WORLD REVIEW OF ANIMAL PRODUCTION

Summaries

Crossbreeding swine in Canada

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 3-and 4-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 and growth and carcass quality. Landrace x Yorkshire was the highest cross in reproductive performance followed by Large Black x Lacombe. The best 3 breed-cross for market was Hampshire x (Landrace Yorkshire) followed by Hampshire x (Duroc Lacombe). Four-breed crosses produced from mating crossbred parents were generally similar in performance or slightly inferior to 3-breed crosses obtained from mating purebred boars to crossbred sows.

The results in general indicated that crosses involving the coloured breeds were generally inferior to the other crosses. The data also provided evaluation of the merit of the various breeds in crossing.

Increasing ewe fertility in Arab countries

Low reproductivity of the ewe seems to be a dominant feature among the majority of sheep breeds raised in Arab countries. Thus, efficiency of meat production (the main product) for those breeds is highly affected by such low fertility rate. In this article four different possibilities for increasing fertility were discussed. These include the possibilities of early breeding, reducing barrenness, increasing twinning rate and obtaining more than one lamb crop per year. Published work on these different aspects is very limited.

Preliminary results indicated that early breeding from local ewe lambs is possible, though conception rate is very low and reasons behind such low conception rate should be investigated. Most published work indicated that barrenness in local ewes is high and approches the value of 20% or more. Such high level of barrenness may be due to nutritional and/or climatic stresses. Twinning rate varies from 10-30% among local breeds. Twinning rate could be raised by improving the non-genetic factors (flushing), as well as the genetical constitution of the ewes through selection or crossing with breeds of high twinning rate. Crossing, however, is considered the most rapid and feasible method for improving such trait.

Increasing the frequency of lambing for local breeds is possible without the use of artificial means, and expected increase of the output of lambs is 50%. However, the value of the extra lambs obtained from applying such system should outweigh the extra costs utilized.

Water concept in female livestock

A total of 48 laying hens at 14 months of age from the Egyptian Fayoumi breed were used to test water concept in the field of body composition. The data revealed that while water content in the fat-free body was constant against the fat percentage, it increased with increasing body weight ($P < 0.01$), body fat ($P < 0.05$) and fat-free body ($P < 0.01$). This is an indication to refute the water concept in female and the two-compartment model of body compositon. Mathematical equations were reported to predict body composition in chickens, sheep, dairy cattle and deer from in-vivo determination of body water by the dilution technique.

Modelling approach to animal production under grazing conditions in different types of grassland in Japan

The efficiency of energy conversion from solar radiant flux into cattle production is about 0.003% on average for practical farm production in grazing on Japanese hilly grasslands. This value is only one twentieth compared with those calculated for the conversion through alfalfa crop experimental field production (0.078), the intaken and digestible portion (0.0325) and milk production (0.24) in laboratory measurement; 0.062% for the whole.

Modelling approach would be one effective research tool for the analysis of such gaps of efficiencies between the practical farm production and those in the laboratory from the ecological point of view, and further for the target of breeding. The report by Okubo *et al.* (1975) was reviewed as an example of such modelling approach to animal production research. The model enables to estimate the difference of regional productivity in plant and cattle growth in Japanese country, and also the effect of grazing pressure on plant parts in each season.

Rumen activity and blood urea of sheep as affected by climatic conditions

Four Osemi and Four Merino rams were used in experiments to investigate rumen activity and blood urea as affected by environment. The animals were exposed for four months to

Crossbreeding Swine in Canada

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Introduction

In recent years crossbreeding has assumed a role of growing importance in the swine industry in Canada. As consumer demand and government regulations change, 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 very important in order to improve production efficiency and maximize profit to keep the industry viable and progressive.

The availability of breeds differing in their productive characteristics is an important source of flexibility that can allow more rapid adjustments to changing economic conditions. However, crossbreeding is the only way in which this latent flexibility can be utilized rapidly, and it is thus a valuable tool in producing change. Crossbreeding also allows commercial breeders to capitalize on heterosis and combine in a production unit several desirable traits not usually found in one breed.

There are various systems of combining breeds in crossbreeding. Each has its advantages and disadvantages. Bichard and Smith (1971) examined many of these various systems and concluded that the optimum system in swine is likely to involve a two-breed-cross dam line mated to a 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. Dickerson (1973) studying the question more deeply and assigning relative economic weights to the different traits involved, reached the same conclusion.

While there is little controversy among breeders and scientists about the system itself, the choice of both sire and dam lines is complicated according to Glodek (1974) by the many problems involved in the economic evaluation of the overall performance of the various combinations. Although the performance of some crosses in certain traits can be predicted with reasonable degree of accuracy from the performance of the parental breeds, in other traits 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. Therefore, a crossbreeding experiment was initiated in Eastern Canada to evaluate the relative performance of various crosses among several breeds in North America which are also used in other parts of the world; especially those that have intensive swine production industries.

In a preparatory phase eight pure breeds were crossed to produce 28 combinations of two-breed crosses (Fahmy, Bernard and Holtmann, 1971). 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

ability. The Yorkshire, Landrace, Hampshire, Duroc, Berkshire, Large Black, and Tamworth breeds met these requirements. The Lacombe breed was also included because it was established in Canada by the Canadian Department of Agriculture and it had become fairly popular representing 5 to 10% of all purebred registrations (1960-1970).
The first phase of the experiment designed to evaluate the performance traits of the 28 two-breed crosses was subdivided into three stages:

(*a*) to study the reproductive performance of the sows measured in terms of kilograms of weaned pigs. (Holtmann, Fahmy, MacIntyre and Moxley, 1975),

(*b*) to study the potential of the sows for producing high quality pigs for slaughter (Fahmy, Holtmann and MacIntyre, 1975), and

(*c*) to study the performance at slaughter of the crossbred male-sibs destined for market (Fahmy and Bernard, 1971).

The second phase of the experiment was designed to evaluate the performance at slaughter of crossbred pigs from various combinations obtained from crossbred sows ranking highest for reproductive performance. This phase was divided into two stages:

(*a*) evaluation of three-breed-cross pigs sired by boars from five breeds commonly used as sire lines (Fahmy, Holtmann and MacIntyre, 1976), and

(*b*) evaluation of three and four-breed-cross pigs sired by purebred and crossbred boars (Fahmy and Holtmann, 1977).

The objective of this review is to summarize the results obtained from the different phases of the experiment and try to draw a conclusion as to which crosses were highest in overall performance.

The preparatory phase: mating purebreeds to produce crossbred litters

Procedure:

The animals used to produce the crosses were 293 female and 40 male pigs purchased in the spring of 1968 at the age of 2 to 3 months from commercial breeders in the United States and Canada. Landrace (Ld), Lacombe (Lc), Hampshire (H), Duroc (D), Berkshire (B) and Large Black (LB) males and females, Yorkshire (Y) females and Tamworth (T) males were obtained. To assure a good sampling of the breeds involved, restrictions were imposed on the number of animals obtained from each source. No more than 2 pigs were purchased from the same litter, no more than 4 pigs by the same sire and no more than 8 pigs from the same breeder. All the males purchased came from station or home (R.O.P.) tested parents. When the animals reached breeding age (approximately 7 months) they were mated in an incomplete diallel design to produce the 28 different crosses to be tested (Table 1).
Estrus was synchronized in the gilts to concentrate farrowings within short periods. Gilts in estrus were detected by introducing vasectomized boars into the pens once daily, and were hand mated according to a predesigned mating program. Pregnant sows were transferred to farrowing quarters one week before their expected date of farrowing. Young pigs had access to creep feed by the time they were 8 to 12 days old. They were weaned at 5 weeks of age.
The following data were collected on the sows and their litters: weight at puberty (first estrus), number of services per conception, number of normal teats, gestation length, litter size at birth (total and alive), at 21 days and at weaning, litter weight at birth, 21 days and at weaning, and body weight change of sows during nursing, fetal placenta delivered after normal parturation were collected from 115 gilts representing the seven breeds (Fahmy, 1971). Colostrum and milk samples were collected from a sample from each breed (Fahmy, 1972).

TABLE 1 - Breeds, experimental design and number of litters involved in the preparatory phase.

	Breed of sire							Total
	Tamworth	Large Black	Berkshire	Duroc	Hampshire	Lacombe	Landrace	
Yorkshire	11	13	11	10	10	13	12	80
Landrace	13	11	13	12	11	13		73
Lacombe	13	10	11	16	17			67
Hampshire	13	13	13	14				53
Duroc	12	12	14					38
Berkshire	14	13						27
Large Black	12							12
Total	88	72	62	52	38	26	12	350

Colostrum samples were obtained within 3 hrs after farrowing by manual expression of the udder. Milk samples were obtained on the 14± 1,28±1, and 35±1 days of lactation by manual expression following intravenous injection of 1-5 ml of pitocin (Parke Davis Co).

Results

Fertility

Of the 293 gilts purchased, 221 (75.4%) produced litters (Table 2). Six (20.0%) of the Duroc gilts failed to conceive, compared with an average of 14% for the three white breeds (Yorkshire, Landrace and Lacombe) and 4.5% for Berkshires. Three of the 10 Large Black gilts, including one which was pregnant, died from various causes, and three pregnant Landrace gilts died before farrowing. Differences among breeds in number of services per conception were statistically nonsignificant.

Puberty and number of teats

The difference of 9 kg in weight at puberty between Hampshire, the heaviest, and Berkshire and Landrace, the lightest breeds was nonsignificant (Fig. 1). The white breeds had more teats and lost more weight during nursing than the four coloured breeds (Fig. 2 and 3).

Length of gestation period

Length of gestation period for Landrace, Lacombe, Hampshire and Duroc sows as significantly shorter than those for Yorkshire, Berkshire, and Large Black sows (Fig. 4). Gestation period for litters sired by Hampshire boars were significantly shorter than those for litters sired by Berkshire or Large Black boars. Differences among other breeds were nonsignificant.

Litter size and weight

Yorkshire and Lacombe sows had the largest litters at birth and weaning, followed by Landrace and Duroc sows (Fig. 5-6). Within breed of sow, litters sired by Tamworth boars were the largest while those sired by Hampshire ranked smallest. Lacombe, Landrace and Yorkshire sows also had the heaviest litters at the two ages studied (Fig. 7-8). Litter weights for the four coloured breeds were generally lower than the overall mean.

