SWINE GENETICS

NSIF NATIONAL SWINE IMPROVEMENT FEDERATION

Fact Sheet Number 9

Application of Selection Concepts for Genetic Improvement

Correct use of selection concepts is essential if genetic improvement is to proceed at a rapid rate. Therefore, seedstock breeders and commercial pork producers need to fully understand the principles of selection which directly influence the amount of genetic improvement made per year. This fact sheet explains the primary concepts necessary to gain an understanding of genetic improvement. Then it discusses the effect of applying selection concepts on genetic improvement.

Genetic Improvement

Genetic improvement (also known as genetic progress) in within-herd performance is a result of increasing the frequency of desirable genes and decreasing the frequency of the undesirable genes in the herd. Genetic improvement from selection can occur regardless of the type of management, feed, or facilities used in a herd. However, the greatest genetic improvement is most likely to be realized when animals are reared in a herd environment similar to the commercial production environment.

Genetic improvement does not result from changing the management, facilities, feeds, etc., even though, by making such changes, the herd average for a particular trait may improve. The reason is that changing these environmental factors does not change either the genes carried by the animals or the genotypes obtained from these genes; therefore, genetic improvement will not result.

How Genetic Improvement Is Achieved

To obtain genetic improvement, the breeding value of the animals must be estimated from the phenotypes (that which can be observed or measured) of the animals themselves and (or) those of their relatives. The phenotypes may be performance records on the prospective replacement stock, performance records on the relatives of the prospective replacement stock, or a visual evaluation of the animals or their relatives. Visual evaluation is not recommended for traits which can be measured.

For example, using a scale to measure average daily gain or an ultrasound machine to evaluate backfat thickness gives more accurate evaluations of a pig than would visual appraisal. Although these objective measurements may not be perfect, they are much better than the visual appraisal method.

In any case, there must be a mechanism in place that will permit the ranking of the tested animals from best to worst within a contemporary group for the traits under selection. A contemporary group consists of animals of the same breed and sex that were farrowed within three or four weeks of each other, housed together, fed the same feed, and managed as much alike as possible. The recommended method for comparing the genetic merit of prospective breeding animals from a contemporary group is to estimate their breeding values (EBV) or their expected progeny differences (EPD) from their own performance records and the performance records of their relatives (see NSIF-FS8, Estimating Genetic Merit). The animals with the best estimated breeding values should be retained as replacement animals, and those with the poorest estimated breeding values should be culled from the herd.

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The Amount of Genetic Improvement That Can Be Expected per Generation

The amount of genetic improvement obtained in each generation of selection depends on three items. These three factors are:

1. accuracy of the phenotypic evaluation(s) or the performance records in predicting the animal's true breeding value or genotype (A),

2. intensity or degree of selection based on the phenotypic evaluations practiced on animals (I), and

3. amount of genetic or true breeding value variation among animals for the trait under selection (G).

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This is usually written as follows:

Genetic improvement/generation = A x I x G.

Note that if any one of these three factors is equal to zero, the product of the calculation is zero, indicating that no genetic progress can be expected regardless of the size of the other two factors.

Let's consider each of these components separately and examine how each affects genetic improvement.

Accuracy

The first component, accuracy, indicates how well the evaluated phenotype for a particular trait relates to the animal's genotype for that trait. Accuracy is a measure of the degree of confidence that we have in the estimated or predicted breeding value. Accuracy is measured on a scale of 0 to 1, with 1 indicating an exact association between the phenotypic evaluation and the animal's true breeding value, and 0 indicating there is no relationship between the phenotypic records and the true breeding value of the animal. The higher the accuracy, the more precisely the breeding value has been predicted.

Accuracy will be lower (closer to 0) if heritability of the trait is low or if errors in measuring the trait are high (see NSIF-FS7, Performance Records on Relatives). Accuracy will decrease if performance data for selection decisions were only from relatives not closely related to the candidate for selection. For example, the great-grandsire would be expected to have only 12.5% of the genes in common with his great-grand offspring. Therefore, using performance evaluation based upon information on the grandsire would be much less accurate than that from performance information on a number of littermates (which have 50% of their genes in common) or on the individual itself. Using performance information on littermates as well as on the individual, however, would be more accurate than using performance information on either alone (see Table 1). If even more relative information were available, the accuracy will increase even more and therefore, the breeding value would be estimated more precisely and we would have more confidence in the EBV or EPD.

