# SWINE BREEDING SYSTEMS
## for Alternative Pork Chains:
## Breeding Programs

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## Introduction

The pork industry has developed into multiple pork chains with particular specifications for targeted markets. These specifications can include final product attributes, scripted production practices or both. To meet these varying specifications for differing pork chains, pork producers must match their production management and marketing practices to the requirements of their targeted market. This includes developing a breeding program that utilizes breed combinations that best align with the specifications of the pork chain(s) they target. This fact sheet will compare various crossbreeding systems, performance expectations of those systems and methods of operation.

## Crossbreeding

Crossbreeding is an important tool. If used correctly, it offers pork producers an opportunity to genetically improve their production efficiency and, ultimately, lower production costs. The use of crossbreeding is widespread because offspring from matings between individuals from different breeds are typically hardier, grow faster and perform better than purebreds. This improvement in performance of the crossbred individual over the average performance of its purebred parents is called *heterosis* or *hybrid vigor*. It is thought that, during breed formation, portions of the gene pairs that control a trait became homozygous (two gene copies that are the same) for undesirable genes, which cause some suppression in performance. Crossing animals from different breeds breaks up these undesirable gene combinations. Differing genes within gene pairs in the crossbred individual lead to improved performance.

Heterosis is expressed in both the growing and the adult pig. Crossbreds typically have a better survival rate throughout their lives than purebreds and typically grow faster. This improved performance in the crossbred individual is often referred to as individual heterosis. Crossbred dams are expected to have larger litters than their purebred counterparts with a higher survival rate through weaning, and wean heavier pigs. Heterosis in dams that results in improved offspring performance is often called maternal heterosis.

The expected improvement in performance from heterosis is summarized for several traits in Table 1. For example, individual heterosis for number born alive is 1 percent. This means that litter size for purebred dams

**Table 1. Heterosis advantage for production traits.**

| Purebred | Percentage advantage over | |
|---|---|---|
| Item | First cross purebred sow | Multiple cross crossbred sow |
| **Reproduction** | | |
| Conception rate | 0.0 | 8.0 |
| Pigs born alive | 1.0 | 8.0 |
| Litter size at 21 days | 9.0 | 23.0 |
| Litter size weaned | 10.0 | 24.0 |
| 21-day litter weight | 10.0 | 27.0 |
| **Production** | | |
| Days to market | 6.5 | 6.5 |
| Feed/gain | 2.0 | 2.0 |
| **Carcass Composition** | | |
| Backfat thickness | -2.0 | -2.0 |
| Loin muscle area | 1.0 | 2.0 |
| Marbling | 0.3 | 1.0 |

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farrowing a crossbred litter should be 1 percent larger than for dams of the same breed farrowing purebred litters. For a two-breed-cross sow farrowing a litter that is a three-breed cross, the expected improvement is 8 percent. This demonstrates how strategically developing crossbred sows can easily and repeatedly improve maternal performance. This is further demonstrated in Figure 1 with an example of Yorkshire and Landrace dams. The purebred average for Yorkshire is 11.1 pigs born alive. If a purebred Yorkshire farrows a crossbred litter, the expected average number born alive is 11.2. For Yorkshire-Landrace $F_1$ females bred to a boar of a third breed, however, the expected average number born alive is 11.6, even though the Yorkshire-Landrace average is 10.9. The 0.7 increase in pigs per litter above the purebred average is due to heterosis that occurs when a crossbred litter is farrowed by a crossbred dam.

Crossing animals that have breed ancestry in common, often referred to as backcrossing, allows for reformation of some of the original undesirable gene pairs. This reduces heterosis. For example, in Figure 2 are the expectations for average number born alive for Yorkshire and Landrace purebred females, for Yorkshire-Landrace $F_1$ females and for backcross females produced by mating a Yorkshire boar to Yorkshire-Landrace $F_1$ females. The performance expectation for backcross females is lower because of declines in heterosis.

