

A COMPARISON OF PASTURE AND CONFINEMENT
MANAGEMENT SYSTEMS FOR RAISING SWINE

By

IRVIN T. OMTVEDT

Bachelor of Science

University of Wisconsin

Madison, Wisconsin

1957

Submitted to the faculty of the Graduate School of the
Oklahoma State University of Agriculture and
Applied Science in partial fulfillment
of the requirements for the degree of
MASTER OF SCIENCE
May, 1959

FEB 29 1960

A COMPARISON OF PASTURE AND CONFINEMENT
MANAGEMENT SYSTEMS FOR RAISING SWINE

Thesis Approved:

J. A. Whitley Jr.
Thesis Adviser

J. C. Hellier

Robert M. Mason

Dean of the Graduate School

ACKNOWLEDGMENT

The author wishes to express his appreciation to Dr. J. A. Whatley, Jr. of the Animal Husbandry Department for his guidance during the course of this study and in the preparation of this thesis.

Grateful acknowledgment is also given Dr. R. D. Morrison of the Department of Mathematics for his assistance in operating the high-speed computer, and for his helpful suggestions in preparing the data for analysis.

He also wishes to thank Wilson and Company, Oklahoma City, for their cooperation and assistance in obtaining the carcass data used in this study.

TABLE OF CONTENTS

	Page
INTRODUCTION	1
REVIEW OF LITERATURE	3
Pasture and Confinement Management Systems for Raising Swine .	3
Nutritional Anemia in Baby Pigs	7
Genotype-Environmental Interactions	13
Summary of the Review of Literature	23
EXPERIMENTAL	25
RESULTS AND DISCUSSION	32
Farrowing to Weaning Results	32
Litter Size and Percentage Survival	32
Weaning Weights	36
Feed Consumption	41
Post-Weaning Results	41
Average Daily Gain	41
Feed Efficiency	45
Probed Backfat Thickness	46
Carcass Information	47
Live Animal Scores	48
SUMMARY	53
LITERATURE CITED	55
APPENDIX	59

LIST OF TABLES

Table	Page
I. Composition of Experimental Swine Herd	25
II. Live Animal Scoring System	30
III. Line of Breeding and Live Weights for Carcass Information Barrows	31
IV. Farrowing to Weaning Summary	33
V. Feed Consumed from First Week After Farrowing to Weaning .	33
VI. Percentage Survival from Time of Injection to Weaning . .	34
VII. Line Summary for Litter Size and Percentage Survival . . .	37
VIII. Average 56 Day Pig Weight in Pounds	38
IX. Line Summary for Weaning Weights	40
X. Post-Weaning Performance Summary	42
XI. Line Summary for Average Daily Gains and Feed Efficiency .	44
XII. Line Summary for Average Probed Backfat Thickness Adjusted to 200 Pound Barrow Equivalent	47
XIII. Line Summary for Carcass Information	49
XIV. Line Summary for Live Animal Scores	51
XV. Pre-Weaning Rations	60
XVI. Post-Weaning Rations	61
XVII. Iron Supplements used in Iron Trials	62
XVIII. Correction Factors used to Adjust Probed Backfat Thickness to a 200 Pound Equivalent	63
XIX. Sample of Analyses. Observation Matrix and Analysis of Variance for Post-Weaning Average Daily Gains	64

INTRODUCTION

Due to recent advancements in nutrition and improved feeding and management practices, swine production has changed considerably during the past few years. In contrast to the long-established practice of raising swine on pasture, an increasing number are now being raised in confinement on concrete floors.

Producers have developed a keen interest in this relatively new method of raising swine, and many have incorporated a confinement-type management system into their operations. However, considerable controversy exists as to the relative merit of pasture and confinement management systems. The advantages claimed for this system include more rapid gains, more effective use of pasture lots for cropland, and generally the amount of feed and water handling is reduced. However, disadvantages include increased overhead, greater sanitation problems resulting in higher labor costs, and greater disease problems such as nutritional anemia. Also, unsound feet and legs are generally associated with confinement-raised pigs; therefore, pigs raised on pasture are preferred for breeding stock.

Since little experimental evidence is available, further investigations are needed to compare the performance of pigs raised under these two management systems. To study this, the pigs from five lines of breeding were raised under pasture and confinement systems in the spring of 1958 at the Fort Reno station. These litters were also subjected to an iron study in which two levels of iron injections were compared to no

injection under these two management systems. Evaluative criteria used were rate and efficiency of gain, feed consumption, probed backfat thickness, live animal scores, and carcass merit.

REVIEW OF LITERATURE

Since this study extended over three general areas, the review of literature has been divided into three sections: Pasture and confinement management systems for raising swine; nutritional anemia in baby pigs; and genotype-environmental interactions.

Pasture and Confinement Management Systems for Raising Swine

Kristjansson (1957) compared the performance of littermate samples of pigs raised on pasture and in confinement from weaning to a 200 pound live weight. Two barrows and two gilts from each of four litters by each of four Canadian Yorkshire boars were fed. One barrow and one gilt from each of these 16 litters were self-fed in a conventional piggery and the other barrow and gilt from the same litter were self-fed the same ration on pasture. Weights were taken at 56 days of age, 140 days of age, and when the pigs weighed between 190 and 200 pounds. Carcass measurements were also obtained on each of the 64 pigs in this study. The pigs self-fed on pasture tended to gain slower and had somewhat shorter carcasses than pigs self-fed the same ration in the piggery. It was also noted that the pigs self-fed on pasture had slightly larger loin eye areas than the pigs self-fed in a piggery. The following table summarizes the results.

	Avg. Daily Gain (56-140 days)	Backfat Thickness	Carcass Length	Loin Area
Pasture	1.28	1.30	29.8	3.69
Confinement	1.39	1.32	30.3	3.61

Workers at Georgia (Hale et al., 1959) compared pasture and confinement raising of hogs in three successive trials. In their first trial, they used 200 choice, crossbred feeder pigs to determine whether performance of growing fattening pigs confined to small concrete dry lots was different from that of comparable pigs raised on small Bermuda grass pasture plots. Both groups made fairly rapid gains during the test period, but the pigs on pasture gained slightly faster than those in confinement. The majority of the pigs in the concrete floored pens were stiff, had sore feet and a rough hair coat. Since the protein supplement was not fortified with vitamins, the workers thought that a mild vitamin deficiency existed among the confinement pigs which was prevented by the forage made available to the pigs on pasture. They pointed out that this could possibly account for some of the differences in rate of gain detected between the two managements. The pigs fattened on concrete dry lots required slightly less feed per pound of gain than did those raised on pasture. In the second trial, the composition of the protein supplement was changed in order to increase the palatability and the amounts of vitamins present, and they also used oat pasture instead of Bermuda grass. In this trial, the pigs fattened on concrete gained at essentially the same rate as did those fattened in pasture plots but the pasture pigs were more efficient in terms of feed utilization. When the pigs were slaughtered at 210 pounds, a slightly higher average dressing percentage, a slightly larger loin eye muscle and slightly more backfat was noted on the confinement pigs. In their third trial, the pigs were fed and managed essentially the same as in trial 2, except that Starr millet supplied the forage for the pasture pigs instead of oats. In this trial

the pigs on pasture gained slightly faster than the confinement pigs, but there was essentially no difference in the feed required to produce a pound of gain between the two management systems. The carcass results were similar to those of trial 2, in that the average dressing percentage, the carcass length, the backfat thickness, and the area of loin eye muscle tended to be greater for the pigs fed in concrete dry lots. The following table gives the summary of the results:

	Average of the Three Trials				Carcass Information			
	No. Pigs	Avg. Dly. Gain	Feed/ lb. Gain	No.	Dressing Percent	Length	Backfat	Loin
Pasture	260	1.82	3.61	72	71.66	29.8	1.74	3.87
Confinement	260	1.71	3.64	72	72.60	30.1	1.79	3.97

On the basis of these three trials, it was concluded that pigs on pasture gained significantly faster than did those in concrete dry lots, but pigs raised under both management systems made good gains. The overall summary indicated that there was essentially no difference in the feed efficiency between the two systems. Pigs fattened in concrete dry lots had a slightly higher dressing percentage than comparable pigs fattened in pasture plots. Some differences in carcass length, area of loin eye muscle and thickness of backfat were also noted, but they were not statistically significant.

A similar study was reported by Whatley et al. (1959) for the performance of fall pigs raised under pasture and confinement management systems. In the fall of 1957, 42 sows were divided into three equal groups according to age and line of breeding. The 15 sows and their litters in group 1 and the 14 sows and their litters in group 2 were moved from the farrowing barn to alfalfa pasture lots six days after

farrowing, and both groups were treated alike until the litters were weaned at about 56 days of age. After weaning, they continued the 77 pigs from group 1 sows on pasture lots, and moved the litters from the group 2 sows (86 pigs) into concrete floored pens where each litter was fed in a separate pen. The 10 sows making up the third group raised their litters in individual 10' x 22' concrete floored pens until weaning, and after weaning the litters were continued in the same confinement pens. All groups were self-fed the same rations. The test was concluded when the pigs averaged 150 days of age and the different groups of pigs averaged between 141 and 168 pounds. Weaning records showed that the pigs raised on pasture averaged 3.7 pounds more at weaning than did those raised in confinement, but there was essentially no difference in the percentage survival between the two management systems. It was also noted that the sows in confinement consumed more feed than those on pasture, but the pigs on pasture consumed more feed than the pigs in confinement. However, total feed per pound of pig weaned was essentially the same for both systems. The weaning results are summarized in the following table:

Farrowing to Weaning Summary						
	No. Litters	Percent Survival	Avg. 56 Day Wt.	Lbs. Feed Consumed/ lb. Pig Weaned		
				Sow	Creep	Total
Pasture	29	73	36.2	2.73	0.71	3.44
Confinement	13	72	32.5	3.00	0.45	3.45

After weaning, the pigs on the pasture-confinement combination system gained the fastest and most efficiently, with little difference between the pasture-pasture and the confinement-confinement management systems. The following table gives the post-weaning summary:

Post-Weaning Summary					
	No.	Initial	Final	Avg. Daily	Feed/
	Pigs	Wt.	Wt.	Gain	lb. Gain
Pasture-Pasture	77	35.7	141	1.13	3.77
Pasture-Confinement	86	36.3	168	1.45	3.65
Confinement-Confinement	71	33.4	148	1.19	3.85

Nutritional Anemia in Baby Pigs

McGowan and Crichton (1923) were the pioneer investigators in this field. They were among the first to observe the presence of anemia in suckling pigs raised in confinement. Anemia was prevalent in British swine breeding establishments where sows and their litters were housed in pens with concrete floors. The sows would farrow normally but when their pigs were 3-4 weeks old, they took on a "stocky" appearance due to edema of the skin, and their breathing became abnormal. On post-mortem examination, it was found that the heart was greatly dilated, there was an excess of pericardial fluid, and the lungs were edematous with effusion into the pleural cavity. The blood was also extremely watery and pale, and the hemoglobin level was often 15 percent below normal. The pigs which did live were very emaciated, ceased to grow, lost their appetites, and usually were diarrheic. Excellent results were obtained in preventing and curing anemia by feeding large amounts of ferric oxide to the sows.