Table 1. Accuracy of Selection Based on Individual Performance and/or Littermate Performance Records.

		Accuracy of selection for		
Trait	**Heritability of trait**	**Animal's own record**	**7 Littermate records**	**Animal's own record and 7 littermate records**
Number born alive	.10	.32	.37	.46
Number at 21 days	.06	.24	.30	.37
21-day litter weigh	.15	.39	.43	.53
Days to 250 lb.	.30	.55	.53	.67
Backfat probe	.40	.63	.56	.73
Feed efficiency	.30	.55	.53	.67
Average daily gain	.30	.55	.53	.67
% lean	.48	.69	.59	.77

Table 2. Effect of Number and Percentage of Animals Retained from a Contemporary Group of 100 Potential Replacement Gilts on Selection Intensity.

Numbers of animals selected	Percentage of animals selected	Selection* intensity
1	1	2.51
5	5	2.02
10	10	1.73
25	25	1.26
50	50	.79
75	75	.42
100	100	0

* *Selection intensity would be negative if selection of animals were in the down direction, such as for fewer days to 250 lb, decreased backfat probe and improved feed efficiency.*

Selection Intensity

The second component that determines the rate of genetic improvement is the amount of selection practiced, commonly called the "selection intensity." Selection intensity for a performance trait depends on the proportion of animals that are selected relative to the total number of animals that comprise the performance test group (contemporary group). It must be re-emphasized that pigs compared in a performance test group should be of approximately the same age (preferably no more than 3 or 4 weeks apart in farrowing dates), managed in a similar manner, raised in the same facility, fed the same diet, and of the same breed and sex.

Selection intensity values range from -3 to +3. The minus sign (-) indicates that selection emphasis is on a trait in the down direction, such as for low backfat thickness, fewer days to 250 lb., or low feed efficiency values. The plus sign (+) indicates that selection emphasis is in the up direction, such as for high average daily gains and high NSIF index values. A value of 0 indicates one of two cases. A 0 could indicate that selection has not taken place because all (100%) the animals were kept as replacement stock. Or a 0 could indicate that the average performance of the selected animals equaled the contemporary test group average because some of the animals

Table 3. Effect of the Number of Animals Tested Per Contemporary Group on Selection Intensity for a Performance Trait When the Highest Ranking 10 Gilts are Selected.

Number of animals selected	Number of animals tested	Percentage of animals selected	Selection intensity*
10	100	10	1.73
10	75	13	1.59
10	50	20	1.37
10	25	40	.94
10	10	100	0

* *Selection intensity would be negative if selection of animals were in the down direction such as for fewer days to 250 lb, decreased backfat thickness and improved feed efficiency.*

Table 4. True Breeding Value (Genetic) Variation for Traits of Interest to Swine Producers.

Trait	True breeding value variation
Number born alive	.79 pigs per litter
Number at 21 days	.58 pigs per litter
Adjusted 21-day litter weight	6.20 pounds
Days to 250 pounds	7.12 days
Backfat probe (A-mode)	.06 inches
Backfat probe (B-mode)	.13 inches
Feed efficiency	.14 pounds feed/pound gain
Average daily gain	.11 pounds per day
% lean	1.04 %
NSIF indexes	25.00 index points

Table 5. Effect of Generation Interval on Genetic Improvement* per Year in NSIF Index Units.

Number of	Boars are used in the herd for				
litters per sow	3 months	6 months	1 year	2 years	3 years
1	41.0	41.6	39.8	35.0	31.5
2	40.5	41.1	39.5	35.1	31.9
3	38.5	39.0	37.8	33.9	31.0
4	36.1	36.7	35.8	32.4	29.0
5	33.9	34.6	33.8	31.0	28.7
6	31.9	32.6	32.0	29.6	27.6

* *This value needs to be added to 100 to obtain the NSIF index of the progeny of the selected boars and gilts.*

kept as replacement stock were below average, even though only a portion of the available animals were kept as replacements.

