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P. J. David
University of Nebraska-Lincoln

R. K. Johnson
University of Nebraska-Lincoln, rjohnson5@unl.edu

T. E. Socha
University of Nebraska-Lincoln

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SELECTION PRACTICES AND GENETIC AND PHENOTYPIC TRENDS ESTIMATED FROM NEBRASKA SPF SWINE FIELD RECORDS^{1,2}

P. J. David³, R. K. Johnson⁴ and T. E. Socha⁵

University of Nebraska, Lincoln 68583-0908

ABSTRACT

Records collected during 1971 through 1979 from 101,606 pigs raised in 18 herds that were members of the Nebraska SPF Swine Accrediting Association were evaluated for phenotypic trends and predicted and observed genetic trends. Traits considered were backfat at 100 kg (BF) and weight at 140 d of age (WT). Phenotypic change on average was beneficial for BF ($-.05$ mm/yr) but undesirable for WT ($-.2$ kg/yr). However, the average observed genetic trend was nil for BF and $.6$ kg/yr for WT. An average, predicted response based on observed selection differentials and estimates of within herd-sex genetic parameters was in good agreement with observed response for BF, but was three times higher for WT.

(Key Words: Pigs, Phenotypic Trend, Genetic Trend, Backfat, Weight.)

Introduction

Cumulative genetic improvement in the commercial swine industry is provided entirely by the source of purchased breeding stock (Richard, 1971). In the United States, these purchased stocks are most often purebred sires. Therefore, it is important that purebred breeders utilize selection practices that maximize genetic response in economically important traits.

It has been demonstrated that selection for decreased fat (Hetzer and Harvey, 1967) or for increased growth rate (Rahnefeld and Garnett, 1976) was successful in swine research herds. Documentation that selection in American purebred herds results in genetically improved breeding stock is limited.

Cox and Smith (1968) used Duroc and Hampshire hogs sampled from Iowa breeders and reared at university facilities to assess genetic trends for backfat and gain on test. The test period was from 98 to 154 d of age. Duroc hogs had a decrease in genetic merit for gain

($-.55$ kg/yr) and a slight increase in backfat ($.04$ mm/yr). Hampshires were increasing in gain at the rate of $.55$ kg/yr, but also were increasing in the genetic level of backfat ($.49$ mm/yr).

Dickerson et al. (1976, 1977) compared control pigs from a 20-yr selection experiment with pigs commercially available in 1975. Differences were interpreted to be 20 yr of genetic change in the American swine industry. Industry hogs had 25% less backfat and grew 9% faster than control hogs.

Several studies of genetic change have been conducted in Europe (Smith, 1962; Ollivier, 1974; Puff, 1976; Standahl, 1979; Mitchell et al., 1982). The general conclusion from these reports is that in European swine herds evaluated for genetic progress during the 1950's, 1960's and early 1970's, favorable changes were made in backfat and growth rate. Kennedy (1984) estimated trends in the sire and dam transmitting ability in 178 herds in Ontario, Canada, and found that annual trends for age to 90 kg were positive ($.1$ to 1.0 d/yr). Sire trends for backfat were small and nonsignificant ($-.02$ to $.04$ mm/yr), but there were sizable and significant reductions in average dam transmitting abilities for backfat ($-.10$ to $-.21$ mm/yr).

The objective of this research was to estimate phenotypic and genetic trends in several Nebraska purebred herds. Observed genetic trends were compared to predicted change obtained from estimates of genetic parameters and selection intensities.

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³Present address: PIC, Inc., P.O. Box 348, Franklin, KY 42134.

⁴Anim. Sci. Dept.

⁵Nebraska SPF Swine Accrediting Assoc., Vet. Basic Sci., Univ. of Nebraska, Lincoln 68583-0906.

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Materials and Methods

The data set was described in David et al. (1983). Briefly, records collected during 1971 through 1979 from 18 Nebraska purebred herds were analyzed. Herd-sex subclass numbers and the years spanned by data from each herd were presented in David et al. (1983). Total number of observations included in these analyses were 101,606 and the number per herd ranged from 1,217 to 20,035.

