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Comparative performance of purebred and crossbred Large White and Landrace pigs: a literature review

G. M. Macbeth

Summary

Relative performances of purebred Large White and Landrace pigs and their crosses were determined by pooling results from a global literature search.

The average ratios of Landrace over Large White performance for litter size, feed conversion ratio (food:gain), days to bacon and backfat depth are 0.963±0.011 (s.e.), 1.032±0.003, 1.006±0.011 and 1.008±0.027.

Individual heterosis estimates, expressed as a percentage difference from the purebred mean, for litter size at weaning, feed conversion ratio (food:gain), days to bacon and backfat depth averaged 4.5%±0.5%, −1.8%±0.6%, 4.6%±0.8% and 1.5%±1.5%. Studies of paternal heterosis were few but suggest that crossbred boars have higher conception rates but do not sire larger litters. Maternal heterosis for litter size averaged 5.1%±1.6%. Maternal heterosis estimates for other traits were too few and variable to draw conclusions.

INTRODUCTION

Crossbreeding systems, although more complex and costly to carry out than pure breeding, are in widespread use in the pig industry because they exploit heterosis in economically important traits. A wide range of different crossbreeding systems is possible for example, terminal first cross, backcross, rotational cross. It is not economically feasible to compare these systems empirically due to the large number of animals, costly facilities and many variables associated with such an evaluation. Geneticists must resort to computer simulation studies using current knowledge of quantitative genetic theory and experimental observations on the levels of performance expected from pure breeds and crosses between them in economically important traits.

For modelling to be applicable, it is important that global values of heterosis estimates are used in simulation studies. This paper collates the results of studies which give heterosis estimates for Large White (Yorkshire) and Landrace crosses. These breeds, which have favourable reproductive and performance characteristics compared to other available breeds have been crossed to utilise hybrid vigour since the turn of the century (Lush *et al.* 1939).

GENETIC THEORY

Mechanism and prediction of heterosis

Heterosis may be defined as the amount by which the performance of the offspring exceeds the mean of its parents. It is usually expressed as a percentage of the parental mean. Dominance of genes is thought to be the main mechanism of heterosis. As the parental breeds become more genetically distant the difference in frequency of specific alleles between the breeds increases. This leads to an increase in heterozygosity in crosses between the breeds and, when dominant genes are involved, heterosis results.

There are three basic types of heterosis; individual, maternal and paternal. Individual heterosis is due to heterozygosity of the animal under observation and is related to the genetic difference between its parents. Maternal and paternal heterosis effects are imparted to the individual through the provision of favourable environments by its crossbred female and male parents respectively.

The performance of a number of different ways of crossing the breeds can be predicted from the knowledge of both the absolute performance values of each breed and estimates of heterosis in crosses between them (Dickerson 1969). The accuracy of these predictions depends on the reliability of empirical estimates of relative breed performances and values of heterosis. This study reviews the literature on estimates of these values.

Assumptions and calculations used to determine heterosis

Genetic differences between regional isolates of each breed could have been brought about by regional differences in selection and genetic drift. Neither of these forces are thought to be great for traits displaying most heterosis. Drift is inversely related to population size which should be high in different areas. Traits which display a high degree of heterosis have low heritabilities and are therefore unlikely to diverge between regions due to differences in selection. Thus regional strain differences within the breeds were assumed to be negligible in this study and heterosis estimates collated from different studies were assumed to be from a random sample from the same normally distributed population. Crosses among inbred lines generally lead to a much higher heterosis effect (Sellier 1970) and studies which deliberately increased the inbreeding coefficient before crossing were excluded from this review. In the absence of information on differences between Large White and Landrace in maternal effect, records of reciprocal crosses were pooled.

The equations used to estimate the percentage individual heterosis (HI) and maternal heterosis (HM) are as follows:

$$HI=100\ [AB-(AA+BB)/2]/[(AA+BB)/2] \quad ....(1)$$

$$HM=400\ [A(BA)-1/2(AB+AA)]/(3AA+BB) \quad ....(2)$$

where AA is the performance of pure breed A,

BB is the performance of pure breed B,

AB is the performance of the first cross between breeds A and B, and A(BA) is the performance of the backcross.

