THE JOURNAL OF AGRICULTURE
OF THE UNIVERSITY OF PUERTO RICO

Issued quarterly by the Agricultural Experiment Station of the University of Puerto Rico, for the publication of articles by members of its personnel, or others, dealing with any of the more technical aspects of scientific agriculture in Puerto Rico or the Caribbean Area.

Vol. XXXIII October, 1949 No. 4

CROSSBREEDING FOR SWINE PRODUCTION IN PUERTO RICO

A. González Chapel[1], and J. I. Cabrera[2]

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[1] Associate Animal Husbandman
[2] Assistant Animal Husbandman

INTRODUCTION

It is very difficult to estimate the real worth of the swine industry in Puerto Rico. According to the 1940 census, (21), there were 206, 244 swine in the Island. It is evident that the industry is not occupying the place that it should occupy in the economy of the Island. The major portion of the pork consumed in Puerto Rico is imported. Roberts, in the Soil Survey of Puerto Rico, published in 1942, (15), stated:

"According to the 1938–39 Annual Book on Statistics, $2,729,524 worth of pork and sausages and $2,373,103 worth of lard were imported from the United States during that fiscal year. This would indicate that a better quality of lard-producing hog should be raised. If as much advancement had been made in the production of corn as had been made in the production of sugar cane during the last 20 years, the hogs, corn, and in fact, the Island as a whole, would be much better off today."

During the fiscal year 1945–46, shipments of swine and swine products from the United States amounted to approximately $12,000,000 (12). These shipments were distributed as follows:

Item	*Amount*	*Value*
Hogs, live	3	193.00
Pork, not canned:		
Fresh or frozen	1,738,984 lbs.	479,226.00
Hams and shoulders, cured	4,485,145	1,441,883.00
Bacon	3,267,476	527,780.00
Other pork, pickled or salted	12,657,476	1,508,738.00
Pork, canned	2,654,546	1,082,548.00
Lard, including neutral lard	24,637,249	4,143,198.00
Sausages		3,237,690.00
Total		$12,421,256.00

Many factors have prevented the proper development of the industry. However, the most important have been the inadequacy of the Island's supply of feedstuffs combined with the high cost of imported commercial concentrate feed and the low productive capacity of the swine stock available in the Island. Other contributing factors have been the diseases and the poor management practices.

This work is mainly concerned with the problem of the breeds of swine although some feeding and management aspects of swine production are included.

No systematic or continuous effort had ever been made to help the swine

industry by finding out which breeds or types of swine, whether Native or imported, are well adapted to Puerto Rico or by the development of new or better adapted strains. The identification or development of swine genetically superior to those now being raised in the Island would make more profitable the swine enterprise possibly resulting in greater local production of pork from locally produced feedstuffs.

The main objectives of this study were to find out any practical differences between the Native swine and some of the standard breeds in Puerto Rico with respect to their productive capacity; if differences were apparent, to see which breeds were the best in the characters considered; to determine the performance of crosses of the Native with the standard breeds so as to enable the selection of crosses which appeared to have most promise as foundation stock for development of new improved strains for Puerto Rico; also to demonstrate the advantage of crossbreeding, if any, for pork production in the Island and to find out if reasonable profits could be expected by using imported concentrate feeds.

Review of Literature

The effects of climate and other environmental factors upon humans and animals have been studied extensively in the last few years in tropical and subtropical regions, for which none of the established breeds of animals seem well suited.

The evidence on effect of high temperature and high humidity as reported in humans, cattle and other animals indicates that physiological response of animals to tropical and subtropical climates is different to their response to temperate and cold climates. (2, 5, 8, 13, 14, 17).

The high temperature of tropical and subtropical regions apparently lowers the productivity of non-adapted animals, possibly by reduction of the metabolic rate and by other unknown causes. High humidity may aggravate the detrimental effect of high temperature on productivity.

Robinson and Lee (16) found that the tolerance of the pig to hot atmospheres resembles that of the fowl and the rabbit. Humidity is important at high temperatures but not at intermediate temperatures. Unlike the fowl and the rabbit, the pig's reactions to heat include a definite rise in pulse rate.

The average minimum annual temperature for Puerto Rico is 66.9° and the average maximum annual temperature is 86°. At Aibonito, where the Livestock Production Farm of the Agricultural Experiment Station is located, the lowest temperature recorded has been 40° and the highest 92°. (4).

The Island receives sunlight for at least 3,258 hours every year. (1).

Records of rainfall in Puerto Rico (20) indicate an average maximum

annual precipitation of 136 inches and a minimum of 27 inches. Because of the high mean temperatures and high rate of evaporation, the effectiveness of the rainfall is considerably less than it would be in cooler climates, and it is further reduced below that of many cooler regions because of the almost constant air movement.

Humidity is nearly always high. In some parts of the Island it is over 75 per cent most of the time.

The literature on adaptation of the different standard breeds of swine to Puerto Rico is very scarce. Bagué (1) reported data on 617 litters farrowed by imported Duroc Jersey and Hampshire sows of the Puerto Rico Reconstruction Administration herd and some of their daughters in the Island, from July, 1937 to December, 1940. He concluded that both breeds were well adapted to Puerto Rican conditions and that their pre-weaning performance compared favorably to pre-weaning performance of swine in the United States.

Experimental work on crossbreeding with hogs has been underway for many years at different places. Lush, Shearer and Culbertson (7), in a review of the literature on crossbreeding of swine, stated that most of the experimenters have reported some degree of advantage for crossbreeding but with much individual variation in the results. From data obtained through 10 years of work at the Iowa Station with 1015 pigs in 108 litters, they concluded that:

(a) The hybrid vigor from crossbreeding amounts to about 5.18 per cent increase in growth rate, in economy of gain and perhaps little more than that in vitality and fertility.

(b) Crossbred pigs outgained the purebreds by about .09 to .12 pound per day. Because of this the crossbreds reached a market weight of 225 pounds around 10 days to two weeks earlier than the purebreds.

(c) It took 25 to 30 pounds less feed to bring the crossbreds to 225 pounds than was required for the purebreds. Most of this difference, perhaps all of it, resulted from the more rapid gains.

(d) Breeds probably differ in their response to crossing; the family or strains within breeds probably differ also.

Hammond, cited by Lush et al. (7), studied the weights of hogs of several breeds and crosses at several ages up to about 11 months, as shown at the Smithfield Stock Show in England. He says,

"In several cases the cross is larger than the heavier of the parent breeds. In many instances where the difference in weight between the breeds crossed is large, the cross, although not actually heavier than the largest parent, is heavier than the mean of the parent breeds."

Shaw and MacEwan of the University of Saskatchewan, cited by Lush et al. (7), in reporting the weaning weights of 91 purebred pigs and 700

crossbreds produced by various combinations of five breeds, give the average weight of all purebreds as 35.7 pounds as compared with 39.4 pounds for all crossbreds. In the feeding trials 77 purebred pigs gained an average of 1.15 pounds per day and required 440 pounds of feed for each 100 pounds of gain as compared to 1.24 pounds daily gain and a feed requirement of 429 pounds for 325 crossbreds.

The Missouri Agricultural Experiment Station, cited by Lush et al. (7), reported a comparative feeding trial in 1936, in which 20 purebred Duroc Jersey pigs and 20 purebred Poland China pigs were compared with 20 pigs representing reciprocal crosses of the two breeds. The crossbred pigs made an average daily gain of 1.34 pounds per day and required 320 pounds of feed per 100 pounds of gain. The purebred Poland Chinas averaged 1.26 pounds in daily gain on a feed requirement of 300 pounds for each 100 pounds of gain. The purebred Duroc Jersey gained 1.08 pounds per day and required 317 pounds of feed per 100 pounds of gain.

Lush, Shearer and Culbertson (7), summarises the results of crossbreeding as follows:

"With small numbers it is to be expected that some experiments would show no advantage for crossbreeding, since characteristics such as growth rate, vitality and fertility are widely variable within breeds, within herds, and even within litters. However, nearly all those who have studied this question have found advantages (not always "statistically significant" ones) for the crossbred pigs, and therefore the conclusion seems unescapable that, in general, crossbred pigs tend to be somewhat more vigorous and thrifty than would be expected from the average of the two parent breeds. Because of this added vigor the crossbreds generally show a lower death rate up to weaning time and consequently larger and heavier litters weaned. Also, they generally gain weight a little more rapidly on a little less feed than the purebreds."

Developing better breeds for tropical climates is being done with cattle and other animals at different parts of the world. It is possible to find differential response of the different breeds of animals to the tropical environment. Crossing standard breeds with native stocks appears to be a definite possibility for obtaining adaptability together with relatively high productivity (14).

Materials and Methods

The comparison of the different breeds and crossbreds, reported in this paper, was started at the La Plata Animal Production Substation of the Agricultural Experiment Station, University of Puerto Rico, on March, 1946, and the feeding trials extended to August, 1948. Prior to these trials, several breeds and crossbreds had been tested at La Plata. On the basis of information gathered during the preliminary work, the Hampshire breed and the crossbreds Hampshire x Native and Hamphsire x Duroc were not included in the main testing which was started on March, 1946. The fol-

lowing breeds and crossbreds were included in one or more of the different trials reported here: Duroc Jersey, Native, Duroc x Native, Landrace Large Black x Duroc, Landrace Large Black x Native, Tamworth x Duroc, and Tamworth x Native.

