A COMPARISON OF CROSSBRED AND PUREBRED PROGENY FROM DIALLEL MATINGS IN SWINE

by

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CHAPTER I

INTRODUCTION

Crossbreeding for market animal production has been practiced for many years, not only with hogs but also with other classes of livestock. Hybrid vigor or heterosis is the most important reason for widespread application of crossbreeding in commercial production.

Most benefits of crossbreeding are observed in the F_1 generation, but one exception is the use of hybrid F_1 females as dams. Among the experiments concerning crossbreeding with swine, the two breed cross is the simplest. This allows purebred boars to sire crossbred pigs and purebred pigs in the same generation. Performance of crossbreds can be compared to pure parental breeds. Double matings have been used to compare purebred and crossbred pigs. Although results vary, crossbreds are usually superior to purebreds.

One obstacle to efficient commercial use of crossbreeding lies in the complexity of the breeding plans involved. Certain breeds show greater heterosis than others, and maximum use of heterosis requires crossbreeding involving specific cross combinations.

In the present study both purebred and crossbred progeny resulted in the same litter by inseminating a mixture of semen containing an equal number of sperm from two breeds in a diallel mating scheme. Matings involved Yorkshires, Durocs and Landraces. The objective of the study was to compare heterosis and combining ability of these breeds mated in all possible combinations for economically important traits.

CHAPTER II

REVIEW OF LITERATURE

Experiments on crossbreeding with swine

The two-breed cross in which both parents are purebred is the simplest form of crossbreeding. Many experiments concerning crossbreeding with swine provided data for only one of the parental breeds involved in the cross (Shaw and MacEwan 1936; Robison 1948; and others). Experiments comparing performance of crossbreds with that of contemporary purebreds were reported by Winters et al. (1935), Hutton and Russel (1939), and Lush, Shearer and Culbertson (1939). In a review by Fredeen (1957), crossbred litters at birth were intermediate in size to those from the parental breeds. However, a greater percentage of the crossbred pigs survived so litter size at market age frequently excelled that of the better purebred parent. Similarly, average pig weight at birth was intermediate, but weight at weaning and subsequent ages the crossbreds surpassed the parental average by 8 to 18 percent. Crossbreds were slightly superior in feed efficiency to the parental average (3 to 4 percent).

Double matings were utilized in some single cross experiments to compare purebreds and crossbreds. Among reports by Hays (1919), Shaw and MacEwan (1936), U.S. Dept. of Agriculture (1947), Lush et al. (1939), and Robison (1948), the one by Lush et al. (1939) was most representative of experiments of this type. Sows were mated to boars of her breed and then immediately remated to a boar of another breed, thus providing purebred and crossbred pigs with the same maternal environment. Lush et al. (1939) compared purebred and crossbred progeny from 36 double-mated Duroc and Poland China sows. The experiment extended over an 8-year period from 1926 to 1933, and crossbreds excelled their purebred littermates in all factors studied. Crossbreds had a lower percent stillborn pigs, were more vigorous at birth, had 15 percent better survival until weaning, were 2.5 percent heavier at birth and 10.7 percent heavier at weaning. Crossbreds also had 6.5 percent better postweaning gain and required 8.5 percent less feed per unit of gain. Lush et al. (1939) pointed out that most of the differences found in the Iowa experiments were not quite statistically significant but indicated an advantage for crossbreds.

Winters (1935) first advocated criss-crossing and rotational crossing, basing his recommendation on breeding experiments. In an early experiment he crossed Duroc, Poland China and Chester Whites. The first-cross, three-breed-cross, and back-cross groups were all superior to purebreds. The first-cross and back-cross groups were approximately equal in superiority, but both were excelled by the three-breed-cross.

These results were substantiated by various reports published in Europe and America. Fredeen (1957) reviewed experiments up to 1956 pointing out that in most cases adequate comparison with the parental breed has been lacking and statistically significant differences between purebreds and crossbreds have seldom been observed in individual experiments. The variability encountered in measuring performance traits of swine is so great that the number of animals employed must be prohibitively large in order to show statistical significance. Moreover, because of differences in breeds employed or in type of experimental control provided, few experiments lend themselves to direct comparison.

Gaines and Hazel (1957) reported significant differences between reciprocal crosses. Pigs produced by mating Poland China boars to Landrace sows were superior in growth rate to those produced from Landrace boars mated to Poland China sows.

Smith, Moorman and McLaren (1960) studied the performance of straightbred (Duroc, Hampshire, Poland and Landrace) and cross litters to compare productivity of various straightbreds, two, three and four-breed crosses. Two, three and four-breed cross litters were 13, 34 and 20 percent larger, respectively, at market time than straightbred litters. Advantages of two-breed cross litters was due to greater survival ability of the pigs, while the advantage for the three and four-breed cross litters reflected both greater litter size at birth and greater survival. Crossbred pigs gained faster from birth to market and were from 6.1 to 8.1 percent heavier at 180 days than straightbred pigs. Crossbred litters were heavier ($P<.05$) than straightbred litters at 154 and 180 days reflecting the effect of greater pig survival and faster growth.

Johnson, Omtwedt and Walters (1973) studied growth rate, feed utilization and carcass traits of purebred and reciprocal crosses involving Durocs, Hampshires and Yorkshires. Crossbreds gained 0.067 kg per day faster than purebreds and reached 100 kg 9.9 days sooner

(P<.01). Duroc-Hampshire crossbreds had 0.13 cm less probed backfat and consumed 0.18 kg more feed per day than purebreds. Duroc-Yorkshire crosses were longer (P<.05) than the average of the parent breeds, while Hampshire-Yorkshire crosses had more backfat (P<.01) and a lower percent lean cuts (P<.05).

Heterosis

Heterosis is defined as the difference between the mean of crossbreds and parents (Falconer, 1960). Heterosis observed in swine crossbreeding appears to be greatest for traits expressed early in life and decreases as the individual develops. Greater viability and increased pre-weaning growth rate show definite heterosis in the crossbred population. The advantage of crossbreds in average daily gain and feed efficiency are modest and carcass composition appear to exhibit little if any heterosis (Fredeen, 1957).

Gregory and Dickerson (1952) studied heterotic effects on rate and economy of gain, digestibility, and carcass composition by comparing crosses with parental groups under full feeding and also under equalized feed intake per unit live weight. Three inbred lines (two inbred lines of Poland Chinas and one of Hampshire) and outbred Durocs were used in this study. When full-fed, linecrosses and top-crosses ate 7 and 2 percent more feed, were 9 and 7 percent more efficient and gained 30 and 13 percent faster than the parental mean. These differences were highly significant; however, there were no differences in digestibility of the ration. Linecrosses between breeds gained more rapidly and more economically (P<.05) than linecrosses within breeds. Little difference occurred between the full-fed linecrosses and full-fed inbreds in net carcass value; however, the topcrosses yielded carcasses superior ($P<.05$) to the parental mean. The full-fed topcrosses yielded carcasses with greater muscular development and less fat than the mean of the parental groups. These results indicate that heterosis manifests itself through accelerated muscle and bone growth and is accompanied by increased appetite and more efficient utilization of food energy.

Even when restricted to the same level of feed intake as the full-fed inbred lines, the linecross pigs gained 13 percent ($P<.05$) and topcross pigs 26 percent ($P<.01$) faster. They required 9 percent and 19 percent ($P<.01$) less feed per unit gain, respectively, but differed only slightly in ability to digest the ration and in carcass composition. Compared with the two parental lines (i.e., an inbred line and the outbred Durocs) at the same level of feed intake, topcross pigs gained 10 percent more rapidly, required 10 percent less feed and showed a marked superiority ($P<.05$) in "net carcass value per unit of live weight". Topcross carcasses contained less fat ($P<.05$) and slightly more muscle than the mean of the parental groups.

Gregory and Dickerson (1952) concluded that hybrid vigor clearly produces a greater stimulus for growth of muscle and bone and that a more efficient metabolic system permits expression of this stimulus even without increasing rate of feed consumption.

Explanation of heterotic effects appears to require acceptance of one or more forms of non-additive gene action. Overdominance may be of greatest importance in traits of viability and litter size (Dickerson, 1952), while simple dominance and epistasis may be the primary forms of gene action involved in heterotic effects associated with post-weaning traits.

Donald (1955) concluded that additive gene effects are more important than non-additive effects in "metric traits", except for reproductive traits when their relative importance is reversed. Modification of traits (such as proportion of bone, lean meat and fat) may be sought through selection aimed at changing gene frequency, but improvement in number and size of young at weaning may best be secured through controlled heterozygosity.

Hetzer, Hankins and Zeller (1951) studied performance of crosses among six inbred lines of swine reporting the lower the relationship between inbred lines the higher the heteroitic effect. Genetic diversity of breeds (Sierk and Winters, 1951; England and Winters, 1953) and relative degree of inbreeding or homozygosity of different breeds are possible explanations certain breed crosses showing greater heterosis than others. However, certain inbred lines "nick" better than others to an extent that does not hinge on the measured intensity of inbreeding (Craft, 1953).

Bereskin, Shelby and Hazel (1971) evaluated the effects of crossing Durocs and Yorkshires on carcass traits. Interaction of breed of sire with breed of dam, providing a measure of heterosis, noted for backfat ($P<.01$), percent ham ($P<.01$) and percent ham and loin ($P<.05$). They reported a negative heterosis by current market standards for these carcass traits. Divergent physiological patterns of the parent breeds were suggested as a possible cause.

Combining ability

Combining ability is usually divided into general and specific combining ability. According to Sprague and Tatum (1942), general combining ability refers to the average performance of a line in hybrid combinations, while specific combining ability applies to crosses that do relatively better or worse than would be expected on the basis of average performance of the lines involved. These workers found in crosses among unselected lines of corn that general combining ability was more important than specific combining ability, an indication that in such lines additive effects were either more common or produced greater effects on yield than dominant or epistatic gene action. In contrast, crosses among inbred lines previously selected for general combining ability had greater variance for specific combining ability than for additive effects.

Craft (1953) summarized a number of studies indicating that crosses of inbred lines of the same breed of swine usually showed advantages in growth rate in comparison with non-inbred stock of the same breed. When three or more lines were represented in the crosses, the number of pigs raised per litter usually exceeded the number raised in litters from non-inbreds. Crosses of lines of different breeds have generally shown higher levels of performance than crosses of lines from the same breed. Results indicated that lines should be selected for "nicking" or specific combining ability within a breed and between breeds.

