What the Commercial Pork Producer needs to know about Genetic Improvement

M. Todd See
Department of Animal Science
North Carolina State University

Introduction
The Commercial Pork Producer’s role in genetics is generally to take the end result of a genetic improvement program and manage animals in a manner to maximize expression of their genetic potential. For pork producers there are two main goals: 1) Improve efficiency of production, and 2) Improve end product quality. There are two approaches that can be taken to accomplish these goals: 1) improve management, nutrition and environment and, 2) improve genetic quality. The intent of this publication is to provide pork producers the information necessary to understand how genetic improvement programs interrelate with production management.

For genetic improvement there are three basic methods:

1. **Selection** – Genetically superior animals are used for breeding resulting in differential reproductive rates where more desirable individuals leave more offspring than less desirable individuals. Selection makes use of additive genetic variation and is used for long-term genetic improvement. At the commercial level most selection emphasis should be placed on identifying the breeding stock supplier.

2. **Mating Systems** - A systematic approach to mating of selected animals to produce non-additive genetic change, observed as heterosis. Heterosis does not occur for all crosses or for all measures of performance. In addition, heterosis must be recreated each generation by the mating system. At the commercial level heterosis is typically achieved by crossing terminal boar lines with maternal sow lines that differ in breed composition to produce market hogs.

3. **Importation** - Bringing in genes for specifically required characters into an otherwise satisfactory population. This is most commonly achieved by bringing in new terminal sire lines. While more drastic and not always economically practical, depopulating and repopulating a herd can be the most rapid and simplest form of genetic improvement for commercial production.

For genetic improvement there are three basic methods:

Genetic improvement is normally obtained by utilizing some combination of these systems. However, these systems will each differ in how they relate to production management.

**Genetic Relationships Between Performance Traits**
For genetic improvement through selection, variation amongst animals is required. Variation observed in a population is composed of two primary factors, **genotype** and **environment**. Conventional selection relies on the fact that use of exceptional individuals, as parents of the next generation will result in a positive change in the average performance of the population.
Selection operates only on the genetic component of an animal’s record. The environmental component is not passed from parent to progeny and, therefore, needs to be accounted for when determining the value of an animal as a parent. Some environmental factors such as parity of sow or sex can be accounted for mathematically. However, other factors such as health, management and feed are accounted for through contemporary grouping and are referred to as unknown sources of environmental variation.

When making genetic decisions, economically important traits should be emphasized, but it is also important to understand effect of selection on different traits. Table 1 provides heritability estimates that indicate strength of inheritance for each trait. Heritability is the percent of variation in performance due to genetic effects. For example, backfat has a heritability of approximately 40%. Thus, about 40% of the variation (the phenotypic differences between animals raised in the same group) in backfat is due to gene effects while the remaining variation is due to environment. Response to selection will be slower for lowly heritable traits like number of pigs born alive because they are affected by environmental factors to a greater extent. Most litter traits have a low heritability, while production and carcass traits have higher values as shown in Table 1. In addition, an estimate of the standard deviation (SD) and economic value for each trait is also provided. The SD indicates how much variation exists in the population and can be used to estimate where an individual animal ranks in the population. The SD is also a useful indication of how much variation should be expected in observed performance. For example, 96% of the population will normally fall within two standard deviations of the mean. Economic values for performance traits indicate the relative economic importance of each trait, allowing producers to know how much emphasis to place on each measure. Economic values are provided in dollars for a full unit improvement in the trait of interest, for example each additional pig born alive is worth an additional $13.50 to the producer while a reduction in backfat is worth $1.50 for through contemporary grouping and are referred to as unknown sources of environmental variation.

