AN ABSTRACT OF THE THESIS OF

Wesley Charles McEwen For the M. S. In Animal Husbandry

Date Thesis Presented April 28, 1952

Title EFFECTIVENESS OF SELECTION FOR PRODUCTIVE CHARACTERISTICS IN DEVELOPING THE MONTANA NO. 1 HOGS

Abstract Approved Redacted for Privacy

Major Professor

One of the most important productive characteristics of hogs is reproductive efficiency. Reproductive efficiency is best measured by litter size at weaning. Litter size at birth and weight of the pigs at birth are among the most important factors affecting litter size at weaning. It has been demonstrated that less than five per cent of pigs weighing 1.5 pounds or less at birth survive to be weaned.

It was the purpose of this study to determine the selection for litter size and birth weight of the pigs and the effects of this selection on subsequent generations during the development of the Montana No. 1 line of hogs.

The data for this study were made available through the agencies cooperating in the development of the Montana No. 1 hogs, the Montana Agricultural Experiment Station and the Bureau of Animal Industry, United States Department of Agriculture.

To facilitate comparisons between generations all litters farrowed by sows which were her second or third litter were eliminated from the study. A significant difference between the average birth weight of pigs farrowed by gilts whose dams were gilts and the average birth weight of pigs of gilts whose dams were sows was determined by analysis of variance. The pigs farrowed by gilts by sows were heavier. All spring litters farrowed by gilts bygilts were used in the study from farrowing records taken from 1939 to 1949.

The selection for litter size, based on the average litter size of the litters from which the individual pigs were selected, was for larger litters. There was an increase in the average litter size of litters farrowed by gilts by gilts. However, environmental influences accentuated the changes in litter size greatly during the period of development studied.

The amount of selection, based on the birth weight of the individual pigs selected, weighted for the number of times their genetic influence was weighted on the succeeding generation was not positively associated with the birth weight of their offspring.

The selection for birth weight based on the average birth weight of the litter from which the individuals were selected was associated with the birth weight of their offspring.

It was concluded that the average birth weight of the litter from which individual pigs are selected is the best indication of their inherent ability to utilize available environmental conditions as well as their ability to provide an adequate uterine environment for their offspring.

There was selection for pigs from litters with average birth weights below that of the average of the population from which they were selected.

There was a decrease in the average birth weight of the live pigs farrowed.

It has been demonstrated that environmental influences are the major cause of variations in the birth weights of new born pigs within the litter. It is therefore possible that the ability of a sow to farrow pigs of greater uniformity at birth is a heritable characteristic. Using the within litter standard deviation of birth weights of live pigs farrowed for each litter as an index to the uniformity, the amount of selection for this character was determined. It was found that there was an association between the uniformity of the birth weights of the litters from which the parents were selected and the uniformity of birth weights of their litters. It was concluded that the characteristic is heritable. There was selection and progress made in the development of the line toward more uniform litters at birth.

EFFECTIVENESS OF SELECTION FOR PRODUCTIVE CHARACTERISTICS IN DEVELOPING THE MONTANA NO. I HOGS

by

WESLEY CHARLES McEWEN

A THESIS

submitted to

OREGON STATE COLLEGE

in partial fulfillment of
the requirements for the
degree of

MASTER OF SCIENCE

June 1952

APPROVED

Redacted for Privacy

Professor of Animal Husbandry

In Charge of Major

Redacted for Privacy

Head of Department of Animal Husbandry

Redacted for Privacy

Chairman of School Graduate Committee

Redacted for Privacy

Dean of Graduate School

Date thesis is presented April 28, 1952

Typed by Mrs. L. M. Clarno

ACKNOWLEDGEMENTS

Appreciation is expressed to Dr. Ralph Bogart, Professor, Department of Animal Husbandry, for his helpful suggestions and cooperation in preparing this thesis.

To Dr. Jerome C. R. Li, Associate Professor, Mathematics Department, a word of appreciation for his assistance in analyzing data presented in this thesis.

Appreciation is expressed to Dr. Fred F. McKenzie, Chairman, Department of Animal Husbandry, Oregon State College, Corvallis, Oregon; Dr. T. C. Byerly, in charge Animal Husbandry Division Agricultural Research Center Beltsville, Maryland; Mr. J. R. Quesenberry, Superintendent, Range Livestock Experiment Station, Miles City, Montana, and Mr. Fred Wilson, Head Department of Aninal Husbandry, Montana State College, Bozeman, Montana, for their part in making available the data used in this thesis.

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EFFECTIVENESS OF SELECTION FOR PRODUCTIVE CHARACTERISTICS IN DEVELOPING THE MONTANA NO. I HOGS

INTRODUCTION

> "Tell me what you eat and I will tell you what you are. The destiny of a people depends upon the nature of its diet." (1, p.1)

Within the substance of this thought is perhaps the fundamental reason for any and all research in livestock production. The meat-eating peoples of the world have long been known to be the more aggressive, more progressive groups. It is the purpose of such research then, to increase the efficiency of animal production to meet the even increasing demand for animal products for human consumption. A proper diet is not only important to the individual, but to his society as well. The importance of the palatability and nutritive value which is added to the human diet by animal products needs only to be mentioned.

Consideration of the factors concerned with efficient animal production brings out the importance of the reproductive efficiency of our farm animals. Reproduction is necessarily concerned directly or indirectly in the production of animal foods for our diet. The secretion of milk of the dairy animal is initiated by the phenomenon of reproduction. The eggs on our breakfast table are a direct product of the phenomenon of reproduction. The meats in our diet are, of course, a result of reproduction. It is therefore apparent that higher reproductive efficiency will result in fewer breeding animals needed to produce the animal products for the human diet, consequently less vegetable matter will be required to produce a unit of animal product.

Striking evidence showing the increased efficiency of converting vegetable matter into animal products by increased reproductive efficiency in swine is presented by Weaver and Bogart (31, p.4). Their data show that sows producing 10 pigs per litter required only 341 pounds of feed per 100 pounds of hog marketed, while sows producing only 4 pigs per litter required 571 pounds of feed per 100 pounds of hog marketed. The figures for feed represent the feed of the sow from breeding to farrowing, the feed for the sow and the litter till the time the pigs were weaned, and the feed for the pigs up to six months of age. They also pointed out that, in addition to lower feed costs per 100 pounds of live hog marketed, there were more pigs from the good producing sows and these pigs grew faster. It is therefore evident that the overhead and labor expenses would be less per given amount of pork marketed from the higher producing sows.

The economic importance of increased reproductive efficiency in swine can best be brought out by a few figures from the United States Department of Agriculture, Production Marketing Administration, (U.S.D.A. P.M.A.) reports (27, p.5). There were 28,000 sows which raised approximately 7 pigs each in Oregon in 1949. If there could have been an increase of one pig per litter, this would have meant $444,000 on the state's net agricultural income for 1949 or stated another way, 500 carloads of hogs would not have been shipped into Oregon markets. The use of 500 railroad cars could be of vital importance to the nation in periods of international stress.

Regardless of the fact that many new feeding and management practices such as farrowing crates and pig brooders have been put into use and newly discovered vitamins and antibiotics have been studied, the increases in reproductive efficiency are not in keeping with the expenditures for these environmental improvements. This fact is perhaps best emphasized further from figures from the U.S.D.A. P.M.A. reports. The average number of pigs raised per litter has increased only 1.21 from 1924 to 1949 in the United States (27, p.5). Not all of this increase can be attributed to the mentioned environmental improvements, since all through this period there has been continual selection of animals of higher reproductive efficiency and the use of better breeds and strains has been greatly extended.

