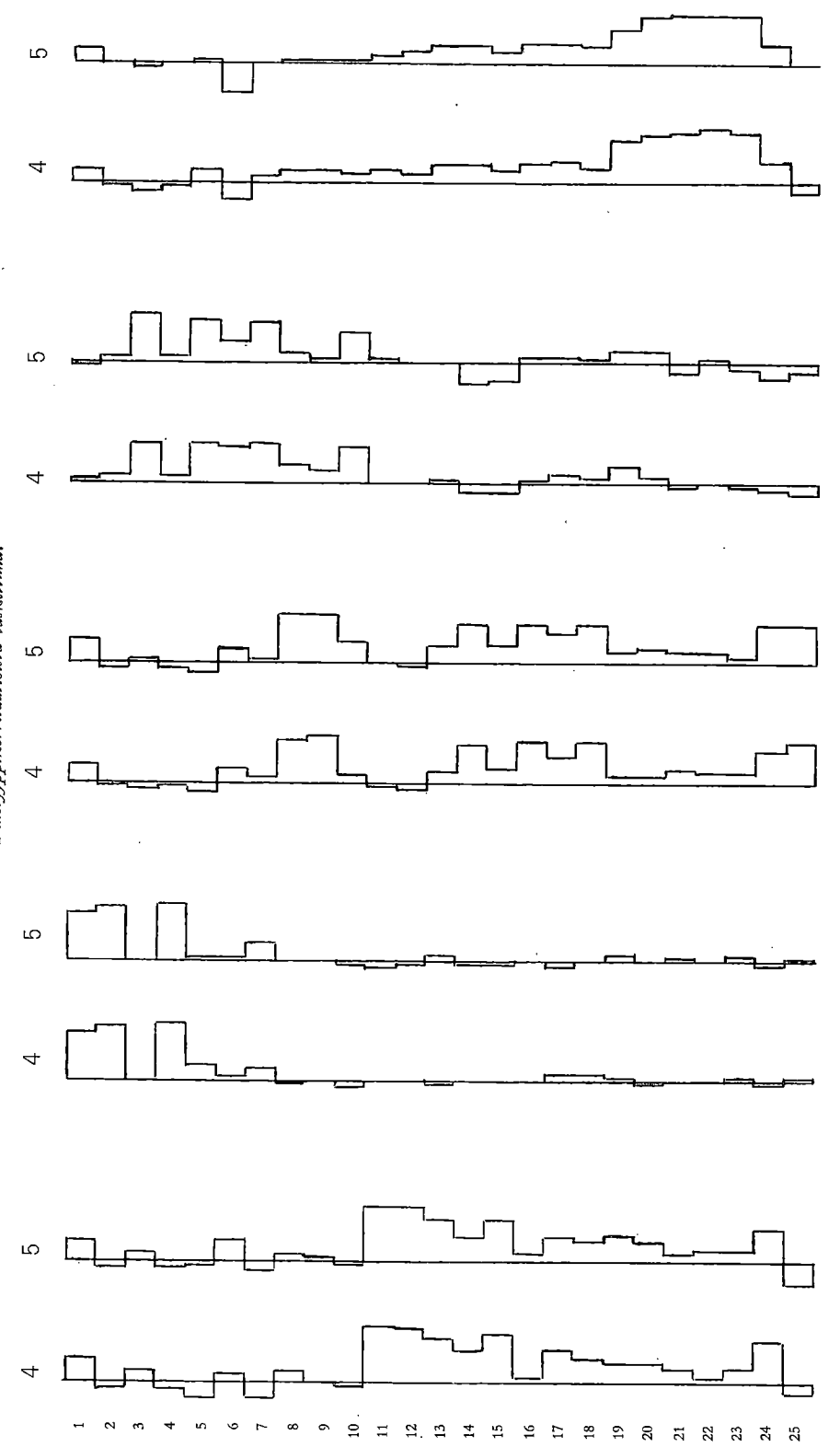
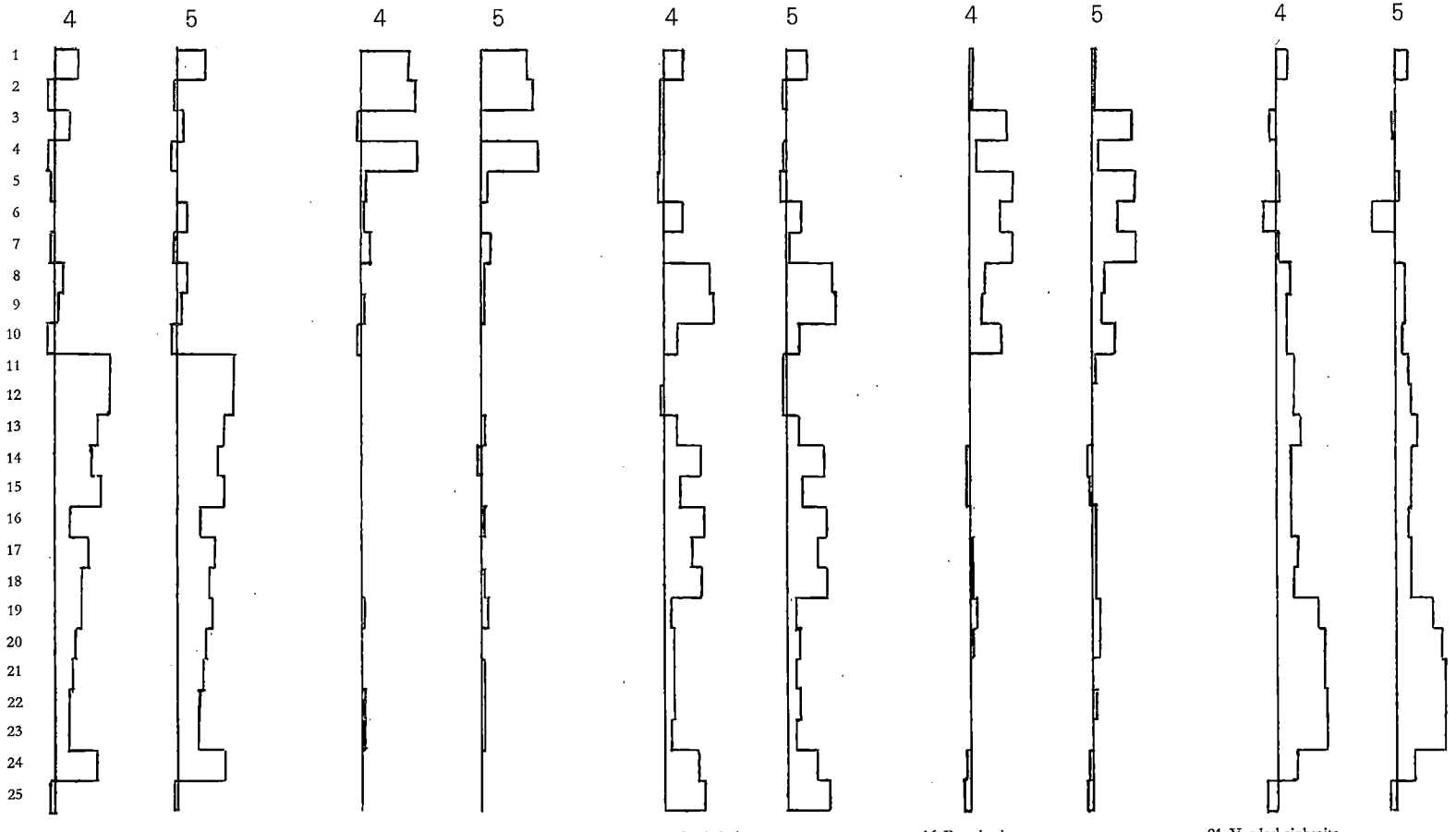



