

# The use of crossbreeding to improve swine production in Canada

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## PREFACE

This document is a summary of the results of a major research project carried out in Eastern Canada over the past decade. The objective of the project was to identify crosses exhibiting the best reproductive performance in order to improve the productivity of the Canadian swine industry. This document was prepared for use by scientific extension specialists, but producers can easily follow its recommendations. For additional information, please contact the author at Research Station, Agriculture Canada, P.O. Box 90, Lennoxville, Quebec J1M 1Z3.

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## SUMMARY

A crossbreeding experiment was carried out in Canada to evaluate the productive and reproductive performance of various combinations of two-breed crosses, and the performance at slaughter of various three- and four-breed crosses obtained from females of some of these two-breed crosses and different terminal sire breeds and crosses. The breeds involved in the crossing were Yorkshire, Landrace, Lacombe, Duroc, Hampshire, Berkshire, Large Black, and Tamworth. These breeds were combined in an incomplete diallel mating design producing 28 two-breed crosses.

The results showed that Hampshire x Landrace was the best overall cross when considering reproduction, growth, and carcass quality. Landrace x Yorkshire was the highest cross in reproductive performance, followed by Large Black x Lacombe. The best three-breed-cross for market was Hampshire x (Landrace x Yorkshire) followed by Hampshire x (Duroc x Lacombe). Four-breed crosses produced from mating crossbred parents were generally similar in performance or slightly inferior to three-breed crosses obtained from mating purebred boars to crossbred sows. The results in general indicated that crosses involving the colored breeds were generally inferior to the other crosses.

## RÉSUMÉ

Une expérience sur les croisements a été entreprise au Canada afin d'évaluer les performances reproductrices des truies issues de différents croisements simples, ainsi que les rendements à l'abattage de produits de croisements triples et quadruples obtenus par fécondation des femelles issues d'un croisement simple avec des verrats de race pure ou hybride. Les races Yorkshire, Landrace, Lacombe, Duroc, Hampshire, Berkshire, Large Black et Tamworth ont été combinées selon un schéma de croisement diallèle incomplet permettant d'obtenir 28 croisements simples.

Les résultats ont montré que le croisement Hampshire x Landrace était le meilleur de tous en ce qui concerne la reproduction, la croissance et la qualité de la carcasse. Du point de vue des performances de reproduction, le croisement Landrace x Yorkshire s'avère le plus intéressant, suivi par le croisement Large Black x Lacombe. Le meilleur croisement triple pour la commercialisation des produits est le croisement Hampshire x (Landrace x Yorkshire) suivi par le croisement Hampshire x (Duroc x Lacombe). Les croisements de quatre races obtenus par l'accouplement de parents hybrides ont donné des performances semblables ou légèrement inférieures aux croisements triples obtenus en accouplant des verrats de race pure à des truies hybrides. D'une façon générale, les croisements impliquant les races de couleur ont donné de moins bons résultats que les autres croisements.

## INTRODUCTION

Crossbreeding has played a role of increasing importance in the Canadian swine industry in recent years. As consumer demand changes, the importance of different productive characters is also likely to change and the objectives of the industry may have to be modified. Knowledge of crossbreeding systems and their effect becomes essential to improve production efficiency and maximize profit to keep the industry viable and progressive.

The availability of breeds with different productive traits enables producers to keep up with economic changes. Crossbreeding also allows commercial producers to take advantage of heterosis and combine in one production unit several desirable traits not generally found in a single breed.

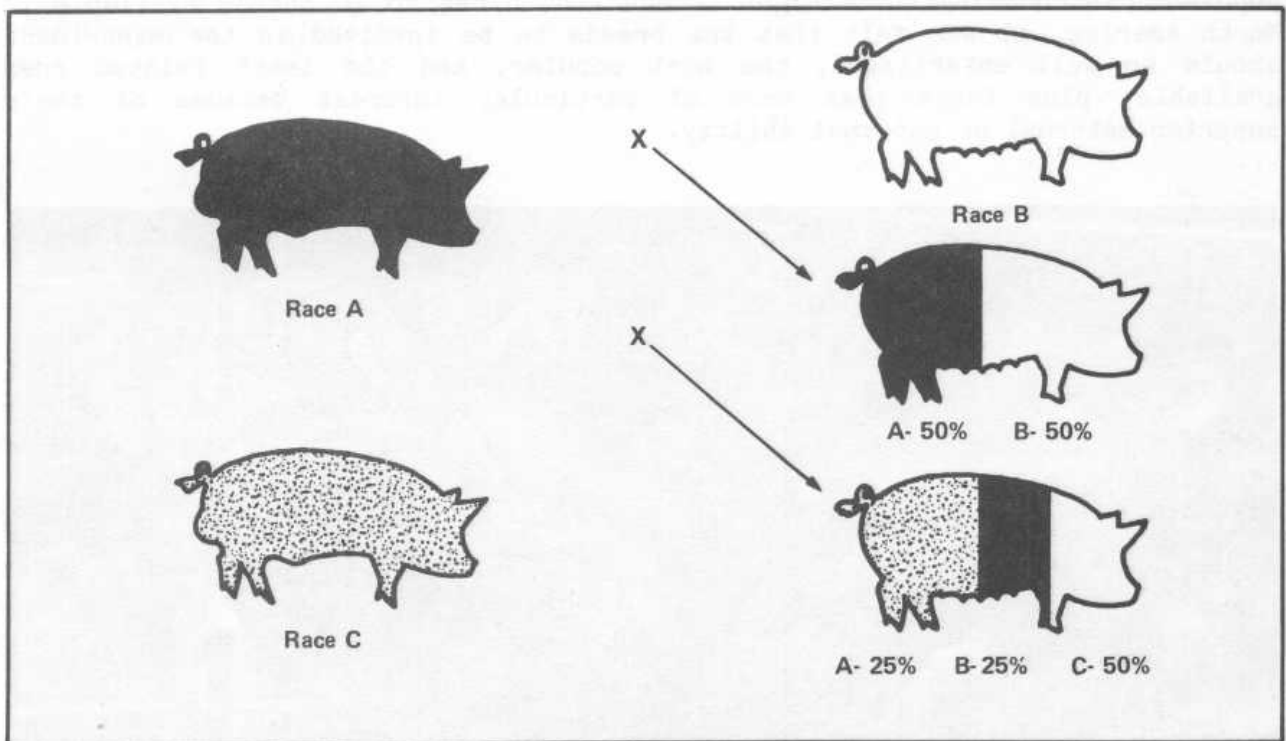


Fig. 1. A three-breed cross

There are advantages and drawbacks to every crossbreeding system. British and American researchers have examined various crossbreeding systems and have concluded that in swine production, the optimum system is to mate a dam from a two-breed cross with a sire from a third breed. The maternal line is chosen on the basis of high maternal qualities, whereas the choice of the paternal line is based on its ability to transmit fast growth and superior carcass quality to the offspring.

