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EVALUATION OF PUREBREDS AND TWO-BREED CROSSES IN SWINE: REPRODUCTIVE PERFORMANCE

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EVALUATION OF PUREBREDS AND TWO-BREED CROSSES IN SWINE: REPRODUCTIVE PERFORMANCE[1]

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Summary

The data included records on 440 purebred sows and gilts of Duroc, Hampshire and Yorkshire breeding mated in all combinations to produce purebred and two-breed cross litters. A total of 119 purebred gilts (39 with purebred litters and 80 with crossbred litters) were slaughtered 30-days postbreeding and their reproductive tracts evaluated for number of corpora lutea and early embryo development. Farrowing records included 89 purebred and 161 two-breed cross litters produced at the Ft. Reno Experiment Station during the spring and fall of 1971 and the summer of 1972.

Reproductive failures (females not exhibiting estrus or open at slaughter or open at farrowing) amounted to 13.4% of the total number of females selected to be mated. There was little difference between the percentage of failures for sows or gilts; however, Yorkshires had a failure rate of 23.4% compared to 8.5% for Durocs and Hampshires.

Duroc and Yorkshire gilts each averaged 13.8 corpora lutea, which was 1.7 more ($P<.01$) than that for Hampshire gilts. Gilts with crossbred litters averaged 6.3% more embryos at 30-days postbreeding, 8.7% more pigs at farrowing and 17.9% more pigs at weaning than dams with purebred litters. Although the differences were not significant, the Duroc and Hampshire gilts with crossbred litters tended to have more normal embryos than did Duroc and Hampshire gilts with purebred litters; however, there was little difference in number of embryos between purebred and crossbred litters from Yorkshire gilts. Using a boar of another breed on Duroc dams increased litter size by 1.44 ± .59 pigs at farrowing and by 1.54 ± .49 pigs at 42 days. Crossbreeding increased the litter size for Hampshire dams by 0.61 ± .61 pigs at farrowing and 1.33 ± .52 pigs at 42 days. Yorkshire dams with crossbred litters had 0.37 ± .66 more pigs per litter at farrowing and 0.30 ± .55 more pigs per litter at 42 days than Yorkshires with purebred litters. The survival rate for crossbred pigs compared to purebred pigs was 7.6% higher for Duroc dams and 17.9% higher for Hampshire dams; however, there was no difference in the survival rate of purebreds and crossbreds from Yorkshire dams. There was little evidence for differences in embryo length or average pig weight per litter between purebreds and crossbreds from any breed of dam. Yorkshire dams had larger litters at each age and the survival rate of pigs from Yorkshire dams was approximately 12% higher than the survival rate of pigs from Duroc and Hampshire dams.

Introduction

Most measurements of sow productivity tend to be lowly heritable and respond well to crossbreeding. Crosses of inbred lines of swine have resulted in increases over the average of the lines making up the cross ranging from 0 to 20% in number of pigs farrowed and 6 to 40% in number of pigs weaned (Craft, 1953; Dickerson *et al.*, 1954; O'Ferrall *et al.*, 1968). Craft (1953) concluded that crosses of inbred lines from different breeds generally have shown considerably more heterosis than crosses of lines within a breed.

Only a few crossbreeding experiments utilizing non-inbred parents have been reported. Litter size of the cross *vs.* purebred litter is variable (Winters *et al.*, 1935; Lush, Shearer and Culbertson, 1939; Robison, 1948; Cunningham,

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1967; Smith and McLaren, 1967). However, all of these studies were consistent in reporting increased survival rates for the crossbred pigs.

Lush *et al.* (1939) suggested that breeds may differ in their response to crossing. Craft (1953) and Bradford, Chapman and Grummer (1958) have shown that the comparison of inbred lines for litter traits was of little value in predicting the performance of a line as a dam line in crossing. Since there is little information available involving crossbreeding with the modern-day breeds of swine raised under confinement management systems, data on the purebred performance and combining ability are needed in order to develop breeding programs that will yield maximum performance.

This paper provides information concerning the reproductive performance of purebred Duroc, Hampshire and Yorkshire females when producing purebred and crossbred litters. Productivity was evaluated 30-days postbreeding, at farrowing, at 21-days postfarrowing and when litters were weaned at 42-days of age.

