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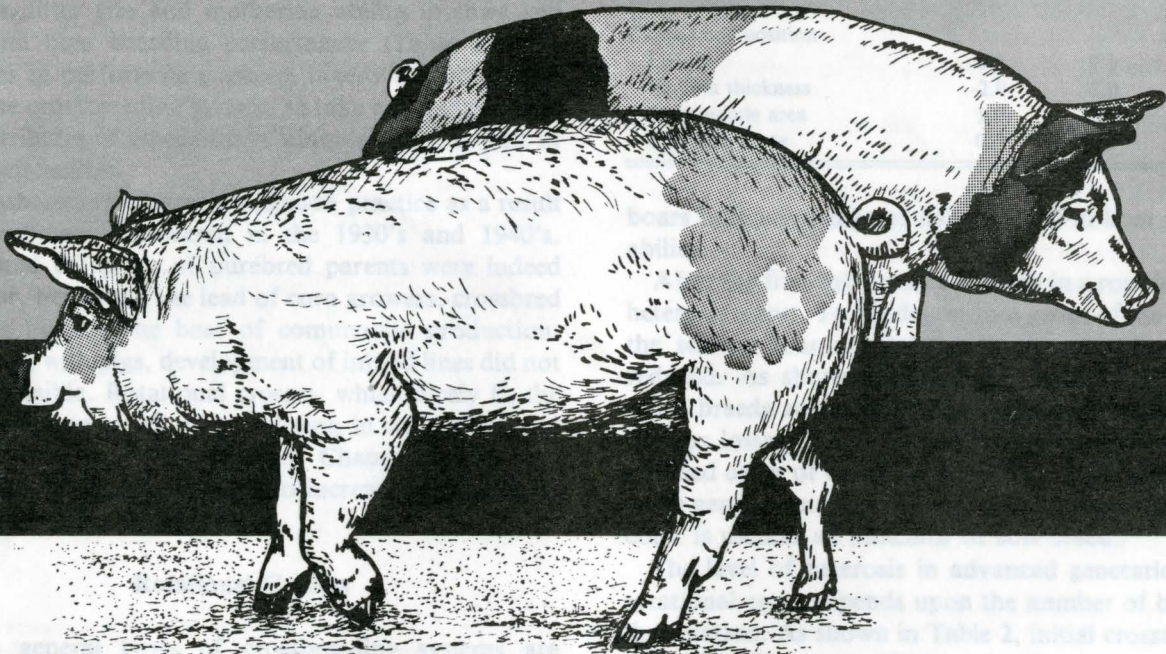
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Crossbreeding Systems For Commercial Pork Production

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equilibrium characteristics for each rotation, is shown in
the right hand column of Table 2.



Issued in furtherance of Cooperative Extension work, Acts of May 8 and June 30, 1914, in cooperation with the U.S. Department of Agriculture. Leo E. Lucas, Director of Cooperative Extension Service, University of Nebraska, Institute of Agriculture and Natural Resources.



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Crossbreeding Systems for Commercial Pork Production

By William T. Ahlschwede, Extension Swine Specialist and Rodger K. Johnson, Professor, Animal Science*

Years of experience and research show that crossbreeding pays. The hybrid vigor gained through crossbreeding improves performance of both the breeding herd and individual pigs. Surveys indicate that more than 90% of market hogs in the U.S.A. are crossbreds. However, crossbreeding is not sufficient to assure profitable performance. Rather, specifying which breeds to cross and how to cross them is needed to describe a crossbreeding system. Choices among crossbreeding systems can dramatically affect profit levels.

The value of crossbreeding depends upon hybrid vigor. Hybrid vigor, or heterosis, is the superiority of the crossbred compared to its parental breeds. In pigs, hybrid vigor appears important for pig survival and growth, litter size and mothering ability in sows and gilts and boar breeding performance (Table 1). Differences in performance among breeds can be utilized by some crossbreeding systems to take advantage of the best attributes of breeds while minimizing the impact of their deficiencies.

Crossbreeding became a common practice as a result of crossbreeding research in the 1930's and 1940's. Crossbred offspring of purebred parents were indeed superior. Following the lead of corn growers, crossbred females became the base of commercial production. However, with pigs, development of inbred lines did not prove feasible. Rotational crosses, which nicely fit the most common styles of production in the 1950's and 1960's, were generally adopted. Changes in the way hogs were produced have led to increased adoption of terminal crosses in the 1980's.

Rotational Crosses

Two general types of crossbreeding systems are described. Rotational crossbreeding systems utilize replacement gilts from the market crosses and change breeds of boar each generation. A three-breed-rotation uses three breeds of boars, rotated in order, one breed per generation (Figure 1). A rotation of two breeds is called a criss-cross. Rotations of up to six breeds have been used to advantage. Rotations using crossbred

Table 1. Heterosis advantage for production traits.

