AN ANALYSIS OF THE DEPENDENCY STRUCTURE BETWEEN A GILT'S PREBREEDING AND REPRODUCTIVE TRAITS. II. PRINCIPAL COMPONENT ANALYSIS

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AN ANALYSIS OF THE DEPENDENCY STRUCTURE BETWEEN A GILT'S PREBREEDING AND REPRODUCTIVE TRAITS. II. PRINCIPAL COMPONENT ANALYSIS[1]

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SUMMARY

Seventeen variables measured before breeding and three measures of reproduction were taken on 339 purebred Duroc, Hampshire and Yorkshire gilts and 192 two-breed cross gilts resulting from matings among these breeds. Eight principal components accounted for 90% of the dependency structure existing among the 17 traits measured before breeding. Two principal components accounted for 97% of the dependency structure existing among the three reproductive traits.

The first principal component (PC11) from the prebreeding traits was a general measure of growth ability and accounted for 28% of the variation in the 17 measurements. The second principal component (PC12) contrasted slow growing gilts from fast growing litters with fast growing gilts from slow growing litters and accounted for 14.5% of the total variation. The heritability for PC11 was .71 and indicates that selection for gilts with high values for PC11 (above average growth) would be very successful.

The first principal component (PC21) from the reproductive traits contrasted gilts having large numbers of embryos and good embryo survival with gilts having few embryos and poor embryo survival. The second principal component (PC22) contrasted gilts having high ovulation rates and poor embryo survival with gilts having low ovulation rates and good embryo survival. PC21 and PC22 accounted for 57.2% and 39.5%, respectively, of the dependency structure existing between ovulation rate, embryo numbers and embryo survival rate.

Based on the correlations of principal components from growth traits with principal components from reproductive traits, the following conclusions were made: If litter averages are indications of the genetic potential of a gilt selected from that litter, then gilts with a high genetic potential (good litter averages) that exhibit that potential (good individual performance) have high PC11 values and are genetically superior for ovulation rate but are genetically inferior for embryo survival rates (high PC22 values). Gilts with a good genetic potential (good litter average) that fail to meet that potential (poor individual performance) have high PC12 values and are genetically inferior for ovulation rate but genetically superior for embryo survival rate (low PC22 values).

(Key Words: Growth, Reproduction, Gilts, Principal Components.)

INTRODUCTION

Multivariate techniques, other than path coefficients and multiple regression, have been used only to a very limited extent in the field of animal science. Principal component analysis is a multivariate technique for reducing p correlated measurement variables to a smaller set of statistically independent linear combinations of the original measurements. This technique attempts to find linear compounds of the original variables which can account for the dependency structure existing among the original measurements. This technique was used by Wright (1932) and more recently by Carpenter *et al.* (1971) and Brown *et al.* (1973).

The primary objective of this study was to

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[1] Journal Article 3152 of the Agricultural Experiment Station, Oklahoma State University, Stillwater. Research conducted by the Department of Animal Science and Industry (Project 1444) in cooperation with the U.S.D.A., Agricultural Research Service, Southern Region.

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use principal components as a means of evaluating the relationship of prebreeding traits with reproductive traits. Because of the nature of a principal component analysis there were two intermediate objectives or steps: to evaluate the relationships among the prebreeding traits and to evaluate the relationships among the reproductive traits.

MATERIALS AND METHODS

This study included the records of 339 purebred Duroc, Hampshire and Yorkshire gilts and 192 two-breed cross gilts resulting from matings among the three breeds. The method of handling these gilts was described in detail by Young *et al.* (1977). The prebreeding traits evaluated were: the size of litter the gilt was born in (NB) and weaned in (NW); her birth weight (BW), weaning weight (WW), average daily gain (ADG) and age at 100 kg (AGE); the average of the litter from which the gilt came for birth weight (LBW), weaning weight (LWW), average daily gain (LADG) and age at 100 kg (LAGE); the deviation of the gilt's record from the litter average for birth weight (BWD), weaning weight (WWD), average daily gain (ADGD) and age at 100 kg (AGED); as well as breeding age (BRAGE), breeding weight (BRWT) and days from 100 kg to breeding (DAYS). The reproductive traits measured were: number of corpora lutea (CL), number of embryos (EMB) and number of corpora lutea per embryo (CL/E). The phenotypic and genetic correlations among all traits were reported by Young *et al.* (1977). The phenotypic correlation matrix previously reported served as input data for the principal component analysis.