**Figure 1. Comparison of $F_1$ and purebred sow performance for the Yorkshire and Landrace breeds.**
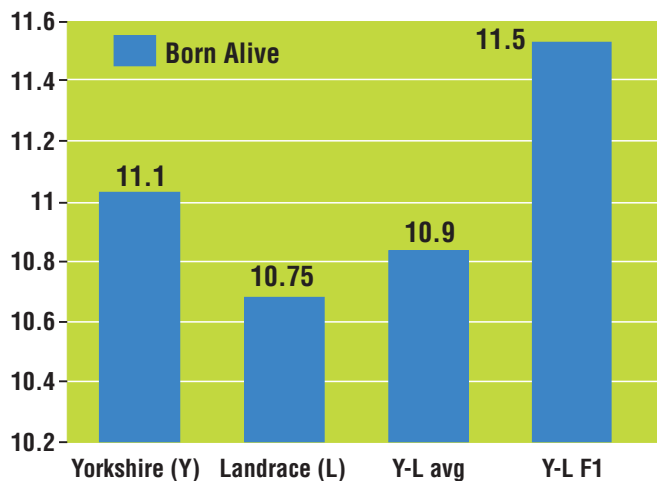


**Figure 2. Yorkshire by Landrace sow expectations.**
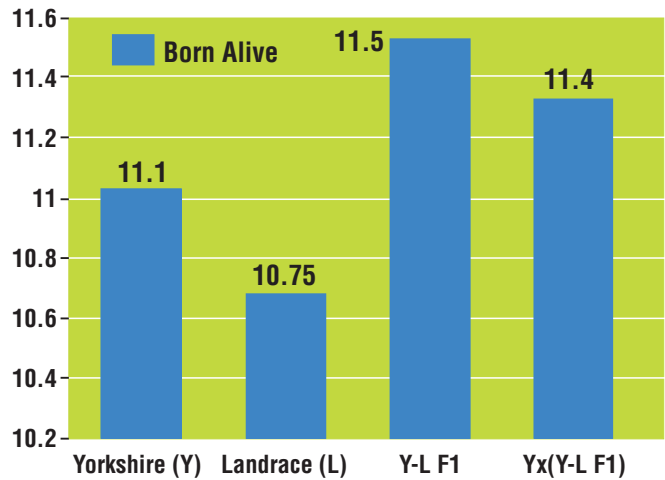


## Breeding Systems

Various schemes for crossing breeds can assist producers in developing a breeding program that best fits their management program and target markets. The following crossbreeding systems should be investigated for use in various pork production and marketing chains. Performance expectations using example breeds have been calculated for each breeding system for comparison purposes.

*Rotational systems.* Rotational systems have been popular in the pork industry. They are easy to understand and require the purchase of only boars or semen. Replacement females are produced internally from each of the boar breeds used in the rotation. Rotational systems do not allow for optimal exploitation of heterosis, however. Table 2 shows the expectation of heterosis levels through each advancing generation of a rotational crossbreeding system. In the first one to three generations, depending on the number of breeds involved, pigs do exhibit 100 percent heterosis, but as the generations advance, heterosis levels, both individual and maternal, decline to an equilibrium level. Heterosis within the two-breed rotation declines to 67 percent compared with the initial cross; the four-breed rotation stabilizes near 93 percent. A three-breed rotation is expected to maintain 86 percent of possible heterosis (Table 3).

**Table 2. Heterosis in rotational crosses.**

| Crossbreeding system | Generation number | | | | | | |
|---|---|---|---|---|---|---|---|
| | 1 | 2 | 3 | 4 | 5 | 6 | Equilibrium |
| Two-breed rotation | 100.0 | 50.0 | 75.0 | 62.5 | 68.9 | 67.2 | 66.7 |
| Three-breed Rotation | 100.0 | 100.0 | 75.0 | 87.5 | 87.5 | 84.4 | 85.7 |
| Four-breed rotation | 100.0 | 100.0 | 100.0 | 87.5 | 93.8 | 93.8 | 93.3 |

Rotational systems may be simple in concept but can be difficult to implement correctly. Sow herds in rotation programs will be sired by every breed of boar in the rotation, but producers using rotational programs typically maintain only one breed of boar on the farm at a time. This dictates that producers will breed a percentage of the sows to a boar of the same breed as their sire. This causes a reduction in heterosis and consequently a reduction in performance and vigor.