Doyle et al. (1927) and Craig (1930) described the symptoms of anemia in baby pigs as having conspicuous gross lesions, grayish-yellow mottling of the liver, and a marked dilation of the heart. They also noted that the blood and muscles had a characteristic pale color. Doyle et al. (1927) described the microscopic pathology of anemic pigs and stated that the

most prominent changes were a marked degenerative fatty infiltration of the liver and the presence of hematopoietic centers in the liver, spleen and bone.

The onset of secondary infections in anemic pigs is often believed to be inevitable because of the animals' low resistance to pathogens. Craig (1930) reported that anemic pigs were highly susceptible to subcutaneous injections of pathogens, while non-anemic pigs receiving the same material showed no lesions. Bullard (1931) fed four types of organisms to anemic and non-anemic pigs and studied the effects of disease resistance. After the feeding of Salmonella aertryche and Salmonella enteritidis, agglutinins appeared earlier in the anemic than in the non-anemic pigs. This was probably due to the ability of the organisms to penetrate the intestinal mucosa as a result of lowered resistance caused by anemia.

Early workers found that close confinement, early farrowing, adverse climatic conditions and heavily infested parasitic areas were contributing factors to an environment in which anemia developed very readily (Rydberg et al., 1959). Doyle et al. (1927) conducted three experiments to compare the incidence of anemia under outside and inside conditions. They kept 146 pigs under inside conditions and 131 pigs under outside conditions, and found that the anemia was nearly four times as prevalent under inside conditions and that the death rate between one and eight weeks of age was also nearly four times higher. Death rate in the anemic pigs between one and eight weeks of age was almost 20 times higher than the death rate among non-anemic pigs. Craig (1930) obtained similar results when studying the incidence of anemia under outside and inside conditions.

Kernkamp (1935) noted a higher frequency of anemia in the northern sections of the United States during late winter and early spring seasons of the year. He pointed out that this was primarily due to the fact that the pigs were confined and were not given free access to soil. The administration of 4 to 5 milligrams of iron per kilo body weight was sufficient to prevent the disease from developing. It was noted that spontaneous recovery was common even when pigs still remained under conditions conducive to the development of anemia. This recovery often occurred when pigs started eating cereal foods at about 5 to 7 weeks of age.

A number of experiments have shown that access to soil greatly reduces anemia. Doyle (1932) stated that if young pigs were given access to blue-grass sod, beginning within the first week after birth, they would usually be amply protected against anemia. He pointed out that any type of sod would probably be just as satisfactory as blue-grass, providing it was of equal palatability. Green feeds, which were sod-free, had no effect on preventing anemia when fed to the sows and their pigs.

Kernkamp (1935) obtained a similar response with the addition of soil to pens of pigs raised in confinement. Access to soil greatly reduced the occurrence of anemia between 2 and 6 weeks after farrowing.

Moe et al. (1935) obtained data on hemoglobin values and weight at weekly intervals from birth to four weeks of age on four groups of pigs treated differently. Each group was fed and housed similarly on concrete floors, except that one group of pigs was kept free from soil; the second group had free access to 50 pounds of moist soil in one corner of their pens; the third group had free access to a similar quantity of soil which was supplemented with 4.5 grams of ferrous sulfate and 0.75 grams of

copper sulfate; and the fourth group had free access to a similar quantity of soil with 9 grams of ferrous sulfate and 1.5 grams of copper sulfate. The hemoglobin levels declined from birth to one week of age for each group, but the three treated groups did not decline to the extent of the untreated litters. Hemoglobin levels increased between the first and second week for each group; however, the difference in favor of the treated groups was significant over the untreated. No great differences were observed between those with unsupplemented and supplemented soil. However, those with soil supplemented with 9 grams of ferrous sulfate and 1.5 grams of copper sulfate showed a significantly higher hemoglobin level at the third and fourth weeks than either of the other groups. The pigs receiving soil supplemented with 9 grams of iron and 1.5 grams of copper were also significantly heavier than the other groups at three and four weeks of age, and both groups having access to soil supplemented with iron and copper were significantly heavier at weaning than either of the other groups.

Hart et al. (1929) found that severe anemia can be prevented in suckling pigs kept indoors by administering soluble iron salts. Their results showed, however, that feeding sows considerable amounts of iron and copper had no effect upon delaying the development of anemia in their pigs. Doyle et al. (1927) found that vitamins in the sows' rations had no noticeable effect upon the occurrence of anemia in their litters.

Rydberg et al. (1959) showed that dams treated two weeks before farrowing with an intra-muscular injection of 10 ml. of an iron-dextran solution produced pigs which maintained a higher hemoglobin level during the critical post-partum period than did pigs from untreated dams or from dams

treated four weeks prior to farrowing. The differences in hemoglobin levels in the pigs from untreated dams and in pigs from dams treated four weeks before farrowing were not significant.

McDonald et al. (1955) stated that the causes of anemia in the first few weeks of life were due to rapid growth of pigs with a concurrent increase in blood volume and to the insufficient amounts of iron available from the sow's milk to supply full complement of hemoglobin to the increased number of red blood cells. They noted that iron-dextran (5 percent iron) is absorbed and utilized for hemoglobin regeneration when injected intramuscularly into anemic pigs. Rydberg et al. (1959) pointed out that this method is a way of by-passing the mucosal barrier and gives greater assurance of correct dosage for each pig.

Kernkamp (1957) injected an iron-dextran compound into the skeletal muscle for the treatment and control of iron-deficiency anemia in baby pigs. He obtained highly satisfactory results using a single injection of 100 mg. of iron at four days of age. This amount appeared to be sufficient to maintain high levels of hemoglobin and hematocrit for at least the first three postnatal weeks, and/or until food other than the dam's milk was taken. It was noted that this injection promptly restored normal levels of hemoglobin and hematocrit in pigs anemic from iron deficiency.

Similar results were obtained by Rydberg et al. (1959) for pigs raised in confinement and injected with an iron-dextran compound. They studied the effects of three different methods of iron administration on hemoglobin level of 62 pigs. In the first trial, one group received no iron (control), the second group received an iron pill at 5 days and at 19 days

of age (287.6 mg. of reduced iron per tablet), the third group received 3 ml. of a liquid iron citrate orally at 5 days of age and at 19 days of age (3 ml. contained 33 mg. of iron), and the fourth group received one 2 ml. injection of an iron-dextran compound at 5 days of age (100 mg. of iron). In the second trial, the same types of treatments were used, but the iron tablets and liquid iron citrate were administered at 15 and 29 days of age, and the fourth group received a single iron-dextran injection at 15 days of age. The iron dextran injected pigs were heavier and had a higher hemoglobin count in both trials. The iron-dextran injected pigs averaged 4.2 pounds more than the controls at 26 days of age in the first trial, and 3.8 pounds more than the controls at weaning in the second trial. The pill treatment ranked second to the iron-dextran in both trials with respect to weight and hemoglobin levels. The groups receiving the liquid iron citrate orally weighed more than the controls in both trials, but in the first trial, the 26 day hemoglobin count was lower than that of the controls.

Maner et al. (1958) compared iron injections with oral administration in two trials with baby pigs raised on concrete. In the first trial, iron-dextran injected pigs were compared with pigs whose dams' udders were sprayed daily with a ferrous sulfate solution. No significant differences were noted between the two groups for rate of gain, hemoglobin or hematocrit values. In the second trial, 171 pigs were used to compare the effects of one injection of iron-dextran, two injections of iron-dextran, and daily spraying of the sow's udder with a ferrous sulfate solution, in preventing anemia. The pigs receiving one injection at three days of age produced significantly slower weight gains and had lower

hemoglobin and hematocrit values, than either the pigs receiving an injection at three days and at ten days of age, or the pigs receiving the oral iron treatment. They also administered iron-cobalt-copper pills weekly to one group of pigs which received only one injection of iron-dextran, and noted that similar growth, but lower hematocrit and hemoglobin values, were obtained at three weeks when compared to the pigs receiving the two injections. From these results, they concluded that one injection of iron-dextran (100 mg. of elemental iron) may not always be adequate for suckling pigs.

Genotype - Environmental Interactions

The presence of interactions between heredity and environment have been realized for some time, but very little attention has been devoted to them until recently. Wright (1939) recognized the fact that the relationship between genotype and environment was not necessarily additive. He suggested that if non-additive genotype-environmental interactions existed, a race would have to be bred for each ecological niche that was large enough to support one.

McBride (1958) stated that since there was no direct evidence for the presence or absence of genotype-environmental interactions, geneticists have generally adopted the "a priori" approach which suggests that animals be bred in the environment for which they were required.

Lerner (1950) probably reflected the thinking of most investigators at that time when he stated that, for most practical purposes, genotype-environmental interactions could be neglected. Recognizing the fact that these interactions could be of importance, he noted that the breeder's

usual aim is to obtain a population which is characterized by an average genotype superior to all other genotypes under all possible environments. Yet, if nonlinear interactions exist between genotype and environment, such a goal may not be possible to achieve.

Lush (1948) pointed out that the general importance of interactions between heredity and environment was uncertain, and that there was reason to think that it was generally underestimated in animal breeding. If genotype-environmental interactions did exist, they would have serious implications from the standpoint of livestock improvement. Their presence in certain definable areas would necessitate development of specialized strains for each area of interest. Chapman (1958) discussed the consequences of genotype-environmental interactions with respect to progress through selection. He stated that, theoretically, there is no available basis for precise generalization of results. Thus, in order for one to learn the extent of genotype-environmental interactions for each trait in each class of livestock, the animals representing each of these groups would have to be exposed to each environment in which one has interest.

It was not until Hammond (1947) suggested that animals should be reared in slightly favorable environments that research was stimulated in this field. From his survey of the literature, Hammond concluded: "The character required is best selected under environmental conditions which favor its fullest expression, and that once developed, it can also be used in other environments, provided that other characters specially required by that new environment, are also present in the animal."

Falconer and Latyszewski (1952) pointed out that in order for Hammond's thesis to be valid, there should be no genotype-environmental

interactions. In addition, for selection to be more effective in good environments, the good environment should be capable of reducing the random environmental variation which normally lowers the correlation between genotype and phenotype. In other words, the heritability of the character should be higher in a good environment than in a poor one. They pointed out that if genotype-environmental interactions do exist, selection should be practiced in the environment in which the improved population is destined to perform.