Materials and Methods

Data for this study came from the first phase of the Oklahoma swine crossbreeding project being conducted at the Ft. Reno Experiment Station. Purebred Durocs, Hampshires and Yorkshires were mated in all combinations to produce purebred and two-breed cross litters. The formation and maintenance of the foundation herds from which the boars and gilts came was previously described by Johnson, Omtvedt and Walters (1973).

The present study included 301 gilts and 139 sows. Fifty-nine of these females were considered to have reproductive failures and the data of 12 were not used because of injury, illness or disease to the dam. Of the remaining females, 119 were gilts slaughtered 30 days postbreeding (39 with purebred and 80 with crossbred embryos) and 250 farrowed litters (89 purebred and 161 crossbred). Gilts slaughtered 30-days postbreeding were evaluated for number of corpora lutea, number of live embryos, ratio of number of live embryos to the total number of corpora lutea and embryo length in millimeters. Litter records were evaluated in terms of litter size, total litter weight and average pig weight per litter (unadjusted for litter size) at 0, 21 and 42 days and the percentage of number of pigs weaned of the pigs farrowed per litter (survival rate.)

The basic plan for this phase of the study was to mate each of six boars of each breed to three gilts of each breed. One of the three gilts of each breed mated to each boar was randomly designated to be slaughtered 30-days postbreeding and the reproductive tract evaluated for early embryo development. This procedure was followed in making matings for the spring 1971 farrowing season, in which slaughter and farrow information is included on 45 and 89 gilts, respectively. In order to increase the numbers available for evaluating early embryo development, about half of the gilts that farrowed in spring 1971 were randomly selected to produce a second litter in fall 1971. Approximately the same number of gilts as the previous season were also mated. A new group of boars of each breed was used and the matings were made in the manner described above. In this season, each boar was mated to at least two gilts and one sow of each breed. All of the sows and enough gilts to produce 10 litters for each of the nine mating types were retained for farrowing with the remaining gilts slaughtered. This resulted in 74 gilts being slaughtered and 90 litter records for fall 1971.

Because of management difficulties in the fall 1971 farrowing season, excessive post-farrowing losses occurred and sows and gilts that farrowed in the season were remated in late winter to farrow in summer 1972. These sows were randomly mated in the same manner as described for the other seasons to a new group of boars of each breed. No sows were slaughtered and 71 litters from this season are included in the analyses.

All litter records for all sows in fall 1971 and summer 1972 were adjusted to a gilt equivalent based on the observed differences between sows and gilts in fall 1971. Adjustments were made from the average difference between observed means for sows and gilts of each breed type. The average difference for each trait was subtracted from the observed value for all sow litters. The adjustments were 0.15, 0.49 and 0.46 for number of pigs per litter, 1.59, 7.32 and 14.85 kg for litter weight and 0.18, 0.98 and 1.94 kg for average pig weight per litter at birth, 21 and 42 days, respectively, and 4.17% for survival rate from birth to weaning. The same adjustment factor was used for sows of all breed groups; however, it is possible the difference between sows and gilts may depend on the breed involved. Numbers in this study were too small to detect this.

Estrus was detected with the assistance of a teaser boar and hand mating was used in all seasons. The gilts and sows were maintained throughout the gestation period in dry lots equipped with individual feeding stalls in

TABLE 1. NUMBER OF GILT LITTERS EVALUATED 30–DAYS POSTBREEDING AND NUMBER OF GILT AND SOW LITTERS FARROWED IN EACH SEASON FOR EACH MATING TYPE

	1971 Spring		1971 Fall			1972 Summer
Mating type[a]	Gilts slaughtered	Gilts farrowed	Gilts slaughtered	Gilts farrowed	Sows farrowed	Sows farrowed
D X D	5	11	8	7	6	9
H X D	4	10	8	6	2	9
Y X D	5	10	13	5	5	7
H X H	5	10	9	6	6	10
D X H	5	11	7	7	5	6
Y X H	6	11	8	5	5	9
Y X Y	6	9	6	5	3	7
D X Y	6	9	7	4	5	9
H X Y	3	8	8	4	4	5
Totals	45	89	74	49	41	71

[a]D = Duroc, H = Hampshire, Y = Yorkshire. First letter indicates breed of sire and the second letter indicates breed of dam.

groups of 16 head per lot. They were brought to the farrowing crates and then moved with their litters to a nursery barn 3 to 7 days after farrowing. Sows and litters were maintained in the nursery, one litter per pen, until weaned at 42 days of age. The pigs were given access to creep feed after the 21-day weights were obtained.

