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pork industry handbook

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Crossbreeding Programs for Commercial Pork Production

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Crossbreeding is a widely accepted and recommended practice in commercial swine production. Nearly 90% of our commercial producers raise crossbred hogs for slaughter. Although breed selection is important, to capitalize on heterosis, genetic improvement will come basically through selection of superior sires from within each breed.

Crossbreeding is used to combine desirable characteristics of different breeds and to capitalize on hybrid vigor (heterosis). Heterosis is defined as the average superiority of the crossbred progeny over the average of their parents. When crossbred pigs perform above the average of the two parental breeds, heterosis results (Fig. 1). This superiority may be more (Fig. 1) or less (Fig. 2) than one of the breed's performance, depending on the breeds crossed; however, it must be above the parental average. When the crossbred pigs perform at parental breed average, no heterosis exists.

Heterosis occurs when genetically different lines or breeds are crossed, and it is greatest for traits with low heritabilities. Traits such as litter size, litter weaning weight and survival rate respond best to crossbreeding. Carcass traits are highly heritable and are not improved by crossbreeding (Table 1). If the crossbred is to produce an excellent carcass, both parents must have superior carcass characteristics.

When a boar of a different breed is used on purebred dams, litter size (0.5%) is not significantly increased (Table 1). Since the mother breed in the original cross will influence litter size, breeds that are noted for large litters should be used as foundation females.

Even if litter size at farrowing is not increased, purebred sows will wean about 10% more crossbred than purebred pigs. A greater survival rate results from heterosis responses in the crossbred pigs. A 24% increase in litter weaning size can be expected when a crossbred sow is used. This improvement is due to an increased number of pigs born alive and greater baby pig survival to 21 days.

Pig survival and growth are the real benefits of a systematic crossbreeding program. When crossbred sows are used, about 28% greater 21-day litter weights can be realized per female exposed as compared to purebreds.

Table 1. Average percent heterosis advantage for various swine traits.*

Trait	First cross using purebred female†	Multiple cross using crossbred female‡
	% advantage over purebreds	
Reproduction		
No. pigs born alive	0.5	8.0
Litter size—21 days	9.0	23.0
Litter size—weaning	10.0	24.0
Production		
21-day litter wt.	10.0	27.0
21-day litter wt. /female exposed	5.0	28.0
Days to 220 lb.	7.5	7.0
Feed/lb. gain	2.0	1.0
Carcass composition		
Length	0.3	0.5
Backfat	1.5	1.5
Loin eye area	1.0	2.0
Marbling score	0.3	1.0

*Composite results from Oklahoma and Iowa NC-103 regional swine project.

†997 litters using Duroc, Chester, Hampshire, Yorkshire breeds and all possible crosses.

‡611 litters using Duroc, Chester, Hampshire, Yorkshire breeds and all possible crosses.

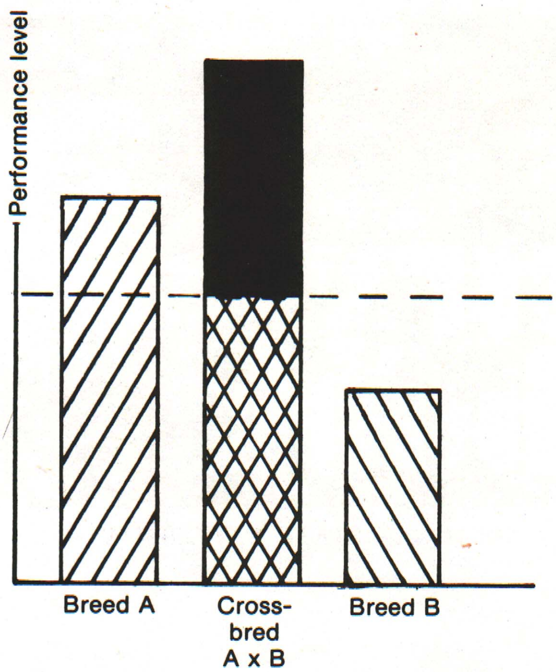

Figure 1. Heterosis response in crossbred offspring superior to both parent breeds.