Pigs born to Landrace sows were the heaviest at birth and weaning, while those born to Berkshires and Yorkshires were the lightest at both ages. Pigs sired by Hampshire boars were generally, though nonsignificantly, heavier than those sired by other breeds. This may be attributed to the smaller litters sired by Hampshire boars in the present data.

Placental weight

The average weights of placental membranes in the seven breeds, adjusted for litter size and weight, showed that Yorkshire and Berkshire gilts had the lightest placentas, (2.11 and 2.08 kg respectively) and Duroc followed by Large Black and Lacombe had the heaviest (2.44, 2.39 and 2.33 kg, respectively). The differences between the former breeds and Duroc were significant.

Milk composition

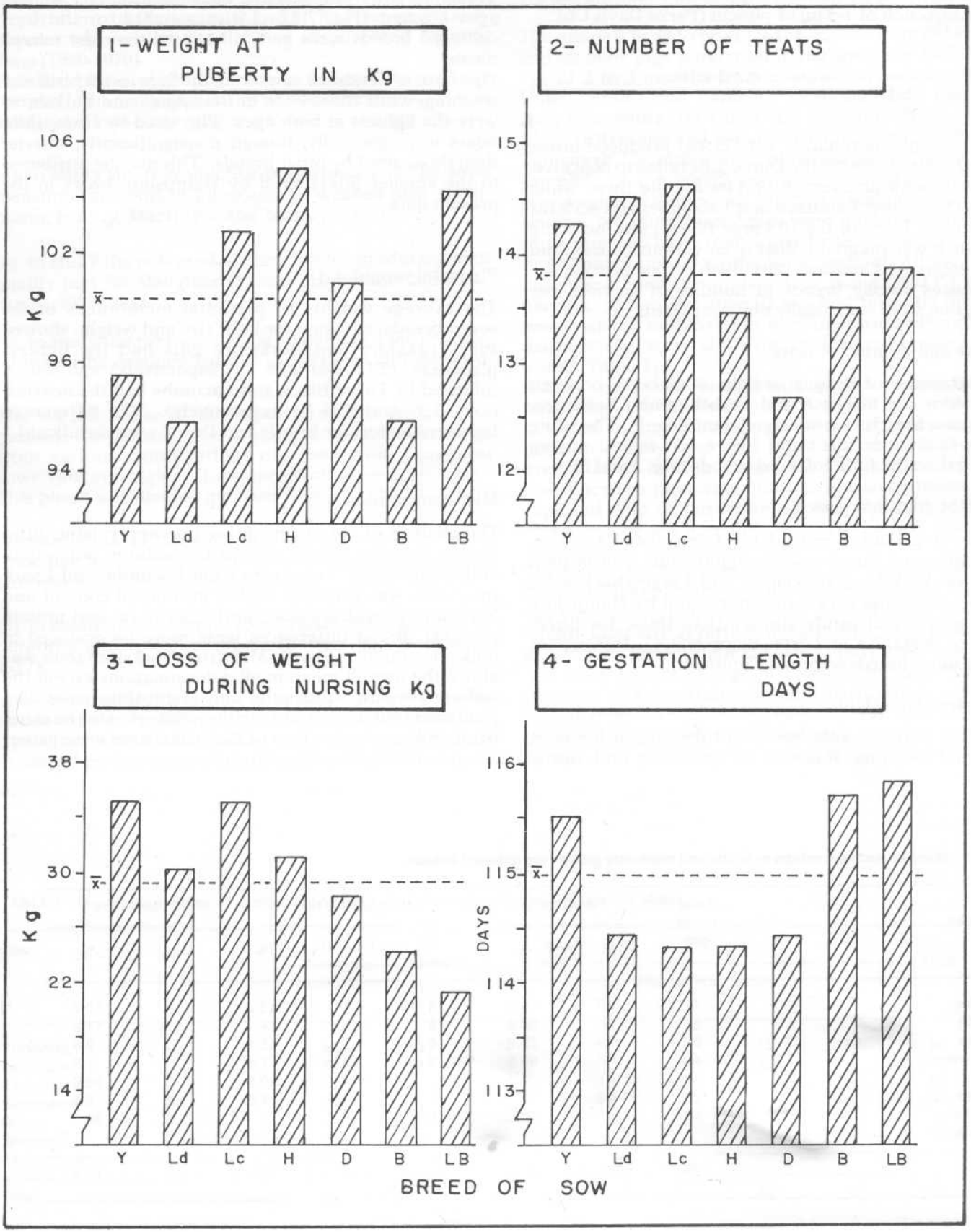
The analysis of colostrum showed no appreciable differences between breeds, except for sodium, potassium, and magnesium. Colostrum from Lacombe and Landrace sows was generally higher in mineral content and Yorkshire provided colostrum higher in fat and protein percent. Breed differences were more pronounced in milk constituents (Fig. 9). Milk from Yorkshire sows was above the overall mean in all determinations except the sodium content. Lacombe and Hampshire sows also produced milk higher in nutritive content. On the other hand, milk and colostrum of Berkshire sows were generally poorer than the other breeds.

TABLE 2 - Number and percentage of fertile and nonfertile gilts in the different breeds.

Breed	Total no. of gilts	Fertile gilts		Reproductive failure			Other failure*	
		No.	%	No estrus	No conception	%	No.	%
Yorkshire	75	57	76.0	4	6	13.3	8	10.7
Landrace	64	44	68.8	5	4	14.1	11	17.2
Lacombe	52	39	75.0	6	2	15.4	5	9.6
Hampshire	40	34	85.0	2	1	7.5	3	7.5
Duroc	30	21	70.0	2	4	20.0	3	10.0
Berkshire	22	19	86.4	0	1	4.5	2	9.1
Large Black	10	7	70.0	0	0	0	3	30.0
Tamworth								
Total	293	221	75.4	19	18	12.6	35	11.9

* Included gilts died, slaughtered, abnormal and sold for various reasons other than reproductive failure.

Fig. 1-4 - Weight at puberty, number of teats, loss of weight during nursing and gestation length in seven breeds of swine in this and other figures Y-Yorkshire, Ld-Landrace, Lc-Lacombe, D-Duroc, H-Hampshire, B-Berkshire, Lb-Large Black and T-Tamworth.