Item	First cross	Multiple cross	Crossbred boar
	purebred sow	crossbred sow	
Percentage advantage over purebred			
Reproduction			
Conception rate	0.0	8.0	10.0
Pigs born alive	0.5	8.0	0.0
Littersize 21 days	9.0	23.0	0.0
Littersize weaned	10.0	24.0	0.0
Production			
21-day litter weight	10.0	27.0	0.0
Days to 220 lb.	7.5	7.0	0.0
Feed/gain	2.0	1.0	0.0
Carcass composition			
Length	0.3	0.5	0.0
Backfat thickness	-2.0	-2.0	0.0
Loin muscle area	1.0	2.0	0.0
Marbling score	0.3	1.0	0.0

boars take advantage of hybrid vigor in boar breeding ability.

After the first full round of breeds in a rotation, some heterosis is lost. To the degree that genes of the breed of the service boar are present in the sow, heterosis is reduced. As shown in Table 2, rotations of three or more breeds retain relatively high levels of heterosis. Serious losses of heterosis in rotations occur when the planned order of breed use is not followed. This is likely when generations of sows are not kept separate or when color is used as an indicator of sow breed.

The level of heterosis in advanced generations of a rotational cross depends upon the number of breeds in the rotation. As shown in Table 2, initial crosses all express 100% heterosis. With succeeding generations, the heterosis level modulates (the first six generations are shown) until an equilibrium is reached. The heterosis equilibrium characteristic for each rotation, is shown in the right hand column of Table 2.

Rotational crosses are general purpose crosses. Offspring of each generation are used for market production and as replacement gilts. Since breeds appear first as the sire of the market hogs and a generation later as the sire of the sows, performance both as market hogs

*Adapted from Pork Industry Handbook #39.

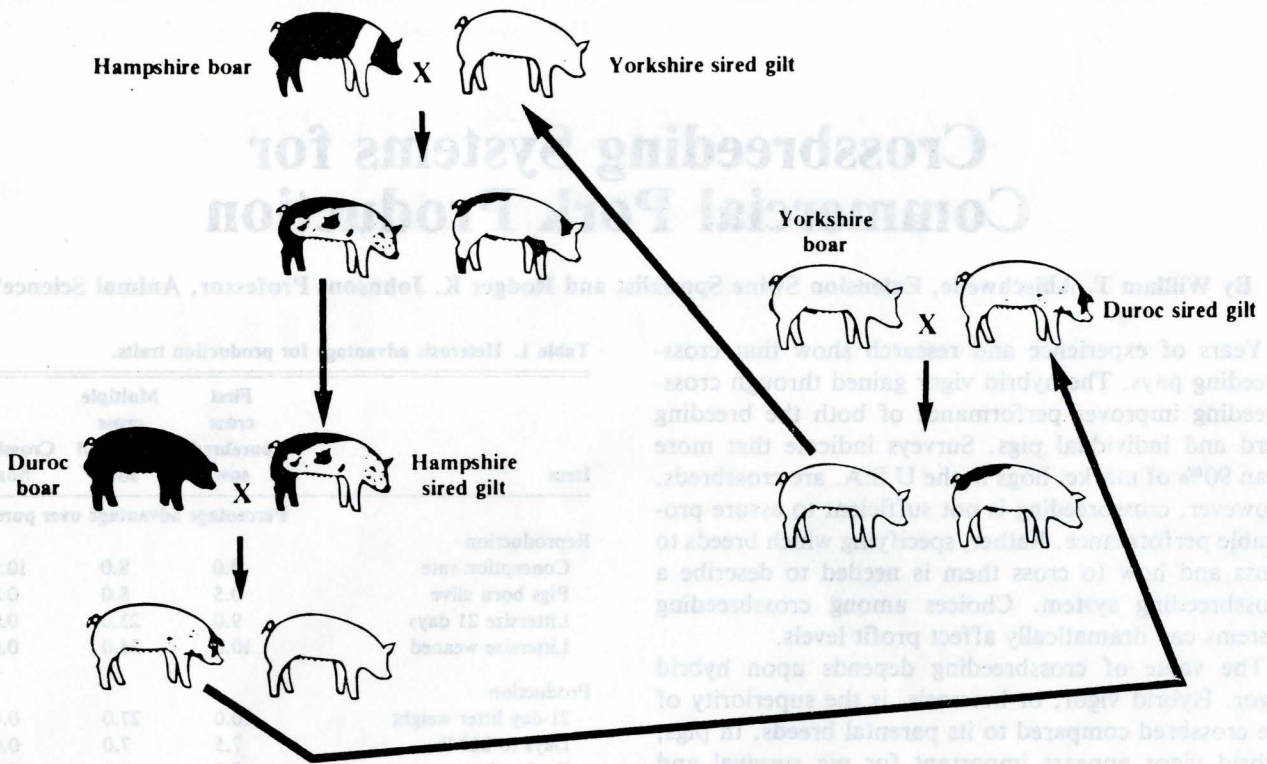


Figure 1. Three breed rotation crossbreeding system.

and as breeding stock is considered in choosing breeds. There is little opportunity to take advantage of the differences among the breeds used in the cross. Performance in rotations would be maximized if there were no breed differences in performance. We would want them to be as good as the best in every trait.

Terminal Crosses

Terminal crosses take their name from the fact that the system terminates with the market cross. Replacement gilts are not saved from the matings designed for market production. A simple terminal cross would be a Yorkshire sow mated to a Hampshire boar with all of the offspring marketed. Replacement gilts are produced

by matings other than the market crosses. Because breeds are used in specialized roles, (in this example, the Hampshire boar sires market hogs but not replacement gilts) terminal crosses can take advantage of breed differences.

