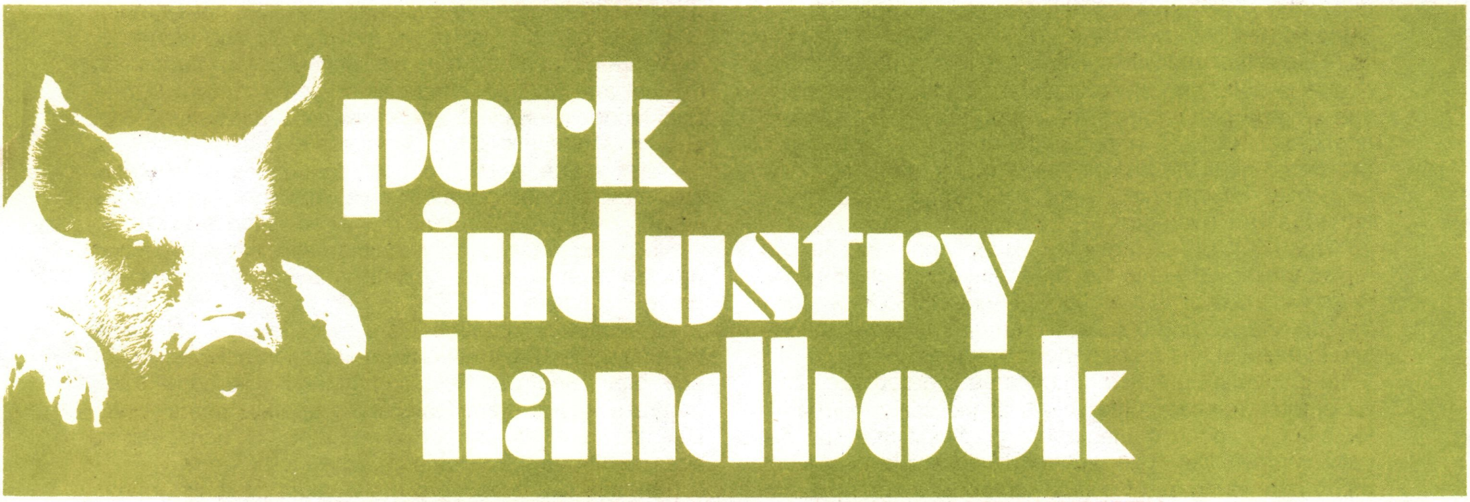
Pork Industry Handbook – Genetic Principles and Their Applications
Michigan State University
Cooperative Extension Service
Erik R. Cleveland, University of Georgia, William T. Ahischwede, University of Nebraska, Charles J. Christians, University of Minnesota, Rodger K. Johnson, University of Nebraska, Allan P. Schinckel, Purdue University
October 1986
8 pages

Extension Bulletin E-2015, New, October 1986



COOPERATIVE EXTENSION SERVICE • MICHIGAN STATE UNIVERSITY

Genetic Principles and Their Applications

Authors
Erik R. Cleveland, University of Georgia
William T. Ahlschwede, University of Nebraska
Charles J. Christians, University of Minnesota
Rodger K. Johnson, University of Nebraska
Allan P. Schinckel, Purdue University

Reviewers
Glenn N. Conatser, West Lafayette, Indiana
Gordon E. Dickerson, USDA/ARS, Lincoln, Nebraska
Steven L. Kerns, Clearfield, Iowa

Introduction

Seedstock producers should have as their goal the genetic improvement of swine performance to reduce production costs and to improve the quality of pork products for consumers. Commercial producers who obtain their breeding stock from seedstock suppliers can improve their herds when seedstock producers apply sound genetic improvement programs. The long-term improvement of the nation's swine herds is completely dependent on the seedstock industry.

Various management practices can improve swine performance; however, even with the best management, performance will not continue to improve without a long-term selection program. Therefore, it is important that commercial and seedstock producers understand basic genetic principles and how application will improve the value of their herds.

Inheritance

The gene is the unit of inheritance, and every animal has both desirable and undesirable genes. Some have more desirable genes than others; and because they do, producers should select breeding stock with the greatest percentage of desirable genes.

Genes normally occur in pairs. Parents randomly pass only one gene from each pair to their offspring, so it is possible for a different set of genes to be passed to each offspring. There are more than 50,000 pairs of genes found in an individual hog. Littermates or full-sibs are likely to share about 50% of the same genes, while half-sibs have about 25% of their genes in common; this occurs because full-sibs share the same parents, while half-sibs have only one parent in common.