Abbildung 1. Die aus dem Material 4- und 5jähriger Stuten erhaltenen rotierten Faktoren.
*Kuva 1. Neli- ja viisivuotiaista tamma-aineistosta saadut rotatoidut faktorit.*

Aus den Phänotypkorrelationen berechnet.
*Fenotyppikorrelaatioista lasketttuna.*

Aus den genetischen Korrelationen berechnet.
*Geneettisistä korrelaatioista laskettuna.*




1 Zugkraft kg
*Vetovoima, kg*
2 Zugkraft %
*Vetovoima, %*
3 Schrittschnelligkeit
*Käyntinopeus*
4 Stufenzahl
*Porrasluku*
5 Trabschnelligkeit
*Juoksunopeus*

6 Bewegungen
*Liikkeet*
7 Charakter und Temperament
*Luonne*
8 Typen
*Tyypit*
9 Rumpf
*Runko*
10 Beine
*Jalat*

11 Widerristhöhe
*Säkäkorkeus*
12 Kruppenhöhe
*Lantaskorkeus*
13 Rumpflänge
*Vartalon pituus*
14 Brustumfang
*Rinnan ympärys*
15 Brusttiefe
*Rinnan syvyys*

16 Brustbreite
*Ryntään leveys*
17 Vordere Kruppenbreite
*Lantasen etuleveys*
18 Hintere Kruppenbreite
*Lantasen takaleveys*
19 Knieumfang
*Polven ympärys*
20 Umfang des Vorderbeines
*Etusäären ympärys*

21 Vorderbeinbreite
*Etusäären leveys*
22 Umfang des Hinterbeines
*Takasäären ympärys*
23 Hinterbeinbreite
*Takasäären leveys*
24 Gewichtsabschätzung
*Painon arvio*
25 Feistheitsgrad
*Lihavuusaste*

geregelt werden. Es mag einleuchten, dass regelmässige Bewegungen Voraussetzung einer grossen Trabgeschwindigkeit ist.

Dass die Schrittgeschwindigkeit der beste Messwert dieses Faktors zu sein scheint, steht in gewissem Masse in Einklang mit der Aussage FROELICHS (1926), dass »ein guter Schritt ein ziemlich sicheres Kennzeichen auch für alle anderen guten Gänge ist, während umgekehrt die letzteren noch nicht einen regelmässigen und fördernden Schritt bedingen».

Besonders im älteren Schrifttum hat man das Verhältnis zwischen Körperbau und Leistungsfähigekit viel bearbeitet (z.B. FROELICH 1926) und ist zu der Auffassung gekommen, dass eine gute Leistungsfähigkeit beim Körperbau gewisse Massverhältnisse voraussetzt. Diese Auffassung hat im übrigen die Pferdezucht recht stark geprägt. In neueren Arbeiten hat die Auffassung über Leistungsfähigkeit sich geändert. So schreibt LÖRTSCHER (1958) u.a.: »Für kein anderes Nutztier bestimmen Körperbau und -verfassung den Gebrauchswert in so hohem Masse wie beim Pferd. Seiner Exterieurbeurteilung kommt deshalb im Handel wie in der Zucht erhöhte Bedeutung zur Abschätzung der Leistungseignung zu.» Aber er setzt fort: »Die Schnelligkeit, der Mut und die Ausdauer des Reitpferdes und die Kraft und der Arbeitswille des Zugpferdes lassen sich aber erst in der Renn- und Zugnutzung effektiv ermitteln.» Dies trifft zweifellos alles zu, aber es dürfte sich darum handeln, ob man den zweckmässigen Körperbau überhaupt zu bewerten versteht, da es so ausserordentlich viele auf die Leistungsfähigkeit einwirkende Teilfaktoren gibt. Zum mindesten stützen die Ergebnisse der vorliegenden Untersuchung diesen skeptischen Standpunkt. Zugleich sprechen sie für das Verfahren, bei dem die Leistungsproben den Ausgangspunkt der Zuchtwahl bilden und bei dem man den Körperbau sich frei entwickeln lässt. Hier sei des weiteren hingewiesen auf die Auffassung KRÜGERS (1958), wenn er u.a. sagt: »Über die Grösse, Beschaffenheit und Funktionstüchtigkeit der Organe, über die Zusammenarbeit von Körperteilen und Körperfunktionen, über Willen, Temperament, Naturell kann die Exterieurbeurteilung nicht, nicht genügend oder nur während einer Leistungsprüfung aussagen.»

Ich nehme an, dass diese Auffassungen durch die nunmehr gewonnenen Ergebnisse der Faktoranalyse eine starke Stütze erhalten, ebenso wie auch die folgenden Gedanken KRÜGERS: »Geschwindigkeitsprüfungen sind kein Ersatz für Dauerkraftprüfungen» oder: »Die Zug- und Rennleistungsprüfungen sind gleichzeitig Prüfungen für die physiologische Leistungsfähigkeit und für die Psyche eines Tieres und damit für wichtige Grundlagen der Konstitution.»

Obschon sich zwischen Exterieur und Leistungsfähigkeit gar kein deutlicher Zusammenhang zu erkennen lässt, ist das Ausmerzen direkter Fehler im Körperbau (und im Charakter) angebracht.

Die absolute Zugkraft schwerer und grosser Pferde ist natürlich grösser als die der leichten und kleinen. Das geht auch aus den jetzt erhaltenen Ergebnissen hervor, sowohl schon aus den Korrelationskoeffizienten als auch aus den weiter unten zu besprechenden Faktoren I, III und V.