Although there is little controversy among breeders and scientists about the system itself, the choice of both sire and dam lines is complicated by the many problems involved in the economic evaluation of the overall performance of the various combinations. The performance of some crosses in certain traits can be predicted with a reasonable degree of accuracy from the performance of the parental breeds. In other traits, however, especially those related to reproduction, the performance of the crosses may not be easily predicted because of the exhibited phenomenon of heterosis and the differences among breeds in their general and specific combining ability. A crossbreeding experiment was therefore initiated in eastern Canada to evaluate the relative performance of various crosses among eight North American breeds which are also used in other parts of the world, especially those that have intensive swine production industries. The Yorkshire, Landrace, Hampshire, Duroc, Berkshire, Large Black, Tamworth, and Lacombe breeds were chosen for the experiment. The Lacombe breed was included because it was developed in Canada by the Canadian Department of Agriculture and it had become fairly popular. In choosing these eight breeds from close to 20 breeds available in North America, it was felt that the breeds to be involved in the experiment should be well established, the most popular, and the least related ones available, plus those that were of particular interest because of their superior maternal or paternal ability.

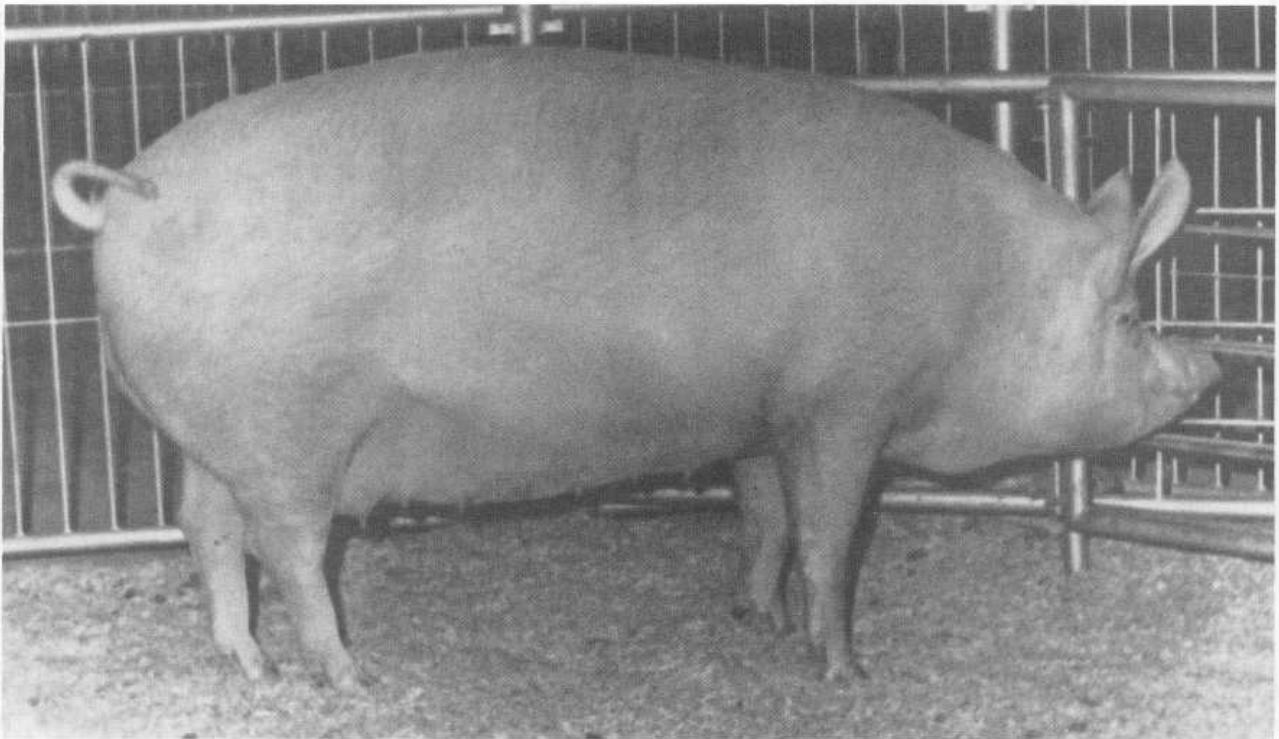


Fig. 2. A Yorkshire sow

The white Yorkshire breed (Y) originated in England. The first animals were brought to this country in 1895. The Yorkshire is a prolific breed and its sows are excellent mothers and milk producers. Carcass quality, growth rate, and feed efficiency are generally high.