Simple traits like hair color are controlled by a few pairs of genes. Complex traits, such as age to 230 lb., backfat, feed efficiency, and litter size may be controlled by hundreds of pairs of genes. A given gene pair may affect more than one trait, and this results in traits being genetically correlated or related. Daily gain and daily feed intake, for example, are positively correlated traits; therefore, selection for increased daily gain should result in increased daily feed intake.

The genetic makeup (genotype) of an animal is the group of gene pairs affecting a particular trait. Even though an individual's genotype for most traits is never known, one can predict which animals have the best genotypes based on their attributes or performance (phenotype). For example, a boar probing 0.66 in. of backfat at 230 lb. should have a better genotype for this trait than one from the same group probing 0.70 in.

The expression of genes controlling some traits is affected by the environment to a greater extent than others. For example, the environment has little or no effect on hair color; however, a pig that received a poor environment (stale feed, drafty winter pen, overcrowding) would take more days to reach 230 lb.

How Genetics Affects a Change in Performance

Selection is the process of choosing certain individuals within the herd or from other herds for breeding purposes. The herd improves genetically because selection increases the frequency of desirable genes and decreases the frequency of undesirable genes. The genetic change per year for a single trait is dependent on three factors: selection differential, heritability, and generation interval for the herd.

Selection differential. Selection differential is the difference in performance between the average of those selected and the average of the group from which they were selected. Individual animals differ in performance due to genetic and environmental effects. For example, the average performance for a group of on-farm tested boars might be 0.73 in. of backfat at 230 lb. Most boars performed near the contemporary group average; a few performed exceptionally well, while some were much fatter than the average.

The idea of saving only exceptional animals as replacements results in the largest selection differentials, i.e., saving a boar that probed 0.66 in. at 230 lb. in contrast to one probing 0.70 would result in a larger selection differential and more genetic progress.

Management practices that increase group size allow for greater selection differentials at the seedstock farm, for example, good management practices that specifically improve litter size weaned. Also, avoid castrating boars at a young age for seedstock producers. Measure performance on every possible candidate in the group. Performance testing of only one small part of the herd could result in some superior animals not being evaluated. After finishing the performance test, castrate the poorest performing boars and slaughter the lowest performing gilts.

Producers should remember that as more traits are included in a selection program, the selection differential is lowered for each trait. Selecting for traits which are not economically important results in less progress in the area of important traits. So it is necessary to limit your selection criteria to only economically important traits that respond to selection.

Depending on their goals, seedstock producers should emphasize different traits. Producers raising a maternal breed such as Chester White, Landrace, or Yorkshire could stress selection for reproductive traits, such as age at puberty, litter size, and 21-day litter weights. If reproductive traits are promoted, not as much emphasis can be placed on growth rate and leanness. In paternal breeds such as Berkshire, Duroc, Hampshire, Poland, and Spotted, emphasis could be on growth rate and leanness. Sexual aggressiveness as well as foot and leg soundness should be stressed in all breeds.

After a seedstock producer determines which traits are important, the producer must strive to remain consistent and follow through in the selection program to achieve the desired genetic improvement. A selection program that changes objectives every few years will prove ineffective.

If seedstock producers are to be successful swine breeders, they must have large selection differentials for both boars and gilts. Selecting superior gilts adds to the progress made from selecting superior boars since selected females can become dams of home-raised sires. Both parents contribute genes to progeny.

Commercial producers make most of their genetic change through boar selection with gilt selection being of secondary importance (see Fig. 1). However, gilt selection becomes more critical if all replacement females are purchased.

Heritability is the percent of the variation in performance due to genetic effects. In other words, it is the strength of inheritance. For example, backfat has about a 40% heritability. Thus, about 40% of the variation (the phenotypic differences between animals in the same contemporary group) in backfat at 230 lb. is due to gene effects while the remaining variation is due to the environment.