If, for example, 100 animals were tested in a contemporary group, the fewer the number of animals selected for breeding based only on estimated breeding values for a particular trait (the lower the percentage retained for breeding), the greater the selection intensity and thus the greater the amount of genetic improvement that should be realized (Table 2). Table 2 also shows that if all of the tested animals are selected, no genetic improvement will result since no selection was practiced.

Another factor that affects selection intensity and, therefore, the amount of genetic improvement is the percentage of the available animals that are tested. For example, if the selection objective was to keep the best 10 gilts from a potential contemporary group of 100 gilts, selection intensity would not be maximized if fewer than all 100 of the gilts were tested (Table 3). In fact, Table 3 shows that if only 10 of the 100 available gilts were tested and then selections were made only from the tested animals, no genetic improvement would result. This occurs because all the animals tested were required as replacement animals and the selection intensity therefore equaled zero. Anything that can be done to maximize the number of animals tested and thereby minimize the percentage of animals selected will increase the amount of genetic improvement that can be made in each generation, provided the animals are given exactly the same opportunity to perform.

Amount of True Breeding Value Variation

The third and final component that determines genetic improvement of each generation is the amount of genetic or true breeding value variation among animals for a particular trait of interest. The values used by NSIF for some traits are given in Table 4. This variation is difficult for most breeders to measure and identify, but maintaining a number of different sire lines in a herd closed to outside breeding stock would maintain genetic variation in a herd. For large closed herds or herds which are open to breeding stock from outside the herd, genetic variation is probably not a big concern and probably can't be changed or influenced to a great extent by the producer.

Genetic Improvement per Generation

Let's examine an example to determine the amount of genetic improvement possible for the days to 250 lb. In this example, 25 gilts with the fewest days to 250 lb from a group of 100 tested gilts in the contemporary group are selected along with 5 boars with the fewest days to 250 lb from a contemporary group of 100. The calculated selection intensity, I, is the average of the gilts and boars, which is (-1.26 + (-2.02))/2 = 1.64 (see Table 2). The accuracy, A, is .55 (Table 1), and G is 7.12 (Table 4), then

Genetic improvement/generation

= A x I x G

= .55 x (-1.64) x 7.12

= -6.42 days.

If the average of the contemporary group was 175 days to 250 lb, the offspring of these selected boars and gilts would be expected to average 168.6 days to 250 lb (175 days - 6.42 days) for that generation.

Principles of Selection and Their Effect on Genetic Improvement

Effect of Age of Boars and Sows

The genetic improvement formula (Response A x I x G) previously discussed gives the amount of response per generation and not per year. Measuring response per year is more meaningful. One item that affects the rate of genetic improvement per year is the generation interval (T). Generation interval is the age of the boars and sows in a herd at the time the boars and gilts that will replace them are farrowed. Genetic progress per year is usually written as:

Genetic progress/year = (A x I x G)/T,

where A, I, G are as previously defined and T equals the average age of boars and sows when their replacement offspring are farrowed.

Taking our example, the genetic progress per generation in days to 250 lb was -6.42 days:

If the sows are allowed to have 3 litters and boars are kept for 1 year, then, on average, the boars and sows are 1.5 years of age when their offspring are farrowed, if selection takes place continuously. Therefore, average generation interval is (1.5 + 1.5)/2 = 1.5 years, and:

Genetic improvement/year

= (-6.42)/1.5

= -4.28 days to 250 lb.

Another example of the effects of boar and sow age on genetic improvement is given in Table 5 and illustrates the effect that older animals have on the amount of genetic progress per year. Assume a 120-sow herd farrowing 20 litters per month with an average litter size of 8 raised (4 males and 4 females). Twenty (20) of the 80 available gilts need to be selected each month if sows are kept only for 1 litter, 10 if sows are kept for 2 litters, and similarly, for 3, 4, 5 and 6 litters/sow. Also, assume that 1 boar is needed for each 15 sows or 8 boars for the 120 sow herd and boars are used for

Table 6. Effect of Contemporary Group Size on Selection Intensity with 10% of the Animals Being Selected.