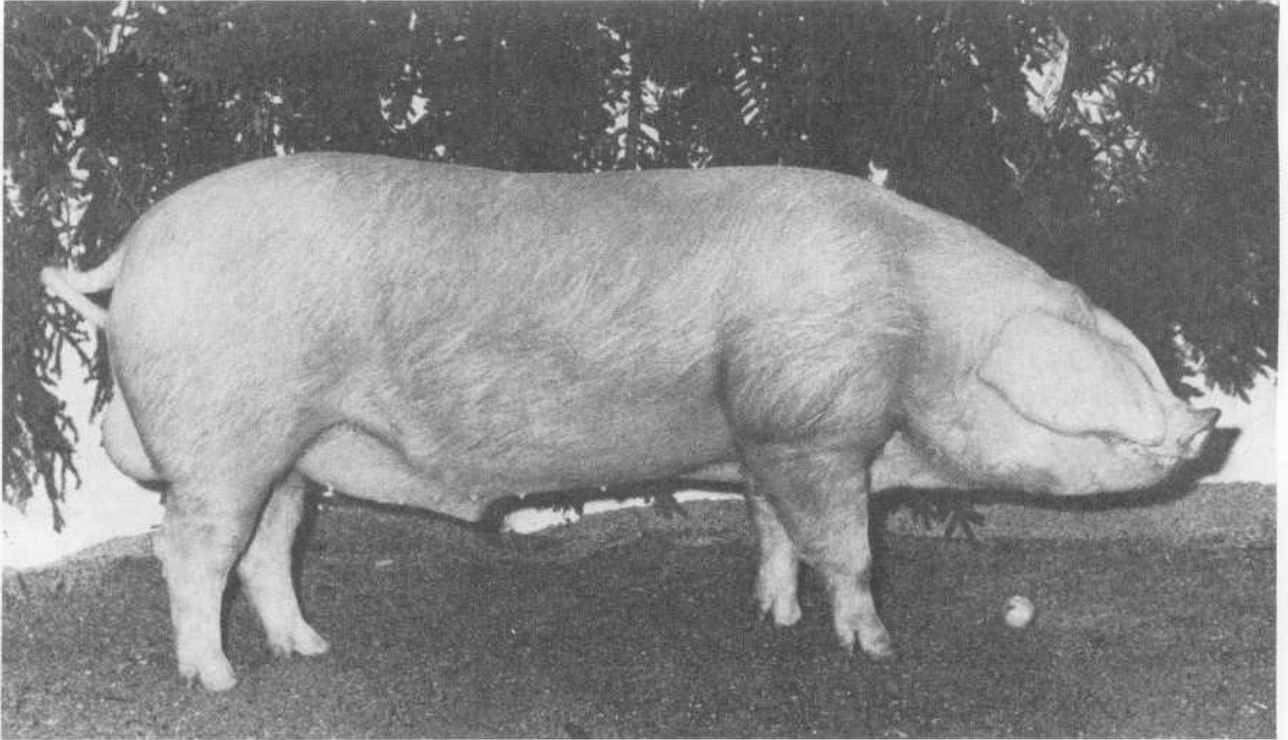


Fig. 3. A Landrace boar

The Landrace breed (Ld) originated in Europe, particularly in Denmark. Canada received its first Landrace animals in the mid-1950s. The Landrace is a white breed of excellent prolificacy. The animals fatten well and produce carcasses equal in quality to those of the Yorkshire breed.

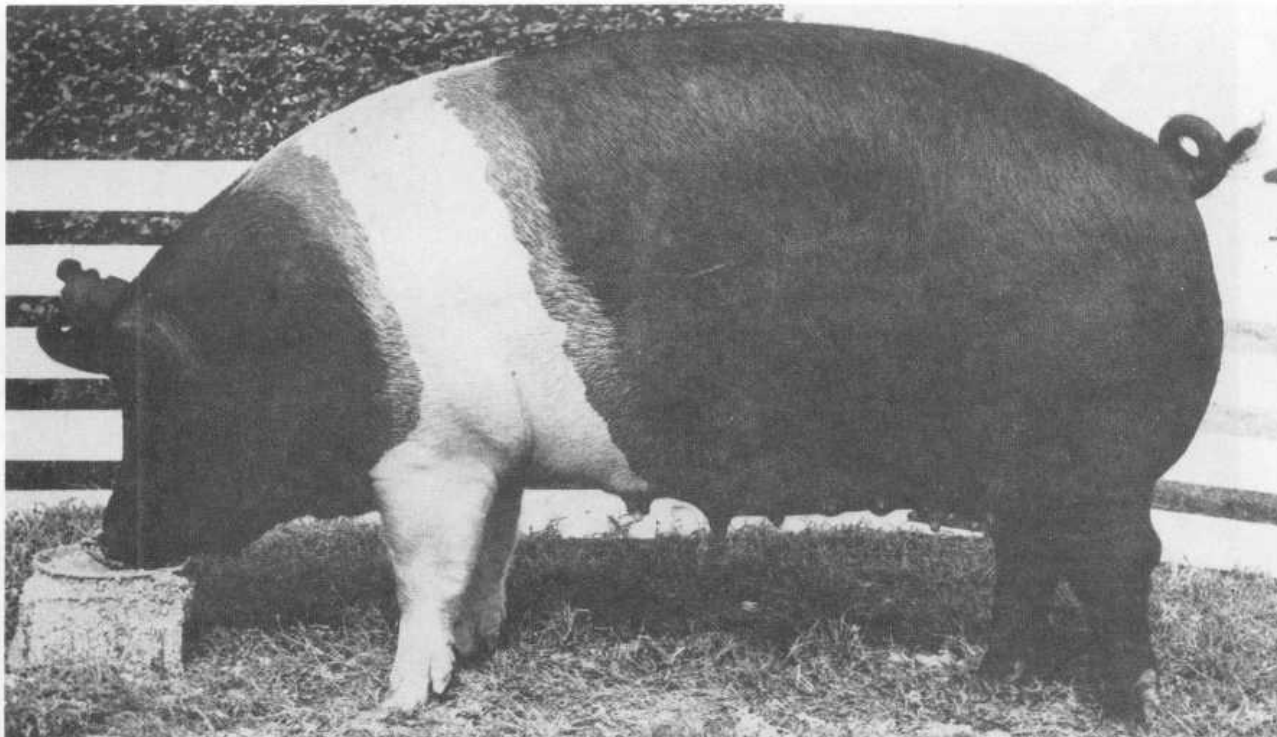


Fig. 4. A Hampshire sow

The Hampshire (H) is another English breed. The first animals were brought to this country in 1910. Hampshire pigs are fast-growing, with an even distribution of fat. They produce carcasses of excellent quality, without excess back fat. The sows are not very prolific but have fairly good maternal qualities.

The Duroc Jersey breed (D) was developed from two lines of red swine that originated in Guinea, Spain, and Portugal. It appeared in Canada around 1940. Animals of the breed have above-average growth, partly as a result of their high feed intake, and they are generally vigorous and alert.

Berkshire breed (B) originated in south central England. Animals were first imported into Canada around 1838. The Berkshire is a prolific, fast-growing pig and produces carcasses of good quality.

The Large Black (LB) breed was developed in England from two populations of black pigs: the improved Essex (a medium-sized pig), and the Cornwall (a large pig). Animals of the breed were imported into Canada around 1920. The Large Black is known mainly for its hardiness and good maternal characteristics. The sows do well outdoors on pasture. They raise large litters but have only average fecundity.



The Tamworth (T) was imported into Canada from England around 1877. The animals are vigorous and active. The sows are good milk producers and have good maternal characteristics. The breed has become less popular in Canada with the increased popularity of the white breeds.