Although many other crosses could have been made, there was obviously a limit to the scope of the work that could be attempted and it was felt that the diversity of the genetic material involved would probably result in one or more crosses, as good or almost as good, as would likely be discovered in a much wider search.

The Duroc Jersey pigs used came from stock originally imported by the Puerto Rico Reconstruction Administration in 1937. According to Bagué (1) the original imported stock was bought for the P.R.R.A. by men from the U. S. Bureau of Animal Industry and were duly certified and registered in the United Duroc Record Association, Peoria, Illinois. No outside blood was introduced to the original stock at La Plata and it had been under selection for growth rate and general conformation for about at least 4 years prior to the start of this experiment.

The Native stock was obtained through purchases of Native pigs throughout the Island approximately five years before this work was started. During that time, they were also bred with special emphasis on growth rate and general conformation. At the start of this experiment, therefore, this stock was no longer representative of the Island stock, but was an example of what could be done with the Native stock given proper selection and good management practices.

The Tamworth boars used came from the Mayagüez Agricultural College where they had been inbred for a number of years.

The Landrace Large Black boar was furnished by the Beltsville Federal Experiment Station at Maryland. This boar was a product of a cross of the Landrace and the English Large Black and had 13.8 per cent inbreeding.

From March, 1946, to August, 1948, four farrowing seasons were held. The first one consisted of 9 Duroc Jersey, 11 Native and 7 Landrace Large Black x Native litters; the second included 10 Native, 3 Landrace Large Black x Native, 6 Duroc x Native, and 4 Landrace Large Black x Duroc litters; the third consisted of 4 Duroc Jersey, 5 Landrace Large Black x Native, 7 Duroc x Native, 5 Landrace Large Black x Duroc, 6 Tamworth x Duroc, and 7 Tamworth x Native litters; the fourth included 4 Native, 5 Landrace Large Black x Native, 3 Duroc x Native, 6 Landrace Large Black x Duroc, 5 Tamworth x Duroc, and 5 Tamworth x Native litters. A total of 112 litters were thus considered in the pre-weaning information gathered.

Pre-weaning data recorded and considered here included number of pigs farrowed, still-born pigs, farrowing weight, number of pigs weaned, and weaning weight. The pigs were weaned at 56 days.

At weaning time pigs from some of the litters, representing all the breeds, were put into feeding trials. The facilities available prevented the use of samples from all the litters farrowed. Whenever possible a boar, a barrow, and two gilts, from each litter selected, were included in the post-weaning testing but in some instances three or four gilts were included. Generally, the pigs having the best weaning weight in each litter were selected, but in few cases pigs with outstanding desirable characteristics were included regardless of the weaning weight.

The pigs on feeding trials were weighed every 14 days until they reached approximately 180 to 200 pounds. At the start and at the end of the trial they were weighed for three consecutive days. For comparison of the breeds in this work, the data of the gain to 154 days of age was only considered. The feed consumption was also recorded at intervals of 14 days.

Four feeding trials were made, that is, one following each farrowing season, as follows:

1. From June 16, 1946 to January 9, 1947. A total of 69 pigs entered this trial, including 16 boars, 18 barrows and 35 gilts from 6 Duroc, 8 Native, and 5 Landrace Large Black x Native litters.

2. From February 14, 1947 to June 30, 1947. A total of 78 pigs entered this trial, including 18 boars, 18 barrows and 42 gilts from 9 Native, 3 Landrace Large Black x Native, 4 Duroc x Native and 4 Landrace Large Black x Duroc litters.

3. From August 28, 1947 to March 11, 1948. A total of 80 pigs entered this trial, including 24 boars, 22 barrows, and 34 gilts from 4 Duroc, 4 Landrace Large Black x Native, 5 Duroc x Native, 4 Landrace Large Black x Duroc, 5 Tamworth x Duroc and 4 Tamworth x Native litters.

4. From March 20, 1948 to August 31, 1948. A total of 59 pigs entered this experiment including 14 boars, 13 barrows and 32 gilts from 3 Native, 3 Landrace Large Black x Native, 3 Duroc x Native, and 5 Landrace Large Black x Duroc litters.

Thus, a grand total of 286 pigs entered the four feeding trials including 74 boars, 69 barrows and 143 gilts from the different breeds and crossbreds compared.

Post-weaning data recorded and considered here included rate of gain as measured by average daily gain of each pig since the start of the trial to 154 days of age, or for 98 days on feed; and efficiency of food utilization as measured by the feed consumed per one hundred pounds of gain.

The pigs on feeding trials were confined since weaning on pens 10′ x 10′. These pens were exatly alike and were close together in an area of approximately 2 acres. The feed was given ad libitum in self-feeders provided for each pig.

The feed given to the pigs on the trials was standard commercial concentrate feed imported from the United States. Merker grass was added

daily to their ration. The same men took care of all the pigs throughout the experiment.

The methods of analysis of variance outlined by Snedecor (18) were used in the study of the pre-weaning information. A method adapted by Capó (3) to the solution of normal equations was used in the study of the post-weaning information. Other special statistical analyses used are explained in the text. In the tables of analysis of variance one asterisk represents statistical significance at the 5 per cent level of probability and two asterisks represents statistical significance at the 1 per cent level of probability.

Presentation of the Results

comparison of the breeds

Pre-weaning performance

A summary of the pre-weaning information obtained for the purebred and crossbred litters is shown in table 1. There was no statistical significance for the differences in many of the characteristics. This could have been due to the small number of litters studied and to the wide variation within the breeds.

The standard deviations for all breeds and crossbreds in the different characteristics are presented in table 2.

In the discussion that follows, the Duroc Jersey and the Native breeds are compared not only with each other but also in the results obtained from crosses between them and with the Landrace Large Black and the Tamworth breeds. In addition, a comparison is made between all crossbreds, the Natives vs. the Native crossbreds, and the Durocs vs. the Duroc crossbreds.

Comparison of purebreds

Duroc Jersey vs. Native.—The Duroc Jersey breed surpassed the Native in each of the six main characteristics considered. However, none of the differences, except that of the average birth weight of the pigs, 0.59 lbs. and that of the litters, 9.54 lbs., were statistically significant. In table 3 the analysis of variance for these two characteristics is presented.

The Natives were represented in trials 1, 2 and 4; the Durocs in trials 1 and 3. However, the differences between the trials for each breed were not significant except for average weaning weight of the Duroc pigs which were significantly heavier in trial number 1 than in trial number 3. A comparison of the Durocs and the Natives for trial number 1 showed that the differences between the two breeds in this characteristic were statistically non-significant.

TABLE 1

Summary of pre-weaning information of purebred and crossbred litters

Breed	Characteristics							
	Total litters Farrowed	Average size of litters	Ave. birth wgt. of pigs lbs.	Ave. birth wgt. of litters lbs.	Ave. no. of pigs weaned per litter lbs.	Ave. weaning wgt. of pigs lbs.	Ave. weaning wgt. of litters lbs.	Percentage of pigs farrowed that lived to weaning
Duroc Jersey	13	11.07	2.65	29.34	6.31	26.43	166.77	57.00
Native	25	9.61	2.06	19.80	6.12	23.53	144.00	63.68
Duroc x Native	16	10.56	2.12	22.39	7.50	28.17	211.28	71.02
Landrace Large Black x Duroc	15	10.93	2.74	29.95	8.33	27.10	225.74	76.21
Landrace Large Black x Native	20	10.00	2.09	20.90	6.05	29.12	176.18	60.50
Tamworth x Duroc	11	12.54	2.71	33.98	9.82	26.64	261.60	78.30
Tamworth x Native	12	12.42	2.20	27.32	7.16	23.07	165.18	57.64

The Natives weaned 6.68 per cent more of the pigs that they farrowed than the Durocs

Landrace Large Black x Duroc vs. Landrace Large Black x Native.—The Landrace Large Black x Duroc cross was better than the Landrace Large Black x Native cross in all the characteristics considered except average weaning weight of the pigs. The Landrace Large Black x Native pigs weighed more at weaning but the weaning weight of the Landrace Large Black x Duroc litters was still heavier because they weaned more pigs per litter.

The differences in three characteristics were statistically significant: in average birth weights of the pigs, 0.65 lbs., and in that of the litters, 9.05 lbs., and in average weaning weights of the litters, 49.56 lbs. In table 4 the corresponding analyses of variance is shown.