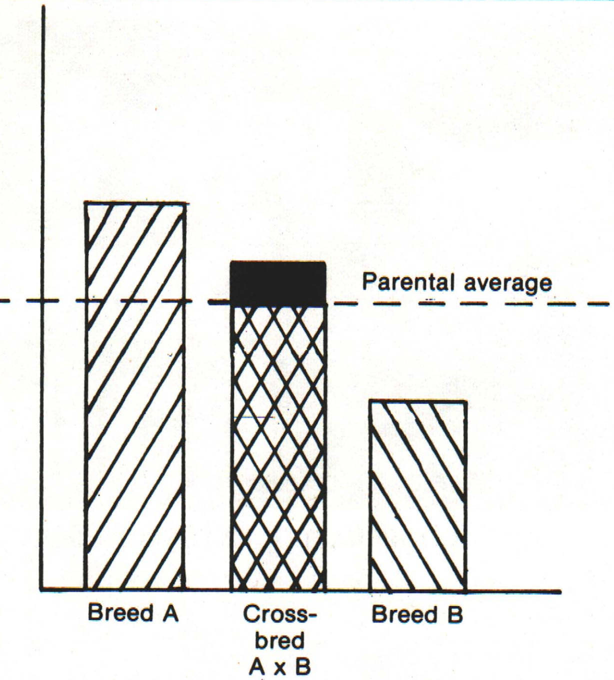

Figure 2. Heterosis response in crossbred offspring superior to one parent breed.

Because of lower death loss and increased pig growth rate, most commercial producers should utilize the crossbred brood sow rather than a purebred sow for commercial swine production. Crossbred pigs reach market weight at an earlier age and have a slight improvement in feed efficiency as compared to purebred pigs.

Even though traits of intermediate and high heritabilities are not greatly influenced by crossbreeding, you can improve overall efficiency by selecting superior parents. Real breed differences in male and female reproductive efficiency exist; therefore, choice of breeds appears to be critical in a crossbreeding program.

In summary, crossbreeding can increase:

- Litter size
- Survival
- Growth rate.

Crossbreeding will not:

- Increase muscle
- Decrease fat thickness
- Improve carcass quality.

Breed Evaluation

Comparing swine breeds accurately for all economically important traits is difficult. Although some crossbreeding experiments are being conducted to evaluate specific breed crosses, all breed combinations have not been adequately compared. Genetic breed composition and frequency of desirable gene combinations for particular traits do change over time. Therefore, evaluating breeds and their combining ability with other breeds must be a continuous and endless process.

For accurate breed evaluation, all breeds must be adequately sampled and handled the same. There are some data that show breed trends and their combining ability. Although all breeds are not represented and numbers are limited for some breeds, a summary of recent crossbreeding studies conducted at Iowa, Oklahoma, North Carolina, and Canada give us some breed trends. Therefore, conclusions and recommendations will be based on these results. Our recommendations should not be taken to eliminate those breeds that have not been compared or adequately sampled for experimental comparisons.

Since the Berkshire and Landrace breed numbers are small, a breed average may not reflect accurate trends. Comparison of published swine crossbreeding experiments indicates Yorkshire females excel in birth and weaning litter size and 21-day litter weight (Table 2). The Landrace female ranks high in her pig's birth and weaning weight and 21-day litter weight. This trend is noted when various two-breed cross females are compared and is evidence of the Landrace female's mothering ability (Table 3). The Chester White female excels in 21-day litter weight per female exposed, which is a measure of overall reproductive efficiency (Table 2).

Crossbred females of Yorkshire and Landrace breeding rank highest in all reproductive traits evaluated (Table 3). The combination of these two breeds results in a sow superior to any other breed combination. These results reflect the importance of the selection of one of the white breeds in the initial cross and their influence in total reproductive performance.