The Lacombe (Lc), a white breed, was the first to be developed in Canada. It originated at the Agriculture Canada Research Station at Lacombe, Alta., and has been recognized as a breed since 1957. A strict selection process was used to develop the Lacombe. The traits considered were the number of piglets at weaning, rate of gain, and carcass quality.

In the preparatory phase of the program, 28 crosses were produced from 293 female and 40 male pigs purchased in the spring of 1968 at the age of 2-3 months from commercial producers in the United States and Canada. Males and females were obtained from Landrace, Lacombe, Hampshire, Duroc, Berkshire, and Large Black breeds; only Yorkshire females and Tamworth males were purchased. To ensure a proper sampling of the eight breeds involved, only a limited number of animals were obtained from each source. For example, not more than two pigs of the same litter, not more than four pigs from the same sire, and not more than eight pigs from the same producer were purchased. All males purchased were from parents that had been tested at the farm or station under the specifications of record of performance (ROP). When the animals reached sexual maturity (about 7 months), they were mated to produce the 28 crosses that were subsequently tested.

#### PHASE 1

##### 1. A: Reproductive performance of sows from 28 crosses

The crossbred offspring were born in 1969 and 1970. The piglets were weaned at 35 days of age. The females selected for breeding were those of average pre-weaning growth rate, about 8-10 kg at 35 days. Shortly after weaning, the healthy females were shipped to four cooperative stations: Laval University, Sainte-Foy, Que.; Macdonald College, Sainte-Anne-de-Bellevue, Que.; Nappan Experimental Farm, Nappan, N.S.; and Kemptville College of Agricultural Technology, Kemptville, Ont.

On average, 36 females per cross were available in the initial stages of the experiment. Seventeen of these were kept at Lennoxville, seven went to Laval, six to Macdonald, four to Nappan, and two to Kemptville.

To minimize as much as possible the implications caused by breed of sire, full- and half-sib Poland China boars were used for mating all the females.

All two-breed cross gilts were weighed at 112 days of age and at the first detected heat. The gilts and sows were weighed within 18 hours of farrowing and 21 days post-farrowing. The litter size, sex, weight of the individual piglets (including those stillborn) at or shortly after birth, and weight of the piglets at 21 days were all recorded.

## 1.1 Results

### 1.1.1 Weight at 112 days

Significant differences among the various crosses were observed. The crosses with Landrace or Large Black ancestors either from the sire or dam sides produced the heaviest weights at 112 days. The crosses with Yorkshire or Berkshire ancestors were the lightest (Table 1).

### 1.1.2 Sexual maturity

The effect of cross on age at puberty was significant. The crosses involving Yorkshire and Tamworth were significantly younger at puberty than those involving the other six breeds (Table 1).

Table 1. Least squares means (and ranking) for weight at 112 days and age at sexual maturity (first estrus)

Breed of dam	Breed of sire						
	Tamworth	L. Black	Berkshire	Duroc	Hampshire	Lacombe	Landrace
Weight at 112 days. General average = $48.8 \pm 0.29$ kg							
Yorkshire	46.6 (21)	48.3 (17)	43.8 (28)	45.8 (24)	46.4 (23)	49.7 (25)	45.7 (25)
Landrace	50.4 ( 9)	52.3 ( 1)	50.0 (10)	51.6 ( 4)	52.2 ( 3)	48.3 (17)	
Lacombe	50.5 ( 8)	50.0 (10)	44.8 (27)	51.2 ( 6)	52.3 ( 1)		
Hampshire	48.2 (19)	49.0 (15)	46.6 (21)	47.1 (21)			
Duroc	49.2 (14)	51.4 ( 5)	51.2 ( 6)				
Berkshire	44.9 (26)	48.7 (16)					
L. Black	49.8 (12)						
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Age at sexual maturity. General average = $210 \pm 1.4$ days							
Yorkshire	200 (03)	216 (21)	203 ( 6)	202 ( 5)	206 (10)	210 (12)	200 ( 3)
Landrace	210 (12)	217 (23)	207 (11)	218 (25)	214 (18)	212 (16)	
Lacombe	212 (16)	216 (21)	215 (20)	210 (12)	204 ( 8)		
Hampshire	204 ( 8)	214 (18)	222 (27)	216 (21)			
Duroc	198 ( 2)	210 (12)	231 (28)				
Berkshire	197 ( 1)	203 ( 6)					
L. Black	218 (26)						

### 1.1.3 Fertility

Of the 1013 gilts available, 87% farrowed, but only 81% weaned their first litter. In the case of second litters, 83% farrowed and 80% weaned their litter (Table 2).

The B x Y and T x D sows had the highest percentage of farrowing first litters (93.3 and 95%, respectively), whereas the lowest percentages were those of T x LB and H x Ld (73.2 and 76.6%, respectively).

The effect of cross on the percentage farrowing for the second litter was not significant. The highest ranking crosses for this trait were LB x H (96.6%), and B x Y and LB x Y (90.4%), whereas D x Ld (69.8%) and T x LB (68.8%) ranked lowest.

Table 2. Causes of reproductive failure and percentage of sows farrowing and weaning a litter

	First litter		Second litter	
	No.	%	No.	%
Total number of sows	1013	100.0	859	100.0
Reduced by				
Injuries, mortality, abnormalities, etc.	24	2.4	13	1.5
No estrus	39	3.8	116	13.5
Number of sows with estrus	950	93.8	730	85.0
Number not conceiving	27	2.7	1	0.1
Number of sows conceiving	923	91.1	729	84.9
Number not farrowing	35	3.4	14	1.6
Abortions	4	0.4	3	0.3
Number of sows farrowing	884	87.3	712	83.0
Litters with mummified fetuses	44	4.3	15	1.7
Unweaned litters	22	2.2	10	1.2
Number of sows weaning a litter	818	80.8	687	80.1

#### 1.1.4 Pre-weaning mortality percentage

The lowest mortality at birth was in litters with Tamworth ancestry, whereas those with Large Black had the highest percentage (Table 3). From birth to 21 days, the litters with Large Black ancestry had the lowest percentage, followed by those with Landrace and Hampshire. However, litters with Berkshire ancestry had the highest pre-weaning mortality percentage. Mortality from 21 to 42 days was similar in the different crosses. The difference in total mortality between the Ld x Y the best and B x Lc the worst crosses was 11.2%. Duroc Jersey x Lacombe, T x Ld, and T x H were among the crosses that ranked high in total mortality percentage.