Selection is less effective for such lowly heritable traits as number farrowed or number weaned (see Table 1) because they are affected by the environment to a greater extent. Due to the importance and large variability, pork producers should not ignore lowly heritable

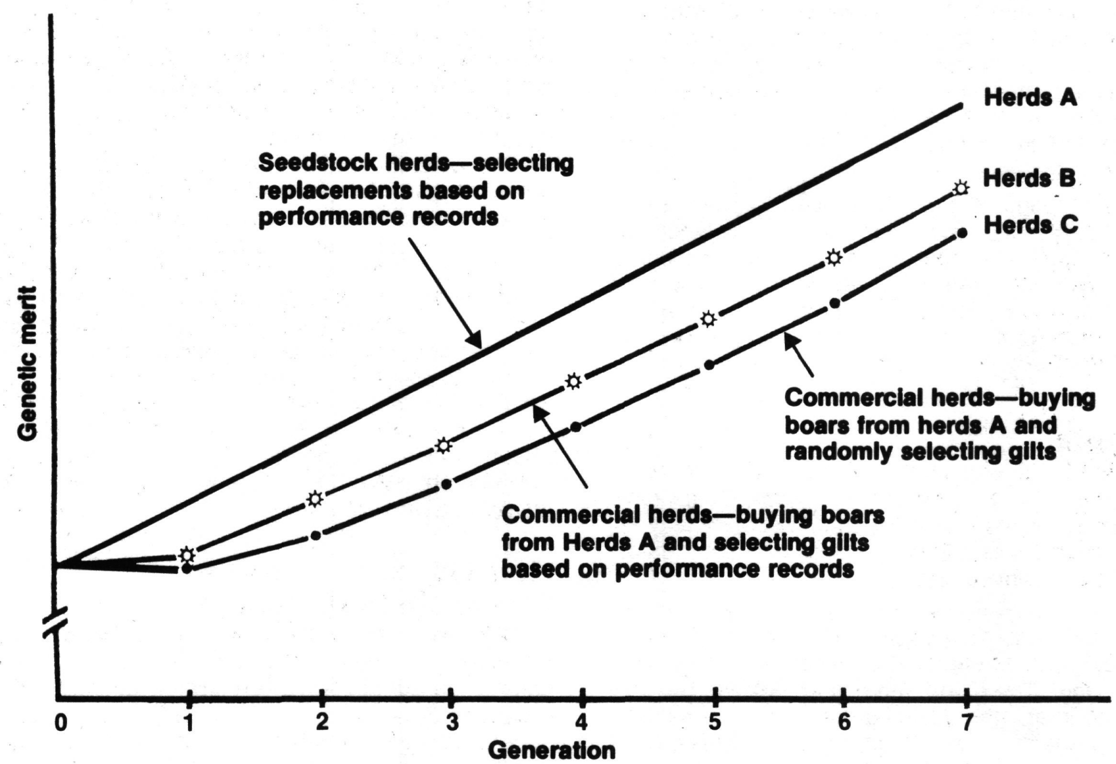


Figure 1. Progress in commercial herds as influenced by rate of genetic improvement in seedstock herds.

reproductive traits in their selection programs. Since errors are more likely to be made when selection is based on only one record, several records on the individual and information from relatives are important for these traits. More progress can be made through family or line selection rather than individual selection if the heritability of the trait is low. Most litter traits have a low heritability, while production and carcass traits have higher values as shown in Table 1.

Table 1. Heritability estimates of some economically important traits.

Trait	Heritability, %
Litter survival to weaning	0
Number farrowed	10
Number weaned	10
Birth weight	20
Weaning weight	20
Feed efficiency	25
Growth rate	30
Age at puberty	35
Backfat	40

Heritabilities can differ between herds. To help increase heritabilities, producers should (1) treat all animals the same within a contemporary group, (2) take complete and accurate records, and (3) adjust records for non-genetic sources of variation.

Generation interval. The generation interval for a herd is the average age of the parents when their selected offspring are born. Herds that have mostly older breeding animals will have long generation intervals. A long generation interval slows progress since improvement is measured as genetic change per year. A shorter generation interval results in faster genetic progress as long as better animals are used as replacements. The generation interval can be decreased by replacing old parents. Even when selecting for reproductive traits, there is little or no justification for keeping purebred sows beyond the third or fourth litter in a seedstock herd. Seedstock producers should replace sires with sons that have better breeding values.

Comparing Animals

Comparisons are more accurate when individuals are compared to other animals from the same contemporary group. A contemporary group is a set of animals of the same breed, or cross, managed together under the same conditions. A contemporary group might consist of sows farrowing in the same building, or managed in the same outside lot, during the same one or two week period. If a scheduled production system is not used, a contemporary group might consist of sows farrowing in a given building during the same month. Contemporary boars are born during the same period and fed a common ration in the same building or lot.