The gilts used to study ovulation rates and early embryo development were slaughtered approximately 30-days postbreeding on a weekly basis. The entire reproductive tract was recovered, the ovaries removed and the number of corpora lutea counted. The embryos were removed, counted and crown-rump measurements made while embryos were still enclosed in the amnion. Gilts returning to estrus after being mated during each estrus throughout the 8-week breeding period were also slaughtered and their reproductive tracts observed for gross abnormalities.

Records on all gilts and sows that farrowed at least one live pig are included except records of nine sows and gilts that had serious difficulties at parturition or that had been injured or ill prior to parturition or shortly after parturition such that the entire litter was lost. The records of three gilts slaughtered 30-days post-breeding were deleted because of serious injury prior to slaughter.

All litter traits from birth to weaning were subjected to a preliminary analysis to determine the importance of sire effects. The data were analyzed by least squares according to the following model: $y_{ijklm} = \mu + R_i + B_j + (RB)_{ij} + s_{k(j)} + D_\ell + (RD)_{i\ell} + (BD)_{j\ell} + (RBD)_{ij\ell} + e_{ijk\ell m}$, where $y_{ijk\ell m}$ = observed value of the dependent variable for the m^{th} litter in the $ijk\ell^{th}$ subclass, μ = fitted mean, R_i = effect of the i^{th} season, B_j = effect of the j^{th} sire breed, $s_{k(j)}$ = effect of the k^{th} sire in the j^{th} sire breed, D_ℓ = effect of the ℓ^{th} dam breed, $(RB)_{ij}$, $(RD)_{i\ell}$, $(BD)_{j\ell}$ and $(RBD)_{ij\ell}$ = interaction effects and $e_{ijk\ell m}$ = random element. All effects except $s_{k(j)}$ and $e_{ijk\ell m}$ are considered fixed effects and $s_{k(j)}$ and $e_{ijk\ell m}$ are considered random effects with zero means and variances σ_s^2 and σ^2, respectively. The mean squares and degrees of freedom for sire effects and residual only from these analyses are presented in table 2. Sire mean squares were not significant for any trait suggesting that the sire component of variance is zero or quite small for these traits. Reddy, Lasley and Mayer (1958) also demonstrated that sires were not an important source of variation for litter size. Sire effects were then deleted from the model and all 30-day postbreeding traits, except number of corpora lutea, and litter traits from birth to weaning were analyzed by least squares according to the reduced model with the effects as described above. For the trait average embryo length per litter 30-days postbreeding the partial regression of embryo length on days pregnant was added to the model. The model for number of corpora lutea per gilt included only the effects of season, breed of dam and their interaction.

The primary interest in this phase of the study was the performance of a purebred dam of each breed when mated pure as compared to when mated to a boar of another breed. For each trait least squares means and specific comparisons among means were made from linear functions of the least squares estimates of the effects in the model.

TABLE 2. DEGREES OF FREEDOM AND MEAN SQUARES FOR SIRES AND ERROR FOR LITTER TRAITS FROM BIRTH TO WEANING

		No. pigs/litter at			Litter weight, kg			Avg pig weight/litter			Survival
Item	df	Birth	21 days	42 days	Birth	21 days	42 days	Birth	21 days	42 days	rate
Sires	32	6.63	5.36	5.47	8.41	167.4	845.7	0.04	0.75	4.40	462.3
Error[a]	191	6.72	4.68	4.64	7.75	117.7	572.8	0.04	0.66	3.02	541.9

[a]Error degrees of freedom for 21 and 42 day traits equals 184.