For a more detailed and technical discussion of principal component analyses see Anderson (1958), Morrison (1967) and Overall and Klett (1971). Brown *et al.* (1973) provides an example of the interpretation of principal components. The correlation matrix and standardized variates are normally used in the calculation of principal components when the traits measured are in different units or are largely different in magnitude. Principal component analysis is a method for reducing p correlated variables to a smaller set of statistically independent linear combinations of the original measurements which have unique properties. The first principal component is that weighted combination of the several original variables which accounts for a maximum amount of the total variation represented in the complete set of original variables. The rth principal component is that weighted combination uncorrelated with the first $r-1$ principal components which accounts for a maximum amount of the remaining variation among the original variables (Overall and Klett, 1971).

The magnitude and sign of the coefficients within a given component determines the importance and grouping, respectively, of the ith measurement within that component (Brown *et al.*, 1973). Within a component, measurements that are weighted by large coefficients are more important than those weighted with small coefficients. Within a component, measurements whose coefficients have the same sign are grouped together and contrasted against the group of opposite sign.

Principal components were obtained separately for the traits measured before breeding and for the reproductive traits. In this study, it was decided, prior to analysis, to calculate enough principal components to account for at least 90% of the total variation in the dependency structure of the original response variates. A value for each principal component was calculated for every gilt and was considered as a new trait. Using the paternal half-sib method, genetic and phenotypic correlations between principal components and of principal components with the original variates of the opposite group were calculated. Heritability estimates were also calculated for the principal components.

The traits measured before breeding were denoted as group 1 and the reproductive traits were denoted as group 2. The jth principal component from group i will be denoted as PCij.

RESULTS AND DISCUSSION

Principal Components for Prebreeding Traits. The principal components obtained for traits measured before breeding are presented in table 1. Ignoring the near zero coefficients for NB and NW, the coefficients for all measurements in the first principal component (PC11) are fairly similar in magnitude. However, except for one character, the coefficient for the gilt's individual value is slightly greater than the coefficient for the litter average which in turn is slightly greater than the coefficient for the gilt's deviation from litter average. This indicates that

TABLE 1. COEFFICIENTS OF PRINCIPAL COMPONENTS OBTAINED FROM TRAITS MEASURED BEFORE BREEDING (GROUP 1)

Item	PC11	PC12	PC13	PC14	PC15	PC16	PC17	PC18
NB	-.06	-.24	.36	.02	.52	-.01	.05	-.13
BW	.25	.14	-.32	.36	.14	.34	.23	-.11
LBW	.20	.32	-.18	.07	.09	.56	.11	.27
BWD	.13	-.18	-.26	.47	.12	-.19	.22	-.51
NW	-.02	-.11	.33	-.02	.58	.26	.13	.22
WW	.30	.01	-.30	-.10	.28	-.25	-.33	.23
LWW	.21	.32	-.17	-.32	.16	-.02	-.32	-.11
WWD	.18	-.31	-.24	.21	.21	-.32	-.09	.42
ADG	.37	-.16	.18	-.21	-.09	.05	.18	-.16
LADG	.11	.15	.05	-.11	-.14	-.31	.70	.40
ADGD	.19	-.41	.05	-.12	-.25	.36	-.08	-.02
AGE	-.41	.13	-.05	.22	.01	.02	-.04	.12
LAGE	-.32	-.23	-.11	.27	-.16	.14	-.12	.29
AGED	-.23	.45	.05	.00	.21	-.16	.08	-.19
BRAGE	.12	.22	.40	.45	-.14	-.04	-.25	.14
BRWT	.31	.06	.20	.17	-.10	-.17	-.02	.04
DAYS	.30	.18	.36	.25	-.10	-.04	-.17	.01
% total variation	28.3	14.5	12.3	9.0	8.4	6.9	6.0	4.6