McBride (1958) stated that there was no clear evidence at that time to justify or even to judge the validity of Hammond's premises. It was, therefore, in the spirit of criticism that a number of workers, especially Falconer and Latyszewski (1952), Falconer (1953), and Johnansson (1953), approached the study of the relationship between genotype and environment.

Haldane (1946) was the first to attempt to classify the types of genotype-environmental interactions. He described four types of interactions between two kinds of genotypes and environments with no relationships between them, and gave no attention to differences between environments and between genotypes.

McBride (1958) also used two genotypes and two environments to classify interactions into four types:

Type 1. Intra-population, micro-environment

Type 2. Intra-population, macro-environment

Type 3. Inter-population, micro-environment

Type 4. Inter-population, macro-environment

Differences in climates, management practices, etc. were referred to as

macro-environmental variation, while fluctuations occurring when all animals are apparently treated alike, or those that Wright (1921) referred to as "intangible," were considered as micro-environmental variation. There is no direct evidence for (or against) the existence of Type 1, but its absence is usually assumed in biometrical genetics. Type 2 interactions are important when one is concerned with selection within breeds or strains. The presence of this type necessitates the practice of selection within the environment for which the organism is required. It is generally thought that Type 3 has little importance in the field of applied genetics, according to McBride, but Type 4 could have an important influence in animal and plant breeding. The existence of many highly adapted local races suggests that inter-population, macro-environment (Type 4) interactions may be extremely prevalent.

Genotype-environmental interactions are well known in plant breeding and are reported in nearly every publication on variety trials (Kristjansson, 1957). However, little is known about the extent and frequency of these interactions in the large animal population. There are very few references in the literature of experiments specially designed to investigate genotype-environmental interactions.

Young (1953) studied genotype-environmental interactions in three strains of mice reared under four different temperature and feeding conditions. In one of four trials, there was a strain-food and a strain-food-temperature interaction for growth rate. A strain-food interaction for reproductive behavior was also noted in one of the two experiments.

Falconer and Latyszewski (1952) studied the effectiveness of selection in mice reared under two planes of nutrition. Selection was within

litters based on growth rate from 3-6 weeks of age. One strain (High) was full-fed and the other strain (Low) was restricted to about 75 percent of the normal food intake. In general, they found that selection was effective in changing the growth rate. They noted that selection caused an increase in growth rate of 1.5 percent in the full-fed and an increase of 1.3 percent in the restricted mice. Exchanges of nutritional levels were made between the strains after five, seven, and eight generations of selection. Under the restricted conditions, the low stock was superior to the high stock. Also, the high stock showed no improvement over the controls under these low conditions. Low stock transferred to the high conditions was slightly inferior to the high stock, but showed a marked improvement over the controls. The workers concluded that improvement of the genotype for rapid growth under a high plane of nutrition carried with it no improvement for growth under a low plane of nutrition. However, improvement of the genotype for growth on a low plane of nutrition did carry with it a considerable amount of improvement for growth on a high plane of nutrition.

In another experiment, Falconer (1953) selected within litters for both large and small size (weight at six weeks). He used the same distinguishing diets as above, and at the end of 11 generations of selection, the two strains differed by 11 grams, or 50 percent of the initial weight. The divergence between the strains increased regularly and showed no sign of slowing down as selection progressed. Selection in the negative direction resulted in the high stock showing adaptation to low conditions, but the low stock did not show gain under the high conditions.

Chapman (1958) studied selection under high and low planes of nutrition in rats and noted that after four generations, positive selection

for gain under high and low conditions resulted in about the same genetic improvement. The low stock appeared somewhat superior to the high stock under both high and low conditions.

Considerable work has been conducted in the poultry field with respect to genotype-environmental interactions. Gutteridge and O'Neil (1942) compared the growth and egg production of three strains of Barred Plymouth Rocks at three different locations in Canada and detected no significant genotype-environmental interactions. Similar results were obtained by Merritt and Gowe (1956) for ten broiler strains tested at three different locations.

Gowe and Wakely (1954) were unable to demonstrate a significant genotype-environmental interaction for hen-housed or survivor's egg production from four sire families tested on five farms. They noted an indication of interaction in laying house mortality but concluded that, under commercial conditions, genotype-environmental interactions were of little practical importance.

Hill and Nordskog (1956) tested 55 varieties at 13 locations during a three year period for egg production and mortality. Evidence for a year-variety interaction in egg production, and for a variety-year and variety-location interaction in mortality were noted.

Lowry et al. (1956) compared the egg production of full sibs under floor and cage management systems. Since there was no evidence of genotype-environmental interactions, they concluded that selection under either management system would be equally effective for performance under the same or the other management system. McBride (1958) obtained similar results when comparing floor and cage management systems. It was noted,

however, that the "peck order" was responsible for many of the differences in egg production observed between birds housed intensively on the floor as compared to those housed in cages. In spite of this, no significant genotype-environmental interaction was found between families housed under these two management systems. He suggested that behavior patterns, such as "peck order" in fowl, is another condition which may give rise to environmental variations of the intangible variety.

Gowe (1956) tested the egg production of seven White Leghorn strains in batteries and in floor pens. No interaction for hen housed egg production, sexual maturity, egg weight or mortality were found, but a highly significant strain-management interaction for survivor's egg production and for body weight was noted. On the basis of these results, he concluded that some strains adapt better to cages than others do.

Fuchs and Krueger (1957) noted a tendency for a strain-management interaction for 10 strains of chickens reared in a large pen as compared to separate pens while holding all other conditions relatively constant.

Workers in Georgia (Huston et al., 1957) tested the egg production of three breeds under two temperature conditions. One breed layed equally well under both environments and was superior to the other two breeds, but the very poor production of the other two breeds at high temperatures suggests a genotype-environmental interaction.

McBride (1958) reviewed the work of Osborne (1952), Shaller and Sheldon (1955) and Abplanalp (1956) on interactions between family genotype and date of hatch as affecting sexual maturity in fowl. He noted that Abplanalp found no significant interactions, while the other two workers had shown significant interactions. Abplanalp, however, reared the birds from each hatch separately.

Johnson and Asmundson (1957) reported a significant interaction between family genotype and date of hatch for growth to eight weeks in turkeys. In the year that the interaction was detected, however, the poults in two hatches had been subjected to abnormally high brooding temperatures. In the other year examined, no marked interactions were noted.

King and Young (1954) wintered three breeds of sheep under four environments consisting of a warm temperature-high plane of nutrition, warm temperature-low plane of nutrition, cold temperature-high plane of nutrition, and a cold temperature-low plane of nutrition. They noted a breed-environment interaction for growth rate and wool growth.

Morley (1956) investigated the presence of genotype-environmental interactions in Australian Merino sheep. Each of 24 sire groups (half-sibs) was divided equally into 2 lots, and placed on high and low planes of nutrition. Significant differences between treatments for grease fleece weight, clean fleece weight, staple length and body weight at 6, 12 and 17 months of age were obtained. Sire-treatment interactions were observed for body weights at 12 and 17 months, but not for any of the other traits measured. These results indicated that, in this situation, fleece production on one plane of nutrition provided a good indication of fleece production on the other plane of nutrition, but this was not true for body weight at latter stages of growth.

Bonnier et al. (1948), in a study of monozygous cattle twins, reported non-linear interactions between heredity and environment for growth, milk yield, and butter fat percentage.

Hancock and Payne (1955) attempted to subject genetically identical animals to two types of environments which were essentially identical in all respects except climate. Eight sets of identical twins were separated at five months of age; one member of each set was raised in New Zealand and the other twin was raised in the Fiji Islands. Changes in the differences in gains between sets of twins from period to period during growth indicated a marked genotype-climate interaction. Thus, it was concluded that individual European type cattle differ in their suitability for tropical climates. Payne and Hancock (1957) studied the production of these twins and concluded that the Fiji Island climate adversely affected the production of this random sample of temperate-type cattle. They noted that the Fiji Island twins did not respond uniformly to tropical climate stress. Two of the twins produced at almost the same level as their co-twins in New Zealand, while the level of production of the other six were below that of their New Zealand co-twins.

Brunstand and Fowler (1959) studied the carcass characteristics of 32 gilts obtained from the eighth generation of a selection experiment designated to study the relationship between nutrition and improvement of animals for meat production through breeding. Gilts selected from a background of full feeding had a larger loin eye area (0.5 sq. in.) than gilts selected from a background of limited feeding. Therefore, they concluded that better selection for meat type hogs, as based on muscular development, can be accomplished under full feeding, while the muscling is allowed to express itself to the fullest extent. Their data, therefore, support Hammond's (1947) thesis that a character can best be selected for under environmental conditions which favor its fullest

expression. They noted an interaction between selection background and plane of nutrition on yield of trimmed primal cuts. Selection under full feeding favored a higher yield of trimmed primal cuts when such animals were placed under limited feeding.

Kristjansson (1957) attempted to evaluate the importance of genotype-environmental interactions in Canadian Yorkshire swine. A significant sire interaction was obtained for loin area, and the sire-management interactions approached significance for rate of gain, advanced registry carcass score and average backfat thickness. There was a marked shift in the ranking of sires for certain traits under the two managements. The ranking shift was particularly striking for area of loin, rate of gain and advanced registry carcass score.

Mean Loin Area (Sq. in.), Adjusted for Hot Carcass Weight									
	Sire 1	Sire 2	Sire 3	Sire 4	Treat. Avg.	Ranking of Sires			
						1st	2nd	3rd	4th
Piggery	3.86	3.56	3.54	3.47	3.61	S ₁	S ₂	S ₃	S ₄
Pasture	3.64	3.85	3.56	3.74	3.69	S ₂	S ₄	S ₁	S ₃
Sire Means	3.74	3.71	3.55	3.61		S ₁	S ₂	S ₄	S ₃

Fowler and Ensminger (1958) studied the response to selection under full and limited feeding regimes for nine generations. Selection was based on an index for productivity and daily gain from weaning to 150 pounds. In the seventh, eighth and ninth generations, exchanges of stock between the environments were made. The stock selected under low conditions and raised under high conditions had a higher average daily gain than those selected and raised under high conditions. However, the stock selected and raised under high conditions had higher average daily gains than those selected and raised under low conditions. Results showed that the pigs selected under the low conditions were more efficient

in feed utilization than those selected under high conditions for any one generation, and the pigs selected under low conditions and transferred to high conditions were more efficient than those selected and raised under high conditions. It was also noted that stock selected under low conditions were more efficient than those selected under high conditions and transferred to the low conditions.