A more common terminal cross is mating Landrace x Yorkshire first cross (F₁) females to Hampshire x Duroc first cross (F₁) boars (Figure 2). The sow in this case is a cross between two breeds which have reputations as good sows. The sire is a cross of two breeds with reputations for efficient lean gain and fast, efficient gain. In this way, terminal crosses allow breeds to be used in roles that take advantage of their strengths, while minimizing their deficiencies. This allows terminal

Table 2. Heterosis percentage in rotational crosses.

Crossbreeding system	Generation number						Equilibrium
	1	2	3	4	5	6	
	Heterosis						
Two breed rotation "crisscross"	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
Five breed rotation	100.0	100.0	100.0	100.0	93.8	96.9	96.8
Six breed rotation	100.0	100.0	100.0	100.0	100.0	96.9	98.4
Crisscross with F ₁ boars (four breeds)	100.0	75.0	87.5	81.3	84.4	82.3	83.3

crosses to be more productive than rotational crosses. In this example, maximum use of heterosis is realized. The boar and the sow are both first crosses with 100% heterosis, important for breeding performance, litter-size, and maternal performance. Since there are no common breeds in the parents, the offspring also have 100% heterosis, important for piglet vigor, survival, and rapid gain.

In terminal crossbreeding systems, replacement gilts are not selected from the market crosses. They must either be purchased or produced in special matings. Because of this, terminal crosses were generally not used by commercial pork producers. Historically, rotational crosses fit the production systems. However, production systems have changed. Many intensely managed pork producing units today are able to program the special gilt producing matings into their schedule without difficulty. Terminal crosses are becoming more popular.

Opportunities exist to combine rotational and terminal crossbreeding systems. Many producers have used rotational crosses among breeds that excel in maternal performance to produce replacement gilts for terminal matings. These systems, called rotaterminals, combine the ease of operation of a rotation with the specialization and high productivity of terminal crosses.

Crossbred Boars

The use of crossbred boars has sparked discussion and controversy in the industry in recent years. In the

mid 1970's their use was sufficient to stimulate stories in the popular press. By the late 1970's, research trials had been conducted that clarified their attributes. Crossbred boars were found to excel purebred boars in breeding performance as measured by farrowing rate of sows and gilts to which they were exposed. They were more vigorous, active breeders. While this advantage may appear small (Table 1), timely pregnancies are crucial to intensely managed pork producing operations. In addition to the improved conception rates identified in research trials, commercial pork producers report fewer problems and longer useful lives with crossbred boars.

Crossbred boars can be part of a crossbreeding system. Purebred boars, crossbred boars, and combinations of purebred and crossbred boars are being used in productive, profitable crossbreeding systems, which maintain high levels of heterosis. The availability of both purebred and crossbred boars allows increased flexibility in planning and operating crossbreeding systems. In the discussion that follows, both types of boars are used. Whether purebred or crossbred boars are used, the success of the breeding systems depends upon following the system.

Evaluating and Choosing Crossbreeding Systems

One would like to choose the crossbreeding system that would provide the most favorable economic outcome. However, the many factors involved in determining the outcome of a system make it difficult to effec-