#### 1.1.5 Litter size and weight

The Ld x Y and H x Ld sows farrowed the largest litters (11 pigs), whereas those of D x H and LB x H crosses farrowed the smallest litters. Litters of crosses involving the three white breeds (Y, Ld, and Lc) were significantly larger than those of the colored breeds (except the Duroc), with those involving the Large Black ranking smallest. The pigs with Large Black and Landrace ancestry were significantly heavier at birth than those with Lacombe, Hampshire, Duroc, and Berkshire, which in turn were significantly heavier than those with Yorkshire and Tamworth ancestry. Litter weight at birth, which is the product of litter size and average pig weight, was heaviest in the crosses involving the Landrace breed.

Table 3. Percentage (and ranking) of piglet mortality and litter weight at 21 days

Breed of dam	Breed of sire						
	Tamworth	L. Black	Berkshire	Duroc	Hampshire	Lacombe	Landrace
Percentage of mortality of litter. General average = 18.8 ± 2.0							
Yorkshire	16.7 ( 8)	13.7 ( 5)	18.8 (14)	20.7 (23)	17.1 (10)	19.6 (16)	10.4 ( 1)
Landrace	12.8 ( 3)	20.5 (21)	18.2 (12)	20.8 (24)	17.3 (11)	21.1 (25)	
Lacombe	17.0 ( 9)	18.6 (13)	21.6 (28)	12.3 ( 2)	21.1 (25)		
Hampshire	12.8 ( 3)	16.2 ( 7)	19.6 (16)	19.9 (18)			
Duroc	19.0 (15)	20.4 (20)	20.5 (21)				
Berkshire	20.2 (19)	21.1 (25)					
L. Black	15.2 ( 6)						
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Litter weight at 21 days. General average = 40.5 ± 0.39 kg							
Yorkshire	43.4 ( 5)	41.0 (12)	39.9 (19)	40.4 (16)	41.5 (10)	41.0 (12)	47.9 ( 1)
Landrace	40.3 (17)	44.5 ( 4)	41.8 ( 9)	41.0 (12)	45.4 ( 3)	38.1 (21)	
Lacombe	41.9 ( 8)	45.8 ( 2)	37.8 (22)	42.9 ( 6)	40.3 (17)		
Hampshire	42.0 ( 7)	40.8 (15)	36.5 (26)	33.5 (28)			
Duroc	37.1 (24)	41.7 (11)	37.7 (23)				
Berkshire	34.2 (27)	39.0 (20)					
L. Black	37.1 (24)						

The Ld x Y and H x Ld sows, which farrowed the largest litters, also weaned the largest litters. There were marked differences in pre-weaning average daily gain of pigs for the different crosses. Pigs with Large Black and Yorkshire ancestry grew faster than those of other breeds. At weaning, the crosses involving the Landrace, Yorkshire, and Large Black breeds had the heaviest litters, the Landrace mainly because of its heavier pigs and the Yorkshire for being high in number of pigs per litter and average piglet weight (Table 3).

## 1.2 Conclusion

Because reproductive performance of the sow is a complex character involving various traits, the ideal method for evaluating it is to construct an index to combine all these traits according to their contribution to the total productivity and their economic importance. It is difficult to define and estimate the economic merit of many traits such as age at puberty, farrowing percentage, and farrowing interval. Litter weight at weaning is commonly used as the best single measurement to predict sow productivity because it combines litter size, pig growth rate, pre-weaning mortality, and mothering ability of the sows. In this report, sow fertility was combined with litter weaning weight by expressing sow productivity as the kilograms of weaned pigs per sow in two farrowings. The crosses are ranked in Table 4 according to that measurement. Landrace x Yorkshire cross ranked the highest, followed by LB x Lc, whereas the crosses that ranked lowest were T x LB, D x H, and T x B. Generally, the crosses involving the three white breeds, Yorkshire, Landrace, and Lacombe, and the Large Black were superior to those involving the other four breeds; however, their specific combining abilities are important and, hence, not all crosses between these breeds produced superior hybrid sows.

Table 4. Average weight of weaned piglets based on two litters

Breed of dam	Breed of sire						
	Tamworth	L. Black	Berkshire	Duroc	Hampshire	Lacombe	Landrace
Overall mean = 68.1 kg							
Yorkshire	75.8 ( 4)	72.7 ( 7)	75.0 ( 5)	72.2 ( 9)	64.0 (21)	67.2 (18)	80.6 ( 1)
Landrace	67.3 (17)	70.9 (12)	73.6 ( 6)	63.8 (22)	71.0 (11)	61.0 (24)	
Lacombe	68.6 (15)	80.0 ( 2)	64.1 (20)	69.0 (14)	71.4 (10)		
Hampshire	72.5 ( 8)	77.0 ( 3)	59.8 (25)	53.3 (27)			
Duroc	67.0 (19)	70.2 (13)	61.8 (23)				
Berkshire	58.2 (26)	67.6 (16)					
L. Black	52.4 (28)						

1. B: Potential of crossbred sows for producing market hogs

The pigs used in this stage were 762 males and 765 females obtained from sows of the 28 crosses mated to Poland China boars. After weaning their first litters, the sows were rebred to produce their second litters. Nine Poland China boars were used for mating at two stations, two full-sibs and one unrelated at Nappan, and three full-sibs and three unrelated boars at Lennoxville. The three-breed-cross pigs were sold as weaners to cooperating commercial producers in the neighborhood of the stations who fed them to weights ranging from 75 to 105 kg. The pigs were slaughtered from July 1970 until July 1972 inclusive. Back fat measurement according to the Canadian Grading System for pigs (the sum of maximum depth of shoulder and loin fat), carcass dressed weight, and age at slaughter were obtained.

An index was used to combine age at slaughter and back fat thickness in one measure of performance to rank the different crosses.

The dam's breed combination was a significant source of variation for both age at slaughter and back fat thickness. The progeny of LB x D sows were the fastest growing, those of T x D were the slowest growing, these differing by 20.2 days in age at slaughter (Table 5). Nonsignificant differences in age at slaughter were found among the eight highest ranking crosses.