Results

Reproductive Efficiency. The distribution of reproductive successes and failures of sows and gilts of each breed is presented in table 3. A total of 440 sows and gilts were selected to be mated during the seasons studied. Fifty-nine (13.4%) of these resulted in reproductive failures because either they were never detected in estrus (consequently never mated) or were mated but not pregnant when slaughtered or not pregnant at farrowing time. The chi-square test for differences in probability (Conover, 1971) was used to test the hypothesis that the probability of a reproductive failure was the same for gilts of all breeds of dam. The resultant test statistic was highly significant ($P < .01$), consequently this hypothesis was rejected. The percentage of reproductive failures for Duroc, Hampshire and Yorkshire gilts was 7.0, 6.0 and 23.8%, respectively. Although the sows had previously farrowed a litter, the percentage of failures for sows tended to be similar to that observed for gilts for each of the breeds. The percentage of reproductive failures for Duroc, Hampshire and Yorkshire sows was 16.3, 8.7 and 22.7%, respectively. This provides evidence that more Yorkshires than Durocs or Hampshires would need to be retained for breeding in planning for any specific number of farrowings.

Very few gross abnormalities of reproductive tracts were apparent in the open gilts that were slaughtered. A few cystic ovaries and sexually immature ovaries with no evidence of regressing corpora lutea were observed. The frequency of these abnormalities was too limited to determine if they could be a possible explanation for the breed differences observed. Although no measure of physiological age was made, all gilts were between 210 and 270 days of age at the beginning of each breeding season and all problem breeders had the opportunity to have at least three complete estrous cycles before being slaughtered. For this reason and the fact that the proportion of sows that had reproductive failures was similar to that observed for gilts, it is unlikely that the observed breed differences were due to differences in sexual maturity at breeding.

Early Embryo Development. The analyses of variance for number of corpora lutea, number of live embryos, percent live embryos of corpora lutea and embryo length for gilts slaughtered 30-days postbreeding are presented in table 4. There was no evidence for any major season or breed of sire effects for the traits evaluated. Breed of dam effects were a highly significant ($P < .01$) source of variation for all traits except the percent live embryos of corpora lutea, while mean squares for breed of

TABLE 3. TOTAL NUMBER OF FEMALES SELECTED TO BE MATED AND DISTRIBUTION OF REPRODUCTIVE SUCCESSES AND FAILURES FOR EACH BREED

	Breed of dam		
Item	Duroc	Hampshire	Yorkshire
No. of females selected to be mated	149	146	145
No. of gilts slaughtered pregnant	43	42	38
No. of gilts that farrowed	50	52	39
No. of open gilts[a]	7	6	24
No. of sows that farrowed	41	42	34
No. of open sows[a]	8	4	10
Total no. of reproductive failures	15	10	34
Percent of females selected to be mated that failed	10.1	6.8	23.4

[a]Includes all that were never observed in estrus plus those bred but not pregnant.

TABLE 4. ANALYSES OF VARIANCE FOR NUMBER OF CORPORA LUTEA, NUMBER OF LIVE EMBRYOS, PERCENT LIVE EMBRYOS OF CORPORA LUTEA AND AVERAGE EMBRYO LENGTH FOR GILTS SLAUGHTERED 30-DAYS POSTBREEDING

Source	df	No. of corpora lutea	No. of live embryos	Percent live embryos of C.L.	Avg embryo length, mm
Season (S)	1	12.161	0.681	327.323	14.868
Breed of sire (BOS)	2	—	0.185	21.510	4.573
Breed of dam (BOD)	2	36.532**	42.218**	255.212	35.363**
S X BOS	2	—	3.593	94.698	12.508
S X BOD	2	1.184	0.590	7.637	0.750
BOS X BOD	4		4.529	262.793	6.778
S X BOS X BOD	4		13.202	274.248	2.079
Covariate[a]	1	—	—	—	1328.692**
Error[b]	113	5.250	6.636	355.153	7.090

[a]Regression on days pregnant.
[b]Error degrees of freedom for number of live embryos, percent live embryos of C. L. and average embryo length are 101, 101 and 100, respectively.
**P< .01.

sire by breed of dam interaction for all traits were generally small in comparison to the respective error mean square. This suggests the sire breed is relatively unimportant for the dam productivity traits measured 30-days postbreeding. The mean squares for interaction of season with other effects in the model were generally smaller than the error mean squares providing no evidence for interactions of any effect with season in these data. The partial regression coefficient of average embryo length on the number of days pregnant was 1.55 ± .116 mm. Simultaneous fitting of the linear and quadratic regressions provided no evidence for a quadratic response within the range of days of pregnancy at the time of slaughter in this study ($\overline{X}$ = 29.15, SD = 2.68 days).