To operate a rotational system correctly, producers must maintain on the farm boars from each breed within the rotation. Simple programs can be developed to identify the breed of boar that sired each sow so that the sow will be mated to the correct breed of boar. Using a comprehensive artificial insemination program simplifies this. If most or all of the matings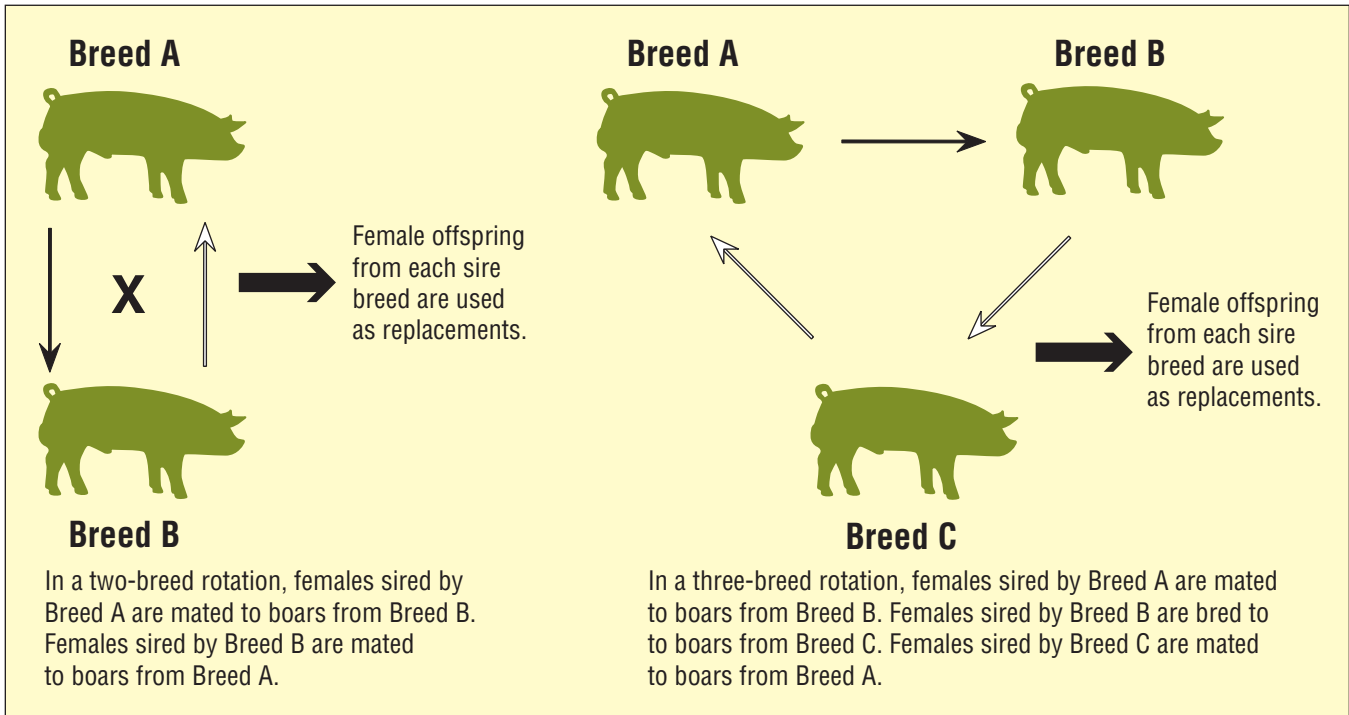 are completed by artificial in-semination, it is a relatively easy process to order semen from each breed of boar needed. Correct operation of a two-breed and three-breed rotation program is illustrated in Figure 3.