The importance of the weight of the live pig at birth in increasing the reproductive efficiency in swine is best brought out by Weaver and Bogart (31, p.6). They found that pigs under 1.5 pounds at birth had a mortality of 94.5 per cent at weaning while pigs 2.5 to 3.0 pounds in weight at birth suffered only 31.3 per cent mortality at weaning.

This study is an attempt to determine how the reproductive efficiency in swine may be raised by selection toward a permanent genetic improvement. The study consists of the determination of the effectiveness of selection for higher reproductive efficiency in an inbred line of swine developed from a crossbred foundation specifically for more efficient pork production.

The reproductive efficiency of swine is best measured by the litter size at weaning (23, p.211). Naturally the important factors contributing to this are the litter size at birth, the vigor of the pigs, and the mothering ability of the sow. This study will be primarily concerned with the birth weight of the live pigs farrowed and secondly with the number of pigs farrowed.

REVIEW OF LITERATURE

Planned experiments measuring the additive genetic effects of selection have been reported for oil content of corn by Winter (34, pp.451-476), for egg production in poultry by Marble and Hall (18, pp.1-38), for body size in mice by MacArthur (17, pp.142-157), for age of puberty in rats Warren (28, pp.58-59), for growth rate in swine by Krider (13, pp.3-15) for food utilization in rats by Morris (20, pp.1-54), and efficiency of gain in swine by Dickerson and Grimes (5, pp.665-687). It is important to note though, that these have all been planned experiments designed specifically to determine the quantitative genetic effects of a character. Published studies of the effectiveness of selection other than these which were designed for that purpose are not to be found in the literature. However, such studies undoubtedly form fundamental parts of many breeding programs at research centers.

The determination of the effectiveness of selection, basically a genetic study, brings forth the fundamental basis of all genetic studies: the degree to which an individual or group of individuals resembles a related group(14, p.293). To minimize statistical error and for convenience of calculation it has become generally accepted that determinations of additive genetic effects on a character between individuals with a path coefficient of relationship of less than 0.25 are impractical (15, p.297).

The results of biometrical methods of determining the efficiency of selection, heritability, have coincided very well with results obtained by actual selection methods. Dickerson and Grimes (5, p.670) used parent-offspring regressions on data obtained from selection for efficiency of gain in swine. Lush (15, p.292-301) points out, however, that all methods of estimating the ratio of additive genetic effects to all effects on a character contain, not only the additive genetic effects, but a portion of the variation due to genetic-environmental interaction and permanent environmental effects.

Lush (16, p.329-343) conducted an extensive study of birth weights in pigs at Iowa. It was determined by elimination of variance, that 47 per cent of the environmental variation was common to litter mates, and 47 per cent was not common to litter mates and 6 per cent was due to the heredity of the pigs. Of the heritable differences in pigs, 2 per cent was due to breed differences attributed to the sire. Of the total variation, 29 per cent was attributed to random errors in weights, suckling before weights were obtained, and the heredity of the dam.

Numerous studies have been conducted to determine the effects of inbreeding on productivity in swine. Hodgson (10, pp.209-217) developed three highly inbred lines of Poland China swine by full brother-sister mating. He reported difficulties in obtaining matings between litter mates, and that the number of pigs born alive was less among the inbreds than in outbreds.

Winters, et. al. (35, pp.1-38) reported that with no change in inbreeding of the litter, each addition one per cent increase of inbreeding in the sows was accompanied by a decrease of 0.058 pounds pig born alive per litter. Rate of gain between weaning and 200 pounds decreased at an average of 0.0035 pounds daily for males and 0.0029 pounds daily for females per one per cent increase in inbreeding. He concluded that the experiment showed clearly that there is a definite tendency for the offspring of each generation to revert to a performance lower than that of the parents and toward the population's mean, and that this tendency retards progress by selection.

Hays (9, pp.5-49) reported results obtained from a project with Berkshire swine initiated at the Delaware experiment station in 1908, which indicated that the certainty of pregnancy and size of litters were reduced by inbreeding and that mortality was greater among the inbreds than among crossbreds. The birth weight was apparently not affected by inbreeding, since the inbred pigs weighed slightly more at birth than did the outbreds and crossbreds.

There was a decrease in birth weight of inbred pigs reported by Willham and Craft (32, pp.5-42), which occurred in the first and fourth generations of inbreeding. The differences between the birth weight of outbred pigs and the inbred pigs was significant. They also reported a significant difference between the decline and recovery of hemoglobin following birth. The inbreds failed to regain their hemoglobin level as rapidly as the outbred pigs.

Godbey (6, p.1-16) reported a study conducted with inbred Berkshires at the South Carolina Station. The inbreeding did not seem to affect the birth weight of the pigs but did seem to reduce the weaning weight.

Hughes (11, pp.199-203) working with the Berkshire breed of swine at California practiced brother-sister matings without loss of litter size. He reported that no noticeable loss or vigor of pigs occurred, and that the pigs in the inbred litters were more uniform in size than those in the outbred litters.

Definite effects of inbreeding on the birth weight of pigs and on litter size are rather difficult to ascertain from the review of literature made, since the results obtained are often contradicting.

Winters and associates (36, pp.288-296) conducted a statistical study of factors affecting survival in pigs from birth to weaning. They reported that with inbreeding increasing each generation, a positive relationship between inbreeding of the dams and survival of the young indicated selection for higher vigor (survival) was effective. The most important factors effecting survival determined were: 1. inbreeding of the litter, 2. inbreeding of the sow, 3. size of the litter at birth, and 4. birth weight of the pigs. When the effects of average birth weight were held constant it was noted that birth weight was a more important factor affecting survival than either size of the litter or inbreeding. A 20.26 pound increase in total 56 day weight of the litter was determined for each additional live pig at birth. An increase in weaning weight of the litter of 15.9 pounds for each one pound increase in the average birth weight was determined when the litter size and survival were held constant. The average birth weight of the litter had the greatest effect upon both survival and total weaning weight of the litter. Both of these factors are capable of being expressed before birth as well as afterwards.

Dickerson (4, p.520) found evidence to suggest that selection for low feed requirements to be also selected for some genes mildly antagonistic for suckling ability of the dam. He later postulated that sows whose intra-uterine environment produced heavy birth weights transmit genes for smaller birth weight to their pigs (5, p.670). He found a negative and highly significant regression of offspring on sire for birth weight as compared with a small and non-significant regression of offspring on dam.

John Hammond (7, p.338) said in an introduction to a study of factors effecting the prenatal growth that fertility in domestic animals is largely influenced not by the factors controlling the number of eggs shed, but by the number of eggs developing till birth. This is certainly true in swine because it has been generally accepted that a sow produces on the average about eighteen eggs or ova and fails to produce more than an average of about six pigs per litter.

Determinations of the number of ova shed that are fertilized unfortunately, have been limited. However, a few studies have been made which give a relative figure. It was found in a study of the genetalia of sows from 1 to lo days pregnant that, of the ova represented by corpora lutea, 22.2 per cent were missing (7, p.341). The figure undoubtedly represents not only ova not fertilized but the fertilized eggs that degenerated before the examination was made, besides those which were not recovered.