INDIVIDUAL AND MATERNAL HETEROSIS

Individual and maternal heterosis could affect similar economically important reproductive and productive performance traits such as litter size, growth rate, feed conversion efficiency and carcass quality. These are reviewed together in this paper.

Maternal heterosis in conception rate may also exist although data for Large White and Landrace crosses was not found. Studies with the use of breeds other than Large White and Landrace have shown the difference in conception rates between purebred and crossbred females to be insignificant (Johnson and Omtvedt 1975; Johnson *et al.* 1978).

Litter size

In Figure 1 are plotted heterosis estimates for sizes of litters at varying ages. Heterosis measured at age zero, is for litter size at birth. Other estimates made at various ages after birth reflect the differences in survival between the two pure breeds and their crosses. In general individual heterosis tends to increase from birth to weaning. Estimates of individual heterosis in litter size averaged 2.9±0.5% at birth, and 4.5±0.6% between the ages of 28 and 56 days. This post-natal rise in heterosis was significant ($P<0.5$). The only estimate of individual heterosis in litter size after weaning (Skarman 1965) showed a slight increase.

Maternal heterosis for litter size was consistently positive at birth and weaning and showed no significant change over that period (Figure 1). These estimates averaged 4.2%±0.6% at birth and 5.1%±1.6% at 56 days.

The Large White breed produced 3.7%±1.1% more pigs at weaning than the Landrace.

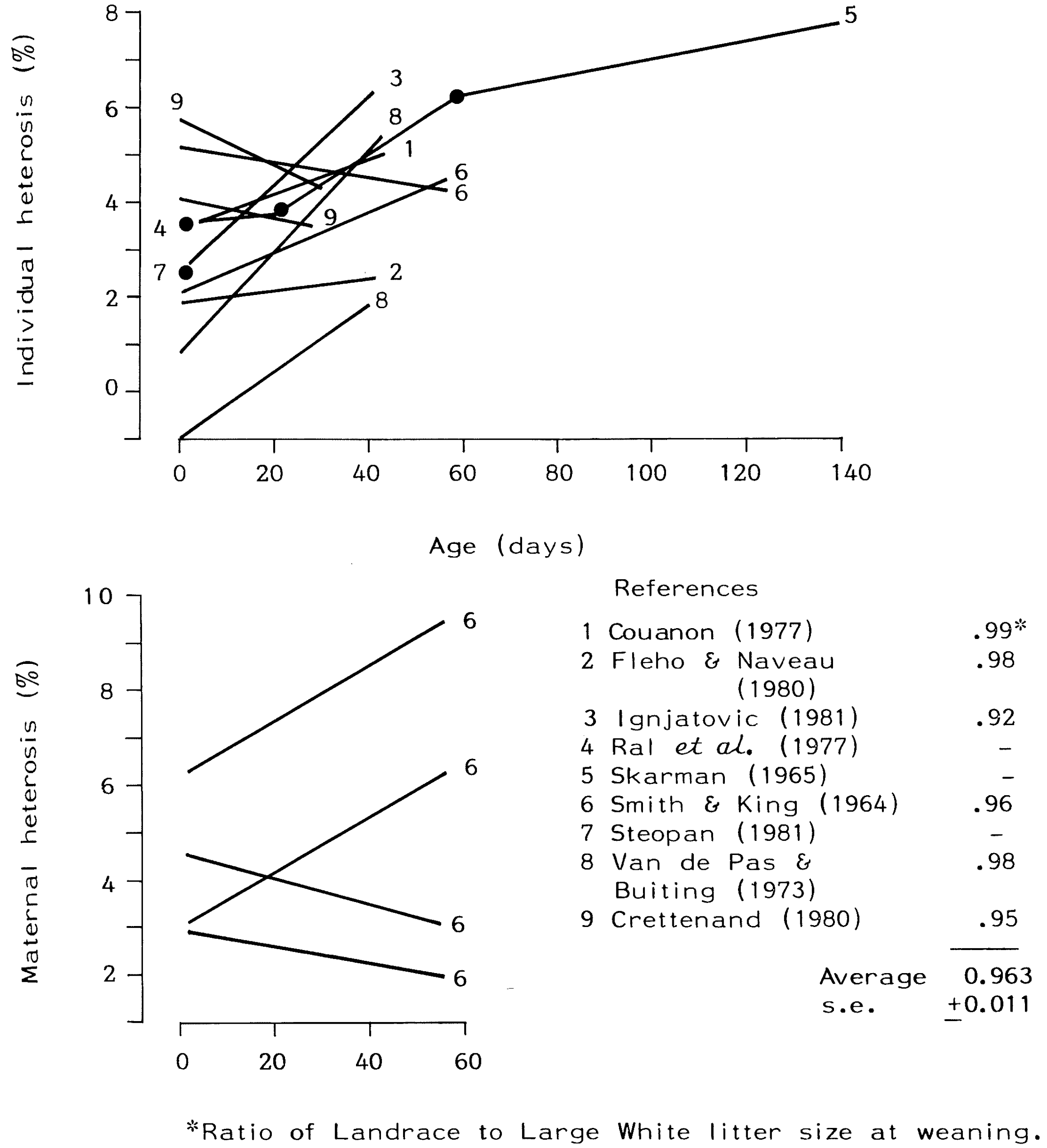
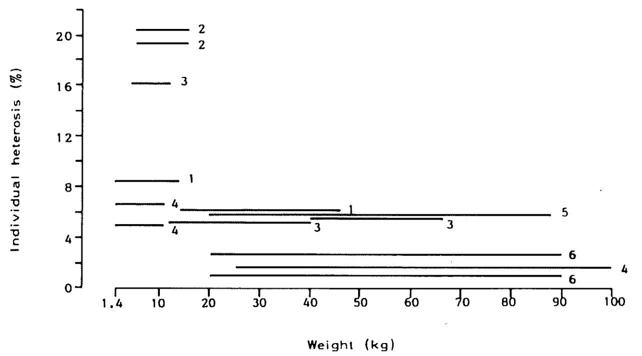