in this component the gilt's individual record is the most important. The first principal component was interpreted as a general measure of growth ability. Gilts with large values for PC11 were from litters which exhibited good growth at all ages while the gilt's own record was also good and even above litter average. Basically, this component contrasts slow growing gilts from slow growing litters with fast growing gilts from fast growing litters. It is somewhat surprising that this basic contrast did not account for more than 28% of the variation among the original variates. Similar values for this component do not necessarily mean similar growth patterns. For example, assume two gilts have exactly the same measurements for all traits except that the first gilt was one standard deviation above average for BW but average for ADG and the second gilt was average for BW but was .68 of a standard deviation above average for ADG. Since all measurements are standardized, these gilts will have the same value for PC11 but will have different growth patterns.

The second principal component (PC12) contrasts the gilt's individual performance with the average performance of the litter she came from. For every character, the coefficient for the deviation of the gilt's performance from litter average has the opposite sign as the coefficient for the litter average. This component contrasts slow growing gilts from small, fast growing litters with fast growing gilts from large, slow growing litters. This component accounted for 14.5% of the variation among the original variates.

Gilts with large values for the third principal component (PC13) came from large litters where the pigs had low birth weights and low weaning weights with the gilt's own record being below litter average for these traits; however, the litter grew well in the feedlot and the gilt was above litter average for growth and age at 100 kg and was heavier and older at breeding. This component contrasts gilts which came from large litters and got off to a poor start due to competition in the large litter but grew well in the feedlot with gilts which came from small litters and got off to a good start but their performance declined in the feedlot.

The fourth principal component (PC14) gave very little weight to NB or NW and accounted for only 9.0% of the variation among the original variates. Gilts with large values for this component came from litters with high average birth weights with the gilt's birth weight being above litter average, but as time passes the litter's performance deteriorates to below average and the gilt's performance deteriorates even faster so that she is below litter average for average daily gain, has more days from 100 kg to breeding and is older and heavier at breeding.

The fifth principal component (PC15) gives considerable weight to NB and NW and accounts for 8.4% of the total variation. Gilts with high values for PC15 came from large litters at birth and weaning where the pigs had large birth weights and weaning weights but poor average daily gains with the gilt being above litter average for birth and weaning weights and below litter average for average daily gain and also young and light in weight at breeding. The above average performance of these gilts before weaning may result from the superior maternal ability of their dams. This component contrasts gilts which are from large litters and get off to a good start but slow down in the feedlot with gilts from small litters that get off to a poor start but do well in the feedlot.

Similar interpretations can be developed for PC16, PC17 and PC18. Because they account for so little of the total variation and in order to conserve space, this will be left to the reader.

Principal Components for Reproductive Traits. The principal components derived for the three reproductive traits are presented in table 2. Two of the three possible principal components accounted for almost 97% of the generalized variance existing among these three variables.

The first principal component for this group (PC21) explained 57% of the total variation. This component gives relatively little weight to ovulation rate and, in general, it contrasts gilts having large numbers of embryos and good embryo survival rates with gilts having few embryos and poor embryo survival rates. The second principal component (PC22) gives relatively little weight to embryo numbers and contrasts gilts having high ovulation rates and poor embryo survival rates with gilts having low ovulation rates but good embryo survival rates. Embryo survival was measured as number of corpora lutea per embryo. Low values for this trait indicate good embryo survival. These two basic contrasts explain most of the dependency structure existing between ovulation rate, number of embryos and embryo survival rate.

