A review on the utilization of crossbred sows and boars in swine production*

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Introduction

Although the advantages of crossing different strains or breeds of livestock have been known for a long time, the use of crossing in commercial swine production became widespread only in the last two decades or so. Corn breeders succeeded in developing inbred lines of corn, which exhibited great heterosis when later crossed. Their success in profiting from this phenomenon encouraged swine breeders to apply the same principle. The results obtained with swine were however, costly and much below expectation. Maintaining inbred lines was costly and difficult due to the deterioration in reproductive performance, and crossing the inbred lines only restored the level of performance to that of the original stock with no apparent economic advantage. The diversity in performance of swine breeds, presented the possibility of taking advantage of the heterosis without the need to suffer from the cost and inconvenience of inbreeding. Easy access to different swine breeds from different parts of the world, made the use of exotic breeds advantageous in improving certain traits and profitable in taking advantage of the heterosis.
Bichard and Smith (1972) and Dickerson (1973) examined various systems of improving production by crossbreeding. They concluded that the optimum crossing system is likely to involve a two-breed cross dam line mated to terminal sire line. The dam line is chosen on the basis of its high maternal ability, whereas in the sire line the choice is based on the ability to transmit to the progeny fast growth and superior carcass quality. This conclusion was reached after examining various crossbreeding experiments which showed clearly that the heterosis exhibited by the crossbred sow in reproductive traits is important. The expected advantages of crossbred sows is presented in Table 1.
Heterosis (H) has been commonly defined as being the percent increase in performance of the reciprocal crosses over the mean of the two parents i.e.

$$H\% = 100\ [(AB + BA) - (A + B)/A + B]$$

Logically, in order that the crossbreeding becomes economically advantageous, the crosses should have a higher performance than the better parent i.e.

$$\frac{100\ [(AB + BA) - A/A]}{2}$$

This term will be referred to in this paper as H_B.
In practice, the difference between a cross in which the better parent is the dam and that parent breed is the actual advantage (or disadvantage) the one-breed breeder would expect from crossing i.e.

$$100\ [\ B♂A♀ - A/A]$$

This term will be referred to as H_S.
The decision of whether to use crossbred or purebred parents may depend on how we estimate the heterosis, as H, H_B, or H_S. In this article the use of crossbred females and males will be presented to illustrate when this use can be advantageous to commercial swine breeders.

The use of crossbred female

Puberty

All reports in the literature indicate that generally crossbred gilts reach puberty at younger age than the purebreds (Table 2).
The heterosis estimates range from 4 to 11%. In most of the crosses studied by the five workers the reciprocal crosses performed better than the best parent (11 out of 13 crosses). Except for the study of Johnson *et al.*, (1978), comparing the cross in which the dam was the better breed with the purebreed (H_S) gave lower estimates of superiority indicating that no real advantage, or even a disadvantage as in the study of Clark *et al.*, (1970), resulted from crossing the better breed in a combination.

Ovulation rate

Johnson *et al.*, (1978) showed that the heterosis of ovulation rate for crosses among Duroc, Hampshire and Yorkshire breeds was only .3%. Crosses between Hampshire and both Duroc and Yorkshire gave negative heterosis estimates (Table 3).
Crossing Yorkshire and Duroc sows with Hampshire boars resulted in a 4.3 and 5.5% reduction in ovulation rate from that expected from the two pure breeds. Dyck (1971) reported that crossbred Lacombe × Yorkshire sows ovulated 1.03 ova more than the average of the two parents; they were however almost similar in ovulation to the pure Lacombe sows, the better of the two breeds in ovulation. Ovulation rate as one trait closely related to fitness was supposed to show a higher degree of heterosis, but from the scarce information reported in the literature it seems not to be the case.

Litter performance

Maternal heterosis estimates (H%) of litter performance reported by Johnson *et al.*, (1978) and Schneider *et al.*, (1982) are presented in Table 4 together with average estimates reported by Sellier (1976) for experiments carried out in Europe. Litter size and weight showed a sizable heterosis. This heterosis was also evident when calculated as H_B or H_S (Table 5).
This indicates that crossbred dams are favoured to produce larger and heavier litters at birth and at weaning than those of the better breed.

TABLE 1 - Expected advantages of crossbred sows.