## Die Körperbaufaktoren

### *Faktor I*

Der erste Faktor scheint vor allem Höhe, Brusttiefe und Rumpflänge zu regeln; es ist der Faktor, der sich in der in diesen Eigenschaften hervortretenden Varianz am meisten auswirkt. Sein Einfluss äussert sich, wenn auch zweitrangig, in der Kruppenbreite, aber weniger in den übrigen Breitenmassen. Er ist somit in erster Linie ein in den Höhen- und Längenmassen erscheinender Grössenfaktor (K), dessen sekundäre Wirkung auch das Gewicht und mit ziemlicher Stärke des weiteren die nach Kilogramm bemessene Zugkraft erfasst. Es ist zu beachten, dass dieser Faktor eine mässig grosse, aber der Richtung nach negative Ladung

in den Punktwerten des Feistheitsgrades bedeutet. Die Ladung tritt im Geno- stärker als im Phänotyp hervor. Ferner ist zu beachten, dass das Gewicht der Stuten eine gemessene Gewichtsbewertung ist, deren Abhängigkeit von Brustumfang und Rumpflänge in diesem Falle rein mathematisch sein kann. Dies betrifft selbstverständlich auch die übrigen Faktoren, die über beträchtliche Ladungen in den genannten Eigenschaften verfügen. Doch kann angeführt werden, dass das wirkliche Gewicht des Hengstmaterials von den einzelnen Faktoren auf recht ähnliche Weise wie das abgeschätzte Gewicht der Stuten abhängig zu sein scheint.

*Faktor III*

Der Anteil des dritten Faktors an der Varianz des Gewichtes ist von gleicher Grössenordnung wie der des ersten. Während aber der Einfluss des ersten Faktors auf das Gewicht offenbar in erster Linie von der durch ihn geregelten Schwankung der Grösse abhängig ist, vollzieht sich der des dritten in hohem Masse gemäss der Varianz des Feistheitsgrades. Darauf weist ausser der erheblich grossen Ladung im Feistheitsgrad selber auch der starke Einfluss des Faktors auf diejenigen Eigenschaften — hintere Kruppenbreite und Brustbreite — hin, bei denen auch der Anteil des übrigen Gewebes, nicht nur der des Knochengerüstes beträchtlich auf das Messungsergebnis einwirkt. Auch das Mass des Brustumfangs untersteht den Schwankungen des Feistheitsgrades.

Der Faktor besitzt die grössten Ladungen in den Punktwerten des Rumpfes und der Typen. Es ist offensichtlich, dass auch bei der visuellen Beurteilung dieser Züge der Feistheitsgrad seine eigene Stelle einnimmt. Damit soll indessen nicht geleugnet werden, dass der jetzt in Rede stehende Faktor wirklich auch diejenigen Verhältnisse und Masse — vor allem Breitenmasse — regelte, die in die Vorstellung von einem wohlgebauten Arbeitspferd eingehen. Die Deutung des Faktors ist schwierig, und vorläufig hat man sich wohl damit zu begnügen, ihn als Massivitätsfaktor (M) zu bezeichnen. Die mittelmässige Ladung in der nach Kilogramm angegebenen Zugkraft mag gerade eine Folge der Massivitätsschwankung sein.

*Faktor V*

Der fünfte Faktor ist trotz seinen klaren Zügen schwer auszulegen. Seine Wirkung beschränkt sich auf die Regelung der Beinmasse, woneben er eine mittelmässige negative Ladung in den Bewegungen hat. In gewissem Grade regelt er auch andere Masse, ist aber in dieser Beziehung ein viel schwächerer Faktor als I und II. Vorläufig hat man sich bei der Beschreibung dieses Faktors mit der groben Benennung dritter Körperbaufaktor (R) zu begnügen.

## Besprechung der Ergebnisse

Die nunmehr erhaltenen Ergebnisse der Faktoranalyse haben vom Blickpunkt der finnischen Pferdezucht keine umwälzende neue Kenntnis gebracht, dürften aber doch die von den Forschern selbst gebildeten Auffassungen von den Zusammenhängen zwischen den zu züchtenden Eigenschaften geklärt und bestätigt haben. Vor allem hat sich dabei das Messen der Zugkraft als in bezug auf das Gewicht ($\approx$ Grösse) relative Zugkraft als richtig erwiesen. Ferner ist aus den Resultaten zu schliessen, dass die auf Muskelkraft und energische, ruhige Zugweise gegründete, vom Gewicht ($\approx$ von der Grösse) unabhängige Zugkraft, nur durch Zugproben gemessen, des weiteren zu entwickeln ist. Ebensowenig ist das Entwickeln der vom Arbeitspferd geforderten Zugkraft durch Steigern der Trabgeschwindigkeit möglich — umgekehrt wie man in Finnland so allgemein angenommen hat —, da das Entfallen von Zugkraft und Geschwindigkeit auf verschiedene Faktoren deren gegenseitige Unabhängigkeit erweist. Etwas ganz

anderes ist es, wenn man vom Arbeitspferd neben der Zugkraft auch eine mittelmässige Schrittgeschwindigkeit und Regsamkeit verlangt; diese Eigenschaften sind durch eine Gangprüfung am besten zu beurteilen.

Es ist bedauerlich, dass die Festigkeit bei der Beurteilung des Exterieurs der Pferde unberücksichtigt geblieben ist. Sie hätte die zwischen den Faktoren des Körperbaus bestehenden Unterschiede beleuchten und ihrerseits auch die Ähnlichkeit der mit den Hengst- und Stutenmaterialien gewonnenen Ergebnisse verbessern können.

## Zusammenfassung

Auf Grund der Interkorrelationen der in der Stammbucheintragung von insgesamt 2354 Stuten registrierten Eigenschaften ist eine Faktoranalyse angestellt worden. Die fünf vorgenommenen Faktoren waren in den Materialien der 4- wie auch der 5jährigen Stuten übereinstimmend, desgleichen nach Berechnung der Phänotyp- wie auch der genetischen Korrelationen. Insbesondere die Faktoren der Leistungsfähigkeit, sowohl die Zugkraft als auch der Geschwindigkeits- und Temperamentfaktor, waren ihren Ladungen nach recht ähnlich wie die früher bei dem Hengstmaterial ermittelten entsprechenden Faktoren. Dies weist darauf hin, dass es möglich ist, durch Faktoranalysen Eigenschaftsgruppen zu bilden, die, durch ihre gemeinsamen Faktoren geregelt, eng miteinander verbunden zu sein scheinen, während sie zugleich als Gruppen voneinander unabhängig sind. Von dieser Grundlage aus betrachtet, weist das Ergebnis darauf hin, dass die Leistungsfähigkeit des Pferdes, mag es sich nun um die Zugkraft oder die Geschwindigkeit handeln, eine vom äusseren Körperbau unabhängige Neigung ist, die nur durch Leistungsprüfungen beurteilt und, auf deren Ergebnisse gestützt, gezüchtet werden kann.

## LITERATUR

FALCONER, D. S. 1960. Introduction to Quantitative Genetics, 365 p. Edinburgh and London.

FROELICH, G. 1926. Lehrbuch der Pferdezucht. 682 p. Berlin.

HARMAN, H. H. 1960. Modern Factor Analysis. 469 p. Chicago.