TABLE 2. COEFFICIENTS OF PRINCIPAL COMPONENTS OBTAINED FROM REPRODUCTIVE TRAITS (GROUP 2)

Item	PC21	PC22
CL	.23	.87
EMB	.74	.14
CL/E	-.64	.48
% total variation	57.2	39.5

TABLE 3. HERITABILITY ESTIMATES AND STANDARD ERRORS FOR ALL PRINCIPAL COMPONENTS

Trait	h^2	SE
PC11	.71	.21
PC12	.28	.20
PC13	.73	.21
PC14	.31	.20
PC15	.55	.20
PC16	.74	.21
PC17	-.24	.17
PC18	.03	.19
PC21	-.28	.17
PC22	.50	.20

Heritability Estimates. The heritability estimates and standard errors for all principal components are presented in table 3. The sire component of variance was negative for PC17 and PC21 resulting in negative estimates of heritability for these components.

The heritability estimates for PC12, PC14 and PC18 were not large or significant when compared to their standard errors. PC11, PC13 and PC16 had heritabilities that were greater than .70 and significant. The component which would seem to describe the most desirable gilt from a growth standpoint would be PC11. Thus, the high heritability found for this component, indicates that selection for gilts with high values for PC11 would be very successful. The heritabilities of PC15 and PC22 were around .50 and significant.

Genetic and Phenotypic Correlations. The phenotypic (r_p) and genetic (r_g) correlations of variables in group 1 with principal components from group 2 are reported in table 4. The sire component of variance was negative for PC21 thus preventing the estimation of the genetic correlations for this trait. Genetic correlations of WW and AGE with PC22 were large ($|r_g|>.60$). Genetically, PC22 was moderately correlated with ADG, ($r_g = .51$) and lowly correlated with LBW, NW, LWW, BRAGE, BRWT and DAYS. This suggests that selection of gilts with genetic ability for good growth, *especially for good growth rate in the feedlot,* will result in gilts with genetic ability for high ovulation rate but poor embryo survival rate. The phenotypic correlations of variables in group 1 with principal components from group 2 were small. Only one of the 34 phenotypic

TABLE 4. PHENOTYPIC (r_p) AND GENETIC (r_g) CORRELATIONS OF VARIABLES IN GROUP 1 WITH PRINCIPAL COMPONENTS OF GROUP 2[a]

	PC21		PC22	
Trait	r_g	r_p	r_g	r_p
NB	–[b]	-.03	+	.04
BW	+	.00	-.06	.09
LBW	–	.05	.32	.05
BWD		-.06		.07
NW	–	.05	.30	.07
WW	–	.08	1.29	.11
LWW	+	.11	.15	.03
WWD		-.01		.11
ADG	+	.07	.51	.12
LADG	+	.04	+	.06
ADGD		-.07		.02
AGE	–	-.03	-.73	-.15
LAGE	–	-.06	-.35	-.13
AGED		.03		-.06
BRAGE	+	.14	.16	.09
BRWT	+	.14	.35	.25
DAYS	+	.14	.37	.14

[a] If $|r_p| > .16$ then $P < .05$.

[b] Sign of the covariance.

correlations, about 3%, was significant. This indicates that none of the variables measured before breeding would be very helpful in selecting replacement gilts with reproductive patterns described by PC21 or PC22. The absence of any large phenotypic correlations even though several of the genetic correlations are large implies a rather large negative environmental correlation for some of the individual growth traits with PC21 and PC22, especially when the heritabilities of both of the correlated traits are relatively high. This may indicate that replacement gilts should be genetically superior for growth but should be developed slower than are slaughter pigs.