*Terminal systems.* Conceptually, terminal breeding programs exploit all possible heterosis within each cross and capitalize on breed strengths. Heterosis is typically maintained at 100 percent in both the pigs and the sows. Breeds are selected and used in a systematic fashion to utilize their strengths within the cross. Typically, breeds such as Yorkshire, Landrace or Chester White, which excel for sow productivity, are used to produce two-breed or three-breed specialized maternal-cross females. Boars from breeds that are noted for postweaning performance, carcass merit or meat quality, such as Duroc, Hampshire and Berkshire, are mated to these

**Table 3. Performance expectations for different crossbreeding programs.**

| Breed | Trait | | | |
|---|---|---|---|---|
| | Number born | Number weaned | Postweaning avg. daily gain (lb/day) | Backfat thickness inch |
| A | 10 | 7.6 | 1.68 | 0.75 |
| B | 10.5 | 7.9 | 1.79 | 0.8 |
| C | 11 | 8.2 | 1.76 | 0.9 |
| D | 11.5 | 8.5 | 1.76 | 0.9 |
| **Crossbreeding system** | | | | |
| Rotational system with breeds B, C, D | 11.5 | 9.4 | 1.90 | 0.93 |
| Terminal system with CxD females and B as a terminal sire | 11.9 | 9.8 | 1.94 | 0.90 |
| Rota-terminal system with a C by D maternal rotation and B as a terminal sire | 11.7 | 9.3 | 1.94 | 0.90 |

**Figure 3. Two- and three-breed rotational programs.**



**Breed A**

**X**

Female offspring from each sire breed are used as replacements.

**Breed B**

In a two-breed rotation, females sired by Breed A are mated to boars from Breed B. Females sired by Breed B are mated to boars from Breed A.

**Breed A**    **Breed B**

**Breed C**

Female offspring from each sire breed are used as replacements.

In a three-breed rotation, females sired by Breed A are mated to boars from Breed B. Females sired by Breed B are bred to to boars from Breed C. Females sired by Breed C are mated to boars from Breed A.

maternal cross females to produce market pigs. Figure 4 illustrates a terminal cross program. In this example, all females used on the farm would be purchased as well as the boars or semen used to produce the market pigs. Performance expectations (Table 3) have been calculated for a terminal system that utilizes a two-breed $F_1$ female for the sows and mates sows to a terminal breed that is superior for postweaning performance to produce market pigs.
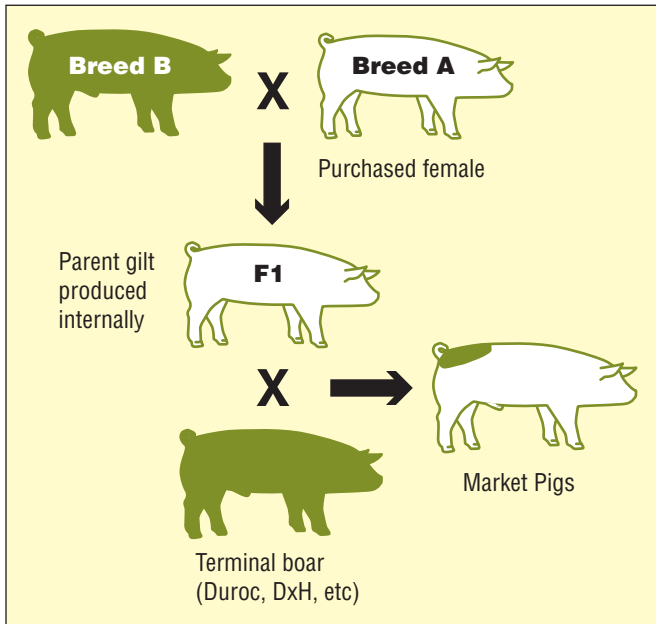
This program does have increased annual variable or out-of-pocket costs but typically yields the highest profit. In an effort to reduce regular cash expenditures, a variation of this program – grandparent terminal system – is shown in Figure 5. A small percentage (10 to 20 percent) of the sow herd consists of purchased females used to produce replacement gilts. These internally produced gilts make up the bulk (80 to 90 percent) of the sow herd. These internally produced females are mated to terminal boars to produce market pigs. This system has lower out-of-pocket costs and just slightly lower profitability expectations than the terminal program.