The least squares mating-type means, standard errors and specific comparisons among means for the embryo data are presented in table 5. Differences in ovulation rates for the three breeds were observed. Duroc and Yorkshire gilts each averaged 13.8 corpora lutea, which was 1.7 corpora lutea per gilt more (P < .01) than that observed for Hampshire gilts. Since gilts of each breed were approximately

TABLE 5. LEAST SQUARES BREEDING GROUP MEANS AND STANDARD ERRORS AND SPECIFIC COMPARISONS AMONG MEANS FOR LITTER TRAITS OF GILTS SLAUGHTERED 30-DAYS POSTBREEDING

Item[a]	No. slaughtered	No. corpora lutea/gilt	No. live embryos/gilt	Percent live embryos of corpora lutea	Avg embryo length/gilt
		Breeding group means			
D X D	13		10.64±.73	74.23±5.37	24.49±.76
H X D	12	13.80±.37	11.42±.77	84.19±5.60	25.21±.79
Y X D	18		10.88±.71	79.83±5.22	25.44±.76
H X H	14		8.63±.72	74.54±5.26	26.02±.75
D X H	12	12.07±.37	9.84±.75	82.74±5.52	26.38±.78
Y X H	14		9.87±.72	82.08±5.26	24.22±.76
Y X Y	12		11.42±.75	83.88±5.47	23.29±.77
D X Y	13	13.75±.39	11.28±.74	84.32±5.42	23.81±.78
H X Y	11		11.92±.80	84.80±5.82	23.67±.81
		Comparison of purebred gilts with purebred and crossbred embryos			
DW/cross - DW/pure			0.51±.90	7.78±6.58	0.84±.93
HW/cross - HW/pure			1.23±.88	7.87±6.46	-.72±.92
YW/cross - YW/pure			0.18±.93	0.68±6.83	0.45±.96
2-Breed cross-Purebreds			0.64±.52	5.44±3.83	0.19±.54

[a]D = Duroc, H = Hampshire, Y = Yorkshire.

the same age, some of this difference could be due to breed differences in physiological age at breeding and not breed genetic differences; however, physiological age of these gilts was not determined. Although the differences were not significant, purebred Duroc and Hampshire gilts with crossbred embryos had more live embryos (0.51 and 1.23, respectively) and a higher percentage of corpora lutea represented as live embryos (7.78 and 7.87%, respectively) than purebred gilts with purebred litters. There was little difference between Yorkshire gilts with purebred and crossbred litters for these traits. The average embryo length per gilt adjusted to the overall mean days pregnant of 29.15 days, but unadjusted for number of embryos, revealed no evidence for differences in embryo length between gilts with purebred and crossbred embryos.

Rather distinct breed of dam differences in number of live embryos per gilt and average embryo length per gilt were apparent. Duroc and Yorkshire gilts each averaged significantly more live embryos (1.53 and 2.09, respectively) than Hampshire gilts. Although breed of dam differences in percentage of corpora lutea represented as live embryos were not significant, assuming no difference in conception rates, the lower value in this trait for Duroc and Hampshire dams appears to be due primarily to a greater early embryonic death loss for purebred Duroc and Hampshire litters than for crossbred litters from Duroc and Hampshire dams. Embryos from Yorkshire gilts were 1.95 mm shorter than embryos from Hampshire gilts ($P < .01$) and 1.46 mm shorter than embryos from Duroc gilts ($P < .05$).

Litter Records at 0, 21 and 42 Days. The analyses of variance for the farrowing, 21-day and weaning data are given in table 6. Season was a significant source of variation for all traits except survival rate. In general litters farrowed in 1971 fall were smaller and lighter at all ages than those farrowed in 1971 spring and 1972 summer.