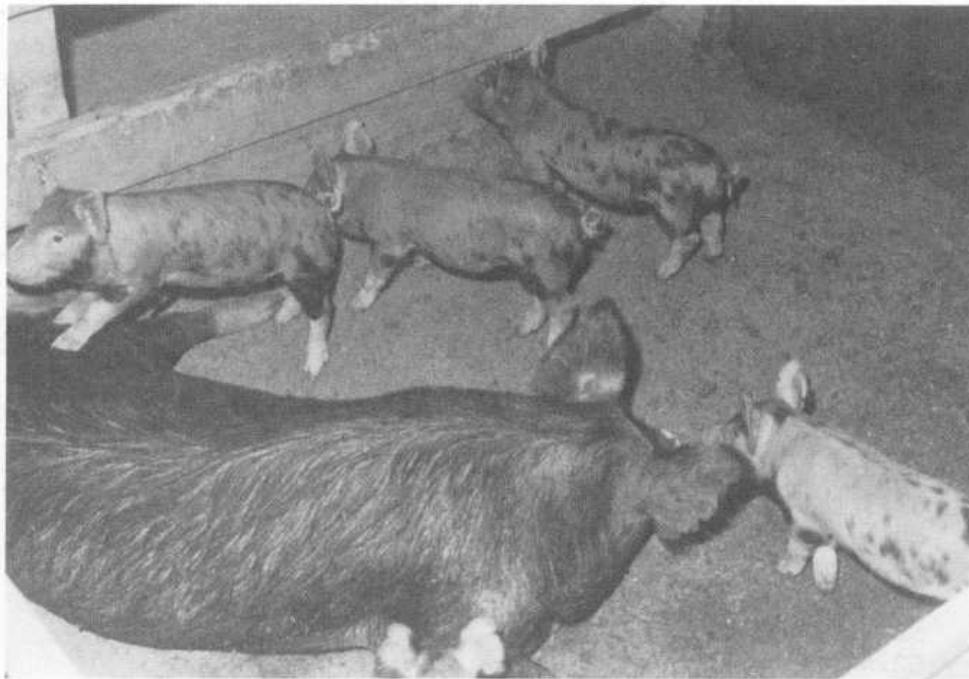


Fig. 5. A Berkshire sow with its Tamworth x Berkshire litter. This is not the best of combinations.

The pigs with the least depth of back fat (6.64 cm) were those born to H x Ld sows which were significantly different from all other crosses except Lc x Y, whereas those with the thickest back fat (8.14 cm) were from LB x B sows which were significantly different from the top 23 crosses. The top ranking crosses according to the index were those involving H x Ld, H x Lc, LB x D, Lc x Ld, and H x Y sows (Table 5).

Table 5. Least squares means (and ranking) for age at slaughter, back fat thickness, and index combining these two measurements

Maternal grandmother	Maternal grandfather						
	Tamworth	L. Black	Berkshire	Duroc	Hampshire	Lacombe	Landrace
Age at slaughter. General average = 202.4 ± 0.97							
Yorkshire	208.6 (26)	196.7 ( 2)	206.0 (20)	201.3 (13)	197.8 ( 5)	202.7 (17)	200.3 (10)
Landrace	197.2 ( 4)	198.3 ( 6)	200.3 (10)	205.5 (19)	200.9 (12)	199.9 ( 9)	
Lacombe	201.3 (13)	206.2 (21)	206.9 (22)	201.3 (13)	197.1 ( 3)		
Hampshire	202.5 (16)	198.7 ( 8)	208.3 (25)	204.0 (18)			
Duroc	211.6 (28)	191.4 ( 1)	208.2 (27)				
Berkshire	198.4 ( 7)	207.6 (24)					
L. Black	207.3 (23)						
-----							
Thickness of back fat. General average = 7.53 ± 0.115							
Yorkshire	7.48 (20)	7.63 ( 5)	7.41 (10)	7.73 (21)	7.44 ( 8)	7.29 (17)	7.69 (13)
Landrace	7.72 (22)	7.84 (26)	7.60 (16)	7.47 (12)	6.64 ( 1)	7.22 ( 2)	
Lacombe	7.63 (17)	7.74 (25)	7.35 ( 6)	7.68 (19)	7.23 ( 3)		
Hampshire	7.24 ( 4)	7.59 (15)	7.45 (11)	7.37 ( 7)			
Duroc	7.53 (14)	8.00 (27)	7.42 ( 9)				
Berkshire	7.69 (20)	8.14 (28)					
L. Black	7.72 (22)						
-----							
Index							
Yorkshire	0.74 (23)	-0.61 (16)	0.31 (19)	0.12 (18)	-0.72 ( 5)	-0.28 (11)	-0.06 (14)
Landrace	-0.43 ( 7)	-0.13 (13)	-0.19 (12)	0.32 (20)	-1.36 ( 1)	-0.73 ( 4)	
Lacombe	-0.02 (15)	0.77 (24)	0.34 (21)	0.05 (17)	-1.08 ( 2)		
Hampshire	-0.36 (19)	-0.40 ( 8)	0.66 (22)	-0.01 (16)			
Duroc	1.18 (27)	-0.82 ( 3)	0.61 (25)				
Berkshire	-0.31 (10)	1.48 (28)					
L. Black	0.89 (26)						

## PHASE 2

### 2. Evaluation of three- and four-breed crosses

The five highest ranking crosses in terms of reproductive performance were Ld x Y, H x Ld, LB x Lc, LB x Ld, and D x Lc. These crosses, in addition to D x Y, were used in the second phase of the experiment.

The data used in the evaluation of the three-breed crosses came from 1132 barrows produced by 620 gilts of the six two-breed crosses mated to five breeds of boars--Yorkshire, Landrace, Lacombe, Hampshire, and Duroc. In all, 20 combinations were produced.

To evaluate four-breed crosses and to compare their performance with three-breed crosses, the crossbred sows used in the evaluation of three-breed crosses were mated to crossbred boars Ld x Y, D x Y, and D x Lc. From each litter two piglets were chosen at random for the study.

In this same phase, three-breed crosses were also produced by mating the same crossbred boars to crossbred sows (groups of partial backcrossing), and by mating purebred boars to crossbred sows (12 combinations). In all, 25 combinations were studied in this phase.

The pigs were born at Lennoxville, Laval, and Nappan in 1973 (evaluation of three-breed crosses), and at Lennoxville and Laval in the spring of 1974 (evaluation of three- and four-breed crosses). The pigs were weaned at the age of 3 weeks and fed a starter ration until they reached a liveweight of about 22 kg. They were then divided into small groups, allowing 0.75 m<sup>2</sup> of space per pig.