Some commercial producers may buy these F_1 cross gilts. Because of the increased possibility of disease contamination, most producers retain their own crossbred gilts. The influence of sire breed on reproduction then must be evaluated. Of the breeds experimentally evaluated, it is apparent sire breeds do influence reproductive performance (Table 4). The Yorkshire used as a sire breed ranks high as did the Yorkshire female for birth and weaning litter size, and 21-day litter weight. In contrast to the female breed evaluation, Yorkshire sires excel Chester White for 21-day litter weight per female exposed. These results reflect a measure of the Chester White female fertility (Table 2) and the Yorkshire breeding ability (Table 4).

Crossbred females of Berkshire and Yorkshire or Landrace breeding rank high in 21-day litter weight per female exposed (Table 3). Crossbred females of Hampshire and Landrace breeding excel in 21-day litter weight.

As a sire breed, Durocs influence pig birth weight, and litter size weaned (Table 4). This advantage in weight is continued throughout the growth phase (Table 5).

Crossbreeding results show the Duroc breed to be superior to the Chester White, Hampshire, and Yorkshire breeds for days to 220 lb. This trend is prevalent at 20 U.S. Central Test Stations (Table 6). Duroc boars had the highest average daily gain followed by the Hampshire, Spotted, and Yorkshire breeds. These same breeds ranked high for feed efficiency.

Since production traits are moderately heritable, breed selection becomes less important as compared to reproduction traits. The individual boar's performance record for growth and feed efficiency must be emphasized for genetic improvement.

Composition of this growth is highly heritable. Carcass measurements, such as length, backfat thickness, loin eye area and marbling score, are indicators of body composition and quality.

The Yorkshire and Hampshire breeds have longer carcasses as noted from crossbreeding studies (Table 5). The Hampshire breed had larger loin eye areas and lower backfat thickness of the breeds compared.

This trend is noted from Central Test Station data where Yorkshires were the longest, Hampshires had the lowest backfat thickness and Poland China had the largest loin eye area (Table 7).

Although breed differences exist, body composition can be most effectively changed by individual selection within a breed. Since carcass analysis requires the sacrifice of the animal, individual selection can be best accomplished by backfat probe or ultrasonic evaluation. These measurements do not give an indication of carcass quality, like marbling. Therefore, some carcass information on littermates of the selected parents is of value in a total genetic improvement program.

Crossbreeding Systems

Even though crossbreeding provides an opportunity to reap the benefits of many genetic sources, an unplanned crossing program will not yield success or profit for the pork producer. A crossbreeding system must be selected that will capitalize on heterosis, take advantage of breed strengths and fit your management program.

Two basic systems may be considered, namely, the rotational cross or terminal cross. The rotational cross system combines two or more breeds where a different breed of boar is mated to the replacement crossbred females produced the previous generation. In a terminal cross system, slaughter hogs are sired by the same breed boar with all offspring marketed. The female stock is usually purchased through a system primarily emphasizing reproductive performance.

Rotational Cross Systems

The two-breed rotational cross uses boars of two different breeds in alternate generations, retaining

Table 2. Relative reproductive performance of female breeds.*

Trait	Breed					
	Berkshire	Chester White	Duroc	Hampshire	Landrace	Yorkshire
Number of litters	19	145	348	393	44	379
Litter size born alive	87	99	89	84	94	100
Litter size weaned	83	95	86	84	89	100
Pig birth weight	82	81	94	94	100	82
Pig weaning weight	87	87	95	96	100	94
21-day litter weight	74	89	84	86	96	100
21-day litter weight /female exposed	84	100	78	94	89	94

*Composite results from Iowa, Oklahoma, North Carolina and Canada crossbreeding projects. Best breed performance is given 100 and compared to each breed.