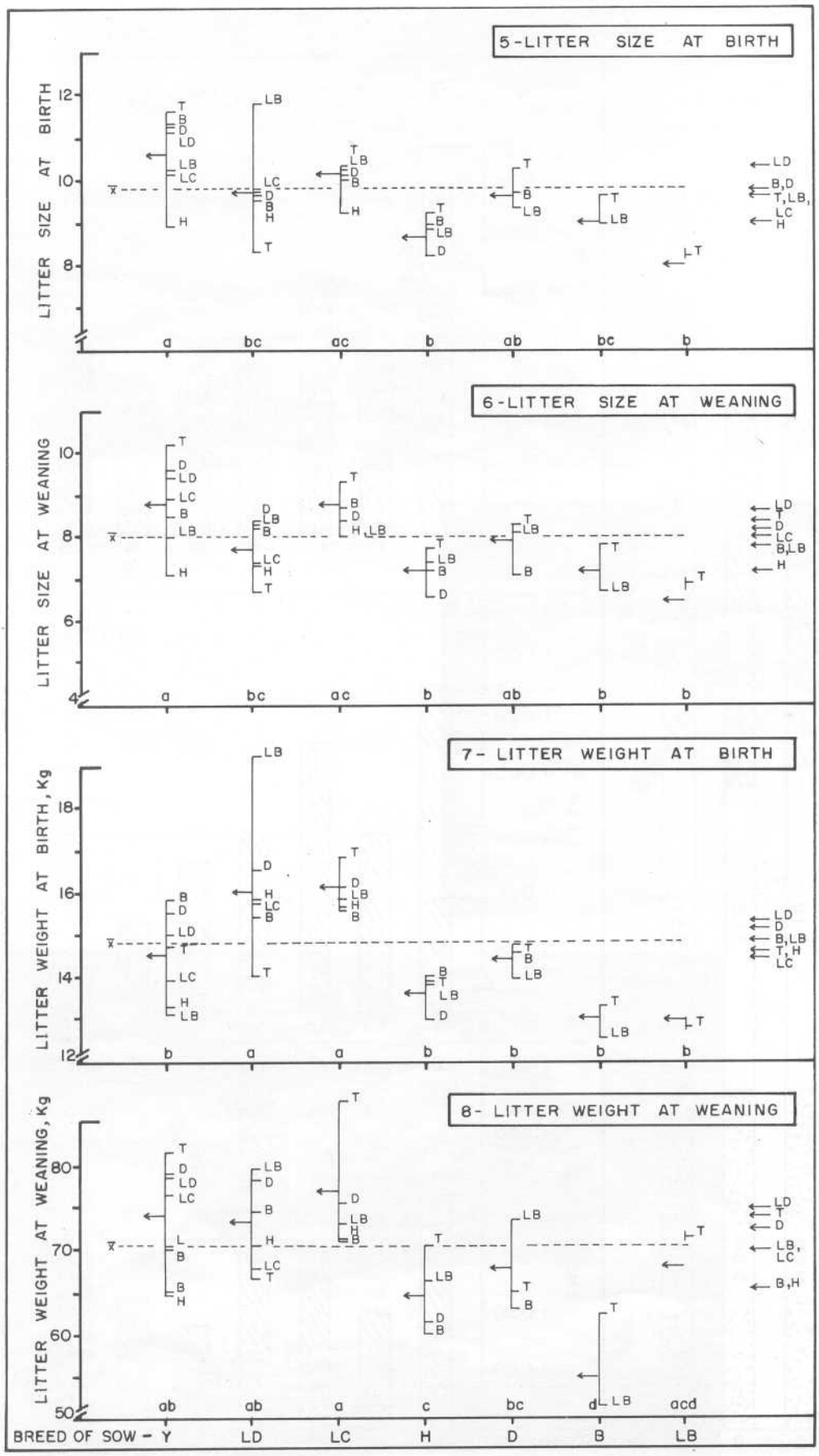
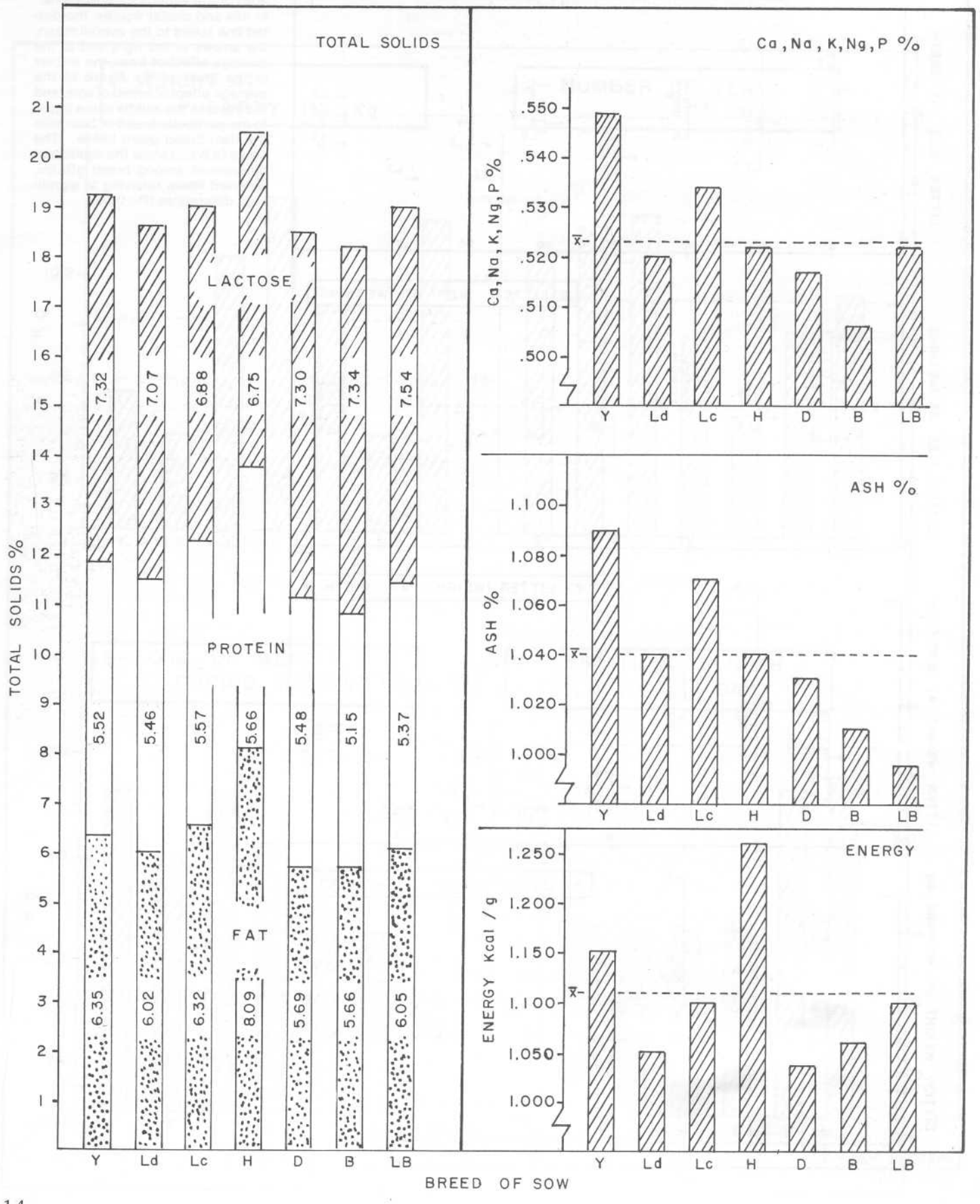
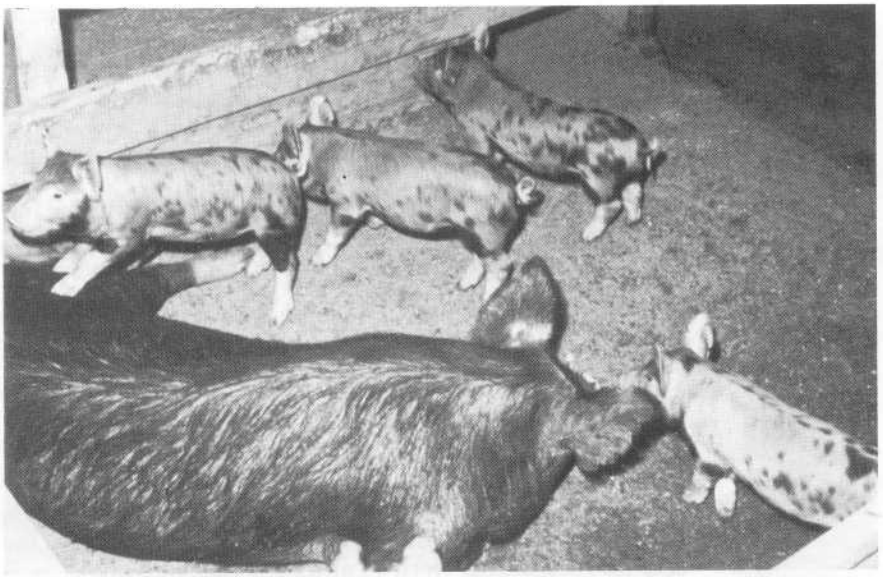


Fig. 5-8 - Litter size and weight at birth and at weaning (21 days of age) of the various combinations. In this and similar figures, the dotted line refers to the overall mean, the arrows at the right end to the average effect of boar, the arrows in the body of the figure to the average effect of breed of sow, and the litters in the middle of the figure to the particular breed of boar with the dam breed given below. The litters (a b c...) show the significant differences among breed groups, different litters referring to significant differences ($P < 0.05$).

Fig. 9 - Milk characteristics in the different breeds.





Berkshire sow with its Tamworth x Berkshire litter, not a very impressive combination.

Yorkshire sow nursing Landrace x Yorkshire piglets, this cross was the highest ranking in reproductive performance.

Panorama of colours, Duroc x (Large Black x Landrace) piglets of one litter

Phase 1: a: The reproductive performance of sows from 28 crosses

Procedure:

The crossbred progeny were born during 1969 and 1970. The piglets were weaned at 35 days of age. The healthy females were sent shortly after weaning to four cooperating stations, namely Laval University, Ste-Foy (200 km northeast), Macdonald College, Montreal (150 km west), Nappan Experimental Farm, Nova Scotia (480 km east) and Kemptville College of Agricultural Technology, Ontario (320 km west). The females selected for breeding were those of average pre-weaning growth rate (about 8 to 10 kg at 35 days).

An average of 36 gilts per cross (Table 3) was available at the initial stages of the experiment distributed as follows: 17 at Lennoxville, 7 at Laval, 6 at Macdonald, 4 at Nappan and 2 at Kemptville.

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

All two-breed cross gilts were weighed at 112 days of age and at first-detected oestrus. The gilts and sows were weighed within 18 hrs of farrowing and at 21 days post-farrowing. Records were taken on the total number of pigs farrowed per litter, sex and individual weights of pigs at birth or soon after birth whether born alive or dead, and at 21 days of age.

Results

112-day weight

Significant differences were found between crosses. The difference between H x Lc and LB x Ld, the heaviest, and B x Y, the lightest, crosses was 8.5 kg (Fig. 10). The crosses with Landrace and Large Black ancestry either from the sire or dam sides averaged 50.1 and 49.9 kg respectively and were the heaviest, whereas Yorkshire and Berkshire (46.6 and 47.1 kg respectively) were the lightest.

Puberty

Of the 1013 gilts available 93.8% showed first oestrus and 3.8% were not detected in oestrus before 300 days of age while 2.4% were removed from the experiment due to other causes. There were only small differences between crosses in the percentage of gilts showing first oestrus except for the Lc x Y, T x LB and LB x D crosses which had relatively low percentage (82.8, 86.1 and 88.9%, respectively) as compared to the other crosses (ranged from 93.6 to 99.6%).

The crosses of Tamworth with Berkshire, Duroc and Yorkshire were the youngest at puberty (197 to 200 days, Fig. 11), whereas the crosses of Berkshire with Duroc and Hampshire were the oldest (231 and 222 days, respectively). The effect of cross on age at puberty was significant ($P<0.05$). The crosses involving Yorkshire and Tamworth were significantly younger at puberty than those involving the other six breeds.

Fertility

Of the 1013 gilts available 87% farrowed but only 81% weaned a litter. The corresponding percentage for second farrowings were 83 and 80%, respectively.

The B x Y and T x D sows had the highest percentage of farrowing first litters (93.3 and 95.0%, respectively) whereas the lowest percentages were those of T x LB and H x Ld (73.2 and 76.6%, respectively). However, the differences between breeds were non-significant (ranged from 91.3% for B to 85.3% for LB).

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%), B x Y and LB x Y (90.4%) while D x LD (69.8%) and T x LB (68.8%) ranked lowest.

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 (Fig. 12). Litters of crosses involving the three white breeds (Y, Ld and Lc) were significantly larger than those of the coloured breeds (except the Duroc) with those involving the Large Black ranking smallest. Average birth weight of the pigs ranged from 1.53 kg in LB x LD and LB x B to 1.32 kg in D x Y crosses. 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 signficant heavier than those with Yorkshire and Tamworth ancestry. Litter weight at birth, which is

TABLE 3 - Experimental design, breeds and number of gilts per cross (and litters from which they came).