Puberty	earlier
Ovulation	higher
Embryo survival	higher
Litter size	larger
Progeny growth	faster
Feed utilization	more efficient
Carcass quality	better

TABLE 2 - Puberty in the female pig.

Reference	C-P (day)	Percent H	Percent H_B	Percent H_S
Foote *et al.* (1956)	−26.6	11.0	1.5	0.9
Zimmerman *et al.* (1960)	−21.7	10.6	7.8	—
Clark *et al.* (1970)	−14.0	5.9	1.8	−2.2
Johnson *et al.* (1978)	−11.7	4.3	3.5	4.9
Hutchens *et al.* (1982)	− 7.8	4.0	3.0	—
Average	−14.1	6.2	3.5	1.2

C = Crossbreds, P = Purebreds

TABLE 3 - Ovulation in the female pig.

Reference	Cross	C-P	Percent H	Percent H_B	Percent H_S
Johnson *et al.* (1978)	D-H	− .11	− .8	−1.5 D	−5.5
	D-Y	.64	4.7	3.9 Y	4.5
	H-Y	− .42	−3.1	−4.5 Y	−4.3
Average		.04	.3	− .7	−1.8

		C-P	S%*
Dyck (1971)	Lc-Y	1.03	7.9

C = Crossbreds, P = Purebreds, D = Duroc
H = Hampshire, Y = Yorkshire, Lc = Lacombe
*S=% difference of one cross over the two parents.

TABLE 4 - Maternal heterosis for reproduction traits

Trait	Johnson 1981* $\bar{x}$	Johnson 1981* %	Sellier 1976 $\bar{x}$	Sellier 1976 %
No embryos	.71	4.4		
L.S. Birth	.93	9.9	.75	8.0
L.S. 21 d	.93	13.0	.85	11.0
L.W. 21 d	6.40	16.7	8.0	10.0

LS = Litter size, LW = Litter Weight
*average estimates from Johnson *et al.* (1978) and Schneider *et al.* (1982a)

Production traits

Johnson *et al.*, (1978) and Schneider *et al.*, (1982b) reported heterosis estimates for gain, feed efficiency and carcass quality as maternal effects (Table 6). These estimates were very low suggesting that the influence of the crossbred sow on the production traits of its progeny is rather insignificant. The estimates of H_B and H_S were either 0 or negative, again showing the little effect the crossbred dam has on the production traits of its progeny.

The use of crossbred males

Puberty

Very little has been reported on the difference between purebred and crossbred boars in age and weight at puberty. The results of Sellier *et al.*, (1971) on a rather limited sample indicated that the purebred boars reached the age of first semen collection at earlier age and at lighter weights than did the crossbred boars (Table 7).

TABLE 6 - Maternal heterosis for production traits.

Trait	Johnson *et al.* (1978) H	Johnson *et al.* (1978) H_B	Johnson *et al.* (1978) H_S	Schneider *et al.* (1982b) H	Schneider *et al.* (1982b) H_B	Schneider *et al.* (1982b) H_S
Average Daily Gain	− .2	−1.1	−1.4	−1.2	−4.2	
Gain/feed	− .1	−1.2	−1.1			
Carcass length	0	− .4	− .7	.2	− .2	
Backfat	−2.3	− .9	−3.9	.3	−4.0	
Loin-eye area	4.0	− .9	−1.4	− .2	−2.5	

TABLE 7 - Puberty in the male pig.

	Age and weight 1st collection n	Age	S%	wt. kg	S%
Yorkshire (Y)	4	176		105	
Landrace (L)	4	187		111	
L x Y	4	229	−26	130	20
Hampshire (H) x L	4	186		122	
H x Y	4	212		123	

Sellier *et al.* 1971

TABLE 5 - Heterosis for reproductive traits.

Reference	Litter size at birth H	Litter size at birth Percent H_B	Litter size at birth Percent H_S	Litter size at 21d H	Litter size at 21d Percent H_B	Litter size at 21d Percent H_S	Litter weight at 21d H	Litter weight at 21d Percent H_B	Litter weight at 21d Percent H_S
Johnson *et al.* (1978)	10.5	6.5	7.3	18.3	15.7	15.7	19.8	15.6	15.7
Schneider *et al.* (1982a)	10.3	4.1		7.7	2.2		11.9	8.3	

Mating behavior

There is no adequate method to quantify the mating behavior of boars. Wilson *et al.*, (1977) used various measures to assess the mating behavior of Duroc and Hampshire boars and their two reciprocal crosses. In all the measures studied, the crossbred boars were superior to the purebreds (Table 8).