TABLE 2

Standard deviations for six characteristics of purebred and crossbred litters

Breed	Characteristics					
	Ave. size of litters pigs	Ave. birth wgt. of pigs lbs.	Ave. birth wgt. of litters lbs.	Ave. no. of pigs weaned per litter pigs	Ave. weaning wgt. of pigs lbs.	Ave. weaning wgt. of litters lbs.
Duroc Jersey	2.39	0.39	4.75	2.95	4.94	73.55
Native	2.33	0.32	5.81	2.67	3.87	60.81
Duroc x Native	3.31	0.45	6.01	2.07	5.24	87.78
Landrace Large Black x Duroc	2.46	0.38	3.94	2.85	6.30	68.73
Landrance Large Black x Native	4.54	0.41	8.56	2.58	5.10	72.29
Tamworth x Duroc	2.74	0.43	6.38	2.23	5.58	75.37
Tamworth x Native	3.87	0.32	7.64	3.13	7.46	83.02

The Landrace Large Black x Duroc cross was represented in trials 2, 3 and 4. The Landrace Large Black x Native in trials 1, 2, 3 and 4. However, the differences between the trials in each breed were not statistically significant, except for average number of pigs weaned per litter. A comparison of the two crossbreds in this characteristic for trials 2, 3 and 4 shows that the differences between them were statistically non-significant and that the interaction was negligible. However, the effect of the trials was statistically significant showing that some factor in trial number 4 made the average number of pigs weaned per litter to be smaller than in trials 2 and 3, for the two breeds. The effect of trials is shown in the analysis of variance of table 5.

The Landrace Large Black x Duroc crossbreds weaned 15.71 per cent more of the pigs farrowed than the Landrace Large Black x Native.

TABLE 3

Analysis of variance of the average birth weight of the pigs and of the litters. (Durocs and Natives)

Source of variation	d/f	Individuals		Litters	
		Sum of squares	Mean square	Sum of squares	Mean square
Between breeds	1	2.9740	2.9740**	697.0186	697.0186**
Within breeds	36	4.2481	0.1180	1084.1465	30.1152

TABLE 4

Analysis of variance of the average birth weight of the pigs, of the litters and of the average weaning weight of the litters. (Landrace Large Black x Duroc and Landrace Large Black x Native)

Source of variation	d/f	Sum of squares	Mean square
Birth weights of the pigs			
Between breeds	1	3.3444	3.3444**
Within breeds	32	5.0398	0.1575
Birth weights of the litters			
Between breeds	1	688.3771	688.3771**
Within breeds	32	1534.7505	47.9609
Weaning weights of the litters			
Between breeds	1	27,449.5020	27,449.5020*
Within breeds	31	155,480.3928	5,015.4965

TABLE 5

Analysis of variance of the average number of pigs weaned per litter. (Landrace Large Black x Duroc and Landrace Large Black x Native)

Source of variation	Degrees of freedom	Sum of squares	Mean square
Breeds	1	20.5101	20.5101
Trials	2	51.3378	25.6689*
Interaction	2	1.1835	0.5918
Individuals	22	127.9000	5.8136

The variation within the breeds in the different characteristics was considerable.

Tamworth x Duroc vs. Tamworth x Native.—The Tamworth x Duroc cross surpassed the Tamworth x Native in each of the six main characteristics

considered. The differences were statistically significant in all the characteristics except litter size and average weaning weight of the pigs.

The corresponding analyses of variance are presented in table 6.

The Tamworth x Duroc and Tamworth x Native were represented in trials 3 and 4. The differences between the trials were not statistically

TABLE 6

Analysis of variance of the average birth weight of the pigs, of the litters, of the average number of pigs weaned per litter and of the average weaning weight of the litters. (Tamworth x Duroc and Tamworth x Native)

Source of variation	d/f	Sum of squares	Mean square
Birth weight of the pigs			
Breeds	1	1.4296	1.4296**
Trials	1	0.0573	0.0573
Interaction	1	0.0678	0.0678
Individuals	19	2.8464	0.1498
Birth weight of the litters			
Breeds	1	545.1556	545.1556**
Trials	1	10.9578	10.9578
Interaction	1	0.1579	0.1579
Individuals	19	1038.1018	54.6369
Pigs weaned per litter			
Breeds	1	39.6651	39.6651*
Trials	1	1.6759	1.6759
Interaction	1	1.7648	1.7648
Individuals	19	153.8619	8.0980
Weaning weight of the litters			
Breeds	1	41,241.4962	41,241.4962*
Trials	1	22,657.0132	22,657.0132
Interaction	1	539.1560	539.1560
Individuals	19	109,397.5869	5,757.7677

significant except for average weaning weight of pigs which was significantly better in trial number 4. The interaction was however, negligible, showing that both breeds were similarly affected by the effects of trials. The analysis of variance of the effect of the trials is shown in table 7.

The Tamworth x Duroc weaned 20.66 per cent more of the pigs farrowed than the Tamworth x Native.

Duroc x Native vs. Duroc and Native.—The Duroc x Native cross fared better than the Native in each of the six characteristics but the differences

were not statistically significant except that between the average weaning weights of the pigs, 4.64 lbs., and that between the average weaning weights of the litters, 67.28 lbs. In table 8 the analyses of variance for these two characteristics is shown.

The Durocs were superior to the cross in litter size and birth weights of pigs and litters, but they were inferior in number of pigs weaned and in weaning weights of pigs and litters. The differences were statistically significant in favor of the Durocs in average birth weight of the pigs, 0.53 lb.,

TABLE 7

Analysis of variance of the average weaning weight of the pigs. (Tamworth x Duroc and Tamworth x Native)

Source of variation	d/f	Sum of squares	Mean square
Breeds	1	61.8313	61.8313
Trials	1	308.5595	308.5595**
Interaction	1	14.1879	14.1879
Individuals	19	601.1481	31.6394

TABLE 8

Analysis of variance of the average weaning weights of the pigs and of the litters. (Duroc x Native and Native)

Source of variation	d/f	Sum of squares	Mean square
Weaning weight of the pigs			
Between breeds	1	210.2083	210.2803**
Within breeds	39	771.7875	19.7894
Weaning weight of the litters			
Between breeds	1	42,344.0968	42,344.0968**
Within breeds	39	204,377.9376	5,240.4599

and average birth weight of the litters, 6.95 lbs. Table 9 shows the corresponding analyses of variance.

The differences were statistically significant in favor of the cross in average weaning weight of the pigs, 1.74 lbs. A comparison was made of trial number 3, where the two breeds were represented, because the differences between the trials were statistically significant for these characteristics in the Duroc breed. The analysis of variance is shown in table 10.

The Duroc x Native weaned 7.34 per cent more of the pigs farrowed than the Natives and 14.02 per cent more than the Durocs.

In nearly all of the characteristics the Duroc x Native varied more than the purebreds.

Summary.—Although the differences were not always statistically significant, the Durocs and the Duroc crosses fared better in nearly all the characteristics than the Natives and the corresponding Native crosses. Statistical significance in favor of the Durocs and the Duroc crosses was found in birth weight of pigs and of litters. The Duroc crosses were also significantly better than the Native crosses in weaning weight of litters. In addition, the Tamworth x Duroc cross weaned more pigs than the Tamworth x Native. The superiority of the Duroc x Native cross was more evident over the Natives than over the Durocs.

TABLE 9

Analysis of variance of the average birth weights of the pigs and litters. (Duroc x Native and Duroc)

Source of variation	d/f	Sum of squares	Mean square
Birth weight of the pigs			
Between breeds	1	1.9983	1.9983**
Within breeds	27	4.8191	0.1784
Birth weight of the litters			
Between breeds	1	388.1970	388.1970**
Within breeds	27	817.3813	30.2734

TABLE 10

Analysis of variance of the average weaning weight of the pigs. (Duroc x Native and Duroc)

Source of variation	d/f	Sum of squares	Mean square
Between breeds	1	151.0321	151.0321**
Within breeds	9	114.3331	12.7037

Comparison of crossbreds

General comparison of all crossbreds. The average litter size was similar for all the crossbreds, varying from an average litter of 10 pigs in the Landrace Large Black x Native to 12.54 pigs in the Tamworth x Duroc. None of the differences were statistically significant. The Landrace Large Black x Duroc litters were more uniform in this characteristic than the other crossbreds.

The average birth weights of the Landrace Large Black x Duroc pigs and of the Tamworth x Duroc were significantly superior to those of the other crossbreds.

The average birth weights of the litters of the Landrace Large Black x Duroc and of the Tamworth x Duroc were also significantly better to those

of the other crossbreds. The uniformity of the Landrace Large Black x Duroc litters, with a standard deviation of 3.94 lbs., was exceptional when compared to the relatively wide variation within the other crossbreds.

In respect to the average number of pigs weaned, there were statistically significant differences between the trials in some of the breeds. A comparison of the trials in which the five crossbreds were represented, that is, trials 3 and 4, was made. The Tamworth x Duroc was found to be significantly superior to the Tamworth x Native and Landrace Large Black x Native, but the other differences were not significant.

The same analysis was applied to the average weaning weight of the pigs. The Landrace Large Black x Native and the Duroc x Native were found to be superior to the Tamworth x Native, but the other differences were not significant.

The average weaning weight of the litters of the Landrace Large Black x Duroc and of the Tamworth x Duroc was significantly superior to that of the Landrace Large Black x Native and of the Tamworth x Native. The other differences were not significant. Here again, the Landrace Large Black x Duroc litters were more uniform than those of the other crossbreds.