Breed of dam	Breed of sire							Totals
	Tamworth	Large Black	Berkshire	Duroc	Hampshire	Lacombe	Landrace	
Yorkshire	36 (11)	38 (13)	33 (11)	36 (10)	35 (10)	36 (13)	35 (12)	249 (80)
Landrace	37 (13)	34 (11)	37 (13)	38 (12)	38 (11)	38 (13)		222 (73)
Lacombe	36 (13)	35 (10)	38 (11)	39 (16)	38 (17)			186 (67)
Hampshire	36 (13)	33 (13)	36 (13)	36 (14)				141 (53)
Duroc	34 (12)	38 (12)	39 (14)					111 (38)
Berkshire	39 (14)	37 (13)						76 (27)
Large Black	38 (12)							38 (12)
Totals	256 (88)	215 (72)	183 (62)	149 (52)	111 (38)	74 (26)	35 (12)	1013 (350)

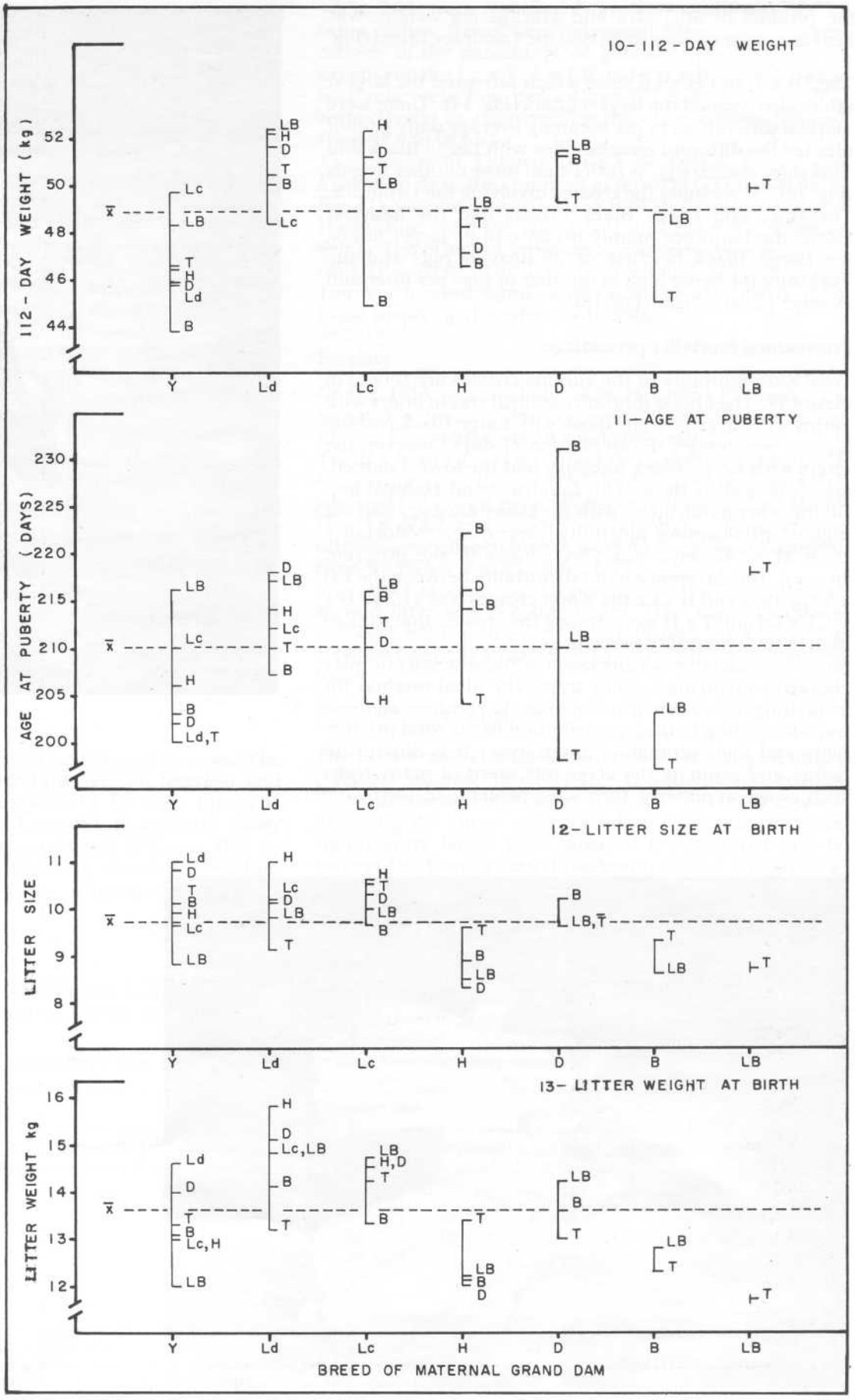
the product of litter size and average pig weight, was heaviest in the crosses involving the Landrace breed (Fig. 13).
The Ld x Y and H x Ld sows which farrowed the largest litters also weaned the largest litters (Fig. 14). There were marked differences in pre-weaning average daily gain of pigs for the different crosses. Pigs with Large Black and Yorkshire ancestry grew faster than those of other breeds (Fig. 16). At weaning the crosses involving the Landrace, Yorkshire and Large Black breeds had the heaviest litters, the Landrace mainly because of its larger litters, the Large Black because of its heavier pigs and the Yorkshire for being high in number of pigs per litter and average piglet weight (Fig. 15).

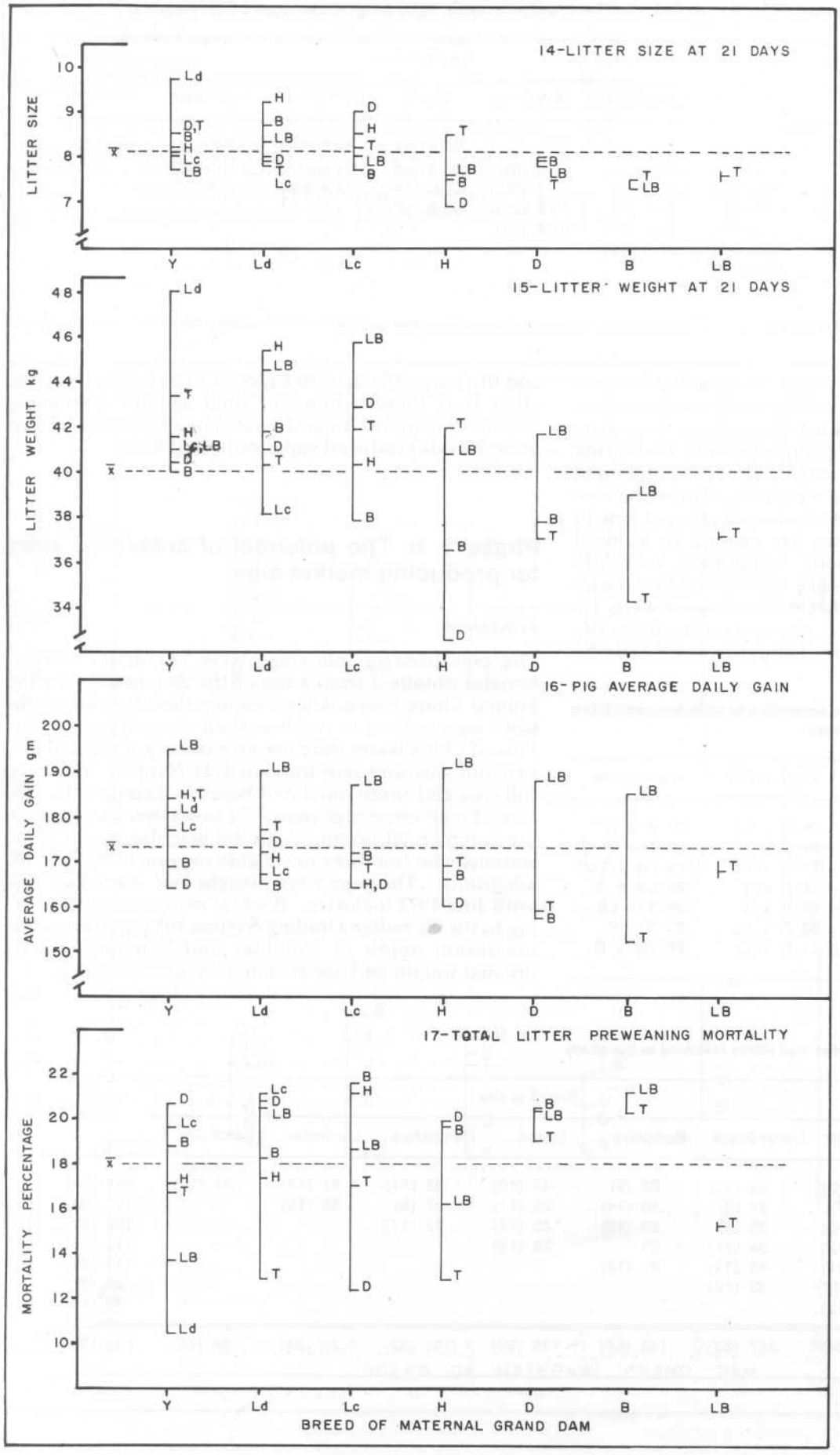
Preweaning mortality percentage

Total litter mortality of the various crosses are shown in Figure 17. The lowest mortality at birth was in litters with Tamworth ancestry while those with Large Black had the highest percentage. From birth to 21 days however, the litters with Large Black ancestry had the lowest percentage followed by those with Landrace and Hampshire. On the other hand, litters with Berkshire ancestry had the highest preweaning mortality percentage. Mortality from 21 to 42 days was very 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%. D x Lc, T x Ld and T x H were among the crosses that ranked high in total mortality percentage.
Since 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, farrowing

Hampshire blood is somewhere there. Upper picture Yorkshire x (Hampshire x Landrace) piglets, lower picture Duroc x (Hampshire x Landrace).

Fig. 10-13 - Weight at 112. day of age, age at puberty and litter size and weight at birth for the 28 crosses.





Figures 14-17 - Litter size and weight at 21 days, pig average daily gain and total litter preweaning mortality for the 28 crosses.

TABLE 4 - Average kilograms of weaned pigs after two litters for the different crosses. Farrowing percentages x litter weight at 21 days.

Breed of dam	Breed of sire						
	Tamworth	Large Black	Berkshire	Duroc	Hampshire	Lacombe	Landrace
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)					
Large Black	52.4 (28)						
Overall mean: 68.1 kg							

interval, etc. however, litter weight at weaning is commonly regarded and used as the best single measurement to predict sow productivity since it combines litter size, pig growth rate, pre-weaning mortality and mothering ability of the sows. In the present 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 with 80.6 kg followed by LB x Lc (80.0 kg), while 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 5 - Ranking of the 28 crosses according to an index combining age at slaughter and backfat thickness.