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<table>
<thead>
<tr>
<th>Trait</th>
<th>Heritability (%)</th>
<th>Standard Deviation</th>
<th>Economic Value</th>
</tr>
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<tbody>
<tr>
<td>Number born alive</td>
<td>10</td>
<td>2.5</td>
<td>13.50</td>
</tr>
<tr>
<td>21 day litter weight</td>
<td>15</td>
<td>16.0</td>
<td>.50</td>
</tr>
<tr>
<td>Feed efficiency</td>
<td>30</td>
<td>.25</td>
<td>-13.00</td>
</tr>
<tr>
<td>Days to 250 pounds</td>
<td>35</td>
<td>13</td>
<td>-.17</td>
</tr>
<tr>
<td>Backfat probe</td>
<td>40</td>
<td>.20</td>
<td>-15.00</td>
</tr>
<tr>
<td>Percentage lean</td>
<td>50</td>
<td>1.5</td>
<td>1.10</td>
</tr>
</tbody>
</table>

Genetic correlation ($r_g$) describes the relationship between two traits, in that a gene or more than one gene may be responsible for an enzyme or other product that influences both traits. Genetic correlations range from -1 to 1. A positive genetic correlation indicates that selection for an increase in one trait will result in an increase in the other. A negative genetic correlation indicates that selection for an increase in one trait will result in a decrease in the other. Sign of the genetic correlation does not indicate the favorability of the relationship, only the statistical relationship.

Due to genetic correlations selection for decreased fat will increase days to market ($r_g = -.20$), reduce pounds of feed required per pound of gain ($r_g = .33$), and greatly increase percent muscle ($r_g = -.85$). Therefore, by improving carcass composition, pigs will generally be slower growing, have decreased appetites and be more efficient. If number born alive is improved, small increases in 21 day litter weight ($r_g = .12$) are observed, and feed efficiency ($r_g = -.15$) and growth rate ($r_g = -.20$) are enhanced slightly. Reproductive traits have little relation to carcass traits ($r_g = 0$).

**Heterosis Effects on Performance Targets**

Crossbreeding is an important part of commercial swine production systems because of improvement in efficiency from heterosis and potential to exploit differences between breeds. A terminal, static cross in which all offspring are market animals takes the greatest advantage of differences in strengths of lines or breeds. Lines that have superior genetic merit for reproduction provide females and lines that are superior for production traits provide males. Pigs marketed then have high genetic potential for production and the sow herd has high merit for reproductive traits. Heterosis has the most significant benefit in maternal performance and factors affecting fertility in boars (Table 2). Ultimately in commercial pork production, selection and crossbreeding are combined to achieve the highest level of performance.

An example of heterosis is a cross between Yorkshire and Landrace. Let’s assume that number of pigs born alive average 10 and 11 for Yorkshire and Landrace, respectively, and that daughters produced from this cross average 11.5 pigs/litter. In the absence of heterosis, daughters from this cross would be expected to produce 10.5 pigs/litter. Therefore heterosis in this example results in 1 more pig/litter in comparison to the expected 10.5, which equals a 9.5% advantage. Thus, heterosis for number born alive in these YxL females can be calculated as follows:

$$\text{Direct heterosis for number born alive} = \left[\left(11.5 - \left((10+11)/2\right)\right) / 10.5\right] \times 100 = 9.5\%$$

In commercial production, knowing levels of maternal, paternal and individual heterosis are important when setting performance targets. One fairly common example is the comparison of F1 females (YxL) to backcross females (YxYL). Expected heterosis of a cross is determined by the amount of genes the parents have in common. This can be determined by the amount of breed in common, i.e. Yorkshire and Landrace are unrelated, and therefore, the offspring have 100% of available heterosis. Therefore, a F1 has 100% heterosis and a backcross has 50% heterosis. In the previ-
ous example, the YxL female had a 1 pig/litter advantage due to heterosis; however, if the YxYL female were used in the sow herd this advantage, due to heterosis, is expected to be only .5 pigs/litter.

Table 2. Estimates of Heterosis for Measure of Swine Performance

<table>
<thead>
<tr>
<th>Trait</th>
<th>Heterosis (%)</th>
</tr>
</thead>
<tbody>
<tr>
<td><strong>Maternal Heterosis</strong></td>
<td></td>
</tr>
<tr>
<td>21 day litter weight</td>
<td>20</td>
</tr>
<tr>
<td><strong>Paternal Heterosis</strong></td>
<td></td>
</tr>
<tr>
<td>Conception rate</td>
<td>10 - 14</td>
</tr>
<tr>
<td><strong>Direct Heterosis</strong></td>
<td></td>
</tr>
<tr>
<td># of Embryos</td>
<td>7</td>
</tr>
<tr>
<td>Litter size</td>
<td>7 - 10</td>
</tr>
<tr>
<td>Testicle weight</td>
<td>20</td>
</tr>
<tr>
<td>Total sperm</td>
<td>30</td>
</tr>
<tr>
<td>Avg. Daily Gain</td>
<td>5</td>
</tr>
<tr>
<td>Feed Efficiency</td>
<td>5</td>
</tr>
<tr>
<td>Backfat</td>
<td>?</td>
</tr>
</tbody>
</table>