Number of animals selected	Contemporary group size	Percentage of animals selected	Selection intensity
1	10	10	1.54
2	20	10	1.64
5	50	10	1.71
10	10	10	1.73
40	400	10	1.75
100	1000	10	1.76

Table 7. NSIF Index and Rank of 20 Potential Replacement Gilts.

Gilt number	NSIF index	Gilt rank	Comment
23-4	155	1	
3-8	150	2	Bad feet and legs
14-3	145	3	
35-11	140	4	Poor underline
2-5	135	5	
9-9	125	6	
14-7	120	7	
23-8	115	8	Not show type
1-10	105	9	Bad feet and legs
33-2	100	10	
	129		Average of 10 best
1-4	95	11	
3-6	90	12	
26-8	80	13	
23-1	80	14	
7-3	75	15	
5-4	70	16	Poor underline
13-1	65	17	
22-7	60	18	
17-3	50	19	
21-2	45	20	
	100		Average of all 20

Table 8. Summary of Possible Selection Differentials for Gilt Selection Based on Different Criteria.

Selection scenario	Selection differential calculation
Maximum possible selection differential for 10 best gilts	129 - 100 = 29 Index Units
10 best gilts kept after culling on feet soundness and underlines	116 - 100 = 16 Index Units
Selection differential lost because of culling on feet soundness and underlines	29 - 16 = 13 Index Units
Percent of maximum selection differential realized	16/29 = .55 x 100 = 55%
10 best gilts kept after culling on feet soundness, underlines, and type	112.5 - 100 = 12.5 Index Units
Selection differential lost because of culling on feet soundness, underlines, and type	29 - 12.5 = 17.5 Index Units
Percent of maximum selection differential realized	12.5/29 = .43 x 100 = 43%

either 3 months, 6 months, 1 year, 2 years, or 3 years before they are replaced by young stock from within the herd.

Results shown in Table 5 indicate that boars probably should not be used for more than 1 year and sows should not be kept for more than 3 litters if a high level of genetic improvement per year is to be attained. Older boars and sows could be used to produce F1 gilts, so their above average productivity and remaining productive life can be utilized for the benefit of the breeder.

The Effect of Contemporary Group Size

Contemporary group size affects genetic improvement through selection intensity and accuracy of selection. The effect of contemporary group size on selection intensity is illustrated in Table 6. If the objective is to select 10% of the available gilts for breeding purposes, then, as the size of the contemporary groups increase, the selection intensity also increases. Table 6 also reveals that a minimum of 20 animals per contemporary group is needed to obtain the majority of the possible selection intensity and little is gained by increasing group sizes beyond 50 animals. This is also the case when evaluating sows for sow productivity.

Small contemporary group sizes also affect the accuracy of selection. An extreme example is if only 2 sows comprise a contemporary group. Obviously, one will be above average and one will be below average, so deviations from the average will not be very informative as to the genetic merit of either animal. It should be emphasized that small contemporary groups will reduce the proportion of potential genetic improvement that could have been achieved compared to optimal contemporary group size.

Effect of Culling Unsound Animals and Those with Poor Underlines

Tables 7 and 8 illustrate the effect of culling for other traits on the genetic improvement of the trait that is desired to be improved genetically. Assume 20 gilts comprise a contemporary group and that it is desired to select the 10 gilts with the highest NSIF indexes. If some gilts are unsound or have poor underlines, however, it will be necessary to select animals with poor NSIF indexes to avoid these problems.

This example illustrates that selection on more than one trait, such as culling because of unsoundness and poor underlines, decreases the amount of genetic improvement possible in the primary trait (in this example, NSIF index). It also indicates that culling based on traits that have little economic importance, such as type, will hinder the rate of genetic improvement even more. This practice should be minimized if the objective is to improve economically important traits.

Conclusions and Summary

The amount of genetic improvement a purebred or seedstock herd achieves each year depends on the accuracy of performance records with respect to the true breeding values of the pigs, the amount of selection practiced based on the performance information, the genetic variability in the trait, and the generation interval. Genetic improvement is not difficult to achieve if performance is measured and selection practiced in a consistent and sustained manner. To improve the production efficiency of commercial operations, seedstock herds must maximize the potential genetic progress per year in the economically important traits.

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