That the number of corpora lutea is representative of the number of ova shed appears to be controversial. A few cases where the number of foetuses exceeded the number of corpora lutea in the ovaries have been tabulated (2, p.345-351). This might not be too difficult to explain if it were not for the fact that in most work reviewed it was observed that, even though the number of foetuses per sow steadily decreased throughout the gestation period, the proportion of corpora lutea to foetuses remained relatively constant. Both of these facts would tend to indicate that a degeneration of corpora lutea takes place during gestation.

The uterine environment of the developing embryo has been the subject of most of the investigations of factors affecting prenatal development in swine. It has been observed that the number of embryos in each horn of the uterus is generally equal and that the number of corpora lutea in the corresponding ovaries is not representative of this equality and is frequently less than the number of embryos (30, p.73). The possibility of abdominal migration of the ova to the opposite horn, demonstrated in the rabbit, necessitated the ligation of one horn of the uterus with the removal of the corresponding ovary in four gilts to demonstrate the occurrence of intra-uterine migration of ova in sows (30, pp.74-75).

The appearance of degenerate embryos and foetuses in horns of uteri containing large numbers of foetuses suggests that over-crowding in the uterus could be responsible for atrophy or degeneration. Hammond (7, pp.338-341) concluded, however, that foetal atrophy is not caused by over-crowding in the uterus because the size of the embryo is not dependent on the number in the horn and because the foetal membranes continue to live after foetal degeneration has progressed considerably.

The later work of Warwick (30, p.66) tends to contradict the conclusions arrived at by Hammond. Warwick made measurements of the linear uterine space occupied by foetuses and found, from frequency tabulations, that the smaller the space per foetus, the larger the number of degenerate foetuses, and that no horns with an average space of over 45 cm per foetus contained degenerate foetuses.

Warwick (30, pp.59-84) found evidence sufficient to conclude that the position of the embryo in the uterus with respect to the right or left horn or the enumerated sequence of order in the horn from the bifurcation had no effect on the development of the foetus.

Parks (21, p.299) also concluded that there is no association between the foetal position and the size of the foetus.

Warwick found a significant correlation of from 0.32 to 0.64 between the length of the foetus and the weight of the foetal membranes and the weight of the foetus (30, p.78). This indicates that the anatomical distribution of foetal nourishment might provide a differential sufficient to effect wide variations in foetal development.

It is obvious when the studies of foetal sex ratio are reviewed, that a large percentage of the degenerate foetuses are male. Parks concluded that the sex ratio in pigs at conception is approximately 150 males to 100 females (21, p.293). He found that male foetuses averaged about 7 per cent heavier and that no association between foetal position and sex existed (21, p.292).

Most recent studies of fertility in swine have been concerned with complete reproductive failures in sows. Here again the indications are that impaired fertility in sows and gilts is an inherent condition since most of the studies were initiated by observations of poor reproductive performance in specific lines of breeding.

Warnick and associates (29, p.569) state that approximately one fifth of all breeding sows fail to conceive when mated. Phillips and Zeller (22, p.439) in a 12 year period found that 21.9 per cent of sows bred during the breeding season failed to conceive and 36.4 per cent of all matings were infertile.

It was concluded by Warnick and associates (29, pp.569-577) that embryonic death before 25 days after breeding apparently is the major cause of repeat-breeding in sows without anatomical abnormalities. Embryonic death in parous females was 67.4 per cent while only 23.9 per cent in non-parous females. Another factor associated with embryonic death was brucellosis infection. Embryonic death in infected animals was 87.5 per cent and 46.5 per cent in non-infected animals. In this study it was found that the embryonic death rate in infected sows was markedly higher than in gilts (100 per cent as compared with 51.3 per cent) in animals with no genetal abnormalities.

That the eggs shed by the ovary are not fertilized because of insufficient numbers of sperm or failure of the sperm to reach the oviducts seems rather unlikely. The boar is attributed with producing more semen than any other farm animal. McKenzie, Miller and

Bauguess (19, p.24) found that the boar usually produces from 300 to 500 cc of semeniferous fluids per ejaculate. It is generally accepted that the boar's penis passes through the cervix during copulation, so there is little doubt that the deposition of semen could normally be of importance in effecting litter size.

Workers at Wisconsin (26, p.551) found on the examination of reproductive tracts of sows approximately 45 minutes after forced matings that the horns of the uterus were markedly distended with semeniferous fluids due to the deposition of a gelatinous seminal plug in the cephalic region of the cervix which prevented a backflow of semen. On examining two sows artificially inseminated with 75 cc undiluted semen deposited in the anterior end of the cervix, a thin film of semen was seen throughout the length of the uterine horns (26, p.551).

A gelatin-like plug in the oviducts which entrapped the ova was found in the uterus of sows treated with gonadotrophins by workers at Wisconsin (26, p.553). The plug was more or less surrounding the eggs and was more consistant and definite in sows treated in the follicular stage. In every case observed the plug enclosed practically every egg. Sperm were observed in the zona pellucidas of two out of 96 ova of luteal sows while an average of 513 fertilized ova were recovered from an equal number of follicular sows (26, p.566).

From reviews of statistical studies of birth weights of pigs, studies of inbreeding in swine and studies of the gross examination of genetalia from sows, the embryonic pig, and of seminal productivity of the boar it seems that there are numerous heritable traits of a morphalogical or physiological nature that represent a sizeable economic loss to the swine industry by complete loss of fertility in the sow, decreased fecundity, and variability in the birth weight or vigor of the new born pig.

MATERIALS

In 1936 the United States Range Livestock Experiment Station, Miles City, Montana, in cooperation with the Montana Agricultural Experiment Station and the Bureau of Animal Industry, United States Department of Agriculture, started the development of the Montana No. 1 line of swine. The foundation animals consisted of 3 purebred Landrace boars and 12 sows plus eight Hampshire animals. The line resulting from this foundation is now approximately 45 per cent inbred and consists of approximately 55 per cent Landrace and 45 per cent Hampshire blood. The litter records from this project constitute the data used in this study.

Although there were actually two strains developed from this common foundation, a red and a black, only the black is used in this study. In selecting for the black, the red appeared and although there were no matings of black and red individuals after 1942 the data from the red strain were not omitted until after 1945. In 1945 crosses were made between the black and red strains to determine the homozygosity of the black individuals.

Nothing is known of the amount and kind of selection practiced other than that which has been published.

> "The principal object of this work was to combine the more desirable qualities of each of these breeds into a single strain or breed. Special emphasis was given to performance characters, including prolificacy, feed lot performance, mothering ability, etc. In addition, slaughter tests provided information on the desirability of carcasses." (12, p.4)

METHODS

To facilitate ease in handling the data which were received in a ledger type binding, all information pertaining to the study was transfered to 5 x 8 inch index cards. The original information on each litter, indexed by litter number, which was transfered to the index cards consisted of each individual pig's number, its birth weight, the sire and dam of the litter, the date the litter was farrowed, the number of females and males born alive, and dead, and the total farrowed. Information such as peculiarities of the individual, the sire, the dam or the entire litter was indicated in appropriate places on the card.