**Figure 4. Terminal breeding system.**



Purchased Crossbred gilt

**X**

Market Pigs

Terminal boar (Duroc, DxH, etc)
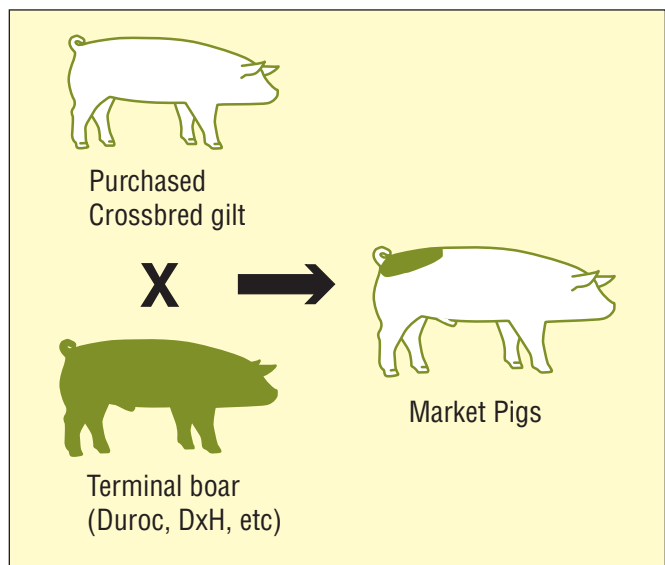
*Rota-terminal systems.* Rota-terminal breeding systems are somewhat of a blend of rotational and terminal systems. Rota-terminal systems use a rotation within a small portion of the herd (10 to 20 percent) to generate replacement females. Breeds used to produce replace-

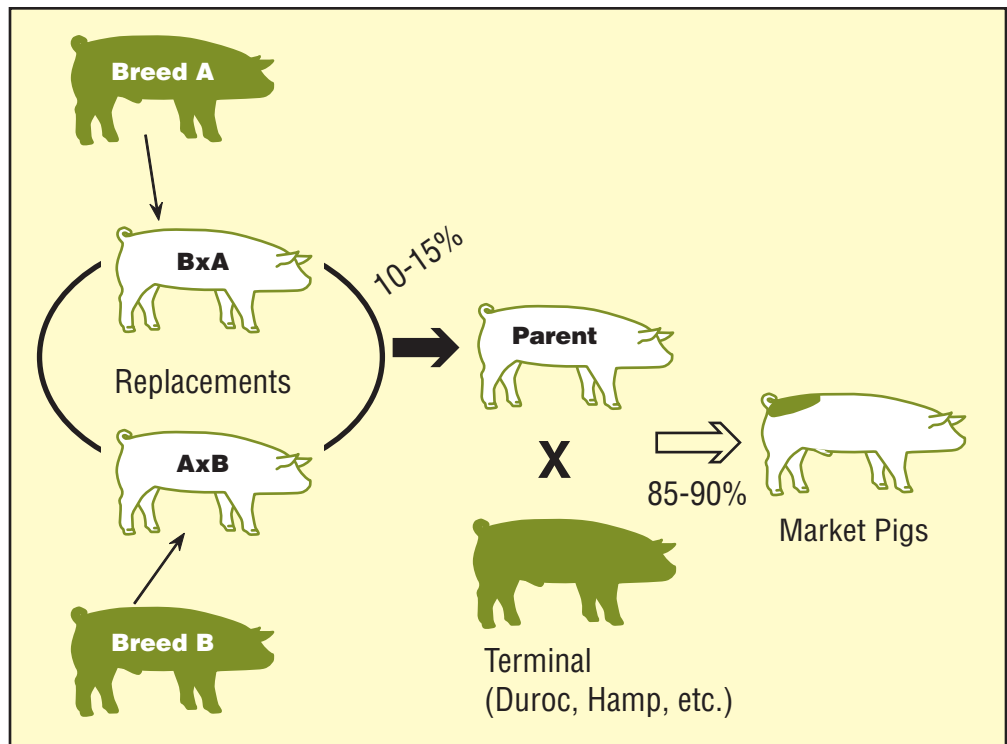**Figure 5. Grandparent terminal system.**



A common question about rota-terminal programs is whether it is better to have two or three breeds within the maternal rotation.  In a two-breed maternal rotation, maternal heterosis retention is 67 percent; in a three-breed rotation, maternal heterosis retention is 86 percent.  Higher heterosis levels imply improved maternal performance. If a three-breed maternal rotation is considered, the next question is: what third breed or line should be included within the maternal rotation? This question is a good one and may be best answered with an example. In Table 4 are performance levels of four example breeds or lines (A, B, C, D). The table also contains the expectations for three maternal rotations using various combinations of the four breeds.