The phenotypic and genetic correlations of variables in group 2 with principal components from group 1 are presented in table 5. Genetic correlations for EMB could not be calculated because of the negative sire component of variance found for this trait. Genetic correlations for PC18 were considerably greater than one and reflect the very small sire component of variance found for that trait. PC11 was highly and favorably correlated, genetically, with CL (r_g = 1.05) but not CL/E (r_g = .18). The genetic correlations of PC12 with CL and CL/E were –.86 and –.81, respectively. Gilts with high values for PC11 exhibited good performance at all stages of growth while gilts with high values for PC12 were poor performing gilts from good performing litters. Litter averages should be some indication of genetic potential for a gilt selected from that litter. The results seem to suggest that gilts which have the genetic potential for good growth (high litter average) but fail to meet that potential (poor individual performance) are genetically superior for PC12 and embryo survival rate but are genetically inferior for ovulation rate. All phenotypic correlations of variables in group 2 with principal components from group 1 were very small and only the correlation of .21 between PC11 and CL was significant.

The phenotypic and genetic correlations of principal components from group 1 with principal components from group 2 are presented in table 6. Again, genetic correlations for PC21 could not be calculated due to the negative sire component of variance found for this trait. The

TABLE 5. PHENOTYPIC (r_p) AND GENETIC (r_g) CORRELATIONS OF VARIABLES IN GROUP 2 WITH PRINCIPAL COMPONENTS OF GROUP 1

	CL		EMB		CL/E	
Trait	r_g	r_p	r_g	r_p	r_g	r_p
PC11	1.05	.21	+[a]	.11	.18	.02
PC12	-.86	.03	+	.12	-.81	-.09
PC13	.37	.09	+	.11	.07	-.04
PC14	-.28	.08	+	.07	-.27	.03
PC15	.06	.06	–	.01	.29	.01
PC16	-.18	-.07	–	-.09	-.32	-.01
PC17	–[a]	-.01	+	-.10	–	.07
PC18	1.50	.04	–	.10	2.02	-.05

[a] Sign of the covariance.

TABLE 6. PHENOTYPIC (r_p) AND GENETIC (r_g) CORRELATIONS OF PRINCIPAL COMPONENTS OF GROUP 1 WITH PRINCIPAL COMPONENTS OF GROUP 2

Trait	PC21 r_g	PC21 r_p	PC22 r_g	PC22 r_p
PC11	+[a]	.09	.62	.19
PC12	+	.11	-.69	.00
PC13	+	.10	.24	.07
PC14	+	.03	-.19	.09
PC15	–	.01	.08	.05
PC16	+	-.06	-.22	-.07
PC17	+	.09	–	.01
PC18	–	.08	1.32	.02

[a] Sign of the covariance.

genetic correlations of PC11 and PC12 with PC22 were .62 and −.69, respectively. Large values of PC22 denoted gilts with high ovulation rates and poor embryo survival rates. Assuming that a high litter average indicates a high genetic potential, these data indicate that a gilt with a high genetic potential which exhibits that potential (high PC11 values) will be genetically superior for ovulation rate and genetically inferior for embryo survival rate (high PC22). Gilts with a high genetic potential that fail to meet that potential (high PC12) are genetically inferior for ovulation rates and genetically superior for embryo survival rates (low PC22). All phenotypic correlations of principal components in group 1 with principal components in group 2 were very small and were not significant.

In general, these data indicate that there are some fairly large genetic correlations between growth measures and reproductive measures. However, the phenotypic correlations between growth and reproduction are small due to large environmental correlations of opposite sign. This suggests that replacement gilts should be genetically superior for growth but they should be grown out more slowly than slaughter pigs are grown out. This may suggest new management practices for replacement gilts. It may be advantageous for a commercial producer to select replacement gilts which are heavy at birth and weaning and are from large litters. Rather than full feeding, it may be better to reduce growth rate by limiting feed intake from weaning to breeding but raise them to normal breeding weights. Other evidence for this system has been presented by Aherne (1975). Gilts fed *ad libitum* from 45 kg to breeding farrowed 1.2 fewer pigs and weaned one less pig than gilts which were fed at a level of 85% of the *ad libitum* intake over the same period.

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