Rank. cross	Rank. cross	Rank. cross	Rank. cross
1 H x Ld	8 LB x H	15 T x Lc	22 B x H
2 H x Lc	9 T x H	16 D x H	23 T x Y
3 LB x D	10 T x B	17 D x Lc	24 LB x Lc
4 Lc x Ld	11 Lc x Y	18 D x Y	25 LB x D
5 H x Y	12 B x Ld	19 B x Y	26 T x LB
6 LB x Y	13 LB x Ld	20 D x Ld	27 T x D
7 T x Ld	14 Ld x Y	21 B x Lc	28 LB x B

Phase 1: b: The potential of crossbred sows for producing market pigs

Procedure:

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 neighbourhood of the stations who fed them to weights ranging from 75 to 105 kilograms. The pigs were slaughtered from July 1970 until July 1972 inclusive. Backfat 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.

TABLE 6 - Design and number of pigs and litters involved in the study.

Breed of dam	Breed of sire							Totals
	Tamworth	Large Black	Berkshire	Duroc	Hampshire	Lacombe	Landrace	
Yorkshire	37 (10)*	39 (12)	23 (9)	47 (10)	32 (11)	41 (12)	34 (10)	257 (74)
Landrace	20 (9)	31 (9)	40 (14)	28 (11)	27 (9)	35 (12)		181 (64)
Lacombe	39 (13)	25 (8)	29 (10)	45 (14)	42 (17)			180 (62)
Hampshire	28 (12)	34 (11)	23 (10)	28 (15)				113 (48)
Duroc	42 (11)	45 (11)	31 (12)					114 (34)
Berkshire	52 (17)	33 (12)						85 (29)
Large Black	18 (12)							18 (12)
Totals	236 (84)	207 (63)	146 (55)	148 (50)	101 (37)	76 (24)	34 (10)	948 (323)

* number of litters.

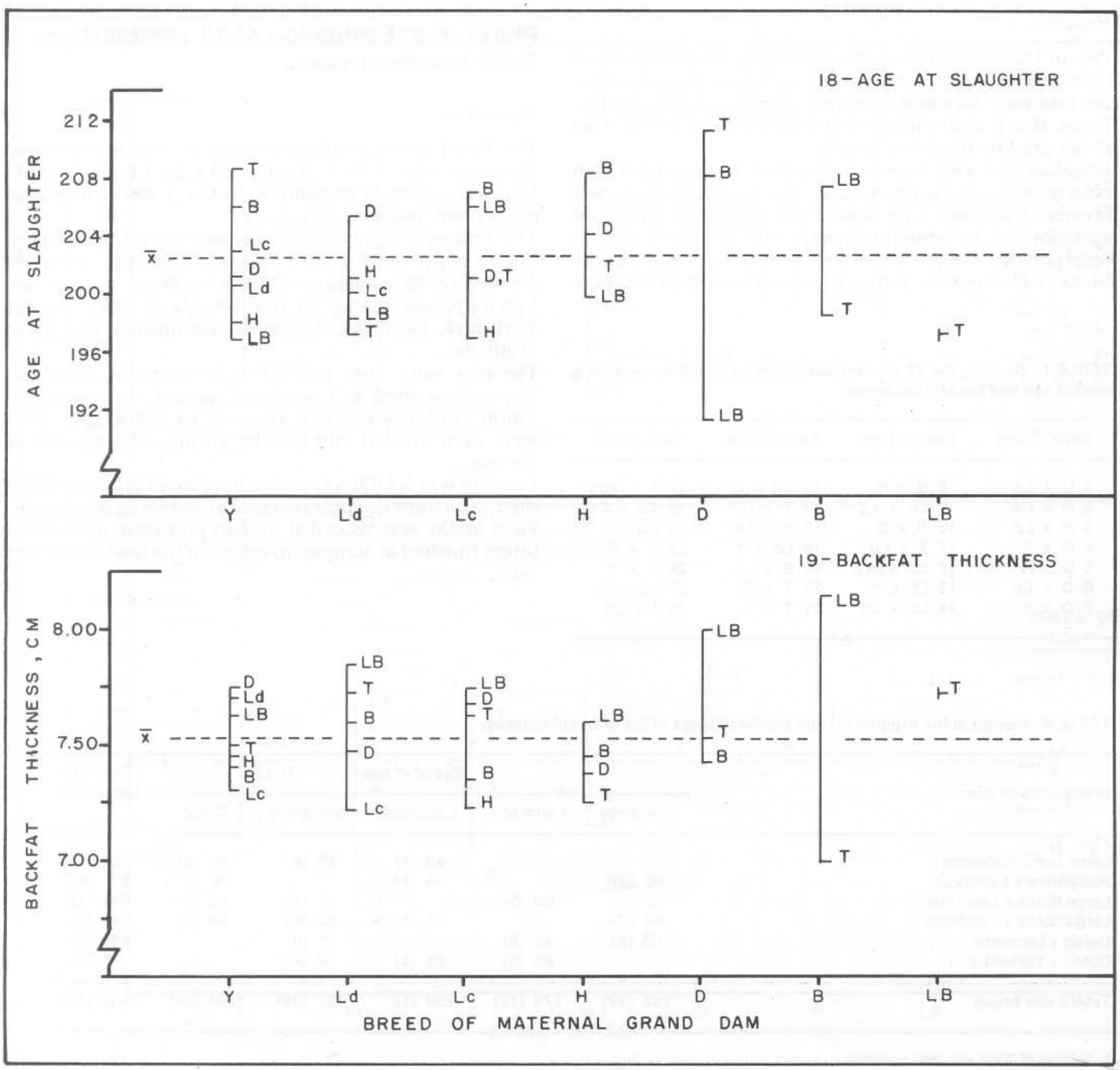
An index was used to combine age at slaughter and backfat thickness in one measure of performance to rank the different crosses.

Results

The dam's breed combination was a significant source of variation for both age at slaughter and backfat 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 (Fig. 18). Non-significant differences in age at slaughter were found among the eight highest ranking crosses.

The pigs with the least depth of backfat (6.64 cm) were those born to H x Ld sows which were significantly different from all other crosses except Lc x Y, while those with the thickest backfat (8.14 cm) were from LB x B sows which were significantly different from the top 23 crosses (Fig. 19). 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).

Fig. 18 and 19 - Age at slaughter and backfat thickness of 3 breed cross from poland China boars and females from 28 crosses.



Phase 1: c: Market performance of male pigs from the 28 crosses

Procedure

Data were collected from 948 castrated male market pigs slaughtered during 1969 and 1970. The pigs represented the 28 different combinations (Table 6). The pigs were born and raised until weaning (at 35 days of age) at the Lennoxville Research Station. All pigs were fed free choice to about 90 kg liveweight by a commercial producer. They were then marketed at two commercial abattoirs. Age at slaughter, carcass weight, and total backfat thickness (the sum of the maximum measurements over the shoulder and loin areas) were recorded.

Results

Pigs of Duroc and Hampshire breeding, whether derived from the male or female parent, and those from Lacombe sows were younger at market weight and pigs sired by Large Black and Tamworth had greater fat cover than those sired by the other breeds.

Breed of sire and breed of dam had highly significant effects on the two traits studied. The interaction between breeds of sire and dam was also a significant source of variation on backfat thickness. The youngest pigs to reach market weight were the Duroc x Landrace, Large Black x Hampshire, Large Black x Duroc and Duroc x Yorkshire crosses. Those with the least backfat were by Hampshire sires and out of Yorkshire, Landrace, and Lacombe sows (Figs. 20 and 21). The relative economic value of market age to backfat thickness was found at that time to be in the range of 2 to 1. An overall index was calculated for each cross, combining market age and backfat thickness, each weighted according to its relative economic importance. Listing of the 28 crosses in descending order according to the index (Table 7) indicates that the Hampshire and Duroc breeds when crossed with the white breeds produced the best performing crosses of market pigs, while crosses among the Tamworth, Large Black, and Berkshire breeds were the poorest.

TABLE 7 - Ranking the 28 crosses according to an index combining market age and backfat thickness.

Rank. Cross	Rank. Cross	Rank. Cross	Rank. Cross
1 D x Ld	8 B x H	15 LB x D	22 T x Lc
2 H x Ld	9 LB x Lc	16 T x H	23 LB x Ld
3 H x Lc	10 B x D	17 B x Ld	24 LB x Y
4 H x Y	11 T x Ld	18 Ld x Y	25 T x B
5 D x H	12 LB x H	19 B x Lc	26 B x Y
6 D x Lc	13 Lc x Y	20 T x D	27 LB x B
7 D x Y	14 Lc x Ld	21 T x Y	28 t x LB

Phase 2: a: Evaluation of 20 combinations of three-breed-crosses

Procedure

The five highest ranking crosses in 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 involved in the second phase of this study.

The data used in this first stage came from 1132 castrated males representing 20 crosses. The pigs were the 3-breed-cross progeny of 620 gilts from the six two-breed-crosses mated to five breeds of sires, namely Yorkshire, Landrace, Lacombe, Hampshire and Duroc (Table 8).

The pigs were born in 1973 at Lennoxville, Laval and Nappan, weaned at 3 weeks of age fed on a pig starter ration until they reached about 22 kg live weight. They were then divided into smaller groups allowing 0.75 m^2 per pig.

Feeding was *ad libitum* on a commercial growing-finishing ration until the pigs reached about 90 kg live weight. Feed intake was recorded on two pigs from each of 103 litters finished at Nappan to estimate the feed conversion ratio.

TABLE 8 - Design of the experiment and number of pigs of the different crosses.