Henderson (1948, 1953) developed mathematical models and formulas for estimating general, maternal, specific and sex-linkage effects in swine crosses involving multiple classifications with disproportionate subclass numbers. Harvey (1960) extended the model to include the linecrosses for the estimation of heterosis simultaneously. In studies of 8 litter characteristics in single crosses among 12 inbred lines of Poland China swine, Henderson found general combining ability accounted for 5 percent of the variation whereas from 5 to 15 percent could be ascribed to specific effects. Neither sex-linkage nor line differences in mothering ability contributed to the variability among crosses.

Durham, Chapman and Grummer (1952) compared performance of top-cross pigs sired by boars from eight inbred lines with pigs sired by noninbred boars in 44 Wisconsin farm herds. Topcrosses and straight-breds did not differ significantly in weight at 154 days, but lines differed in their general combining ability for this trait and sow productivity.

Hetzer et al. (1961) studied litter performance of single crosses among six inbred lines for pig weight at 98 and 140 days of age, daily gain from weaning to market and six carcass yield and measurement characteristics. Maternal influences were noted ($P<.05$) for litter weight at 140 days, total yield of carcass, yield of bacon, and yield of fat cuts. General combining effects were significant ($P<.05$) and highly significant ($P<.01$) in all post-weaning weights and carcass traits except total yield of carcass. No specific combining effects existed for any of the traits except bacon yield. Difference in specific combining were unimportant, and general combining effects and maternal influences were about equally important in their contribution to the variation for most traits.

Magee and Hazel (1959) studied the 154-day weights of the three-line cross pigs of twelve Poland China inbred lines. Differences in general combining ability accounted for 4 percent of the variation within the same season and farm group ($P<.05$). Line maternal effects were not significant in these data.

Cobb (1958) reported the results from topcrossing boars of seven inbred lines on four different breeds of purebred sows. Top-cross groups differed significantly ($P<.05$) for 140 day weight, daily gain to market weight and certain carcass characteristics indicating that the lines differed in ability to combine with purebreds for these traits.

CHAPTER III

MATERIAL AND METHODS

Experimental Animals

Data were obtained from animals in two trials conducted at the Taiwan Livestock Research Institute in 1971 and 1972. In the first trial Yorkshires, Durocs and Landraces were randomly selected from the Taiwan Government Farms. These animals had descended from the original breeding stock introduced from the United States by several importations except some of the Landrace animals were imported from Europe and Japan before 1969. In the second trial the same three breeds were imported from the United States in 1971.

Methods

Experimental Plan. Twenty-seven suitable gilts from each breed were randomly sorted into mating groups and mated artificially. Three boars of each breed were used. In the first trial estrus synchronization was induced by feeding 100 mg of ICI 33828 to each gilt daily for 20 days whereas in the second trial no estrus synchronization was practiced. Three boars and 27 gilts in each of the three breeds resulted in three purebred and six crossbred mating groups (Table 1). By inseminating a mixture of semen containing an equal number of spermatozoa from two boars of different breeds, litters consisting of both purebred and crossbred pigs were produced, including reciprocal crosses. One-third of the gilts of each breed were bred to boars of two breeds other than their own which provided litters consisting of

TABLE 1. MATING SCHEME (DIALLEL MATING)

	SIRE BREED									
	Yorkshire (Y)			Duroc (D)			Landrace (L)			Total
	Y_1	Y_2	Y_3	D_1	D_2	D_3	L_1	L_2	L_3	
Dam Breed	Within Litter Mating Groups									Whole Litters
Yorkshire (Y')										
$Y'_1 \ldots Y'_9$	3YY'	3YY'	3YY'	3DY'[a]	3DY'	3DY'				9YDY'[b]
$Y'_{10} \ldots Y'_{18}$	3YY'	3YY'	3YY'				3LY'	3LY'	3LY'	9YLY'
$Y'_{19} \ldots Y'_{27}$				3DY'	3DY'	3DY'	3LY'	3LY'	3LY'	9YLY'
Sub-total	6YY'	6YY'	6YY'	6DY'	6DY'	6DY'	6LY'	6LY'	6LY'	
			18YY'			18DY'			18LY'	27( )Y'
Duroc (D')										
$D'_1 \ldots D'_9$	3YD'	3YD'	3YD'	3DD'	3DD'	3DD'				9DYD'
$D'_{10} \ldots D'_{18}$				3DD'	3DD'	3DD'	3LD'	3LD'	3LD'	9DLD'
$D'_{19} \ldots D'_{27}$	3YD'	3YD'	3YD'				3LD'	3LD'	3LD'	9YLD'
Sub-total	6YD'	6YD'	6YD'	6DD'	6DD'	6DD'	6LD'	6LD'	6LD'	
			18YD'			18DD'			18LD'	27( )D'
Landrace (L')										
$L'_1 \ldots L'_9$	3YL'	3YL'	3YL'				3LL'	3LL'	3LL'	9YLL'
$L'_{10} \ldots L'_{18}$				3DL'	3DL'	3DL'	3LL'	3LL'	3LL'	9DLL'
$L'_{19} \ldots L'_{27}$	3YL'	3YL'	3YL'	3DL'	3DL'	3DL'				9YDL'
Sub-total	6YL'	6YL'	6YL'	6DL'	6DL'	6DL'	6LL'	6LL'	6LL'	
			18YL'			18DL'			18LL'	27( )L'
Total	$18Y_1$(')			$18D_1$(')			$18L_1$(')			
		$18Y_2$(')			$18D_2$(')			$18L_2$(')		
			$18Y_3$(')			$18D_3$(')			$18L_3$(')	
			54Y(')			54D(')			54L(')	

Y = Yorkshire, D = Duroc, L = Landrace. [a]DY' = Duroc sire, Yorkshire dam

[b]9YDY' = nine litters out of Yorkshire gilts (mixed semen from Yorkshire and Duroc sires)

two different types of crossbred pigs. The semen from each boar was checked for number and normality of spermatozoa. Semen was diluted with a solution of powdered skim milk and glucose so the number of spermatozoa in the final concentration was 100 million sperm per ml and stored at a temperature of 15°C. In order to improve conception rate and number of pigs per litter, gilts were inseminated twice during each heat with a time interval of ten hours. A semen mixture of 50 ml was inseminated each time. Pigs were identified by differences in hair color, skin color, type of ears and other body conformation traits.

Traits Studied

1. Number of pigs and individual pig weights at 0, 21, 56 and 154 days of age in within litter mating groups.
2. Age to 95.3 kg.
3. Feed efficiency within litter mating group from 56 days to 154 days and to 95.3 kg liveweight.
4. Carcass measurements and cut yields:
   a. Dressing percentage
   b. Carcass length
   c. Carcass backfat thickness
   d. Loin eye area
   e. Percentage of four lean cuts
   f. Percentage of five primal cuts
   g. Percentage of ham and loin

Feeding and Management. Gilts in the first trial were individually fed medicated feed and turned on pasture after mating until ten days before farrowing, whereas in the second trial all gilts were individually penned on concrete floors throughout the experiment. The pigs were farrowed and raised in confinement. Balanced rations based on NRC's nutrient requirement of swine were fed.

Pigs were ear-notched and injected with iron-dextran at birth. Male pigs were castrated at 5 days of age. All pigs were vaccinated for hog cholera when about 42 days of age. Pigs were weaned at 56 days of age, and pigs of the same mating group within a litter were penned together and self-fed. Pigs were weighed at birth, 21, 56 and 154 days and were weighed off test when they weighed about 95.3 kg. Feed consumption was recorded as the total feed eaten by the pigs in each mating group in the same litter from weaning to 154 days of age and also from 56 days of age to 95.3 kg weight.

Slaughter and Carcass Data. Slaughter pigs were transported in groups of 20 to the Pintung Packing Plant 90 km from the station. Barrows from a within litter mating group were randomly selected from evaluation of carcasses cut either by American or Japanese cutting method. Gilts were used when barrow were not available. Pigs were held off feed and water for approximately 24 hours prior to slaughter. Carcasses were split immediately after slaughter and chilled for 48 hours before cutting.

Carcass breaking and trimming by the Japanese method are described in standard procedures for cutting and trimming by the

Japanese Meat Association (1968). The same cuts of a carcass are prepared by the American cutting method and the Japanese cutting methods, but in the latter a different procedure is followed: besides leaving the leaf fat attached to the carcass, the feet are removed at the hock joint on the ham and the knee joint of the shoulder, the picnic shoulder is separated from the loin between the fifth and sixth ribs, the ham is separated from the loin between the last lumbar vertebra and the first sacral vertebra, the loin and belly are separated along a straight line instead parallel to the back line, and the cutting line is lower resulting in a smaller belly cut.

Carcass length was measured from the anterior edge of the first rib to the anterior edge of the aitch bone. Carcass backfat thickness was measured on both sides of the split carcass at the first rib, last rib and last lumbar vertebra and the average of the six carcass backfat measurements was used. Loin eye area was measured posterior to the 10th rib.

Chilled carcass dressing percentage, percent four lean cuts, percent five primal cuts and percent ham and loin were obtained. Percent four lean cuts represented the total weight of trimmed hams, loin, boston butts and picnic shoulders. Percentage of five primal cuts included trimmed hams, loins, boston butts, picnic shoulders and bellies.

Statistical Method

Analysis of Variance. The data were analyzed by the method of least squares for multiple classification with disproportionate subclass numbers (Kemp, 1972). All sources of variation were considered as fixed effects were year, six, breed of dam, breed of sire and interactions of year with breed of dam and sire were included as sources of variation. The adjustment factors for the effects of sex, liveweight at slaughter and carcass cutting methods were computed by least squares analysis. The interactions of sex with the other effects were omitted because they were assumed negligible.

Least Squares Means. Least squares means and standard errors for year, sex, breed of dam and sire and their interactions were computed and used to obtain estimates of heterosis, maternal effect, and general and specific combining abilities with the mating groups including three purebred and six crossbred groups (Yu, 1974).