Chapman (1958) discussed the results obtained from genotype-environmental interaction studies with mice, rats, and swine and concluded: (1) Selection for the trait under conditions different from those in which the progeny are to be reared is not likely to be more effective than under conditions in which the progeny are subsequently to be measured, and (2) If broad adaptation for gain is desirable, selection under limited feeding seems to be indicated; remembering, however, that there are other traits to be considered and that changes in them may be enough to offset any advantage from greater adaptability for the selected trait. Also, it appears that different genes are being selected in the different environments. Based on Fowler and Ensminger's results, Chapman suggested that the major genetic change in the low stock was one of efficiency of feed utilization, whereas in the high stock the genetic changes were mainly for appetite or capacity to consume feed.

Summary of the Review of Literature

Results from previous experiments show that the pasture-raised pigs have a heavier average weaning weight than those raised in confinement. Early workers noted a higher incidence of anemia among pigs raised in confinement as compared to those raised outdoors. Various methods have

been used to meet the iron requirement, but the most desirable results have been obtained by injecting the baby pigs with iron dextran. The literature reviewed indicates that pigs raised in confinement after weaning gain faster than those raised in pasture plots.

Many poultry studies have not revealed significant genotype-environmental interactions, but such relationships have been demonstrated for laying house mortality, sexual maturity, and egg production in different locations and under different management systems. In general, however, the interactions observed thus far should have no great importance under commercial conditions.

Very few experiments have been especially designed to investigate genotype-environmental interactions in large animals, but the literature available indicates that interactions due to temperature, plane of nutrition, and management systems do exist. More work is needed in this field in order to learn the importance and frequency of these genotype-environmental interactions, but it can be generally concluded that selection of breeding stock would be best accomplished, in most instances, under conditions similar to those in which the progeny are to be raised.

EXPERIMENTAL

This study included all the sows and litters farrowed during February and March of 1958 in the Fort Reno experimental swine herd (Project 808). The herd included the following lines of breeding and ages of sows:

TABLE I
COMPOSITION OF EXPERIMENTAL SWINE HERD

Line of Breeding	Total Number	No. Sows	No. Gilts	Description
OK 3	11	3	8	Mildly inbred Duroc Line
OK 14	11	11	0	Purebred Hampshire Line
8-9 X 14	10	2	8	Duroc-Beltsville No. 1 boars mated to Hampshire females
14 X 8-9	17	0	17	Hampshire boars mated to Duroc-Beltsville No. 1 females
C	16	0	16	Control Line (selected for no gain)
C ₁				6 mated to 2 Duroc boars
C ₂				5 mated to 1 Beltsville No. 1 boar
C ₃				5 mated to 1 Hampshire boar
Total	65	16	49	

All the sows in this study were fed the same ration (see appendix) on pasture during gestation, and were farrowed in the station's central farrowing barn. The sows were brought into the farrowing barn 109 days

after breeding and remained there until their litters were six days of age.

Before farrowing, all sows were equalized into two groups according to age and line of breeding. Group 1 dams were designated to raise their litters on pasture until weaning, and Group 2 dams were to raise their litters in confinement until weaning. The sows and their litters were placed under these two management systems six days after farrowing. Thirty-one sows and their litters (305 pigs) were placed in eight alfalfa pasture lots, and 34 sows remained in confinement in individual concrete floored pens with their litters (367 pigs) until weaning.

An additional study was conducted with these same litters to learn the effects of iron injections under different types of management systems. This study was not intended to be a specially designed experiment, or to be included as a part of the Pasture vs. Confinement experiment, but rather was initiated as an observation trial to lend practical information on two types of iron injections under the types of management systems used at Fort Reno. Because of differences in breeding, age of dam, time of farrowing, unequal numbers, etc., the data could not be satisfactorily analyzed by statistical methods. The differences, however, were relatively large, and since they had an important bearing on the weaning results of the Pasture vs. Confinement experiment, they are included in this report.

The first iron trial included 28 litters (254 pigs) from the five lines of breeding. Each litter was divided into three groups at five days of age. Group A of each litter received 2 cc. of iron-dextran injection (100 mg. elemental iron); Group B received 1 cc. of an iron-cobalt-folic acid injection (5 mg. elemental iron); and Group C served as a control

group and received no injection. The complete list of ingredients for each injection is included in the appendix. When the litters were six days old, they were distributed over four types of management systems. Nine litters were placed on alfalfa pasture and nineteen litters were housed on concrete floors in confinement. The litters raised on concrete received three different types of management: Five litters received an iron solution (see appendix) in the baby pig waterers placed in the creep feeding pens; four litters received fresh dirt in their pens; and the remaining 10 litters received no iron supplement.

In the second iron trial, six sow litters and 22 gilt litters (213 pigs) were used to compare the iron-dextran and the iron-cobalt-folic acid injections on pasture and in confinement. Each litter was divided into two groups at five days of age; half of the litter received 2 cc. of iron-dextran and the other half received 1 cc. of the iron-cobalt-folic acid injection. Nineteen of these litters were placed on pasture when they were six days of age, and nine litters were housed on concrete floors in confinement until they were weaned at eight weeks of age.

The average individual 56 day weight of those living at weaning, and the percent survival from five days of age to weaning, were used as the two measures of response in this study. An individual summary was made for each of the three iron groups with respect to the post-weaning management systems. Since these summaries were essentially the same within each of these iron groups for each of the types of management systems, it was thought that the iron treatment had no significant bearing on the post-weaning Pasture vs. Confinement results and thus it is not included in this report.

The sows on pasture and those in confinement were self-fed the same rations, and the pigs were all creep-fed the same pelleted ration as shown in the appendix. The alfalfa pasture was not a full stand, but furnished excellent and adequate forage for the four sows and their litters in each pasture group. Each of the eight pasture lots were approximately one and one-half acres in size and contained five year old alfalfa that had been pastured by pigs during two previous seasons.

All litters were weaned when they were between seven and eight weeks of age and the individual weaning weights were adjusted to a 56 day weight by the correction factor suggested by Whatley and Quaife (1937):

$$\text{Corrected Weight} = \frac{\text{Actual Weight} \times 41}{\text{Actual Age} - 15}$$

At weaning, all pigs were allotted according to age, line of breeding and pre-weaning treatment into one of four types of management systems. One half of each litter stayed on the same type of management system as prior to weaning, and the other half of each litter was placed on the other type of management system. This gave four kinds of management combinations: (1) pasture to weaning and pasture after weaning; (2) pasture to weaning and confinement after weaning; (3) confinement to weaning and pasture after weaning; and (4) confinement to weaning and confinement after weaning.

Each of the 31 litters raised in the eight pasture lots prior to weaning were divided into two groups at weaning. A total of 97 pigs stayed on pasture after weaning, and were allotted to four of the pasture lots, and 97 pigs were placed in confinement on concrete floored pens. These 194 pigs constituted the pasture-pasture and pasture-confinement management systems.

Each of the 34 litters raised in confinement prior to weaning were likewise divided into two groups at weaning. One half of each of the litters (93 pigs) remained on confinement after weaning, and the other half of each of these litters (97 pigs) was allotted to four pasture lots. These 200 pigs constituted the confinement-confinement and the confinement-pasture management systems.

The eight pasture lots used after weaning were the same as those used for the sows and their litters prior to weaning. The alfalfa stand was five years old and had been grazed by pigs two previous seasons, but the forage conditions were considered to be adequate. Between 20 and 29 pigs of similar age and pre-weaning treatment were fed in each of these lots. Four lots contained the pasture-pasture pigs and the other four lots contained the confinement-pasture pigs.

Twenty-four concrete floored confinement lots (10 x 22 feet) were used to house all the confinement pigs after weaning. Each lot contained from 5 to 13 pigs of similar age, line of breeding and pre-weaning treatment.

Water sprinklers were used for cooling both the pasture- and confinement-fed pigs. All lots were self-fed the same free-choice ration of shelled corn and a protein-mineral supplement which is included in the appendix (Table XVI).

All pigs were weighed at weaning, at one month after weaning, and at two-week intervals when they were approaching 200 pounds. Pigs were removed from the lots as each pig weighed over 200 pounds on these bi-weekly weigh days. At this time, each pig was probed at four locations along the back with a leanmeter. Each probe was made approximately one

inch on each side of the midline at about the fifth rib and fourth lumbar vertebra. The average of these four probes was used as the measurement for backfat thickness. These live animal probes were then adjusted to a 200 pound weight by correction factors worked out by Durham and Zeller (1955) and are included in the appendix. These adjusted probes were then corrected for sex differences by adjusting them to a barrow equivalent. This was done by adding 0.20 inch to the boars' 200 pound probes, and by adding 0.13 inch to the gilts' 200 pound probes (Enfield, 1957).

Each pig was also scored for length, meatiness, and soundness of legs by a committee of three, and the committee average was recorded for each trait. The scoring system is as follows:

TABLE II
LIVE ANIMAL SCORING SYSTEM

Score	Length (inches)	Meatiness (sq. in. of loin)	Legs (description)
9	31.0	5.5	Straight legs, well balanced toes strong pasterns, free from knots and enlargements on legs
8	30.5	5.0	
7	30.0	4.5	
6	29.5	4.0	Slightly crooked legs, uneven toes, slightly weak pasterns, or slight knots or enlargements.
5	29.0	3.5	
4	28.5	3.0	
3	28.0	2.5	Crooked legs, uneven toes, weak pasterns, large knots on legs, enlarged knees or hocks, etc.
2	27.5	2.0	
1	27.0	1.5	

A sample of barrows from each line of breeding and management system was slaughtered at Wilson and Company, Oklahoma City. Carcass length, average backfat thickness, and loin eye area at the tenth rib were obtained on these 56 pigs. Each side of the carcass was measured from

the front of the first rib to the aitch bone and the average length of the two sides was used for the carcass length. The backfat thickness was measured at the 1st rib, 7th rib, last rib and last lumbar vertebra on each side of the carcass, and the average of these eight measurements was used as the measurement for carcass backfat thickness. The number of barrows from each line of breeding and management system, and their average live weights, are summarized in the following table.

TABLE III
LINE OF BREEDING AND LIVE WEIGHTS FOR
CARCASS INFORMATION BARROWS

Line	Pasture- Pasture	Pasture- Confine.	Confine.- Pasture	Confine.- Confine.	Total
OK 3	2	2	2	2	8
OK 14	2	2	1	2	7
14 x 8-9	6	6	4	6	22
C ₁	2	2	2	2	8
C ₂	2	2	0	0	4
C ₃	1	2	2	2	7
Total Number	15	16	11	14	56
Avg. Live Wt.	213	208	210	212	211

Since the average live weights were approximately equal for each of the four management systems, no adjustments were made in the carcass measurements.