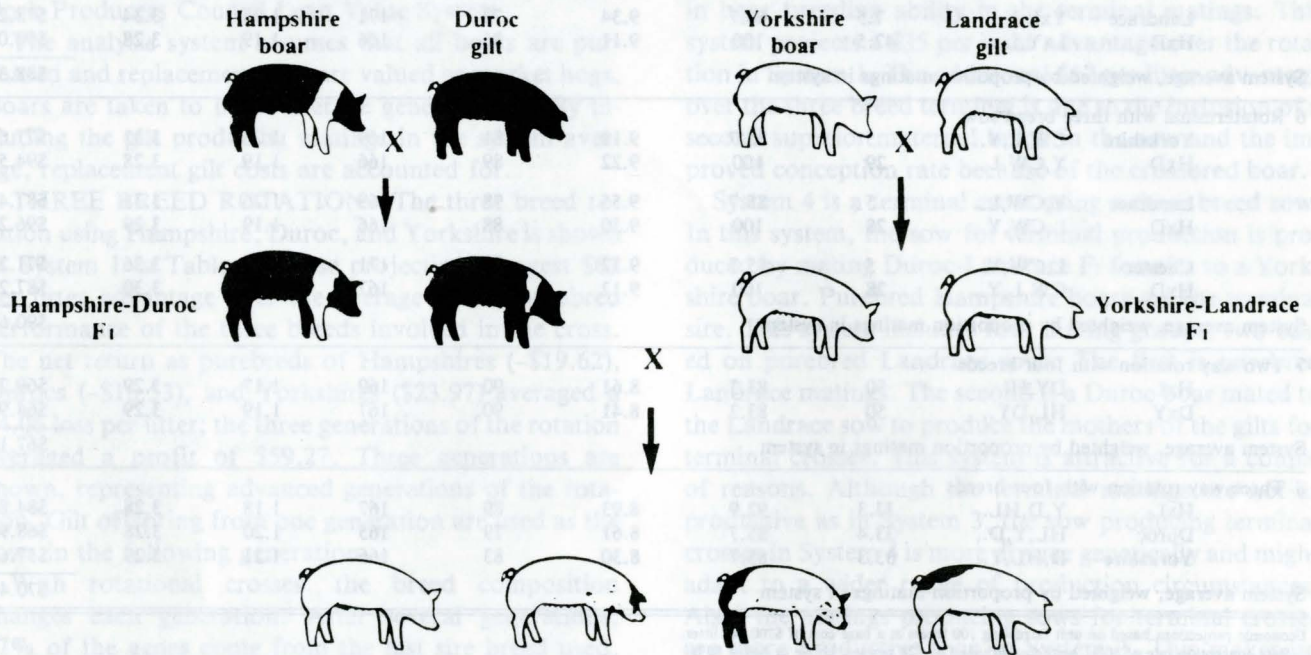


Figure 2. Four breed terminal crossbreeding system.

Table 3. Expected outcome for crossbreeding systems.

Mating system	Sire	Dam	Proportion matings in system	Percent offspring heterosis	Pigs marketed per litter	Conception rate %	Days to market	Fat thickness	Growing-finishing F/G	Net per litter
Purebred matings										
	Hampshire	Hampshire		0	5.94	85	183	1.00	3.30	-\$19.62
	Duroc	Duroc		0	6.34	85	172	1.20	3.33	-\$16.53
	Yorkshire	Yorkshire		0	7.78	72	177	1.20	3.35	\$23.97
	Landrace	Landrace		0	8.40	69	180	1.25	3.40	\$33.05
	Chester	Chester		0	7.35	85	185	1.30	3.45	-\$4.25
Purebred average										\$3.32
1 Three breed rotation										
	Hampshire	YxD,H..	33.3	85.7	8.56	80	169	1.10	3.26	\$75.94
	Duroc	HxY,D..	33.4	85.7	7.96	83	165	1.16	3.27	\$51.29
	Yorkshire	DxH,Y..	33.3	85.7	8.02	85	166	1.19	3.28	\$50.61
System average, weighted by proportion matings in system										\$59.27
2 Three breed terminal										
	Yorkshire	Yorkshire	5	0	7.78	72	177	1.20	3.35	\$23.97
	Duroc	Yorkshire	15	100	8.08	72	162	1.22	3.27	\$46.35
	Hampshire	DxY	80	100	8.81	81	166	1.12	3.25	\$86.24
System average, weighted by proportion matings in system										\$77.14
3 Four breed terminal										
	Yorkshire	Yorkshire	5	0	7.78	72	177	1.20	3.35	\$23.97
	Landrace	Yorkshire	15	100	8.08	72	166	1.25	3.31	\$51.58
	HxD	LxY	80	100	9.55	87	166	1.19	3.28	\$107.28
System average, weighted by proportion matings in system										\$94.76
4 Four breed terminal, Y x D,L sow										
	Landrace	Landrace	2	0	8.40	69	180	1.25	3.40	\$33.05
	Duroc	Landrace	4	100	8.30	69	164	1.25	3.30	\$47.24
	Yorkshire	DxL	121	100	8.94	80	164	1.24	3.29	\$77.07
	Hampshire	YxD,L	82	100	9.18	78	167	1.13	3.26	\$96.26
System average, weighted by proportion matings in system										\$90.73
5 Rotaterminal with two breed sow										
	Yorkshire	LxY,L..	7.5	66.7	9.10	72	170	1.23	3.32	\$73.48
	HxD	YxL,Y..	42.5	100	9.08	87	165	1.18	3.27	\$91.07
	Landrace	YxL,Y..	7.5	66.7	9.34	72	171	1.25	3.34	\$78.29
	HxD	LxY,L..	42.5	100	9.11	86	166	1.19	3.28	\$90.07
System average, weighted by proportion matings in system										\$88.37
6 Rotaterminal with three breed sow										
	Yorkshire	CW,L,Y..	5	85.7	9.18	81	169	1.26	3.33	\$77.61
	HxD	Y,CW,L..	29	100	9.22	89	166	1.19	3.28	\$94.57
	Landrace	Y,CW,L..	5	85.7	9.55	78	169	1.26	3.33	\$87.42
	HxD	L,CW,Y..	28	100	9.30	88	166	1.19	3.29	\$96.28
	Chester	L,CW,Y..	5	85.7	9.32	75	171	1.29	3.36	\$71.28
	HxD	CW,L,Y..	28	100	9.12	90	167	1.21	3.30	\$87.25
System average, weighted by proportion matings in system										\$90.63
7 Two way rotation with four breeds										
	HxL	DY,HL..	50	83.3	8.61	90	169	1.17	3.29	\$69.27
	DxY	HL,DY..	50	83.3	8.41	90	167	1.19	3.29	\$64.94
System average, weighted by proportion matings in system										\$67.11
8 Three-way rotation with four breeds										
	HxL	Y,D,HL..	33.3	92.9	8.93	89	167	1.18	3.28	\$84.84
	Duroc	HL,Y,D..	33.4	85.7	8.61	79	165	1.20	3.28	\$68.96
	Yorkshire	D,HL,Y..	33.3	85.7	8.30	83	166	1.21	3.29	\$57.63
System average, weighted by proportion matings in system										\$70.48

Economic projections based on unit farrowing 100 litters at a base cost of \$300 per litter.