Differences between two purebred groups were computed from differences between purebred averages.

$$P_{(DD'-YY')} = DD' - YY'$$

$$P_{(LL'-YY')} = LL' - YY'$$

$$P_{(LL'-DD')} = LL' - DD'$$

Differences between averages for respective reciprocal crossbreds were calculated.

$$C_{(YL-YD)} = \frac{1}{2}\left[(YL' + LY') - (YD' + DY')\right]$$

$$C_{(DL-YD)} = \frac{1}{2}\left[(DL' + LD') - (YD' + DY')\right]$$

$$C_{(YL-DL)} = \frac{1}{2}\left[(YL' + LY') - (DL' + LD')\right]$$

Specific combining ability (SCA) is the difference between the average of the two breed reciprocal crosses and the average of the two parental purebreds.

$$SCA_{(YD)} = \frac{1}{2} \left[(DY' + YD') - (YY' + DD') \right]$$

$$SCA_{(YD)} = \frac{1}{2} \left[(LY' + YL') - (YY' + LL') \right]$$

$$SCA_{(DL)} = \frac{1}{2} \left[(LD' + DL') - (DD' + LL') \right]$$

Heterosis is quantitatively measured by the difference between purebred and crossbred least squares means. Since three breeds were involved in this study, computation of heterosis (H) represented by the breed crosses was

$$H = \frac{1}{6} (DY'+YD'+LY'+YL'+LD'+DL') - \frac{1}{3} (YY'+DD'+LL')$$

General combining ability (GCA) is the average performance of the purebred and combinations with the two other breeds as compared with the general mean of all crossbred combination of the three breeds.

$$GCA_Y = \frac{1}{4} (YL'+YD'+LY'+DY')-C_{\overline{X}}$$

$$GCA_D = \frac{1}{4} (DL'+DY'+LD'+YD')-C_{\overline{X}}$$

$$GCA_L = \frac{1}{4} (LD'+LY'+DL'+YL')-C_{\overline{X}}$$

where $C_{\overline{X}} = \frac{1}{6} (DY'+LY'+YD'+YL'+LD'+DL')$

Maternal effect (M) was computed from the difference between reciprocal corsses.

$$M_Y = \frac{1}{2} \left[(DY'+LY')-(YD'+YL') \right]$$

$$M_D = \frac{1}{2} \left[(YD'+LD')-(DY'+DL') \right]$$

$$M_L = \frac{1}{2} \left[(DL'+YL')-(LD'+LY') \right]$$

CHAPTER IV

RESULTS AND DISCUSSION

This study includes 1251 purebred and crossbred barrows and gilts produced in 150 litters or 241 within litter mating groups in 1971 and 1972 at the Taiwan Livestock Research Institute. Five hundred and thirty-one pigs in 65 litters were produced in 1971 and 720 pigs in 85 litters in 1972. The number of observations for the various traits listed by mating groups are shown in Table 2.

Analysis of variance tables are presented in Appendix Table 1 to 5.

Year. Differences between the two years were important for most traits (Table 3, 4, 5, 6 and 7). In the second year 0.82 and 0.73 pig more ($P<.05$) in within litter mating groups were found at 21 and 56 days of age respectively (Table 3). Weights (Table 4) at birth, 21 and 154 days were almost the same for the two years, but weight at 56 days was 2.48 kg less ($P<.01$) and it took the pigs produced in the second year 11.2 more days ($P<.01$) to reach 95.3 kg. Second year pigs were more efficient, averaged 0.28 and 0.20 less ($P<.01$), in feed per unit gain (Table 5). Carcasses of the second year were 1.59 cm longer ($P<.01$), had 0.47 cm less backfat thickness ($P<.01$) and had 1.45 cm^2 more loin eye area ($P<.01$) Table 5). The percent lean cuts was higher during the second year when cut by the American method or for pooled data but were lower by the Japanese method ($P<.01$) (Table 6 and 7). Bruner and Swiger (1966) studied data from pigs at the Ohio Swine Evaluation Station and reported that differences among years

TABLE 2. DISTRIBUTION OF PIGS BY MATING GROUPS AND NUMBER OF MATING GROUPS FOR TRAITS MEASURED

TRAITS	YY'	DD'	LL'	DY'	LY'	YD'	LD'	YL'	DL'	TOTAL
No. of pigs in a within litter mating group (No. of mating groups)										
0 day	21	28	32	28	26	23	27	29	27	241
21 day	18	27	30	28	24	23	25	27	25	227
56 day	18	27	30	28	23	23	25	27	25	226
154 day	18	26	30	28	23	22	25	27	25	224
Individual pig weight (No. of pigs)										
0 day	70	149	182	169	170	107	128	163	113	1251
21 day	54	111	149	146	148	81	108	118	91	1006
56 day	52	107	146	140	144	78	108	113	91	979
154 day	52	101	143	139	141	77	107	108	89	957
Age to 95.3 kg (No. of pigs)										
	51	98	137	137	138	76	106	104	88	935
Feed efficiency (No. of mating groups)										
56-154 day	18	26	30	28	23	22	25	27	25	224
56 day-end	18	26	30	28	23	22	25	27	25	224
Carcass traits (No. of pigs)										
Japanese cutting	11	28	32	20	22	24	24	21	30	212
American cutting	19	36	35	29	32	32	34	31	37	285
Pooled	30	64	67	49	54	56	58	52	67	497

and interactions of years with breed and season were important for most traits. Since selection is practiced within year and breed, the effects of year and breed by year interaction are not used for adjusting in a testing program but were included in the analysis to increase the precision of estimating other effects. Year effects in this study were confounded with differences within breeds.

Sex. Least squares means for sex showed that male pigs were 0.04 kg heavier at birth and 2.94 kg heavier ($P<.01$) at 154 days than females (Table 4). Barrows reached market weight (95.3 kg) 6.6 days earlier ($P<.01$) than gilts (Table 4). Barrow carcasses were 0.8 cm shorter, had 0.2 cm more backfat and were 2.83 cm^2 smaller in loin eye area ($P<.01$) (Table 5). Percent lean cuts for carcasses of barrows was also less than for gilts (Table 6 and 7). These differences were all highly significant ($P<.01$). Bereskin et al. (1973) reported that at birth males were 0.03 kg heavier than females in the same litter. In an experiment to evaluate the effects of crossing Yorkshires and Durocs, Bereskin et al. (1971) reported that barrows were 2.08 cm shorter in carcass length, had 0.12 cm more backfat, 0.32 percent more ham, 1.72 percent less loin, 1.40 percent less ham and loin and 4.26 cm^2 less loin eye area. However, these differences were not significant. Results of sex differences in the present study were very similar to those reported by Bruner and Swiger (1966), when differences between barrows and gilts were important for all traits studied except carcass weight; barrows had shorter carcasses, were fatter, had smaller loin eye areas and smaller percentage lean cuts ($P<.01$).

Breed of Dam and Breed of Sire. Tables 8, 9, 10, 11, and 12 show the least squares means and differences caused by breed of dam and breed of sire for number of pigs in a mating group of littermates, production performance and carcass traits. Landrace sires had 1.17 more pigs ($P<.05$) in a littermate mating group than Yorkshire sires at 154 days. Landrace dams produced pigs that were significant ($P<.05$) 0.48, 1.48 and 3.51 kg heavier than those of Duroc dams at 21, 56 and 154 days, respectively. Landrace dams also produced pigs that were 0.47, 1.45, and 2.87 kg heavier ($P<.01$) than those out of Yorkshire dams at 21, 56 and 154 days (Table 9). Duroc dams were superior ($P<.01$) to Yorkshire dams only in their influence on birth weight of pigs (Table 9). Consequently, pigs out of Landrace dams reached 95.3 kg an average of 10.69 and 6.26 days earlier ($P<.01$) than pigs from Yorkshire and Duroc dams, respectively (Table 9). Hetzer et al. (1953) crossed females from seven inbred lines and males of four different breeds with Landrace line superior to all others for weight at birth, 21 and 56 days of age. Pani et al. (1963) also reported that crossbred pigs from Landrace dams, sired by Poland China boars, were 4.1 kg heavier at 154 days of age than pigs produced by the reciprocal mating, although the difference was not significant.

Landrace sired pigs exceeded ($P<.01$) pigs sired by Yorkshires in weights at birth, 21, 56, and 154 days, averaging 0.11, 0.36, 0.83 and 3.34 kg heavier, respectively (Table 9); while pigs by Duroc sires were 0.10 and 0.40 kg heavier ($P<.01$) than pigs by Yorkshire sires at birth and 21 days. Weights at 56 and 154 days were not different for pigs by Yorkshire sires and Duroc sires. Pigs by Landrace sires reached 95.26 kg 6.34 days earlier ($P<.01$) than those by Yorkshire sires (Table 9). Duroc sired pigs were 5.05 days younger at 95.3 kg ($P<.01$) than those by Yorkshires (Table 9). The Landrace was also superior in crossing with other breeds either as a sire or dam, indicating high general combining ability in this breed.

Progeny of Duroc sires were 0.14 more efficient ($P<.05$) in converting feed to pork than those by Yorkshire sires (Table 10). Mating group littermates by Landrace sires were second most efficient, and those by Yorkshires were least efficient.

Carcasses from pigs out of Yorkshire and Landrace dams averaged 1.27 cm and 0.90 cm longer ($P<.01$) than those from pigs out of Duroc dams (Table 10). The same was true for carcasses of pigs sired by Yorkshire and Landrace boars since they were 0.76 cm and 1.05 cm longer ($P<.01$) than for Duroc sires, respectively (Table 10). Yorkshire dams produced progeny that had less backfat and larger loin eye area than progeny out of Duroc or Landrace dams, which resulted in higher percentages of lean cuts (Table 11). Progeny of Duroc sires produced carcasses that were 1.62 ($P<.05$) and 1.11 (not significant) percent higher in four lean cuts than those from Landrace and Yorkshire sires cut by the American method. In general, progeny of Duroc sires and those of Yorkshire dams were superior in carcass merit.