All the data was punched on IBM cards and the majority of the analyses were computed by the high-speed computer. The post-weaning results were analyzed by the abbreviated Doolittle Method reported by Anderson and Bancroft (1952). The remainder of the results were analyzed by methods described by Snedecor (1956). An outline of the analyses is included in the appendix.

RESULTS AND DISCUSSION

This section is divided into two parts: Farrowing to Weaning Results and Post-Weaning Results. Farrowing to Weaning Results will be discussed with respect to litter size and percentage survival, weaning weights, and feed consumption. Average daily gain, feed efficiency, probed backfat thickness, carcass information, and live animal scores will be discussed under Post-Weaning Results.

Farrowing to Weaning Results

Litter Size and Percentage Survival:

Sows were allotted to either the confinement or the pasture management system prior to farrowing, and it was not known how many pigs each sow would farrow. Due to chance in allotting, the sows designated for the confinement management system averaged one pig more per litter at farrowing than did the sows designated to raise their litters on pasture (Table IV). The average birth weights were similar for both groups. The pasture pigs averaged 0.05 lbs. heavier than the confinement pigs, but this difference was not significant.

At weaning the average litter size was the same for the sows on both types of management systems; thus indicating a higher death loss among the pigs raised in confinement. This difference of eight percent in the percentage survival was not significant. Furthermore, this difference is exaggerated by the inadequate iron treatment for some of the pigs in confinement. The 1957 results (Whatley et al., 1959) showed that there was

TABLE IV

FARROWING TO WEANING SUMMARY

Management	No. of Litters	Average No. per Litter		Percent Survival	Average Weight in Lbs.		
		Farrowed	Weaned		Birth Wt. Per Pig	56 Day Weight Pig	Litter
Pasture	31	9.8	7.2	73.5	2.70	37.0	276
Confinement	34	10.8	7.2	66.2	2.65	32.8	242

TABLE V

FEED CONSUMED FROM FIRST WEEK AFTER FARROWING TO WEANING

Management	Average Lbs. Feed Consumed			Lbs. Feed Consumed Per Lb. of Pig Weaned		
	Per Sow	Per Litter	Total	Sow Feed	Creep Feed	Total
Pasture	698.9	238.5	937.4	2.62	0.89	3.51
Confinement	816.0	80.6	896.6	3.34	0.33	3.67

essentially no difference in the death losses between the pasture and confinement management systems.

The two iron trials conducted on these same pigs showed that death loss was greatly reduced among the confinement pigs and to a lesser extent among the pasture pigs when an adequate iron treatment was administered. This is in agreement with the results obtained by McGowan and Crichton (1923), and Moe *et al.* (1935), as their results showed a higher incidence of anemia among pigs raised in confinement as compared to those raised on soil.

Considering the overall average, the percentage survival from six days of age to weaning (Table VI) was highest for the pigs receiving the iron dextran injection (100 mg. of elemental iron), and lowest for those receiving no injection. Ninety percent of the iron dextran injected pigs reached weaning age as compared to 80 percent of the controls. The iron dextran injection tended to have its greatest effect of the survival rate for pigs raised in confinement (85 percent compared to 70 percent). Rydberg *et al.* (1959) concluded that 100 mg. of elemental iron in the form of iron dextran was sufficient for anemia prevention.

TABLE VI
PERCENTAGE SURVIVAL FROM TIME OF INJECTION TO WEANING

Group	Pasture	Confinement	Confinement and Iron in Water	Confinement and Dirt in Pen	Overall Average
A ¹	90	85	95	100	90
B ²	90	70	100	82	84
C ³	83	70	90	88	80
Average	88	75	95	90	

¹Injected with 2 cc. of iron dextran (100 mg. elemental iron).

²Injected with 1 cc. of iron-cobalt-folic acid (5 mg. elemental iron).

³Controls, received no injection.

The results shown in Table VI also indicate that litters raised on concrete, without additional iron supplement, had the highest death losses. The addition of iron in the drinking water, or the addition of fresh dirt in the pen, increased the survival rate from 75 percent to 95 percent and 90 percent respectively. Doyle (1932), Kernkamp (1935), Moe et al. (1935) and others found that access to soil greatly reduced the incidence of anemia.

In the second iron trial, iron dextran injections (100 mg. of elemental iron) were compared to iron-cobalt-folic acid injections (5 mg. of elemental iron) under pasture and confinement conditions. Results from this trial showed that the pigs receiving the iron dextran had a lower death loss than those receiving the iron-cobalt-folic acid injections. Eighty-eight percent of the confinement pigs which received the iron dextran injections reached weaning age as compared to 76 percent of those receiving the iron-cobalt-folic acid injections. However, there was no difference in the survival of pigs receiving the two types of injections when raised on pasture (90 percent of the injected pigs survived to weaning).

Based on the results of these two iron trials and the results reported by Rydberg et al. (1959), it is believed that 100 mg. of elemental iron is an adequate preventative treatment for anemia. Therefore, a more useful appraisal of death losses under these two management regimes could be obtained by comparing the percentage survival within the groups of pigs that were injected with 2 cc. of iron dextran (Group A) under confinement and pasture conditions. By doing this, the difference in percentage survival between the pasture and confinement regimes was reduced from eight

percent of three percent. When considering only the pigs which received the iron dextran injections, 90 percent of the pasture pigs and 87 percent of the confinement pigs reached weaning age.

The line summary (Table VII) shows that there was a significant difference ($P < .05$) between lines for the average number of pigs farrowed and weaned per litter. It should also be noted that there was a marked difference in the overall survival rate for the different lines. Although the overall survival rate was highest among the pasture pigs, OK 14, 8-9 x 14, and C₁ lines actually had a higher survival rate among the confinement raised litters than among the pasture litters. This management-line interaction for survival rate was significant ($P < .05$), and indicates that pigs of different breeding tend to react differently to these different types of management systems. It appears that some individual pigs and lines would perform relatively better than others under the confinement type of management system while others perform relatively better under a pasture system. This means that certain lines or breeds might be better adapted to certain management systems than others. The design of this experiment was not adequate to accurately determine the extent of this interaction, and further studies must be conducted to learn its significance.

Weaning Weights:

Results from this trial were similar to those obtained in the fall of 1957 by Whatley et al. (1959), in that sows on pasture weaned heavier litters than those in confinement. The pasture litters averaged 34 pounds heavier than the confinement litters at weaning, and the average individual

56 day weights of the pasture pigs were 4.2 pounds heavier than those for the pigs raised in confinement. This difference is significant, but it is partly accounted for by the inadequate anemia prevention among the confinement pigs.

TABLE VII

LINE SUMMARY FOR LITTER SIZE AND PERCENTAGE SURVIVAL

Line	Avg. No. Farrowed Per Litter		Avg. No. Weaned Per Litter		Percent Survival	
	Pasture	Confinement	Pasture	Confinement	Pasture	Confinement
OK 3	6.2	10.3	6.0	6.5	97	63
OK 14	11.6	12.5	6.4	7.7	55	61
8-9 x 14	9.6	9.0	6.8	7.0	71	78
14 x 8-9	10.1	10.8	8.5	6.7	84	62
C ₁	10.3	9.7	9.7	9.3	94	97
C ₂	11.0	12.7	8.0	8.7	73	68
C ₃	11.3	10.5	5.0	4.5	44	43

Results (Table VIII) indicate that the pigs receiving the iron dextran injections (Group A) averaged 6.2 lbs. heavier than those receiving the iron-cobalt-folic acid injections (Group B), and 7.1 lbs. heavier than those receiving no injection (Group C). The iron dextran injection affected the weaning weights in the same manner as it did the percentage survival. It had its largest effects upon the pigs raised in confinement without additional iron supplement, and its smallest effects upon the pigs raised on pasture. Considering only the confinement raised pigs, those injected with 100 mg. of elemental iron (Group A) averaged 12.5 lbs. heavier than those injected with only 5 mg. of elemental iron (Group B), and 14.5 lbs. heavier than the controls.

It should also be noted that the addition of iron supplement in the form of fresh dirt, or in the form of an iron solution in the drinking

water, increased the average weaning weight of the pigs. The pigs receiving the fresh dirt averaged 5.6 lbs. heavier than those on confinement without additional iron supplement, and the group receiving iron in their drinking water averaged 6.6 lbs. heavier than those on confinement without additional iron supplement.

TABLE VIII
AVERAGE 56 DAY PIG WEIGHT IN POUNDS

Group	Pasture	Confinement	Confinement and Iron in Water	Confinement and Dirt in Pen	Overall Average
A ¹	36.9	36.9	38.7	36.2	37.1
B ²	35.9	24.4	33.4	32.8	30.9
C ³	34.7	22.4	32.6	32.6	30.0
Average	35.9	28.3	34.9	33.9	

¹Injected with 2 cc. of iron dextran (100 mg. elemental iron).

²Injected with 1 cc. of iron-cobalt-folic acid (5 mg. elemental iron).

³Controls, received no injection.

The results obtained in the second iron trial were similar to those obtained in the first trial. The pigs which were raised on concrete in confinement and injected with iron dextran averaged 3.6 lbs. heavier than those that were injected with the iron-cobalt-folic acid (36.1 lbs. compared to 32.5 lbs). However, no important difference was detected in the average 56 day weights for the two types of injections under pasture conditions (37.4 lbs. compared to 37.7 lbs.).

Since the iron dextran injections increased the average weaning weights of the confinement pigs, but had little effect on the weights of the pasture raised pigs, it is believed that the differences observed for average weaning weight between groups was also an exaggeration. In

comparing the weaning weights of the pasture and confinement raised pigs which were injected with iron dextran (100 mg. of elemental iron), the difference between the two management systems was reduced to 1.7 lbs. in favor of the pasture pigs.

TABLE IX
LINE SUMMARY FOR WEANING WEIGHTS

Line	Average Litter Weight, Lbs.		Average 56 Day Pig Weight, Lbs.	
	Pasture	Confinement	Pasture	Confinement
OK 3	223	204	37.1	31.5
OK 14	232	238	36.3	31.1
8-9 x 14	224	236	32.9	33.7
14 x 8-9	344	219	40.5	32.9
C ₁	331	296	34.2	31.8
C ₂	326	288	40.7	33.2
C ₃	167	204	33.4	45.4

The line differences were significant ($P < .05$) for average litter weight and average pig 56 day weight. It should be noted that, although the pasture management system, on the average, produced heavier litters and heavier pigs at weaning, this was not true for all of the lines of breeding in this study. The OK 14, 8-9 x 14, and C₃ lines weaned heavier litters under the confinement system than under the pasture type management, and the 8-9 x 14 and C₃ lines weaned heavier pigs under the confinement management. This management-line interaction was significant ($P < .05$) for both traits. It should be pointed out, however, that the numbers sampled were relatively small in the C₃ line, and this interaction could be due to chance. Further investigation will be necessary before drawing conclusions as to the importance of this interaction.