Base conception rate of 80%, herd cost adjusted by \$28 per sow above or below 80%.

Base litter size marketed as 7.5 pigs, litter cost adjusted by \$8 per pig above or below base.

Base age to market at 220 pounds was 180 days. Nonfeed costs of \$14 per pig, adjusted by \$0.05 per day above or below base.

Feed for growing-finishing charged at \$140 per ton.

Hogs were marketed at 220 pounds at a base price of \$45/cwt. with 1.15 in. last rib fat thickness. Premiums and discount based on fat thickness were 1% for each 0.1 in. below or above base value.

tively evaluate. Farm objectives vary, facilities differ, and desired breeds and crosses are not always available.

Recent studies using computers to model crossbreeding systems have helped clarify the differences among systems. At least five separate computer programs which analyze crossbreeding systems have been utilized in these studies. The computerized models, some of which are very complex, take into account breed differences for each of the traits studied, the mode of inheritance for specific traits, relationships among traits, the economic impact of each of the traits, and market prices of inputs and production. These studies offer guidance in choosing among various systems.

Results from one of the crossbreeding systems analysis programs mentioned above are shown in Table 3. Matings are grouped into systems. For each type of mating, projections of performance for six traits were made using the breed averages shown in Table 4 and the heterosis values given in Table 1. An expected economic outcome for each mating type was also calculated. The economic system represents conditions experienced in the early 1980's, with credit given for faster and more efficient gain, higher conception rates, larger litters weaned, and for leaner hogs at market. An expected outcome for each system was calculated as a weighted average of the mating outcomes, weighted by the proportion of the mating in the system. With a \$45 per cwt market price, purebred performance with Hampshires, Durocs, Yorkshires, Landrace and Chester Whites average \$3.32 per litter profit when market hogs were sold at 220 lb (first section of Table 3). Credit for learner pigs at market was based upon the National Pork Producers Council Lean Value System.

The analysis system assumes that all boars are purchased and replacement gilts are valued as market hogs. Boars are taken to be of average genetic merit. By including the gilt producing matings in the system average, replacement gilt costs are accounted for.

THREE BREED ROTATION—The three breed rotation using Hampshire, Duroc, and Yorkshire is shown as System 1 in Table 3. These projections suggest \$63 per litter advantage over the average of the purebred performance of the three breeds involved in the cross. The net return as purebreds of Hampshires (-\$19.62), Durocs (-\$16.53), and Yorkshires (\$23.97) averaged a \$4.06 loss per litter; the three generations of the rotation averaged a profit of \$59.27. Three generations are shown, representing advanced generations of the rotation. Gilt offspring from one generation are used as the sows in the following generation.

With rotational crosses, the breed composition changes each generation. After several generations, 57% of the genes come from the last sire breed used, 29% from the grandsire and 14% from the great grandsire. If the breeds in the rotation are different for important traits, wide swings in performance and profit can be expected from generation to generation. This is

apparent in Table 3. Littersize raised is considerably higher in the Hampshire sired generation because of the Yorkshire influence in the sow, and the pigs are leaner. These differences led to an expected economic advantage of \$25 more profit per litter for this generation. Swings in performance and profit of this magnitude are expected with rotational crosses.

TERMINAL CROSSES—System 2 in Table 3 is a three-breed terminal cross, with Duroc-Yorkshire F_1 sows mated to Hampshire boars to produce the market hogs. These matings are on the third line of the system. The second line is the matings that produce replacement gilts, Yorkshire sows bred to Duroc boars. The first line in the system shows the matings that produce the Yorkshire gilts used as sows in the second line. The average for the system is calculated on 5% purebred Yorkshire matings (line 1), 15% Duroc x Yorkshire matings (line 2) and 80% terminal matings (line 3). This system projects an advantage of about \$18 per litter over the rotational cross in System 1. The same breeds are used in both systems. The advantage is due to higher levels of heterosis in both sows and pigs, the beneficial effect on littersize of a high percentage of Yorkshire in the sows of all matings and the improved carcass value due to the Hampshire sire in the terminal crosses.

System 3 in Table 3 is a four breed terminal using both F_1 sows and F_1 boars to produce the market crosses. The system is similar to System 2, except that Landrace-Yorkshire F_1 sows are used and F_1 Hampshire-Duroc boars sire the terminal crosses. This system combines two good maternal breeds in the sow producing most of the pigs and takes advantage of the heterosis in boar breeding ability in the terminal matings. This system projects a \$35 per litter advantage over the rotation in System 1. The additional \$17 per litter advantage over the three breed terminal is due to the inclusion of a second superior maternal breed in the sow and the improved conception rate because of the crossbred boar.

System 4 is a terminal cross using a three breed sow. In this system, the sow for terminal production is produced by mating Duroc-Landrace F_1 females to a Yorkshire boar. Purebred Hampshire boars are the terminal sire. This system includes four mating groups, two based on purebred Landrace sows. The first is purebred Landrace matings. The second is a Duroc boar mated to the Landrace sow to produce the mothers of the gilts for terminal crosses. This system is attractive for a couple of reasons. Although the terminal matings are not as productive as in System 3, the sow producing terminal crosses in System 4 is more diverse genetically and might adapt to a wider range of production circumstances. Also, the matings producing sows for terminal crosses are more productive than in System 3. This makes up for some of the reduced performance predicted in the terminal phase.