Interaction Effects and Least Squares Mean Comparisons

The least squares means for the nine mating groups and specific comparisons among these means for number of pigs in a within litter

TABLE 3. LEAST SQUARES MEANS, STANDARD ERRORS AND DIFFERENCES FOR NUMBER OF PIGS IN WITHIN LITTER MATING GROUPS BY YEAR

Item		Number of pigs in a within litter mating groups			
		0 day	21 day	56 day	154 day
Year					
1971	mean	5.03	3.92	3.87	3.84
	s.e.	0.30	0.30	0.28	0.28
1972	mean	5.21	4.74	4.60	4.45
	s.e.	0.26	0.24	0.23	0.23
1972 - 1971		0.18	0.82*	0.73*	0.61

* P<.05

TABLE 4. LEAST SQUARES MEANS, STANDARD ERRORS AND DIFFERENCES FOR INDIVIDUAL PIG WEIGHTS AND AGE TO 95.3 kg BY YEAR AND SEX

		Individual pig weights and age to 95.3 kg				
		0 day weight,kg	21 day weight,kg	56 day weight,kg	154 day weight,kg	age to 95.3 kg, day
Year						
1971	mean	1.32	4.83	14.66	65.50	196.79
	s.e.	0.01	0.07	0.19	0.72	1.37
1972	mean	1.35	4.72	12.18	66.02	207.99
	s.e.	0.01	0.05	0.15	0.59	1.21
1972 - 1971		0.03	-0.09	-2.48**	0.52	11.20**
Sex						
Female	mean	1.31	4.75	13.41	64.29	205.70
	s.e.	0.01	0.06	0.17	0.64	1.22
Male	mean	1.35	4.80	13.44	67.23	199.08
	s.e.	0.01	0.06	0.16	0.63	1.19
Male - Female		0.04**	0.05	0.03	2.94**	-6.62**

**P<.01

TABLE 5. LEAST SQUARES MEANS, STANDARD ERRORS AND DIFFERENCES FOR FEED EFFICIENCY AND CARCASS MEASUREMENTS BY YEAR AND SEX

Item		Feed/Gain 56-154 day	Feed/Gain 56 day-end	Carcass length cm	Carcass backfat cm	Loin eye area cm^2
Year						
1971	mean	3.21	3.44	76.77	3.52	29.04
	s.e.	0.03	0.03	0.18	0.04	0.35
1972	mean	2.93	3.24	78.36	3.05	30.49
	s.e.	0.03	0.02	0.15	0.03	0.30
1972 - 1971		-0.28**	-0.20**	1.59**	-0.47**	1.45**
Sex						
Female	mean	-	-	77.96	3.19	31.18
	s.e.	-	-	0.23	0.05	0.46
Male	mean	-	-	77.16	3.39	28.35
	s.e.	-	-	0.11	0.02	0.22
Male - Female		-	-	-0.80**	0.20**	-2.83**

** P<.01

TABLE 6. LEAST SQUARES MEANS, STANDARD ERRORS AND DIFFERENCES FOR CARCASS CUT YIELDS BY YEAR, SEX AND CUTTING METHOD

		4 lean cuts, %			5 lean cuts, %		
Item		American	Japanese	Pooled	American	Japanese	Pooled
Year							
1971	mean	55.75	65.92	60.63	76.39	77.93	77.04
	s.e.	0.46	0.48	0.39	0.51	0.54	0.40
1972	mean	63.70	63.03	63.92	81.95	74.49	78.71
	s.e.	0.39	0.44	0.34	0.43	0.49	0.35
1972 - 1971		7.95**	-2.89**	3.29**	5.56**	-3.44**	1.67**
Sex							
Female	mean	60.37	65.72	63.37	79.50	77.46	78.82
	s.e.	0.67	0.59	0.52	0.74	0.65	0.54
Male	mean	59.07	63.23	61.17	78.83	74.97	76.93
	s.e.	0.25	0.36	0.26	0.28	0.40	0.26
Male - Female		-1.30+	-2.49**	-2.20**	-0.67	-2.49**	-1.89**
Cutting							
American	mean			60.51			80.02
	s.e.			0.36			0.37
Japanese	mean			64.03			75.73
	s.e.			0.37			0.37
Japanese - American				3.52**			-4.29**

** P<.01
* P<.05
+ P<.10

TABLE 7. LEAST SQUARES MEANS, STANDARD ERRORS AND DIFFERENCES FOR HAM AND LOIN PERCENTAGE AND DRESSING PERCENTAGE BY YEAR, SEX AND CUTTING METHOD

Item		Ham and loin percentage, %			Dressing percentage, %		
		American	Japanese	Pooled	American	Japanese	Polled
Year							
1971	mean	37.52	38.99	38.09	78.12	77.11	77.48
	s.e.	0.37	0.33	0.28	0.32	0.28	0.19
1972	mean	43.09	37.40	40.61	77.28	77.10	77.23
	s.e.	0.32	0.30	0.25	0.27	0.25	0.19
1972 - 1971		5.57**	-1.59**	2.52**	-0.84*	-0.01	-0.25
Sex							
Female	mean	41.08	39.10	40.29	78.02	77.07	77.45
	s.e.	0.54	0.40	0.38	0.47	0.34	0.28
Male	mean	39.53	37.27	38.42	77.38	77.13	77.27
	s.e.	0.21	0.25	0.19	0.18	0.21	0.14
Male - Female		1.55**	-1.81**	-1.87**	-0.64	0.05	-0.18
Cutting							
American	mean			40.71			
	s.e.			0.26			
Japanese	mean			37.99			
	s.e.			0.26			
Japanese - American				-2.72**			

* P<.05
** P<.01

TABLE 8. LEAST SQUARES MEANS, STANDARD ERRORS AND DIFFERENCES FOR NUMBER OF PIGS IN WITHIN LITTER MATING GROUPS BY BREED OF DAM AND BREED OF SIRE

		Number of pigs in a within litter mating groups			
Item		0 day	21 day	56 day	154 day
Breed of dam					
Y'	mean	5.26	4.77	4.69	4.60
	s.e.	0.37	0.36	0.34	0.33
D'	mean	4.97	4.02	3.97	3.84
	s.e.	0.35	0.32	0.31	0.30
L'	mean	5.13	4.18	4.09	4.00
	s.e.	0.33	0.31	0.30	0.29
Differences	D'-Y'	-0.29	-0.75	-0.76	-0.76
	L'-Y'	-0.13	-0.59	-0.60	-0.60
	L'-D'	0.16	0.16	0.16	0.16
Breed of sire					
Y	mean	4.64	3.82	3.69	3.57
	s.e.	0.37	0.36	0.34	0.34
D	mean	5.24	4.33	4.22	4.14
	s.e.	0.34	0.31	0.30	0.29
L	mean	5.48	4.82	4.81	4.74
	s.e.	0.34	0.32	0.31	0.30
Differences	D-Y	0.60	0.51	0.53	0.57
	L-Y	0.84	1.00	1.12	1.17*
	L-D	0.24	0.49	0.59	0.60

Y', D' and L': Yorkshire, Duroc and Landrace gilts
Y, D and L: Yorkshire, Duroc and Landrace boars
* $P<.05$

TABLE 9. LEAST SQUARES MEANS, STANDARD ERRORS AND DIFFERENCE FOR PIG WEIGHTS AND AGE TO 95.3 kg BY BREED OF DAM AND BREED OF SIRE

Item		Individual pig weights, kg				Age to 95.3 kg, day
		0 day	21 day	56 day	154 day	
Breed of dam						
Y'	mean	1.28	4.61	12.92	64.38	207.43
	s.e.	0.02	0.08	0.22	0.84	1.57
D'	mean	1.35	4.62	12.95	65.02	203.00
	s.e.	0.02	0.08	0.21	0.81	1.54
L'	mean	1.36	5.09	14.40	67.89	196.74
	s.e.	0.01	0.07	0.20	0.77	1.46
differences						
	D' - Y'	0.07**	0.01	0.03	0.64	-4.43
	L' - Y'	0.08**	0.48**	1.48**	3.51**	-10.69**
	L' - D'	0.01	0.47**	1.45**	2.87**	-6.26**
Breed of sire						
Y	mean	1.26	4.52	13.13	63.93	206.19
	s.e.	0.02	0.09	0.24	0.92	1.75
D	mean	1.36	4.92	13.19	66.09	201.14
	s.e.	0.01	0.07	0.20	0.75	1.43
L	mean	1.37	4.88	13.96	67.27	199.85
	s.e.	0.01	0.07	0.19	0.74	1.40
differences						
	D - Y	0.10**	0.40**	0.06	2.16	-5.05**
	L - Y	0.11**	0.36**	0.83**	3.34**	-6.34**
	L - D	0.01	-0.04	0.77**	1.18	-1.29

Y', D' and L': Yorkshire, Duroc and Landrace gilts
Y, D and L: Yorkshire, Duroc and Landrace boars
** $P<.01$

TABLE 10. LEAST SQUARES MEANS, STANDARD ERROR AND DIFFERENCES FOR FEED EFFICIENCY AND CARCASS MEASUREMENTS BY BREED OF DAM AND BREED OF SIRE

Item		Feed/Gain 56-154 day	Feed/Gain 56 day-end	Carcass length cm	Carcass backfat cm	Loin eye area cm^2
Breed of dam						
Y'	mean	3.05	3.32	78.11	3.22	30.67
	s.e.	0.04	0.04	0.21	0.04	0.41
D'	mean	3.03	3.33	76.84	3.31	29.51
	s.e.	0.04	0.03	0.19	0.04	0.38
L'	mean	3.13	3.37	77.74	3.33	29.12
	s.e.	0.04	0.03	0.18	0.04	0.36
differences						
	D'-Y'	-0.02	0.01	-1.27**	0.09	-1.16*
	L'-Y'	0.07	0.05	-0.37	0.11	-1.55**
	L'-D'	0.10	0.04	0.90**	0.02	-0.39
Breed of sire						
Y	mean	3.15	3.41	77.72	3.32	28.97
	s.e.	0.04	0.04	0.21	0.04	0.41
D	mean	3.00	3.27	76.96	3.22	30.77
	s.e.	0.04	0.03	0.19	0.04	0.37
L	mean	3.07	3.34	78.01	3.31	29.56
	s.e.	0.04	0.03	0.19	0.04	0.37
differences						
	D-Y	-0.15	-0.14*	-0.76**	-0.10	1.80**
	L-Y	-0.08	-0.07	0.29	-0.01	0.59
	L-D	0.07	0.07	1.05**	0.09	-1.21**