Summary.—In pre-weaning performance, the Landrace Large Black x Duroc and the Tamworth x Duroc were, in general, better than the other crossbreds. The Duroc x Native was slightly better than the Landrace Large Black x Native and the Tamworth x Native.

Native vs. Native crossbreds.—A comparison of the pre-weaning performance of the purebred Native and the crossbred Native is shown in table 11. The only differences which were statistically significant were those between the Native and the Duroc x Native for average weaning weights of the pigs and the litters, and between the Native and the Landrace Large Black x Native for average weaning weight of the pigs. However, a look at the table will show that although there was no statistical significance in every case, the crossbreds, in general, fared better than the Native in each of the six main pre-weaning characteristics considered here. The crossbreds, Duroc x Native, Landrace Large Black x Native and Tamworth x Native, not only farrowed more pigs but the pigs and the litters weighed more at birth. They also weaned more pigs with better weaning weights, individually and by litters.

The added vitality of the crossbred pigs was more noticeable in the percentage of still-born pigs than in the extra number of pigs weaned. The 25 Native litters consisted of 240 pigs of which 19, or 7.92 per cent were born dead. The Native crossbred litters were composed of 48 litters with 500 pigs of which 35, or 7.00 per cent, were born dead.

Duroc vs. Duroc crossbreds.—The pre-weaning performances of the pure-

TABLE 11

Comparison of pre-weaning performance of purebred and crossbred Native litters

Breed	Total litters farrowed	Ave. size of litters	Ave. birth wgt. of pigs lbs.	Ave. birth wgt. of litters lbs.	Ave. no. of pigs weaned per litter	Ave. weaning wgt. of pigs lbs.	Ave. weaning wgt. of litters lbs.	Percentage of pigs farrowed that lived to weaning
	Characteristics							
Native	25	9.61	2.06	19.80	6.12	23.53	144.00	63.68
Duroc x Native	16	10.56	2.12	22.39	7.50	28.17	211.28	71.02
Advantage of the crossbreds		0.95	0.06	2.59	1.38	4.64	67.28	7.34
Landrace Large Black x Native	20	10.00	2.09	20.90	6.05	29.12	176.18	60.50
Advantage of the crossbreds		0.39	0.03	1.10	−0.07	5.59	32.18	3.18
Tamworth x Native	12	12.42	2.20	27.32	7.16	23.07	165.18	57.64
Advantage of the crossbreds		2.81	0.14	7.52	1.04	−0.46	21.18	−6.04

TABLE 12

Comparison of pre-weaning performance of purebred and crossbred Duroc Jersey litters

Breeds	Total litters farrowed	Ave. size of litters	Ave. birth wgt. of pigs lbs.	Ave. birth wgt. of litter lbs.	Ave. no. of pigs weaned per litter	Ave. weaning wgt. of pigs lbs.	Ave. weaning wgt. of litters lbs.	Percentage of pigs farrowed that lived to weaning
	Characteristics							
Duroc Jersey	13	11.07	2.65	29.34	6.31	26.43	166.77	57.00
Duroc x Native	16	10.56	2.12	22.39	7.50	28.17	211.28	71.02
Advantage of the crossbreds		−0.51	−0.53	6.95	1.19	1.74	44.51	14.02
Landrace Large Black x Duroc	15	10.93	2.74	29.95	8.33	27.10	225.74	76.21
Advantage of the crossbreds		−0.14	0.09	0.61	2.02	0.67	58.97	19.21
Tamworth x Durco	11	12.54	2.71	33.98	9.82	26.64	261.60	78.30
Advantage of the crossbreds		1.47	0.06	4.64	3.51	0.21	94.83	21.30

bred Duroc and the crossbred Duroc are presented in table 12. The Duroc was significantly better than the Duroc x Native in birth weight of pigs and litters. The Tamworth x Duroc was found to be superior to the Duroc in number of pigs weaned and weaning weight of the litters. Although the other differences were not statistically significant it can be observed from the table that the crossbreds were, with few exceptions, better than the Duroc in most of the six main characteristics considered here.

The added vitality of the crossbred pigs is clearly seen when comparing the number weaned, the percentage of pigs farrowed that survived to weaning and the percentage of still-born pigs of the purebred Durocs with the crossbreds. The crossbred pigs, Duroc x Native, Landrace Large Black x Duroc, and Tamworth x Duroc, weaned 1.19, 2.02 and 3.51 more pigs respectively than the Duroc. The increase in the percentage of pigs farrowed that lived to weaning was 14.02, 19.21 and 21.30 per cent more, respectively. The 13 Duroc litters consisted of 144 pigs of which 18 were born dead, or 12.50 per cent of the pigs farrowed; the 42 Duroc crossbred litters were composed of 471 pigs of which 30 were born dead, or only 6.37 per cent of the pigs farrowed.

Post-weaning performance

The statistical analysis of the data of the post-weaning performance of the different breeds and crossbreds was made following a method adapted by Capó (3) for the solution of a system of simultaneous linear equations with a large number of independent variables. In this case there were 11 variables, that is, 7 breeds and 4 trials. Different analyses were made for the boars, the barrows, and the gilts for daily rate of gain and efficiency of food utilization.

Although it was recognized that litters were an important source of variation they were not considered as such in the analysis made, because the main objective was to find out differences between the breeds. The litters were considered to be random samples of the potentialities of each breed.

Rate of gain

Boars.—In table 13 the information obtained on the daily rate of gain of the boars of the different breeds in the four trials is presented.

In general, and excepting the Tamworth crosses, the Native crossbred boars gained faster than the Natives and the Duroc crossbred boars gained faster than the Durocs. The differences were statistically significant in favor of the Landrace Large Black x Duroc over the Landrace Large Black x Native, the Native, the Tamworth x Duroc and the Tamworth x Native; in favor of the Duroc x Native and the Duroc over the Native and the Tamworth x Native; and in favor of the Landrace Large Black x Native

over the Tamworth x Native. The other differences, including those between the trials, were not statistically significant.

Gilts.—The information gathered on the daily rate of gain of the gilts of the different breeds is shown in table 14.

TABLE 13

Daily rate of gain of boars of the different breeds and crossbreds up to 154 days of age.
(*In pounds*)

Breeds	Trials				Average for breeds
	1	2	3	4	
Native	1.20	1.25	—	1.23	1.22
Landrace Large Black x Native	1.31	1.37	1.30	1.41	1.34
Tamworth x Native	—	—	0.92	—	0.92
Duroc x Native	—	1.29	1.47	1.36	1.38
Duroc	1.43	—	1.28	—	1.37
Landrace Large Black x Duroc	—	1.54	1.32	1.50	1.45
Tamworth x Duroc	—	—	1.20	—	1.20
Average for trials	1.31	1.33	1.25	1.39	1.31

TABLE 14

Daily rate of gain of gilts of the different breeds and crossbreds up to 154 days of age.
(*In pounds*)

Breeds	Trials				Average for breeds
	1	2	3	4	
Native	1.01	1.03	—	1.02	1.02
Landrace Large Black x Native	1.15	1.17	1.24	1.30	1.20
Tamworth x Native	—	—	1.05	—	1.05
Duroc x Native	—	1.27	1.25	1.30	1.28
Duroc	1.35	—	0.98	—	1.19
Landrace Large Black x Duroc	—	1.27	1.19	1.37	1.30
Tamworth x Duroc	—	—	1.16	—	1.16
Average for trials	1.17	1.14	1.13	1.28	1.17

In general, the Native crossbred gilts gained faster than the Natives and the Duroc crossbred gilts, excepting the Tamworth x Duroc, gained faster than the Durocs. The differences were significant in favor of the Landrace Large Black x Duroc over the Native, the Tamworth x Native, the Tamworth x Duroc and the Landrace Large Black x Native; in favor of the Duroc x Native over the Native and the Tamworth x Native; and in favor

of the Duroc and the Landrace Large Black x Native over the Native. The other differences, including those between the trials, were not statistically significant.

Barrows.—Table 15 gives the information obtained on the daily rate of gain of the barrows of the different breeds in the four trials.

TABLE 15

Daily rate of gain of barrows of the different breeds and crossbreds up to 154 days of age. (*In pounds*)

Breeds	Trials				Average for breeds
	1	2	3	4	
Native	1.09	1.22	—	1.06	1.15
Landrace Large Black x Native	1.24	1.25	1.40	1.28	1.29
Tamworth x Native	—	—	1.06	—	1.06
Duroc x Native	—	1.38	1.26	1.31	1.32
Duroc	1.41	—	1.25	—	1.35
Landrace Large Black x Duroc	—	1.25	1.26	1.44	1.32
Tamworth x Duroc	—	—	1.06	—	1.06
Average for trials	1.25	1.27	1.21	1.31	1.25

In general, the Native crossbred barrows gained faster than the Natives. The rate of gain of the Duroc crossbred barrows, with the exception of the Tamworth x Duroc, was similar to that of the Durocs.

The differences were significant in favor of the Duroc, Landrace Large Black x Duroc, Duroc x Native and Landrace Large Black x Native over the Native, Tamworth x Duroc and Tamworth x Native. The other differences, including those between the trials, were not statistically significant.