Records from each pig for weight at 140 d (WT) were first adjusted for variation in age, and records for backfat at 100 kg (BF) were adjusted for weight when records were collected (David et al., 1983). These data were then fitted within herd-sex subclasses to a model that included the effects of contemporary group and age of dam, from the first through the fourth powers, as a covariable. The number of contemporary groups per year ranged from 2 to 13 per herd. Age of dam was expressed in months at the time of the birth of a pig. Age of dam effects were expected to be asymptotic; thus the fourth order effect of age of dam was included in the model.

Phenotypic trend was evaluated for each herd-sex subclass by the regression of performance on time after adjusting the data for age of dam with the regression coefficients obtained from the above analysis. Genetic trends for WT and BF were estimated by $-2b$, where b is the pooled within-sire regression of progeny deviation from contemporary group mean on time (Smith, 1962). The data were first adjusted for contemporary group and age of dam effects as described above, and analyses were done within herd-sex subclasses. Including contemporary group as a classification variable removed average environmental fluctuations between groups.

Genetic trend estimates utilized records that had overlapping generations. The within-sire regression coefficient estimates the average change in sire progeny performance, relative to the mean performance, over time. Smith (1962) points out that this estimate will be biased if sires are selected for subsequent use on the basis of progeny performance. Improper adjustment for age of dam effects, assortative mating by age and assigning mates by genetic merit also would result in biased estimates of genetic trend.

Sires introduced into the herd and sires old enough to have had progeny data available at the time of mating were most likely to have

been mated assortatively by genetic potential or by age. Therefore, estimates of genetic change were obtained by first removing progeny from introduced sires, then by removing progeny of sires greater than 21.5 mo of age when progeny were born, and finally by deleting progeny from both classifications. The number of observations for WT in the estimates of genetic trend from all the data are presented in table 1 for each herd-sex subclass. The percentage of all the records that remained after deleting records of progeny by introduced sires ranged from 55 to 94%. The percentage of progeny by sires selected from within the herd averaged 72% for males and 74% for females. From 16 to 84% of the observations remained after deleting progeny by older sires from the data set. Averaged over herds, about 53% of the records were from progeny by sires older than 21.5 mo when the progeny were born. Deleting progeny of introduced and older sires left fewer than 50% of the original number of observations in all but four herds.

These analyses did not provide any consistent evidence across herds for bias from assortative mating. Differences between estimates within herds were extremely variable among herds. Also, the standard errors of the estimates of genetic trend increased markedly when each subset of the data set was removed. Therefore, only estimates of genetic trend obtained from analyses of the entire data set are presented herein.

Expected genetic change in BF and WT due to within-herd selection was calculated from the regression of the genotype for BF or WT on the retrospective index multiplied by the selection differential of the index. An index in retrospect (Dickerson et al., 1954) was calculated for each herd-sex subclass to obtain a measure of the relative weightings given to each trait during selection. The relative weightings were obtained by solving the equation $Pb = S$, where P is the phenotypic correlation matrix, b is the vector of relative weights, i.e., the standard partial regressions of each trait multiplied by the standardized selection differential of the index, and S is the vector of standardized selection differentials.

Selection differentials for BF, WT, NBA (number of live piglets/litter at birth of the litter in which the pig was born) and the index of these traits calculated by the SPF Association were calculated as the within-contemporary-group deviation of boars and gilts that

TABLE 1. NUMBER OF OBSERVATIONS FOR WEIGHT AT 140 D AND NUMBER OF MALES AND FEMALES ON WHICH SELECTION DIFFERENTIALS WERE OBSERVED FOR EACH HERD

