THE PERFORMANCE TESTING OF BOARS

II. PHENOTYPIC AND GENETIC CORRELATIONS

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Abstract. In this study the interrelationships between the various characteristics for the boar material described in the first part were analysed. For this purpose the phenotypic, genetic and intra-sire correlation matrix as well as stepwise multiple regression analyses were calculated by computer for the material of 138 boars. The results showed that there was a very strong correlation between fat thickness and testing score ($r_G = -0.95$***, $r_P = -0.88$***). Of the total variation in the testing score 85.2 % was accounted for by the variation in fat thickness. Although the testing score is made up of the points for fat thickness and growth, the latter accounted for only 9.2 % of the variation in the score Daily growth was positively associated with the testing score and negatively with the amount of feed units required per growth kilogram, but significantly so only for the intra-sire correlations; the genetic correlations being even, contrary to expectation. The association between growth rate and fat thickness was positive ($r_G = 0.47$***). Of the total variation in feed efficiency the testing score accounted for 35.6 %. A high testing score was associated with a favourable feed efficiency ($r_G = -0.63$***).

By correlation studies attempts were also made to find out whether it would be possible to shorten the testing period without decreasing the accuracy. The correlations show that the growth rate can be predicted with an appreciable degree of accuracy already from the weight at the 8th testing week. The correlations between the above weight and growth rates were: $r_G = 0.84$***, $r_P = 0.82$***.

From the associations between different characteristics one can decide on the suitability of testing and the consequences of selection for particular traits.

Phenotypic and genetic correlations between various traits

On the IBM 1620 computer of the Helsinki University Computing Centre the phenotypic, genetic and the intra-sire correlation matrix (table 1) was calculated. The total variation was calculated by analyses of variance procedures and the between and within sire variance was separated. The between sire correlation matrix, from which the within sire variance is subtracted, represents the genetic correlations between the traits. Under experimental conditions the phenotypic and genetic correlations are often equal in size. Table 1 shows the difference between the coefficients in the present material.

Correlation between test score and various traits. The association of different characteristics with the test score is important because the selection of boars for breeding takes place on the basis of this score. Firstly one notices that there is a very strong correlation between the test score and the thickness of the fat, especially when the latter is reported per 88 kg live weight. The genetic correlation (r_G = — 0.95***) is even higher than the phenotypic one (r_P = — 0.88***).

The test score is composed of the points given for the fat and for the growth. Therefore one would expect that also the growth rate would be associated rather strongly with the test score. This is not so, however. From Table 1 it appears that this correlation is not significantly different from zero irrespective of whether the growth is recorded per day or as the number of days at a weight of 88 kg. The signs of the genetic correlations are surprising. The daily growth is negatively correlated with the test score (r_G = — 0.38***) while the age at a weight of 88 kg is positively correlated (r_G = 0.22*). This means that a slow daily growth and a high age at 88 kg live weight have resulted in high test scores. The following explanation seems relevant in the case. Boars with a slow growth have received a high testing score because of the points given for thin fat. From Table 1 it is apparent that the slow growing boars have had a thinner fat layer than the fast growing ones. Luckily the intra-sire correlations show the right direction, the daily growth shows a correlation of 0.35*** to the testing score, and the age at a weight of 88 kg one of — 0.36***. Thus the fast growing individuals from the same litter group have received a higher test score than the slow growing ones.

There is a fairly close correlation between feed efficiency and testing score. The coefficients, phenotypic as well as genetic, are of the order — 0.6***, irrespective of whether the feed utilization is reported as feed units consumed per kg growth or as total amount of feed units required to reach a weight of 88 kg (at the testing station).

C o r r e l a t i o n b e t w e e n g r o w t h r a t e a n d o t h e r t r a i t s. The growth rate was reported both as daily growth at the station and as the number of days required to reach a live weight of 88 kg. In the latter figure the growth at the home farm is included. The correlation between the above growth measurements was r_P = — 0.73*** and r_G = — 0.59***. The association between daily growth and feed efficiency was surprisingly low even phenotypically (r_P = — 0.30***), while the genetic one was not significantly different from zero. The age at a live weight of 88 kg is genetically even negatively associated with the feed efficiency (r_G = — 0.27***). This means that individuals growing slowly have been more efficient feed utilizers than those growing fast. On the other hand, when calculating the correlation within sires the correlations between growth rate and feed efficiency are according to expectation. Individuals of the same group with a fast growth have thus also been more efficient feed converters. The genetic correlation between growth rate and fat thickness was 0.47***, when calculated between daily growth and fat at a weight of 88 kg and — 0.43***, when the growth was reported as the number of days to reach a weight of 88 kg. The corresponding phenotypic coefficients were 0.24** and — 0.22**. Thus boars with a slow growth have produced a thinner fat layer than those growing fast.