Breedcross of dam	Breed of sire					Total dam breedcross
	Yorkshire	Landrace	Lacombe	Hampshire	Duroc	
Landrace x Yorkshire			60 (5)	48 (6)	60 (6)	168 (17)
Hampshire x Landrace	60 (3)*		55 (1)		56 (2)	171 (6)
Large Black x Lacombe	56 (6)	56 (5)		41 (2)	60 (6)	213 (19)
Large Black x Landrace	67 (7)		57 (5)	63 (8)	56 (6)	243 (26)
Duroc x Lacombe	60 (6)	49 (6)		51 (6)		160 (18)
Duroc x Yorkshire		65 (6)	58 (5)	59 (6)		177 (17)
Total / sire breed	243 (22)	170 (17)	230 (16)	257 (28)	232 (20)	1132 (103)

* Number of litters with feed conversion records.

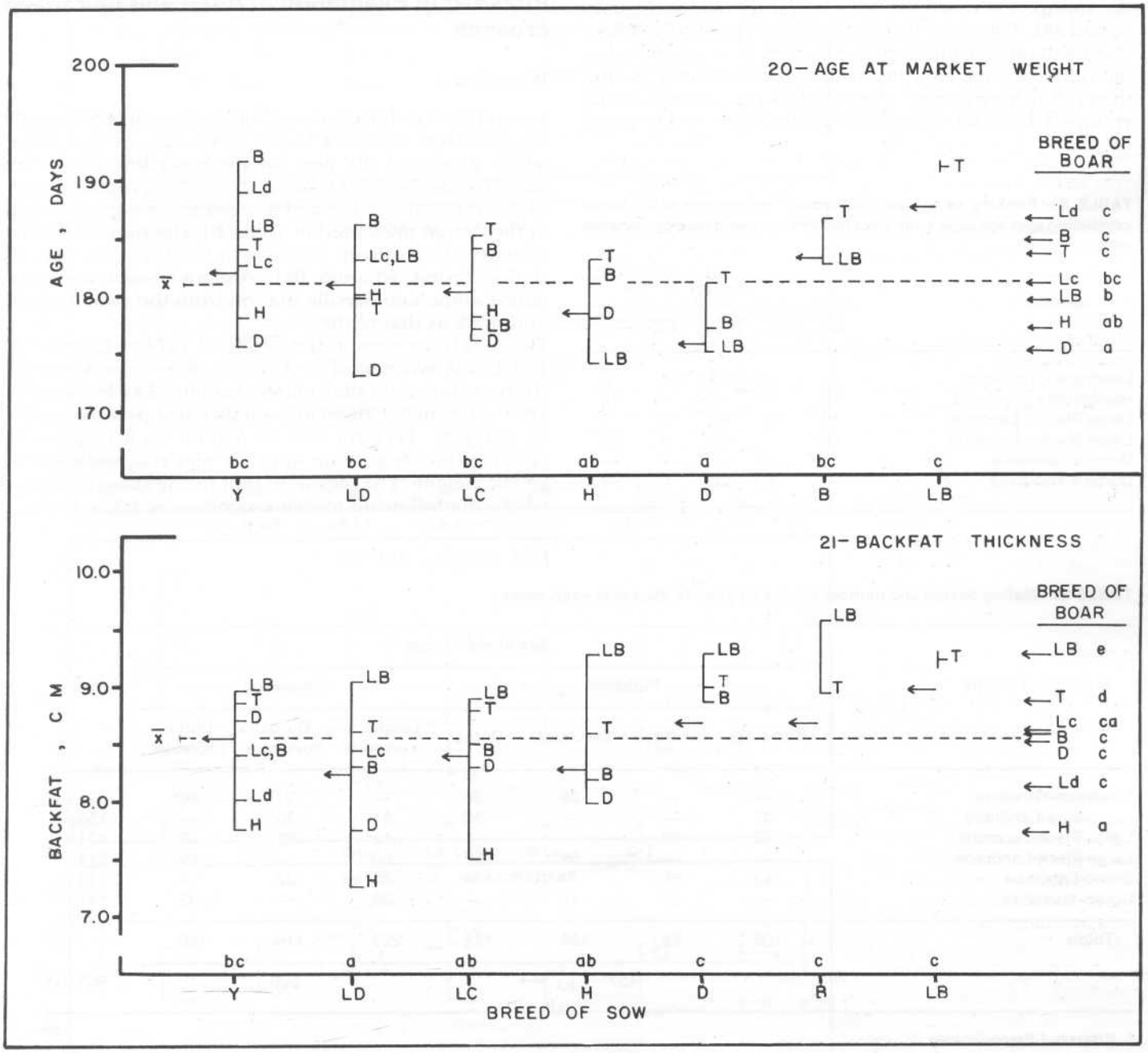
At slaughter, the following measurements were taken: weight of the chilled carcass; backfat measurement (sum of maximum depth at shoulder and loin); and the area of eye muscle measured by a planimeter. Age at slaughter, number of days on feed and average daily gain were calculated.

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

Results

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 backfat measurement.

Fig. 20-21 - Age at market weight and backfat thickness of males from 28 crosses.



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 (Figure 22). Within breed of dam, the pigs sired by the Hampshire were generally the most efficient. Differences between breed cross of dam were generally small; the only significance was that between Ld x Y, the most efficient, and D x Ld the least efficient crosses. It must be mentioned that the number of pigs involved in this aspect of the experiment was very limited, average 10 pigs per cross.

Growth rate

The fastest 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 (Figures 23 and 24). 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 gains before and during the finishing period. On the other hand, Hampshire-sired pigs were generally the oldest to reach slaughter weight.

Carcass quality

Hampshire-sired pigs were decisively superior in carcass quality to those sired by the other breeds with Duroc-sired pigs ranking second (Figures 25 and 26), while 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 9).

TABLE 9 - Ranking of the various crosses according to an index combining average daily gain, backfat thickness and feed conversion ratio.

Dam cross	Sire breed				
	York-shire	Land-race	La-combe	Hamp-shire	Duroc
Landrace x Yorkshire	—	—	17	1	3
Hampshire x Landrace	18	—	19	—	16
Large Black x Lacombe	14	8	—	5	7
Large Black x Landrace	12	—	10	4	15
Duroc x Lacombe	11	13	—	2	—
Duroc x Yorkshire	—	9	20	6	—

Phase 2: b: Evaluation of three and four breed crosses

Procedure

Two pigs were chosen at random from each of 504 mostly second litters farrowed by the same sows of the crosses which produced the pigs for the preceding phase. Purebred and crossbred boars were used to produce twenty five combinations of 3-and 4-breed-cross pigs according to the design presented in Table 10. The purebred boars were purchased from breeders in Quebec, they were all station tested, whereas the crossbred boars were produced at the Lennoxville Station from the same foundation stock as that of the sows.
The pigs were born in the spring of 1974 at Lennoxville and Laval, weaned after 3 weeks of age and fed a pig starter ration until they reached about 22 kg live weight. They were then divided into smaller groups allowing 0.75 m^2 per pig. Feeding was *ad libitum* on a commercial growing-finishing ration until the pigs reached about 90 kg live weight. The pigs were sent to one slaughter house where the following measurements were taken (or later

TABLE 10 - Mating design and number of pigs finished to market in each cross.

Breedcross of dam	Sire breed / cross							Total
	Purebred				Crossbred			
	Yorkshire	Landrace	Lacombe	Duroc	Landrace Yorkshire	Duroc Yorkshire	Duroc Lacombe	
Landrace-Yorkshire	—	—	36	36	—	21	46*	139
Hampshire-Landrace	32	—	—	36	51	36*	—	155
Large Black-Lacombe	33	30	—	—	40*	32*	39	174
Large Black-Landrace	—	—	55	50	59	—	49*	213
Duroc-Lacombe	43	35	—	—	35*	30	—	143
Duroc-Yorkshire	—	29	42	—	38	—	32	141
Totals	108	94	133	122	223	119	166	
			457			520		965

* Refers to 4-Breed-Crosses

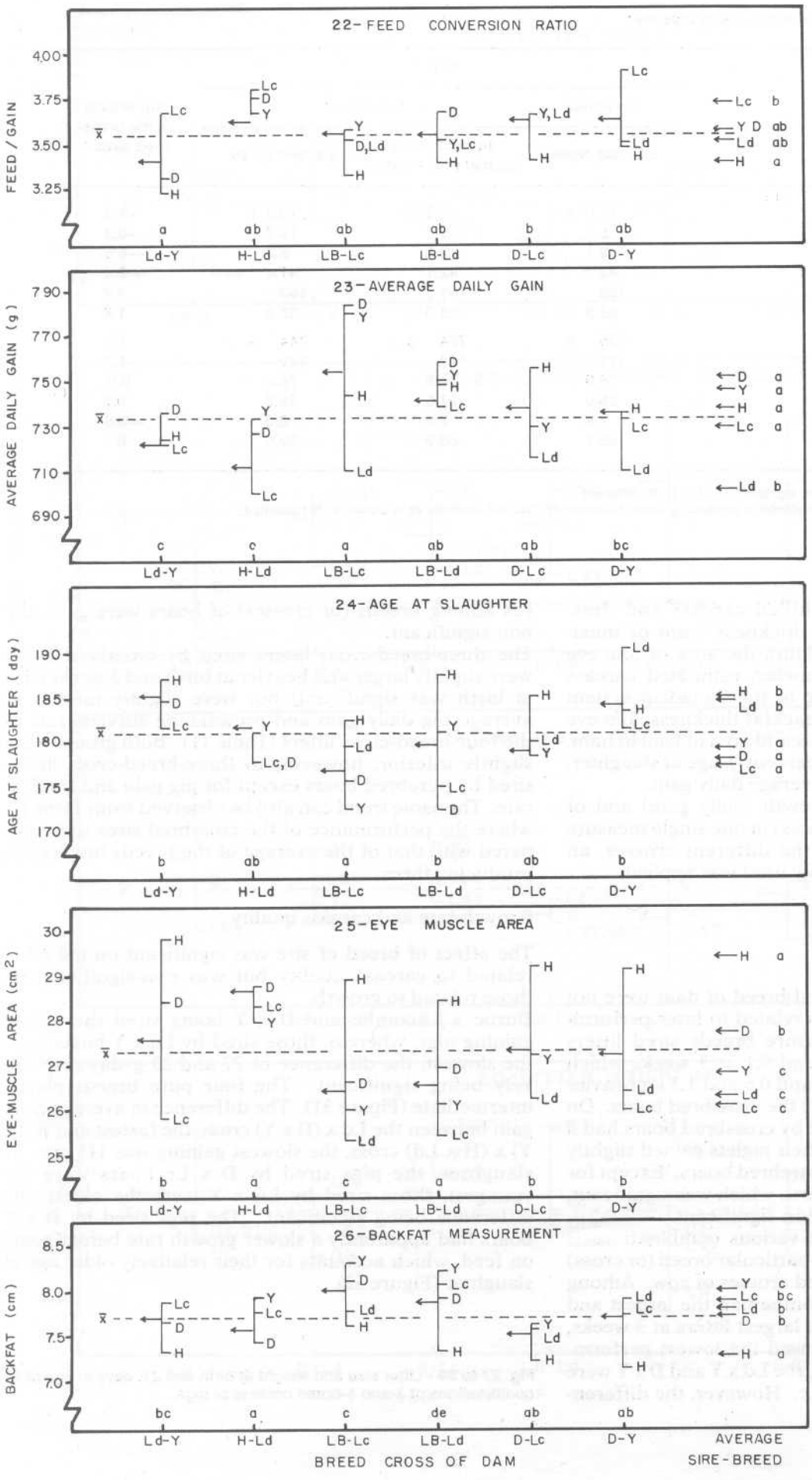


Fig. 22-26 - Feed conversion ratio, growth and some carcass characteristics of 20 combinations of 3-breed-cross pigs.