ROTATERMINAL SYSTEMS—Rotaterminal systems are shown as System 5 and 6 in Table 3. In these

Table 4. Performance averages assigned to breeds used in crossbreeding systems analysis procedures.

Breed	Conception rate	Litter size	Piglet survival	Days to 220 lb.	Fat thickness	Feedlot feed/gain
	%	no.	%		in.	
Hampshire	85	9.0	66	183	1.0	3.30
Duroc	85	9.6	66	172	1.2	3.33
Yorkshire	72	10.8	72	177	1.2	3.35
Landrace	69	10.0	84	180	1.3	3.40
Chester White	85	10.5	70	185	1.3	3.45

Table values refer to purebred performance.

(Source: NC-103 research project publication and test station averages.)

Johnson, R.K. 1980. *Heterosis and Breed Defects in Swine*. North Central Regional research publication No. 262.

systems, replacement gilts are produced with rotational crosses. These females are then mated to terminal boars for market production. These systems are run similarly to rotations, except that most of the matings produce only market crosses. Depending upon the choice of service sire, any sow can produce either replacement gilts or market hogs. Production in the terminal matings of the rotaterminal are generally not as profitable as in the analogous terminal matings in System 3 primarily because maternal heterosis is lower. For the system, some of this difference is made up because gilt production is less expensive, being based on crossbred sows.

System 5 is a rotaterminal based on a Yorkshire-Landrace crisscross. The first line in the system shows the matings producing Yorkshire sired replacement gilts. The gilts produced in this mating appear in the second line as the sow producing terminal crosses by a Hampshire-Duroc F₁ boar, and in the third line of the system mated to Landrace boars to produce replacement gilts. The Landrace sired gilts are used as the sow for terminal matings in line 4 of this system and as the mothers of Yorkshire sired gilts in line 1. This system projects a \$30 a litter advantage over the three breed rotation. While the breed composition of System 5 is similar to System 3, the reduced level of maternal heterosis in terminal matings (66.7% vs. 100%) accounts for the \$6 per litter disadvantage for the system.

System 6 is based on a three breed rotation of Yorkshire, Landrace and Chester White. The increased maternal heterosis and individual heterosis in gilt producing matings accounts for the \$2.26 per litter advantage over System 5. However, an additional breed of boar and type of mating is required.

ROTATIONS WITH CROSSBRED BOARS—The last section of Table 3 shows two rotations using crossbred boars. System 7 is a crisscross among four breeds using two types of F₁ boars. This gives the breed balance found in the four breed terminal. The heterosis level in the sow and pig is similar to a three breed rotation. This system projects nearly \$8 per litter advantage over the three breed rotation. The maternal contribution of the Landrace and improved conception rate of crossbred boars account for the difference.

System 8 is a three way rotation, using purebred Yorkshire and Duroc boars along with an F₁ Hampshire-

Landrace boar. This system attempts to balance white and colored breed influences, while reducing some of the generation to generation fluctuations in performance characteristics of rotational crosses. The increased level of heterosis accounts for the \$3.37 per litter advantage over System 7.

Large differences in performance and profit potential among the crossbreeding systems are indicated in Table 3. While the numbers of Table 3 are produced by computer simulation, the calculations are based upon results of real breeding experiments. The budget used was based on costs reported by pork producers who keep records. Further, the results reported here seem to closely follow the experiences of producers who use the various systems.

Large differences in projected profits should not be translated directly into a recommendation that all producers use the mating system with the largest estimated profit reported here. The projections shown are for a small number of possible crossbreeding systems. The systems shown are chosen to illustrate differences and represent the most common applications. However, it appears that the advantages of the terminal systems can be realized by most pork producers.

Rotation crosses have generally been recommended for commercial production since the advantages of crossbred pigs were demonstrated in the 1940's. The attributes of terminal crosses were known, but production methods favored the use of rotations. Seasonal farrowing coupled with replacement of the whole breeding herd at one time made rotations easy to use. Extensive production systems minimized the advantage of specialized maternal breeds. Small production units did not allow subdivision for replacement gilt production. And health programs were not sufficiently strong to encourage purchasing replacement gilts. All of these factors are different today. Terminal crossbreeding systems more closely fit the production systems being used for commercial production than do the rotations.

Operating rotational crosses properly has become difficult on most pork producing farms. Rotational crosses save replacement gilts from the market crosses, changing the breed of boar each generation in a prescribed order. With multiple farrowing in modern facilities, it is desirable to replace cull sows with gilts after each

farrowing. The gilt being of the new generation, is to be bred to the next breed of boar in the rotation. Many producers lack the breeding pens, sow identification, and personnel necessary to assure that sows are bred to the correct breed of boar. Too often the replacement gilt is bred to the same breed of boar used to breed the group of sows she will join, the breed of boar of her sire. These mistakes (the mating of sows and gilts to boars of the breed of their sire) are common and costly. In a rotational system using purebred boars, these backcross matings cut heterosis in half. In a three breed rotation, heterosis is cut from 85.6% to 42.8%, with accumulated production losses which average \$40 per backcross mating.