Figure 1. Heterosis in litter size with Landrace and Large White crosses measured at different ages of the litter.

Growth rate

Most published information on growth rate is in the form of liveweight gain per day. In Figure 2 individual heterosis estimates in growth rate are summarised from six studies over the liveweight ranges indicated. The heterosis values for pre-weaning daily gain, although highly variable, appear to be greater than those for post-weaning daily gain and averaged 12.7%±2.8%, 3.5%±0.8% and 2.6%±0.8% at weights of 10, 30 and 80 kg respectively. An average heterosis value of 5.0% in growth rate was determined by pooling all estimates up to 75 kg which is approximately the average slaughter liveweight of pigs in Australia (AMLC 1984). Assuming similar purebred and crossbred piglet birth weights, the individual heterosis in daily gain from birth to 75 kg would have the same expectation as heterosis in days to slaughter weight at 75 kg. Results of Hutchens *et al.* (1982), Skarman (1961), Skarman (1965) and Paska (1969) have reported the advantage of individual heterosis for days to slaughter as being 5%, 7%, 4% and 2% at approximate weights of 95 kg, 45 kg, 62 kg and 90 kg respectively. These values are consistent with the above value of 5.0% calculated from daily gain to slaughter and were pooled with it to give an average of 4.6%±0.8%.

Estimates of the ratios of growth rate in purebred Large White to Landrace tabulated in Figure 2, averaged 1.01±0.01. Consequently any type of cross between these two breeds should give a faster growing pig than either purebred due to the existence of individual heterosis in this trait.



		LR/LW growth rate
1	Skarman (1965)	1.03
2	Smith and King (1964)	1.08
3	Steopan (1981)	1.01
4	Van de Pas and Buiting (1973)	.99
5	Ettala (1973)	-
6	Paska (1969)	.99
7	Kihlberg (1982)	.98
8	Macbeth (unpub. data)	.99
9	Anon. (1982)	1.00
10	N.Z. Data (pers. com.)	.98
	Average ± s.e.	1.006 ± .011

Figure 2. Growth rate in Large White (LW) by Landrace (LR) crosses indicating the weight range over which individual heterosis estimates were made.