C o r r e l a t i o n s b e t w e e n »d i s t u r b i n g» i n f l u e n c e s a n d t e s t r e s u l t s. Disturbing influences in the boar performance tests have been the varying weights and ages at the beginning of the test and at the end of the test period when measuring the thickness of the fat. The former were very strongly and significantly correlated especially with growth rate and feed efficiency, both phenotypically and genetically. Of the latter, the weight at the time of the ultrasonic measurement was genetically significantly associated only with the thickness of the fat; phenotypic correlations, on the other hand, were noted for several traits. The latter are mainly a result of the method of testing. For example, the strong correlation between the growth rate and the weight at the time of measurement is due to the fact that all three boars of the same group were measured at the same time. Naturally the one with the largest weight at this time was also the one with the fastest growth. On the other hand, the age at the time of measurement is also genetically associated with several test results. This is understandable as the age at this time indicates the growth rate in the same manner as the age at a weight of 88 kg. The genetic correlation between the two traits mentioned was in fact 0.80***.

A s s o c i a t i o n o f w e i g h t s a n d f e e d e f f i c i e n c y a t 8 a n d 1 1 w e e k s w i t h t e s t r e s u l t s. In order to study the possibilities of shortening the period of testing, the weights were recorded also at 8 and 11 weeks and the feed consumption for the first 8 weeks was registered. One can observe the strong correlations between the above weights and the growth traits. The genetic correlation between daily growth and weight at 8 weeks was 0.84*** and the phenotypic one 0.82***. The corresponding coefficients to the age at 88 kg of weight were $r_G = -0.53$*** and $r_P = -0.66$***. On the other hand, the weights at 8 and 11 weeks are in a varying degree associated with the feed efficiency. The correlations with the fat thickness and the test score were very low. Economically it is important to note that the weight at 8 weeks was almost as strongly correlated with the test results as the weight at 11 weeks so that the information obtained at the earlier stage is about as valuable as that obtained at the later stage. The genetic correlation between the weights at 8 and 11 weeks was 0.98***.

Most important characteristics as revealed by multiple regression analyses

In order to find the variables most useful in predicting the variation in the important characteristics of the boars, i.e. growth rate, feed efficiency, thickness of fat and testing score, stepwise multiple regression analyses were done (Efroymson 1960). The material was analysed on the Elliot 503 — computer of the State Computing Center. As independent variables those given in Table 1 were used.

P r e d i c t i o n o f t e s t i n g s c o r e. The testing points are not a characteristic as such. However, as the selection of the boars takes place on the basis of the score, it is important to know which characteristics are the most useful ones in predicting these points. In the analysis results for 126 boars were included. Table 2 shows that the thickness of fat at a live weight of 88 kg alone accounted for 85.2 % of the total variation in the testing score. By inclusion of the growth characteristics, age at a weight of 88 kg and points for growth, 98.4 % of the variation was accounted for. From the sign of the regression coefficients can be seen that a fast growth increased the testing score. This is probably due to the fact that the predictions were also influenced by the intra-sire correlations (compare Table 1).

P r e d i c t i o n o f g r o w t h r a t e. There has been much discussion as to which criterion is more suitable for expressing the growth rate, daily growth in the interval 20—88 kg at the station or age at a live weight of 88 kg. In the regression analysis of Table 3 both of these were included as dependent variables. Moreover, the testing score was included among the dependent variables in order to note the effect of the same char-