Herd	No. of observations		No. with observed selection differentials					
			Males			Females		
	Males	Females	BF ^a	WT	NBA	BF	WT	NBA
A	1,187	1,898	11	11	11	204	207	205
B	1,239	1,254	13	14	14	76	76	76
C	2,285	2,699	19	19	19	172	177	177
D	3,600	4,221	10	10	10	231	235	235
E	7,472	12,563	110	113	113	1,221	1,226	1,226
F	3,263	4,382	28	31	31	429	445	445
G	2,714	3,319	10	10	10	240	255	255
H	385	832	20	20	20	101	104	104
I	1,375	2,098	38	38	38	189	189	189
J	6,058	10,862	35	35	35	698	713	713
K	1,026	3,126	11	11	11	167	167	167
L	1,381	1,915	15	15	15	131	132	132
M	1,114	1,430	10	10	10	105	110	110
N	600	653	9	9	9	86	93	93
O	2,560	3,299	11	12	12	223	225	225
P	1,340	1,852	11	11	11	124	124	124
Q	2,672	2,838	15	15	15	331	341	341
R	1,325	1,412	25	25	25	109	113	113

^aBF = backfat, WT = weight, NBA = number born alive per litter.

were selected and became parents, from the mean of the contemporary group. Several changes were made in the index calculated by the SPF Association during the years included in this study. The initial index included BF and WT, and during 1976 to 1977, NBA was included in the index calculated for individual herds. The coefficients for each trait were also adjusted to reflect estimates of phenotypic variances and covariances that were calculated from the data. Changes for each herd were made between contemporary groups, and were not implemented at the same time for all herds. The file of data contained only the calculated index for each pig, thus only standardized selection differentials for the SPF index are presented. The selection differential of the retrospective index (SD_I) was calculated as: $SD_I = b'S$.

Observed and potential selection differentials were compared for each trait to measure intensity of selection applied relative to maximum possible intensity. Potential selection differentials for each herd-sex-contemporary group were the average of selection differentials calculated for the top-ranking individuals down to the number actually selected in each peer group.

Predicted response in BF and WT was calculated as follows:

$$E(\Delta G_{BF}) = \frac{4b_1\sigma_{S_{BF}}^2 + 4b_2\sigma_{S_{BF,WT}}}{b_1^2\sigma_{P_{BF}}^2 + b_2^2\sigma_{P_{WT}}^2 + 2b_1b_2\sigma_{P_{BF,WT}}} \times SD_I,$$

$$E(\Delta G_{WT}) = \frac{4b_1\sigma_{S_{BF,WT}} + 4b_2\sigma_{S_{WT}}^2}{b_1^2\sigma_{P_{BF}}^2 + b_2^2\sigma_{P_{WT}}^2 + 2b_1b_2\sigma_{P_{BF,WT}}} \times SD_I,$$

where,

b_1 = index weight for BF from retrospective index,

b_2 = index weight for WT from retrospective index,

$\sigma_{P_i}^2$ = phenotypic variance for i, where i is equal to BF or WT,

$\sigma_{P_{BF,WT}}$ = phenotypic covariance between BF and WT,

$\sigma_{S_i}^2$ = sire component of variance for i, where i is equal to BF or WT,

$\sigma_{S_{BF,WT}}$ = sire component of covariance between BF and WT, and

SD_1 = selection differential of the retrospective index.

Variance components used were from David et al. (1983). The sire components of variance and covariance were multiplied by four to give estimates of additive genetic components.

Genetic trend and predicted response for NBA were not estimated because in many herds, particularly in the early years of data collection, information on the sire of the dam of a litter was not available. This information was necessary to calculate within-sire regressions of progeny performance on time and to estimate heritability.

Results

The numbers of males and females on which selection differentials were observed for each herd are presented in table 1. These numbers are not the actual number of hogs selected for replacements from within the herd during this time period. Instead they are the number of males or females that were born, had performance for WT recorded and subsequently produced offspring during the time span considered for the particular herd subclass. Differences in numbers selected for WT and BF are due to selection of individuals without BF performance recorded caused by selection of breeding stock with WT performance that was

too poor to make the minimum requirement of the SPF program before BF was measured.