KRÜGER, L. 1958. Leistungskontrolle in der Haustierzucht. 4. Leistungsprüfungen in der Pferdezucht. Handb. der Tierzüchtung. Band 1, pp. 475—481. Hamburg und Berlin.

LÖRTSCHER, H. 1958. Die Beurteilung des Gebrauchswertes der Haustiere auf Grund ihres Exterieurs. Ibid. 1, pp. 489—515.

VAHERVUO, T. & AHMAVAARA, Y. 1958. Johdatus faktorianalyysiin. 183 s. Porvoo.

VARO, M. 1947. Hevosen iän ja vetovoiman keskinäisestä suhteesta. Koetoim. ja käyt. 4.

—»— 1965a. Über die Zusammenhang der bei Pferden zu Züchtenden Züge. Die Hengste. Selostus: Hevosen jalostettavien ominaisuuksien keskinäisestä yhteydestä. Oriit. Ann. Agric. Fenn. 4: 38—45.

—»—1965b. Some coefficients of heritability in horses, Selostus: Hevosen eräiden ominaisuuksien periytyvyydestä. Ibid. 4: 223—237.

SELOSTUS

# Hevosen jalostettavien ominaisuuksien keskinäisestä yhteydestä

## Tammat

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Yhteensä 2 354 tamman kaptakirjauksessa rekisteröityjen ominaisuuksien interkorrelaatioiden perusteella on suoritettu faktorianalyysi. Otetut viisi faktoria eli tekijää olivat sangen yhdenmukaiset sekä 4- että 5-vuotiaiden tammojen aineistoissa samoin kuin sekä fenotyyppiettä geneettisistä korrelaatioista laskettuina. Erityisesti suorituskyvyn faktorit, niin vetovoima (V) kuin nopeus- ja tempperamentti faktorikin (NT), olivat latauksiltaan sangen samanlaisia kuin aikaisemmin oriaineistolla saadut vastaavat faktorit. Tämä viittaa siihen, että faktorianalyysilla on mahdollista muodostaa ominaisuuksista ryhmiä, jotka yhteisten tekijäinsä säätelеminä näyttävät liittyvän läheisesti toisiinsa, samalla kun ne ryhminä ovat toisistaan riippumattomia. Tältä pohjalta tarkasteltuna tulos viittaa siihen, että hevosen suorituskyky, olkoonpa kysymys vetovoimasta tai nopeudesta, on ulkonaisesta rakenteesta riippumaton taipumus, joka on vain suorituskokeilla arvioitavissa ja niiden tuloksiin nojautuen jalostettavissa.

Rakenteen faktoreina erottuivat toisistaan kokofaktori (K), joka säätelee painoa, lähinnä koon (mittojen) vaihtelun, ja massiivisuusfaktori (M), joka puolestaan vaikuttaa painoon lähinnä lihavuusasteen vaihtelun perusteella. Kolmas rakennefaktori (R) näyttää säätelevän lähinnä jalkamittoja.

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# PRELIMINARY TRIALS WITH FODDER CARROTS

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Root crops are the highest-yielding of the crops grown in Finland. They also have a beneficial effect on the condition of the soil, with only clover and other legumes being superior in this respect. Furthermore, root crops are excellent as fodder because of their digestibility and palatability. The main drawback in growing root crops is the high labour cost. Owing to the shortage of labour and rising wages, it appears that interest in cultivating root crops will decline, particularly since leafy fodder crops are easier to cultivate and their entire yield can be readily harvested by forage harvester.

The fodder root crops hitherto grown in Finland have been species of the genera *Brassica* and *Beta*. Only small amounts of carrots have been grown for fodder. In early trials conducted on sandy soil, fodder carrots gave as high dry matter and fodder unit yields as other root crops (SIMOLA 1931). On peat soil, fodder carrots yielded higher than other root crops with the exception of sugar beet (VESIKIVI 1938).

Similarly in Sweden, root fodder crops are mainly those of the genera *Brassica* and *Beta* (SUNDELIN 1924, ELIASSON and SUNDELIN 1949). In Norway the situtation is apparently the same (e.g. GULLI 1929, KLOKK 1930, NISSEN 1947). In early Norwegian trials fodder carrots were not as high-yielding as other root crops (SEBELIEN 1916), but later their succes on peat soil was recognized (HAGERUP 1940).

In Denmark fodder carrots made up about 5 % of the total area devoted to fodder root crops at the beginning of this century (HELWEG 1908, 1911). On sandy soil, applications of farmyard manure resulted in carrot yields superior to those of swede and mangel. When only chemical fertilizers were applied, carrot yields were inferior to the other root crops (HANSEN and HANSEN 1913). In later Danish trials fodder carrots consistently gave lower yields than the other root crops tested (Tidsskr. Planteavl 1930). At the present, fodder carrots are not grown in Denmark.

The reason for the lack of interest in growing carrots as a fodder crop is the fact that they require even higher cultivation costs than other root fodder crops. Owing to their slow germination and sparse foliage, carrots have a very poor competitive ability against weeds. In order to prevent the delicate seedlings from being completely smothered by weeds, it is usually necessary to sow so densely that subsequent thinning is indispensable. Thinning and hand weeding are the main factors which make the growing of carrots more laborious than that of other root crops.

Two new herbicides, prometryne and linuron, now offer the possibility of revolutionizing

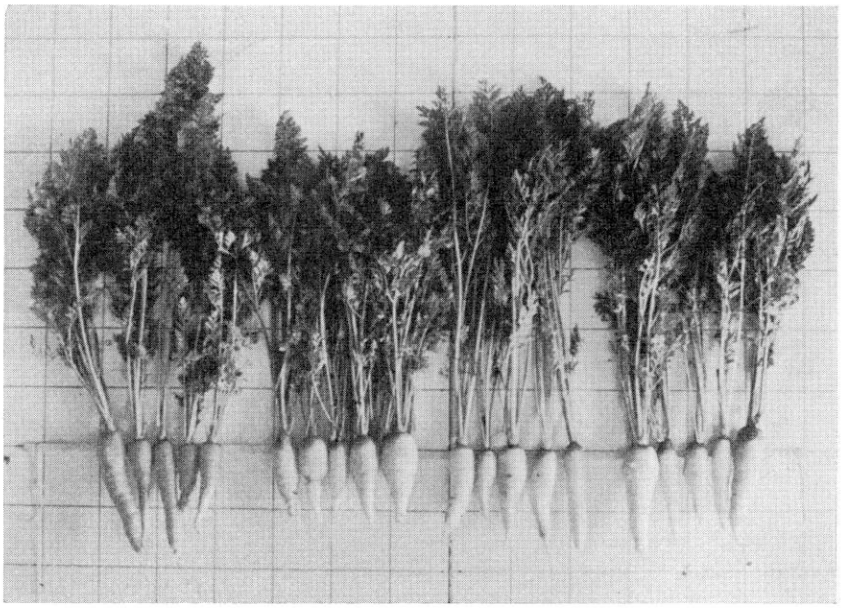

Fig. 1. Fodder carrot varieties grown on clay soil at Tikkurila, 1964. From left: St. Valery, Champion, Rheinische Riesen and Jaune de Lobberich.

carrot cultivation. These compounds control most annual dicotyledonous weeds and keep the soil virtually free of weeds during the entire growing season. Consequently it is not necessary to hand-weed or harrow (cf. Crop production 1963), and seeding can be carried out so sparsely that even thinning can be dispensed with (Table 1).