TABLE 11 - Average Performance of 3- and 4-breed crosses.

	Sire			
	Purebred	Crossbred		Superiority of the cross-bred sires *
	3-breed cross	3-breed cross (partial back-cross)	4-breed cross	
Litter size at birth	11.0 a	10.8 a	10.2 b	—9.3
Litter weight at birth (kg)	15.5	15.2	14.7	—6.3
Litter size at 21 days	9.1	9.0	8.7	—6.5
Litter weight at 21 days (kg)	43.0	42.1	41.4	—6.4
Pig daily gain to 21 days (g)	158	161	163	4.4
Preweaning survival rate	83.3	85.3	85.8	1.8
Daily gain during fattening (g)	735 b	724 c	744 a	1.0
Age at slaughter (days)	171	173	170	1.0
Dressing-out percentage	76.9	76.6	76.2	0.9
Loin-eye area (cm^2)	26.6	27.6	26.8	0.7
Backfat thickness (cm)	7.9	7.9	8.0	—0.6
Lean-yield percent	69.1	68.9	69.0	0

a-c Means followed by different letters are significantly ($P < 0.05$) different.
* As compared to the parental breeds involved in producing them, for example, Duroc-Lacombe vs ½ Duroc + ½ Lacombe.

calculated): weight of the chilled carcass and dressing-out percentage, backfat thickness (sum of maximum depth at shoulder and loin), the area of loin-eye muscle measured by a planimeter, estimated carcass yield of primal cuts according to the Canadian system (this measurement combines backfat thickness, loin eye area, percent ham of the carcass and area of lean in ham, referred to here as "lean yield percent"), age at slaughter, number of days on feed, and average daily gain.
To combine a measure of growth (daily gain) and of carcass quality (backfat thickness) in one single measure of performance for ranking the different crosses, an index similar to those previously used was applied.

Results

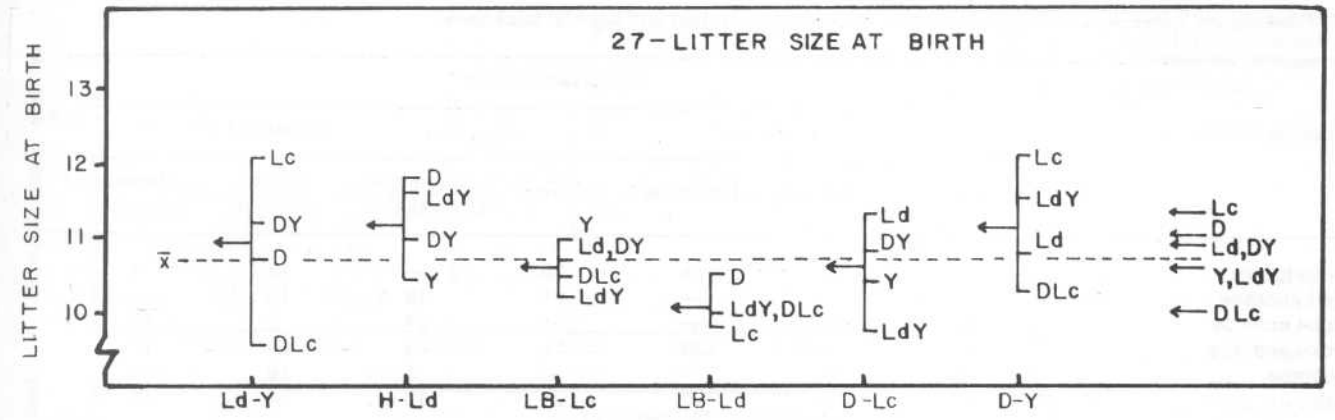
Litter performance

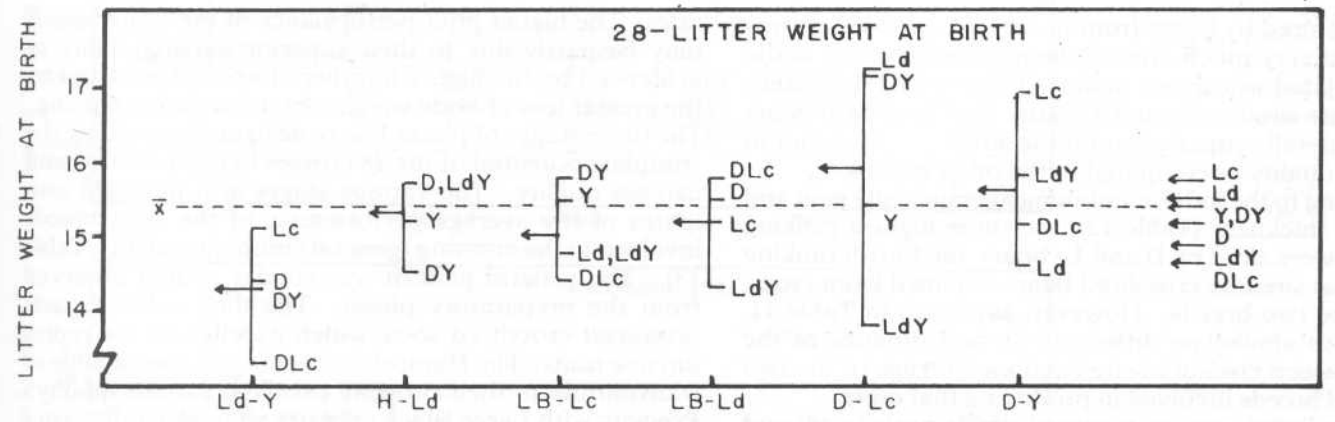
The effects of breed of sire and breed of dam were not significant on any of the traits related to litter performance. Boars from the four pure breeds sired litters averaging 11 piglets at birth and 9.1 at 3 weeks which were 0.5 and 0.2 piglets larger and 0.6 and 1.3 kg heavier respectively than those sired by the crossbred boars. On the other hand, the litters sired by crossbred boars had a 2.3% higher survival rate and their piglets gained slightly (4g/day) faster than those by purebred boars. Except for the difference in litter size at birth which was significant, all the other differences were non-significant.
The litter performance of the various combinations is presented in Figures 27-30. No particular breed (or cross) of sire was superior on all 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, while 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 non-significant.
The three-breed-cross litters sired by crossbred boars were slightly larger and heavier at birth and 3 weeks (size at birth was significant) but were slightly inferior in average pig daily gain and preweaning survival rate to the four-breed-cross litters (Table 11). Both groups were slightly inferior, however, to three-breed-cross litters sired by purebred boars except for pig gain and survival rate. The same trend can also be observed from Table 11, where the performance of the crossbred sires was compared with that of the average of the breeds involved in producing them.