Summary.—In table 16 a summary of the data on daily rate of gain of the pigs is presented.

TABLE 16

Summary of the daily rate of gain of purebred and crossbred pigs up to 154 days of age. (*In pounds*)

Breeds	Gilts	Boars	Barrows
Landrace Large Black x Duroc	1.30	1.45	1.32
Durocs x Native	1.28	1.38	1.32
Landrace Large Black x Native	1.20	1.34	1.29
Duroc	1.19	1.37	1.35
Tamworth x Duroc	1.16	1.20	1.06
Tamworth x Native	1.05	0.92	1.06
Native	1.02	1.22	1.15

The differences between the Landrace Large Black x Duroc, the Duroc x Native and the Duroc were not statistically significant.

With the exception of the Tamworth crosses, the crossbreds and the Duroc were definitely superior to the Native in daily rate of gain.

The Tamworth x Duroc and the Native were better than the Tamworth x Native although the differences were not statistically significant.

Efficiency of food utilization

Boars.—The efficiency of food utilization of the boars of the different breeds, expressed in pounds of feed needed for a gain of 100 pounds in live-weight, is presented in table 17, for the four trials.

TABLE 17

Efficiency of food utilization of boars of the different breeds and crossbreds. (Based on data up to 154 days of age and expressed in term of feed per 100 pounds gain).

Breeds	Trials 1	2	3	4	Average for breeds
Native	370	373	—	381	373
Landrace Large Black x Native	400	350	434	436	404
Tamworth x Native	—	—	419	—	419
Duroc x Native	—	382	380	375	379
Duroc	381	—	331	—	361
Landrace Large Black x Duroc	—	345	415	361	376
Tamworth x Duroc	—	—	378	—	378
Average for trials	382	367	393	381	382

The efficiency of all boars in trial 2 was significantly better than that recorded in trial 3. This was probably due to the behaviour of the Landrace Large Black x Native and Landrace Large Black x Duroc boars in these trials. Some uncontrollable factor or factors caused the efficiency of the Landrace Large Black x Native boars to be better in trial 2 than it was in trials 3, 4 and 1. The Landrace Large Black x Duroc boars needed more feed per 100 pounds of gain in trial 3 than they did in trials 2 and 4.

The Duroc and the Native were more efficient than the Landrace Large Black x Native, the differences being significant at the 1 per cent level of probability. The Landrace Large Black x Duroc, the Tamworth x Duroc and the Duroc x Native were also better than the Landrace Large Black x Native, although the differences were significant at the 5 per cent level of probability. The Durocs were more efficient than the Tamworth x Native; statistically significant at the 5 per cent level. The Native, the Landrace Large Black x Duroc and the Tamworth x Duroc were also better than the

Tamworth x Native, near the 5 per cent point of statistical significance. The other differences were not statistically significant. The Tamworth x Native were more efficient than the Landrace Large Black x Native, although not significantly. That is the probable reason why they appear somewhat better than the Landrace Large Black x Native in the overall analysis.

Gilts.—Table 18 shows the efficiency of food utilization for the gilts of the different breeds.

The efficiency of all gilts in trial 4 was significantly better than that of the gilts in the other trials. This was probably due to some uncontrollable factor or factors that caused the efficiency of the Landrace Large Black x

TABLE 18

Efficiency of food utilization of the gilts of the different breeds and crossbreds. (Based on data up to 154 days of age and expressed in term of feed per 100 pounds gain)

Breeds	Trials 1	2	3	4	Average for breeds
Native	408	399	—	400	402
Landrace Large Black x Native	432	438	430	383	426
Tamworth x Native	—	—	403	—	403
Duroc x Native	—	381	425	359	382
Duroc	384	—	375	—	380
Landrace Large Black x Duroc	—	377	436	361	382
Tamworth x Duroc	—	—	376	—	376
Average for trials	406	396	404	369	395

Native, Duroc x Native and Landrace Large Black x Duroc to be better in trial 4 than in the other trials where they were compared.

All the breeds and the other crossbreds were significantly more efficient than the Landrace Large Black x Native. The other differences were not significant.

Barrows.—The efficiency of food utilization for the barrows of the different breeds is given in table 19.

The efficiency of all barrows in trial 2 was better than that of trial 1, the difference being statistically significant at the 5 per cent level of probability. Some uncontrollable factor or factors caused the efficiency of the Native and Landrace Large Black x Native barrows to be better in trial 2 than in trial 1.

The Durocs were more efficient than the Tamworth x Native and Landrace Large Black x Native; the differences being significant at the 1 per cent level of probability. The Duroc x Native and Native were more efficient

than the Tamworth x Native and Landrace Large Black x Native, although the differences were significant at the 5 per cent level. The Landrace Large Black x Duroc was more efficient than the Tamworth x Native, the difference being significant at the 5 per cent level. They also used less feed than the Landrace Large Black x Native, although the difference was just

TABLE 19

Efficiency of food utilization of the barrows of the different breeds and crossbreds. (Based on data up to 154 days of age and expressed in term of feed per 100 pounds gain.)

Breeds	Trials 1	2	3	4	Average for breeds
Native	412	386	—	395	397
Landrace Large Black x Native	427	409	407	459	423
Tamworth x Native	—	—	429	—	429
Duroc x Native	—	406	400	380	396
Duroc	393	—	376	—	387
Landrace Large Black x Duroc	—	400	411	396	402
Tamworth x Duroc	—	—	406	—	406
Average for trials	409	397	406	403	404

short of the point of significance. The other differences were not statistically significant.

Summary.—Although there were significant differences between the trials in the efficiency of the boars, gilts and barrows a summary of the data is shown in table 20 for the convenience of the reader.

In general, the Duroc crossbred gilts and boars were similar to the Durocs in efficiency of food utilization. The difference between the Duroc barrows and the Duroc crossbred barrows was not statistically significant.

TABLE 20

Summary of the efficiency of food utilization of purebred and crossbred pigs. (Based on data up to 154 days of age and expressed in term of feed per 100 pounds gain.)

Breeds	Gilts	Boars	Barrows
Landrace Large Black x Duroc	382	376	402
Duroc x Native	382	379	396
Landrace Large Black x Native	426	404	423
Duroc	380	361	387
Tamworth x Duroc	376	378	406
Tamworth x Native	403	419	429
Native	402	373	397

The Landrace Large Black x Native and Tamworth x Native were almost always less efficient than the other breeds and crossbreds.

The Natives were in general as efficient as the Duroc crossbreds.

Gain and final weight at 154 days of age

For a better understanding of the data presented on the rate of gain of the pigs, the average total gain from weaning to 154 days of age and the average weight at 154 days of age for all purebreds and crossbred pigs is presented in table 21.

TABLE 21

Average total gain from weaning to 154 days of age and average weight at 154 days for all purebred and crossbred pigs

Breeds	Gilts		Boars		Barrows	
	Gain	Weight at 154 days	Gain	Weight at 154 days	Gain	Weight at 154 days
Landrace Large Black x Duroc	127.4	158	141.7	176	128.8	159
Duroc x Native	125.4	156	134.8	167	129.2	159
Landrace Large Black x Native	117.3	149	131.5	165	126.4	158
Duroc	116.5	143	134.1	165	132.9	162
Tamworth x Duroc	113.4	142	117.2	151	104.0	135
Tamworth x Native	102.6	131	90.0	120	103.7	134
Native	100.4	125	120.2	150	112.9	139

Average number of days to reach 200 pounds of weight

Another way of showing the rate of gain of the pigs of the different breeds and including growth after 154 days of age is presented in table 22.

TABLE 22

Average number of days to reach 200 pounds of weight (approximate)

Breeds	Days		
	Gilts	Boars	Barrows
Landrace Large Black x Duroc	183.3	171.8	179.7
Duroc x Native	183.4	176.5	182.6
Landrace Large Black x Native	192.8	180.6	182.8
Duroc	189.3	175.9	181.0
Tamworth x Duroc	193.0	196.0	191.3
Tamworth x Native	206.5	211.0	194.7
Native	205.2	190.3	197.5

The relative differences between the breeds were similar after 154 days of age. The Landrace Large Black x Duroc gilts reached 200 pounds around 6 days before the Durocs and the boars around 4 days earlier. The advantage for the crossbreds in rate of gain, however, is more evident for the first 154 days of age.

INTERRELATIONSHIP OF CHARACTERISTICS

Pre-weaning characteristics

The relationship between four pre-weaning characteristics was studied using the data obtained from 109 litters of the different breeds and crossbreds. The characteristics considered were litter size, average farrowing weight of the pigs, average number of pigs weaned and average weaning weight of the pigs.

The mean litter size in the 109 litters was 10.56 pigs with a standard deviation of 3.25 pigs; the average farrowing weight of the pigs, 2.31 lbs. with a standard deviation of 0.47 lbs.; the average number of pigs weaned was 7.17 pigs, with a standard deviation of 2.92 pigs and the average weaning weight of the pigs was 26.30 lbs. with a standard deviation of 5.72 lbs.

The correlations found between the characteristics are presented in table 23.