Neely and Robison (1983) used different measures to assess mating behavior. These measurements also showed the superiority of the crossbred boars (Table 9). The authors showed however, that the over aggressiveness of the crossbred boars can have an adverse effect on mating time. They concluded that crossbred boars displayed greater sexual interest and initiated mounting activity sooner and had more mounts with a greater mean proportion of properly oriented mounts.

Testicular characteristics

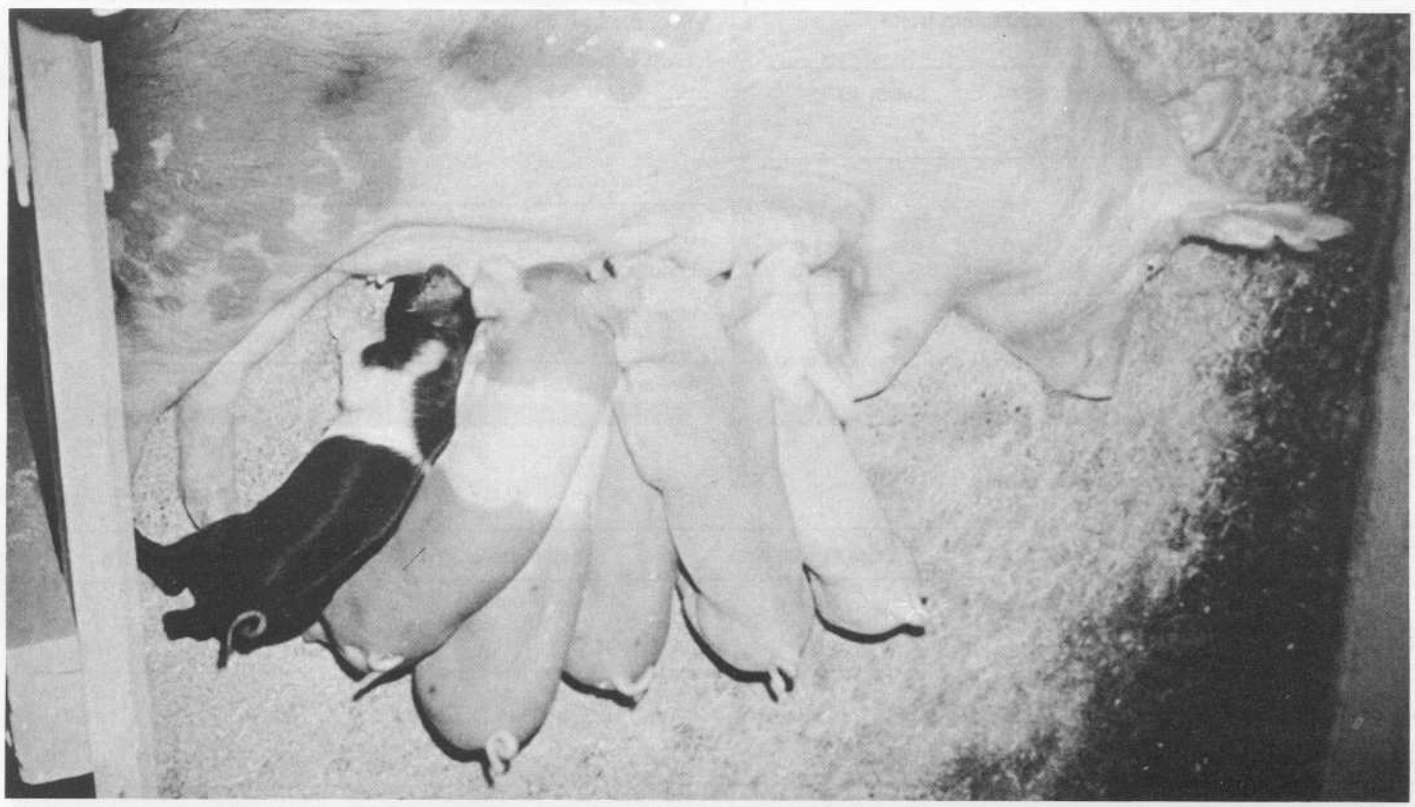
Numerous investigators demonstrated the superiority of the crossbred boars in testis weights and measurements (Table 10). Wilson *et al.*, (1977) and Fent *et al.*, (1980) reported estimates exceeding 15% for the superiority of crossbred boars whereas the estimates of Holzler *et al.*, (1975) and Neely *et al.*, (1980) were in the proximity of 8-9%. Neely *et al.*, also reported estimates of heterosis of 2.5 and 4.5% for the length and width of the testicles. Holzler *et al.*, (1975) and Fent *et al.*, (1980) reported estimates of heterosis of 12.2 and 15.4% for the weight of Cauda epididymides respectively.