The number of males selected by these criteria ranged from 9 to 113 per herd. Although the mean was nearly 23, the median was only 15. The average number of boars selected was 3.8 per herd-year subclass. Numbers of females varied from 76 to 1,226 per herd. Again, a few large herds caused the mean to be higher than the median, 274 and 183, respectively. An average of 46 females was selected per herd-year cell.

Figures 1, 2 and 3 contain average observed and potential selection differentials for WT, BF and NBA, respectively. In general, selection differentials were more desirable for males than for females with the exception of the trait NBA, where the sexes had similar selection differentials. Potential selection differentials are those that each herd could have achieved if, when selecting the same number of replacements from the same contemporary groups, selection had been based solely on performance for the one trait in question. These values exceed the real potential because some slippage due to death loss or infertility is always present. Averaged over herds and sexes the observed selection differentials were 8 kg, -0.6 mm and -0.1 piglets for WT, BF and NBA, respectively. Potential selection differentials were 15.4 kg, -3.6 mm and 3.25 piglets.

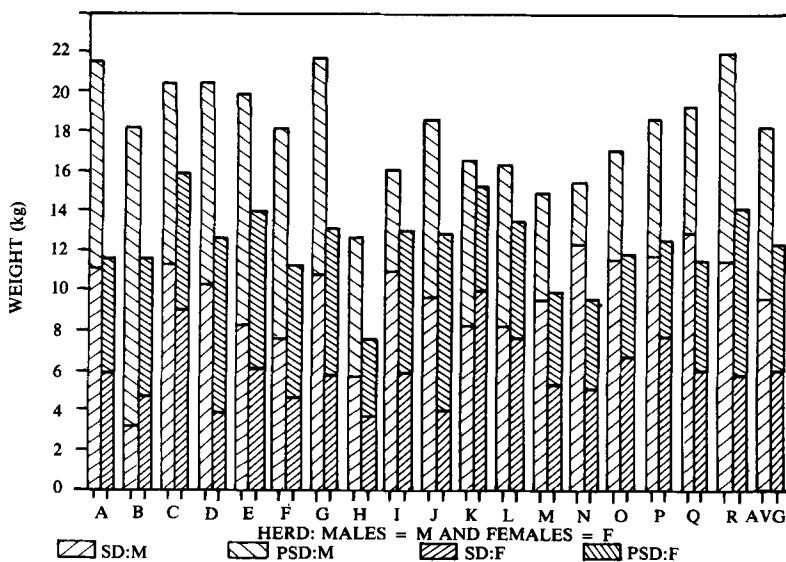


Figure 1. Selection differentials for weight at 140 d (observed = SD and potential = PSD).

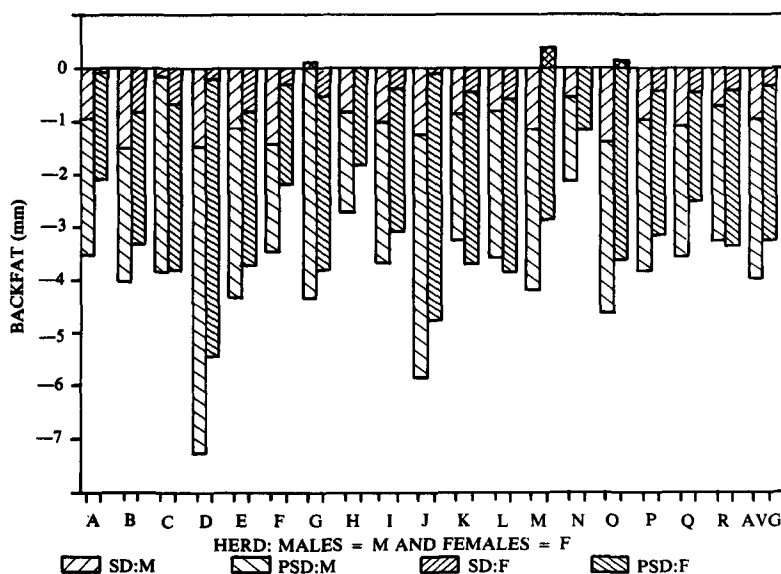


Figure 2. Selection differentials for backfat at 100 kg (observed = SD and potential = PSD).