The breeding management required to operate rotational crosses on intensely managed pork producing farms will support terminal crossbreeding systems as well. With a three breed rotation, the sows must be identified according to their breed of sire and provision made, either through adequate breeding pens or hand mating, to breed with three breeds of boars simultaneously. The same is required of the terminal and rotaterminal systems described in Table 3. The operational advantage of the rotations observed in the 1940's is generally absent today. In addition, production systems are in place which can take advantage of breed differences, particularly in sow productivity.

The key to the operation of terminal crossbreeding systems is the acquisition of sows. Unlike rotations, replacement gilts are not kept from matings designed to produce market hogs. Replacement gilts are produced in special matings. The high levels of productivity experienced with gilts and sows from these special gilt producing matings give the terminal crossbreeding systems their advantage. Operationally, the production of replacement gilts is the key to the terminal crosses.

A second determiner of the success of the terminal crossbreeding systems is the ability to meet the nutritional and environmental needs of the more productive sow herd. Feeding programs and housing systems that supported rotational crosses might not sustain performance with terminal crosses, which wean 1 or 2 pigs more per litter. Adjustments in the care and management of the breeding herd are in order.

If the pork producing industry followed the lead of the poultry industry, replacement females would be purchased. The practice of buying replacement gilts has expanded during the last decade. Buying gilts is functional for every farm that farrows. However, questions of health risk and cost must be answered before judgments of feasibility can be made. Generally, the matings that produce replacement gilts for terminal crosses are not as productive as the terminal crosses. Hence, the purchase price represents, in part, the lost productivity in the breeder's herd.

Most pork producers who farrow have preferred to produce their own replacement gilts. With rotational

crosses, that was built into the system. With terminal crosses, special matings are required. As an example, if Landrace-Yorkshire F₁ gilts are desired, purebred Yorkshire sows and a Landrace boar are required. Both the number and timing of these matings are coordinated with the production schedule so that gilts are available when needed. Yorkshire gilt replacements for these matings can either be purchased or produced. If they are produced, an additional type of mating is required. Yorkshire sows mated to a Yorkshire boar are needed. While it is possible to perform these matings, the small breeding groups, the need to schedule matings, and the performance differences experienced with purebred sows and F₁ animals complicate management of the system.

The rotaterminal systems attempt to make the job of producing home raised gilts easier. In the case of the Yorkshire-Landrace crisscross for replacement gilts, both Yorkshire and Landrace boars are needed to sire replacement gilts. The advantage of this system is that all of the sows in the herd are similar. They are all Yorkshire-Landrace crosses with similar levels of heterosis and performance characteristics. All sows in the herd are potential mothers of replacement gilts. For replacement gilts, Yorkshire sired sows are bred to a Landrace boar, or Landrace sired sows are bred to a Yorkshire boar. Most sows are bred to a terminal boar for market production. This system allows an easier flow of replacement gilts into the system, because sows to produce them are always available. And, because all of the sows are similar crossbreds, matings producing replacement gilts are nearly as productive as market crosses. The disadvantage is that the sow herd expresses only 66.7% of the available heterosis. This accounts for the difference in profit projected between the two systems.

The competitiveness of the terminal crossbreeding systems depends in part upon the proportion of matings committed to the production of replacement gilts. The number of matings required to produce replacements depends upon the litter size in the gilt-producing litters, the number of gilts needed (controlled by culling in the sow herd), and the proportion of replacement gilt candidates selected. The proportion of each type of mating in each of the crossbreeding systems in Table 3 was assigned to provide ample replacement gilts. In System 3, reducing the proportion of nonterminal matings to 10% would increase the expected net for the system by \$5 per litter. In the rotaterminal systems, where the gilt producing litters are more productive, the proportion of replacement gilt producing matings is not as critical.

The proportion of litters producing replacement gilts for a terminal system is an operational characteristic of a farm. It is suggested that initial proportion of litters producing replacement gilts be chosen to supply an excess of gilts. As the operation becomes familiar with the attributes of the sows and determines a functional

culling rate, the proportion of gilt producing matings can be reduced. Since the cost of too many home raised replacement gilts is generally less than the cost of too few, starting with plenty is suggested.

Purchasing Gilts

Purchasing all replacement gilts or the mothers of home raised replacement gilts are practices which deserve attention by pork producers. With terminal crosses, it is often difficult to maintain all of the mating groups needed for gilt production. Purchasing all replacement gilts simplifies the operation to a single mating type. In Systems 2, 3 and 4 in Table 3, the mothers of the market hogs would be purchased. If low replacement rates can be achieved, Systems 3 and 4 with purchased gilts can provide profit levels similar to System 5.

System 4 is an example of a crossbreeding system which lends itself to purchased sow mothers. First cross Landrace X Duroc gilts would be purchased. They would be bred to a Yorkshire boar to produce the sows for terminal crossing. Once in place, annual gilts purchases would be small. Depending upon purchase price, the returns would be similar to System 4 with all gilts being raised at home. The advantages of terminal crossing with purchased sow mothers are that fewer mating types are needed and that all litters are from crossbred sows. Producers with three or more boars can make this system work with little difficulty.