Within a contemporary group, treat all animals the same and provide adequate feeder and waterer space for accurate comparisons. This practice helps reduce, but does not eliminate, environmental effects. Even within a contemporary group, there are many small environmental differences between animals. Thus, each animal receives a slightly different environmental effect.

Include as many animals as possible within a contemporary group. Small group size results in less meaningful comparisons; for example, it makes little sense to compare individuals within a group of as few as five boars.

Since several groups of animals may be tested at a farm within the same time period, it is important to record the contemporary group number for each individual. Then compare only those animals within the same contemporary group, if comparisons are based on individual adjusted performance, without considering other information.

Comparing animals from different breeds is not useful for within-breed selection. Animals from various breeds or lines should be listed as being from different contemporary groups. For example, a test building might house both Duroc and Yorkshire boars born during the same month. When keeping records, the Duroc boars might be listed as being from contemporary group number 1 while the Yorkshire boars would be listed as being from group 2.

To compare animals for economically important traits, performance records must be available. Central and on-farm testing programs provide performance records. Since few boars can be tested at central test stations, seedstock producers are encouraged to enroll in on-farm testing programs. Universities, as well as breed and testing associations, have programs which assist producers with on-farm testing. For more information, visit with your breed representative or Extension swine specialist.

To put all animals on a more comparable basis, adjust performance records for known sources of variation. Backfat thickness is affected by the pig's weight; so to reduce this effect, weigh pigs close to the target weight and adjust backfat values to a constant weight (see Table 2). Another example is adjusting litter weights to a constant age; *Guidelines for Uniform Swine Improvement Programs (USDA Program Aid #1157)* lists adjustment factors. Computer programs simplify adjustment of performance records.

Table 2. Unadjusted and adjusted backfat on four boars.

Boar number	Actual backfat	Weight at probing	Adjusted * † backfat at 230 lb.
	(in.)	(lb.)	(in.)
14-2	.71	245	.66
25-5	.71	230	.71
13-4	.85	235	.83
8-10	.69	225	.70

* The contemporary group average on 87 boars was 0.73 inch.

† Adjusted backfat = actual backfat + (230 - actual weight) x [actual backfat ÷ (actual weight - 25)].

Once records are adjusted, animals can be compared for a given trait by using adjusted performance, deviations, ratios, estimated breeding values, predicted progeny deviations, or a combination of these factors.

Adjusted performance. Table 2 lists both the unadjusted and adjusted backfat values for four boars. With only 0.66 in. of backfat at 230 lb., boar 14-2 is the top individual listed in Table 2 for backfat.

When only adjusted performance records are available, seedstock producers should compute the group average for each trait so customers will know which animals are above average. Commercial producers should select animals that perform better than the group average. Seedstock producers should at least select animals that perform in the upper 5% to 10% of the group, whether from their own or another herd.

Deviation. A simple way to compare animals is to determine how much better or worse each individual is than the average. This difference between an animal's performance and the contemporary group average is called the deviation. It is determined by the following formula: Deviation is equal to the animal's performance minus the average performance of the group.

Example: Boar 14-2 Deviation = .66 - .73 = - .07 in. of backfat.

For backfat, days to 230 lb., and feed/gain, a large negative deviation is desirable. However, for average daily gain, number born alive, and 21-day litter weight, a large positive deviation is desirable.

Ratios. Ratios express an animal's performance relative to the group average. A ratio of 100 represents average performance; ratios above 100 are desirable (Table 3 lists ratios on the four boars).

Table 3. Deviations and ratios on four boars for backfat.

Boar no.	Deviation	Ratio
14-2	-.07	110
25-5	-.02	103
13-4	.1	86
8-10	-.03	104

The backfat thickness of boar 14-2 is 10% (110 ratio) less than the average, while boar 13-4 is 14% (86 ratio) fatter than the average. Use the following formula to calculate the backfat ratio:

Example: Boar 14-2

$$\text{Ratio} = 100 + \left(\frac{.73 - .66}{.73} \times 100\right) = 110$$

For traits such as average daily gain, litter size and litter weights, the ratio formula is modified. The following formula is an example:

Estimated breeding values and predicted progeny deviations. The genetic worth of an individual as a parent is its breeding value. The advantage or disadvantage an individual's offspring shows over the progeny of average boars is called the progeny deviation (one-half the sire's breeding value). Breeding values and progeny deviations measure genetic merit whether they are old sires and sows or young boars and gilts.

True genetic worth is never known; however, it is possible to predict breeding values and progeny deviations based on performance information. Predictions are based on the individual's own record plus any additional information available such as performance records of sibs, parents, and progeny.