Sperm production

Crossbred boars were found to produce larger volumes of semen than purebreds. Sellier *et al.* (1971) working on Yorkshire, Landrace, Yorkshire × Landrace, Hampshire × Yorkshire and Hampshire × Landrace boars, reported that while the two purebreeds produced an average of 210 ml per ejaculation, the crossbred boars produced 253 ml. which gives an estimate of 20.5% superiority of the crosses over the purebreeds. The corresponding figures in the study of Conlon and Kennedy (1978) were 126, 290 ml and 129%. In the studies of Sellier *et al.*, (1971), Wilson *et al.*, (1977) and Conlon and Kennedy (1978), the sperm concentration was similar in the crossbred and purebred boars (Table 11). However, due to the larger volumes of semen produced by the crossbred boars, the number of spermatozoa counted per ejaculation was higher in the crossbred as compared to the purebred boars (Table 11). The average superiority of the crossbred over the purebred boars from the five studies reported in the literature was 19%.

Reproductive efficiency

Conception and embryo survival: Baker (1973) reported that crossbred boars settled more gilts and that the number of live piglets born per litter was greater with the crossbreds.



Crossbred sow nursing her 3-breed-cross litter

TABLE 8 - Mating behavior.

	No.	Mated each time	One failure	> one failure	Time to mount (sec.)	Time to ejac. (sec.)
P.	36	11	10	15	127	159
C.	36	28	8	0	111	169
C-P					−16 (13%)	10 (−6%)

Wilson *et al.* (1977); P = Purebreds, C = Crossbreds

TABLE 9 - Mating behavior

	Percent		
	H	H_B	H_S
Mating %	210		
Interest score	52		
Time 1st mount	34	40	18
Time in pen	20	21	19

Neely & Robison (1983)

TABLE 10 - Testes weight.

	Percent			
Reference	H	H_B	H_S	S
Wilson *et al.* (1977)	16	11	6	
Neely *et al.* (1980)	8	− 2.5	.7	
Holzler *et al.* (1975)	—	—	4.2	8.6
Fent *et al.* (1980)	18.9			
Cauda epididymides				
Fent *et al.* (1980)	15.4			
Holzler *et al.* (1975)			10.6	12.2

The higher percent of gilts found pregnant after mating with crossbred boars was confirmed by the work of Wilson *et al.*, (1977) and Conlon and Kennedy (1978) presented in Table 12. Wilson *et al.*, (1977) also showed that while 28% of the purebred boars failed to impregnate the female, only 12% of the crossbreds failed to do so. Survival rate of embryos sired by crossbred boars was also higher than of those sired by purebreds (Wilson *et al.*, 1977).

Litter size at birth and thereafter: King (1968) reported that litters sired by crossbred boars from Pietrain, Lacombe and Hampshire breeds were 0.9 and 1.2 piglets larger than those sired by the purebred boars of the three breeds, and that Pietrain × Hampshire boars performed better than the best of the two pure breeds (the Hampshire). The superiority of the Pietrain × Hampshire crossbred boars in litter size was also reported by King and Thorpe (1974) in comparing with pure Large White boars, and again by King (1975) in comparing with different pure breeds. These seem to be the only reports in the literature in which an advantage of the crossbred boars on litter size was indicated. The results of Schlote *et al.*, (1974), Lishman *et al.*, (1975), Fahmy and Holtmann (1977), Smith *et al.*, (1978) and Drewry (1980) indicated no difference between purebred and crossbred boars in litter size or that purebred were superior to crossbred boars in this regard (Table 13).

Feed conversion ratio

King (1968) reported very little difference between the progeny of three types of crossbred boars and the progeny of pure Large White boars in the efficiency of feed utilization. These results confirmed the findings of Rempel *et al.*, (1964)

TABLE 11 - Sperm production.