Table 1. Costs of weeding, thinning and harrowing in some fodder root crop trials at Tikkurila, 1964—65.

| Species | Time hours/ha | Labour cost mk/ha | Rel. |
|---|---|---|---|
| Swede | 360 | 540 | 100 |
| Beet | 360 | 540 | 100 |
| Carrot | 20 | 30 | 6 |

In Finland, the amount of annual grass weeds is negligible. If carrots are sown in soil from which perennial weeds have been eradicated, the only measures required after sowing are herbicidal spraying and, if necessary, control of insect pests. Since the cost of prometryne and linuron treatment amounts to only 100—200 Finnmarks per hectare and will probably decrease in the future, fodder carrots will become — after leafy turnips — the second cheapest root fodder crop to grow in Finland. In the case of *Beta* and *Brassica* species, adequately effective herbicides have not yet been developed. It is true that, at the present, harvesting and storage of carrots involve more difficulties than for other root crops, but these problems, too, may be solved in the future.

Only a few comparative root crop trials using this new method have thus far been conducted in Finland. In 1964 and 1965 trials were arranged by the Department of Plant Husbandry at four locations. Previous to these trials, and partly at the same time, tests were performed in 1963 and 1964 with 13 different varieties of European fodder carrots in order to select the highest-yielding ones for the comparative trials.

## Variety tests

Two variety tests were arranged, one in 1963 on humus soil and the second in 1964 on clay soil; both were located at Tikkurila. Fertilization

Fig. 2. Fodder carrot varieties grown on clay soil at Tikkurila, 1964. From left: Yellow Belgian, White Belgian, Regulus I and Blanche des Vosges.

consisted of a multi-nutrient mixture corresponding to 60 kg N, 55 kg P and 80 kg K per hectare. The seed rate was 0.07—0.11 g per row metre. The average interval between plants in the rows was 3—4 cm, which was perhaps too small, at least for the cone-shaped varieties. After emergence the seedlings were sprayed with prometryne (1.0 kg/ha) in 1963 and with linuron (1.75 kg/ha) in 1964. Two treatments with parathion were made to control insect pests. Otherwise the plots were left undisturbed, i.e. were neither thinned, weeded nor harrowed.

The results (Tables 2 and 3) show that in 1963 the three highest-yielding varieties were Fourragère, Yellow Belgian and Jaune de Lobberich. In the second year 1964 the order was Fourragère, Rheinische Riesen and Yellow Belgian. The average for both years (Table 2) was Fourragère, Yellow Belgian and Rheinische Riesen.

Table 2. Mean yields of 13 European fodder carrot varieties in two trials at Tikkurila, 1963—64.

| Variety | Roots | | Tops | | Total dry matter | |
|---|---|---|---|---|---|---|
| | fresh yield tons/ha | dry matter kg/ha | fresh yield tons/ha | dry matter kg/ha | kg/ha | rel. |
| Yellow Belgian, Sharpe | 39.5 | 4 370 | 26.3 | 4 130 | 8 500 | 100 |
| Fourragère, Tezier Frères | 38.5 | 4 140 | 34.0 | 5 330 | 9 470 | 111 |
| Rheinische Riesen, Tezier Frères | 42.1 | 4 470 | 25.3 | 3 950 | 8 420 | 99 |
| White Belgian, Sharpe | 34.2 | 3 640 | 28.5 | 4 460 | 8 100 | 95 |
| Jaune de Lobberich, Tezier Frères | 38.5 | 4 060 | 23.1 | 3 620 | 7 680 | 90 |
| Blanche des Vosges, Tezier Frères | 34.0 | 3 630 | 25.5 | 4 000 | 7 630 | 90 |
| St. Valery, Sluis en Groot | 31.6 | 3 990 | 23.3 | 3 630 | 7 620 | 90 |
| London Torg Kämpe, Weibull's orig. | 34.3 | 3 650 | 16.6 | 2 590 | 6 240 | 73 |
| James Halvlang, Daehnf. X, Daehnfeldt | 27.2 | 3 440 | 17.5 | 2 740 | 6 180 | 73 |
| Champion, Daenø X, Daehnfeldt | 24.4 | 2 740 | 17.2 | 2 710 | 5 450 | 64 |
| Regulus I, Weibull | 26.8 | 2 990 | 14.3 | 2 240 | 5 230 | 62 |
| James Lang, Hinderupp. X, Daehnfeldt | 17.6 | 2 170 | 16.7 | 2 720 | 4 890 | 58 |
| Regulus II, Weibull | 22.5 | 2 650 | 12.8 | 2 000 | 4 650 | 55 |

Table 3. Some characteristics of 13 European fodder carrot varieties grown at Tikkurila, 1963—64.

| Variety | Roots | | | | | Tops | |
|---|---|---|---|---|---|---|---|
| | colour | length cm | diameter cm | root position [1] | dry matter % | height cm | % of total dry yield |
| Yellow Belgian | yellow | 16 | 3.4 | 0.0 | 11.0 | 47 | 49 |
| Fourragère | white | 17 | 3.2 | +3.5 | 10.6 | 58 | 56 |
| Rheinische Riesen | yellow | 15 | 3.6 | 0.0 | 10.5 | 38 | 47 |
| White Belgian | white | 24 | 3.6 | +3.5 | 10.6 | 56 | 55 |
| Jaune de Lobberich | yellow | 15 | 3.8 | 0.0 | 10.6 | 45 | 47 |
| Blanche des Vosges | white | 13 | 4.5 | 0.0 | 10.6 | 49 | 52 |
| St. Valery | red | 17 | 3.3 | 0.0 | 12.5 | 43 | 48 |
| London Torg Kämpe | red | 10 | 3.8 | 0.0 | 10.6 | 43 | 42 |
| James Halvlang | red | 10 | 3.8 | —1.0 | 12.6 | 44 | 44 |
| Champion | wh-yel. | 15 | 4.6 | —1.5 | 11.2 | 47 | 50 |
| Regulus I | red | 13 | 3.9 | 0.0 | 11.1 | 37 | 43 |
| Regulus II | red | 12 | 3.3 | —1.0 | 11.5 | 35 | 43 |
| James Lang | red | 19 | 3.5 | 0.0 | 13.4 | 40 | 53 |

[1]) Average distance between the root end and the soil surface, cm.