TABLE 1. PHENOTYPIC, GENETIC AND INTRA — SIRE CORRELATIONS BETWEEN DIFFERENT

			(1)	(2)	(3)	(4)	(5)
FU/GROWTH	(1)	P	1.0000				
		G	1.0000				
		I	1.0000				
WEIGHT AT END OF TEST (WHEN MEASURING BACK FAT)	(2)	P	–.3439***	1.0000			
		G	–.0758	1.0000			
		I	–.5234***	1.0000			
AGE AT END OF TEST (WHEN MEASURING BACK FAT)	(3)	P	–.1386	.4178***	1.0000		
		G	–.2307**	.5181***	1.0000		
		I	–.0456	.3402***	1.0000		
TESTING SCORE	(4)	P	–.6002***	.3453***	.1933	1.0000	
		G	–.6348***	.0998	.2370**	1.0000	
		I	–.5830***	.5892***	.1273	1.0000	
DAILY GROWTH	(5)	P	–.2990**	.2815**	–.4952***	–.0574	1.0000
		G	.0367	.0500	–.4870***	–.3849***	1.0000
		I	–.6041***	.4823***	–.5113***	.3549***	1.0000
AGE/88 KG	(6)	P	.1031	–.3003***	.6958***	–.0332	–.7337***
		G	–.2721**	–.0428	.8043***	.2237*	–.5901***
		I	.4487***	–.5293***	.5503***	–.3640***	–.8999***
AVERAGE FAT THICKNESS	(7)	P	.3038***	.2838**	–.1169	–.6989***	.3611***
		G	.5773***	.3218***	–.1704	–.8648***	.4673***
		I	.0292	.2606**	–.0319	–.4558***	.2232*
FAT/88 KG	(8)	P	.4621***	–.1842	–.3185***	–.8819***	.2439**
		G	.6292***	–.0626	–.3802***	–.9496***	.4699***
		I	.3101***	–.3029***	–.2276*	–.7887***	–.0352
FU/20—88 KG	(9)	P	.8453***	–.4488***	–.0379	–.6413***	–.4818***
		G	.7661***	–.2145*	–.1420	–.6054***	–.2388**
		I	.9168***	–.6385***	.0938	–.6888***	–.7393***
INITIAL WEIGHT	(10)	P	–.1188	.3321***	–.1366	.3180***	.4741***
		G	–.0751	.2194*	–.0556	.2335**	.4203***
		I	–.1967	.5347***	–.3131***	.4979***	.6009***
INITIAL AGE	(11)	P	–.3178***	.1668	.2718**	.1454	.4150***
		G	–.3394***	.1417	.3060***	.0905	.4985***
		I	–.4282***	.3125***	.2146*	.3634***	.3138***
WEIGHT AT 8 WEEKS	(12)	P	–.1030	.3591***	–.3689***	.0685	.8243***
		G	.0663	.1913	–.3393***	–.1465	.8413***
		I	–.3125***	.5794***	–.4237***	.4292***	.8189***
WEIGHT AT 11 WEEKS	(13)	P	–.1790	.3493***	–.3726***	.0623	.8650***
		G	.0035	.1674	–.3342***	–.1517	.8683***
		I	–.4175***	.5938***	–.4461***	.4314***	.8855***
FU/8 FIRST WEEKS AT STATION	(14)	P	.2244*	.1854	–.5489***	–.3012***	.8099***
		G	.4165***	.0987	–.5312***	–.5082***	.8808***
		I	.0057	.3184***	–.5925***	.0771	.7304***

P = 0.05 R > 0.18, P = 0.01 R > 0.23, P = 0.001 R > 0.30

P = PHENOTYPIC CORRELATIONS
G = GENETIC »
I = INTRA — SIRE »

TRAITS FOR PERFORMANCE TESTED BOAR (138 BOARS).