The larger proportion of potential selection differential observed for WT than for BF and NBA might have been anticipated due to SPF procedures which required a minimal weight for certification. Boars had to have a WT of at least 77 kg and gilts must have had a minimum WT of 68 kg to be certified. The requirement was followed closely because 98% of all select-

ed stock met those minimums. The selection differential for WT from this restriction was expected to be 4.3 kg for gilts and 3.5 kg for boars. The average of these two figures (3.9) was half as large as the observed average.

The observed and potential selection differentials (standardized) for the index produced by the SPF Association are presented in figure

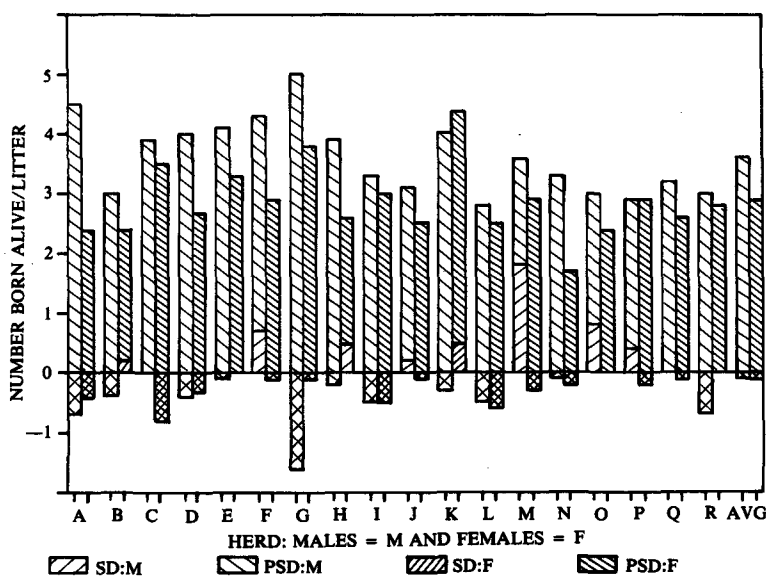


Figure 3. Selection differentials for litter size at birth (observed = SD and potential = PSD).

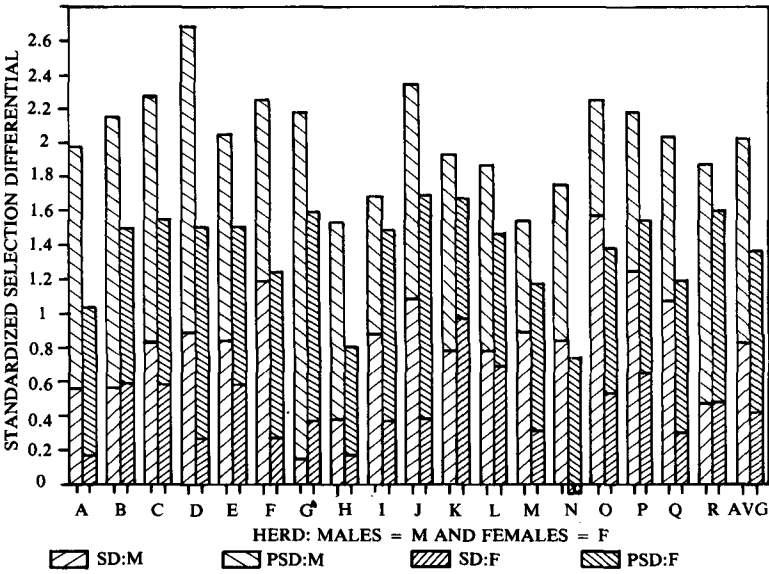


Figure 4. Selection differentials for SPF index (observed = SD and potential = PSD).