## Comparative trials

In the comparative root crop trials, the three carrot varieties used were Yellow Belgian, Jaune de Lobberich and Rheinische Riesen, since seed of the highest-yielding variety, Fourragère, was not available at the start of the trials. The genus *Brassica* was represented by the Finnish swede variety Mustialan Lanttu and the genus *Beta* by the Danish fodder sugar beet Rød Øtofte (Daehnfeldt).

Four trials were located on sandy soil and two on clay soil. In one trial farmyard manure (20 tons/ha) was applied, while in the other trials varying amounts of artificial fertilizers were used. The row distance was 45 cm.

The swedes and the beets were sown in the usual manner, using relatively high rates of seed, 3—5 and 10 kg/ha. After emergence the stands were thinned so that the distance between plants was 20 cm. Harrowing was done twice.

Carrots were sown at a low seed rate, ranging from 0.03 to 0.07 g per row metre, and the stand was neither thinned nor harrowed. At the lowest seed rate, 0.03 g/rm, two adjacent rows were sown at a distance of about 5 cm. The average spacing between plants was 3.5—6.5 cm in the different trials. Owing to variations in sowing and germination, however, the actual spacing ranged from 2 cm to as much as 2 metres. After emergence the plots were sprayed with linuron at a rate of 1.5 kg/ha (= 3.0 kg/ha 50 % preparation).

According to the results (Tables 4 and 5), the dry matter yields of carrots were usually lower than those of swede and beet. On sandy soil all the carrot varieties yielded less than beets in three out of four trials, whereas the best carrot variety Yellow Belgian was significantly inferior to swede only in two trials out of four. Carrots yielded an average of 13—16 % less than swedes in these trials.

On clay soil carrots yielded only about half that of swedes. In these trials beets were inferior to swedes and only in one trial did they give definitely higher yields than carrots. It is obvious that on clay soil carrots grow more poorly than on lighter soil types. In both trials on clay soil, the carrots suffered from drought in early summer and there were consequently large gaps in the stand, amounting to as much as 30—40 % of the area of the plots.

## Discussion

It is evident that the yields of different root crops depend greatly on cultural practices, particularly on the row distance and spacing between plants. Since carrots are relatively small plants,

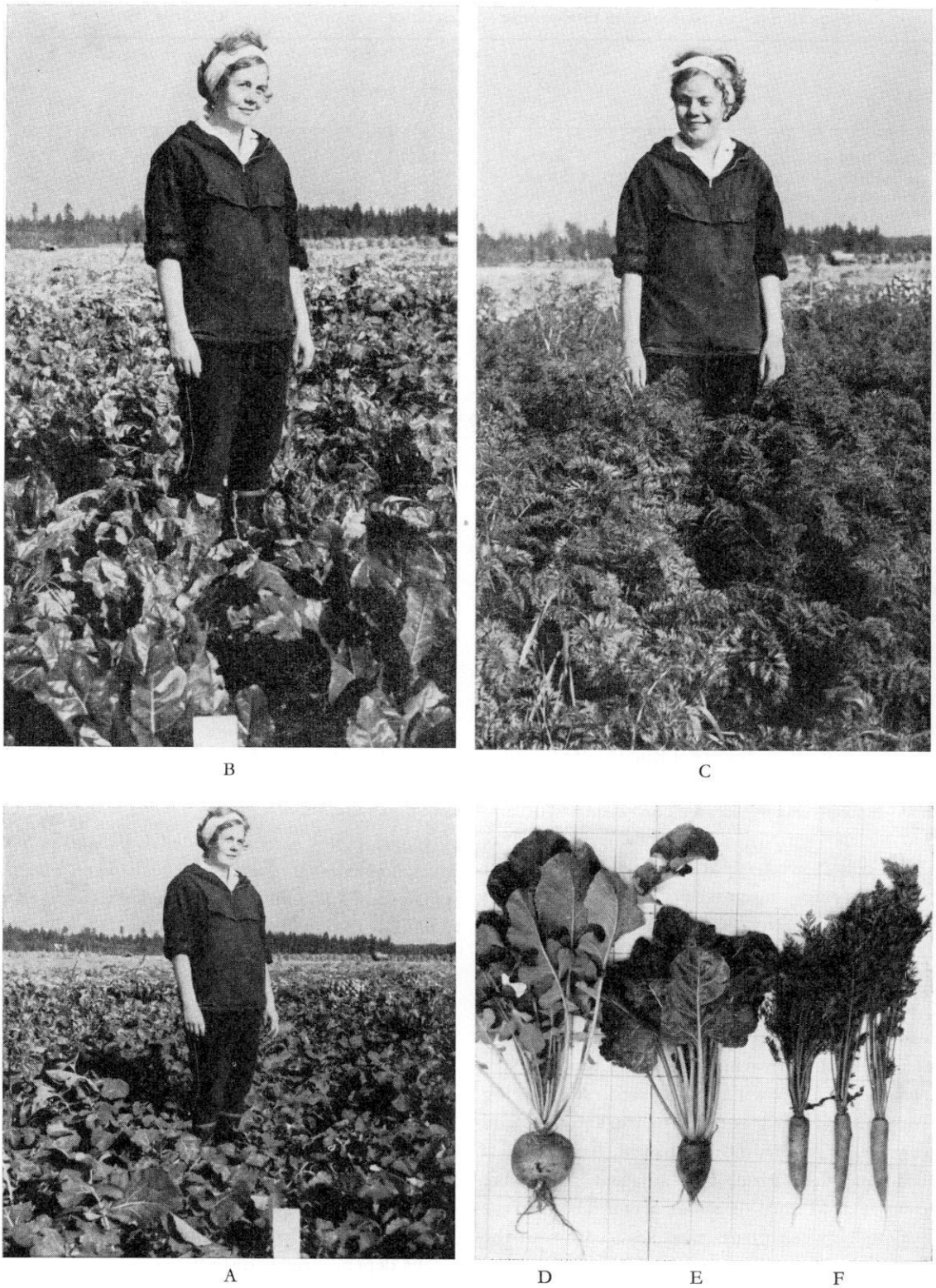


Fig. 3. Comparative trials with root fodder crops. A, B and C = stands of swede, fodder sugar beet and fodder carrots on clay soil at Paimio, 1965; carrot grown by non-cultivation method. D, E and F = samples from the same crops grown on sandy soil at Tikkurila, 1966. Varieties: Swede Mustialan Lanttu, fodder sugar beet Rød Øtofte and fodder carrot Yellow Belgian.