Breed of sire effects were significant for number of pigs per litter and litter weight at 21 and 42 days and for survival rate from birth to weaning. Breed of dam effects were also significant for all litter traits except number of pigs per litter at birth and average pig weight per litter at 42 days. Breed of sire by breed of dam interactions were significant for all litter traits except average pig weight per litter at birth and 42 days and for survival rate. Contrary to reports by Reddy *et al.* (1958) and O'Ferrall *et al.* (1968) these data suggest sire breeds do

TABLE 6. ANALYSES OF VARIANCE FOR NUMBER OF PIGS, LITTER WEIGHT AND AVERAGE PIG WEIGHT PER LITTER AT BIRTH, 21 AND 42 DAYS

		No. of pigs			Litter weight, kg			Avg pig weight/litter, kg			Percent
Source	df	Birth	21 days	42 days	Birth	21 days	42 days	Birth	21 days	42 days	survival
Season (S)	2	43.42**	15.20*	14.91*	169.46**	605.7**	5459.0**	0.204**	2.51*	50.96**	931.0
Breed of Sire (BS)	2	12.25	29.74**	28.64**	5.70	523.1*	3248.6**	0.037	0.55	0.35	2173.1*
S X BS	4	10.77	8.35	7.59	15.35	62.5	532.7	0.023	1.29	1.56	245.4
Breed of Dam (BD)	2	17.31	36.09**	42.93**	80.84**	1084.0**	6538.2**	0.981**	2.71*	5.73	3702.4**
S X BD	4	9.25	11.73*	9.77	11.26	233.7	1251.2	0.024	1.97*	3.98	511.6
BS X BD	4	19.27*	20.68**	22.29**	24.27*	469.0**	2379.0**	0.076	2.53**	4.76	959.7
S X BS X BD	8	4.81	3.43	2.69	12.26	119.5	606.2	0.020	0.35	1.88	798.3
Error[a]	223	6.74	4.80	4.76	7.82	124.6	613.7	0.042	0.67	3.20	549.6

[a]Error degrees of freedom for 21- and 42-day traits equals 216.
*$P < .05$.
**$P < .01$.

differ in their effect on litter size and litter weight but that this effect depends on the specific breed of dam involved in the mating. This suggests specific combining ability for these traits among the breeds involved.

With the exception of season by breed of dam interactions for number of pigs and average pig weight per litter at 21 days, there was little evidence for interaction of season with other effects in the model. Because the interaction for these traits was a change in magnitude of differences between breed of dam means and not a change in rank, the following discussion will be presented assuming no interaction of season with other effects in the model. This suggests the genetic differences between breeds and the specific combining effects of the breeds were approximately the same in each season. However, since some of the females involved produced litters in each season, there is some correlation in the data. Perhaps a more useable interpretation of this general lack of interaction is to conclude that gilts and sows respond approximately the same in a crossbreeding program.

Breed of sire did not appear to influence average pig weight per litter at any age; however, litters from Yorkshire sires were somewhat larger at birth and consequently heavier than litters produced by Duroc and Hampshire sires. The survival rate for pigs from Yorkshire sires was considerably higher than for pigs from Hampshire and Duroc sires; consequently, litters from Yorkshire sires were considerably larger and heavier at 21 and 42 days than those from other sire breeds. Although there is considerable difference in litter size and litter weight between the two kinds of crossbred litters from Duroc and Hampshire dams, additional data are needed in order to evaluate the influence of the breed of sire in the production of crossbred litters.

Least squares mating-type means, standard errors and specific comparisons among means for number of pigs, litter weights and average pig weights per litter at 0, 21 and 42 days and for survival rate are presented in table 7.

In the following, the performance of purebred dams of each breed when mated pure is compared to the average performance when mated to a boar of another breed. However, if breed of sire effects are important in crossbred litter productivity, the comparison should be made for each sire breed. Purebred dams of all breeds with crossbred litters had more pigs per litter and heavier litters at each age than did purebred dams with purebred litters. These differences were significant at each age for Duroc dams and at 21 and 42 days for Hampshire dams, while they were not significant at any age for Yorkshire dams. Differences in average pig weight per litter between purebreds and crossbreds for each breed of dam at all ages were generally smaller than the associated standard errors and not consistent in sign among breeds. Hampshire dams raised 17.9% more ($P < .01$) of their pigs to weaning when raising a crossbred litter than when raising a purebred litter. The difference in survival rate favoring crossbred litters of 7.6% for Duroc dams was not significant and there was virtually no difference in the survival rate of purebred and crossbred pigs from a Yorkshire dam. Overall, two-breed cross litters were significantly larger and heavier at all ages than purebred litters. The survival rate from birth to weaning for crossbred pigs was 8% higher than for purebreds so that on the average crossbred litters had 1.06 more pigs and weighed 12.23 kg more at weaning than purebred litters.