Table 3. Relative reproductive performance of crossbred females.*

Female breed cross	No. of litters	Litter size born alive	Litter size weaned	Litter size 21-day wt.	Litter size 21-day wt./ female exposed
Chester - Duroc	41	83	79	86	---
Chester - Hamp.	36	92	81	77	---
Chester - York.	37	97	87	86	---
York. - Land.	35	100	100	100	100
Hamp. - Land.	38	100	95	95	88
Hamp. - York.	192	91	87	87	81
Berk. - York.	33	90	85	83	93
Berk. - Land.	37	92	90	87	91
Berk. - Hamp.	36	81	77	76	74
Duroc - York.	193	93	85	82	85
Duroc - Land.	38	92	93	86	79
Duroc - Hamp.	205	86	82	79	76
Duroc - Berk.	39	93	82	79	77

*Composite results from Iowa, Oklahoma, North Carolina, and Canada crossbreeding projects. Best breed performance is given 100 and compared to each breed.

Table 4. Sire breed influence on reproductive performance.*

Trait	Breed			
	Chester White	Duroc	Hampshire	Yorkshire
Numbers of litters	136	388	338	399
Litter size born alive	97	96	98	100
Litter size weaned	92	96	92	100
Birth weight	97	100	97	94
21-day litter weight	84	90	90	100
21-day litter weight /female exposed	89	91	81	100

*Composite results from Iowa, Oklahoma and North Carolina crossbreeding NC-103 project. Best breed performance given 100 and compared to each breed.

Table 5. Influence of sire breed on various production and carcass traits.*

Trait	Breed			
	Chester White	Duroc	Hampshire	Yorkshire
Number of litters	136	388	388	399
Production				
Days at 220 lb.	96	100	98	98
Feed/gain	96	99	100	98
Carcass composition				
Length	99	99	100	100
Backfat	92	94	100	88
Loin eye area	94	97	100	93
Marbling score	100	100	76	76

*Composite results from Iowa, Oklahoma, North Carolina crossbreeding NC-103 project. Best breed performance is given 100 and compared to each breed.

Table 6. Average daily gain and feed efficiency for boars tested to 220 lb. at central test stations.*

Breed	No. of boars tested	Avg. daily gain	Feed efficiency
Berkshire	310	96	94
Chester White	1,017	92	96
Duroc	6,334	100	100
Hampshire	4,127	98	98
Landrace	172	93	90
Poland China	528	95	95
Spotted	1,521	98	96
Yorkshire	3,760	98	99

*Summary of 20 Central U.S. Test Stations. Best breed performance is given 100 and compared to each breed.

Table 7. Carcass traits (adjusted to 220 lb.) by breed for pigs tested at central test stations.*

Breed	No. of pigs tested	Carcass length	Backfat thickness	Loin-eye area
Berkshire	184	96	87	91
Chester White	290	95	88	91
Duroc	1,095	97	88	88
Hampshire	726	98	100	98
Landrace	153	99	78	89
Poland China	203	94	95	100
Spotted	574	97	86	95
Yorkshire	684	100	87	90

*Composite results from National Barrow Show and Minnesota Central Evaluation Stations. Best breed performance is given 100 and compared to each breed.