Table 4. Comparative trials with fodder root crops on sandy soil, 1964—65.

| Species | Dry matter yield, kg/ha | | | |
|---|---|---|---|---|
| | roots | tops | total | rel. |
| Trial at Tikkurila, 1965 | | | | |
| Swede, ML ..... | 6 490 | 1 380 | 7 870 | 100 |
| Beet, RØ ..... | 1 410 | 350 | 1 760 | 22*** |
| Carrot, YB ..... | 4 030 | 3 760 | 7 790 | 99 |
| » , JL ..... | 3 620 | 3 290 | 6 910 | 88* |
| » , RR ..... | 3 230 | 2 970 | 6 200 | 79** |
| Trial at Hyvinkää, 1965 | | | | |
| Swede, ML ..... | 3 210 | 1 720 | 4 930 | 100 |
| Beet, RØ ..... | 3 380 | 3 320 | 6 700 | 136 |
| Carrot, YB ..... | 1 760 | 1 630 | 3 390 | 69*** |
| » , JL ..... | 1 730 | 1 580 | 3 310 | 67*** |
| » , RR ..... | 1 990 | 1 620 | 3 610 | 73*** |
| Trial at Pälkäne, 1964 | | | | |
| Swede, ML ..... | 6 080 | 3 540 | 9 620 | 100 |
| Beet, RØ ..... | 5 760 | 5 530 | 11 290 | 117*** |
| » , JL ..... | 5 620 | 3 270 | 8 890 | 92 |
| » , RR ..... | 5 980 | 3 180 | 9 160 | 95 |
| Trial at Pälkäne, 1965 | | | | |
| Swede, ML ..... | 4 640 | 4 710 | 9 350 | 100 |
| Beet, RØ ..... | 7 100 | 7 290 | 14 390 | 154*** |
| Carrot, YB ..... | 4 550 | 5 150 | 9 700 | 104 |
| » , JL ..... | 4 020 | 4 460 | 8 480 | 91* |
| » , RR ..... | 3 600 | 4 080 | 7 680 | 82** |
| Average | | | | |
| Swede, ML ..... | 5 110 | 2 840 | 7 940 | 100 |
| Beet, RØ ..... | 4 410 | 4 120 | 8 540 | 108 |
| Carrot, YB ..... | 3 450 | 3 510 | 6 960 | 88 |
| » , JL ..... | 3 750 | 3 150 | 6 900 | 87 |
| » , RR ..... | 3 700 | 2 960 | 6 660 | 84 |

Table 5. Comparative trials with fodder root crops on clay soil, 1964—65.

| Species | Dry matter yield, kg/ha | | | |
|---|---|---|---|---|
| | roots | tops | total | rel. |
| Trial at Tikkurila, 1964 | | | | |
| Swede, ML ..... | 8 770 | 3 210 | 11 980 | 100 |
| Beet, RØ ..... | 8 430 | 3 820 | 12 250 | 102 |
| Carrot, YB ..... | 3 370 | 2 930 | 6 300 | 53*** |
| » , JL ..... | 3 370 | 2 520 | 5 890 | 49*** |
| » , RR ..... | 3 710 | 3 170 | 6 880 | 57*** |
| Trial at Paimio, 1965 | | | | |
| Swede, ML ..... | 9 300 | 3 230 | 12 530 | 100 |
| Beet, RØ ..... | 4 350 | 2 840 | 7 190 | 57*** |
| Carrot, YB ..... | 3 250 | 3 580 | 6 830 | 55*** |
| » , JL ..... | 2 820 | 2 680 | 5 500 | 44*** |
| » , RR ..... | 3 420 | 3 090 | 6 510 | 52*** |
| Average | | | | |
| Swede, ML ..... | 9 040 | 3 220 | 12 260 | 100 |
| Beet, RØ ..... | 6 390 | 3 330 | 9 720 | 79 |
| Carrot, YB ..... | 3 310 | 3 260 | 6 570 | 54 |
| » , JL ..... | 3 100 | 2 600 | 5 700 | 46 |
| » , RR ..... | 3 570 | 3 130 | 6 700 | 55 |

they would give higher yields by decreasing the usual row distance of 45—50 cm. Considering mechanical harvesting, it would not seem advisable to reduce the row distance. On the other hand, expensive, modern harvesters commonly used for commercial root crops are not yet used for harvesting fodder root crops. It might, therefore, be worthwhile to experiment with such a technique.

Although carrots gave lower yields than the other root crops in the above trials, the results are encouraging and such trials should be continued. In any case, the potential yielding capacity of fodder carrots is probably higher than is usually believed. Another important advantage of carrots is that they are less susceptible to insect pests than other root crops. Moreover, they are attacked by different species of pests than other root crops. By rotating between carrots and other root crops it would be possible not only to reduce pest damage but also to eliminate many other drawbacks associated with repeated cultivation of the same crop. Furthermore, carrots would provide dietary variation in the fodder. They are known to be especially palatable to animals and are claimed to improve the quality of milk and butter, e.g. by increasing their content of carotin. Even in present-day crop production, where economic demands are predominant, such biological aspects should also be taken into consideration, as has often been expressed by ÅBERG (1953, 1954, 1963).

## Summary

In the years 1963—65 trials with fodder carrots were carried out by using a non-cultivation method based on sparse sowing and herbicidal treatment with linuron and prometryne. The main results were as follows:

1. Of the 13 European fodder carrot varieties tested, the highest yielding were Fourragère, Yellow Belgian and Rheinische Riesen.

2. In trials on sandy soil, fodder carrots yielded less than fodder sugar beets in three out of four trials but significantly less than swedes in only two out of four trials.

3. In trials on clay soil, carrot yields were inferior to swede in two trials and to fodder sugar beet in one trial out of two.

4. The time required for hand weeding, harrowing and thinning was 360 hours/hectare for swede and fodder sugar beet but only 20 hours for carrot.

## REFERENCES

Crop production in a weed-free environment. Blackwell Sci. Publ. 114 p. Oxford

ELIASSON S. & SUNDELIN, G. 1949. Foderrotfrukter. Jordbr.försöksanst., Lantbr.högsk., Särtr. o. förhandsmedd. 37: 1—37.

Forsøg med Rodfrugtarter 1925—30. Tidsskr. Planteavl 39: 594—597.

GULLI, G. 1929. Norsk foredlingsarbeide og anvendelse av norske stammer som ledd i arbeidet for å øke avlingene av våre åkerrotverkster. Norsk Landm. bl. 48: 314—315.

HAGERUP, G. 1940. Gulrot pa myrjord. Medd. Norske Myreselsk. 38: 173—175.

HANSEN, FR. & HANSEN, J. 1913. Gødningsforsøg paa Forsøgstationen ved Askov 1894—1910. Tiddsskr. Planteavl 20: 345—539.

HELWEG, L. 1908. En monografisk skildring af de dyrkede gulerodsformer samt et bidrag til deres kulturhistorie. Ibid. 15: 417—453.

—»— 1911. 18 Aars Dyrkningsforsøg med Rodfrugtarter. Ibid. 18: 645—678.

KLOKK, O. 1930. Mer rotvekster. 32 p. Oslo.

NISSEN, Ø. 1947. Sammenligning av dyrkningsomkostinger og avling av forskjellige rotvekstarter, plantet og sådd. Medd. Norges Lantbr.høgsk. 27: 165—236.