Calculations of the total birth weight, the mean birth weight, and the standard deviation of birth weight of the live pigs farrowed in each litter were also recorded on the index cards. The classification of the litter with reference to the major sources of environmental variation in birth weight other than year and season were also tabulated on the card. Approximately 600 such cards were used in recording the data.

A sample of the indexing method is presented with the data pertaining to litter number 165.

Classification of the data on the basis of the age of the dam presented the problem of determining the age of the sow at the time the litter was farrowed. The information available was the date the sow was born and the date she farrowed the litter.

Figure 1

Litter Number 165
Date Farrowed 3/21/49

Pigs No.	Sex	B'th Wt.
1650	B	2.1
1651	B	2.0
1652	B	2.6
1653	B	2.8
1654	B	2.4
1653	S	2.5
1654	S	1.8
1655	S	2.5
1656	S	2.6
1657	S	2.2
1658	S	2.3
1659	S	2.1

Sire Number 1284B

Dam Number 1514S
Age at Far'ing 323 Days
Litter G'dam Sow

	Number Farrowed Alive,	Dead,	Total	Number Weaned
Males	5	0	5	5
Females	7	0	7	6
Total	12	0	12	11

ΣX	27.9
ΣX^2	65.8900
$(\Sigma X)^2/N$	64.8675
ss	1.0225
s^2	0.0929
s	0.304
$\bar{X}$	2.325

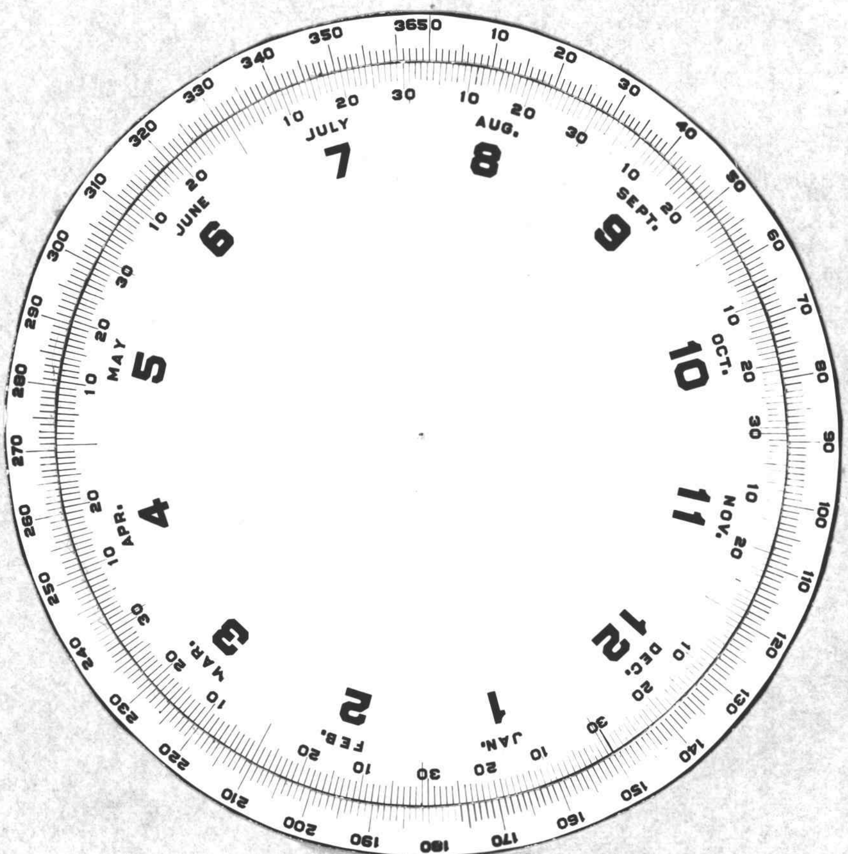
A Representative Sample of the Method of Recording and Indexing The Data and Calculations on Each Litter Used in the Study

Two concentric, equa-radii circular dials were constructed. The circumference of each circle was then divided into 365 equal divisions and the index of the divisions were placed outside the circumference of one and inside the circumference of the other dial. The inner dial was then tabulated for each day and month of the year. The outer dial was enumerated by fives to the total of 365. With the area beyond the circumference of the inner dial removed and the centers fixed, the dials could then be rotated so that the zero index line of the outer dial would indicate a specified date. The number of days between the date indexed by zero and another specified date would then be indexed by the date line on the inner dial. The dials were reduced to a useable size by photographic reduction.

This method of finding the number of days between two dates proved a fast and accurate method except that periods involving February 29th of leap year required adding one day to the number read from the outer dial. A model of the date and days dial is presented on the following page.

The last matings of either Hampshire hogs to Landrace or cross-bred hogs or vice versa were made in 1938 for the 1939 spring litters. Because of this it was concluded that the least amount of homogeneity existed in this group of litters with respect to Hampshire, Landrace or Montana No. 1 lines of breeding, and from this date on the development was from heterogenetic individuals rather than heterogenetic groups. It was for this reason that 1939 was selected as the starting year of the study rather than 1936 when the first litters of the project were farrowed. No litter data previous to 1939

Figure II



The Device Used in
Determining the Age of Gilts at Farrowing

were used.

Since the primary purpose of this thesis is to determine the amount of progress per generation by selection for higher productivity in the development of the line, it was assumed essential to determine the major factors contributing to the variability of each character to be studied. Among the major environmental factors which have been determined, yearly and seasonal variations are easily extracted. Because in swine the reproductive rate makes possible an annual turn-over in generations where this reproductive rate is utilized, and because the greater portion of the litters farrowed were spring litters and because relatively few individuals were selected to reproduce from the fall litters and further because the fall litters were generally second or subsequent litters by a sow, the fall litters were entirely eliminated from the study.

Because the second and later litters by a sow are considered to be larger and the pigs in these litters heavier the data were divided into litters from sows which had farrowed more than one litter and litters which were the first farrowed by a sow at approximately one year of age.

Differences in productivity of sows farrowing their first litter whose dams had farrowed more than one litter previous to the litter from which they were selected, and sows farrowing their first litter which were selected from the first litter farrowed by a sow at approximately one year of age were indicated by Russel and Hutton (24, p.1-28). Although they found no differences in birth weight between the two groups in a herd of Duroc Jersey swine it was considered essential to test for such differences in the data for proper comparisons of generations.

To facilitate simplification of analysis with such a large volume of data estimates of the standard deviation of birth weight of live pigs farrowed were obtained from randomly selected litters from the entire collection of data, and the method of estimating sample size of Harris, Horvitz, and Mood (8, p.391-402) was employed. A sample size sufficient to detect differences of 0.1 pounds live weight at birth between the mean performance of the two groups, litters by gilts by gilts and litters by gilts by sows, was determined.

Randomly selected litters farrowed by the two groups of sows with equal numbers of litters being selected from those farrowed in the spring of 1944, 1945, 1947, and 1948 with respect to year and dam classification were obtained. The data were first analysed for year differences within groups, and because no significant differences was detected between years the data were pooled. By analysis of variance it was determined that the mean birth weight of live pigs farrowed in the first litter by a sow approximately one year of age whose dam had farrowed more than one litter of pigs was significantly greater than the mean birth weight of live pigs farrowed by sows approximately one year of age selected from the first litter farrowed by a sow approximately one year of age.