Feeding was ad libitum on a commercial growing-finishing ration until the pigs reached about 90 kg liveweight. In the evaluation of three-breed crosses, feed intake was recorded on two pigs from each of 103 litters finished at Nappan to estimate the feed conversion ratio.

At slaughter, the following measurements were taken: weight of the chilled carcass, back fat measurement (sum of maximum depth at shoulder and loin), and the area of eye muscle measured by a planimeter. Age at slaughter, number of days on feed, and average daily gain were calculated.

An index similar to that used in phase 1 was constructed and used to evaluate the different crosses. It combined average daily gain during the feeding period, back fat thickness, and feed conversion ratio.

#### 2.1 Evaluation of three-breed crosses

The results of this phase showed that the effects of breed of sire and breed of dam were significant on all the traits studied except for the effect of breed of dam on feed conversion. Significant interactions between breed of sire and breed of dam were found for the back fat measurement.





Fig. 6. Piglets of a Duroc x (Large Black x Landrace) litter

#### 2.1.1 Feed efficiency

The H x (Ld x Y), followed by D x (Ld x Y) was the most efficient cross in feed conversion, whereas the Lc x (D x Y) and Lc x (H x Ld) were the least efficient. Within breed of dam, the pigs sired by the Hampshire were generally the most efficient.

#### 2.1.2 Growth rate

The fastest weight gain during the finishing period was made by D x (LB x Lc) and Y x (LB x Lc), the latter being among the youngest to reach the 90 kg slaughter weight. Pigs sired by Landrace were generally slower in growth rate during the finishing period as compared to the other breeds, contrary to their performance during the prefinishing period. Pigs sired by Lacombe were the youngest to reach slaughter weight; they made rapid weight gains before and during the finishing period. Hampshire-sired pigs were generally the oldest to reach slaughter weight.

### 2.1.3 Carcass quality

Hampshire-sired pigs were decisively superior in carcass quality to those sired by the other breeds with Duroc-sired pigs ranking second, whereas those sired by Yorkshire were the fattest and those by Lacombe had the smallest area of loin-eye.

The highest ranking crosses according to the index were those sired by the Hampshire boars and the combination D x (Ld x Y), whereas the crosses sired by Lacombe ranked lowest (Table 6).

Table 6. Ranking of crosses according to an index combining average weight gain, back fat thickness, and feed efficiency

Cross of dam	Breed of sire				
	Yorkshire	Landrace	Lacombe	Hampshire	Duroc
Landrace x Yorkshire	--	--	-1.29 (17)	3.30 (1)	2.27 (3)
Hampshire x Landrace	-1.35 (18)	--	-2.68 (19)	--	-1.07 (16)
L. Black x Lacombe	-0.94 (14)	-0.18 (8)	--	2.11 (5)	-0.10 (7)
L. Black x Lacombe	-0.66 (12)	--	-0.58 (10)	2.25 (4)	-1.03 (15)
Duroc x Lacombe	-0.64 (11)	-0.73 (13)	--	2.74 (2)	--
Duroc x Yorkshire	--	-0.58 (9)	-2.79 (20)	1.94 (6)	--

## 2.2 Evaluation of three- and four-breed crosses

### 2.2.1 Litter performance

The effects of breed of sire and breed of dam were not significant on any of the traits related to litter performance. Boars from the four pure breeds sired litters averaging 11 piglets at birth and 9.1 at 3 weeks, which were 0.5 and 0.2 piglets larger and 0.6 and 1.3 kg heavier, respectively, than those sired by the crossbred boars. The litters sired by crossbred boars had a 2.3% higher survival rate and their piglets gained slightly (4 g/day) faster than those by purebred boars. Except for the difference in litter size at birth, which was significant (crossbred boars producing three-breed versus four-breed crosses), all the other differences were nonsignificant.

No particular breed (or cross) of sire was superior on all six breed crosses of sow. Among the four pure breeds, the Lacombe had the largest and heaviest litters at birth and the largest litters at 3 weeks, whereas the Landrace boars showed the lowest performance. Among the three crosses, the Ld x Y and D x Y were generally superior to the D x Lc. However, the differences among breeds (or crosses) of boars were generally nonsignificant.

The three-breed-cross litters sired by crossbred boars were slightly larger and heavier at birth and at 3 weeks (size at birth was significant) but were slightly inferior in average pig daily gain and pre-weaning survival rate to the four-breed-cross litters. Both groups were slightly inferior to three-breed-cross litters sired by purebred boars except for pig gain and survival rate.

### 2.2.2 Growth rate and carcass quality

The effect of breed of sire was significant on the traits related to carcass quality but was nonsignificant on those related to growth.

Duroc x Lacombe and D x Y boars sired the fastest gaining pigs, whereas those sired by Ld x Y boars were the slowest. Pigs sired by the four pure breeds placed intermediate. At slaughter, the pigs sired by D x Lc boars were the youngest, those sired by Ld x Y were the oldest, the difference being significant. The pigs sired by D x Y boars had apparently a slower growth rate before starting the finishing ration, which accounted for their relative older age at slaughter.

The pigs sired by boars from the three crossbred groups averaged very much around the population mean in the traits related to carcass quality, together with those sired by Lc and Y boars.

According to the index combining average daily gain and back fat thickness, the three highest ranking crosses were sired by D and Lc boars, the fourth ranking cross was sired by crossbred boars obtained from crossing these two breeds (Table 7).

The pigs of a four-way cross showed a faster growth rate and were generally younger than the pigs of a three-way cross. The differences in carcass quality were negligible.