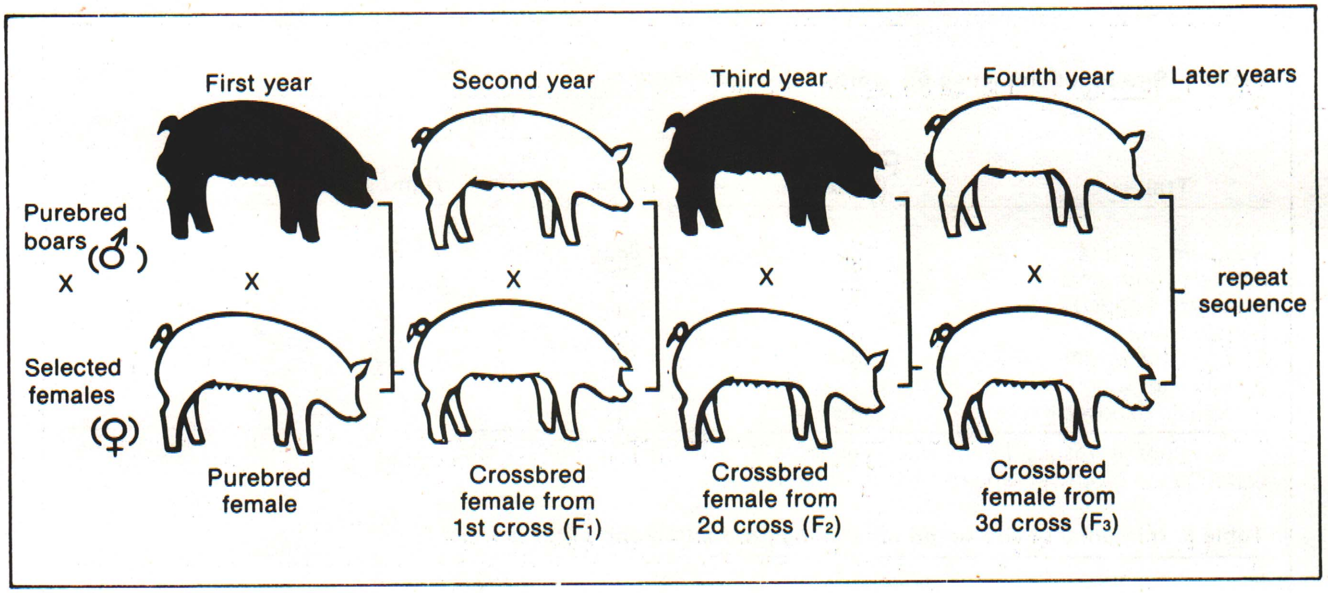

Figure 3. Two-breed rotational cross system.

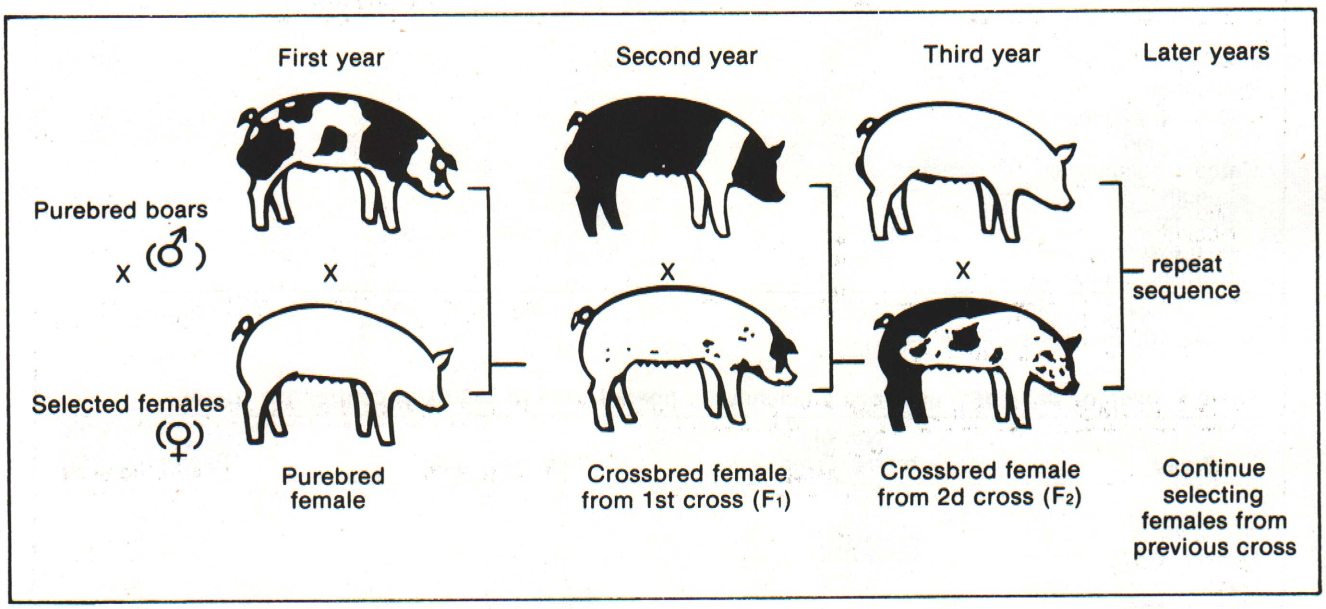

Figure 4. Three-breed rotational cross system.