As it is generally accepted that a female hog is called a gilt until she has farrowed a litter of pigs, and because the first litter of a female is called a gilt litter, future reference to the foregoing differences between the two groups will be litters by gilts by gilts and litters by gilts by sows, the latter being those with live pigs heavier at birth.

Because of the differences found between pigs farrowed by gilts by gilts and pigs by gilts by sows the litters by gilts by sows were eliminated from the study.

Although numerous attempts were made to fit the tabulated frequency of birth weight of live pigs to a normal curve none are presented in the text of this paper. The primary reason for the distribution not being normal can be found in work presented by Lush _et. al_. (16, pp.329-343). These workers noted that the relationship between litter size and birth weight is not linear. Since this is true any attempt at fitting birth weight to a normal curve by using mathematical transformations would lose its value when samples were taken from a population which were not of the same population with respect to litter size.

The situation might be described as one in which two variables are dependent on one another yet the relationship between the two variables is not linear. The use of the variable, birth weight, is so dependent on the other, litter size, that in dealing with the usual swine population, where selection is not random with respect to litter size, the selected group would not fit a normal curve if a transformation were used. It must, therefore, be concluded that determinations using the usual statistical methods are likely to give biased results.

To briefly summarize, the data used include all spring litters farrowed by gilts by gilts used in the development of the Black Strain of the Montana No. 1 line of swine from 1939 to 1949 inclusive. A total of 207 litters were used. This classification of data corresponds well with that used in a study of factors affecting survival of pigs from birth to weaning by workers at Minnesota (36, pp.288-296) with the exception of the classification of data on the basis of the grand-dam of the litter. The primary purpose of segregating the data in this manner was to facilitate a comparison between one generation and another by elimination of as many of the environmental causes of variation as was possible, thus allowing detection of genetic differences.

Based on the assumption that the sum of the deviations from the mean of individual pig birth weights due to factors other than individual maternal uterine effects would be equal to or near zero, the data for each pig and each litter were tabulated so that the amount of selection practiced could be compared with the mean of the population each year selection was practiced in the specified dam groups. An example of how the environmental deviations should be equal to zero is evident if a group of individuals are considered. The genetic productive potential of each individual is altered by environmental influences. The alteration may be expressed as an increase or a decrease in production and if a group of individuals are considered the average of that group should be the mean genetic productive potential of the entire group under that environment. Because all individuals in the study are not subject to the same environment due to differences in year and generation there is undoubtedly some variation each year in the average environment. There seems little reason to doubt that if the environment one year should increase the productivity it should not in another year decrease the productivity and over a period of year average out to a sum of zero, when management practices are held constant.

No analysis was made to determine whether the mean productivity of the selected individuals was significantly greater than the mean of the population from which they were selected because the differences between the means was purely artificial, determined by the intensity of selection desired. Whether the selection was significantly different would also be dependent on the number selected, which in the case of any breeding program would be determined by the reproductive rate, amount of culling and other factors determining the size of the breeding population.

The same general procedure was followed in determining the selection, and gain for uniformity of birth weight. These determinations were based on the within litter standard deviation of the litters from which all parents were selected and the litters from which the dams were selected. Further the selection for litter size was based on the mean litter size of the litters from which all individuals were selected.

As most of the environmental sources of variation in birth weight determined by Lush <u>et.</u> <u>al.</u> (16, pp.329-343), have been eliminated and adopting the assumption that the sum of those remaining will be equal to zero, it is hoped that the best phenotypic index to the genetic factors responsible for birth weight will be revealed. All calculations are based on the same litters and for this reason any of the figures which are obtained are only applicable in determining which index--the selected individual's birth weight, the weighted mean birth weight of the litters from which individuals were selected, or the unweighted mean birth weight of all litters from which the individuals were selected--is most suitable for selecting toward greater birth weights.

Present knowledge indicates that deviations from the mean birth weight of the litter are due largely to environmental influences. Because of this it is hoped that the index used for uniformity of birth weights may give an indication of the degree to which the variations in pre-natal environment are inherent characteristics of the sow. Because it appears that the litter size at birth might be subject to the same influences as is the birth weight of the individual pig or the mean birth weight of the litter, the determination of the ratio of selection to gain can only indicate the degree to which this might be true.

Because there is no way of knowing that the sum of the deviations from the mean each generation due to environmental factors influencing birth weight other than individual maternal effects are equal to zero and because the maternal influences on birth weight and the pigs own genetic influence on it's birth weight are observed as a unit, the final figure obtained cannot be called the heritability of the character.

RESULTS

The analysis of variance for year differences within dam groups is presented in Tables I and II and the analysis of variance for differences in birth weight between dam groups is presented in Table III. It was later determined that the mean birth weight of live pigs farrowed by gilts by gilts for all pigs farrowed in spring litters between 1939 and 1949 was 2.46 pounds and the average for pigs by gilts by sows was 2.68 pounds.

The same procedure was followed in calculations of selection based on the birth weight of the individuals selected, the mean and weighted mean birth weight of the litter from which the individuals were selected and the mean and weighted mean birth weight of the litter from which the dams were selected. The same procedure was followed in determining the selection for litter size.

The intensity of selection is the arithmatic difference between the mean of the selected individuals for the particular index used and the arithmatic mean of birth weights of all individuals which comprise the population from which the selection was made.

The result of selection is the mean birth weight of all progeny of the selected individuals which are in the specified dam group, gilts by gilts. In addition to the specifications pertaining to the selected individuals the progeny litters are by animals whose great grand-dams were gilts too. The net gain from selection is the arithmatic difference between the mean of the progeny and the population from which the parents were selected.

Table I.

Analysis of Variance for Differences in Birth Weights of Pigs Farrowed by Gilts by Sows Between Years

Source of Variation	Degrees of Freedom	Mean Square	F
Year	3	0.7126	1.09
Litter within year	12	0.6543	
Within litter	112	0.1100	
Total	127		

Table II.

Analysis of Variance for Differences in Birth Weights of Pigs Farrowed by Gilts by Gilts Between Years

Source of Variation	Degrees of Freedom	Mean Square	F
Year	3	0.2312	0.38
Litter within year	12	0.6092	
Within litter	129	0.1139	
Total	144		

Table III.

Analysis of Variance for Differences Between Birth Weights of Pigs Farrowed by Gilts by Sows and Birth Weights of Pigs Farrowed by Gilts by Gilts

Source of Variation	Degrees of Freedom	Mean Square	F
Dam groups	1	3.5126	5.87*
Litters within groups	30	0.5985	5.34*
Within litters	241	0.1121	
Total	272		

* Significant at the o.o5 significant level

To determine whether the statistic, the within litter standard deviation of birth weight, is applicable to the usual methods of statistical analysis the Chi-square test of normality was employed. It was determined that the observation did not follow a normal distribution. The result of the test of normality is presented in Table IV.

The mean performance of the population, selected individuals and their progeny, is presented in Tables V to XII.

When the selection was negative and the result negative, or when both are positive, it will be noted that the net gain is positive. Only when the selection has been negative and the result positive or vice versa is the net gain negative.

Although the figure used for uniformity of birth weight is actually the unbiased estimate of the standard deviation of birth weight of pigs within the litter,

$$s = \sqrt{\frac{\sum X^2 - \sum \frac{(\sum X)^2}{N}}{\sum N - K}}$$

where X is the birth weight of the pig, N the number of pigs in the litter, and K the number of litters, as shown in the equation above, for brevity the term, standard deviation is used.