The trend in central and on-farm testing is to use estimated breeding values or predicted progeny deviations. Seedstock producers can use estimated breeding values or predicted progeny deviations to select superior replacements and to cull sires and sows, while commercial producers can use estimated breeding values or predicted progeny deviations to select superior replacements.

There are several ways of computing estimated breeding values (EBV's). When the individual's record is available, estimated breeding values are simple to calculate. The following formula is used: Estimated Breeding Value = heritability x (individual's performance - average performance of the group). The predicted progeny deviation (PPD) is equal to one-half of the estimated breeding value. For example, using the adjusted backfat records in Table 2 and the heritability estimate of .4 for backfat, it is possible to compute the estimated breeding value and predicted progeny deviation.

Boar 14-2 EBV = .4 (.66 - .73) = -.028 in. backfat
PPD = -.028 x .5 = -.014 in. backfat

A boar transmits half of his genes or half of his breeding value. Since boar 14-2 has an estimated breeding value of -.028 in. of backfat, his offspring are expected to probe about .014 in. less backfat than progeny of average sires.

As more information (full-sib, half-sib, progeny records) becomes available, calculations become more complex and a computer is needed. Most computer programs calculate predicted progeny deviations as the measure of estimated genetic merit. Predicted progeny deviations change as more information becomes available to use in the calculations. A sire's predicted progeny deviation will change from one year to the next.

Using sib and ancestral data as added information to the individual's (or parent's) record improves the accuracy considerably for lowly heritable traits, but to a lesser extent for highly heritable traits.

Predicted progeny deviations as well as adjusted records, deviations, ratios, and estimated breeding values are no better than the data collected. Recording a wrong weight affects the predicted progeny deviation of the individual as well as its relatives. Errors result in less accurate predicted progeny deviations. Producers should double check ear notches, pedigree records, contemporary group numbers, dates, and measurements to avoid any errors.

For more accurate predicted progeny deviations, use whole herd testing. This allows each individual to be evaluated more accurately through accumulation of additional information on relatives and larger contemporary group size. As the percentage of animals tested declines, the accuracy of each individual's genetic evaluation decreases. Testing a limited sample of a herd yields limited and possibly biased information.

Seedstock producers wanting to use estimated breeding values, or predicted progeny deviations, have two options. One option is to buy the computer program needed to do the calculations and the necessary hardware. The second option is to mail the records to a central location for processing. Contact your breed secretary or Extension swine specialist for more information on this option.

Selection for several traits. After computing adjusted performance, deviations, ratios, estimated breeding values, and/or predicted progeny deviations on several traits, producers must decide how to use this information in selecting replacements. Some producers set a minimum independent culling level, or standard, for these calculated values. Minimum independent culling levels require that selected animals must perform above a certain level for all traits.

Setting minimum independent culling levels is easy; however, they may overemphasize less important traits. This method of selection does not allow for superior performance in one trait to compensate for average performance in another trait. Independent culling levels should be used to cull animals showing genetic defects or soundness (structural or reproductive) problems.

A more efficient method than independent culling is the selection index. Selection indexes rank individuals based on several traits. Economic and genetic factors are used in deriving indexes. Improved efficiency of lean-pork production is a result of properly designed indexes that correctly emphasize each trait according to its contribution to overall merit. In addition, indexes take into consideration the genetic relationships among traits; some traits are adversely related. For example, selection for less backfat often results in slower gaining hogs. Research has shown that if average daily gain and backfat are included in a properly designed index, both traits will improve. Proper emphasis on growth rate and backfat results in maximum correlated response for feed efficiency. Selection indexes allow superior performance in one trait to compensate for average performance in another trait. Selecting top individuals based on a properly designed index will result in more overall genetic progress than selecting animals that perform above a minimum standard in several traits.

All pork producers may not use the same index. A maternal index is used to improve a prolific breed or line, while a paternal index is used to improve a terminal sire breed. Since the traits measured at test stations are growth and leanness, this index is for paternal or terminal sire selection. A general index is used in selecting dual purpose animals.

Within a test group, individuals with the highest index values are expected to have the best overall genetic merit. Adjusted performance, deviations, estimated breeding values, or predicted progeny deviations can be entered into a selection index. An example of entering adjusted performance into the formula is: Index 1 = 100 + (110 x ADG) - (105 x BF). Example: Boar 14-2 Index = 100 + (110 x 2.1) - (105 x .66) = 262.