Y', D' and L': Yorkshire, Duroc and Landrace gilts
Y, D and L: Yorkshire, Duroc and Landrace boars
** P<.01
* P<.05

TABLE 11. LEAST SQUARES MEANS, STANDARD ERRORS AND DIFFERENCES FOR CARCASS CUT YIELDS BY BREED OF DAM AND BREED OF SIRE

Item		4 lean cuts, % American	4 lean cuts, % Japanese	4 lean cuts, % Pooled	5 lean cuts, % American	5 lean cuts, % Japanese	5 lean cuts, % Pooled
Breed of dam							
Y'	mean	59.69	64.95	62.55	78.70	76.34	77.76
	s.e.	0.52	0.59	0.46	0.58	0.65	0.47
D'	mean	60.01	63.99	62.09	79.49	75.86	77.81
	s.e.	0.50	0.54	0.43	0.55	0.60	0.44
L'	mean	59.47	64.49	62.18	79.32	76.44	78.06
	s.e.	0.45	0.53	0.41	0.50	0.59	0.42
differences							
	D'-Y'	0.32	-0.96	-0.46	0.79	-0.48	0.05
	L'-Y'	-0.22	-0.46	-0.37	0.62	0.10	0.30
	L'-D'	-0.54	0.50	0.09	-0.17	0.58	0.25
Breed of sire							
Y	mean	59.52	64.82	62.29	79.08	76.37	77.87
	s.e.	0.51	0.62	0.47	0.56	0.69	0.48
D	mean	60.63	64.28	62.70	79.78	76.15	78.18
	s.e.	0.48	0.54	0.42	0.53	0.60	0.43
L	mean	59.01	64.32	61.83	78.64	76.13	77.58
	s.e.	0.50	0.51	0.42	0.55	0.56	0.43
differences							
	D-Y	1.11	-0.54	0.41	0.70	-0.22	0.31
	L-Y	-0.51	-0.50	-0.46	-0.44	-0.24	-0.29
	L-D	-1.62*	0.04	-0.87	-1.14	-0.02	-0.60

Y', D' and L': Yorkshire, Duroc and Landrace gilts.
Y, D and L: Yorkshire, Duroc and Landrace boars
* $P<.05$

TABLE 12. LEAST SQUARES MEANS, STANDARD ERRORS AND DIFFERENCES FOR HAM AND LOIN PERCENTAGE AND DRESSING PERCENTAGE BY BREED OF DAM AND BREED OF SIRE

Item		Ham and loin percentage, %			Dressing percentage, %		
		American	Japanese	Pooled	American	Japanese	Pooled
Breed of dam							
Y'	mean	40.54	38.27	39.58	78.08	77.43	77.72
	s.e.	0.42	0.40	0.33	0.36	0.34	0.24
D'	mean	39.97	37.85	38.91	77.60	76.93	77.22
	s.e.	0.40	0.37	0.31	0.35	0.31	0.23
L'	mean	40.41	38.46	39.58	77.42	76.94	77.13
	s.e.	0.37	0.36	0.30	0.32	0.31	0.22
differences							
	D'-Y'	-0.57	-0.42	-0.67	-0.48	-0.50	-0.50
	L'-Y'	-0.13	0.09	0.00	-0.66	-0.49	-0.59
	L'-D'	0.44	0.61	0.67	-0.18	0.01	-0.09
Breed of sire							
Y	mean	40.04	38.08	39.15	77.66	76.77	77.22
	s.e.	0.41	0.42	0.34	0.35	0.36	0.25
D	mean	41.08	38.22	39.79	77.68	77.43	77.47
	s.e.	0.38	0.37	0.30	0.35	0.29	0.22
L	mean	39.79	38.30	39.12	77.76	77.11	77.38
	s.e.	0.40	0.35	0.30	0.35	0.29	0.22
differences							
	D-Y	1.04	0.14	0.64	0.02	0.66	0.25
	L-Y	-0.25	0.22	-0.03	0.10	0.34	0.16
	L-D	-1.29	0.08	-0.67	0.08	-0.32	-0.09

Y', D' and L': Yorkshire, Duroc and Landrace gilts
Y, D and L: Yorkshire, Duroc and Landrace boars

mating group, performance and carcass traits are presented in Tables 13, 14, 15, 16, 17, 18, and 19. Interaction of breed of dam and breed of sire reflects non-additive genetic effect. Comparing least squares means among mating groups provides a measure of differences between purebreds, between crossbreds and between mating groups, heterosis, general combining ability, specific combining ability and maternal effects.

Number of Pigs in a Within Litter Mating Group. Number of pigs in a within litter mating group was two more ($P<.05$) at birth for purebred Landraces than for purebred Yorkshires (Table 13). Duroc groups averaged a non-significant 1.75 more pigs than the purebred Yorkshire groups.

Among the crossbred groups, Yorkshire x Landrace crossbreds had 1.28 more pigs ($P<.05$) than the Duroc x Landrace crossbreds (Table 13).

A comparison among the nine mating groups revealed that in spite of the fact that equal volumes of semen and numbers of sperm from two boars of different breeds were mixed before artificial insemination, the numbers of pigs in littermate mating groups were disproportionate. When littermate mating groups were purebreds and crossbreds or both were crossbreds, there were on the average 3.51 purebred Yorkshire littermates at birth, whereas there were 5.58 purebred Landrace littermates and 5.26 purebred Durocs (Table 13). The number of littermates among crossbred groups, ranged from 4.34 pigs for Duroc sires and Landrace dams to 6.15 pigs for Landrace sires and

Yorkshire dams. The number of littermates from the Yorkshire by Duroc mating was a nonsignificantly 1.01 pigs larger than that from Duroc by Landrace mating. Lush _et al._ (1939) reported there was no general tendency either for more purebreds or for more crossbreds to be produced in the double mating litters. However, Sumption (1960) reported that in the case of multisiring, sperm of Berkshire, Minnesota No. 1 and Yorkshire sires were less competitive than those from Duroc and Hampshire sires. In this study Landrace and Duroc sires were more effective competitors when a semen mixture was inseminated.

Specific combining ability between Yorkshire and Landrace was significant for the number of pigs in a within litter mating group since their crosses produced 1.26 more pigs ($P<.05$, Table 18).

Heterosis was not significant, but the average number of pigs in crossbred mating groups was larger than in purebred mating groups (Table 13). On the average, there were 0.50, 0.42, 0.43 and 0.36 more pigs in crossbred mating groups accounting for 9.8, 9.7, 10.1 and 8.7 percent more pigs at birth, 21, 56 and 154 days of age, respectively. This indicated a few more pigs in a within litter crossbred mating group when a semen mixture from two boars of two breeds was inseminated.

Weights. Highly significant ($P<.01$) differences in weight existed at all ages except at birth among purebreds. Landrace pigs were heavier ($P<.01$) than Duroc and Yorkshire; consequently, purebred Landrace reached 95.3 kg 14.9 and 23.6 days sooner ($P<.01$) than Duroc and Yorkshire, respectively (Table 14). Although Durocs were some heavier than Yorkshires at most ages, Durocs reached 95.3 kg 8.8 days later (P<.05) than Yorkshires.

Among the crossbreds the Duroc x Landrace pigs were heavier at all ages (P<.05 at 21 and 154 days) and reached 95.3 kg 5.4 days sooner (P<.05) than the Yorkshire x Landrace crossbreds (Table 14). Yorkshire x Duroc crossbreds were slightly heavier than Yorkshire x Landrace crossbreds, but the difference between these two crossbreds was not significant.

Among the nine mating groups all crossbred groups of pigs were heavier (P<.01) than purebred Yorkshire and Duroc pigs and reached 95.3 kg body weight sooner (P<.01) than the two purebreds. The Duroc x Landrace (DL') pigs were heaviest at all ages and reached 95.3 kg at the earliest age. At 154 days of age DL' pigs were 17 kg heavier (P<.01) than Yorkshire purebreds (YY') which were lighter at all ages and reached 95.3 kg 36.4 days later (P<.01) than Yorkshire purebreds (Table 14). Duroc x Yorkshire (DY') group was second heaviest at 154 days of age and the second group to reach 95.3 kg weight (P<.01).

Specific combining ability was highly significant (P<.01) for weights of Yorkshire x Duroc (YD' and DY') crossbreds and for Duroc x Landrace (DL' and LD') crossbreds at 21, 56 and 154 days of ages (Table 14). It was also highly significant (P<.01) for weights of Yorkshire x Landrace (YL' and LY') at 154 days of age. Average ages at 95.3 kg for Yorkshire x Duroc, Duroc x Landrace and Yorkshire x Landrace crossbred combinations were 27.4, 16.4, and 17.5 days, respectively, less than those for their parental purebreds (P<.01, Table 14).

Heterosis existed since there were highly significant differences ($P<.01$) in weights at 21, 56 and 154 days and age to 95.3 kg favored of the crossbreds. On the average crossbreds were 0.33, 1.39 and 10.39 kg heavier ($P<.01$) than the purebreds at 21, 56, and 154 days, respectively (Table 14). These results were in agreement with studies by Gregory and Dickerson (1952), England and Winters (1953), Gaines and Hazel (1957) and Smith _et al._ (1960). A useful quantitative measure of heterosis is the difference between purebred and crossbred least squares means as a fraction of the general least squares mean for a trait (Bereskin _et al._, 1971). Traits such as weights at birth, 21, 56 and 154 days showed about 0, 6.9, 10.3 and 15.8 percent heterosis, respectively. The crossbreds reached 95.3 kg 20.4 days sooner ($P<.01$) than the purebreds, which indicated 10.1 percent heterosis. The crossbred advantage was 10.5 days more than the 9.9 days reported by Johnson _et al._ (1973). In general this study is in agreement with earlier studies by Winters _et al._ (1935), Hutton and Russell (1939) and Lush _et al._ (1939), when pig weights at birth were intermediate to those of the parental breeds but at weaning and subsequent ages crossbreds surpassed the parental averages by 8 to 18 percent.

Moderate Yorkshire maternal effects on pig weight were present during the early stage of nursing, poor at weaning, but improved at 154 days. Duroc dams were poor through all ages and were inferior ($P<.01$) for weight of pigs at 21 days of age (Table 19). Landrace dams had a negative maternal effect on birth weight but favorable effects at other ages with a significant ($P<.01$) advantage for pig weight at 21 days of age.