The ratio of gain to selection is the difference between the mean of the population and the mean of the parents selected to the difference between the population from which the parents were selected and the mean of the progeny of the selected parents.

The relationship between the selection for birth weight based on the mean birth weight of the individual selected and the result of

Table IV.

Chi-square Test of Normality
For 204 Standard Deviations of Birth Weights
of Pigs Within Litter

Within Litter Standard Deviation	Observed Frequency	Theoretical Frequency	$\frac{(O-T)^2}{T}$
0.0 to 0.10	11	14.40	0.80
0.10 to 0.20	26	21.24	1.06
0.20 to 0.30	53	34.98	9.28
0.30 to 0.40	42	41.45	0.01
0.40 to 0.50	42	40.31	0.07
0.50 to 0.60	15	28.07	6.08
0.60 to 0.70	6	15.15	5.53
0.70 to 0.80	9	8.40	0.01
Totals	204	204.00	22.94

Chi-square with 5 d.f. = 22.94*

*Significant: The 5% point of Chi-square with 5 d.f. is 11.07

The mean of 204 standard deviations is 0.3750

The standard deviation of 204 standard deviations is 0.1891

Table V.

Selection for Birth Weight Based on the Mean Birth Weight of the Individuals Selected

Year	Population Mean lbs./pig	Parent Mean lbs./pig	Progeny Mean lbs./pig	Number of Litters
1939	2.58	2.60	2.48	11
1940	2.54	2.59	2.34	18
1941	2.43	2.38	2.30	7
1942	2.39	2.88	2.32	6
1943	2.38	2.95	2.54	1
1944	2.44	2.80	2.38	5
1947	2.39	2.55	2.42	1
1948	2.36	2.50	2.32	17

Selection and Result of Selection

Year	Net Selection lbs. pig	Net Result lbs. pig	Weighted Net Selection lbs. pig	Net Gain lbs. pig
1939	0.02	-0.10	0.22	-0.10
1940	0.05	-0.20	0.90	-0.20
1941	-0.05	-0.13	-0.35	0.13
1942	0.49	-0.07	2.94	-0.07
1943	0.57	0.16	0.57	0.16
1944	0.36	-0.06	1.80	-0.06
1947	0.16	0.03	0.16	0.03
1948	0.14	-0.04	2.38	-0.04
Total	1.74		8.62	-0.15

Mean selection per year = $\frac{8.62}{66}$ = 0.13 pounds pig.

The ratio of gain to selection $\frac{-0.15}{1.74}$ = -0.086 pounds pig gained for each pound selected for.

Table VI.

Selection for Birth Weight Based on the Mean Birth Weight of the Litters From Which the Parents Were Selected

Year	Population Mean lbs./pig	Parent Mean lbs./pig	Progeny Mean lbs./pig	Number of Litters
1939	2.58	2.95	2.48	11
1940	2.54	2.45	2.34	18
1941	2.43	2.43	2.30	7
1942	2.39	2.55	2.32	6
1943	2.38	2.75	2.54	1
1944	2.44	2.78	2.38	5
1947	2.39	2.25	2.42	1
1948	2.36	2.44	2.32	17

Selection and Result of Selection

Year	Net Selection lbs. pig	Net Result lbs. pig	Weighted Net Selection lbs. pig	Net Gain lbs. pig
1939	0.37	-0.10	4.07	-0.10
1940	-0.09	-0.20	-1.63	0.20
1941	0.00	-0.13	-0.00	0.13
1942	0.16	-0.07	0.96	-0.07
1943	0.37	-0.16	0.37	-0.16
1944	0.34	-0.06	1.70	-0.06
1947	-0.14	-0.03	-0.14	0.03
1948	0.08	-0.04	1.36	-0.04
Total	1.55		6.69	-0.07

Mean selection per year = $\frac{6.69}{66}$ = 0.101 pounds pig.

The ratio of gain to selection $\frac{-0.07}{1.55}$ = -0.045 pounds pig gained for each pound selected for.

Table VII.

Selection for Birth Weight Based on the Unweighted Mean Birth Weight of the Litters From Which the Parents Were Selected

Year	Population Mean lbs./pig	Parent Mean lbs./pig	Progeny Mean lbs./pig	Number of Litters
1939	2.58	2.60	2.48	11
1940	2.54	2.41	2.34	18
1941	2.43	2.36	2.30	7
1942	2.39	2.50	2.32	6
1943	2.38	2.54	2.54	1
1944	2.44	2.47	2.38	5
1947	2.39	2.42	2.42	1
1948	2.36	2.34	2.32	17

Selection and Result of Selection

Year	Net Selection lbs. pig	Net Result lbs. pig	Weighted Net Selection lbs. pig	Net Gain lbs. pig
1939	0.02	-0.10	0.22	-0.10
1940	-0.13	-0.20	-2.34	0.20
1941	-0.07	-0.13	-0.49	0.13
1942	0.11	-0.07	0.66	-0.07
1943	0.16	0.16	0.16	0.16
1944	0.03	-0.06	0.15	-0.06
1947	0.03	0.03	0.03	0.03
1948	-0.02	-0.04	-0.34	0.04
Total	0.57		-1.95	0.33

Mean selection per year = $\frac{-1.95}{66}$ = -0.029 pounds pig.

The ratio of gain to selection $\frac{0.33}{0.57}$ = 0.578 pounds pig gained for each pound selected for.

Table VIII.

Selection for Birth Weight Based on
the Mean Birth Weight of the Litters
From Which the Dams Were Selected

Year	Population Mean lbs./pig	Parent Mean lbs./pig	Progeny Mean lbs./pig	Number of Litters
1939	2.58	2.09	2.48	11
1940	2.54	2.62	2.34	18
1941	2.43	2.58	2.30	7
1942	2.39	2.61	2.32	6
1943	2.38	2.87	2.54	1
1944	2.44	2.51	2.38	5
1947	2.39	2.25	2.42	1
1948	2.36	2.42	2.32	17

Selection and Result of Selection

Year	Net Selection lbs. pig	Net Result lbs. pig	Weighted Net Selection lbs. pig	Net Gain lbs. pig
1939	-0.49	-0.10	-5.39	0.10
1940	0.08	-0.20	1.44	-0.20
1941	0.15	-0.13	1.05	-0.13
1942	0.22	-0.07	1.32	-0.07
1943	0.49	0.16	0.49	0.16
1944	0.07	-0.06	0.35	-0.06
1947	-0.14	0.03	-0.14	-0.03
1948	0.06	-0.04	1.02	-0.04
Total	1.70		0.14	-0.27

Mean selection per year = $\frac{0.14}{66}$ = 0.002 pounds pig.

The ratio of gain to selection $\frac{-0.27}{1.70}$ = -0.159 pounds pig gained for each pound selected for.

Table IX.