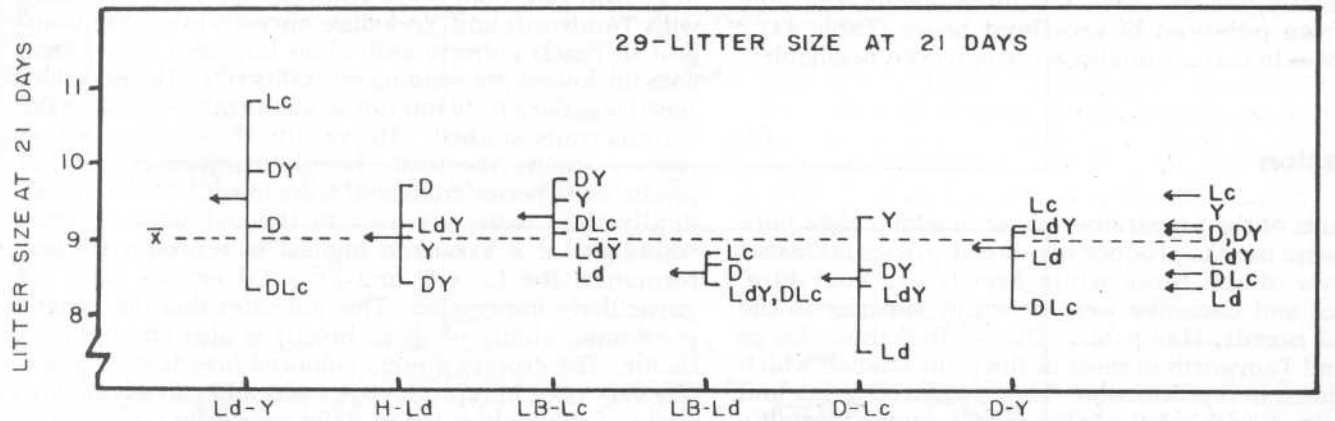
Growth rate and carcass quality

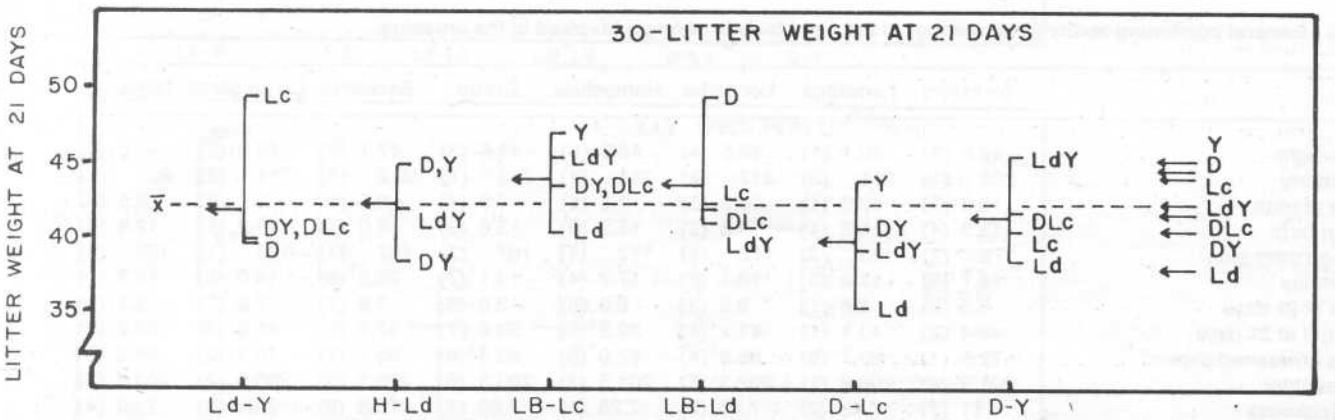
The effect of breed of sire was significant on the traits related to carcass quality but was non-significant on those related to growth.
Duroc x Lacombe and D x Y boars sired the fastest gaining pigs, whereas, those sired by Ld x Y boars were the slowest, the difference of 27 and 23 g/day respectively being significant. The four pure breeds placed intermediate (Figure 31). The difference in average daily gain between the Ld x (D x Y) cross, the fastest and (Ld x Y) x (H x Ld) cross, the slowest gaining was 115 gm. 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 going on feed, which accounts for their relatively older age at slaughter (Figure 32).

Fig. 27 to 30 - Litter size and weight at birth and 21. days of age of 25 combinations of 3-and 4-breed crosses of pigs.









BREED CROSS OF DAM

AVERAGE SIRE BREED

TABLE 12 - Ranking the crosses according to an index combining daily gain and backfat thickness.

Breedcross of dam	Sire breed / cross						
	Purebred				Crossbred		
	Yorkshire	Landrace	Lacombe	Duroc	Landrace Yorkshire	Duroc Yorkshire	Duroc Lacombe
Landrace-Yorkshire	—	—	6	3	—	15	4
Hampshire-Landrace	8	—	—	1	19	13	—
Large Black-Lacombe	20	25	—	—	24	9	18
Large Black-Landrace	—	—	22	11	23	—	17
Duroc-Lacombe	6	21	—	—	5	16	—
Duroc-Yorkshire	—	14	2	—	12	—	10

The pigs sired by boars from the three crossbred groups averaged very much around the population mean in the traits related to carcass quality (Figures 33-35) together with those sired by Lc and Y boars. Pigs sired by D boars were generally superior and those sired by Ld inferior in carcass quality as compared to the other groups.

According to the index combining average daily gain and backfat thickness (Table 12), 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. However, as shown in Table 11, there was almost no difference in performance of the pigs between crossbred sires and the average of the two parental breeds involved in producing that cross.

The four-breed-cross pigs gained significantly faster and were slightly younger than the three-breed-cross pigs either from purebred of crossbred boars (Table 11). Differences in carcass quality were however, negligible.

Discussion

The results of the preparatory phase in which eight pure breeds were used to produce two-breed crosses indicated that sows of the three white breeds *i.e.* Yorkshire, Landrace and Lacombe were generally superior to the coloured breeds, Hampshire, Duroc, Berkshire, Large Black and Tamworth in most of the traits studied which were related to reproduction. They produced larger and heavier litters with relatively lower preweaning mortality rates. The higher litter performance of the white breeds may be partly due to their superior nursing ability as evidenced by the higher number of normal teats and by the greater loss of body weight observed during nursing.

The three stages of phase 1 were designed to evaluate the complete potential of the 28 crosses in reproduction and carcass quality. The various stages also provided estimates of the average performance of the eight breeds involved in the crossing (general combining ability, Table 13). The general pattern was similar to that observed from the preparatory phase. 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 preweaning 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 in spite of that individually they were superior to the coloured 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 coloured breeds were generally very poor in reproductive traits and carcass quality. Eight of the highest ten ranking crosses in reproductive

TABLE 13 - General combining ability (and ranking) of the eight breeds of origin involved in the crossing.

	Yorkshire	Landrace	Lacombe	Hampshire	Duroc	Berkshire	Large Black	Tamworth
112 day weight	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	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)	9.9 (4)	9.5 (5)	9.1 (8)	9.5 (5)
Litter wt at birth	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	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	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	72.5 (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	201.9 (4)	200.3 (1)	202.3 (5)	201.3 (3)	203.3 (6)	205.1 (8)	200.9 (2)	203.8 (7)
Backfat thickness	7.51 (5)	7.45 (2)	7.45 (5)	7.28 (1)	7.60 (7)	7.58 (6)	7.81 (8)	7.50 (4)

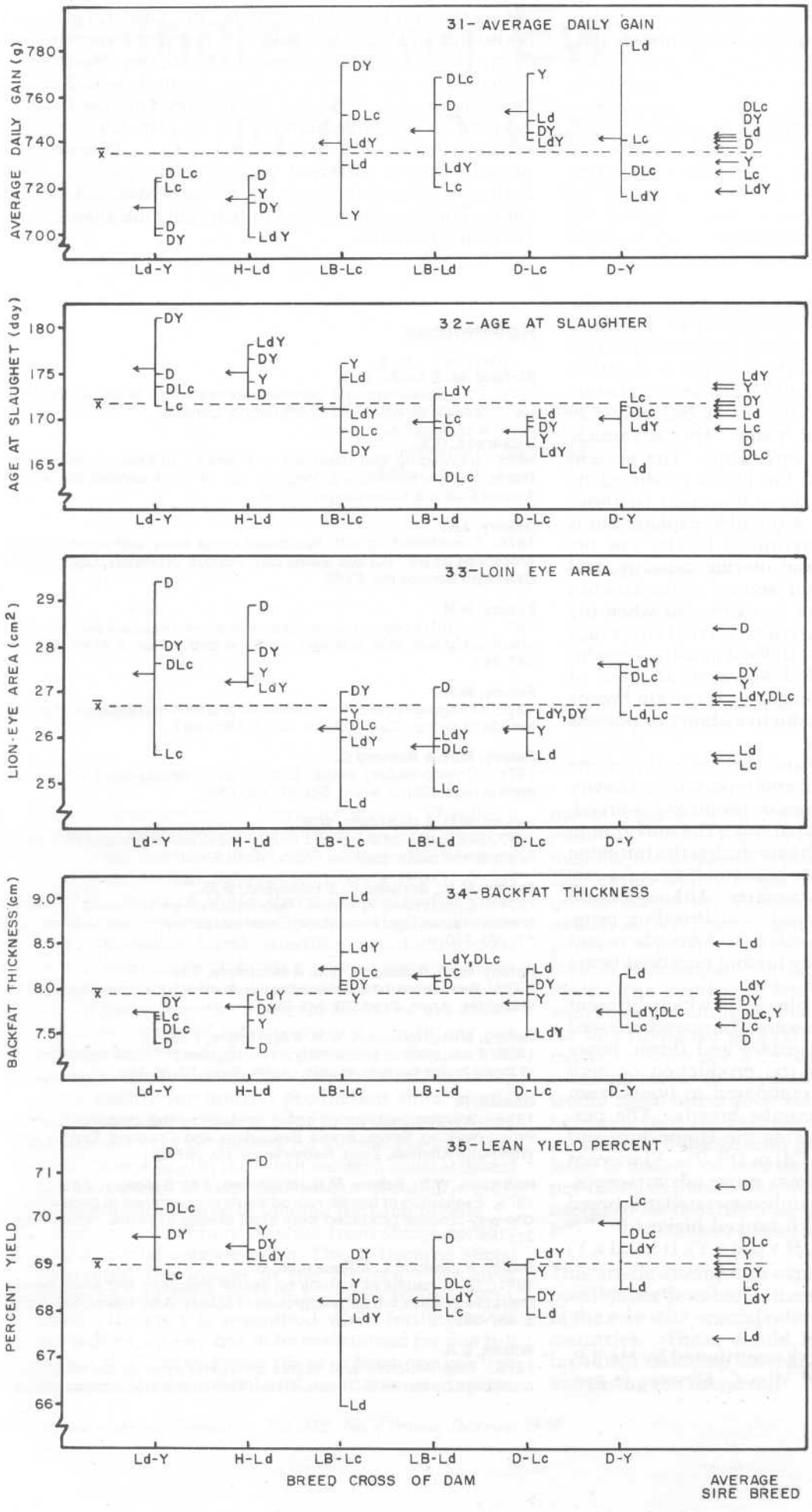


Fig. 31-35 - Growth and some carcass characteristics of 25 combinations of 3-and 4-breed crosses of pigs.

performance and seven of those in carcass quality involved crosses among white and coloured 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 3rd in litter weight at weaning, first in their potential for producing superior 3-breed-cross pigs for slaughter while male pigs destined for slaughter ranked second in market performance.

In the last 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. The work of Sellier *et al.* (1971) and Wilson (1976) 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 primarily determined by the sow according to its ovulation rate and uterine capacity, and any hybrid vigour observed for semen characteristics and breeding behaviour cannot be expressed when the sows are hand mated. In this context, no real advantage in litter performance can be capitalised in using crossbred boars. It must be recalled however, 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 and reported by Drewry (1976) showed no real advantage in producing 4-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. Although these results should not necessarily rule out breeding programs involving four breeds; however 4-breed-crosses should probably be produced by mating purebred boars to 3-breed cross dams.

The results of the two stages 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 3-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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