An example of entering deviations into the formula is: Index 2 = 100 + 110 (individual ADG - avg. ADG for group) - 105 (individual BF - avg. BF for group). Example: Boar 14-2 Index = 100 + 110 (2.1 - 2.1) - 105 (.66 - .73) = 107.

Table 4. Index values on four boars.

Boar no.	ADG	Test group ADG	BF	Test group BF	Index 1	Index 2
14-2	2.1	2.1	.66	.73	262	107
25-5	2.3	2.1	.71	.73	278	124
13-4	2.2	2.1	.83	.73	255	100
8-10	1.9	2.1	.70	.73	236	81

Selecting Seedstock Suppliers

Most pork producers buy boars to obtain genetic improvement, to control inbreeding, or to maximize heterosis (hybrid vigor). The importance of buying boars from the right suppliers cannot be overemphasized. Consider buying from seedstock suppliers that provide on-farm performance-tested breeding stock, especially suppliers making genetic progress. The rate of genetic improvement in commercial herds is equal to the rate of progress made by seedstock suppliers (Fig. 1).

The following practices lead to genetic progress in a seedstock herd: (1) selecting the best performing boars and gilts from within-herd on-farm tests, and (2) buying top performing tested boars from other herds that emphasize selection based on performance records. Commercial and seedstock producers must make judgements about which seedstock producers have good improvement programs. Visit with potential seedstock suppliers about their objectives and selection practices. Evaluate each potential supplier on their history of testing and progress made through selection. Performance testing by itself does not result in improvement, *improvement comes from selecting replacement boars and gilts that excel in performance.*

Crossbreeding

Crossbreeding means mating animals from different breeds. Commercial pork producers use crossbreeding to produce hybrid vigor and to combine the attributes of various breeds. Crossbreeding can improve hog performance; further improvement is a result of selecting replacements on the basis of superior performance.

Hybrid vigor (heterosis) exists when crossbred pigs perform better than the average of the parental breeds. The performance of a given cross may be more or less than the performance of the best parental breed; therefore, parental breed is important. Heterosis does not exist when crossbred pigs perform at the average of the parental breeds.

Generally, heterosis is measured as the percent improvement in performance of crossbreds over the average of their parents breeds. The heterosis percentage for a given trait differs somewhat among crosses. Only average heterosis percentages (based on a number of crosses) are presented in Table 5. Heterosis percentage varies among performance traits. The least heritable traits (reproduction) have the highest degree of heterosis and highly heritable traits (carcass) have the lowest. Production traits such as growth rate are moderately heritable and show a moderate degree of heterosis.

Table 5. Average percent heterosis advantage for various swine traits.*

Trait	First cross using purebred females as parents	Multiple cross using crossbred females as parents
	% Advantage of offspring over parents	
Reproduction		
Number pigs born alive	0.5	8.0
Litter size—21 days	9.0	23.0
Production		
21-day litter weight	10.0	27.0
21-day litter weight/ female exposed	5.0	28.0
Days to 220 lb.	7.5	7.0
Feed per pound gain	2.0	1.0
Carcass		
Backfat	1.5	1.5
Loin eye area	1.0	2.0

* PIH-39, Crossbreeding Programs for Commercial Pork Production.

Heterosis comes in three forms: individual, maternal, and paternal. Crossbred pigs express individual heterosis which results in faster gains and better survival rates than purebred animals from parental breeds. Maternal heterosis causes crossbred sows to farrow more pigs and to wean larger, heavier litters than purebred animals from parental breeds. Paternal heterosis causes crossbred boars to reach puberty earlier and express more sexual aggressiveness than purebreds.

To maximize individual heterosis, make sure the sow and boar are of different breeds. If these parents share any breed in common, a loss of heterosis will result. For example, mating a Duroc boar to a Duroc-Landrace F_1 gilt (backcross) results in only 50% of the maximum individual heterosis being achieved in the offspring

(Table 6). Crossbred pigs with 100% of the maximum heterosis grow 7.0% faster than purebred animals from parental breeds (Table 5). Since backcross pigs have 50% of the maximum heterosis, they will grow about 3.5% (.5 x 7.0%) faster than purebreds.