Selection for Birth Weight Based on the Unweighted Mean Birth Weight of the Litters From Which the Dams Were Selected

Year	Population Mean	Parent Mean	Progeny Mean	Number of Litters
	lbs./pig	lbs./pig	lbs./pig	
1939	2.58	2.52	2.48	11
1940	2.54	2.58	2.34	18
1941	2.43	2.59	2.30	7
1942	2.39	2.58	2.32	6
1943	2.38	2.87	2.54	1
1944	2.44	2.51	2.38	5
1947	2.39	2.25	2.42	1
1948	2.36	2.42	2.32	17

Selection and Result of Selection

Year	Net Selection	Net Result	Weighted Net Selection	Net Gain
	lbs. pig	lbs. pig	lbs. pig	lbs. pig
1939	-0.06	-0.10	-0.66	0.10
1940	0.04	-0.20	0.72	-0.20
1941	0.16	-0.13	1.12	-0.13
1942	0.19	-0.07	1.14	-0.07
1943	0.49	0.16	0.49	0.16
1944	0.07	-0.06	0.35	-0.06
1947	-0.14	0.03	-0.14	-0.03
1948	0.06	-0.04	1.02	-0.04
Total	1.21		4.04	-0.27

Mean selection per year = $\frac{4.04}{66}$ = 0.061 pounds pig.

The ratio of gain to selection $\frac{-0.27}{1.21}$ = -0.223 pounds pig gained for each pound selected for.

Table X.

Selection for Litter Size Based on
the Mean Litter Size of the Litters
From Which the Parents Were Selected

Year	Population Mean Pigs/litter	Parent Mean Pigs/litter	Progeny Mean Pigs/litter	Litters
1939	10.11	9.91	8.00	11
1940	8.36	9.50	8.94	18
1941	8.61	9.07	9.71	7
1942	9.10	10.50	8.01	6
1943	8.52	6.50	5.00	1
1944	8.93	8.90	5.40	5
1947	9.77	10.00	9.00	1
1948	8.63	8.53	9.32	17

Selection and Result of Selection

Year	Net Selection Pigs	Net Result Pigs	Weighted Net Selection Pigs	Net Gain Pigs
1939	-0.20	-2.11	-2.20	2.11
1940	1.14	0.58	20.50	0.58
1941	0.36	1.10	2.52	1.10
1942	1.40	-1.09	8.40	-1.09
1943	-2.02	-3.52	-2.02	3.52
1944	-0.03	-3.53	-0.15	3.53
1947	0.23	-0.77	0.23	-0.77
1948	-0.10	0.69	-1.70	-0.69
Total	5.48		25.58	8.29

Mean selection per year = $\frac{25.58}{66}$ = 0.39 pigs per litter.

The ratio of gain to selection $\frac{8.29}{5.48}$ = 1.51 pigs gained for each pig selected for.

Table XI.

Selection for Uniformity in Birth Weights Based on Comparisons of Within Litter Standard Deviations of the Litters From Which All Parents Were Selected

Year	Population Mean (s)	Parent Mean (s)	Progeny Mean (s)	Number of Litters
1939	0.750	0.758	0.296	11
1940	0.427	0.614	0.412	18
1941	0.416	0.606	0.393	7
1942	0.420	0.364	0.410	6
1943	0.327	0.365	0.304	1
1944	0.422	0.650	0.417	5
1947	0.353	0.380	0.308	1
1948	0.356	0.411	0.405	17

Selection and Result of Selection

Year	Net Selection	Net Result	Weighted Net Selection	Net Gain
1939	0.008	-0.266	0.088	-0.266
1940	0.187	-0.015	2.361	-0.015
1941	0.190	-0.023	1.330	-0.023
1942	0.056	-0.010	-0.336	0.010
1943	0.037	-0.023	0.037	-0.023
1944	0.228	-0.005	1.140	-0.005
1947	0.027	-0.045	0.027	-0.045
1948	0.055	0.049	0.935	0.049
Total	0.788		6.254	-0.318

Mean selection per year = $\frac{6.254}{66}$ = 0.9475 pounds pig increase within litter in standard deviation.

The ratio of gain to selection $\frac{-0.318}{0.788}$ = -0.4035 pounds pig increase in within litter standard deviation for each pound selected for.

Table XII.

Selection for Uniformity in Birth Weights Based on the Within Litter Standard Deviations of the Litters From Which the Dams Were Selected

Year	Population Mean (s)	Parent Mean (s)	Progeny Mean (s)	Number of Litters
1939	0.750	0.328	0.296	11
1940	0.427	0.396	0.412	18
1941	0.416	0.812	0.393	7
1942	0.420	0.340	0.410	6
1943	0.327	0.292	0.304	1
1944	0.422	0.290	0.417	5
1947	0.353	0.389	0.308	1
1948	0.356	0.347	0.405	17

Selection and Result of Selection

Year	Net Selection	Net Result	Weighted Net Selection	Net Gain
1939	0.432	-0.266	-4.752	0.266
1940	-0.031	-0.015	-0.558	0.015
1941	0.396	-0.023	2.772	-0.023
1942	-0.080	-0.010	-0.480	0.010
1943	-0.035	-0.023	-0.035	0.023
1944	-0.142	-0.005	-0.710	0.005
1947	0.036	-0.045	0.036	-0.045
1948	-0.009	0.049	-0.153	-0.049
Total	1.161		-3.880	0.202

Mean selection per year $= \frac{-3.880}{66} = -0.5878$ pounds pig increase within litter in standard deviation.

The ratio of gain to selection $\frac{0.202}{1.161} = 0.174$ pounds pig increase in within litter standard deviation for each pound selected for.

the selection was negative (Table V). If the sum of the environmental factors affecting the birth weight is equal to zero this corresponds to the negative regression of offspring on parent obtained by Dickerson and Grimes (5, pp.665-687).

It will be noted in Tables VI, VIII, and IX that the ratio of gain to selection for birth weight based on the mean and unweighted mean birth weight of the litters from which the dams were selected, and the mean birth weight of the litters from which all parents were selected is also negative. On the other hand, the ratio for the selection based on the unweighted mean birth weight of the litter from which all parents (Table VII) were selected is positive.

The gain to selection ratio for litter size was found to be 1.51 (Table X). This finding certainly indicates that environmental factors affecting litter size have only accentuated the selection and the sum of the deviations is not equal to zero.

The result of the apparent selection for uniformity of birth weight is in direct contrast to the result of the study of birth weight. In this case the gain to selection ratio for the selection based on the within litter standard deviation of the litter from which the dams were selected (Table XII) was positive and the ratio based on the within litter standard deviation of birth weight of the litter from which all parents were selected was negative (Table XI).

DISCUSSION

It is important to note that, although there is no direct indication of the environmental influences on the mean birth weight of the population each year, there is a negative trend and there are definite indications that this trend is genetic. In almost every case, where the number of progeny litters is large, the progeny mean is not only below the mean of the population from which the parents were selected, but also below the mean of the population of which they are a part. Each year the population consists not only of litters by gilts whose dams were gilts and whose grand-dams were also gilts, but also litters by gilts whose dams were gilts and whose grand-dams were sows. A lag in generations is therefore apparent, because of the fact that the grand-dams of gilts which farrowed litters each year were selected to farrow a second or subsequent litter instead of their offspring having the opportunity to reproduce. It is this lag in generation which tends to hold the population mean above that which it might have been if the turn-over in generations had been constant, and makes a genetic trend towards lighter pigs at birth apparent.

A point of interest is that when selections were made in the development of the Black line on the basis of coat color (1945) it was accompanied by a slight increase in birth weight.