TABLE 13. LEAST SQUARES MATING GROUP MEANS, STANDARD ERRORS AND SPECIFIC COMPARISONS FOR NUMBER OF PIGS IN WITHIN LITTER MATING GROUPS

	Number of pigs in a within litter mating groups			
Item	0 day	21 day	56 day	154 day
$\bar{X}$	5.12	4.33	4.24	4.15
YY'	3.51±0.68	3.43±0.72	3.35±0.69	3.35±0.67
DY'	6.11±0.58	5.35±0.52	5.15±0.50	4.99±0.49
LY'	6.15±0.63	5.53±0.59	5.57±0.57	5.47±0.56
YD'	4.95±0.64	3.84±0.57	3.70±0.55	3.49±0.55
DD'	5.26±0.58	3.99±0.53	3.86±0.51	3.82±0.50
LD'	4.70±0.59	4.23±0.56	4.23±0.54	4.20±0.52
YL'	5.46±0.57	4.20±0.55	4.00±0.52	3.86±0.51
DL'	4.34±0.59	3.65±0.55	3.65±0.53	3.61±0.51
LL'	5.58±0.55	4.71±0.52	4.63±0.50	4.55±0.49
Purebreds				
$P_{DD'-YY'}$	1.75	0.56	0.51	0.47
$P_{LL'-YY'}$	2.07*	1.28	1.28	1.20
$P_{LL'-DD'}$	0.32	0.72	0.77	0.73
Crossbreds				
C_{YL-YD}	0.27	0.27	0.36	0.42
C_{DL-YD}	-1.01	-0.66	-0.48	-0.34
C_{YL-DL}	1.28*	0.93	0.85	0.76
Specific combining ability				
$SCA_{(YxD)}$	1.15	0.89	0.82	0.66
$SCA_{(YxL)}$	1.26*	0.80	0.80	0.71
$SCA_{(DxL)}$	-0.90	-0.41	-0.30	-0.28
Heterosis	0.50	0.42	0.43	0.36
General combining ability				
GCA_Y	0.38	0.26	0.22	0.18
GCA_D	-0.26	-0.20	-0.20	-0.20
GCA_L	-0.12	-0.06	-0.02	0.01
Maternal effect				
M_Y	0.93	1.42	1.51	1.56
M_D	-0.40	-0.47	-0.43	-0.45
M_L	-0.53	-0.96	-1.08	-1.10

* $P<.05$

TABLE 14. LEAST SQUARES MATING GROUP MEANS, STANDARD ERRORS AND SPECIFIC COMPARISONS FOR INDIVIDUAL PIG WEIGHT AND AGE TO 95.3 kg

Item	Individual pig weight, kg				Age to
	0 day	21 day	56 day	154 day	95.3, day
$\overline{X}$	1.33	4.77	13.43	65.76	202.39
YY'	1.22±0.03	4.15±0.17	11.80±0.49	55.34±1.85	226.83±3.51
DY'	1.29±0.02	4.79±0.10	13.24±0.30	69.46±1.12	194.97±2.14
LY'	1.32±0.03	4.89±0.12	13.73±0.34	68.34±1.28	200.50±2.43
YD'	1.31±0.03	4.66±0.14	13.89±0.40	69.76±1.51	195.10±2.87
DD'	1.37±0.02	4.48±0.13	11.25±0.36	56.48±1.37	218.04±2.62
LD'	1.38±0.03	4.73±0.13	13.71±0.35	68.81±1.33	195.87±2.52
YL'	1.26±0.02	4.76±0.13	13.68±0.36	66.67±1.38	196.65±2.62
DL'	1.42±0.03	5.47±0.13	15.07±0.37	72.32±1.40	190.40±2.65
LL'	1.40±0.02	5.02±0.11	14.44±0.32	64.67±1.22	203.19±2.32
Purebreds					
$P_{DD'-YY'}$	0.15	0.33	-0.55	1.14	-8.79*
$P_{LL'-YY'}$	0.18	0.87**	2.64**	9.33**	-23.64**
$P_{LL'-DD'}$	0.03	0.54**	3.19**	8.19**	-14.85**
Crossbreds					
C_{YL-YD}	-0.01	0.10	0.14	-2.11	3.54
C_{DL-YD}	0.10	0.38**	0.83*	0.95	-1.90
C_{YL-DL}	-0.11	-0.28*	-0.69	-3.06*	5.44*
Specific combining ability					
$SCA_{(YxD)}$	0.01	0.41**	2.04**	13.70**	-27.41**
$SCA_{(YxL)}$	-0.02	0.24	0.58	7.50**	-16.44**
$SCA_{(DxL)}$	0.02	0.35**	1.55**	9.99**	-17.48**
Heterosis	0.00	0.33**	1.39**	10.39**	-20.44**
General combining ability					
GCA_Y	-0.03	-0.11	-0.25	-0.67	1.22
GCA_D	0.02	0.03	0.09	0.86	-1.50
GCA_L	0.02	0.08	0.16	-0.19	0.27
Maternal effect					
M_Y	0.02	0.13	-0.30	0.68	1.86
M_D	-0.01	-0.44**	-0.35	-1.60	-1.60
M_L	-0.01	0.31*	0.66	0.92	0.92

* P<.05
** P<.01

TABLE 15. LEAST SQUARES MATING GROUP MEANS, STANDARD ERRORS AND SPECIFIC COMPARISONS FOR FEED EFFICIENCY AND CARCASS MEASUREMENTS

Item	Feed Gain 56-154 day	Feed/Gain 56 day-end	Carcass length cm	Carcass backfat cm	Loin eye area cm^2
$\bar{X}$	3.07	3.34	77.56	3.29	29.77
YY'	3.14±0.08	3.47±0.07	78.10±0.43	3.12±0.09	30.49±0.84
DY'	3.01±0.06	3.22±0.05	77.93±0.28	3.24±0.06	31.13±0.56
LY'	3.01±0.07	3.27±0.06	78.30±0.30	3.31±0.06	30.40±0.59
YD'	3.10±0.07	3.34±0.06	77.14±0.32	3.37±0.06	28.52±0.63
DD'	2.99±0.06	3.36±0.05	75.76±0.31	3.28±0.06	30.36±0.60
LD'	3.00±0.06	3.30±0.06	77.61±0.31	3.28±0.06	29.63±0.61
YL'	3.20±0.06	3.41±0.06	77.92±0.30	3.49±0.06	27.89±0.60
DL'	3.01±0.06	3.23±0.06	77.19±0.31	3.14±0.06	30.82±0.61
LL'	3.19±0.06	3.46±0.05	78.12±0.28	3.37±0.06	28.65±0.55
Purebreds					
$P_{DD'-YY'}$	-0.15	-0.11	-2.34	0.16	-0.13
$P_{LL'-YY'}$	0.05	-0.01	0.02	0.25*	-1.84
$P_{LL'-DD'}$	0.20	0.10	2.36	0.09	-1.71
Crossbreds					
C_{YL-YD}	0.05	0.06	0.58	0.09	-0.68
C_{DL-YD}	-0.05	-0.02	-0.13	-0.10	0.40
C_{YL-DL}	0.09	0.08	0.71	0.19**	-1.08
Specific combining ability					
$SCA_{(YxD)}$	-0.01	-0.13*	0.60	0.10	-0.60
$SCA_{(YxL)}$	-0.07	-0.13*	0.00	0.15**	-0.43
$SCA_{(DxL)}$	-0.08	-0.15*	0.46	-0.12*	0.72
Heterosis	-0.05	-0.13*	0.35	0.04	-0.10
General combining ability					
GCA_Y	0.02	0.02	0.14	0.05	-0.25
GCA_D	-0.02	-0.02	-0.21	-0.05	0.29
GCA_L	0.00	0.01	0.07	-0.00	-0.05
Maternal effect					
M_Y	-0.14	-0.13*	0.58	-0.16*	2.55
M_D	0.04	0.10	-0.19	0.13*	-1.89
M_L	0.10	0.04	-0.40	0.02	-0.66

* P<.05
** P<.01

TABLE 16. LEAST SQUARES MATING GROUP MEANS, STANDARD ERRORS AND SPECIFIC COMPARISONS FOR PERCENT FOUR LEAN CUTS

Item	Four lean cuts, % American	Japanese	Pooled
$\bar{X}$	59.72	64.48	62.27
YY'	59.38±1.00	64.35±1.31	62.34±0.95
DY'	60.95±0.69	65.36±0.82	63.29±0.63
LY'	58.73±0.74	65.13±0.83	62.01±0.66
YD'	60.32±0.75	66.05±0.96	63.09±0.71
DD'	60.15±0.74	62.62±0.90	61.67±0.68
LD'	59.56±0.76	63.29±0.90	61.52±0.68
YL'	58.87±0.71	64.07±0.92	61.43±0.67
DL'	60.78±0.72	64.85±0.95	63.13±0.69
LL'	58.75±0.71	64.54±0.79	61.97±0.63
Purebreds			
$P_{DD'-YY'}$	0.77	-1.73	-0.67
$P_{LL'-YY'}$	-0.63	0.19	-0.37
$P_{LL'-DD'}$	-1.43	1.92	0.30
Crossbreds			
C_{YL-YD}	-1.83	-1.11	-1.47
C_{DL-YD}	-0.47	-1.64	-0.87
C_{YL-DL}	-1.37	0.53	-0.60
Specific combining ability			
$SCA_{(YxD)}$	0.87	2.22	1.19
$SCA_{(YxL)}$	-0.27	0.15	-0.44
$SCA_{(DxL)}$	0.72	0.49	0.50
Heterosis	0.44	0.95	0.41
General combining ability			
GCA_Y	-0.15	0.36	0.05
GCA_D	0.53	0.10	0.35
GCA_L	-0.38	-0.46	-0.39
Maternal Effect			
M_Y	0.25	0.18	0.39
M_D	-0.93	-0.44	-0.91
M_L	0.68	0.26	0.52