(6)	(7)	(8)	(9)	(10)	(11)	(12)	(13)	(14)
1.0000								
1.0000								
1.0000								
-.3503***	1.0000							
-.4333***	1.0000							
-.2400**	1.0000							
-.2162*	.8853***	1.0000						
-.4297***	.9235***	1.0000						
.0536	.8313***	1.0000						
.2977**	.2819**	.4962***	1.0000					
-.0427	.4604***	.5723***	1.0000					
.6662***	.0655	.4115***	1.0000					
-.4059***	-.0668	-.2305**	-.6269***	1.0000				
-.2439**	-.0762	-.1798	-.6969***	1.0000				
-.7247***	-.0494	-.3392***	-.5640***	1.0000				
.1596	-.0967	-.1740	-.5610***	.5867***	1.0000			
.2604**	-.0889	-.1477	-.6615***	.6497***	1.0000			
-.0877	-.1471	-.3076***	-.5055***	.3578***	1.0000			
-.6570***	.2466**	.0805	-.5249***	.8361***	.5594***	1.0000		
-.5321***	.3056***	.2371**	-.4754***	.8174***	.6317***	1.0000		
-.8629***	.1443	-.1763	-.6136***	.8884***	.3782***	1.0000		
-.6610***	.2640**	.1075	-.5617***	.8005***	.5842***	.9787***	1.0000	
-.5239***	.3085***	.2526**	-.4969***	.7852***	.6544***	.9823***	1.0000	
-.8950***	.1858*	-.1362	-.6794***	.8430***	.3997***	.9716***	1.0000	
-.7320***	.4912***	.4121***	-.1321	.5744***	.2831**	.8653***	.8470***	1.0000
-.7090***	.6276***	.6110***	-.0197	.5001***	.3172***	.8642***	.8481***	1.0000
-.8033***	.2337**	.0594	-.3168***	.7710***	.1715	.8713***	.8463***	1.0000

acteristics on these (growth and testing score). From Table 3 it can be seen that weight at 11 weeks of age accounted for a considerable part (76.4 %) of the total variation in daily gain, but age at a weight of 88 kg for much less (43.3 %) and the latter for none of the variation in the testing score. The variation in the initial weight of the boars influenced all dependent variables. By inclusion of the feed consumption in the interval 20—88 kg live weight, a far greater part of the total variation in testing score was accounted for.

Prediction of feed efficiency. The dependence of the feed efficiency on other characteristics is especially important because its development has taken place on the basis of these interrelationships. Table 4 reveals that of the total variation in feeding efficiency 35.6 % was accounted for by the testing score. By inclusion of the daily gain, 46.4 % of the variation was accounted for.

Table 2. Prediction of testing score for tested boars by means of stepwise multiple regression analysis (126 boars).

Step	Variable	Df	F-value	R	R^2
1.	fat/88 kg	124	722.7***	0.923	0.852
2.	age/88 kg	123	204.4***	0.972	0.944
3.	points for growth	122	11.0**	0.974	0.948

Table 3. Prediction of growth rate for tested boars by means of stepwise multiple regression analysis (138 boars)

Step Variable	Predicted characteristics							
	Daily growth				Age/88 kg		Testing score	
	DF	F-value	R	R^2	R	R^2	R	R^2
1. weight at 11 weeks	136	404.1***	0.864	0.746	0.658	0.433	—	—
2. initial weight	135	150.3***	0.938	0.879	0.687	0.472	0.439	0.192
3. fu/20—88 kg	134	23.9***	0.947	0.897	0.684	0.468	0.756	0.571

Table 4. Prediction of feed efficiency for tested boars by means of stepwise multiple regression analysis (138 boars).

Step	Variable	Df	F-value	R	R^2
1.	testing score	136	76.6***	0.596	0.356
2.	daily growth	135	28.5***	0.681	0.464
3.	weight at 11 weeks	134	28.6***	0.745	0.555

Discussion

For the success of the performance test it is vital that during the testing period the characteristics best revealing the breeding value of the boars are measured. When analysing the results for boars tested in 1965—68 on four testing stations it was clearly revealed that when the boars are selected on a testing score, one primarily breeds for thin fat. The genetic correlation (for boars weighing 88 kg) between thickness of fat and testing score was — 0.95***, and the former alone accounted for 85.2 % of the total variation in the testing score.

As the testing score is made up by combining the points for fat and growth, it is surprising to note the small influence of the growth rate. The genetic correlation between daily growth and testing score was in fact negative (r_G = — 0.38***). Perhaps this is due to the fact that the association between thickness of fat and growth rate was positive (r_G = 0.47***), which resulted in a thin fat layer for the slowly growing boars. On the other hand, when the boars, because of a thin fat layer, obtained many testing points, this led to high testing scores also for the slowly growing individuals. However, looking at the intra-sire correlations it can be noted that there was a positive association between the testing score and growth rate, which means that the faster growing individuals out of a group of 3 boars also had higher testing scores. Perhaps the difference in sign noted for the intra-sire correlations is due to the change in feeding over the years and to the restricted standards.