Feed Consumption:

Results in Table V show that sows on pasture consumed less feed than those in confinement, but the pigs on pasture consumed more creep feed than those in confinement. Whatley et al. (1959) noted this same trend in their results for the previous season. The sows in confinement each consumed approximately 217 pounds more feed, or about 0.72 lbs. more feed per pound of pig weaned, than those on pasture. The litters on pasture, however, consumed 148 lbs. more feed than those in confinement or, on the average, consumed about 0.56 lbs. more feed per pound of pig weaned than those in confinement. During the period from one week after farrowing to weaning, the confinement raised litters averaged 11.2 pounds of creep feed consumed per pig weaned compared to 32.7 lbs. of creep feed per pig weaned for the litters raised on pasture. It should be noted that even though the sows and litters on pasture consumed about 41 lbs. more feed per sow and litter, they actually required 0.16 lbs. less feed per lb. of pig weaned.

Post-Weaning Results

Average Daily Gain:

Weights were taken 28 days after weaning to determine if a change in the type of management regime affected the gains during the first month. This difference was significant at the 5 percent level. The pigs that were raised on pasture until weaning and were then shifted to concrete floored pens in confinement gained 1.41 lbs. per day during the first month compared to 1.18 lbs. per day for those raised in confinement until weaning and then shifted to the pasture lots (Table X). It was observed

TABLE X
POST-WEANING PERFORMANCE SUMMARY

Pre-Weaning Mgt. Post-Weaning Mgt.	Pasture Pasture	Pasture Confinement	Confinement Pasture	Confinement Confinement
Number of Pigs	97	97	93	97
Average Daily Gain, Lbs.				
First Month	1.26	1.41	1.18	1.30
Overall	1.47	1.62	1.32	1.47
Average Lbs. Feed Per Lb. Gain	3.46	3.29	3.55	3.50
Average 200 Lb. Adj. Probe, in.	1.54	1.57	1.52	1.58
Live Animal Scores				
Length	6.3	6.0	6.4	6.3
Meatiness	5.3	5.1	5.2	5.1
Leg	5.9	5.4	5.9	5.2
Carcass Information				
No. of Barrows	15	16	11	14
Avg. Wt., Lbs.	213	208	210	212
Avg. Length, in.	29.4	29.4	29.4	29.7
Avg. Backfat, in.	1.68	1.66	1.65	1.64
Avg. Loin Area, sq.in.	3.29	3.24	3.17	3.30

that the pigs in this latter group (confinement-pasture) required a period of time to become adjusted to the change in environment. The pasture-confinement pigs, on the other hand, tended to adjust to their new conditions rather rapidly.

Considering the entire post-weaning period, the pigs on the pasture-confinement combination system gained significantly faster ($P < .01$) than the pigs on the confinement-pasture system, (1.62 lbs. per day compared to 1.32 lbs. per day). Both the pasture-pasture and the confinement-confinement pigs gained 1.47 lbs. per day.

These results are similar to those obtained by Kristjansson (1957) and Whatley et al. (1959). In both experiments, they found that the pigs raised in confinement gained faster than those raised on pasture. Hale et al. (1959), on the other hand, reported the results from three trials in Georgia, and they noted that the pasture pigs made faster gains than the confinement pigs.

There were distinct line differences (Table XI) with respect to average daily gains on these four types of management systems. The management-line interaction was significant ($P < .05$) for overall average daily gain, and is in agreement with the Canadian work. Kristjansson (1957) noted that the management-sire interaction approached significance for rate of gain in his study.

The first month after weaning results show that the pasture-confinement combination system was the most desirable for all lines except OK 3 and C₃ which had their highest gains under the confinement-confinement system.

TABLE XI

LINE SUMMARY FOR AVERAGE DAILY GAINS AND FEED EFFICIENCY

Line	AVERAGE DAILY GAIN IN LBS.										Lbs. Feed Per Lb. of Gain for Confinement Litters		
	For First Month After Weaning					Overall Post-Weaning Period					Past- Conf.	Conf- Conf.	Avg.
	Past- Past.	Past- Conf.	Conf- Past.	Conf- Conf.	Avg.	Past- Past.	Past- Conf.	Conf- Past.	Conf- Conf.	Avg.			
OK 3	1.05	1.16	1.14	1.26	1.15	1.48	1.62	1.40	1.56	1.52	3.15	3.24	3.20
OK 14	1.11	1.22	1.04	1.14	1.13	1.34	1.46	1.19	1.31	1.31	3.51	3.60	3.56
8-9 x 14	1.18	1.42	1.14	1.17	1.23	1.52	1.64	1.23	1.50	1.47	3.30	3.34	3.32
14 x 8-9	1.44	1.59	1.16	1.34	1.38	1.50	1.64	1.33	1.42	1.50	3.31	3.54	3.42
C ₁	1.31	1.49	1.36	1.39	1.39	1.54	1.61	1.46	1.48	1.52	3.28	3.53	3.40
C ₂	1.30	1.41	1.21	1.38	1.32	1.52	1.74	1.34	1.62	1.55	3.32	3.87	3.60
C ₃	1.15	1.28	1.38	1.66	1.37	1.28	1.47	1.45	1.44	1.40	3.41	3.59	3.50

With the exception of the C_3 line, there was no marked shifting in the ranking of the desirability of the different managements for overall gain. The C_3 line pigs made their best gains on the pasture-confinement type management, but they made their poorest gains on the pasture-pasture type management, whereas the other six lines made their poorest gains on the confinement-pasture combination. It should also be noted that there was a marked shift in the overall ranking of the lines when comparing the first month with the overall average daily gain. For example, the OK 3 line had next to the slowest gains for the first month after weaning, but ranked second to the C_2 line in the overall average daily gain. The OK 14 line, on the other hand, had the slowest gains at both times.

Feed Efficiency:

The pasture-confinement combination pigs were significantly more economical ($P < .02$) than the confinement-pasture combination pigs. The pigs in the pasture-confinement management system required 3.29 lbs. feed per lb. of gain compared to 3.55 lbs. of feed per lb. of gain for the confinement-pasture pigs. The pasture-pasture and the confinement-confinement combination managements required 3.50 lbs. and 3.46 lbs. per lb. of gain, respectively. This is in agreement with the 1957 results obtained by Whatley et al. (1959). However, the Georgia workers (Hale et al., 1959) noted a tendency for the pasture pigs to be more efficient than the confinement pigs.

Since the pasture pigs were not allotted according to line of breeding, it was impossible to measure feed efficiency by lines for the pigs raised on pasture after weaning. The litters raised in confinement after weaning were allotted according to line of breeding; therefore, it was

possible to obtain line summaries for the pasture-confinement and the confinement-confinement management systems. Results in Table XI show that all lines were more efficient with respect to feed utilization under the pasture-confinement system than under the confinement-confinement system.

Probed Backfat Thickness:

The live animal probes were adjusted to a 200 lb. weight and corrected for sex differences by adjusting them to a barrow equivalent (see appendix for adjustment factors). These adjusted probed backfat measurements indicate that there was a tendency for the confinement-fed pigs to be slightly fatter than the pasture-fed pigs. Although these differences were highly significant ($P < .01$), they were relatively small and were not substantiated by the carcass backfat measurements taken on the sample of barrows that were slaughtered. However, other workers have noted similar trends in their experiments with pasture and confinement management systems. Kristjansson (1957) and Hale et al. (1959) found that confinement-raised pigs tended to have more backfat than those raised on pasture.

The seven lines used in this experiment responded differently to these four types of management systems (Table XII). The line differences were highly significant ($P < .01$) and approached significance for the management-line interaction. The Canadian work (Kristjansson, 1957) indicated that such an interaction may also exist within a breed, as their results showed that the management-sire interaction approached significance for backfat thickness.

The line summary shows that the OK 3 line had the highest probed backfat thickness under all the management systems. With the exception of the

C₂ line, the fattest pigs within each line were those raised on either the pasture-confinement or the confinement-confinement type of management system.

TABLE XII
LINE SUMMARY FOR AVERAGE PROBED BACKFAT THICKNESS
ADJUSTED TO A 200 POUND BARROW EQUIVALENT

Line	Pasture- Pasture	Pasture- Confinement	Confinement- Pasture	Confinement- Confinement	Avg.
OK 3	1.74	1.76	1.67	1.70	1.72
OK 14	1.56	1.54	1.61	1.61	1.58
8-9 x 14	1.46	1.58	1.46	1.46	1.49
14 x 8-9	1.49	1.52	1.42	1.49	1.49
C ₁	1.55	1.62	1.56	1.63	1.60
C ₂	1.65	1.56	1.46	1.63	1.57
C ₃	1.50	1.51	1.51	1.57	1.52

Carcass Information:

Before discussing the results of the carcass measurements obtained on the 56 carcass pigs, it should be pointed out that this was a relatively small sample; therefore, the real differences between managements may not be properly represented in these data. A more complete sample from each management system should be measured in order to get a more accurate estimation of these differences.

The results (Table X) from the 56 barrows slaughtered in this study indicated that there was no significant difference in carcass length, backfat thickness, and loin eye area for the four types of management systems. However, the carcass length tended to be somewhat longer for

the confinement-confinement pigs and was approaching significance ($P < .07$). Canadian results (Kristjansson, 1957) indicated that the pigs raised in confinement were longer and fatter and had a somewhat smaller loin eye area. Hale et al. (1959) also noted that the pigs raised in confinement appeared to have longer carcasses and more backfat, but their results indicated that the confinement raised pigs had a larger loin eye area than the pasture raised pigs.

The line summary (Table XIII) indicates relatively marked variation between lines. Although the overall summary showed that the confinement-confinement pigs had a somewhat longer carcass, this was not true for all the lines. In fact, only the 14 x 8-9 and the G_3 lines actually were longer in the confinement-confinement treatment. This same type of variation was noted for backfat thickness and loin eye area. Overall, there was a tendency for the confinement pigs to be the fattest, but this was not true for all of the lines; the OK 14 and the 14 x 8-9 lines were leaner on the confinement-confinement type of management system than on the pasture combination systems. This management-line interaction approached significance in this study, and agrees with the Canadian results. Kristjansson (1957) found a significant management-sire interaction for loin eye area, and also noted a marked shift in ranking of the sires within the breed for loin eye area.