Use crossbred females produced from parents of different breeds to maximize maternal heterosis. Mating parents that share a common breed in their background results in replacement gilts with less heterosis. For example, a two-breed rotational cross achieves only 67% of the maximum maternal heterosis (see Table 6). Crossbred sows with 100% of the maximum heterosis farrow about 8.0% more live pigs (see Table 5). However, two-breed rotational cross sows will farrow about 5.4% (.67 x 8.0%) more live pigs than sows from those parental breeds. Thus, producers should use crossing systems that make good use of heterosis (see Table 6). After selecting a system, it is important to follow the plan strictly to achieve the expected gains due to heterosis.

Table 6. Percentage of the maximum heterosis obtained from various crossbreeding systems.

System	% Heterosis Offspring	% Heterosis Maternal
F_1 (initial cross, A x B)	100	0
Backcross (A x A-B)	50	100
2-breed rotation	67	67
3-breed rotation	86	86
4-breed rotation	93	93
Terminal cross using F_1 sows	100	100
Rotaterminal using a 2-breed rotation	100	67
Rotaterminal using a 3-breed rotation	100	86

Mating errors, such as a backcross, lead to less heterosis.

Crossbreeding also is used to combine the strengths of different breeds. Each breed has strengths as well as weaknesses. Some breeds contribute to better mothering ability (maternal breeds) in crossbred sows; other breeds have better growth or carcass characteristics (paternal breeds). Specialized crossing systems (terminal, rotaterminal) make good use of breed strengths, while minimizing some weaknesses. Figure 2 shows an example of one specialized crossing system. Use a specialized system that makes good use of heterosis and is adaptable to your management scheme.

For specialized crossing systems, use maternal breeds (or crosses) to produce crossbred replacement gilts. Within maternal breeds, buy breeding stock from seedstock producers with a history of selecting replacements based on reproductive traits. Use boars from paternal breeds to sire the majority of the market hogs. Within paternal breeds, buy breeding stock from seedstock producers with a history of selecting replacements based on growth rate and leanness.

For more information on selecting breeds and crossing systems, read *Crossbreeding Programs for Commercial Pork Production (PIH-39).*

Inbreeding, Linebreeding, and Outcrossing

Since all animals within a breed are at least distantly related, inbreeding usually refers to mating animals more closely related than the average of the breed. An example is a first-cousin mating. Related animals often share some common genes (genes occur in pairs), and mating related animals results in offspring with more pairs of identical genes.