TABLE 17. LEAST SQUARES MATING GROUP MEANS, STANDARD ERRORS AND SPECIFIC COMPARISONS FOR PERCENT FIVE LEAN CUTS

	Five lean cuts, %		
Item	American	Japanese	Pooled
$\bar{X}$	79.17	76.21	77.88
YY'	78.49±1.10	75.56±1.46	77.50±0.97
DY'	79.75±0.77	76.68±0.91	78.36±0.65
LY'	77.85±0.82	76.78±0.92	77.40±0.68
YD'	79.96±0.84	77.62±1.06	78.77±0.73
DD'	79.34±0.82	74.76±1.00	77.32±0.70
LD'	79.16±0.85	75.21±0.99	77.35±0.70
YL'	78.78±0.78	75.91±1.02	77.35±0.69
DL'	80.26±0.80	77.00±1.06	78.85±0.71
LL'	78.92±0.78	76.39±0.87	77.98±0.64
Purebreds			
$P_{DD'-YY'}$	0.85	-0.80	-0.18
$P_{LL'-YY'}$	0.43	0.83	0.48
$P_{LL'-DD'}$	-0.42	1.63	0.66
Crossbreds			
C_{YL-YD}	-1.54	-0.80	-1.19
C_{DL-YD}	-0.15	-1.04	-0.46
C_{YL-DL}	-0.40	0.24	-0.73
Specific combining ability			
$SCA_{(YxD)}$	0.95	1.99	1.15
$SCA_{(YxL)}$	-0.39	0.37	-0.37
$SCA_{(DxL)}$	0.58	0.53	0.45
Heterosis	0.38	0.96	0.41
General combing ability			
GCA_Y	-0.21	0.21	-0.04
GCA_D	0.49	0.09	0.32
GCA_L	-0.28	-0.31	-0.28
Maternal effect			
M_Y	-0.57	-0.03	-0.18
M_D	-0.46	-0.43	-0.55
M_L	1.02	0.46	0.72

TABLE 18. LEAST SQUARES MATING GROUP MEANS, STANDARD ERRORS AND SPECIFIC COMPARISONS FOR HAM AND LOIN PERCENTAGE

Item	Ham and loin percentage, %		
	American	Japanese	Pooled
$\bar{X}$	40.31	38.20	39.35
YY'	40.07±0.81	37.76±0.90	39.23±0.69
DY'	41.85±0.56	38.60±0.56	40.36±0.46
LY'	39.70±0.60	38.47±0.57	39.13±0.48
YD'	40.10±0.60	38.83±0.65	39.37±0.51
DD'	40.03±0.60	37.07±0.62	38.65±0.49
LD'	39.79±0.62	37.65±0.61	38.70±0.49
YL'	39.97±0.57	37.64±0.63	38.84±0.49
DL'	41.36±0.58	38.99±0.65	40.37±0.50
LL'	39.90±0.57	38.77±0.54	39.52±0.45
Purebred			
$P_{DD'-YY'}$	-0.04	-0.69	-0.58
$P_{LL'-YY'}$	-0.17	1.01	0.29
$P_{LL'-DD'}$	-0.13	1.70	0.87
Crossbreds			
C_{YL-YD}	-1.14	-0.66	-0.88
C_{DL-YD}	-0.40	-0.39	-0.33
C_{YL-DL}	-0.74	-0.27	-0.55
Specific combining ability			
$SCA_{(YxD)}$	0.92	1.30	0.92
$SCA_{(YxL)}$	-0.15	-0.21	-0.39
$SCA_{(DxL)}$	0.61	0.40	0.45
Heterosis	0.46	0.49	0.32
General combining ability			
GCA_Y	-0.06	0.02	-0.04
GCA_D	0.31	0.16	0.24
GCA_L	-0.26	-0.18	-0.20
Maternal effect			
M_Y	0.74	0.30	0.64
M_D	-1.66	-0.55	-1.33
M_L	0.92	0.25	0.69

TABLE 19. LEAST SQUARES MATING GROUP MEANS, STANDARD ERRORS AND SPECIFIC COMPARISONS FOR DRESSING PERCENTAGE

Item	Dressing percentage, %		
	American	Japanese	Pooled
$\bar{X}$	77.70	77.10	77.36
YY'	78.43±0.70	77.30±0.75	77.89±0.50
DY'	78.12±0.49	77.87±0.47	77.92±0.33
LY'	77.69±0.52	77.14±0.48	77.36±0.35
YD'	77.30±0.53	76.23±0.55	76.79±0.38
DD'	77.69±0.52	77.39±0.52	77.44±0.36
LD'	77.82±0.53	77.18±0.51	77.43±0.36
YL'	77.26±0.50	76.77±0.53	76.99±0.36
DL'	77.22±0.51	77.03±0.55	77.04±0.36
LL'	77.77±0.50	77.02±0.45	77.35±0.33
Purebreds			
$P_{DD'-YY'}$	-0.74	0.09	-0.45
$P_{LL'-YY'}$	-0.66	-0.28	-0.54
$P_{LL'-DD'}$	0.08	-0.37	-0.09
Crossbreds			
C_{YL-YD}	-0.24	-0.10	-0.18
C_{DL-YD}	-0.19	0.05	-0.12
C_{YL-DL}	-0.05	-0.15	-0.06
Specific combining ability			
$SCA_{(YxD)}$	-0.35	-0.29	-0.31
$SCA_{(YxL)}$	-0.62	-0.21	-0.44
$SCA_{(DxL)}$	-0.21	-0.10	-0.16
Heterosis	-0.39	-0.19	-0.30
General combining ability			
GCA_Y	0.02	-0.03	0.01
GCA_D	0.05	0.04	0.04
GCA_L	-0.07	-0.01	-0.05
Maternal effect			
M_Y	0.62	1.00	0.75
M_D	-0.11	-0.74	-0.34
M_L	-0.51	-0.26	-0.38

Feed Efficiency. Pigs of different mating groups differed ($P<.05$) for feed efficiency from 56 days of age to 95.3 kg weight only (Table 15). No significant difference among purebred progeny was noted; yet, purebred Durocs tended to consume feed more efficiently than purebred Landraces or Yorkshires. The Yorkshire x Duroc, Landrace x Duroc and Yorkshire x Landrace pigs were slightly more efficient ($P<.05$) than purebred Yorkshires or purebred Landraces.

Specific combining ability was significant ($P<.05$) for feed efficiency from 56 days of age to 95.3 kg body weight in Yorkshire x Duroc (YD' and DY'), Yorkshire x Landrace (YL' and LY') and Duroc x Landrace (DL' and LD') crossbreds (Table 15).

General combining ability was not significant for feed efficiency. Maternal effect was different ($P<.05$) for feed efficiency from 56 days to 95.3 kg in Yorkshires (Table 15). Although there was no significant difference for feed efficiency from 56 days to 154 days of age, the data indicated a trend similar to that found from 56 days to 95.3 kg body weight. In general, crossbreds were superior (0.13 less feed per unit of gain or 4% heterosis) to purebreds in feed efficiency. This is in agreement with a reported 3 percent in early studies by Winters et al. (1935), and Hutton and Russell (1939) who reported a 4% advantage for crossbreds.

Carcass Measurements and Lean Cuts. Breed of sire by breed of dam interaction for backfat thickness was significant ($P<.01$). However, there were several significant differences due to breed of sire and breed of dam in carcass measurements (Table 10). Interaction effects of carcass length and loin eye area were not significant.

Yorkshire purebreds had 0.25 cm less (P<.05) carcass backfat thickness than Landrace purebreds (Table 15). Among the crossbreds the Duroc x Landrace had 0.19 cm less (P<.01) backfat than Yorkshire x Landrace crossbreds. A negative heterosis effect as described by Bereskin et al. (1971) was also noted in backfat thickness, loin eye area and dressing percentage, although differences in backfat thickness were the only significant breed of sire by breed of dam interaction.

Yorkshire maternal effect resulted in 0.16 cm less (P<.05) backfat thickness and Durocs caused 0.13 cm more (not significant) backfat on carcasses of their progeny (Table 15). Specific combining ability in the Yorkshire x Landrace crossbreds contributed 0.15 cm more (P<.01) backfat and that of the Duroc x Landrace contributed 0.12 cm less (P<.05) backfat.

Although there were no significant differences in percent four lean cuts, percent five lean cuts or percent ham and loin, small differences among the mating groups were in favor of crossbreds (Tables 16, 17, 18 and 19). In general the overall effect of heterosis for carcass traits was that crossbreds were a little longer, had slightly more backfat thickness and less loin eye area, yet produced slightly larger percentages of lean cuts. Johnson et al. (1973) also concluded that there was little evidence of heterosis for carcass measurements or yield of lean cuts.

CHAPTER V

SUMMARY

In order to compare heterosis and combining ability of Yorkshire, Duroc and Landrace, litters of purebreds and crossbreds or two types of crossbreds in the same litter were produced by inseminating a mixture of semen containing an equal number of sperm from two boars of different breeds. Boars from the three breeds were mated with the gilts in a diallel mating scheme which resulted in three types of purebred progeny and six types of crossbred progeny.

Differences in years were significant for most of the traits studied. Sex significantly affected post-weaning performance and carcass traits. Breed of dam and breed of sire had significant effects on some traits: Landrace sired 1.17 pigs more (P<.01) in a within litter mating group at 154 days of age than Yorkshire. For weight gains of pigs, Landrace showed superior (P<.01) as a sire or as a dam while Duroc appeared to be superior (P<.01) as a sire only. Pigs by Duroc sires had the lowest (P<.05) feed requirement per kg of gain. Pigs by Yorkshire or Landrace (either dam or sire) had longer (P<.01) carcasses. Yorkshire dams and Duroc sires produced progeny slightly superior in carcass merit.

Interaction of breed of dam by breed of sire expressed heterosis for pigs born during both years. Interactions of year by breed of dam and by breed of sire also indicated heterosis that was different in magnitude but in the same direction. Heterosis expressed as significant differences between overall averages of purebreds and crossbreds was not significant but the average number of pigs in crossbred mating groups was larger than those in purebreds and accounted for 9-10% heterosis. Specific combining ability between Yorkshire and Landrace was significant ($P<.05$) for number of pigs in a mating group.

There were significant heterosis effects expressed for heavier ($P<.01$) individual weight of crossbreds at 21, 56 and 154 days of age. Crossbreds reached 95.3 kg 20.4 days sooner ($P<.01$) and were more efficient ($P<.05$) in gain than purebreds. Specific combining ability was also significant for these weights except between Yorkshire and Landrace crosses for weights at 21 and 56 days. There was little evidence of heterosis for carcass measurements and yields. A negative heterosis was found in backfat thickness, but it was not significant. Specific combining ability between Duroc and Landrace and between Yorkshire and Landrace were significant for backfat thickness.