SEBELIEN, J. 1916. Laeren om gjødsel. I. De saakaldte kunstige gjødselstoffer. 2. utg. 299 p. Kristiania.

SIMOLA, E. F. 1931. Rehukaalin ja eräiden juurikasvien vertailevat viljelyskokeet Maatalouskoelaitoksen kasvinviljelyosastolla v. 1931. Valt. maatal.koetoim. tied. 30: 1—13.

SUNDELIN, G. 1924. Foderrotfrukterna, deras förädling och odlingsvärde. Sver. Utsädesför. tidskr. 1923: 20—48.

VESIKIVI, A. 1938. Leteensuon koeasema. Suomen Suovilj.yhd. vuosik. 42: 4—66.

ÅBERG, E. 1953. Foderrotfrukter är värda att odlas. Lantmannen 37: 467—468.

—»— 1954. Rotfrukterna, en odling som bör ökas. Weibulls ill. årsb. 49: 19—21.

—»— Växtföljdsfrågor vid specialiserad drift. Jord-Gröda-Djur 1964: 142—157.

SELOSTUS

## Rehuporkkanan viljelymahdollisuuksista

JAAKKO MUKULA
Maatalouden tutkimuskeskus, Kasvinviljelylaitos, Tikkurila

Suomessa tähän asti viljellyt rehujuurikasvit ovat kaalikasveihin *(Brassica)* ja juurikkaisiin *(Beta)* kuuluvia lajeja. Porkkanaa on maassamme viljelty rehuksi vain vähäisiä määriä. Hietamaalla suoritetuissa kokeissa rehuporkkana on kuitenkin antanut yhtä hyviä kuiva-aine- ja rehuyksikkösatoja kuin muut rehujuurikasvit (SIMOLA 1931). Turvemailla rehuporkkana on satoisuudessa voittanut muut rehujuurikasvit, ei kuitenkaan sokerijuurikasta (VESIKIVI 1938).

Kiinnostuksen puute porkkanaan rehukasvina johtuu siitä, että sen viljelykustannukset ovat olleet korkeammat kuin muiden rehujuurikasvien. Hitaasti itävänä ja hentolehtisenä kasvina se on kilpailukyvyltään rikkaruohoihin nähden erittäin heikko. Jotta sen hennot taimet eivät »hukkuisi» rikkaruohojen joukkoon, on kylvö useimmiten täytynyt suorittaa niin tiheään, että harvennus on käynyt välttämättömäksi. Rikkaruohojen torjunta ja harventaminen ovat tehneet porkkanan viljelyn työläämmäksi kuin muiden juurikasvien.

Uudet rikkakasvihävitteet, prometriini ja linuroni ovat kuitenkin mullistaneet porkkanan viljelytekniikan. Nämä aineet tehoavat useimpiin yrttimäisiin kertarikkaruohoihin (= 2-sirkkaiset siemenrikkaruohot) ja pystyvät pitämään maan miltei rikkaruohottomana koko kasvukauden ajan. Harauksista ja perkauksista voidaan tällöin luopua ja kylvö suorittaa niin harvaan, ettei harvennustakaan tarvita.

Maatalouden tutkimuskeskuksen Kasvinviljelylaitos suoritti uusiin viljelymenetelmiin perustuvia rehuporkkanoiden viljelykokeita 1963—64. Kolmestatoista eurooppalaisesta rehuporkkanalajikkeesta osoittautuivat satoisimmiksi Fourragère, Yellow Belgian ja Rheinische Riesen (taul. 2—3). Hietamaalla rehuporkkanat hävisivät rehusokerijuurikkaalle kolmessa kokeessa neljästä, mutta lantulle merkittävästi vain yhdessä kokeessa neljästä (taul. 4). Savimaalla rehuporkkanat hävisivät lantulle kahdessa suoritetussa kokeessa, mutta rehusokerijuurikkaalle vain yhdessä (taul. 5). Perkaus-, haraus- ja harventamisaika oli lantulla ja juurikkaalla 360 t/ha, mutta porkkanalla vain 20 (taul. 1).

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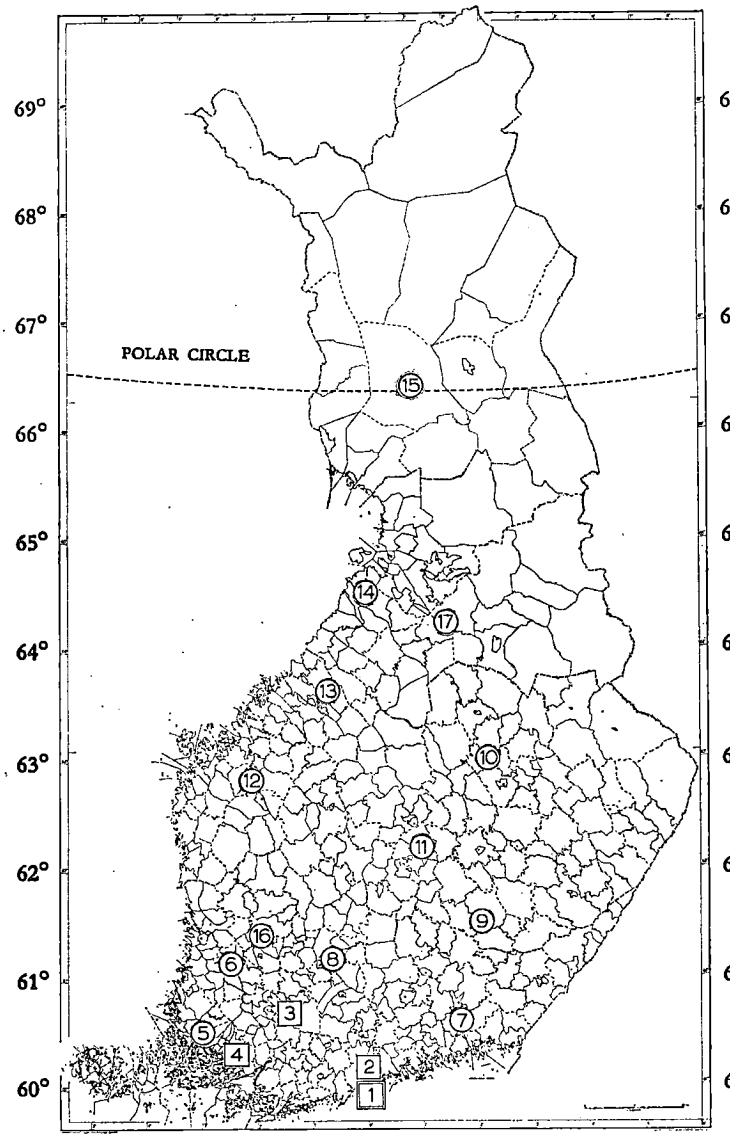


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Helsinki 1966. Valtioneuvoston kirjapaino