4. Actual selection differentials were 41% of potential for boars and 31% for gilts.

Table 2 lists the relative weightings for each trait in the retrospective index for selected

boars and gilts. Since the weightings have been scaled so that their sum for any particular index is 100, the number in the column below a specific trait can be interpreted as the percent-

TABLE 2. RELATIVE WEIGHTS FOR EACH STANDARDIZED TRAIT IN RETROSPECTIVE INDICES^a

Herd	Males			Females		
	BF ^b	WT	NBA	BF	WT	NBA
A	-27	60	-13	8	81	-11
B	-49	30	-20	-27	62	11
C	-13	76	11	-28	60	-12
D	-16	67	-17	-7	73	-19
E	-34	66	0	-28	68	4
F	-38	41	21	-16	78	6
G	13	62	-25	-12	82	6
H	-30	62	9	-3	67	30
I	-20	74	-6	-10	77	-13
J	-22	68	9	-7	81	-12
K	-20	79	-1	0	78	22
L	-22	69	-8	-11	75	-14
M	11	53	36	8	86	-6
N	-3	94	3	7	91	-3
O	-20	58	23	9	86	-5
P	-9	74	17	-2	91	-7
Q	-24	72	3	-18	78	-4
R	-27	57	-16	-30	68	-2
Mean ^c	-19.4	64.6	1.4	-9.3	76.8	-1.6

^aWeights scaled such that their absolute value equals 100 for each herd-sex subclass for each index.

^bBF = backfat, WT = weight, NBA = number born alive per litter.

^cUnweighted mean.

age of the selection emphasis given to the trait in that index.

In all herds WT had at least twice as much impact as BF on the selection decision for females. Similarly, the emphasis was largest for WT in males, with the exception of herds B and F. Intentional selection for BF was more pronounced in males than in females. Backfat in gilts and NBA in males and females were given little emphasis in the selection decision in most herds.

In the only other study using retrospective index techniques to study selection in swine field data, quite different results were obtained (Puff, 1976). Purebred German Landrace breeders in Bavaria had more-detailed performance records on potential breeding stock than did Nebraska SPF breeders. In the Bavarian study of selection in the early 1970's, boar selection was based primarily on full-sib performance for meat-to-fat ratio. More emphasis was placed on feed efficiency and full-sib meat-to-fat ratio than backfat or daily gain in replacement female selection.

Comparisons within contemporary group and age-of-dam of offspring by sires born in the

herd with progeny by sires introduced from other herds are presented in table 3. Mean differences were .0 mm for BF and .3 kg for WT. This comparison assumed random allocation of mates. Differences in castration rates for male offspring from the two sources of sires could bias the comparisons among male offspring. This bias would have occurred if the criteria used to decide which boars to castrate were related to the response variable (BF or WT). A larger proportion of male offspring from sires born within herds were castrated than from introduced sires, except in herds C and R. This seemed to indicate that progeny of introduced sires were treated differently than progeny of sires born within herds in these two herds. Inconsistencies between sexes within herds in estimates of sources of sire differences could also be due to sex \times source-of-sire interaction, or simply random variation. No general trend regarding differences between source-of-sire was observed. Few herds were able consistently (see table 3 for various values of observed probability levels) to identify and obtain outside sires superior in both BF and WT to those selected from within the herd. Female

TABLE 3. DIFFERENCE IN PERFORMANCE OF OFFSPRING FROM INTRODUCED SIRES AND THOSE SIRES BORN WITHIN THE HERD^a

Herd	BF ^b , mm		WT, kg	
	Males	Females	Males	Females
A	.3	.2	.9	.9
B	.4*	.0	-1.8**	-1.3*
C	.0	.3*	.2	.5
D	-.5*	-.2	.8	.3
E	-.4**	-.5**	1.0**	.9**
F	.0	.0	.3	2.1**
G	.3	.2	.0	1.0*
H	1.3	.2	-.7	3.4*
I	.3	.3*	-1.9**	-2.7**
J	-.4	-.2	-.5	.1
K	-.1	.5**	.1	.5
L	-.4	.3	1.4	.7
M	.8	.3	-.6	-.2
N	-.4	-.2	-1.1	-.3
O	-.9*	-.8*	.1	-.1
P	.1	.0	1.3	2.1**
Q	.0	.1	.4	-1.5**
R	.2	.2	2.2**	.4

^aSires-born-on-the-farm least-squares mean minus introduced-sires least-squares mean.