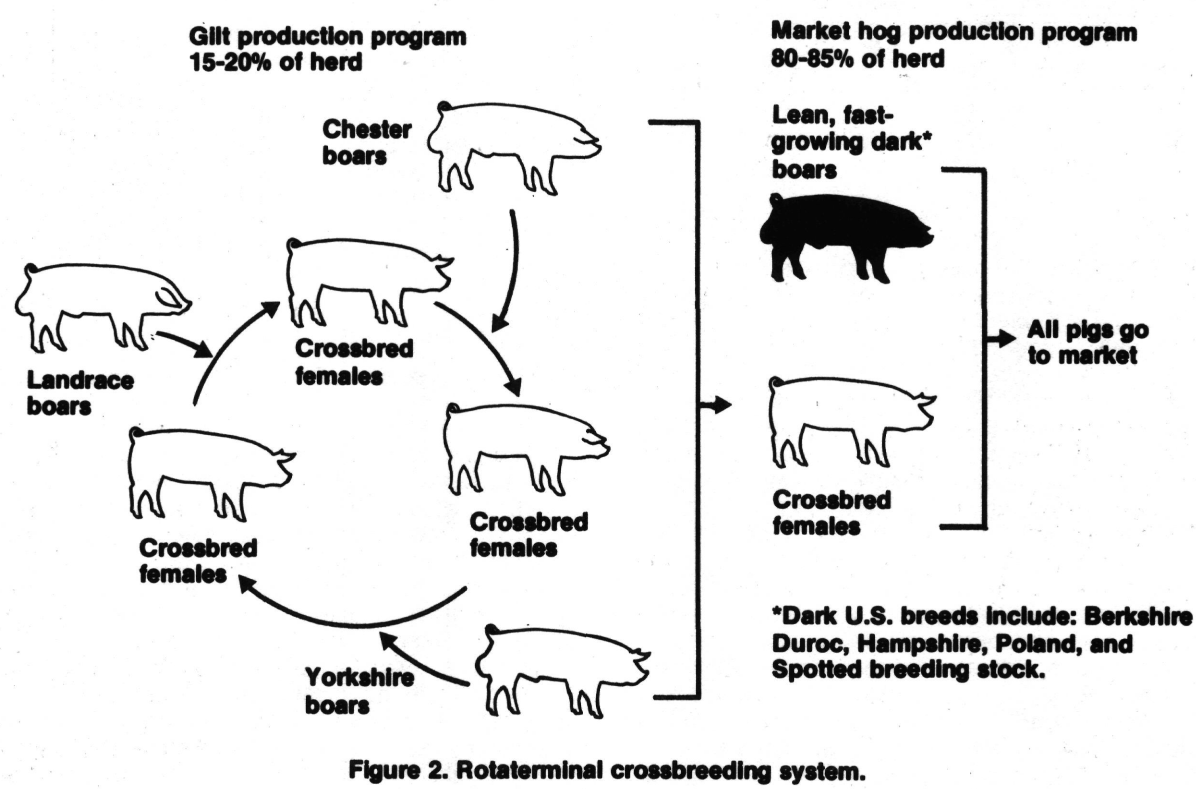


Figure 2. Rotaterminal crossbreeding system.

The inbreeding coefficient measures the likely increased proportion of identical pairs of genes. A higher inbreeding coefficient represents a greater degree of inbreeding. Inbreeding coefficients range from 0 (for non-inbred animals) to 100%. However, inbreeding coefficients over 50% are uncommon in livestock. Table 7 shows inbreeding levels for different matings.

Table 7. Inbreeding coefficients for various matings.

Kind of Mating	Inbreeding (%)
Half first cousin (one common grandparent)	3.12
First cousin (two common grandparents)	6.25
Grandparent-grandoffspring	12.50
Half brother-sister	12.50
Parent-offspring	25.00
Full brother-sister (one generation)	25.00
Full brother-sister (two generations)	37.50
Full brother-sister (three generations)	50.00

Mating animals that share at least one common ancestor in their pedigree results in inbred offspring. A recent ancestor appearing frequently in the pedigree results in more inbreeding. Distant ancestors, even if they appear frequently in the pedigree, will not cause as much inbreeding.

Linebreeding is a mild form of inbreeding that attempts to keep the offspring closely related to some outstanding ancestor. The breeder often attempts to concentrate the genes of an outstanding individual through using sons and grandsons. Seedstock producers sometimes practice linebreeding when outside boars are inferior to home-raised sires.

A rapid rate of inbreeding often depresses reproductive and growth performance. Growth rate and survivability are often lower for inbred pigs. Inbred boars tend to show less interest in breeding and reach puberty at a later age than non-inbred individuals. Inbred sows often produce smaller, lighter litters than non-inbred females.

Inbreeding tends to decrease genetic variation within a line, and changes in the herd's genetic merit, due to chance, are increased with inbreeding.

If deleterious or lethal genes are present, inbreeding will cause more birth defects within that line. Inbreeding tends to concentrate both desirable and undesirable genes. Thus, inbred matings (Example: sire-daughter) can be used to test for undesirable genes.

Seedstock producers often avoid selecting home-raised sires due to the potential dangers of inbreeding. However, home-raised sires can be superior to outside boars, especially for herds that have selected replacements based on performance records for an extended period. Seedstock producers should select top performing home-raised boars as replacements.

Potential dangers of "breeding within" can be prevented by starting your seedstock breeding program with an adequate number of unrelated lines. Maintain an adequate number of sires from the different lines and avoid mating related individuals.

The owner of a herd of as few as five sires can go through a few generations without buying outside boars and not observe high inbreeding levels. Assuming that one boar is kept for every 10 sows, a herd that has five sires can have an average rate of inbreeding of less than 2% per generation if they breed entirely within. If 10 sires are maintained in a closed herd, the rate of inbreeding can be as low as 1% per generation. At these low inbreeding levels, performance should not be adversely affected. Herds with large numbers of sires can breed entirely within for many generations and not experience high inbreeding levels.

The opposite of inbreeding and linebreeding is outcrossing. Outcrossing refers to mating animals less related than the average of the breed. The effects of outcrossing are the opposite of inbreeding. Thus, outcrossing can be used to correct problems which resulted from inbreeding. Mating unrelated, highly inbred, or non-inbred parents results in non-inbred offspring.

Issued in furtherance of Cooperative Extension work in agriculture and home economics, acts of May 8, and June 30, 1914, in cooperation with the U.S. Department of Agriculture. W.J. Moline, Director, Cooperative Extension Service, Michigan State University, E. Lansing, MI 48824.

New-10:86-3M-UP, KMF, Price 25¢, Single Copy Free to Michigan Residents.

O-16656