Table 7. Ranking of crosses according to an index combining average weight gain and back fat thickness

Cross of dam	Breed of sire (purebred)			
	Landrace	Yorkshire	Duroc	Lacombe
Landrace x Yorkshire	--	--	0.84 ( 3)	0.43 ( 6)
Hampshire x Landrace	--	0.42 ( 8)	1.23 ( 1)	--
L. Black x Lacombe	-2.58 (25)	-0.44 (20)	--	--
L. Black x Lacombe	--	--	0.21 (11)	-0.55 (22)
Duroc x Lacombe	-0.45 (21)	0.43 ( 6)	--	--
Duroc x Yorkshire	0.05 (14)	--	--	0.93 ( 2)

	Breed of sire (crossbred)		
	Landrace x Yorkshire	Duroc x Yorkshire	Duroc x Lacombe
Landrace x Yorkshire	--	0.01 (15)	0.54 ( 4)
Hampshire x Landrace	-0.42 (19)	0.10 (13)	--
L. Black x Lacombe	-1.08 (24)	0.29 ( 9)	-0.14 (18)
L. Black x Lacombe	-0.62 (23)	--	-0.08 (17)
Duroc x Lacombe	0.49 ( 5)	-0.06 (16)	--
Duroc x Yorkshire	0.17 (12)	--	0.25 (10)

## CONCLUSION

Phase 1 was designed to evaluate the full potential of the 28 crosses in reproduction and carcass quality. This phase also provided estimates of the average performance of the eight breeds involved in the crossing (general combining ability, Table 8).

The three white breeds produced crossbred sows which excelled in the reproductive traits. The Hampshire produced sows capable of transmitting to their progeny excellent carcass quality. Progeny with Large Black ancestry were generally faster in growth rate than those from the other breeds. Gilts with Tamworth and Yorkshire ancestry were the youngest to reach puberty and, when farrowed, gave litters with the lowest pre-weaning mortality rate. The Berkshire breed was decisively inferior to all the other breeds in the various traits studied. The results showed that not all crosses among the white breeds involved (Y, Ld, Lc) produced superior crossbred sows, even though individually they were superior to the colored breeds. Although Ld x Y ranked highest in reproductive performance, the Lc x Y and Lc x Ld crosses were not particularly impressive. This indicates that the specific combining ability of these breeds is also an important factor.

The crosses among colored breeds were generally very poor in reproductive traits and carcass quality. Eight of the highest 10 ranking crosses in reproductive performance and seven of those in carcass quality involved crosses among white and colored breeds. The findings showed that, with one exception, the crosses which ranked high in reproductive traits such as Ld x Y, LB x Ld, D x Lc, and LB x Lc ranked relatively low in their potential for producing market pigs of high quality both as two breed crosses or as dams for three-breed-cross pigs. The only cross which was superior in both potentials was the H x Ld cross. Sows of this cross ranked third in litter weight at weaning and first in their potential for producing superior three-breed-cross pigs for slaughter. Male pigs destined for slaughter ranked second in market performance.



Fig. 7. A Yorkshire sow nursing her litter of Landrace x Yorkshire piglets. This cross had the best reproductive performance.

In the past few years there has been a great interest in the performance of crossbred as compared to purebred boars. None of the published reports provide a definite answer to the question. French and American research, which was confined to semen characteristics, conception, and survival rates, did show an advantage for using crossbred boars. This advantage, however, seems to be lost at farrowing. The present study and many others found the litters produced by crossbred boars similar in size and weight to those produced by purebred boars. A possible explanation is that litter size is

Table 8. General combining ability (and ranking) of the eight breeds involved in the crosses

	Yorkshire	Landrace	Lacombe	Hampshire	Duroc	Berkshire	L. Black	Tamworth
112-day weight (kg)	46.6 (8)	50.1 (1)	49.5 (4)	48.8 (5)	49.6 (3)	47.1 (7)	49.9 (2)	48.5 (6)
Age at puberty (days)	205 (1)	211 (3)	212 (4)	212 (4)	213 (7)	212 (4)	214 (8)	205 (1)
Litter size at birth	10.0 (3)	10.3 (1)	10.2 (2)	9.5 (5)	9.5 (5)	9.9 (4)	9.1 (8)	9.5 (5)
Litter weight at birth (kg)	13.3 (4)	15.3 (1)	14.3 (2)	13.2 (5)	13.8 (3)	13.0 (7)	13.2 (5)	12.9 (8)
Pig average daily gain (g)	179 (2)	175 (3)	172 (4)	172 (4)	167 (7)	167 (7)	186 (1)	168 (6)
Litter mortality (%)	16.7 (2)	17.3 (3)	18.7 (6)	17.7 (4)	19.1 (7)	20.0 (8)	18.0 (5)	16.2 (1)
Litter size at 21 days	8.4 (2)	8.6 (1)	8.3 (3)	8.0 (5)	8.0 (5)	7.8 (7)	7.8 (7)	8.1 (4)
Litter weight at 21 days (kg)	42.4 (2)	43.1 (1)	41.2 (4)	39.9 (5)	39.0 (7)	37.7 (8)	41.5 (3)	39.2 (6)
Kilograms of weaned pigs (kg)	75.5 (1)	69.7 (3)	68.8 (4)	67.0 (5)	65.3 (8)	65.7 (7)	70.1 (2)	66.0 (6)
Age at slaughter (days)	202 (4)	203 (5)	202 (2)	201 (3)	203 (6)	205 (8)	201 (1)	204 (7)
Back fat thickness (mm)	7.51(5)	7.45(2)	7.45(5)	7.28(1)	7.60(7)	7.58(6)	7.81(8)	7.50(4)

primarily determined by the sow according to its ovulation rate and uterine capacity, and any hybrid vigor observed for semen characteristics and breeding behavior cannot be expressed when the sows are hand mated. In this context, no real advantage in litter performance can be capitalized in using crossbred boars. It must be recalled, however, that the use of crossbred boars may be advantageous if certain breeds chosen are either poor in reproductive ability or possess undesirable traits as purebreds.

The results of the present study and those of a similar one carried out in the United States showed no real advantage in producing four-breed-crosses from mating crossbred parents. The only trait in which they excelled was growth rate during the fattening period. However, the difference was small to make any appreciable change in age at slaughter. These results should not necessarily rule out breeding programs involving four breeds because four-breed-crosses produced from mating purebred boars to three-breed cross sows could have some merit.

The results of phase 2 in which different combinations of market pigs were compared showed that among pure breeds, Hampshire and Duroc boars excelled as terminal sires for the production of high quality pigs for slaughter, as compared to boars from Yorkshire, Landrace, and Lacombe breeds. The performance of backcrosses involving the Hampshire and Duroc breeds such as H x (H x Ld) or D x (D x Y) was not studied in this experiment and may prove advantageous. However, if the breeders are mainly interested in three-breed crosses, the combinations which ranked highest in this experiment were D x (H x Ld), H x (Ld x Y), D x (Ld x Y), and H x (D x Lc).

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