^bBF = backfat, WT = weight.

*P<.05.

**P<.01.

progeny should be used to compare the merit of sires from the two sources, to avoid biases due to differences in proportion of males castrated.

Phenotypic trends for BF and WT are reported in table 4. The trends for NBA were negligible. These are trends estimated separately in female and intact male offspring and not trends in sires or dams. The percentage of males castrated in each herd ranged from 1 to 67%; the average was 29%. Separate estimates of trend were calculated for each sex because the effect of castration of some males on the estimates was unknown. Spearman's rank correlation coefficients between estimates of trend for the sexes were .83 for BF and .84 for WT, indicating quite good agreement between sexes in the estimation of the phenotypic trend.

In most herds, phenotypic changes in BF were favorable. Gilts and boars from two herds were increasing in BF, however. There were as many herds whose performance for WT was decreasing during the 1970's as there were herds in which WT was increasing.

Significant genetic trends in BF were detect-

ed only in females from four herds, negative in three herds and positive in one (table 4). None of the estimates of genetic trend for males was significant. The genetic trend for BF averaged across herds and sexes was near zero ($.0 \pm .10$ mm/yr for females and $.2 \pm .11$ mm/yr for males). The average genetic trend for WT was .6 kg/yr, and was identical for both sexes.

The assumption that genetic trend is equal in dams and sires is necessary to equate the estimates of genetic trend obtained from sires to genetic trend in the herd. Smith (1962) pointed out that "since dams are daughters of sires of the previous generation, it is unlikely that different rates of change could exist in the two sexes over a period of time." Changes in maternal genetic effects are not reflected in the estimates of genetic trend within sires. Within-dam regressions of progeny performance were not calculated to estimate genetic trend in dams because age-of-dam effects were completely confounded with genetic trend in dams.

Estimates of genetic trend from the present study are quite different from those reported by Kennedy (1984). He found that in purebred

TABLE 4. PHENOTYPIC AND GENETIC TRENDS FOR WT^a (KG/YR) AND BF^a (MM/YR) BY HERD-SEX SUBCLASS

Herd	Phenotypic trend				Genetic trend			
	BF		WT		BF		WT	
	Males	Females	Males	Females	Males	Females	Males	Females
A	-1.0**	-1.4**	-.1	.2	.1	.4	4.3**	5.4**
B	-.5**	-.9**	.7**	.3*	-.1	-.5*	.5	.8
C	-.5**	-.5**	.6**	.6**	.2	.2	-.3	-.2
D	.0	-.4**	.0	.3**	-.1	-.4	-.4	-.4
E	-.5**	-.5**	.2**	.0	-.1	-.1	1.0	-.3
F	-.7**	-.7**	-.8**	-2.0**	-.1	-.4*	.7	.5
G	-.3**	-.8**	-.8**	-.1	.1	.2	-.3	.8
H	-1.2**	-.8**	.4	-.8**	2.4	-.8	-1.8	-1.8
I	-.3**	-.5**	2.0**	1.7**	.9	.1	4.8*	1.3
J	.2**	.1**	.7**	.8**	.0	.2	.2	-.1
K	-.4**	-.9**	-.1	-.1	.2	-.3	.0	1.5*
L	-.1**	-.4**	.0	-.1	-.4	-.8**	.2	1.0
M	-.7**	-.8**	-.8**	-1.2**	-.4	.1	3.5**	3.7**
N	-.5**	-.5**	-2.0**	-2.6**	-.1	-.1	-1.2	1.8
O	.3**	.4**	.0	.5**	-.3	-.1	-.9	-1.2**
P	.0	-.4**	-1.4**	-.9**	.7	.9**	1.3	1.5
Q	-.3**	-.5**	.6**	.4**	.7	.5	-.3	1.1
R	.0	.0	-.4**	-.3*	-.1	.2	-1.4	-4.1**
Mean ^b	-.4**	-.5**	-.1	-.2*	.2	.0	.6	.6*

^aBF = backfat, WT = weight.