Genotype by Environment Interactions

A pig’s genes are expressed in the environment where it is reared. Pigs cannot grow in the absence of an environment containing feed and water nor can an inherited resistance to disease be expressed in absence of the disease organism. Therefore, testing and selection of animals should take place in environments that are very similar to those in which the progeny will be raised.

However, it is equally important that testing and selection take place in an environment that allows for differences between genotypes to be distinguished. Take for example, a genotype by environment interaction that is a result of the choice of nutritional program used during the evaluation of lean growth rate. Differences in lean growth and fatness become evident only when adequate levels of energy and amino acids are provided. Another example is that genetic resistance to a disease can only be expressed in presence of the disease organism (Table 3). Pigs that are resistant to the K88 strain of E coli will not necessarily show a reduced incidence of diarrhea unless E coli bacteria is present.

Table 3. Interaction Between Genetic Resistance to E coli K88 and the Presence of the Organism in the Environment

<table>
<thead>
<tr>
<th>Incidence of Diarrhea (%)</th>
<th>Without K88</th>
<th>With K88</th>
</tr>
</thead>
<tbody>
<tr>
<td>Litters by sire A</td>
<td>15</td>
<td>35</td>
</tr>
<tr>
<td>Litters by sire B</td>
<td>10</td>
<td>15</td>
</tr>
</tbody>
</table>

If the environment in which animals are tested and selected differs greatly from the commercial environment, genotype by environment interactions may result in poor performance. A common example of this situation is in the breeding herd where some sow genotypes excel in productivity when housed in gestation crates. These same sows when group housed and placed in a pasture environment may be inferior to another genotype, which is more durable in that environment, but inferior when housed in gestation crates.

Most often quality of commercial environment does not allow full expression of genetic potential. When making changes or upgrades in the source of breeding animals, an upgrade in management and environment are required if new, improved genotypes are to express their full potential.

Genetic Lag

The swine breeding herd is often thought of as a pyramid. The point or top tier(s) of the pyramid represents nucleus animals. These animals are usually pure line animals in a genetic improvement program selected for specific traits. The multiplier tier(s) crosses nucleus lines for production of parent gilts and boars to be used on commercial farms. The commercial tier then crosses parent boar and gilt lines from the multiplier tier to produce market hogs that are slaughtered.

Genetic lag is the time it takes for any genetic improvements made in nucleus animals to trickle down to commercial market hogs. In each tier of the pyramid length of time that animals are used and their relative genetic superiority to younger animals influences the genetic level experienced at the lower levels of the pyramid. Genetic lag will be different in each production system and can easily range from 4 to 10 years. This means that genetic level of performance of market hogs today is due to selection made in nucleus lines 4 to 10 years ago and improvements being made in nucleus herds today will not be observed in market hogs until 4 to 10 years from now. If genetic lag is reduced the pork producer will see genetic improvements in performance of market hogs sooner. Genetic lag is determined by several variables:

1. The number of steps in the breeding system, including multiplier and commercial herds.
2. The relative genetic superiority of boars and gilts transferred to multiplier and commercial levels.
3. The length of time that animals are used in the multiplier and commercial levels.

Genetic suppliers determine rate of genetic progress in nucleus herds by design and implementation of a genetic improvement program. Most genetic suppliers can provide information on the genetic trend (annual genetic improvement) for each trait selected on in their nucleus herd(s). The genetic supplier should be making annual improvements in traits of importance to the commercial producer.