Estimates of maternal heterosis for growth rate in Large White by Landrace crosses were few. Maternal heterosis for 3 to 8 week daily gain determined from reciprocal backcrossing gave an advantage of −2.4%, −3.3%, 0.2% and −2.2% (Smith and King 1964). Results from the same data showed that pigs weaned from crossbred dams were heavier at three weeks but by the eighth week of growth there was no significant advantage over purebred dams. Two estimates of maternal heterosis from Paska (1969) for post-weaning growth rates averaged only 0.8%. Considering the decline in maternal heterosis for daily gain from 3 to 8 weeks and the low values for post-weaning gain it seems likely that maternal heterosis for days to bacon is negligible in Large White and Landrace crosses.

Feed conversion efficiency

Table 1 summarises results from nine studies on the food conversion ratios (intake:gain) of purebred Large White and Landrace and heterosis estimates from their crosses. The Large White breed had a consistently lower food conversion ratio than Landrace, averaging 3.2%±0.3%. The first cross had an individual heterosis advantage in feed conversion of 1.8%±0.6%.

In the absence of published data on maternal heterosis estimates for feed conversion efficiency, it was assumed to be non-existent since the maternal heterosis for daily gain was insignificant and there is a good correlation between daily gain and feed conversion efficiency (Cuthbertson and Pease 1968; Smith *et al.* 1962; Smith and Ross 1965).

Table 1. Feed conversion ratios (intake:gain) of purebred Large White (LW) and Landrace (LR) and their crosses. Heterosis is expressed as percent superiority over the parental mean

Author	Breed type	Feed conversion ratio	Test range	Individual heterosis (%)	Performance ratio LR/LW*
Van de Pas and Buiting (1973)	LW.LW	3.15	25–100 kg		1.036
	LR.LR	3.27			
	LR.LW	3.14		−2.2	
	LW.LR	3.16		−1.6	
Macbeth (unpub.)	LW.LW	2.65	50–90 kg		1.039
	LR.LR	2.75			
Skarman (1961)	LW.LW	3.00	20–90 kg		1.047
	LR.LR	3.14			
	LW.LR	2.96		−3.6	
	LR.LW	3.02		−1.6	
Anon. (1982)	LW.LW	2.54	30–90 kg		1.035
	LR.LR	2.63			
Kihlberg (1982)	LW.LW	2.67	25–100 kg		1.034
	LR.LR	2.76			
Smith (1965)	LW.LW	4.16	23–91 kg		1.026
	LR.LR	4.27			
Skarman (1965)	LW.LW	2.95	15–90 kg		1.026
	LR.LR	3.02			
	LW.LR } LR.LW }	2.99		0.0	
Cuthbertson and Pease (1968)	LW.LW	3.21	20–91 kg		1.019
	LR.LR	3.27			
N.Z. Data (pers. comm.)	LW.LW	2.71	25–85 kg		1.026
	LR.LR	2.78			
Average±s.e.				−1.8±0.6	1.032±.003

* Ratio of Large White to Landrace feed conversion ratios.

Carcass quality

Measures of the ratio of backfat depth for Landrace and Large White are given in Table 2, together with estimates of heterosis. There seems to be a large variation in backfat depth between the two breeds and heterosis in this trait appears to fluctuate about zero. Several reports with a number of other breeds indicate that heterosis may either reduce or increase backfat (Buiting *et al.* 1974; Lean *et al.* 1972; Simovic *et al.* 1979; Steopan 1981; Valjneva 1968; Rempel *et al.* 1964).

The large variation of heterosis estimates for backfat and absence of any consistent trend suggests that there is no significant heterosis in leanness. The study by Skarman (1965) of Landrace and Large White crosses showed that it is possible to attain the earlier reported gains of heterosis in litter size and days to bacon without any reduction of the value of the carcasses.

PATERNAL HETEROSIS

The value of heterosis using crossbred sires is less well established than that from using crossbred dams. Paternal heterosis might be expected in conception rate and reproductive traits, for example litter size at birth. Sellier *et al.* (1971) reported a higher sperm count per ejaculation in crossbred Large White by Landrace boars than purebred boars and expected that this could have a favourable effect on conception rate. Crossbred sires, other than Large White by Landrace, have been reported to result in significantly higher conception rates by Buchanan *et al.* (1983) and non significant increases in conception rates with the use of crossbred sires have been reported by Wilson *et al.* (1977) and Conlon and Kennedy (1978).