Considerable evidence for differences in breeds of dam for litter traits through weaning was also apparent. At birth both Duroc and Yorkshire dams had significantly larger litters than Hampshires while at 21 and 42 days Yorkshire dams had significantly larger litters than both Duroc and Hampshire dams. The 0.4 pig per litter difference in litter size between Duroc and Hampshire dams at 21 and 42 days was not significant. Overall, Yorkshire dams raised about 12% more of their pigs from birth to weaning than did Durocs or Hampshires while there was little difference in survival rate for pigs from Duroc and Hampshire dams.

Pigs from Yorkshire dams weighed less at birth than those from Duroc and Hampshire dams. However at 21 days of age, pigs from Yorkshire dams averaged the heaviest even though they were also from larger litters. This suggests that Yorkshire dams not only were superior mothers in terms of keeping their pigs alive but also in providing a larger supply of milk per pig than did Duroc and Hampshire dams. The fact that the differences between 42 day pig weights were small suggests that the creep feed being fed from 21 to 42 days of age tended to compensate for milk production and perhaps masks breed differences in maternal ability from 21 to 42 days. Ahlschwede and Robison (1971) reported that the covariance between direct genetic and maternal genetic effects changes with time tending to equalize 8-week body weight. These data are in agreement with their results. It should be noted that

TABLE 7. LEAST SQUARES BREED GROUP MEANS AND STANDARD ERRORS AND SPECIFIC COMPARISONS AMONG MEANS FOR NUMBER OF PIGS, LITTER WEIGHT AND AVERAGE PIG WEIGHT PER LITTER AT 0, 21 and 42 DAYS

Breed group[a]	No.[b]	No. pigs/litter			Litter weight, kg			Avg pig weight/litter, kg			Percent survival
		Birth	21 days	42 days	Birth	21 days	42 days	Birth	21 days	42 days	
Means and standard errors											
D X D	33(32)	9.14±.46	5.62±.39	5.37±.39	11.11±.49	23.18±2.00	53.25±4.43	1.26±.04	4.02±.15	9.77±.32	57.28±4.13
H X D	27(26)	9.67±.51	5.90±.43	5.79±.43	12.42±.55	28.65±2.21	61.69±4.91	1.29±.04	4.64±.16	10.32±.35	60.93±4.60
Y X D	27	11.49±.51	8.19±.43	8.03±.43	13.35±.55	33.19±2.20	78.52±4.87	1.15±.04	3.92±.16	9.49±.35	68.78±4.60
H X H	32(27)	8.94±.46	5.31±.43	5.14±.43	10.38±.50	23.28±2.20	47.47±4.87	1.16±.04	4.34±.16	9.22±.35	52.55±4.16
D X H	29	9.65±.51	6.47±.43	6.41±.43	11.68±.55	27.96±2.20	63.08±4.87	1.22±.04	4.28±.16	9.61±.35	67.92±4.60
Y X H	30	9.44±.50	6.68±.42	6.53±.42	11.54±.54	33.26±2.19	66.85±4.79	1.21±.04	4.71±.16	9.90±.34	72.91±4.52
Y X Y	24	9.92±.53	7.32±.43	7.30±.43	9.78±.57	33.79±2.19	75.89±4.86	1.01±.04	4.59±.16	10.34±.35	76.41±4.82
D X Y	27	10.73±.51	8.03±.43	7.97±.43	10.54±.55	37.79±2.20	83.95±4.87	0.99±.04	4.63±.16	10.24±.35	77.33±4.60
H X Y	21	9.85±.56	7.21±.45	7.22±.45	10.41±.60	33.20±2.31	72.51±5.13	1.05±.04	4.45±.17	9.80±.37	72.75±5.07
Comparison of purebred gilts with purebred and crossbred litters											
DW/cross–DW/pure		1.44± .59**	1.43± .50**	1.54± .49**	1.78± .63**	7.74± 2.53**	16.86± 5.61**	-.04± .047	0.26± .19	0.14± .41	7.58± 5.24
HW/cross–HW/pure		0.61± .61	1.27± .52*	1.33± .52*	1.23± .65	7.33± 2.64**	17.50± 5.86**	0.06± .048	0.16± .19	0.54± .42	17.87± 5.48**
YW/cross–YW/pure		0.37± .66	0.30± .56	0.30± .56	0.70± .71	1.70∓ 2.85	2.34± 6.31	0.01± .052	-.05± .21	-.32± .46	-1.37± 5.98
2-breed cross–purebreds		0.81± .36*	1.00± .30**	1.06± .30**	1.24± .38**	5.59± 1.55**	12.23± 3.43**	0.01± .038	0.12± .11	0.12± .25	8.03± 3.22*