TABLE 23

Correlations between four pre-weaning characteristics of swine

Characteristics	Correlation
Litter size and farrowing weight	−.1790
Litter size and pigs weaned	.4808
Litter size and weaning weight	−.1216
Farrowing weight and pigs weaned	.2332
Farrowing weight and weaning weight	.1408
Pigs weaned and weaning weight	−.1086

The correlation between litter size and farrowing weight was statistically significant at the 5 per cent level of probability. This negative correlation indicates that as litter size increases the farrowing weight of the pigs tends to be smaller.

The correlation between litter size and pigs weaned was statistically significant at the 1 per cent level of probability, meaning that the larger the litter size the larger the number of pigs weaned.

The correlation between farrowing weight and pigs weaned was also statistically significant, at the 1 per cent level of probability. This indicates that the heavier the pigs at birth the larger the number of pigs that are weaned.

None of the other correlations were statistically significant.

An attempt was made to predict weaning weight when the information for the first three characteristics is available The equation describing the relationship is:

$$\text{weaning weight} = 24.01037 - .04684a + 2.01581b - .26396c$$

a being the pigs farrowed in the particular litter considered, b the average farrowing weight of the pigs and c the number of pigs weaned. However, the predicting value of this equation is doubtful because none of the regression coefficients are statistically significant.

More success can be obtained in predicting number of pigs weaned when the number of pigs farrowed and the farrowing weight of the pigs is known. The equation describing this relationship is:

$$\text{number of pigs weaned} = -2.6529 + .4849a + 2.03b$$

a being the pigs farrowed in the particular litter considered, and b the average farrowing weight of the pigs.

Post-weaning characteristics

The relationship of rate of gain with efficiency of food utilization and of those two characteristics with weaning weight of the pigs was studied in 276 pigs that entered the feeding trials. The characters were measured as before, rate of gain being the daily gain from weaning to 154 days of age. The efficiency was measured as feed consumed per 100 lbs. of gain. The correlations found are entered in table 24.

TABLE 24

Correlations between rate of gain, efficiency and weaning weight of the pigs of all breeds

Characteristics	Gilts	Barrows	Boars	Combined data
Rate of gain and efficiency.....	−.1650	−.2122	−.2966	−.2270
Weaning weight and rate of gain.....	.5698	.3169	.4149	.5027
Weaning weight and efficiency.....	.2238	.3245	.0670	.1623

For the 136 gilts the correlations between weaning weight and rate of gain, and between weaning weight and efficiency were statistically significant at the 1 per cent level of probability; and just at the 5 per cent level of significance for rate of gain and efficiency.

For the 67 barrows the correlations between weaning weight and efficiency and between weaning weight and rate of gain were statistically significant at the 1 per cent level of probability, and between rate of gain and efficiency at the 5 per cent level.

For the 73 boars the correlations between rate of gain and efficiency and between weaning weight and rate of gain were statistically significant at the 1 per cent level of probability; that between weaning weight and efficiency was not significant, being the only non-significant correlation observed.

For the 276 pigs the correlations between rate of gain and efficiency and between weaning weight and rate of gain were statistically significant at the 1 per cent level of probability, and between weaning weight and efficiency at the 5 per cent level.

From these sets of correlations the following conclusions can be drawn:

1. The negative correlation between rate of gain and efficiency as measured means that the faster the rate of gain, of this group of pigs studied, the smaller the amount of feed consumed and thus the better the feed utilization.

2. The positive correlation between weaning weight and rate of gain indicates that the heavier the weaning weight, the faster the rate of gain of the pigs.

3. The positive correlation between weaning weight and efficiency means that the heavier the weaning weight, the greater the amount of feed consumed by the pigs per 100-lb. gain in weight.

The correlation between weaning weight and rate of gain is, however, of a larger order than that between weaning weight and efficiency. The apparent contradiction in the correlations between weaning weight and the other two characters can be explained by the fact that although the heavier the weaning weight the more feed consumed, it caused also a faster rate of gain and thus, in the long run, a better efficiency.

It is apparent also that selection for rate of gain will in the long run, result in selection for efficiency.

SOME ECONOMIC ASPECTS OF SWINE PRODUCTION

Comparison of sexes

A fitting constant test of statistical analysis was done to compare the significance of the differences in rate of gain and efficiency of food utilization between the gilts, barrows and boars of the different breeds and crossbreds from weaning to 154 days of age.

In table 25 the rate of gain of the pigs of each sex is presented together with the analysis of variance.

There were statistically significant differences between the sexes but the interaction of breeds x sexes was also significant. An examination of the data shows that the boars of all the breeds, with the exception of the Tamworth x Native, had faster rate of gain than the barrows and the gilts. The

barrows of the different breeds were, in general, better than the gilts. The exceptions were the Tamworth x Duroc barrows which were inferior to the gilts of the same breed and the Tamworth x Native which were similar in rate of gain to the gilts.

Probably some of the differences in the rate of gain of the pigs of the different sexes is attributable to differences in the weaning weight of the pigs. The boars used in the feeding trials averaged 33.6 lbs. at weaning, the barrows 30.9 lbs. and the gilts 28.7 lbs. However, differences at weaning between the females and the males are real and can not be eliminated when comparing the actual possibilities of growth of the different sexes.

TABLE 25

Daily rate of gain of gilts, barrows, and boars of the different breeds and crossbreds

Sex	Rate of gain
Gilts	1.173
Barrows	1.248
Boars	1.308
Mean	1.223

Analysis of Variance

Source of variation	Degrees of freedom	Sum of squares	Mean square
Breeds	6	2.9552	0.4925**
Sexes	2	0.9738	0.4868**
Breeds x sexes	12	1.4003	0.1166**
Individuals	255	6.7504	0.0265

The fact that the pigs in this trial were separated from each other during the trial and were individually fed, partly accounts for the faster rate of gain found in the boars as compared to the barrows. The pigs selected to be barrows were castrated approximately one week before weaning and were chosen at random from the males selected for the feeding trials. The disturbance caused by castration, although temporary, may be partly responsible for the difference at weaning between the boars and the barrows.

In table 26 the efficiency of food utilization of the pigs of each sex is shown together with the corresponding analysis of variance.

There were statistically significant differences between the sexes showing that the boars were more efficient than the barrows and the gilts. This was probably due to the faster rate of gain of the boars. The barrows and the gilts were similar in efficiency although the gilts showed a tendency to be more efficient.

TABLE 26

Efficiency of food utilization of gilts, barrows, and boars of the different breeds and crossbreds. (feed per 100 lbs. of gain.)

Sex	Efficiency
Gilts	395
Barrows	404
Boars	382
Mean	393

Analysis of Variance

Source of variation	Degrees of freedom	Sum of squares	Mean square
Breeds	6	57117.31	9519.55**
Sexes	2	18654.31	9327.16**
Breeds x sexes	12	10488.39	874.03
Individuals	255	562126.00	2204.42

Influence of weaning weight on post-weaning performance

In the discussion on the interrelationship of characteristics the correlation between weaning weight and rate of gain was presented. Going a step further, the regression of gain in weight from weaning to 154 days of age on weaning weight was computed. This shows the great dependence of gain on the weaning weight of the pigs. The regression equation for all pigs was of the order: $Y = 76.2018 + 1.4903\ x$; x being the weaning weight of any given pig. The regression in the different sexes varied little from the over-all regression being:

Gilts $-Y = 68.3959 + 1.6367\ x$
Barrows $-Y = 97.0425 + 0.8674\ x$
Boars $-Y = 87.2267 + 1.2834\ x$

Figure 1 illustrates these regressions.

It is apparent that it is of the utmost importance when fattening pigs to start with pigs having a good weaning weight. In that way maximum gains may be expected.

This shows also that some of the differences in rate of gain between the breeds was due to better weaning weight of the pigs of the breeds that showed faster rate of gain. However, the differences in rate of gain are nevertheless real, regardless of the fact that they were partly due to better weaning weight. The pigs selected for feeding trials constituted in most cases the best portion of the randomly selected litters and thus constituted

the maximum expression of the different breeds both in weaning weight and rate of gain.