Evaluating the calculated performance for these rotations shows that the two-breed rotation using breeds C and D is best for litter size born and conception rate. One of the two three-breed rotations, (B, C, D) is better for number weaned, even though breed B has poorer performance for number weaned. Heterosis has a large impact on number weaned. More heterosis is retained

ment females should excel in maternal characteristics. For each mating group (e.g., weekly, biweekly, monthly, etc.), 10 to 20 percent of the sows are mated to maternal boars from a different breed than the sow's sire to produce replacement females. At birth, gilts from these maternal matings must be identified so that, at the completion of the finishing phase, prospective replacement gilts can be easily selected and removed from finishing, acclimatized and integrated into the breeding herd. Within a breeding group, sows not mated for replacement gilt production are bred to terminal boars or with semen from a breed that excels in postweaning performance, carcass merit and/or meat quality. This is further illustrated in Figure 6.

**Figure 6. Rotaterminal breeding system.**

**Table 4. Performance Expectations for Maternal Rotations in a Rota-terminal System.**

| Trait | A | B | Purebred averages | |
|---|---|---|---|---|
| | | | C | D |
| Number born | 10 | 10.5 | 11 | 11.5 |
| Number weaned | 7.6 | 7.9 | 8.2 | 8.5 |
| Conception Rate, % | 70 | 75 | 80 | 85 |

| Maternal rotation | Number born | Maternal rotation expectations | |
|---|---|---|---|
| | | Number weaned | Conception rate, % |
| Two-breed (C, D) | 11.7 | 9.3 | 83.5 |
| Three-breed (B, C, D) | 11.5 | 9.4 | 82.1 |
| Three-breed (A, C, D) | 11.4 | 9.3 | 80.6 |

in the three-breed rotational cross than in the two-breed rotational cross, so number weaned is slightly higher in the three-breed rotational cross.

There is a great deal to learn from inspecting the performance of these example breeds. In this example, breeds C and D would be considered maternal breeds because they have the highest expectation for number born and weaned. Number born and weaned is lower for breed B than for breeds C and D. Breed A is inferior to the other three breeds for these sow productivity traits. This example shows that improvement in maternal performance due to heterosis can overcome the somewhat poorer performance of the third breed, breed B, even compared with a two-breed rotation of two superior maternal breeds such as breeds C and D. Increased heterosis in a three-breed rotation can not overcome inclusion of an inferior maternal third breed, however, such as breed A, when the three-breed rotation is compared with a two-breed rotation of superior maternal breeds such as breeds C and D.

Several important points must be considered when a producer is implementing a rota-terminal breeding scheme to produce replacement females. The first decision must be how many (two or three) breeds or lines will be used in the maternal rotation. The next matter is the implementation of the breeding system. Utilizing a third maternal breed may provide an improved potential for maternal performance if farm management is capable of successfully implementing this system. Management and breeding personnel must be able to correctly identify the breed of sire of gilt replacement candidates. This can be achieved by simple identification systems such as ear notching or tags. In addition, management and breeding personnel must be able to breed designated females with the correct semen or boars. Breeding females with the wrong semen or boar can cause further reductions in heterosis in resulting replacement females (e.g., breed a Yorkshire-sired female to a Yorkshire boar) and reduce maternal performance potential. A three-breed maternal rotation in a rota-terminal breeding program can improve the potential for maternal performance. The potential improvement may be only marginal, however, and if the system is not operated correctly, the actual performance could be poorer than that of a two-breed maternal rotation.

## Conclusion

When developing a breeding system, producers must decide what type of system best fits their management capabilities, production facilities and target market. A terminal crossbreeding system in which all females are purchased from an outside source may be the best system. Whether it is depends on the genetic background of the gilts, their health status and the target market for the producer. Most producers develop replacement females within their farm systems to protect their health status, and to produce replacement gilts with a genetic combination that best fits their production facilities and the ability to produce progeny that meet the specifications of their target markets.