It may also be possible that the above reasons led to the small or even negative genetic correlations between growth rate and feed efficiency (Table 1). The intra-sire correlations between growth rate and feed efficiency were according to expectation (r_I = — 0.60***), when the fast growing individuals of a litter group also had a more favourable feed efficiency. According to earlier results (VARO 1962), it was expected that the weighing of the feed individually for the boars should not prove necessary and that feed efficiency could be developed on the basis of its association with the growth rate. The results of the present study support such a conclusion only as regards the feed consumption within a litter group of boars, but not for different groups. On the other hand, the results of the present study indicate that the feed efficiency is very closely correlated with the testing score (r_G = — 0.63***) and hence a favourable feed conversion will be otained when selecting for the testing score.

Performance testing of boars under station conditions is a relatively expensive procedure as a statisfactory price cannot be asked for the carcasses of rejected animals because of the smell. With respect to the selection efficiency it would, however, be advantageous to increase the number of boars. This study attempted to solve the conflict by investigating whether the boars could be tested at such an early stage that the rejected individuals afterwards could be raised as castrates. For this purpose the accuracy with which the breeding value of the boars could be determined from the results of 8 and 11 weeks of testing was studied. From the stepwise multiple regression analysis it was observed that the 11th week weight accounted for 74.6 % of the total variation in daily growth, but did not account for the variation in the testing score. However, a testing period of 11 weeks is not much shorter than that used up to now, but apparently it was possible to use the 8th week weight with about the same accuracy, as the genetic as well as phenotypic correlation between the weights at these stages was 0.98***. In the stepwise multiple regression analysis the 8th week weight was not included as it did not provide additional information to the 11th week weight. The boars weighed, on an average, 56.2 kg after an 8 week testing period. Measurement of the fat at this stage would apparently provide information of the boar's breeding value in this respect (Rittler *et al.* 1964, Sundgren 1964). The problems encountered in the performance testing of boars are at present being studied.

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SELOSTUS

KARJUJEN FENOTYYPPITESTAUKSESTA

II. OMINAISUUKSIEN VÄLISET RIIPPUVUUSSUHTEET

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Tässä tutkimuksessa on selvitetty ensimmäisessä osassa esitetyn karjuaineiston ominaisuuksien keskinäisiä riippuvuussuhteita. Sitä varten on tietokoneilla tulostettu fenotyyppinen, geneettinen ja isien sisäinen korrelaatiomatriisi sekä askeltavia multippeliregressioanalyysejä 138 karjun aineistosta. Tuloksista voidaan todeta, että silavan vahvuus on korreloitunut testauspisteisiin erittäin voimakkaasti (r_G = — 0.95***), (r_P = — 0.88***). Silavanpaksuus on selittänyt 85.2 % testauspisteiden kokonaismuuntelusta. Vaikka testauspisteet ovat koostuneet silava- ja kasvupisteistä, on kasvunopeus selittänyt testauspisteiden muuntelusta vain 9.2 %. Päiväkasvun positiivinen korreloituminen testauspisteisiin ja negatiivinen kasvukiloa kohden tarvittuun rehuyksikkömäärään on ollut huomattava vain isien sisäisissä korrelaatioissa, geneettiset korrelaatiot ovat olleet jopa odotuksen vastaisia. Kasvunopeuden ja silavanpaksuuden välillä on vuorosuhde ollut positiivinen (r_G = 0.47***). Testauspisteet ovat selittäneet 35.6 % karjujen rehunkäyttökyvyn kokonaismuuntelusta. Runsaaseen testauspistemäärään on liittynyt edullinen rehunkäyttökyky (r_G = — 0.63***).

Riippuvuussuhteiden avulla on yritetty myös selvittää, olisiko mahdollisuutta lyhentää karjujen testausaikaa tulosten siitä kärsimättä. Vuorosuhteet ovat osoittaneet, että kasvunopeutta voidaan päätellä melkoisella varmuudella jo 8. koeviikon painon perusteella. Mainitun painon ja päiväkasvun väliset korrelaatiot ovat olleet r_G = 0.84***, r_P = 0.82***.

Ominaisuuksien välisistä riippuvuussuhteista voidaan päätellä, mitä niistä on tarkoituksenmukaista testata ja mitkä seuraavat mukana voimakkaan korreloitumisen perusteella.