crossbred females for maternal stock (Fig. 3). This crossing system is superior to a single-breed cross where two breeds are crossed and a purebred female is always used to produce crossbred pigs (Table 1). The single-breed cross does not capitalize on the heterosis in the crossbred female. As a producer you may want to generate single-cross (F_1) breeding stock for other commercial producers. This kind of production requires a strict sanitation and health program besides the selection of breeds and sires within breeds genetically superior for the performance level desired by your customers. Because of the added management problems, commercial production for market is usually more profitable.

The two-breed rotational cross is a simple program to follow once a producer chooses the two breeds. These breeds should complement each other. The initial female breed selection should excel in prolificacy and mothering ability. Since the pigs produced and females used are more than 50% one breed, choose two productive breeds that are above average in feed conversion to reduce production costs.

Some producers feel that heterosis runs out after continuous crossing with only two breeds. The second generation does not perform as well as the initial cross. Since ½ of the F_1 crossbred female's genes are inherited from the breed of sire to which she is mated, her offspring will have 1/2 of the heterosis response of the initial (F_1) cross progeny. This reduction in heterosis stabilizes in the sixth generation to about 67% of the F_1 cross.

To capitalize on heterosis, the addition of a third breed to the cross increases the heterosis to 86% in the seventh generation. By using a fourth or more breeds the percent heterosis could be increased; however, the problem of managing 4 or more sire breeds in a total production system becomes very complicated.

The three-breed rotational cross is probably the most popular crossbreeding system. It combines the strong traits of a third breed not available in the other two breeds. Sires from three breeds are systematically rotated each generation and replacement crossbred females are selected each generation (Fig. 4). These females are mated to the sire breed farthest removed in the pedigree.

Since reproductive performance was stressed in the initial two-breed selection, growth, feed conversion, or superior carcass composition may be below your breeding goals and may need emphasis. Your overall production goals and progeny performance will determine the third breed choice and individual sire selection.

Terminal Cross System

The terminal cross system is well adapted to feeder pig production. Since the producers' goal is to sell a large number of fast-growing, lean pigs per female unit, boar breeding ability, uniformity and selection of the terminal sire are important factors.

A two-breed single or rotational cross female mated to a boar of a third breed producing the terminal market pig fits many of the feeder pig production requirements. With a terminal cross, the producer could either buy or produce his own females. In either case, the crossbred female should excel in reproductive performance. The sire breed should produce fast-growing, efficient pigs that produce superior carcass composition and quality.

The sire breed could be either a purebred or crossbred boar, but should be of different breed composition than the crossbred female. Since no replacement gilts are retained from the terminal cross, the sire breed becomes less important, but individual boar's performance becomes a key criterion of selection.

Since only one breed of boar is used, females of different ages and groups can be mixed in the breeding groups.

Although limited research information is available on the use of crossbred boars, indications are that crossbred boars are more aggressive breeders, have fewer problems in leg soundness and improve overall breeding efficiency. A crossbred boar could combine those traits that may not be available in one straightbred breed.

Precaution must be taken in either a terminal or rotational crossing program that the breed composition of the boar is different from the crossbred female. If a breed is repeated, an immediate reduction in heterosis will occur and defeat the purpose of crossing.

Hybrid boars sold by some commercial companies should not be confused with crossbred boars sold by private breeder concerns. Hybrid boars are developed from specific line crosses. These lines have been selected and developed for specific traits. When specific crosses are made, the hybrid boar must be used on specific cross females to maximize heterosis in their offspring.

The commercial pork producer has many selection tools, crossing systems, and genetic breeding stock sources for his use and evaluation. He must capitalize on heterosis and breed strengths and must require complete performance records on all selected breeding stock.

Although there is no one best system, breed, or source of breeding stock, each producer must evaluate his total pork production program and integrate the most profitable combination of elements associated with a crossbreeding program.

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