Breed Evaluation

The genetic merit of the breeds used in crossbreeding represents the foundation upon which performance is based. Heterosis effects and the breeding values of parents are additions to this base in determining final performance. Hence, choice of breed can have a marked effect on profitability. As demonstrated in Table 3, placement of the breed in the crossbreeding system is also important. Knowledge of breed performance is essential in planning crossbreeding systems and predicting performance.

Notions and estimates of breed performance come from many places. The most reliable estimates come from crossbreeding experiments where several breeds and crosses are tested together. In these experiments,

attempts are usually made to include pigs from many sources and lines within the breeds. Table 4 is a summary of the performance of five breeds adapted from the evaluation compiled by project NC-103, a committee of the swine breeding researchers in the U.S.A. A more general summary of the findings of the NC-103 committee is in Table 5.

Table 5. Relative performance of breeds.

Breed	Concep- tion rate	Litter size raised	21-day weight	Age at 220 lb.	Back- fat
Berkshire	+	-	-		
Chester White	+	++	-	--	A
Duroc	A	A	-	+	-
Hampshire	A	-	A	-	++
Landrace	--	++	++	A	--
Poland				A	+
Spotted		--	--	+	-
Yorkshire	-	++	+	+	-

Based on NC-103 review.

Blank cell indicates data unavailable.

A indicates performance near average of breeds studied.

+ indicates performance superior to average.

++ indicates performance substantially superior to average.

- indicates performance inferior to average.

-- indicates performance substantially inferior to average.

Another source of comparative information is test stations, including barrow tests. Since breeders choose the pigs tested, these results are less reliable. Table 6 is a summary of breed performance based upon results of the National Barrow Show performance test of market hogs. Table 7 is based upon results from boar testing stations. Word of mouth reports of how a certain kind of pig performed are also abundant. Since these reports seldom are based upon comparative information, they are of little value.

Breed averages as presented in these tables have the appearance of accuracy and stability. However, there are limitations to the usefulness of the numbers. The NC-103 estimates are based upon studies completed during the 1970's. While it is difficult for a breed to change rapidly, more current estimates would be desirable. The data from test stations and the National Barrow Show are current but selected. If all breeders are equally skillful in selecting pigs to put on test and those who test at stations are a random sample of breeders in a breed, the data might be quite reliable. However, these assumptions are not met, and the data are not very useful.

Table 6. Breed averages of purebred barrows tested at the 1985 and 1986 National Barrow Show.

Breed	No.	ADG lb./day	Age at 220 lb. days	10th rib backfat in.	Loin muscle area sq. in.
Berkshire	47	1.66	176.40	1.15	4.53
Chester White	66	1.64	175.94	1.26	4.50
Duroc	161	1.73	171.89	1.22	4.72
Hampshire	75	1.60	177.53	0.91	5.22
Landrace	34	1.65	172.00	1.22	4.49
Poland	47	1.64	173.47	1.12	5.17
Spotted	65	1.68	171.98	1.20	4.72
Yorkshire	93	1.61	178.24	1.15	4.51

Table 7. Performance of boars in central test stations during 1984, 1985, and 1986.

Breed	No.	ADG lb./day	Feed/ gain	Backfat in.
Berkshire	349	2.10	2.68	0.83
Chester White	326	2.08	2.59	0.82
Duroc	4294	2.27	2.49	0.81
Hampshire	1587	2.17	2.49	0.74
Landrace	685	2.20	2.53	0.78
Poland China	219	2.11	2.68	0.80
Spotted	801	2.09	2.63	0.79
Yorkshire	4028	2.22	2.49	0.79

The breed evaluation data presented here are intended to give guidance in making decisions. Other factors deserve consideration as well.

- **Source of stock:** An increasing proportion of commercial pork producers buy breeding stock from breeding companies. The companies have private breeds and private lines from the breeds. The performance evaluations listed here might not apply.

Within a breed, differences in breeding value exist. While these differences in breeding value are additions to the breed average, and usually not large, in regional situations they can be important.

- **Changes in breed average:** Rapid changes in a national breed average are unlikely. Basically, such changes come about in two ways. The first is through selection. For this to be a factor, selection must be based upon the same performance criteria and followed uniformly by all breeders. The second

is gene migration. An example of this is the importation of European Large White breeding stock into the Yorkshire breed. If the Large White and Yorkshire are different genetically, this migration could substantially change the Yorkshire breed average. A similar situation can be found in the Landrace breed. Importations during the last decade from several European and Canadian Landrace breeds could have changed the Landrace breed average.

- **Regional Availability:** Although a national market exists for breeding stock, some breeds are less available in some areas. When health status and breeding value are considered, further restrictions on breed availability in the area of production are to be expected.

Summary

Large differences among crossbreeding systems in levels of performance and profitability are due primarily to differences among breeds, the beneficial effects of heterosis, and the placement of breeds in systems. Generally, the use of one of the terminal crossbreeding systems with superior sow performance is recommended. Success with any crossbreeding system depends upon carefully following the system and adopting production practices that enhance the chosen system. With all crossbreeding systems, performance can be improved by purchasing breeding stock with superior genetic merit.