[a]D = Duroc, H = Hampshire, Y = Yorkshire, with first letter designating breed of sire.
[b]Numbers in parentheses represent the number of litters for 21- and 42-day traits.
*P< .05.
**P< .01.

21-day pig weight for Hampshires were about the same as for Yorkshires, and 0.25 kg heavier than those for Durocs, but the pigs raised by Hampshires had the lightest 42-day weights.

Discussion

Squires, Dickerson and Mayer (1952) reported outbred Durocs to have 11.85 corpora lutea and 8.03 normal embryos and inbred Hampshires to have 11.43 corpora lutea and 6.73 normal embryos when gilts were slaughtered 25-days postbreeding. These breed differences were not statistically significant and not as large as reported in the present study. Reddy *et al.* (1958) slaughtered purebred Duroc gilts 55-days postbreeding and reported ovulation rate and number of live embryos to be 8.7 ± .75 and 6.6 ± 1.51, respectively. These values are considerably lower than those obtained in the present study.

The average advantage of crossbred litters over purebred litters in number of pigs per litter at 0, 21 and 42 days was 0.81 ± .36, 1.00 ± .30 and 1.06 ± .30 pigs per litter, respectively. This represents an 8.68% advantage in litter size at birth and a 17.86% advantage in number weaned for 2-breed cross litters over purebred litters. Survival rate was also 8.03 ± 3.22% higher for pigs in crossbred litters than for pigs in purebred litters. These crossbred advantages for number of pigs per litter and the increased survival rate of crossbred pigs are in general agreement with several reports in the literature (Winters *et al.*, 1935; Craft, 1953; England and Winters, 1953; Whatley, Chambers and Stephens, 1954; Smith and McLaren, 1967). However in the present study, most of the crossbred superiority was due to mating Duroc and Hampshire dams to a boar of another breed, while Yorkshire dams performed nearly the same whether producing purebred or crossbred litters. Although mating-type comparisons within each breed of dam for number of embryos 30-days postbreeding were not significant, they were in the same direction and of approximately the same magnitude for each breed of dam as were the traits from birth to weaning. This lends further support to the hypothesis that dams of these three breeds exhibit a different response to crossbreeding in litter size.

Previous workers have reported crossbred pigs to be heavier than purebred pigs at birth and at weaning (Winters *et al.*, 1935; Lush *et al.*, 1939; England and Winters, 1953; Cunningham, 1967). None of the differences between average pig weight per litter for purebreds and crossbreds in the present study were significant and all did not favor crossbreds. On the average crossbred pigs weighed 0.01 ± .04 kg more than purebreds at birth and 0.12 ± .25 kg more at weaning. This represents a relatively small increase of 0.9% at farrowing and 1.23% at 42-days in average pig weight per litter for crossbred litters over purebred litters. However, due to the increased litter size, crossbred litters were 17.9 and 20.8% heavier at birth and weaning, respectively, than purebred litters.

These data suggest some response to crossbreeding in early embryo development; however, the primary response to crossbreeding appears to be in litter size at birth and weaning and a greater survival rate for crossbred pigs than for purebred pigs. This response in the present study was due primarily to an increassed livability throughout gestation and from birth to weaning in crossbred litters produced by Duroc and Hampshire dams. Pigs raised by Yorkshire dams had the highest survival rates and there was no difference in livability between purebred and crossbred litters from Yorkshire dams.

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