	H or S%		
Reference	Conc.	Number	Volume
Sellier *et al.* (1971)	−8	28	20
Holzler *et al.* (1975)		−8	
Wilson *et al.* (1977)	4	26	
Conlon & Kennedy (1978)	0		130
Fent *et al.* (1980)		36	
Neely *et al.* (1980)		14	
Average		19	

TABLE 12 - Reproductive efficiency.

	P	C	C-P	S%
(1)% pregnant gilt	56	64	—	8
(2)% pregnant gilt	78	80	—	2.0
(1)% Sires failing to impregnate	28	12		16
(1) No embryos/pregnant gilt	10.7	11.2	.5	4.7
(1)% embryos/C.L.	70	77	7.0	10

(1) Wilson et al. (1977) (2) Conlon and Kennedy (1978)

TABLE 13 - Litter size at birth and weaning.

	H or S%	
Reference	Birth	Weaning
Schlote *et al.* (1974)		−4
Lishman *et al.* (1975)	0	−3
Fahmy & Holtmann (1977)	−9	−6
Smith *et al.* (1978)	−3	−3
Drewry (1980)	1	−3
Schneider *et al.* (1982a)	−9	−7
Average	−5	−4

who found the progeny of crossbred boars to be .5% inferior to those of purebred boars. Later studies by Sellier (1973) and Lishman *et al.*, (1975) showed similar results (Table 14). Curran *et al.*, (1972) reported little difference in feed conversion ratio in pigs sired by purebred boar mated to crossbred dams and those of crossbred boars mated to purebred dams, i.e. when the genetic component of the piglets are similar. They found however, an 11.2% advantage of the crossbred boars when compared to Landrace boars mated to Landrace sows.

Carcass characteristics

The effect of using crossbred boars on the carcass characteristics of the progeny is generally negative (Table 15). The carcasses are shorter and fatter with less lean.

Small litters in some breeds is a good reason for crossbreeding

Conclusions

Conclusions regarding the use of crossbred dams

Although calculating heterosis as the superiority of the crosses over the better parent resulted in smaller estimates, yet the fact that they were still positive and of a certain magnitude in such character as age at puberty, litter size and weight indicates that it is favourable to use crossbred sows in commercial swine operations. Even though a breed can be superior in its performance, on the long run this performance is apt to decline if not mixed with different breeds or at least different strains of the same breed. The decline in performance in the Danish Landrace after generations of isolation from the rest of the world, is an example of the necessity of outbreeding for improving swine production.

TABLE 14 - Feed conversion (FC) & growth rate (GR).

Reference	H or S%	
	FC	GR
Rempel *et al.* (1964)	– .5	– 3.1
Curran *et al.* (1972) 1	0	– 2.5
Curran *et al.* (1972) 2	11.2	10.4
Sellier (1973)	– 1.2	1.9
Lishman *et al.* (1975)	1.6	0
Fahmy and Holtmann (1975)	—	1.0
Schlote *et al.* (1974)	—	.5
Average	2.2	.2

TABLE 15 - Selected carcass traits.

Reference	H or S%		
	Length	eye muscle	back fat
Rempel *et al.* (1964)	—	–12.5	0
Sellier (1973)	.5	—	2.7
Schlote *et al.* (1974)	—	– 1.4	2.1
Lishman *et al.* (197)	–1.4	– 1.3	3.2
Fahmy and Holtmann (1975)	—	.7	.6
Curran *et al.* (1972) 1	–1.9	10.1	10.0
Curran *et al.* (1972) 2	–4.8	14.1	1.5
Schneider *et al.* (1982b)	– .2	α .2	– .1
Average	–1.6	1.4	2.5

Conclusions regarding the use of crossbred boars

Crossbred boars were found to reach puberty earlier, to have superior libido and to produce larger semen volume with higher spermatozoa count than purebred boars. No appreciable difference between the two types of boars was found in the litter size they produce or the growth, feed efficiency or carcass quality of their progeny. Since purebred boars are usually highly selected and often progeny-tested, their use is more popular. The use of crossbred boars may be advantageous if the breeds involved in the cross are either poor in reproductive ability or possess undesirable traits as purebreds, an example of that is the PSE syndrome in the Pietrain breed.

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