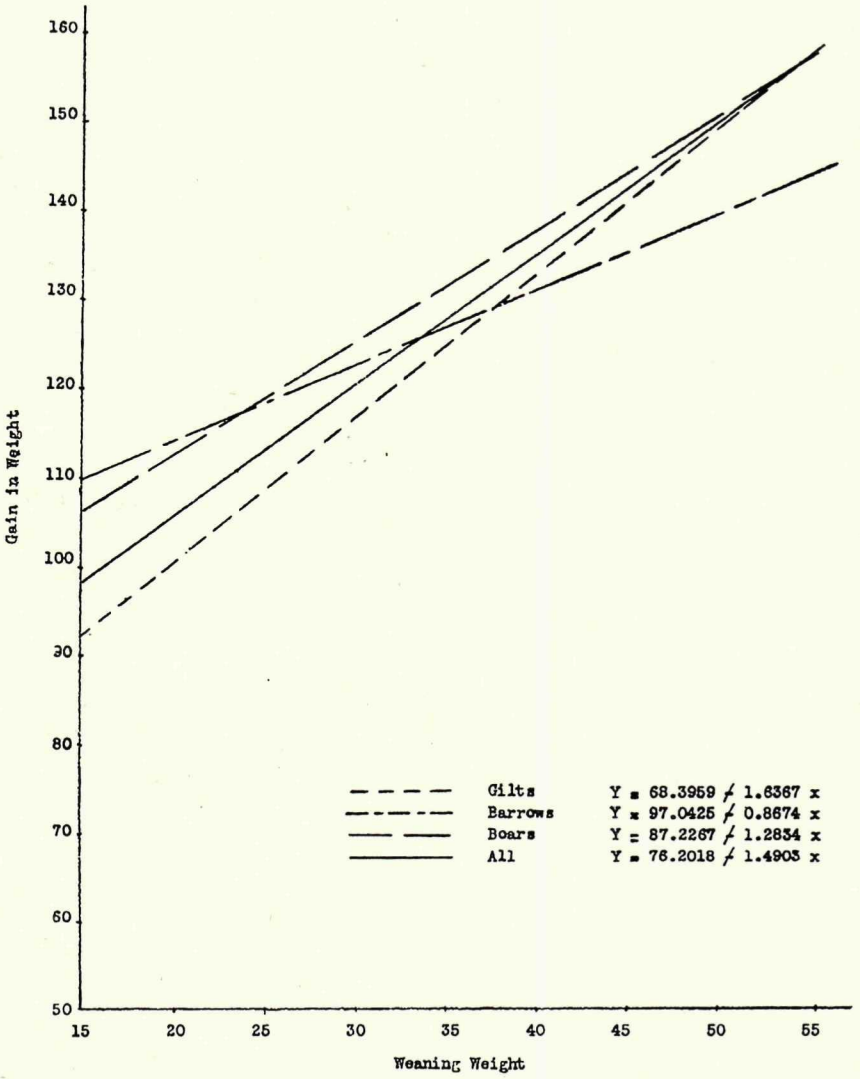

FIG. 1. Regression of gain, from weaning to 154 days of age, on weaning weight

Optimum weight to carry the hogs for maximum profit

Using the gain in weight and feed consumed by the barrows, from weaning to 154 days of age, the optimum weight to carry the hogs for maximum

profit was calculated for some of the breeds used in this study. The calculations were based on Spillman's law of the diminishing increment.

The feed eaten and the gain in weight of the pigs was measured every 14 days since weaning to 154 days of age. For each breed the data collected were plotted in a graph from which the approximate gains made by the pigs when eating feed at 50 lbs. intervals, were obtained. Using these approximate gains, and by the method outlined by W. J. Spillman (19) approximate values of the 2 constants, A and R, were found. These values of the constants were then corrected by the method described by M. Merriman (9), in his method of least squares.

With the corrected constants, and applying again Spillman's formula, the maximum weight for optimum profit were calculated for hog live-weight prices varying from 15 to 31 cents a pound and for feed costs from $3.00 to $5.50 per 100 pounds.

Due to the great variation in the gain of the crossbred barrows the data are presented only for the Duroc barrows (table 27) and the Native barrows (table 28).

The overhead cost of raising swine was assumed constant and not considered in the calculations. It is estimated at $6.02 per 100 pounds of gain, a figure obtained in a study of the swine industry in Puerto Rico made by the Economics Department of the Agricultural Experiment Station in 1944 (11). According to this study the costs of producing swine in the Island were:

	Per cent	Cost
Feed*	38	$3.71
Labor	29	2.78
Use of pens and equipment	7	0.67
Medicines	16	1.56
Interest over investment	5	0.47
Interest over explotation	—	—
Capital	3	0.28
Others	2	0.26
Total	100	$9.73

* Mostly garbage

An example of the use of the tables can be shown by considering a hypothetic situation in which the live-weight price of the hogs were 25 cents a pound and the feed cost $4.25 per 100 pounds. The weight of the Duroc barrows for maximum profit under those conditions is 165 pounds and the feed needed to reach that weight is 538 pounds. The cost of the feed would be $22.87; the overhead cost, $6.02 per 100 pounds of gain, would be $9.93.

The total cost would amount to $32.80. The pig would be sold at $41.25. The return per pig would amount to $8.45. Any reduction of the overhead cost by careful management or by use of fast gaining pigs, such as crossbred pigs, would naturally increase the return per pig.

TABLE 27

Optimum weight to carry the Duroc barrows for maximum profit. Liveweight price (cents per pound)

Feed cost per 100 #	0.15		0.17		0.19		0.21		0.23		0.25		0.27		0.29		0.31	
	F[1]	W[2]	F	W	F	W	F	W	F	W	F	W	F	W	F	W	F	W
3.00	418	143	528	163	593	174	667	185	734	195	796	202	853	209	906	215	955	219
3.25	359	131	451	150	534	164	608	177	675	189	737	195	794	202	846	208	896	213
3.50	304	118	397	139	479	155	563	168	620	178	682	187	739	195	792	202	841	208
3.75	253	196	346	128	428	145	502	159	569	170	631	180	688	188	741	195	790	202
4.00	205	94	298	117	380	135	454	150	521	162	583	173	640	181	693	189	742	196
4.25	160	81	253	106	335	126	409	141	477	154	538	165	595	175	648	183	714	192
4.50	118	69	211	95	293	116	367	132	434	146	496	158	553	168	606	176	665	184
4.75	78	57	171	84	253	106	327	124	394	138	456	150	513	161	566	170	615	178
5.00	40	44	133	73	215	96	306	119	356	130	418	143	475	154	528	163	577	172
5.25	—[3]	—	97	63	179	87	253	106	320	122	382	136	439	147	492	157	541	166
5.50	—	—	62	52	144	77	218	97	286	114	348	128	404	140	457	151	507	160

[1]Feed consumed to reach the optimum weight.
[2]Weight of the animal for maximum profit.
[3] The pigs should not be raised under those conditions.

TABLE 28

Optimum weight to carry the Native barrows for maximum profit. Liveweight price (cents per pound)

Feed cost per 100 #	0.16		0.17		0.19		0.21		0.23		0.25		0.27		0.29		0.31	
	F[1]	W[2]	F	W	F	W	F	W	F	W	F	W	F	W	F	W	F	W
3.00	167	70	246	85	316	96	379	106	436	114	489	120	538	126	583	131	625	135
3.25	116	59	195	75	265	88	329	98	386	107	439	114	487	120	532	125	574	130
3.50	70	49	148	66	219	80	282	91	339	100	406	110	440	114	485	120	527	125
3.75	26	38	105	57	175	71	238	83	296	93	363	103	397	108	442	114	484	120
4.00	—[3]	—	64	47	134	63	198	76	255	86	308	95	356	102	401	109	443	115
4.25	—	—	26	38	96	55	174	71	217	79	269	89	318	97	377	106	405	109
4.50	—	—	—	—	60	47	123	61	181	72	233	82	282	91	327	98	369	104
4.75	—	—	—	—	26	38	89	53	146	66	199	76	248	85	293	93	335	99
5.00	—	—	—	—	—	—	57	46	114	59	167	70	215	79	260	87	303	94
5.25	—	—	—	—	—	—	26	38	83	52	136	63	185	73	230	82	272	89
5.50	—	—	—	—	—	—	—	—	54	45	107	57	155	67	200	76	242	84

[1] Feed consumed to reach the optimum weight.
[2] Weight of the animal for maximum profit.
[3] The pigs should not be raised under those conditions.

The importance of the breed used in swine production is clearly seen when calculating the return per pig with the same figures as above, but for the Native barrows. Under the same conditions the weight of the Native barrows for maximum profit is 89 lbs. and the feed needed to reach that weight is 269 lbs. The cost of feed would be $11.43; the overhead cost,

$5.36; and the total cost $16.79. The pig would sell for $22.25 leaving a return per pig of only $5.46.

Although the possible profits reported here are much less than what would be expected when using garbage as feed, it is nevertheless a reasonable profit. If we consider the other advantages to be derived from using adequate feeds, such as better health of the pigs with corresponding less diseases, and specially healthier sows with healthier litters, the gap between the two different profits narrows considerably.

Crossbreeding of swine in Puerto Rico

The Native sows tested in this experiment had a smaller percentage of still-born pigs than the purebred Duroc Jersey and they also weaned a larger percentage of the pigs that they farrowed. However, the Durocs averaged more pigs weaned per litter with a better weaning weight, which in the long run makes them more profitable than the Natives. In all other pre-weaning characteristics studied the Durocs fared better than the Natives. They also showed a faster rate of gain together with better efficiency.

Basing our judgment on the characteristics studied here it is apparent that the Duroc strain used in this work seems well adapted to the Island and compares favorably with the Native strain, being a much more productive hog than the Native. However, it should be noted that other characteristics which may be of considerable importance were not considered in this study, including among them, breeding efficiency of sows and boars, and resistance to diseases and parasites. The swine used in this experiment were specially protected against parasites and diseases and their behaviour throughout this experiment may differ somewhat from what it would be under usual farm conditions in the Island. It is apparent also from the data gathered that the Duroc pigs, in some of the characteristics, and especially in weaning weight, were inferior to comparable selected herds in the United States. The reason for this should be further investigated.