Live Animal Scores:

Each pig was scored by a committee of three observers for length, meatiness and soundness of legs. The scoring system ranged from 0 to 9 with 0 being inferior and 9 being superior for each of these three traits. Analysis of variance showed that the type of management system had a

TABLE XIII

LINE SUMMARY FOR CARCASS INFORMATION

Line	Carcass Length, inches					Backfat Thickness, inches					Loin Eye Area, sq. in.				
	Past- Past.	Past- Conf.	Conf- Past.	Conf- Conf.	Avg.	Past- Past.	Past- Conf.	Conf- Past.	Conf- Conf.	Avg.	Past- Past.	Past- Conf.	Conf- Past.	Conf- Conf.	Avg.
OK 3	28.0	27.8	28.9	28.8	28.4	1.80	1.83	1.68	1.82	1.78	3.28	2.57	2.60	2.70	2.79
OK 14	29.2	29.8	29.9	29.7	29.6	1.64	1.68	1.58	1.52	1.61	3.43	3.66	3.20	3.16	3.38
14 x 8-9	30.0	29.6	29.7	30.1	29.9	1.66	1.64	1.63	1.60	1.63	3.30	3.20	3.24	3.44	3.30
C ₁	29.3	28.9	28.6	29.2	29.0	1.65	1.38	1.74	1.71	1.62	3.64	3.66	3.58	3.68	3.64
C ₂	28.6	30.8			29.7	1.84	1.75			1.80	2.79	3.21			3.00
C ₃	30.2	29.4	29.8	29.8	29.7	1.40	1.68	1.63	1.60	1.60	3.25	3.20	3.20	3.20	3.20

highly significant effect upon the length and leg scores. The committee tended to score the pasture fed pigs higher than the confinement raised pigs for straightness and soundness of legs (Table X). It should be pointed out, however, that the confinement-fed pigs were generally considered to be satisfactory on their legs. Hale et al. (1959) noted that the majority of the pigs in concrete floored pens had sore feet and were relatively stiff.

The committee tended to score the pasture-confinement combination pigs lower than the other groups for length. This difference was highly significant ($P < .01$), but the difference was rather slight. The pasture-confinement pigs averaged 6.0 for length compared to 6.3 for the pasture-pasture and the confinement-confinement pigs. Converting this numerical score to a carcass length equivalent, 6.0 represents a 29.5 inch carcass, and 6.3 is equivalent to a 29.65 inch carcass. This same trend did not hold true for the carcass sample, however.

A significant difference in the meatiness score was not detected in this study. However, there was a slight tendency for observers to score the pasture-pasture pigs highest for meatiness. This agrees with Kristjansson's work, but was not substantiated by the carcass sample taken from this study.

The average scores for each line are summarized in Table XIV. Line differences were highly significant ($P < .01$) for length score, meatiness score and leg score. The management-line interaction approached significance for all three traits, thus indicating that possibly some of the lines adapt to one type of management system better than the other lines do. Since the design of this experiment was insufficient to accurately

TABLE XIV

LINE SUMMARY FOR LIVE ANIMAL SCORES

Line	Length Score					Meatiness Score					Leg Score				
	Past- Past.	Past- Conf.	Conf- Past.	Conf- Conf.	Avg.	Past- Past.	Past- Conf.	Conf- Past.	Conf- Conf.	Avg.	Past- Past.	Past- Conf.	Conf- Past.	Conf- Conf.	Avg.
OK 3	5.6	4.8	5.7	5.3	5.4	4.7	4.2	4.5	4.2	4.4	6.0	5.7	5.6	4.7	5.4
OK 14	6.0	5.6	5.2	5.2	5.5	5.7	5.1	4.9	4.9	5.1	5.6	5.2	5.2	4.6	5.1
8-9 x 14	6.7	6.1	6.9	6.6	6.6	5.4	5.3	5.0	5.5	5.3	5.7	5.2	5.9	5.7	5.6
14 x 8-9	6.4	6.3	7.0	7.0	6.6	5.6	5.3	5.6	5.5	5.5	6.1	5.6	6.2	5.8	5.9
C ₁	6.2	5.9	6.4	6.3	6.2	5.2	5.0	5.4	4.9	5.2	6.6	5.6	6.3	5.3	6.0
C ₂	7.2	6.8	7.1	7.1	7.0	4.9	4.8	5.4	4.8	5.0	5.5	5.0	5.9	5.1	5.4
C ₃	5.4	6.1	6.2	6.2	6.0	5.0	5.4	5.5	5.8	5.4	5.6	5.0	6.8	4.5	5.4

study these interactions, further investigation is necessary before drawing conclusions as to their practical implications.

SUMMARY

Sows raising litters on pasture weaned heavier pigs and heavier litters at 56 days than those raising litters in concrete floored pens in confinement. Inadequate iron treatment adversely affected the weaning weights of the confinement pigs, but had little effect on the weights of the pasture-fed pigs. The injection of 2 cc. of iron dextran (100 mg. elemental iron) at 5 days of age greatly reduced the weaning weight differences between the pasture and confinement management systems. Weaning weights varied considerably between the lines of breeding under pasture and confinement management systems. Two of the lines weaned heavier pigs and heavier litters under the confinement management than under the pasture system. Sows on pasture consumed less feed than those in confinement, but the pigs on pasture consumed more creep feed than those in confinement.

The most rapid and most efficient gains were made with the pasture-confinement system in which the litters were raised on pasture from six days of age until weaning at 56 days of age, and were then moved to confinement lots for feeding to a market weight of about 210 pounds. Pigs on this pasture-confinement system gained 1.62 lbs. per day and required 3.29 lbs. of feed per lb. of gain compared to 1.32 lbs. per day and 3.55 lbs. of feed per lb. of gain for the confinement-pasture combination system. The management-line interaction was significant ($P < .05$) for average daily gain.

The confinement-fed pigs were slightly fatter, and were not as straight and sound on their feet and legs as the pasture-fed pigs. Lines

varied considerably with respect to backfat thickness under these management systems; the management-line interaction approached significance for probed backfat thickness.

The carcass measurements taken on a sample of pigs slaughtered from each of these management systems failed to indicate significant differences for carcass length, backfat thickness, and loin eye area. There was marked variation between lines, however, and the management-line interactions approached significance for each trait.

Results from this experiment indicate that management-line interactions may exist in many of the traits measured, but the design used was not appropriate for accurate evaluation of their importance. Specially designed experiments are needed to gain additional information on this subject.

LITERATURE CITED

- Abplanalp, H. 1956. Selection procedures for poultry flocks with many hatches. *Poul. Sci.* 35:1285.
- Anderson, R. L. and T. A. Bancroft. 1952. Statistical Theory in Research, 1st Ed. McGraw Hill, New York.
- Bonnier, G., A. Hansson and H. Skjervold. 1948. Studies on monozygous cattle twins. IX. The interplay of heredity and environment on growth and yield. *Acta Agr. Suecana* 3:1. From Kristjansson, 1957.
- Brunstad, G. E. and S. H. Fowler. 1959. Some carcass characteristics of swine in the eighth generation of production under four combinations of full and limited feeding. *J. Animal Sci.* 18:211.
- Bullard, J. F. 1931. The results of feeding various members of the color-typhoid-enteritidis group of organism to anemic and nonanemic pigs. *J. Am. Vet. Med. Assn.* 79:625.
- Chapman, A. B. 1958. Genotype-environmental interactions. *Proc. of Regional Swine Breeding Laboratory Conference*, July 15-16.
- Craig, R. A. 1930. Anemia in young pigs. *J. Am. Vet. Med. Assn.* 76:538.
- Doyle, L. P. 1932. Anemia in young pigs. *J. Am. Vet. Med. Assn.* 80:356.
- Doyle, L. P., F. P. Mathews and R. A. Whiting. 1927. Anemia in young pigs. *J. Am. Vet. Med. Assn.* 72:491.
- Durham, R. M. 1958. Personal communication.
- Durham, R. M. and J. H. Zeller. 1955. Using the probing technique in selecting breeding swine on farms. *J. Animal Sci.* 14:1180 (Abstract).
- Enfield, F. D. 1957. Heritability of carcass length, carcass backfat thickness and loin lean area in swine. M.S. Thesis, Oklahoma State Univ.
- Falconer, D. S. 1953. Selection for large and small size in mice. *J. Genetics* 51:470.
- Falconer, D. S. and M. Latyszewski. 1952. The environment in relation to selection for size in mice. *J. Genetics* 51:67.
- Fowler, S. H. and M. E. Ensminger. 1958. Unpublished data. From Chapman, 1958.

- Fuchs, M. H. and W. F. Krueger. 1957. A comparison of the genetic variation of purebred and strain cross White Leghorns. Poul. Sci. 36:1120.
- Gowe, R. S. 1956. Environment and poultry breeding problems. II. A comparison of egg production of seven S. C. White Leghorn strains housed in laying batteries and floor pens. Poul. Sci. 35:430.
- Gowe, R. S. and W. J. Wakely. 1954. Environment and poultry breeding problems. I. The influence of several environments on the egg production and viability of certain genotypes. Poul. Sci. 33:691.
- Gutteridge, H. S. and J. B. O'Neil. 1942. The relative effect of environment and heredity upon body measurements and production characteristics in poultry. I. Period of growth. Sci. Agr. 22:378..
- Gutteridge, H. S. and J. B. O'Neil. 1942. The relative effect of environment and heredity upon body measurements and production characteristics in poultry. II. Period of egg production. Sci. Agr. 22:482.
- Haldane, J. B. S. 1946. The interaction of nature and nurture. Ann. Eugenics (Lond) 13:197.
- Hale, O. M., W. C. McCormick and B. L. Southwell. 1959. Fattening pigs in concrete floored pens as compared to fattening pigs on pasture. Ga. Tech. Bul. No. 59.
- Hammond, J. 1947. Animal breeding in relation to nutrition and environmental conditions. Biol. Rev. 22:195.
- Hancock, John and W. Payne. 1955. The direct effect of tropical climate on the performance of European-type cattle. I. Growth. Empire J. Exp. Agr. 23:55.
- Hart, E. B., C. A. Elvehjem, H. Steenbock, G. Bohstedt and J. M. Fargo. 1929. A study of the anemia of young pigs and its prevention. J. Nutr. 2:277.
- Hill, J. F. and A. W. Nordskog. 1956. Efficiency of performance testing in poultry. Poul. Sci. 35:256.
- Huston, T. M., W. P. Joiner and J. L. Carmon. 1957. Breed differences egg production of domestic fowl held at high environmental temperatures. Poul. Sci. 36:1247.
- Johansson, I. 1953. The manifestation and heritability of quantitative characters in dairy cattle under different environmental conditions. An. Breed. Abstr. 22:523. (Abstract).