Using Large White and Landrace Lishman *et al.* (1975) found no clear advantage for crossbred over pure bred boars in litter productivity.

Table 2. Backfat thickness of purebred LW and LR and crosses between them. Heterosis is expressed as percent superiority over the parental mean

Author	Breed type	Backfat (mm) at liveweight	Individual heterosis (%)	Performance ratio LR/LW*
Fleho and Naveau (1980)	LW.LW LR.LR	17.25 (100 kg) 16.65		0.965
Macbeth (unpub.)	LW.LW LR.LR	16.6 (90 kg) 18.2		1.096
Kihlberg (1982)	LW.LW LR.LR	16.9 (100 kg) 16.2		0.959
Anon. (1982)	LW.LW LR.LR14.8	14.1 (90 kg)		1.050
Legault and Gruand (1981)	LW.LR	n.a.	1.5	
Van de Pas and Buiting (1973)	LW.LW LR.LR LR.LW LW.LR	30.3 (100 kg) 29.9 31.1 29.5	 3.3 −2.0	0.987
Smith (1965)	LW.LW LR.LR	34.7 (91 kg) 32.6		0.940
Cuthbertson and Pease (1968)	LW.LW LR.LR	28.3 (91 kg) 26.6		0.940
Skarman (1965)	LR.LR & LW.LW LR.LW & LW.LR	30.1 (90 kg) 30.0	 −0.5	
Pecaric *et al.* (1969)	LW.LW LR.LR LR.LW	27 (77 kg) 26 29	 9.4	0.963
N.Z. data (pers. comm.)	LW.LW LR.LR	15.7 (85 kg) 19.0		1.210
Crettenand (1980)	LW.LW LR.LR LW.LR LR.LW	15.9 (105 kg) 15.4 15.5 15.6	 −1.0 −0.3	0.967
Average±s.e.			1.5.±1.5	1.008±.027

* Ratio of backfat depth between Large White and Landrace.

n.a.=not available.

CONCLUSION

Although the heterosis estimates compiled in this review are from widely dispersed representatives of the Large White and Landrace populations there seems to be a high consistency in the ratio of performance measurements made on the two pure breeds. This fact suggests some consistency in the genotypes of the various representatives of each breed and supports the pooling of heterosis estimates from a number of sources. As a result general recommendations, on a global scale, can be made on the likely consequences of crossing these two breeds.

A summary list of individual and maternal heterosis estimates for four economically important traits is given in Table 3. It seems likely that advantages in litter size, feed conversion ratio and days to bacon can be obtained through crossbreeding. A large standard error associated with the individual heterosis estimate of backfat, indicates no clear evidence for heterosis in carcass leanness. More studies of maternal heterosis need to be conducted so that the reliability of those estimates listed in Table 3 can be improved. Literature cited on the use of crossbred boars as a potential means of improving productivity were too few to draw firm conclusions but an increased conception rate seems likely.

Table 3. Summary of heterosis estimates. Percentage heterotic advantage in crosses of LW and LR breeds and LR/LW performance ratios with standard errors. The number of data sources are shown in brackets for each estimate.

Trait	Individual heterosis (%)	Maternal heterosis (%)	Performance ratio LR/LW
Litter size	4.5±0.5 (7)	5.1±1.6 (1)	0.963±0.011 (6)
Feed conversion ratio	−1.8±0.6 (3)	0 (0)	1.032±0.003 (9)
Growth rate	4.6±0.8 (5)*	0 (2)	1.006±0.011 (9)
Backfat depth	1.5±1.5 (5)	0 (0)	1.008±0.027 (10)

* Data from Figure 2 pooled to give one observation.

As mentioned by Bichard (1982), genetic theory is adequate to predict the outcome of any conceivable crossbreeding system. The data gathered in this review will be used in a comparison of a number of systems for combining the Large White and Landrace breeds.

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The author is an officer of the Pig and Poultry Branch of the Queensland Department of Primary Industries stationed at the Animal Research Institute, Yeerongpilly, Q. 4105.