Structure of the genetic transfer system determines the length of time for genetic improvement to transfer between genetic suppliers and commercial producers. Most genetic
production systems have at least three tiers where replacement boars and gilts come to the multiplier level from the nucleus and the multiplier subsequently provides replacement boars and gilts to commercial operations. Every additional multiplication step added to the system increases genetic lag.

Most multiplier herds are operated in typical commercial fashion with standard replacement rates. Selection is usually not performed among crossbred progeny at the multiplier level because of the large proportion of females required and the increased genetic cost that it would create. Genetic improvement is made at the multiplier levels by routine replacements from the nucleus level where continuous genetic improvement is occurring. Genetic lag can be addressed at the multiplier level through selection of boars.

It is generally not cost effective to operate a selection program at the commercial level. However, genetic lag can be reduced by regular replacement of breeding stock with superior individuals and boars can be replaced at an average age of one year to minimize genetic lag. Opportunity to reduce genetic lag at the commercial level is in quality of boars and gilts selected. It is possible to purchase boars of superior genetic merit directly from the nucleus level and this can reduce genetic lag by about six months.

Some commercial producers do operate genetic improvement programs when they are also trying to achieve health benefits by having a closed herd. These systems will typically utilize artificial insemination (AI) to aid genetic improvement and may have within herd multipliers or use a rotational breeding program.

AI can reduce genetic lag in two primary ways:

1. When AI is used the boar: sow ratio will decrease, reducing number of boars needed; allowing fewer, superior boars to be selected.
2. AI offers an opportunity to use superior sires from the nucleus levels at all levels of the production pyramid.

Using AI at any level of the pyramid can reduce genetic lag by approximately six months, depending on the selection intensity placed on natural service and AI boars. Using AI at all levels of production and obtaining gilts from a source with consistent genetic improvement, minimizes genetic lag (3 ½ years).

For commercial managers to reduce genetic lag, most attention should be paid to selection of a breeding stock supplier. The genetic supplier must be realizing genetic progress through performance testing and genetic evaluation and rapidly disseminate this improvement to the commercial producer. Commercial producers must then use genetic information when purchasing breeding animals along with acceptable health, reproductive soundness, and skeletal structure. Incorporation of an AI program will also greatly reduce genetic lag if AI boars are selected from the nucleus level. If no change is made in the way that commercial boars are selected genetic lag may not be changed. And finally, by reducing the time that commercial boars are used to 1 year or less will result in a reduction in genetic lag at the commercial level.

**Porcine Stress Syndrome**

The halothane (stress) gene has a deleterious effect on pork quality. Small carcass advantages of stress-positive pigs over normal pigs are more than offset by reductions in quality and possible death losses that can occur. In pork production it is very important to know the stress status of breeding stock in your herd. Most genetic suppliers can supply the halothane status for their animals. The DNA-based blood test is used to remove stress-positive and stress-carrier animals from the breeding herd.

**How to Maximize Genetic Potential**

In order to maximize genetic potential at the commercial level the nucleus source for breeding herd replacements must be making constant genetic progress. This is done by combining record keeping systems, testing programs, molecular genetics and genetic evaluation systems based on BLUP statistical methodology into a genetic improvement program. A comprehensive genetic improvement program allows breeding stock suppliers to make annual genetic improvement. Breeding herd replacements put into commercial production must also be selected according to genetic potential and compatibility (heterosis). In addition, when replacement gilts are selected within herd some objectivity should be used for keep/cull decisions.

To realize genetic progress an animal must be provided with an environment that will allow it to express its genetic potential. This means having access to appropriate feed, water, facilities, disease, and environment. In order to monitor expression of genetic potential and to make appropriate adjustments to feeding and management programs current, accurate, and useful performance records are required.

**Summary**

By paying close attention to the following points commercial producers can ensure constant genetic improvement:

1. Select a breeding stock supplier that is performance testing and making genetic improvement in traits that are economically important to your operation.
2. Pay close attention to mating programs and maximize heterosis in both breeding animals and market hogs.
3. Examine the cost: benefit relationships of improving nutrition or management practices to allow your pigs to express their genetic potential.
4. Consider production practices like artificial insemination that allow genetic lag to be reduced.

**Reviewed by:**
Dr. Eric van Heugten, North Carolina State University
Dr. Joe Cassady, North Carolina State University