^bUnweighted mean.

*P<.05.

**P<.01.

herds of swine in Ontario, trends in average sire and dam transmitting ability, when averaged over male and female progeny, were positive for age to 90 kg (.1 to 1.0 d/yr for four breeds). Estimates of trend in sires and dams were similar within each breed. For backfat, however, he reported that trends in sire transmitting ability were small and not significant in any breed ($-.02$ to $.04$ mm/yr), while trends in dam transmitting ability were negative and significant for all four breeds studied ($-.10$ to $-.21$ mm/yr). The data used by Kennedy (1984) covered a 4.5-yr period from January, 1977, through June, 1981, while data for the present study covered a 9-yr period from 1971 through 1979.

Spearman's rank correlation coefficients between the estimates of genetic trend in boars and gilts were .39 ($P > .05$) for BF and .58 ($P < .05$) for WT. The causes for this poor agreement in the estimates of genetic change in BF are not known. In some herds more males were castrated in the early years of the study than in later years. Changes over time in proportion of males castrated could cause esti-

mates of genetic trend for the two sexes to be different if the castration decision was based on a trait correlated with BF. Data on how this decision was made were not available. Also, individuals that did not have a minimum WT were not probed for backfat (David et al., 1983). A change over time in the percentage of individuals with BF measurements that was different for males and females could cause the estimates to differ. This is unlikely a factor in these data because the phenotypic correlation between BF and WT was generally small in all subclasses (David et al., 1983). The poor agreement between sexes for estimated genetic trend for BF may simply be due to the small absolute values. If little genetic change was occurring, the observed variation between sexes was mostly random. Genetic changes predicted from within-herd estimates of heritability and selection differentials are presented in table 5. Predictions only for BF and WT were made by calculating a retrospective index for these two traits, obtaining the standardized selection differential for the retrospective index, and multiplying the selection differential times the

TABLE 5. ESTIMATED BREEDING VALUES FOR BF^a AND WT^a OF SELECTED FEMALES AND MALES CALCULATED FROM THE RETROSPECTIVE INDEX^{b,c}

Herd	BF, mm		WT, kg	
	Males	Females	Males	Females
A	-.2	.0	3.6	2.9
B	-.1	-.2	1.1	.2
C	-.2	-.4	3.5	2.5
D	-1.7	-.1	2.0	.3
E	-.2	-.1	1.7	1.2
F	.0	-.1	1.4	.8
G	.5	.0	2.0	1.7
H				
I	.1	.1	1.5	.6
J				
K		.0		1.2
L	-.5	-.1	3.7	.6
M	1.3	-.4	3.7	.8
N		-.1		.0
O				
P	.0	.1	.2	2.1
Q	-.6	-.4	1.4	1.6
R	-.6	-.2	3.9	1.1
Meand	-.2	-.1	2.4	1.2

^aBF = backfat, WT = weight.

^bWithin herd-sex heritabilities and genetic correlations were utilized.

^cAverage expected change per generation is the mean male and female estimated breeding value.

^dUnweighted mean.

genetic regression of each trait on the index. Predicted changes are presented as the average breeding values of selected males and females (table 5). The expected genetic change per generation is the mean predicted breeding value of selected males and females. Genetic change for NBA was not predicted because little selection for NBA was practiced.

With the genetic variation and selection differentials calculated for these herds, little change was expected in BF. Less than 2 mm change in BF was predicted during the entire 9-yr period involved in this study. Expected change in WT, however, was more desirable than the expected change in BF. The estimates of genetic trend (table 4) are expressed per year and cannot be compared directly to the predictions of genetic change in table 5. Generation intervals were not calculated. Assuming a 2-yr generation interval, the intensity of selection practiced in these herds should have resulted in approximately 8 kg change in WT from 1971 to 1979. Predicted response was 50% larger than observed response when averaged across herds.

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