When the results of this study are considered in the light of what has been determined with other livestock, and with other characteristics for swine, some definite conclusions are available. It has long been known that the mean performance of all the progeny of a sire and dam is a much better indication of their combined genotype and the environment the dam contributes to the development of the offspring than is the performance of any one of the offspring alone. The primary difference between hogs and other farm animals is that, due to their multiple births, a rather reliable sample of their progeny is usually obtained from one mating. The mean birth weight of the progeny of a sire and dam obviously represents the genetic adaptability to the prenatal environment besides the hereditary ability of the dam to provide a suitable prenatal environment.

The deviations from the mean birth weight of the litter are obviously largely due to the individual pig's inherent ability to utilize a more favorable or unfavorable environment. The pig cannot develope beyond the limitations of the nutrients supplied in any environment and in the case of the prenatal environment the nutrients are supplied by the dam's ability to utilize feed and to supply nutrients through her uterus. It must be concluded that sows possess uterine conditions which make possible a greater supply of nutrients or conditions more favorable to the development of the foetal membranes and foetus to some and not to others in the uterus at the same time.

In the Montana No. 1 line of hogs it is quite apparent that the limiting factor to birth weight is the prenatal environment. This is explained by the fact that there has been continual selection of pigs which have utilized the more favorable environmental conditions over pigs which were subject to a less favorable environment, but with simultaneous selection from sows which were below average in providing uterine environment favorable to all pigs in the litter. These facts are most obvious when examining Tables V and VII which show the selection for birth weight based on the mean birth weight of the individuals selected and the selection for birth weight based on the unweighted mean birth weight of the litters from which the individuals were selected.

That the mean birth weight of the litter from which the dams or all the parents were selected, weighted for litter size, does not represent the ability of the dam to provide adequate uterine environment is perhaps due to the fact that the birth weight of pigs in small litters tends to be greater than that of pigs in large litters. Because the selection for birth weight and litter size are simultaneous and the population from which they are selected is weighted for litter size the advantage of the litters selected from is distributed to all pigs in those litters instead of being limited to the number of individuals selected from the litter. The advantage realized in this population has in general been negative.

The fact that the unweighted mean birth weight of the litter from which the dams were selected does not indicate the weighted mean birth weight of their progeny too well is perhaps because only half the genotype of the dam is represented in this manner, since the sires genotype cannot be expressed until his daughters reproduce, and the unweighted mean birth weight of the litter from which all parents were selected represents a better sample of the selection made during the development of the line. It is known too that the sire contributes to the average birth weight of his offspring and this influence would also be added to the result obtained by the selection based on the unweighted mean birth weight of the litters from which all parents were selected.

As the deviations from the mean birth weight of the litter are largely due to environmental factors, the possibility exists that these are a heritable characteristic of the sow, since such environmental advantages are realized in the uterus of the sow. The ratio of gain to selection for the within litter standard deviation of the litter from which the dams were selected tends to substantiate this hypothesis because the result was positive. However, that this ratio is negative when determined for all parents selected would tend to detract from acceptance of the hypothesis until it is noted that the general trend is toward a smaller within litter standard deviation. When it is considered that the full expression of the genotype of the sire and dam is not realized in a sex limited character until the daughters reproduce, and because it has been previously suggested that calculations based on the litters from which all parents were selected represents a better sample of the selection practiced in the development of the line, accepting the hypothesis is still possible.

If the ability of the sow to provide uterine nutrition to her offspring is the limiting factor in the development of the pig and it is a highly heritable character, a feasible explanation for a negative regression of offspring on dam is at hand. If the selection is based on the differences between the mean birth weight of the individuals selected and the population from which they are selected the desired results can only be accomplished by the selection of pigs from litters with individuals above the mean of the population. Because this comparison is most often made between litter mates there would be a tendency to select those individuals from litters with an average birth weight below the mean of the population. The selection would then be from litters which were subject to an inferior average uterine environment, consequently a regression of the progeny on these selected individuals would be negative. Instead of the offspring expressing their inherent adaptability to the uterine environment, the dam expressed her genotype for an inadequate uterine environment and limited the expression of the genotype toward adaptability transmitted to her offspring.

CONCLUSION

From the review of literature on the genetic factors affecting the birth weight of live pigs and due to the facts revealed in this study it must be concluded that the selection for heavier pigs at birth should be based on the mean birth weight of the litter from which the pigs were selected. Moreover, the selection for more uniform birth weights of pigs within the litter would be effective when this selection is based on the within litter standard deviation of the birth weight.

The use of the standard deviation of birth weights of pigs within the litter as an indication or index to be used in selecting for more uniform litters at birth needs more refinement if determinations of the heritability of the character are to be made by biometric methods. It was noted in calculating the estimate of the standard deviation for each litter that if the litter size was small, even though the deviations from the mean, (the sum of the squares of the deviations from the mean) were small, when it was attributed by N-1 (the number in the litter minus one) it was not corresponding with the magnitude of the mean square determined where the litter size was large. This might be due to the fact that the sensitivity of the scales used was only one-tenth pound, which was not precise enough to determine the actual differences between the pigs. In an attempt to overcome this difficulty regarding the within litter standard deviation, the sum of the squares divided by the size of the sample, N, instead of N-1 was determined for each litter. Again it was found that the statistic did not follow a normal distribution (see Table IV), and did not appear to be a reliable estimate of the uniformity of birth weights when the litter size was small. It will be noted in Table IV that the observed frequency of the within litter standard deviation below the mean is decidedly lacking. Perhaps this is because the within litter standard deviation tended to increase as the litter size increased and the smaller litters did not provide an accurate determination of the true variability within the litter. It is also possible that the statistic, the within litter standard deviation, does not fit a normal curve because it is based on a statistic, birth weight, which does not fit a normal curve.

The use of a gram scale might provide a measurement of sufficient refinement to permit the use of the within litter standard deviation of birth weights as a statistic.

For practical purposes the use of birth weights measured to the nearest one-tenth pound should be adequate because of the fact that a breeder is always selecting for litter size. If an animal had characteristics of sufficient quality to warrant its selection without regard to litter size the breeder would undoubtedly overlook birth weight too.

Because the characteristics of primary interest in this study, the mean birth weight of the litter and the within litter standard deviation, do not follow a normal curve, no attempt to determine heritability by regressions was made.

The only alternative available for accurate determination of the heritability of the mean birth weight of the litter appears to be a selection experiment specifically designed for that purpose.

The device and method of determining the number of days between two dates, designed and successfully used in this study, should find practical application, not only in general livestock management practices but in research as well. It could be used in determining calving, lambing or farrowing dates and feeding periods for animals on efficiency tests or nutritional studies as well as the age of an animal in days. Commercial enterprises have distributed a similar device to farmers, for use in determining gestation periods.

The significant difference between the mean birth weight of pigs by gilts by gilts and pigs by gilts by sows could be of practical significance. It must be noted, however, that there is a difference of generations represented by these two groups. An undetermined lag in generations, as was previously mentioned, occurred when sows were selected to reproduce second or subsequent litters. The lag in generations may be responsible for the differences detected between the two groups. If not, the practice that many swine breeders use, of not selling bred gilts whose dams were gilts is justified beyond the fact that their dams have only one litter record to establish their inherent ability to produce. It would also be necessary to conclude that the pre-weaning environment, which could include the prenatal environment, affects the productivity of a gilt.

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