Regardless of all these shortcomings it can be concluded that, considering the possibilities of crossbreeding for swine production in Puerto Rico, any superiority of crossbred pigs have to be shown over the purebread imported swine rather than over the Native swine. In this particular study the superiority of the Duroc crossbred pigs over the Durocs has been demonstrated and the advantages found for crossbreeding are as follows:

1. *Fertility*

Although not true in every case, on the average, a slight advantage was found for the crossbred pigs in fertility. It amounts to approximately 1.22 per cent more pigs farrowed per litter.

2. *Vitality*

The still-born pigs in the crossbred litters were only around half of what they were in the Duroc litters.

On the average, around 33 per cent more pigs were weaned in the crossbred litters than in the Durocs and they also weaned around 18 per cent more of the pigs that were farrowed.

The crossbred pigs averaged around one pound more per pig at weaning. Because they weaned more pigs they averaged around 63 pounds more per litter than the Durocs.

3. *Growth rate*

The Landrace Large Black x Duroc and Duroc x Native gilts had a daily rate of gain of approximately 0.10 pounds higher than that of the Durocs, and the boars, of approximately 0.05 pounds. This caused the crossbred gilts to be approximately 10 pounds heavier and the boars 5 pounds heavier than the Durocs at 5 months of age. The faster rate of gain also made the crossbred gilts reach 200 pounds of weight around 6 days sooner than the Duroc gilts. Part of this better rate of gain may be due to better weaning weight, but it is still a real advantage.

In summary, it can be stated that although great variation should be expected when crossbreeding swine, real advantage can be obtained through added vigour of the pigs, which resulted in this particular study in around 1/2 less still-born pigs, around 1/3 more pigs weaned per litter, around 63 lbs. more at weaning per litter and in a faster rate of gain which caused the gilts to weigh around 10 pounds more at 5 months than the purebreds.

General Considerations

Although work in crossbreeding of swine and on most of the productive characteristics discussed here have been extensively done before in other countries, it is felt that the wide divergence in environment, both natural and man-made, between Puerto Rico and other tropical and subtropical regions and those countries in which extensive swine studies have been done, makes necessary the collection of this fundamental information in Puerto Rico. The results to be expected in this kind of work may be widely different in the Island from those obtained in colder climates.

It is very difficult to attempt comparisons using the information ga thered here and that obtained in other places because strictly comparable data are not available. Only a very broad idea of the relative differences encountered is possible by looking at data from other countries.

Lush (6) reported that the average number of pigs farrowed in 3,337 Duroc Jersey litters from different experiment stations in the United States,

and including sows of all ages was 9.78 pigs; the average number of pigs weaned per litter in 2,104 Duroc Jersey litters was 5.62; in respect to weaning weight per litter, in the Missouri and Illinois Stations, where pigs were weaned at 56 days, and including other breeds besides the Duroc Jersey, an average litter weight of 180 and 218 lbs., respectively, was reported

In the few litters studied here the average number of pigs farrowed for the Duroc breed was 11.07; the number weaned was 6.31; and the weaning weight of the litters was 167 lbs.

This may be an indication that the sows of the Duroc strain at La Plata are farrowing and weaning more pigs but with less weight at weaning than sows of that breed in the States. The reason for this, if true, is not clear due to the many factors that could be involved. Further investigation of these differences, however, would be worthwhile.

In this work special stress has been given to the problem of a profitable breed of swine for Puerto Rico. The breeding work now in progress at the Station, with the Native, Duroc and lines developed from crosses, may eventually give an appropriate solution to this problem. Other pressing problems which have prevented the proper development of the swine industry in the Island, are still essentially untouched.

Exploration of the Island's resources for the preparation of an adequate swine feed cheaper than the concentrate feed imported from the States is sorely needed.

More management studies, specially as it concerns actual farm conditions, would be a great help for the industry.

The diseases and parasites of swine with its effect on productivity, should be properly evaluated. Methods of control should be sought. Orlandi and Armstrong (10) studied the effectiveness of sodium fluoride as an ascaricide for swine raised on the ground, but their work though valuable, constitutes only a very small portion of the necessary studies in connection with the broader subject.

More information on the behaviour of imported swine, the interrelationship of the productive characteristics as affected by the tropical environment, and in the rearing of swine in general, is needed for the proper understanding of the problems with which the industry is confronted.

The swine industry in Puerto Rico has great potentialities of expansion. All efforts should be made to make the industry occupy its proper place in the economy of the Island.

Summary

The comparative performances of the Duroc Jersey and Native breeds and the Duroc x Native, Landrace Large Black x Duroc, Landrace Large Black x Native, Tamworth x Duroc and Tamworth x Native crosses were studied for several pre-weaning and post-weaning characteristics of swine.

In the pre-weaning characteristics a total of 112 litters were considered; for the post-weaning characteristics, 143 gilts, 74 boars and 69 barrows were used in individual feeding trials.

Although the differences were not always statistically significant, the Durocs and the Duroc crosses fared better in nearly all the pre-weaning characteristics studied than the Natives and the corresponding Native crosses. The Landrace Large Black x Duroc and the Tamworth x Duroc were, in general, better than the other crossbreds in pre-weaning performance.

The Landrace Large Black x Durocs, the Duroc x Native and the Durocs showed in general a faster rate of gain than the Natives and the other crossbreds.

The Landrace Large Black x Natives and the Tamworth x Natives were almost always less efficient in food utilization than the other breeds and crossbreds.

The most important advantages found for crossbreeding (as compared to Duroc Jersey pigs) were obtained through added vigour of the pigs which resulted in around 1/2 less still-born pigs, around 1/3 more pigs weaned per litter, around 63 lbs. more at weaning per litter and in a faster rate of gain.

The correlation between four pre-weaning characteristics of swine were studied.

Three negative correlations were found. These were between litter size and farrowing weight, litter size and weaning weight and pigs weaned and weaning weight. Three positive correlations, which were those between litter size and pigs weaned, farrowing weight and pigs weaned, and farrowing weight and weaning weight, were also found.

The predicting equation for weaning weight was:

$$Y = 24.0104 - .0468a + 2.0188b - 0.26396c;$$

where: a is the number of pigs farrowed, b is the mean farrowing weight of the pigs and c is the number of pigs weaned, although its predicting value is doubtful. A sounder predicting equation was calculated for number of pigs weaned:

$$Y = -2.6529 + .4849a + 2.03b;$$

where: a and b mean the same as above.

The correlation between three post-weaning characteristics of swine were also studied. Negative correlations were found between rate of gain and feed consumed. Positive correlations were observed between weaning weight and rate of gain and between weaning weight and feed consumed.

It was concluded that selection for rate of gain will, in the long run, result in selection for efficiency.

Statistically significant differences were found between the sexes in rate of gain and efficiency of food utilization. The boars and the barrows gained faster than the gilts. The boars were more efficient than the barrows and the gilts.

The effect of weaning weight on the gain in weight of the pigs up to 154 days of age was measured and equations for the different sexes were developed. The over-all regression equation was:

$$Y = 76.2018 + 1.4903x$$

The importance of fattening pigs with good starting weaning weight is thus stressed.

Based on the gain and feed consumed by the Duroc and Native barrows, tables were prepared showing the maximum weight to which to carry the hogs for maximum profit at given liveweight prices and feed costs.

A short discussion of important problems affecting the swine industry in the Island is presented.

ACKNOWLEDGMENT

The conclusion of this study was possible through the help and cooperation of many persons, who at one time or another contributed to the progress of the work.

Mr. Tomás Quiñones, who died in November 1948, was Swine Herdsman at La Plata, during the period covered in this study. His sincere devotion for swine breeding and unceasing dedication to his work made possible the collection of most of the data presented here.

Dr. R. E. Comstock, now of the North Carolina Institute of Statistics, initiated the work and directed the first feeding trial.

Dr. W. W. Green, now of the University of Maryland, directed the second feeding trial and made suggestions for the better conduct of the work.

Dr. F. Armstrong and Dr. J. D. Rivera Anaya, of the Agricultural Experiment Station of the University of Puerto Rico, took care of the health of the animals throughout the experiment and helped in the selection of individuals for the feeding trials.

Dr. B. G. Capó, of the Agricultural Experiment Station, assisted the authors in the statistical analyses of the data. He suggested the method for the preparation of the tables on optimum weight to carry the hogs and helped throughout the other analyses of the data through useful suggestions and sometimes direct guidance.

Mr. F. Vázquez, of the Agronomy Division, Agricultural Experiment Station, developed the mathematical formulas for use in the preparation of the tables of optimum weight to carry the hogs.

Mrs. Elba G. Marcial, of the Agricultural Experiment Station, made suggestions and helped in the preparation of the manuscript.

We are also indebted to the personnel of the Economics Department of the Agricultural Experiment Station, for permitting the use of some of the results of their unpublished study on the swine industry in the Island.

To all these persons we express here appreciation for their cooperation.

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