This study showed that among the mating groups, progeny from Landrace and Yorkshire (LY' or YL') produced more pigs in a within litter mating group but had slower weight gains and carried more backfat. In contrast Duroc and Landrace crosses (DL' or LD') produced fewer pigs in a within litter mating group but gained weight faster and more efficiently, reached 95.3 kg earlier and carried less backfat. For breeding market swine in a two breed cross, the mating of Duroc sires and Landrace dams is the most desirable cross.

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APPENDIX

APPENDIX TABLE I. ANALYSIS OF VARIANCE FOR NUMBERS OF PIGS IN A WITHIN LITTER MATING GROUPS

Source of variation	df	Mean squares for No. of pigs in a within litter mating groups			
		0 day	21 day	56 day	154 day
Year (Y)	1	1.88	34.78*	27.58*	18.87
Dam breed (B')	2	1.51	9.95	10.15	10.29
Sire breed (B)	2	13.67	16.32	20.65	22.22*
B' x B	4	27.19*	9.23	7.33	5.48
B' x Y	2	3.88	4.31	2.72	1.52
B x Y	2	24.66	17.49	22.21*	22.33*
B' x B x Y	4	11.88	16.20	16.61	14.69
Residual	223[a]	9.28	7.52	6.88	6.57

[a]Residual degrees of freedom for 21, 56 and 154 day were 209, 208 and 206 respectively.

*P<.05

APPENDIX TABLE 2. ANALYSIS OF VARIANCE FOR INDIVIDUAL PIG WEIGHTS AND AGES TO 95.3 kg

Source of variation	df	Mean squares for individual pig weights and age to 95.3 kg				
		0 day weight	21 day weight	56 day weight	154 day weight	Age to 95.3 kg
Year (Y)	1	0.22	2.46	1234.17**	55.01	24691.25**
Sex	1	0.65**	0.53	0.22	2036.27**	10079.18**
Dam breed (B')	2	0.73**	21.18**	201.09**	963.68**	7708.14**
Sire breed (B)	2	1.10**	11.43**	63.11**	700.13*	2613.32*
B' x B	4	0.11	7.13**	127.94**	5033.97**	18575.03**
B' x Y	2	1.09**	0.28	43.61*	111.43	189.93
B x Y	2	0.04	1.99	40.35*	1190.39**	1463.37
B' x B x Y	4	0.25*	6.71**	4.63	49.49	192.58
Residual[a]	1232	0.09	1.56	12.12	172.91	617.53

[a]Residual degrees of freedom for 21 day weight = 987, residual degrees of freedom for 56 day weight = 960, residual degrees of freedom for 154 day weight = 938 and residual degrees of freedom for age to 95.3 kg = 916.

* P<.05
** P<.01

APPENDIX TABLE 3. ANALYSIS OF VARIANCE FOR FEED EFFICIENCY AND CARCASS MEASUREMENTS

Source of variance	df[a]	Mean squares for feed efficiency and carcass measurements					
		Feed/Gain 56-154 day	Feed/Gain 56 day-end	Carcass length	Carcass backfat	Loin eye area	df[b]
Year (Y)	1	3.96**	2.10**	273.43**	23.84**	226.02**	1
Sex	-	-	-	42.68**	2.83**	536.51**	1
Dam breed (B')	2	0.23	0.04	61.03**	0.45+	88.74**	2
Sire breed (B)	2	0.34*	0.33*	48.51**	0.53+	119.09**	2
B' x B	4	0.07	0.21*	8.46	0.69**	17.68	4
B' x Y	2	0.02	0.14	1.24	0.25	3.49	2
B x Y	2	0.00	0.01	1.57	0.07	58.26**	2
B' x B x Y	4	0.06	0.01	19.15**	0.44*	6.76	4
Slaughter weight	-	-	-	960.17**	3.49**	1055.27**	1
Residual	206	0.10	0.08	4.53	0.18	17.52	477

[a]Degrees of freedom in far-left column apply to feed/gain.

[b]Degrees of freedom in far-right column apply to carcass measurements.

*P<.05

APPENDIX TABLE 4. ANALYSIS OF VARIANCE FOR CUT YIELD FROM CARCASSES CUT THE AMERICAN METHOD AND JAPANESE METHOD AND POOLED METHOD

		Mean squares for 4 lean cuts and 5 lean cuts					
		4 lean cuts			5 lean cuts		
Source of variation	df	American	Japanese	Pooled	American	Japanese	Pooled
Year (Y)	1	3914.74**	379.38**	1434.17**	1913.47**	535.38**	2124.40**
Sex	1	47.11	226.14**	314.28**	12.41	225.85**	232.17**
Dam breed (B')	2	6.60	13.31	7.74	13.18	6.00	4.00
Sire breed (B)	2	64.87**	4.66	31.47	31.71	0.89	15.04
Cut[a]	1	-	-	1172.88**	-	-	303.79**
B' x B	4	10.98	32.22	34.64	12.07	28.02	31.27
B' x Y	2	0.82	28.80	16.67	9.49	38.30	33.77
B x Y	2	11.24	28.77	13.15	16.42	15.62	7.97
B' x B x Y	4	11.32	42.87	10.90	15.48	41.06	21.98
Slaughter weight	1	23.22	41.96	71.66	11.67	20.37	23.09
Residual[b]	476	14.03	17.17	22.33	17.23	21.18	23.49

[a]Degrees of freedom for pooled data.

[b]Degrees of freedom for pooled data, degrees of freedom for American cutting = 265 and degrees of freedom for Japanese cutting = 192.

* P<.05

** P<.01

APPENDIX TABLE 5. ANALYSIS OF VARIANCE FOR HAM AND LOIN PERCENTAGES AND DRESSING PERCENTAGES BY CUTTING METHOD

		Mean squares for ham and loin percentage and dressing percentage					
		Ham and loin percentage			Dressing percentage		
Source of variation	df	American	Japanese	Pooled	American	Japanese	Pooled
Year (Y)	1	1923.27**	114.68**	854.60**	43.14*	0.00	6.99
Sex	1	66.02**	119.19**	227.55**	11.45	0.14	2.11
Dam breed (B')	2	7.22	6.31	22.30	9.00	4.64	13.82
Sire breed (B)	2	43.59**	0.69	22.96	9.22	5.86	1.94
Cut[a]	1	-	-	687.52**	-	-	22.68
B' x B	4	9.77	14.74	19.76	3.70	2.25	5.40
B' x Y	2	3.01	12.69	5.15	28.20*	15.33	33.57**
B x Y	2	8.04	6.95	14.20	3.58	6.94	10.77
B' x B x Y	4	12.22	20.23*	9.96	0.85	5.36	4.40
Slaughter weight	1	19.85	15.43	43.49	6.46	5.29	9.21
Residual[b]	476	9.17	8.03	11.68	6.89	5.67	6.27

[a]Degrees of freedom for pooled data.

[b]Degrees of freedom for pooled data (degrees of freedom for American cutting = 265 and degrees of freedom for Japanese cutting = 192).

* P<.05
** P<.01

A COMPARISON OF CROSSBRED AND PUREBRED PROGENY FROM DIALLEL MATINGS IN SWINE

by

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Boars and gilts from the three breeds were used in a diallel mating scheme which allowed a comparison of heterosis and combining ability of Yorkshires, Durocs and Landraces. Purebreds and crossbreds or two types of crossbreds were produced in the same litter by inseminating a gilt with a mixture of semen containing an equal number of spermatozoa from two boars of different breeds. A total of 1251 pigs from 150 litters or 241 within litter mating groups were farrowed in 1971 and 1972 representing three purebred and six crossbred mating groups each year. The traits studied were the number of pigs in a within litter mating group, individual pig weight at birth, 21, 56 and 154 days, age to 95.3 kg, feed efficiency, carcass measurements and cut yields.

Year differences were significant for number of pigs in a within litter mating group at 21 and 56 days and were highly significant for pig weights at 56 days, age to 95.3 kg, feed efficiency, carcass measurements and cut yields. Sex highly significantly affected weights at birth and 154 days, age to 95.3 kg, carcass measurements and cut yields. Breed of dam and breed of sire significantly affected several traits. Landrace boars sired 1.17 more pigs ($P<.01$) in a within litter mating group at 154 days of age than Yorkshire sires. Landrace produced heavier progeny ($P<.01$) both as sires and as dams. Duroc sires produced pigs with the lowest ($P<.05$) feed requirement per kg of gain. Pigs produced by Yorkshire and Landrace (dam or sire) had longer ($P<.01$) carcasses. Pigs produced by Duroc boars yielded leaner carcasses ($P<.05$).

Differences in the numbers of pigs in a within litter mating group existed ($P<.05$) at birth. Landrace and Duroc sires were more effective competitors when a semen mixture was inseminated, resulting in 6.15 pigs by Landrace x Yorkshire and 6.11 pigs by Duroc x Yorkshire. The average number of pigs in crossbred mating groups was larger than in purebreds and accounted for 10 percent heterosis. Specific combining ability between Yorkshire and Landrace was significant for the number of pigs in a within litter mating group.

Heterosis was expressed by heavier ($P<.01$) individual weight at 21, 56 and 154 days and crossbreds reached 95.3 kg 0 days sooner ($P<.01$) and more efficient ($P<.05$) than purebreds. For these traits, the three types of crossbreds exceeded the two parental breeds involved in the cross except for Yorkshire and Landrace cross for weight at 21 and 56 days. There was little evidence of heterosis for carcass measurements and cut yields. A negative heterosis was found in backfat thickness but it was not significant; however, the Duroc and Landrace crossbreds had less ($P<.05$) and Yorkshire and Landrace crossbreds had more ($P<.05$) backfat than the parental breed averages.

Landrace and Yorkshire (LY' or YL') produced more pigs in a within litter mating group but their progeny gained more slowly and had more backfat. In contrast Duroc and Landrace crosses (DL' or LD") produced fewer pigs in a within litter mating group but gained faster and more efficiently, reached 95.3 kg earlier and had less backfat.