- Johnson, A. S. and V. S. Asmundson. 1957. Genetic and environmental factors affecting size of body and body parts of turkeys. IV. Interaction between sire-family and hatch. Poul. Sci. 36:1057.
- Kernkamp, H. C. H. 1935. Soil, iron, copper and iron in the prevention and treatment of anemia in suckling pigs. J. Am. Vet. Med. Assn. 87:37.
- Kernkamp, H. C. H. 1957. A parenteral hematinic for the control of iron-deficiency anemia in baby pigs. North Am. Vet. 38, No. 1.
- King, J. W. B. and G. B. Young. 1954. A study of three breeds of sheep wintered in four environments. J. Agr. Sci. 45:331.
- Kristjansson, F. K. 1957. Observations on genotype-environment interaction in swine. Can. J. Animal Sci. 37:179.
- Lerner, I. M. 1950. Population genetics and animal improvement. Cambridge (Eng.) University Press. Chp. 8:133.
- Lowry, D. C., I. M. Lerner and L. W. Taylor. 1956. Intra-flock genetic merit under floor and cage managements. Poul. Sci. 35:1034.
- Lush, J. L. 1948. The genetics of populations. Ames, Iowa (Mimeo). p. 362.
- Maner, J. H., W. G. Pond and J. K. Loosli. 1958. The effect of oral versus injectable iron on hemoglobin, hematocrit and weight gains of baby pigs. J. Animal Sci. 17:1187. (Abstract).
- McBride, G. 1958. The environment and animal breeding problems. An. Breed. Abstr. 26:349.
- McDonald, F. F., D. Dunlop and C. M. Bates. 1955. An effective treatment for anemia of piglets. British Vet. J. 111:403.
- McGowan, J. P. and A. Crichton. 1923. On the effect of deficiency of iron in the diet of pigs. Biochem. J. 17:204.
- Merritt, R. C. and R. S. Gowe. 1956. Environment and poultry breeding problems. III. The performance of eight crossbred and two purebred broiler strains at three locations. Can. J. Agr. Sci. 36:72.
- Moe, L. H., W. A. Craft and C. P. Thompson. 1935. Supplementing soil with iron and copper for the prevention of anemia in young pigs. J. Am. Vet. Med. Assn. 87:302.
- Morley, F. H. W. 1956. Selection for economic characters in Australian Merino sheep. VII. Interactions between genotype and plane of nutrition. Aust. J. Agr. Res. 7:140.

- Osborne, R. 1952. Sexual maturity in Brown Leghorns. The interaction of genotype and environment. Royal Soc. Edinb. B. Proc. 64:445.
- Payne, W. J. A. and John Hancock. 1957. The direct effect of tropical climate on the performance of European-type cattle. II. Production. Empire J. Exp. Agr. 25:321.
- Rydberg, M. E., H. L. Self, T. Kowalczyk and R. H. Grummer. 1959. The effectiveness of three different methods of iron administration to young pigs. J. Animal Sci. 18:410.
- Rydberg, M. E., H. L. Self, T. Kowalczyk and R. H. Grummer. 1959. The effect of pre-partum intramuscular iron treatment of dams on litter hemoglobin levels. J. Animal Sci. 18:415.
- Shaller, F. and B. L. Sheldon. 1955. Interaction of genotype and environment in determining sexual maturity in the domestic fowl. Aust. J. Agr. Res. 6:171.
- Snedecor, G. W. 1956. Statistical Methods. 5th Ed. Iowa State College Press, Ames.
- Young, G. B. 1953. A study of genotype-environment interaction in mice. J. Agr. Sci. 43:218.
- Whatley, J. A. Jr. and E. L. Quaife. 1937. Adjusting weights of pigs to a standard age of 56 days. Proc. Am. Soc. Animal Prod. 30:126.
- Whatley, J. A. Jr., I. T. Omtvedt, J. B. Palmer and D. F. Stephens. 1959. A comparison of pasture and confinement systems for raising hogs. Okla. Ag. Exp. Sta. Misc. Pub. No. 55.
- Wright, S. 1921. Systems of mating. I. The biometric relations between parent and offspring. Genetics 6:111.
- Wright, S. 1939. Genetic principles governing the rate of progress of livestock breeding. An. Breed. Abstr. 8:332. (Abstract).

A P P E N D I X

TABLE XV

PRE-WEANING RATIONS

Sow Ration*	
Ground Wheat	76.0
Ground Alfalfa Hay	10.0
Soybean Meal	8.0
Tankage	4.0
Bone Meal	1.0
Trace Mineralized Salt	1.0
TOTAL	100.0

*5-6 lbs. hand-fed daily until five days before breeding, then 9 lbs. daily for six weeks. Each was then fed 6 lbs. per day for the remainder of gestation period. Self-fed from 6 days after farrowing until weaning.

Pelleted Creep Ration	
Ground White Kafir	66.8
Soybean Meal	18.0
Fish Meal	3.0
Dried Buttermilk	2.0
Bone Meal	3.0
Trace Mineralized Salt	1.0
Dried Molasses	5.0
Vitamin and Antibiotic Premix	1.2
TOTAL	100.0

TABLE XVI
POST-WEANING RATIONS

First Month (Entire Ration Mixed and Self-Fed)	
Ground Corn	75.000
Soybean Meal	12.500
Tankage	5.125
Alfalfa Meal	5.000
Bone Meal	1.000
Trace Mineralized Salt	0.500
Aurofac	0.500
Hygromix	0.250
Fortafeed	0.100
Quadrex	0.014
Zinc Sulfate	0.011
TOTAL	100.000

After First Month
(Self-Fed Free Choice)

Shelled Corn

Protein and Mineral Supplement Mix	
Soybean Meal	50.00
60 percent Tankage	20.00
Alfalfa Meal	20.00
Bone Meal	4.00
Trace Mineralized Salt	2.00
Limestone	1.50
Aurofac	2.00
Fortafeed	0.40
Quadrex	0.06
Zinc Sulfate	0.04
TOTAL MIX	100.00

TABLE XVII

IRON SUPPLEMENTS USED IN IRON TRIAL

Iron Dextran Injection (Group A)

Trade Name: FERREXTRAN

Manufacturer: Fort Dodge Laboratories, Inc., Fort Dodge, Iowa

Description: Each cc. contains 50 mg. elemental iron (as ferric hydroxide) in complex with low molecular-weight dextran. Phenol 0.25 percent, preservative.

Dosage: 2 cc. at 5 days of age

Iron-Cobalt-Folic Acid Injection (Group B)

Trade Name: CHROMAGEN

Manufacturer: Savage Laboratories, Bellaire, Texas

Description: Each cc. contains:

Cobalt Gluconate	4.5 mg.
Iron Peptonized29.5 mg.
(5 mg. elemental iron equivalent)	
Folic Acid	2.5 mg.
Liver Injection (Beef)	2.5 mg.
Procaine HCl	1.0 percent
Phenol	0.5 percent

Dosage: 1 cc. at 5 days of age.

Iron Solution for Baby Pig Creep Water

Trade Name: CO-FER-MEL

Manufacturer: Allied Laboratories, Inc., Indianapolis and Kansas City

Description: Each fluid ounce contains:

Iron Sulfate	72.0 gms.
Cobalt Sulfate	8.0 gms.
Copper Sulfate	trace
Zinc Sulfate	trace
Dextrose (honey flavor)	trace
Glycerin	5.0 percent

Dosage: 2 ounces per gallon of water

TABLE XVIII

CORRECTION FACTORS USED TO ADJUST PROBED BACKFAT THICKNESS
TO A 200 POUND EQUIVALENT*

Actual Pig Weight in Pounds	Adjustment Factor
150	1.294
155	1.257
160	1.222
165	1.189
170	1.158
175	1.128
180	1.100
185	1.073
190	1.048
195	1.023
200	1.000
205	0.975
210	0.956
215	0.936
220	0.917
225	0.898
230	0.880
235	0.863
240	0.846

* Personal communication (Durham, 1958) based on
results reported by Durham and Zeller (1955).

TABLE XIX

SAMPLE OF ANALYSES
OBSERVATION MATRIX FOR POST-WEANING AVERAGE DAILY GAINS*

	Total	OK 3	OK 14	8-9x14	14x8-9	C ₁	C ₂	C ₃	Past- Past.	Past- Conf.	Conf- Past.	Conf- Conf.	Total A.D.G.
Total	384	52	48	63	114	43	40	24	97	97	93	97	565.10
OK 3	52	52	0	0	0	0	0	0	12	12	12	16	78.83
OK 14	48	0	48	0	0	0	0	0	9	10	16	13	62.72
8-9 x 14	63	0	0	63	0	0	0	0	15	15	17	16	92.36
14 x 8-9	114	0	0	0	114	0	0	0	34	34	21	25	170.51
C ₁	43	0	0	0	0	43	0	0	9	9	12	13	65.16
C ₂	40	0	0	0	0	0	40	0	10	10	11	9	61.96
C ₃	24	0	0	0	0	0	0	24	8	7	4	5	33.56
Past-Past.	97	12	9	15	34	9	10	8	97	0	0	0	142.90
Past-Conf.	97	12	10	15	34	9	10	7	0	97	0	0	156.73
Conf-Past.	93	12	16	17	21	12	11	4	0	0	93	0	122.92
Conf-Conf.	97	16	13	16	25	13	9	5	0	0	0	97	142.55

* Matrix was punched on IBM cards, and the results shown in the analysis of variance were computed by the 650 (high-speed computer). Similar matrices were constructed for probed backfat thickness, carcass information and live animal scores.

Analysis of Variance for Post-Weaning Average Daily Gain			
Source of variation	degrees of freedom	Sum of Squares	Mean Squares
Total, Uncorrected	383	848.5996	16.9902
Line of Breeding	6	1.9270	0.3212
Treatment in Line			
Treatment, Adjusted	3	3.9078	1.3026
Treatment-Line			
Interaction	18	0.9404	0.0522
Error	356	10.2150	0.0287

VITA

Irvin T. Omtvedt

Candidate for the Degree of

Master of Science

Thesis: A COMPARISON OF PASTURE AND CONFINEMENT MANAGEMENT
SYSTEMS FOR RAISING SWINE.

Major Field: Animal Breeding

Biographical:

Personal Data: Born in Rice Lake, Wisconsin, June 12, 1935,
the son of Thomas and Irene Omtvedt.

Education: Received the Bachelor of Science degree from the
University of Wisconsin, with a major in Animal
Husbandry in June, 1957.

Experiences: Fieldman for the Wisconsin Sheep and Swine
Improvement Programs during 1956 and 1957. Served in
the United States Army from August 1957 to February
1958.

Date of Degree: May 24, 1959.